Quantification of Ecosystem Services of Plantations Raised on Coal Mine Overburden Dumps for Economic Valuation

V. M. Mhaiske[1]* and A. D. Rane[1]

[1]College of Forestry, DBSKKV, Dapoli, Dist Ratnagiri, Maharashtra - 415712 (India)

Abstract

Extraction and handling of coal in coal mine area results in damaging the ecosystem. Mining activities are known to be directly related to soil degradation through loss of soil structure, accelerated soil erosion, excessive leaching, compaction, reduced soil pH, accumulation of heavy metals in soils, depletion of organic matter, decreased plant-available nutrients, reduced cation exchange capacity, decreased microbial activity, and consequent reduction in soil fertility. Management of mined spoils is important for reclamation plan to reduce nutrient losses, and gradually restoring the soil fertility. Plantation constitutes one of the most widely accepted and important ways to stabilize the fertility of degraded mined lands and restoration of ecosystem. The present review was conducted to quantify the intangible benefits from the plantation raised on coal mine spoils. The results obtained in this study indicated that plantation is one of the efficient means of restoring soil fertility through improvement in soil organic matter content, carbon content, available nutrients, cation exchange capacity, increased biological activities as well as improvement in physical conditions of the soil. However, the economic valuation of these ecosystem services needs to be assessed trough implementing appropriate valuation methods.

Key words: Coal mine spoils, ecosystem services, quantification, plantations.

Introduction

Coal is the most abundant fossil fuel resource present in India which is extracted with both open-cast as well as underground mining techniques. Nearly 8.2 billion tonnes of coal was produced globally in 2014 (Jason 2016). India is the third largest producer of coal in the world (Gupta and Paul 2015). Jharkhand state leads in coal reserves in the country followed by Odisha, Madhya Pradesh, Chhattisgarh, West Bengal, Andhra Pradesh and Maharashtra.

Total production of coal in India was recorded 639.234 (public sector 94.91 % and private sector 5.09 %) (Mt) during 2015-16 showed 4.93% increment over the previous year. Major contributing states for coal production are Odisha (21.7 %), Chhattisgarh (20.4 %), Jharkhand (18.9%), Madhya Pradesh (16.85 %), Telangana (9.44 %), West Bengal (4.02 %), and Maharashtra (6.0 %). Production of coal from opencast mines from all the sources recorded 592.822 (92.73%) Mt whereas underground mining contributed 48.412 (7.27 %) Mt during 2015-16. Annual domestic demand for coal in India was 910 Mt against the production of 639.234 Mt.

Open-cast mining operations involve removal of huge quantities of overburden and subgrade run of mine as well as dumping and backfilling of excavated area. These have given rise to the danger of dump failures, gully erosion and various associated environmental problems such as soil erosion, dust, noise, and water pollution causing impacts on local biodiversity (Campbell 1992).

The large scale land disturbances associated with mining operations and related concerns about the environmental effects have triggered an increasing number of rehabilitation programmes aimed at the restoration of natural ecosystems which were disturbed by mining. Restoration of mine sites often entails amelioration of physical and chemical characteristics of substrate and ensuring the return of vegetation cover (Schaller 1993).

Plantation is the oldest technology for the restoration of lands damaged by human activity (Filcheva *et al.*

***Correspondence**: vinod.mhaiske@gmail.com
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2000). A primary objective for achieving satisfactory rehabilitation of a mined landscape is to establish a permanent vegetation cover (Parrotta *et al.* 1997). Plantations are known to play an important role in restoring productivity, ecosystem stability, and biological diversity to degraded areas (Schaller 1993). It is significant in protecting the soil surface from erosion and allowing the accumulation of fine particles (Bradshaw 1997). Plantation in mining areas play an essential role in water resource management from local to regional levels, in preservation of biodiversity, providing habitat, sequestering and storing carbon, improving physical, biological and chemical properties of soil, increasing aesthetic and recreational value. Watershed protection, erosion prevention, micro climate control, pollution control etc. are the additional benefits of such plantations.

Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. These maintain biodiversity and the production of ecosystem goods such as seafood, forage timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors (Daily 1997). Based on the Millennium Ecosystem Assessment (MEA) (2005) report and Groot de *et al.* (2002), ecosystem functions and services are grouped into four primary categories as follows.

a. Provisioning services **-** It consists of the processes that combine and change organic and inorganic substances through primary and secondary production into goods that can be directly used by mankind.

b. Regulating services - It relate to the capacity of natural and semi-natural ecosystems to regulate essential ecological processes and life support systems through biogeochemical cycles and other biosphere processes.

c. Cultural services **-** Are those services that contribute to human mental well-being. It includes aesthetic and recreational use, spiritual and religious services and cultural heritage.

d. Supporting services - It relate to the importance of ecosystems to provide habitat for various stages in the life cycles of wild plants and animals, which, in turn, maintain biological and genetic diversity and evolutionary processes.

Plantation on coal mine spoils provides numerous tangible and intangible good and services to improve environmental condition of region. Regarding the tangible benefits, wood is the major output in significant volume and it is easy to quantify and economic value can be evaluate based on market price. However, many goods and specially services (intangible benefits) are not traded, but are still great value. Based on the measurability in economic term, ecosystem services benefits may be tangible and intangible. Benefits are those which can be measured directly or indirectly in monetary term by known methods is called tangible benefits. While intangible benefits are those benefits which cannot be measured by acceptable method and involve several unrealistic assumption. This is because such benefits are not traded in the market *viz.* soil and conservation, soil improvement through physical, chemical and biological process, scenic and aesthetic value, research value, educational value, etc.

Before proceeding for the economic valuation of the intangible ecosystem services of the mining plantation, the quantification of all goods and services is essential. The present study has been conducted on the basis of an in-depth review of existing literature on quantification of intangible benefits of plantations on over burden dump in coal mine areas.

Bulk Density

Generally, low bulk densities in soils indicate high organic matter content, good granulation, high infiltration, and good aeration, resulting in a good rooting medium (NRC 1981). Bulk density reduced to the maximum extent in *Dalbergia sissoo* (180.9%) followed by *Azadirachta indica* (133.3%), *Tectona grandis* (63.6%) during 16 years interval of plantations in Singhurili coal mine (Bohre and Chaubey). Bulk density of reclaimed soil were higher than]= the native forest soil (1.18 cm^{-3}). However, lower 1.32 cm^{-3} bulk density was observed under *Pisum sativum* cultivation as compare with untreated spoils 1.67 cm^{-3} (Gudadhe and Ramteke 2012). Bulk density for untreated spoil was 1.45 cm^{-3} and reclaimed soil was found to be reducing from 1.7 cm^{-3} in over bund plantation of year 2003-04 to 1.6 cm^{-3} in over burden plantation of year 2000-01 (Chaubey *et al.* 2012). Untreated mine spoils before plantation was 1.04 (cm^{-3}) and it increased to 1.19 (cm^{-3}) in 11 year old plantations (Shrestha and Lal 2006). Datta and Agarwal (2002) recorded that it ranged from 1.61 gm cm^{-3} to 1.63 gm cm^{-3} in three years plantation. Bulk density ranged in between 1.60 to 1.64 cm^{-3} in coal mine spoils under tree plantation at 5 years age in Jayant block of Singrauli coalfield in Madhya pradesh state (Singh *et al.* 2004). Rai *et al.* (2010) recorded 1.65 to 1.77 (gm cm^{-3}) increment in lemon grass cultivation on overburden samples.

Carbon sequestration

The soil organic carbon plays a major role in biological activity and fertility of the soil. Higher organic carbon increases the soil porosity that supports the growth of the soil microorganisms. The lower level of organic carbon in mine spoils causes disruption of the ecosystem functioning. Organic carbon is important for the sustainability of vegetation (Dragovich and Patterson 1995).

The rate of organic carbon accumulation recorded to 131 kg $ha^{-1}y^{-1}$ in the North Dakota coal basin in the USA (Wali 1999, West and Wali 2002); Anderson 1977) reported, 282 kg $ha^{-1}yr^{-1}$ and Schafer and Nielsen (1979) observed 256 kg $ha^{-1}yr^{-1}$. Annual carbon sequestration rate of revegetated mine spoil of 19 years in Singrauli coal mine was 253.96 t $ha^{-1}yr^{-1}$ and total carbon in different components (*viz.* plant biomass, mine soil and microbial biomass) was found to be 69.21 t ha^{-1}. The contribution of total plant biomass, mine soil and soil microbial biomass was 44.52 t ha^{-1} (64.33%), 22.89 t ha^{-1} (33.08%), and 2.59 t ha^{-1} (2.59%), respectively (Tripathi et al. 2014). Akala and Lal (2001) recorded carbon sequestration rate in the forest treatment ranged from 0.3 to 2.3 mg $ha^{-1}y^{-1}$ over the 21 years period in reclaimed mine soils in Ohio, USA. Greatest accretion rates of organic carbon in treated mine spoils found in five year old *D. strictus* (1459.9 kg $ha^{-1}y^{-1}$) and least in *T. grandis* plantations (153.4 kg $ha^{-1}y^{-1}$) (Singh et al. 2006). Shrestha and Lal (2006) recorded 0.1 to 3.1 mg/ha/yr and 0.7 to 4 mg $ha^{-1}y^{-1}$ in grass and forest reclaimed mine soil ecosystem, respectively.

