Effect of tree plantations on soil organic carbon in Wardha coalfields of Maharashtra, India

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ABSTRACT

Degradation of local environment due to mining activities is a serious global problem. A huge area of land all over the world has been converted into unproductive lands due to unscientific mining. Ecological restoration through plantations is one of the most effective ways to stabilize the degraded ecosystem in the area. In the present investigations soil organic carbon (SOC) in coal mine spoil and native soil under plantations in Wardha coalfield area of Maharashtra state of India was assessed. Total 64 soil samples (surface and subsurface) were collected from the Chandrapur, Wani and Wani North area of the Western Coalfield Limited, Nagpur, Maharashtra in 2017. The data on SOC of plantations raised on overburden (OB) mine spoil and the native soils were compared with each other. Results of the study showed that an average of 0.83 per cent SOC was found in surface soil and 0.51 per cent in subsurface soil averaging 0.68 per cent SOC in the soil of 0-30 cm depth. Further SOC was found more (0.81%) in native soil than OB spoil (0.68%) soil with an increment by 19.11 per cent over OB spoil. Average SOC in 0-30 cm depth was recorded maximum in Chandrapur (0.82%) followed by Wani (0.74%) and Wani North area (0.55%). It was found that SOC increased with age of plantationss and decreased with soil depth.

Keywords: Plantation; coal mine; SOC; overburden dump; soil; spoil

INTRODUCTION

Coal is the most abundantly found fossil fuel and energy resource in India. The extraction of coal is mainly carried out by opencast as well as underground mining techniques. Nearly 8.2 billion tonnes of coal was produced globally in 2014 (Hayes 2016). India is the third largest producer of coal in the world (Gupta and Paul 2015). Total production of coal in India was recorded 639.23 MT during 2015-16 out of which 94.91 per cent was contributed by public sector. In India production of coal from opencast mines was recorded to the tune of 592.82 MT (92.73%) whereas underground mining contributed only 48.41 MT (7.27%) in 2015-16 (Anon 2017a).

Opencast coal mining causes a number of environmental challenges including soil erosion, dust, water pollution, loss of nutrient qualities, microbial activities of the soil system and ultimately impacts on local floral diversity. Mining operations degrade significant areas of land and replace existing ecosystems with undesirable waste materials in the form of mine spoil dumps as reported by Singh et al (2004).

Mine spoils are not suitable for both growth and development of plant life because of low organic matter content, unfavourable pH, drought arising from coarse texture or oxygen deficiency due to compaction (Agrawal et al 1993). The limiting factors for revegetation of mine spoil may be salinity, acidity, poor water holding capacity, inadequate supply of plant nutrients and accelerated rate of erosion (Jha and Singh 1991). The physico-chemical properties of OB dump materials are site-specific and differ from one dump to another due to different geological deposits of rocks (Lovesan et al 1998).

Sustainable mine restoration programme requires establishment of self-sustainable ecosystem by means of improved ecosystem structure and function with respect to ecological integrity (Stroo and Jencks 1982). Plantation is the oldest technology for the restoration of lands damaged by human activity (Filcheva et al 2000).

The primary objective for achieving satisfactory rehabilitation of a mined landscape is to establish a permanent vegetation cover (Parrotta 1992). Plantations are known to play an important role in restoring productivity, ecosystem stability and biological diversity to degraded areas (Schaller 1993). Vegetation has an important role in protecting the soil surface from erosion and allowing accumulation of fine particles (Mensah 2015). A satisfactory rehabilitation of a mined landscape demands a permanent vegetation cover that will prevent soil erosion permitting in the long-term sustainable soil development as reported by Seaker and Sopper (1984).

In the present study an attempt was made to investigate SOC under tree plantations raised in Wardha coalfield area of Western Coalfield Limited, Nagpur, Maharashtra, India. A comparative assessment of SOC in various aged plantations raised on overburden spoils and native soil was done.

METHODOLOGY

Wardha coalfield covering an area of about 700 sq km lies in the Yavatmal and Chandrapur districts of Maharashtra state. It is surrounded with latitude 20° 29′ 06′′ to 20° 48′ 22′′ and longitude 79° 09′ 15′′ to 79° 26′ 39′′ and located in the central part of India. The study area comprised archean age of rocks which are rich in lime stone, clays, granites, gneisses, quartzites, magnesites, laterites, sandstones etc. The soils are red as well as black cotton soils with high percentage of clay. The area has almost flat to gently undulating topography. The general slope of the area is towards south. The area is drained mainly by the Wardha, the Penganga and the Erai rivers (Anon 2017b). The climate of the region is extremely hot with maximum summer temperature reaching to 48°C and winter temperature droping to 7°C. About 80-85 per cent of the annual rainfall comes during the monsoon season with an average of 930 mm in Yavatmal and 1,249 mm in Chandrapur district. The forests of the Chandrapur and Yavatmal districts belong to southern tropical dry deciduous forests.

