

Performance of tree species and their effect on soil properties in chromite mine spoil areas

Abstract

An experiment was carried out at Kakudia dump of Sukinda chromite mines, Tata Steel Limited, Kalarangiata, Jajpur, which is located near the trijunction of Cuttack, Dhenkanal and Keonjhar districts of Odisha, where 10 tree species from plantation were selected, their growth parameters were measured, volume and biomass was estimated and soil samples were analyzed for heavy metal contents which are collected from the root zone of tree species. Around 12 mines are operating in the area without proper environmental pollution controls, which cause major health hazards. According to estimates from an Indian health group, hexavalent chromium levels in drinking water are around 60% higher than the international norms, and chromite-related illnesses are thought to be the cause of 84.75 percent of fatalities in mining regions with no controls. There has been virtually no attempt to clean up the contamination. The experiment was based on three plantation blocks which consists of ten forest species such as *Melia azedarach* L., *Samanea saman* F. Muell., *Syzygium cumini* L., *Acacia mangium* Wild., *Alstonia scholaris* L., *Pongamia pinnata* L., *Casuarina equisetifolia* L., *Azadirachta indica* A. Juss., *Anacardium occidentale* L., *Neolamarckia cadamba* Roxb. and control with a mine barren spoil and natural forest. *Casuarina equisetifolia* recorded significantly highest height (10.43 m), DBH (13.99 cm), crown length (8.37 m), crown spread (4.2 m), volume (0.354 m³) and biomass (115.74 kg tree⁻¹). *Acacia mangium* was the next best tree species followed by *Anacardium occidentale*, *Neolamarckia cadamba*, *Syzygium cumini*, *Pongamia pinnata*, *Samanea saman*, *Melia azedarach*, *Azadirachta indica* and *Alstonia scholaris*. Also, there is significant and positive correlation found among all the tree growth parameters. Among the growth parameters of trees, positive and significantly highest correlations was observed between tree DBH and tree biomass ($r = 0.997761$) followed by tree volume and tree biomass ($r = 0.980047$).

Keywords: Biomass, Chromite, Heavy metal, Soil properties, Tree species, Mine spoil area

Introduction

By mining minerals from the earth's surface, the rapidly expanding human population and rising need for energy resources have sped up the deterioration of natural environments. Mineral resources are viewed as a nation's industrial and economic foundation (Anwer et al, 2001). One of India's greatest employers, the mining industry employs more than one million people, or around 4% of the country's workforce, and provides roughly 4% of the country's GDP. Due to the fact that minerals make up a significant amount of the raw materials used in the country's industrial activity, the value of the minerals produced has a significant impact on the Indian economy. India produces 89 minerals, including 4 that are used as fuels, 11 that

are metallic, 52 that are non-metallic, and 22 that are minor. The fourth-largest coal deposits in the world, bauxite, titanium ore, chromite, natural gas, diamonds, petroleum, and limestone are all abundant in India (Tordoff et al. 2000; Krzaklewski and Pietrzykowski 2002). According to projections from the 2008 ministry of mines, India has increased its output to move up to the second spot among the world's chromite producers. India also comes in third in the production of coal and lignite, second in barytes, fourth in iron ore, fifth in bauxite and crude steel, seventh in manganese ore, and eighth in Aluminium (Bahrami et al, 2010). With 16.92% of the nation's total mineral reserves, Odisha is one of India's greatest mineral-bearing states. Chromites (98%), nickel (95.10%), graphite (76.67%), bauxite (49.74%), iron ore (33.91%), manganese (28.56%), and coal (27.59%) are among the precious minerals that the state is India's principal source of (Singh *et al*, 2002).

Mineral deposits are a resource that humanity can exploit to its advantage. The non-renewable resources that make up mineral deposits are exploited by man for his needs in material, life support, and energy. Although the nature and form of rock and mineral mining and quarrying have changed significantly through time in many ways and ways, these activities are as ancient as civilization itself (Hooper and Vitousek, 1998; Singh and Singh, 1999). The nomenclature of three eras—Stone Age, Bronze Age, and Iron Age—illustrates the dependency of prehistoric cultures on mined goods, as well as the escalating complexity of society's interaction with mining. The history of mining is, in some ways, the history of civilisation (Khoshoo, 1991). In the current world, mining is seen as one of the necessary evils since it produces the minerals needed to maintain quality of life. It has had a noticeable influence on the environment and the socioeconomic circumstances of the locals while also enhancing quality of life and fostering economic development (Vaghlikar and Moghe, 2003).