Carbon accumulation rate in the lower Lusatia basin mine district (Germany) reclaimed land under pine tree plantation was 6.5% at the age of 32 years (Rumpel et al. 1999). Varela et al. (1993) reported 3.0% organic accumulation after five years of reclamation. Organic carbon increased from 0.63 % to 0.92 % after restoration of coal mine spoils during three year span (FRI 2015). Banergee et al. (2004) observed 0.72% accumulation under *Pongamia pinnata* and 0.70% under *Albizia procera* plantation at Bisrampur, Surguja mine. Mukhopadhyay et al. (2016) observed soil organic carbon content was maximum 23.59 mg kg^{-1} in *Cassia siamea* plantation in rejuvenated sites whereas it was 11.13 mg kg^{-1} in untreated mined spoils in Jharia, Jharkhand. Dissolved organic carbon increased from 28.5 mg kg^{-1} to 63.4 mg kg^{-1} in *Dalbergia sissoo* plantation. Microbial biomass carbon increase from 174 mg kg^{-1} to 480 mg kg^{-1}, active microbial carbon increased from 17.8 mg kg^{-1} to 52.2 mg kg^{-1}, microbial biomass carbon and soil organic carbon ratio increased from 0.016 to 0.020 (Mukhopadhyay et al. 2016). Shrestha & Lal (2006) observed increase in C/N ratio from 9.3 to 15.2 in 10 years reclaimed site with plantation.

Organic carbon in mine spoil under different tree cover, increased during 16 years interval in *Dalbergia sissoo* (358%) followed by *Azadirachta indica* (317.8%), *Pongamia pinnata* (273.8%), *Tectona grandis* (233.3%) and others (Bohre & Chaubey, 2014). Singh et. al. (2004) reported increase (3778 to 5833 mg kg^{-1}) with increase in the age (4 to 6 years) of native tree plantation on mine spoils in dry tropical environment. Similar findings also recorded by Akala and Lal (2001) that soil organic carbon pool increased from 8.4 mg ha^{-1} to 48.4 mg ha^{-1} in 21 year mine soils in Ohio. Total carbon stock at 0-20 cm spoil depth in 4 to 5 year old plantations varied from 8649 to 11128 kg ha^{-1} in *A. lebbeck*, from 4294 to 6582 kg ha^{-1} in *A. procera*, from 3674 to 3808 kg ha^{-1} in *T. grandis* and from 7516 to 10759 kg ha^{-1} in *D. strictus*, respectively (Singh et al. 2006). Dutta and Agrawal (2002) observed increased in organic carbon from 0.46% to 0.60% in *A. auriculiformi* plantation. After 22-25 years reclamation, soil organic carbon differed significantly among forest reclaimed mined soils, ranging from 11.66 to 69.10 mg ha^{-1} (Ye Yuan et al. 2017). Jacinthe et al. (2004) observed higher soil organic carbon concentration in mine reclaimed hardwood plantation than reclaimed grassland (81 vs. 71 mg C ha^{-1}). Value of carbon content in ground flora was found minimum 0.169 t ha^{-1} in 2 year old plantation at Dudhichua and maximum 0.997 t ha^{-1} in 16 year old plantation at Amlohri of Singrauli coalmines Bohre et al. (2012). Soil organic carbon concentration ranged from 2.30 to 7.25 g kg^{-1} at 0-10 cm soil depth in 4 to 5 year old plantations on mine spoil, with the maximum in *A. lebbeck* (7.25 g kg^{-1}) and the minimum in *T. grandis* (2.30 g kg^{-1}) plantation (Singh and Zeng 2008).