Western Coalfields Limited has been carrying out extensive plantations of tree species since 1989 to ameliorate the environment. These plantations have been raised on overburden dumps (OB) and their slopes, back-filled areas, roadside, staff colony, office premises, hospitals guesthouses etc. The total area under plantations was about 2,250 ha of which 1,195 ha was in Chandrapur, 601 ha in Wani and 454 ha in Wani North. The age of the tree plantations varied from 1-28 years in Chandrapur and Wani areas and 1-24 years in Wani North area. The plantations included multipurpose fruit bearing, medicinal, timber, ornamental, non-timber and nitrogen fixing tree species viz *Tectona grandis*, *Dalbergia sissoo*, *Albizia procera*, *Peltophorum pterocarpum*, *Acacia catechu*, *Azadirachta indica*, *Cassia siamea*, *Emblica officinalis*, *Eucalyptus* spp, *Pongamia pinnata*, *Gmelina arborea*, *Acacia auriculiformis*, *Delonix regia*, *Albizia lebbeck*, *Bombax ceiba*, *Acacia nilotica*, *Leucaena leucocephala*, *Gliricidia sepium* and bamboo species.

Present investigations were conducted in tree plantations raised in Chandrapur, Wani and Wani North of Wardha coalfield area. Total 64 sampling locations (Fig 1) were randomly selected based on age group, species composition (timber and non-timber), site characteristics (OB and native soil) and slope and aspect of land. Considering the age of the plantations, trees were grouped into six age classes (1-5, 6-10, 11-15, 16-20, 21-25, 26-30 years).

Soil samples from surface (0-15 cm) and subsurface (15-30 cm) strata were collected from the permanent plots (10 x10 m) marked in the tree plantations raised on coalmine overburden dumps and native soil. For each replicate one composite sample was prepared by mixing three sub-samples collected from three different sites under the respective tree canopy cover. The collected samples were air-dried at room temperature in the laboratory, crushed with mortar and pestle and passed through 2 mm sieve. The mine spoil and native soil samples were analyzed for the soil organic carbon by Walkley and Black method as described by Jackson (1973) and Piper (1950).

RESULTS and DISCUSSION

SOC in surface and subsurface soil

SOC in soil samples collected from plantations of the age group 1-5, 6-10, 11-15, 16-20, 21-25 and 26-

Table 1. Soil organic carbon content (%) in native soil and OB spoil under plantation raised in Wardha coalfield area, Maharashtra

Site	Surface/ subsurface	Age of plantation (years)						Average (study site)	Overall average
		1-5	6-10	11-15	16-20	21-25	26-30		
Chandrapur								0.82	
	Native								
	Surface	1.17	0.73	0.94	1.14	1.37	1.43		1.13
	Subsurface	0.51	0.28	0.66	0.75	1.13	1.15		0.75
	OB								
	Surface	0.20	0.79	0.65	0.83	0.95	1.75		0.86
	Subsurface	0.13	0.50	0.28	0.29	0.71	1.40		0.55
Wani								0.74	
	Native								
	Surface	0.74	0.99	1.09	0.71	1.29	1.05		0.98
	Subsurface	0.24	0.65	0.41	0.34	1.11	0.67		0.57
	OB								
	Surface	0.61	0.58	0.75	1.17	0.82	1.44		0.89
	Subsurface	0.13	0.06	0.47	0.85	0.51	1.18		0.53
Wani North								0.55	
	Native								
	Surface	0.54	0.93	0.77	1.14	0.77	*		0.83
	Subsurface	0.22	0.42	0.48	0.67	0.71	*		0.50
	OB								
	Surface	0.51	0.44	0.67	0.34	0.96	*		0.58
	Subsurface	0.22	0.21	0.33	0.17	0.68	*		0.32
Average									
	Surface	0.62	0.74	0.81	0.88	1.02	1.41		0.83
	Subsurface	0.24	0.35	0.43	0.51	0.80	1.10		0.51
	Native	0.57	0.66	0.72	0.79	1.06	1.07		0.81
	OB	0.30	0.42	0.52	0.60	0.77	1.44		0.68
Overall average		0.43	0.54	0.62	0.69	0.91	1.25		0.68

*Age group not found

	$CD_{0.05}$	$CD_{0.01}$	SE±
Site	2.17	2.59	1.10
OB/native	1.77	2.33	0.90
Surface/subsurface	1.77	2.33	0.90
Age	3.07	4.04	1.55

30 years was found to be 0.62, 0.74, 0.81, 0.88, 1.02 and 1.41 per cent in surface strata and 0.24, 0.35, 0.43, 0.51, 0.80 and 1.10 per cent in subsurface strata respectively. Surface soil showed an average of 0.83 per cent and subsurface soil 0.51 per cent SOC with 22.44 per cent more in surface samples. SOC in surface and subsurface soil samples was observed maximum in 26-30 years age group which gradually decreased with decrease in age of plantations (Fig 2).

Hernandez et al (2009) mentioned that the upper layers of soil generally have more favorable conditions for microbial activity in the processes of OM decomposition which corroborates the results of present study with higher content of SOC in surface than subsurface soil samples. The results are also in agreement with the studies conducted by Nall (2009) who observed less SOC in subsurface than surface soil samples.