The aim of reclamation is to return the minesoil to its natural form by restoring the nutritional qualities of soil through a variety of reclamation techniques. Continuous mining damages vegetation/soil systems and diminishes soil productivity and fertility (Upadhyay et al, 2016). These rebuilt minesoils go through a quick maturation phase with engineering, chemical, and biological methods and are used for the development of grasses, trees, and crops. Therefore, with effective management and preservation, significant ecological and economic advantages may be attained in a short amount of time (Bai and Zhao, 1995). The use of minesoils for crops and plants, to restore productivity and ecosystem sustainability, is a continuous challenge because to the vast variability and complexity of minesoils.

Tree plantings are renowned for their capacity to improve microclimates and restore soil fertility (Singh et al, 2002). Each plant species, however, has unique growth traits that influence how effective they are at stabilizing and enhancing the soil. Numerous ways exist by which certain plant species might alter the dynamics of nutrients and ecological processes (Hooper and Vitousek, 1998; Singh and Singh, 1999). Because soil is one of the main factors influencing how plant develops, the study of soil properties has received particular attention in restoration research. Soil organic carbon (SOC), which is lost during mining and reclamation procedures, is lost in a number of ways. The majority of plants thrive in mine waste, however certain species exhibit atypical development due to nutritional deficiencies and the presence of heavy metals (Bradshaw and Chadwick, 1980; Deo, 2004). Most chromite mining wastes contain many metals, some of which may be present at dangerous proportions (Deo, 2011). The choice of suitable species for revegetation is crucial to the success of biological restoration. The selection of plants for replanting overburden dumps relies on a number of factors, including the temperature, the physical and chemical

characteristics of the dump materials, the terrain, their viability, and the vegetation in the surrounding area (Singh and Jha, 1992).

Because degraded fields have adverse physical and chemical characteristics, it takes longer for plants to develop there (Tordoff et al. 2000; Krzaklewski and Pietrzykowski 2002). Biological reclamation may yield positive outcomes for overburden dump revegetation depending on the choice of suitable species and other factors including temperature, the physical and chemical characteristics of the dump materials, terrain, and nearby vegetation (Singh and Jha, 1992).

The soil surface is protected from erosion by vegetation coverings; thus, every effort should be made to support native species and hasten the genetic diversity recovery in habitat that has been restored. When it comes to ecological restoration, alien species have received a lot of attention in order to speed up reclamation in various mined and naturally damaged regions. Will these species restore ecological functions and produce the desirable natural ecosystem characteristics? However, community succession and need much focus to conduct ecological research (Zhang, 2005) as degradation of natural habitats by anthropogenic activities and faster rate of biodiversity loss witnessed now than ever. Restoration ecology is receiving increasing attention (Pensa et al, 2004). Around the world, mining may be responsible for 20% of all deforestation in developing nations (Bahrami et al, 2010). The mining waste is largely made up of refractory rock pieces that lack the nutrients and organic matter necessary to maintain a diverse range of biological organisms. Low organic matter concentrations and adverse pH are incompatible with both plant and microbial development (Agrawal et al., 1993; Burghardt, 1993).

In Odisha about 98% countries chromite reserve is found in Sukinda block of Jajpur district. The overburdens generated during chromite extraction processes causes severe environmental hazards. So different tree species have been planted on the mine spoil areas by mining companies to restore the ecological habitat. Information regarding performance of different tree species on chromite mine spoil areas of Odisha is scanty and study on soil characteristics of chromite mine spoil areas is also rare. The current study offers a chance to comprehend the development characteristics of several tree species planted during the initial stages of mine spoil restoration and how these trees mitigate the negative effects of mining on the environment.

Materials and Methods

The experiment was laid out in a Randomized Block Design (RBD) with three replications. The experiment was based on three plantation blocks which consists of ten forest species such as *Melia azedarach* L., *Samanea saman* F. Muell., *Syzygium cumini* L., *Acacia mangium* Wild., *Alstonia scholaris* L., *Pongamia pinnata* L., *Casuarina equisetifolia* L., *Azadirachta indica* A. Juss., *Anacardium occidentale* L., *Neolamarckia cadamba* Roxb. and control with a mine barren spoil and natural forest (details in Table 1).