Nitrogen

Nitrogen is the most important nutrient and is required in the greatest amounts by plants. It has a special place in soil processes because it does not occur in a mineral form, and is, therefore, absent from the primary minerals (Bradshaw 1997). Therefore, nitrogen is a key element in soil restoration (Bradshaw and Chadwisk, 1980, Kendle and Bradshaw, 1992). Lower rate of nitrogen accumulation (14.8 kg ha^{-1} yr^{-1}) for organic and mineral horizons in mine soils in North America was recorded by (Schafer and Nielsen, 1979). Ender *et al*. (2011)

recorded 83 to 114 kg ha^{-1} nitrogen in 17 years old age plantation and Gudadhe et al. (2012) reported 669.33 kg ha^{-1} nitrogen after plantation in Chandrapur mining area. Nandeshwar et al. (1996) reported total nitrogen accumulation 40 kg ha^{-1} at 8 to 15 years and 90 kg ha^{-1} to 140 kg ha^{-1} at 15 to 25 years age in coal mine overburden at Singrauli. The available nitrogen increased from 311.2 kg ha^{-1} to 315.5 kg ha^{-1} after four year of plantation (Chaubey et al., 2012). Nitrogen pools 945.14 to 3145.83 kg ha^{-1} was recorded in reclaimed mine soils under 25 year plantation (Ye Yuan et al., 2017). In rejuvenation Jharia coal mines nitrogen content increased from 35.8 mg kg^{-1} to 105 mg kg^{-1} (Mukhopadhyay 2016). The improvement during the period of 16 years reported in *Pongamia pinnata* (227.9%) followed by *Azadirachta indica* (143.9%), *Dalbergia sissoo* (157.7%), *Tectona grandis* (127.8%) (Bohre and Chaubey 2014).

The nitrogen content had increased from 0.005% to 0.014 % in rejuvenated mined spoils in Tetulmari area (FRI 2015). Jha and Singh (1991) reported an increase of 26.5 % of total nitrogen between 5 and 20 years under naturally colonised condition in coal mine spoils. The total nitrogen content in soil around different plantations (0.047-0.062%) is comparable to the results of Srivastava and Singh (1988) who found 0.078% total N in twelve years old naturally vegetated over burden (Chaubey et al., 2012). Total nitrogen increased by 1.3 to 5.6 times after eight year of plantation ranged from 27 ppm to 207 ppm. Available nitrogen was enhanced by 2.6 to 9 times during the 8 years of plantation at Bisrampur, Surguja mines (Banergee et al., 2004). Higher values (0.047 to 0.062 %) of total nitrogen as compared to fresh mine spoil (0.028 %) recorded by Dutta and Agrawal (2002). Srivastava et al. (1989) found lower concentration of total nitrogen in 5 year old mine spoil (20 µg g^{-1}) in comparison to forest soil (75 µg g^{-1}).

Nitrogen accretion rates were found higher under *D. strictus* (105.6 kg $ha^{-1}y^{-1}$) at 0-10 cm spoil depth followed by *A. procera* (80.3 kg $ha^{-1}y^{-1}$), *A. lebbeck* (23.7 kg $ha^{-1}y^{-1}$) and *T. grandis* (7.0 kg $ha^{-1}y^{-1}$), respectively, at 5 years of age (Singh et al. 2006). Jencks et al. (1982) found increasing soil N concentrations with age and estimated annual rates of N accretion under N-fixing black locust (*Robinia pseudoacacia*) of 222 kg $ha^{-1}y^{-1}$ at 5-7 years old, 146 kg $ha^{-1}y^{-1}$ at 10-14 years old and 171 kg $ha^{-1}y^{-1}$ at 16-18 years old. Total Kjeldahl Nitrogen (TKN) concentrations in all plantations of 4 to 5 year old age varied from 0.24 to 0.70 g kg^{-1} at the soil depth of 0-10 cm, with the maximum in *A. lebbeck* (0.70 g kg^{-1}) followed by *D. strictus* (0.67 g kg^{-1}) and *A. procera* (0.46 g kg^{-1}) and the minimum in *T. grandis* (0.24 g kg^{-1}) plantation (Singh and Zeng 2008). Singh et al. (2004) reported ranged between 454 to 574 mg kg^{-1} in mine spoils native tree plantation of 4 to 6 year old under dry tropical environment.