Table 1. Treatment details

Treatment	Common Name	Scientific Name	Family
T ₁	Mahaneem	<i>Melia azedarach</i> L.	Meliaceae
T ₂	Chakunda	<i>Samanea saman</i> F. Muell.	Fabaceae
T ₃	Jamun	<i>Syzygium cumini</i> L.	Myrtaceae

T ₄	Mangium	<i>Acacia mangium</i> Wild.	Fabaceae
T ₅	Chhatian	<i>Alstonia scholaris</i> L.	Apocynaceae
T ₆	Karanj	<i>Pongamia pinnata</i> L.	Fabaceae
T ₇	Jhaun	<i>Casuarina equisetifolia</i> L.	Casuarinaceae
T ₈	Neem	<i>Azadirachta indica</i> A. Juss.	Meliaceae
T ₉	Kajubadam	<i>Anacardium occidentale</i> L.	Anacardiaceae
T ₁₀	Kadamb	<i>Neolamarckia cadamba</i> Roxb.	Rubiaceae



Fig. 1. Sukinda chromite mine

UNDER

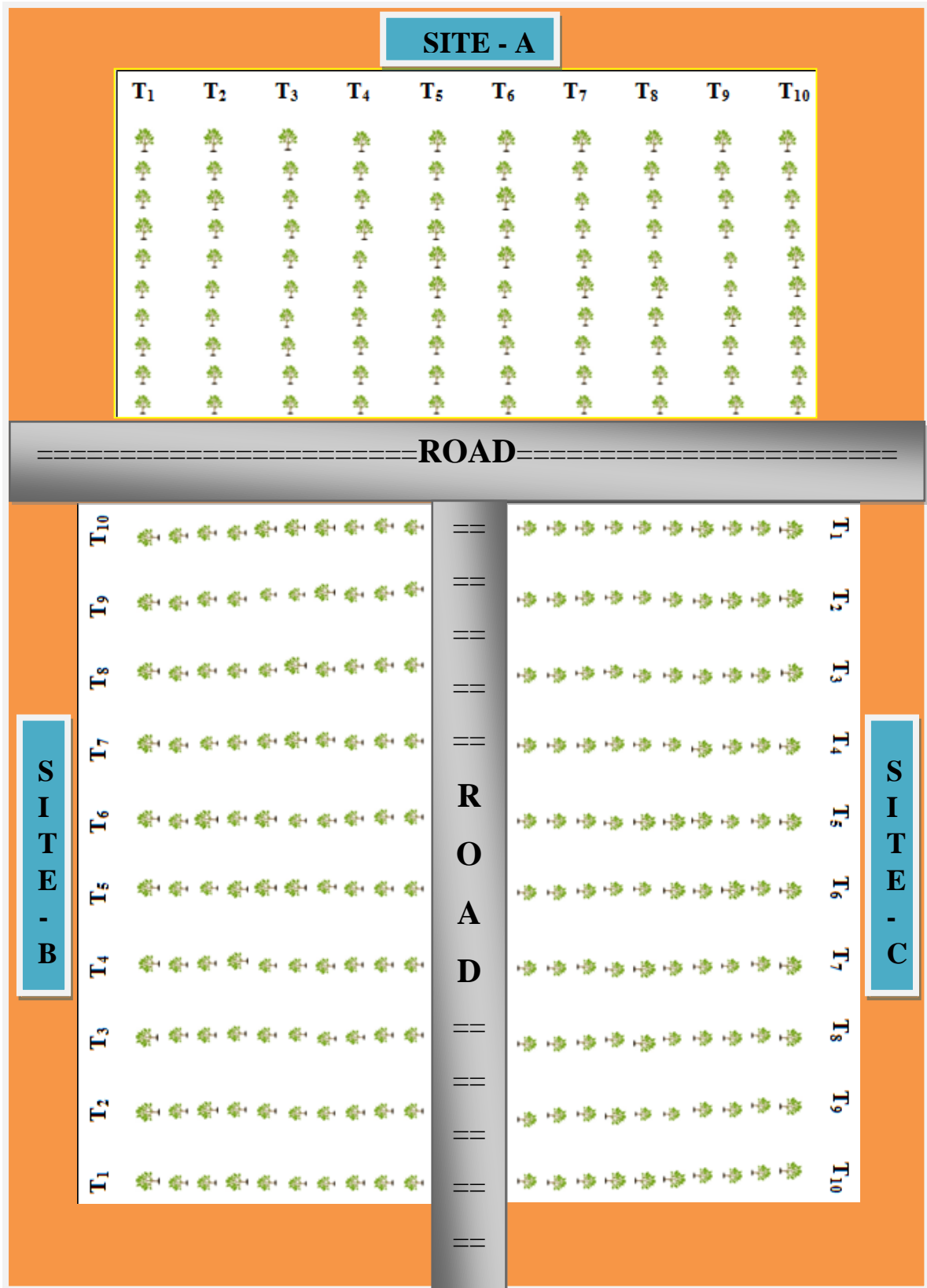


Fig. 2 Layout plan of the plantation site

Results and discussion

Growth performance of tree species

The growth performances of eight-year-old trees are presented in Table 2. Among trees *Casuarina equisetifolia* recorded significantly highest values of all growth parameters than other tree species. *Casuarina equisetifolia* recorded significantly highest height (10.43 m), DBH (13.99 cm), crown length (8.37 m), crown spread (4.2 m), volume (0.354 m³) and biomass (115.738 kg tree⁻¹). *Acacia mangium* was the next best tree species which was found at par with all other tree species for tree height, DBH, number of branches and crown spread but for crown length it was at par with all species except *Melia azadarach* and *Pongamia pinnata*. For tree volume it was at par with all tree species except *Samanea saman*, *Syzygium cumini*, *Pongamia pinnata* and *Azadirachta indica*, for tree biomass it was at par with all species except *Alstonia scholaris*.

Growth performance of *Casuarina equisetifolia* was found to be better in comparison to other tree species. It shows significantly superior height, DBH, crown spread, crown length, volume and biomass over rest of the tree species. In our study, *Casuarina equisetifolia* tree on an average recorded 10.43 