Arvind (2014) found that the foliar nitrogen concentration in mature leaf of leguminous species was between 2.08 % to 2.26% whereas, it was 1.17 to 1.97% in non-leguminous species. Furthermore, the foliar nitrogen concentration in senesced leaves of leguminous species ranged between 1.14 and 1.45% while it ranged between 0.60 and 0.96% in non-leguminous species. The nitrogen resorption efficiency was greater in non-leguminous tree species (56.46 to 69.19%) than the leguminous tree species (53.01 to 55.15%).

Phosphorus

Phosphorus plays a role in the photosynthesis, respiration, energy storage and transfer, cell division, cell enlargement and several other properties in the living plant. Phosphorus is an essential element for plant growth, but deficient in colliery spoil sites. It primarily accumulates in soil as a result of microbial activity, and becomes available through mineralization to inorganic phosphorus (Dalal 1977). Phosphorus moves slowly through soils (Blair 1976) and availability in soils may result from variable microbial activity (Clark et al. 1969). The foliar phosphorus concentration in mature leaf of leguminous species ranged from 0.170 to 0.188% while it was between 0.120 to 0.179 % in non-leguminous species. Moreover, the foliar phosphorus concentration in senesced leaf of leguminous species ranged between 0.071 and 0.094% whereas it ranged between 0.085 and 0.103% in non-leguminous tree species (Arvind Singh 2014).

Gudadhe et al. (2012) estimated 19.76 kg ha^{-1} phosphorus in coal mine spoils after plantation in Chandrapur mining area of Maharashtra state and Mukhopadhyay et al. (2016) recorded increased from 3.40 mg kg^{-1} to 9.44 mg kg^{-1} under *Dalbergia sisoo* plantation in Jharia mine area of Jharkhand state. Similar trends were also observed by Chaubey et al. (2012) and observed increased from 8.38 kg ha^{-1} to 9.25 kg ha^{-1} in three years plantation. Increase (163 to 201 mg kg^{-1}) in the phosphorus with increase in the age (4 to 6 years) of native tree plantation on mine spoils in dry tropical environment was reported by Singh et al. (2004). Total phosphorus among the four plantation species ranged from 0.12-0.19 gm kg^{-1} in 4 to 5 year old plantations on mine spoil in Singrauli (Singh and Zeng 2008). Singh et al. (2006) also recorded increase in phosphorus with plantation age from 212.75 kg/ha/year to 291.7 kg/ha/year.

The values of available phosphorus found during study was 0.0098 to 0.017% as compared with fresh mine spoil 0.010% (Dutta and Agrawal, 2002). Available phosphorus reduced from 0.66% to 0.002% in three year old age plantation in Tetulmari coal mine area, Dhanbad (FRI, 2015). Accretion rates of total P in rejuvenated mine spoils was greatest under five year old *T. grandis* (55.8 kg $ha^{-1}y^{-1}$) and least under *D. strictus* plantation (0.8 kg $ha^{-1}y^{-1}$) at 0-20 cm spoil depth (Singh et al. 2006). The improvement during the period of 16-years in terms of available phosphorus was maximum in *Dalbergia sissoo* (199.8%) followed by *Azadirachta indica* (62.1%), *Pongamia pinnata* (52.4%) *Tectona grandis* (17.7%) (Bohre and Chaubey 2014).

Potash

Potash which refers to mined or manufactured mineral salts containing potassium, is crucial for producing high quality crops and good harvests. It has multiple roles in boosting crop yield, helping plants withstand harsh environments such as frost and cold temperatures, moisture stress, and disease incidence. It also catalyzes the roles of key nutrients, such as nitrogen and phosphorus, and helps in enzymatic reactions in plant cells. Mukhopadhyay (2016) in Jharia coal mine area observed increased in potash from 84.7 mg kg^{-1} to 98.7 mg kg^{-1} *Cassia siamea* plantation. A team of FRI (2015) noticed potash reduced from 0.012 % to 0.053 % in three year plantation at Tetulmari coal mine area, Dhanbad. Chaubey et al. (2012) reported increasing trend of potash from 81.76 kg ha^{-1} to 113.77 kg ha^{-1}. The improvement during the period of 16-years in terms of available potassium was maximum in *Dalbergia sissoo* (262.2%) followed by *Pongamia pinnata* (190.3%), *Tectona grandis* (133%), *Cassia siamea* (121.1%), *Azadirachta indica* (92.3%) in Singuruli coal mine (Bohre and Chaubey, 2014).

Calcium

Calcium (Ca) is considered a secondary plant nutrient. Every plant needs calcium to grow. Once fixed, calcium is not mobile in the plant. It is an important constituent of cell walls and can only be supplied in the xylem sap. Thus, if the plant runs out of a supply of calcium, it cannot remobilize calcium from older tissues. If transpiration is reduced for any reason, the calcium supply to growing tissues will rapidly become inadequate. The Ca of reclaimed soil was found to increase from 118.4 kg ha^{-1} to 338.75 kg ha^{-1} in four year plantation (Chaubey et al. 2012). The improvement during the period of 16-years in terms of calcium was maximum in *Tectona grandis* (154%) followed by *Dalbergia sissoo* (115.9%), *Pongamia pinnata* (113%), *Cassia siamea* (35.9%), *Azadirachta indica* (33.8%) in treated spoils in Singhruli mine (Bohre and Chaubey 2014).

Organic matter

High level of organic matter in mine spoil is expected to improve aggregation and infiltration capacities and increase the availability of nutrients (NRC 1981). Omodt et al. (1975) pointed out that organic matter is influential in augmenting and enhancing plant growth. Soil organic carbon is a function of the quantity of dry matter deposition as litter fall. Study of Ender and associate (2011) showed that organic matter in forest floor of mines spoils reclaimed with maritime pine, black locust and umbrella pine was 4274 kg ha^{-1} to 14641 kg ha^{-1} after 17 year of plantation. Similar results were also recorded by Chaubey et al. (2012) that organic matter increased from 1.55% to 1.627% in four year plantation.

Specific gravity

The specific gravity of soil is an important weight-volume property that is helpful in classifying soils and in finding other weight-volume properties like void ratio, porosity, and unit weight. Lemon grass growth on overburden samples was tested by Rai and Associates (2010) found that specific gravity of soil sample was range between 2.25 to 2.34.

Sodium

The Na of reclaimed soil was found to vary from 19.00 kg ha^{-1} in over burden plantation of year 2003-04 to 21.14 kg ha^{-1} in OB plantation of year 2000-01 (Chaubey et al. 2012).

Heavy metal

Living organisms require varying amounts of heavy metals. Iron, cobalt, copper, manganese, molybdenum, and zinc are required by humans. All metals are toxic at higher concentrations. Excessive levels can be damaging to the organism. Other heavy metals such as mercury, plutonium, and lead are toxic metals that have no known vital or beneficial effect on organisms, and their accumulation over time in the bodies of animals can cause serious illness. As concentration of heavy metals like Cu, Zn, Fe, and Mn is concerned, it showed the decreasing trend with increasing the age of plantations (Chaubey et al., 2012). Similar trend was also reported by Bohre and Chaubey (2014) that their concentration in soil of rhizosphere decreases with increasing the age of the plantations.

pH

A team of FRI, Dehradun (2015) reported change in pH from 6.0 to 7.14 after the restoration work in the span of three years in the mine spoils at Tetulmari under Sijua area of BCCL, Jharkhand state. The pH of reclaimed soil was found to be increasing from 6.30 to 6.68 in four year plantation in Singrauli coalfield area (Chaubey et al. 2012). At Jayant open cast, NCL, Sidhi, pH was 6.40 and it was increased to the neutral (6.61 to 6.86) in three year plantation (Dutta and Agrawal, 2002); at five years age pH recorded between 6.59 to 7.22 (Singh et al. 2004); The pH values recorded before plantation in coal mine spoil was 8.22 and increased 8.96 (Gudadhe et al. 2012); Arvind Kumar Rai et al. (2010) recorded pH 4.74 to 5.86 in lemon grass plantation in dump spoils. Ender et al. (2011) recorded pH 4.45 to 7.57 from soil depth 1 cm to 50 cm under maritime pine, black locust and umbrella pine 17 years plantation on mines spoils. Mukhopadhyay and associates (2016) recorded in un-reclaimed site was 6.10 and under plantation it was ranged between 5.80 to 6.63. The pH has improved to a great extent in *Dalbergia sissoo* (30.5%) followed by *Azadirachta indica* (28.1%), *Pongamia pinnata* (23.8%), *Tectona grandis* (22.5%) and others after 16 years interval of plantations at Singrauli mine (Bohre and Chaubey 2014).