m height, 13.99 cm DBH, 20.27 numbers of branches, 8.37 m crown length, 4.20 m crown width and 0.35 m³ tree⁻¹ volume, and 115.73 kg tree⁻¹ biomass. This may be because the *Casuarina equisetifolia* species may be resistant to the unfavourable soil characteristics inherent in mine debris, such as acidity, metal toxicity, and degrees of dryness. Additionally, nitrogen-fixing root nodules may grow as a result of symbiosis with the bacteria Frankia, which does nitrogen fixation. Proteoid roots are present in *Casuarina equisetifolia*, which also associates with vesicular arbuscular mycorrhizae (Upadhyay et al., 2016).

The second-best tree species in terms of height, DBH, crown length, volume, and biomass were *Acacia mangium* (7.87 m), all of which were higher than those of any other tree species. One of the world's species of trees that grows the quickest and can thrive in any wasteland is the acacia. This may be because there are more natural colonisers now that the tree is older. Similar results were reported by Dutta and Agarwal (2002), who discovered that among the other five alien tree species, Acacia was the dominant species in terms of growth performances. According to Banerjee et al. (2004), *Acacia mangium* outperformed all other species in terms of growth characteristics after eight years of planting, followed by *A. holosericea*, *Dalbergia sissoo*, *Albizia procera*, *Pithecellobium dulce*, *Acacia auriculiformis*, and *Gmelina arborea*.

According to the aforementioned results, *Casuarina equisetifolia* must be regarded as the best and dominating tree species among the other species since it fared better in chromite mine debris. Similar findings were observed by Dutta and Agarwal (2002), who found *Casuarina equisetifolia* and *Acacia mangium* as the most suitable tree species in terms of modification of spoil characteristics during the revegetation process in Northern Coal Field Limited (NCL) mine dump area.