Electric conductivity

Soil electrical conductivity (EC) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, Cation Exchange Capacity (CEC), drainage conditions, organic matter level, salinity and subsoil characteristics. The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity, and clays have a high conductivity (Arvind Kumar Rai et al. (2010). Electrical conductivity was found minimum before plantation in coal mine spoil (216 μ S cm^{-1}) and it increased (222 μ S cm^{-1} to 239 μ S cm^{-1}) after plantation in the coal mine spoil (Gudadhe et al., 2012). Increased EC from 0.103 dS m^{-1} to ranged 0.157 dS m^{-1} to 0.173 dS m^{-1} under lemon grass plantation recorded by Arvind kumar Rai et al. (2010). Mukhopadhyay et al. (2016) recorded 0.811 dS m^{-1} to 0.928 dS m^{-1} in rejuvenated coal mines as compare with un-reclaimed site 1.51 dS m^{-1}. Shrestha and Rattan Lal (2006) showed that EC increased from 0.19 dS m^{-1} to 0.26 dS m^{-1} 24 years plantation on mine spoils. The EC of reclaimed soil was found to be improving from 0.059 ms cm^{-1} in to 0.070 ms/cm in four year OB plantation (Chaubey et al. 2012). Similar increasing trend recorded by Bohre and Chaubey (2014) that EC has improved in 16 years interval in *Tectona grandis* (233.3%) followed by *Azadirachta indica* (220%), *Dalbergia sissoo* (142.9%), *Cassia siamea* (90%) and *Pongamia pinnata* (83.3%) at Singgrauli coal mine.

Soluble Cations

Soluble cations of Ca^{++}, Mg^{++}, Na^{+} and K^{+} increased after plantation in coal mine spoil than before plantation. Ca^{++} increased from 0.47 me l^{-1} to 0.54 me l^{-1}, Mg^{++} increased from 0.026 me l^{-1} to 0.052 me l^{-1}, Na^{+} increased from 0.43 me l^{-1} to 0.53 me l^{-1} and K^{+} 0.065 me l^{-1} to 0.078 me l^{-1} (Gudadhe et al. 2012).

Cation Exchange Capacity

The mineral fertility of the soil depends on cation exchange capacity as the cations are contained in a form in which they are not easily leached by water. Sandy soil has low exchange capacity and consequently has low fertility. The CEC was positively changed after plantation in coal mine spoil from 2.30 meq 100 g^{-1} to 2.50 meq 100 g^{-1} (Gudadhe et al. 2012).

Sand

Sand particles are visible to the naked eye, gritty in feeling, having little or no capacity to hold water or nutrients, and bind other particles. They are loose when wet, very loose when dry. Sand does not absorb water and does not exhibit swelling and shrinkages, stickiness and plasticity. The percentage of sand was lower after plantation in plots of different plant species (64.67%-65.23%) as compared to before plantation of coal mine spoil (67.72%) (Gudadhe et al. 2012). Singh et al. (2004) recorded the contribution of sand in coal mine spoils under tree plantation at five years age was between 77.57 to 84.00%. Less proportion of sand found in plots of different plant species (81.41-84.95%) as compared to fresh mine spoils (89.30%) (Dutta and Agrawal 2002).

Silt

Most silt particles are not visible to the naked eye, but can be seen through an ordinary microscope. They feel smooth when wet and like talcum powder when dry. They have low to medium capacity to attract water, nutrients and other particles. Because of adhering film of clay, they exhibit some plasticity, cohesion, adhesion and absorption and can hold more amount of water than sand but less than clay. Contribution of silt were found higher (24.07% to 24.87%) after plantation in the planted plots as compared to before plantation of coal mine spoil (23.14%) (Gudadhe et al., 2012). Dutta and Agrawal (2002) reported that contribution of silt (12.35-13.60%) was found higher in the planted plots compared to fresh mine spoil (8.2%) in Jayant open cast mining of Northern coal limited Sidhi. Silt percentage in coal mine spoils under tree plantation at 5 years age in Jayant block of Singrauli coalfield was ranged 77.57 to 84.00 % (Singh et al. 2004).

Clay

Clay particles can be seen by an electron microscope and have large surface area. They have electrical charges, both negative and positive, on their surfaces. Because of these properties, clays have high water and nutrient holding capacity and they participate in chemical reactions in the soil. Percentage of clay in five years age plantation on mine spoils was 10.7-21.2 % (Jha and Singh 1991). Gudadhe et al. (2012) reported increased clay from 9.14% to 10.21-11.26%. Clay proportion recorded in fresh mine soil was 2.50% and it was increased in three years plantation showed the range 2.70 to 5.02% (Dutta and Agrawal 2002). Clay contribution ranged in between 8.33 to 16.16 % in coal mine spoils under tree plantation at 5 years age in Jayant block of Singrauli coalfield (Singh et al. 2004).

Water holding capacity

The amount of water holding capability in soil is one of its important characteristics. It rises in soil when soil texture moves from sand to clay. The increment in water holding capacity from 29.26% to 34.01% in comparison to before plantation in coal mine spoil may be attributed to the establishment of plant cover (Gudadhe et al. 2012). Water holding capacity recorded in un-reclaimed site was 25.00% and under three years plantation it was ranged between 27.98 to 35.01 (Dutta and Agrawal 2002). Chaubey et al. (2012) reported water holding capacity increased from 25.06% to 47.74% in over burden plantation in Singrauli coalfield area.

Porosity

Soil porosity refers to the amount of pore, or open space between soil particles. Pore spaces may be formed due to the movement of roots, worms, and insects; expanding gases trapped within these spaces by groundwater; and/or the dissolution of the soil parent material. Soil porosity is important for many reasons. A primary reason is that soil pores contain the groundwater that many of us drink. Another important aspect of soil porosity concerns the oxygen found within these pore spaces. All plants need oxygen for respiration, so a well-aerated soil is important for growing crops. Compaction by construction equipment or our feet can decrease soil porosity and negatively impact the ability of soil to provide oxygen and water. Soil porosity attributes to the fragmentation, redistribution and aggregation of the particles due to vegetation development.

Porosity was found 44.52% under control, and it was ranged between 39.48 to 41.39% under various treatment of lemon grass plantation on over dump material (Arvind Kumar Rai et al, 2010). After plantations in coal mine spoil porosity decreased from 59.4% to 51.4% (Gudadhe et al. 2012). Decrease in the porosity also noticed by Dutta and Agrawal (2002) in three year plantation on mine spoils in Northern Coal Limited, Sidhi, Madhya pradesh state. Porosity in plantation ranged in between 38.49% to 40.34% as compare with fresh mine spoil 45.20%.

Soil Moisture

Soil moisture is very much important for hydrological, biological and biogeochemical processes. Soil moisture is a key variable in controlling the exchange of water and heat energy between the land surface and the atmosphere through evaporation and plant transpiration. Dutta and Agrawal (2002) investigated on effect of tree plantations on the soil characteristics and microbial activity of coal mine spoil land in Jayant open cast mining of Northern Coal Limited, Sidhi. The study suggested that the moisture percentage has increased and was ranged in between 7.42% to 8.95% as compare with fresh mine spoil (6.83%).

Microbes

Soil microbial biomass is a sensitive indicator to respond changes of soil environment and could provide accurate and rapid information of revegetated soil quality. It has an important role in decomposition and nutrient cycling. Evaluating soil microbe populations and their metabolic activity may be utilized to determine the stability of a restored ecosystem. Soil microbe populations are one of the important soil components and exhibit great metabolic versatility and high adaptability to the low nutrient levels and adverse chemical characteristics of mine wastes (Singh et al. 1989) and Tripathi and Singh (2007) stated that microbial biomass acts as source of plant nutrients in dry tropical soils of India. During the eight years, the microbes increased ranging from 38 to 2810 times for bacteria, 702 to 4135 times for actinomycetes and 833 to 1066 times for fungi in disturbed coal mine overburden spoils at Bisrampur, Surguja mine (Banerjee et al. 2004).

Conclusion

From the review, it can be concluded that rejuvenation through forest plantation on coal mine spoils can improve the physical, chemical and biological properties and create better environment through controlling air, water, noise, and soil pollution, improve biodiversity, reduce temperature, increase rainfall, improve micro climate, etc. All these intangible benefits play important role to combat climate change problem of country but economic valuation of such benefits are not practiced in India. Knowing the importance of intangible benefits for environmental conservation of the country it is need to be assessed in economic term by using appropriate method(s). Importance (tangible and intangible value) of goods and services provided by coal mine plantations can be measured and this information can be used to optimize and finance sustainable management of plantations. Further it is suggested that before proceed for the economic valuation of the tangible and intangible ecosystem services of the mining plantation, the quantification of all goods and services is essential to get the correct monetary value.

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