Table 2. Growth parameters, volume and biomass of eight-year-old tree species

Treatment	Tree height (m)	Tree DBH (cm)	No. of branches (nos.)	Crown length (m)	Crown spread (m)	Tree volume (m³ tree⁻¹)	Tree biomass (Kg tree⁻¹)
<i>Melia azedarach</i>	7.22	10.21	10.77	3.26	3.02	0.14	58.41
<i>Samanea saman</i>	6.78	10.27	9.13	3.89	2.72	0.13	59.15
<i>Syzygium cumini</i>	6.23	10.70	11.33	4.04	2.88	0.13	64.63
<i>Acacia mangium</i>	7.87	11.52	9.63	4.99	3.43	0.19	75.83
<i>Alstonia scholaris</i>	7.74	9.78	8.87	3.81	2.73	0.13	53.24
<i>Pongamia pinnata</i>	6.24	10.39	9.06	3.62	2.00	0.12	60.66
<i>Casuarina equisetifolia</i>	10.43	13.99	20.27	8.37	4.20	0.35	115.73
<i>Azadirachta indica</i>	6.39	10.09	12.57	4.82	3.07	0.12	56.941
<i>Anacardium occidentale</i>	7.76	11.33	11.53	4.52	3.36	0.18	73.15
<i>Neolamarckia cadamba</i>	6.82	11.26	12.33	4.38	3.18	0.16	72.17
CD (5%)	1.71	1.39	2.49	1.27	0.83	0.05	19.63

Table 3. Simple correlation analysis among different parameters of tree species

Parameters	Tree height	Tree DBH	No. of branches	Crown length	Crown spread	Tree volume	Tree biomass
Tree height	1	0.832627	0.738248	0.84273	0.810047	0.936863	0.853398
Tree DBH		1	0.860424	0.919429	0.818643	0.969051	0.997761
No. of branches			1	0.911579	0.798919	0.87376	0.879266
Crown length				1	0.824512	0.940625	0.935346
Crown spread					1	0.847545	0.817507
Tree volume						1	0.980047
Tree biomass							1

All the correlations are significant at the 0.05 level

It was revealed from Table 3 that, there is significant and positive correlation among all the tree growth parameters. Among the growth parameters of trees, positive and significantly highest correlation was observed between tree DBH and tree biomass i.e. ($r = 0.997761$) followed by tree volume and tree biomass i.e. ($r = 0.980047$). Minimum correlation ($r = 0.738248$) was observed between tree height and number of branches.

Carbon sequestration by tree species

Carbon is considered as 50% of biomass. So, assuming this, carbon content of all the studied trees of the plantation site was calculated. The soil organic carbon was also calculated and resulted data on hectare basis were presented in Table 4.

The carbon content of *Casuarina equisetifolia* (96.44 t ha^{-1}) was found to be maximum and significantly superior over all the tree species. *Acacia mangium* (63.19 t ha^{-1}) was the next best for carbon content and found statistically at par with all other tree species except *Alstonia scholaris* (44.37 t ha^{-1}).

The soil organic carbon content of *Pongamia pinnata* (38.56 t ha^{-1}) was found to be maximum over all the tree species. *Casuarina equisetifolia* (36.48 t ha^{-1}) was the next best for soil organic carbon followed by *Samanea saman*, *Acacia mangium*. The soil organic carbon content of *Syzygium cumini* (29.41 t ha^{-1}) was recorded lowest among all the tree species studied.

The total carbon sequestered by *Casuarina equisetifolia* (132.92 t ha^{-1}) was found to be maximum over all the tree species. *Acacia mangium* (98.76 t ha^{-1}) was the next best for carbon sequestration followed by *Anacardium occidentale*, *Neolamarckia cadamba*. *Alstonia scholaris* sequestered lowest carbon among all the tree species studied.

Table 4. Total carbon sequestration by tree species

Treatments	Total biomass (kg tree ⁻¹)	Total biomass (t ha ⁻¹)	Carbon sequestered by tree (t ha ⁻¹)	Soil organic carbon (SOC) (t ha ⁻¹)	Total carbon sequestration (t ha ⁻¹)
<i>Melia azedarach</i>	58.41	97.36	48.68	31.81	80.49
<i>Samanea saman</i>	59.15	98.58	49.29	36.07	85.36
<i>Syzygium cumini</i>	64.63	107.72	53.86	29.41	83.27
<i>Acacia mangium</i>	75.83	126.38	63.19	35.57	98.76
<i>Alstonia scholaris</i>	53.24	88.74	44.37	33.66	78.03
<i>Pongamia pinnata</i>	60.66	101.11	50.56	38.56	89.12
<i>Casuarina equisetifolia</i>	115.73	192.88	96.44	36.48	132.92
<i>Azadirachta indica</i>	56.94	94.91	47.46	32.26	79.72
<i>Anacardium occidentale</i>	73.15	121.92	60.96	34.88	95.84
<i>Neolamarckia cadamba</i>	72.17	120.26	60.13	34.23	94.36
CD (5%)	19.63	32.73	16.34	--	--

Conclusion

This study perceived that, in general *Casuarina equisetifolia*, *Acacia mangium* and *Anacardium occidentale* exhibit better performance. *Casuarina equisetifolia* recorded highest growth parameter followed by *Acacia mangium*, *Anacardium occidentale*, *Neolamarckia cadamba*, *Syzygium cumini*, *Pongamia pinnata*. In addition to, this species also sequestered more carbon among all the tree species.

References

- Agrawal M, Singh J, Jha AK and Singh JS. 1993. Coal-based environmental problems in a low rainfall tropical region, *Landscape and Urban Planning*, **5**(2): 27-57.
- Anwer M, Hussain I, McNeilly T and Putwain PD. 2001. Amelioration of NPK on metals polluted bare and vegetated sites of Trelogan mine, *Journal of Biological Science*, **1**: 280-283.
- Bahrami A, Emadodin I, Atashi MR and Bork HR. 2010. Land-use change and soil degradation: A case study, North of Iran, *Agricultural Biology Journal of North America*, **1**: 600-605.
- Banerjee SK, Mishra TK, Singh AK and Jain A. 2004. Impact of plantation on ecosystem development in disturbed coal mine overburden spoils, *Journal of Tropical Forest Science*, **16**(3): 294-307.
- Burghardt W. 1993. Böden auf Altstandorten (Soils of contaminated land), 217-229. In Alfred-Wegener-Stiftung (ed.). Die benutzte Erde. Ernst, Berlin.
- Deo B, Nahak G and Sahu RK. 2011. Studies on the uptake of heavy metals by selected plant species growing on coal mine spoils in sub-tropical regions of India, *Journal of American Science*, **7**(1): 26-34.
- Dutta RK and Agrawal M. 2002. Effect of tree plantations on the soil characteristics and microbial activity of coal mine spoil land, *Tropical Ecology*, **43**(2): 315-324.
- Evans, D.M., Zipper, C.E., Hester, E.T., Schoenholtz, S.H., 2015. Hydrologic effects of surface coal mining in Appalachia (US). *J. Am. Water Resour. Assoc.* **51** (5), 1436–1452.
- Fu, Y., Lin, C.C., Ma, J.J., Zhu, T.C., 2010. Effects of plant types on physico-chemical properties of reclaimed mining soil in Inner Mongolia, China. *Chin. Geogr. Sci.* **20** (4), 309–317.
- Hooper J. 1988. Growth performances and mycorrhizae of native and exotic hardwoods on bituminous strip mine spoils, *Ohio Journal of Science*, **79**(6): 109-207.
- Krzaklewski, W., Pietrzykowski, M. (2002). Selected physico-chemical properties of Zinc and lead in tailings and their biological stabilization. *Water Air Soil Poll.*, **141**: 125-142.

- Pensa, M., Sellin, A., Luud, A., Valgma, I. (2004) An analysis of vegetation restoration on opencast oilshale mines in Estonia. *Restoration Ecology* 12(2):200-206.
- Singh AN and Singh JS. 1999. Biomass, net primary production and impact of bamboo plantation on soil redevelopment in a dry tropical region, *Forest Ecology and Management*, **119**: 195-207.
- Singh AN, Raghubanshi AS and Singh JS. 2002. Plantation as a tool for mine spoil restoration, *Current Science*, **82**(12): 56-78.
- Singh, J. S., Jha, A. K. (1992). Restoration of degraded land: an overview. In: J. S. Singh (ed.) *Restoration of Degraded Land: Concepts and Strategies*. Rastogi Publication, Meerut, India. pp.1-9.
- Tordoff GM, Baker AJM and Willis AJ. 2000. Current approaches to the revegetation and reclamation of metalliferous mine wastes, *Chemosphere*, **41**(2): 219–228.
- Upadhyay, N., Verma, S., Singh, A.P., Devi, S., Vishwakarma, K., Kumar, N., Pandey, A., Dubey, K., Mishra, R., Tripathi, D.K., Rani, R., Sharma, S., 2016. Soil Eco physiological and microbiological indices of soil health: a study of coal mining site in Sonbhadra, Uttar Pradesh. *J. Soil Sci. Plant Nutr.* 16 (3), 778–800.
- Zhang, J. T. (2005). Succession analysis of plant communities on abandoned cropland in the eastern lies plateau of chair. *Journal of Arid Environment* 63: 458-474.