SOC in native soil and OB spoil

Native soil recorded 0.57, 0.66, 0.72, 0.79, 1.06 and 1.07 per cent and OB spoil recorded 0.30, 0.42, 0.52, 0.60, 0.77 and 1.44 per cent SOC under the tree plantations of age groups 1-5, 6-10, 11-15, 16-20, 21-25 and 26-30 years respectively. SOC in native soil (0.81%) was recorded more than OB spoil (0.68%) among the selected age group plantations (Fig 3). SOC continuously increased with increase in age of the plantations irrespective of plantation sites which could

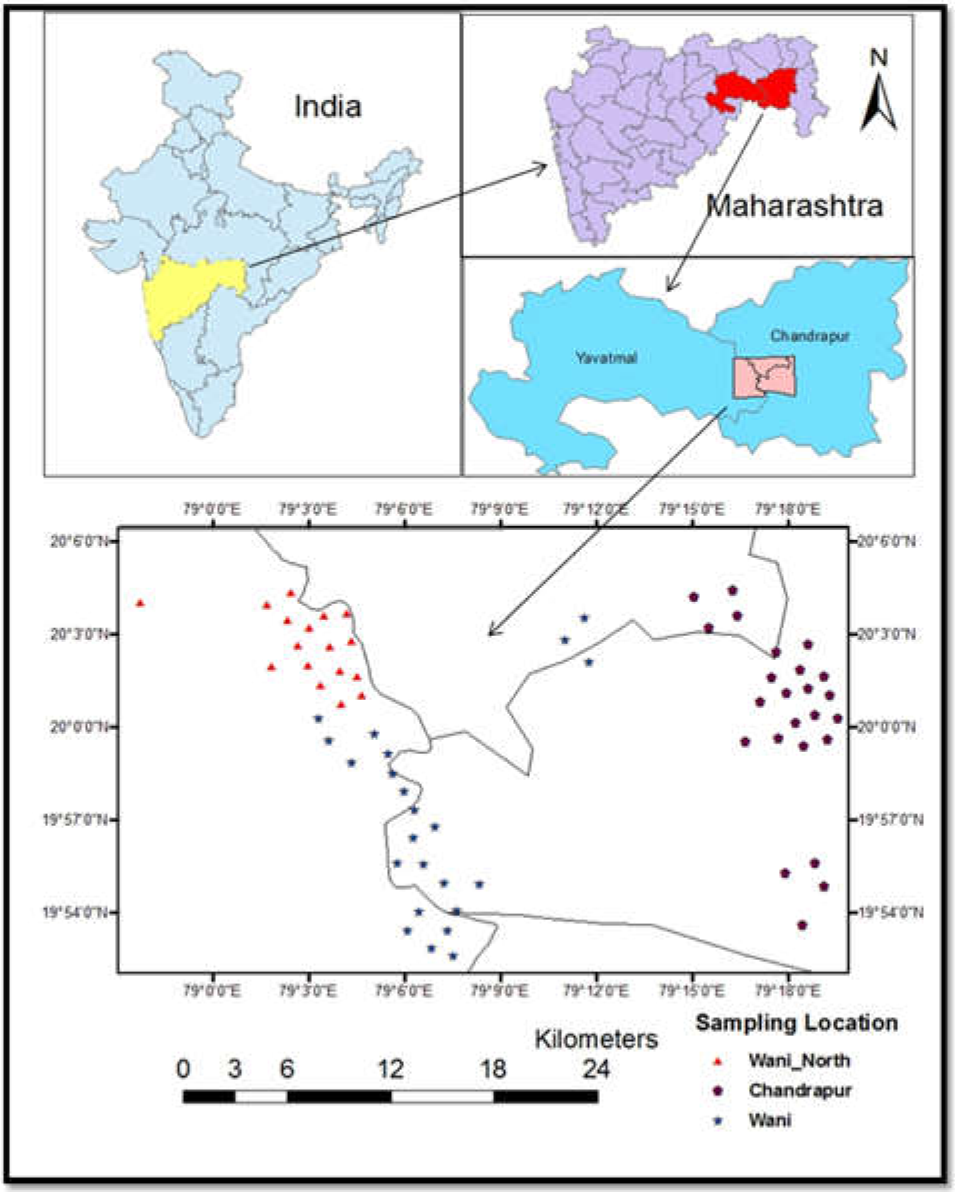

Fig 1. Sampling location map

be due to continuous accumulation of litter and dead wood material in the soil from the trees and converting the litter to SOC through the process of humification. SOC in native soil increased sharply till the age group of 21-25 years and after that this increase declined significantly in the age group of 26-30 years. SOC in OB spoil increased significantly from the age group 21-25 to 26-30 years and became more than SOC in native soil which could be due to better management of tree plantations on OB spoil by the mining authorities.

SOC in different study sites

In the plantations raised at Chandrapur, SOC in native surface and subsurface soil samples was found 1.13 and 0.75 per cent respectively while in OB spoil it was recorded to be 0.86 per cent in surface and 0.55 per cent in subsurface samples. In Wani area SOC in native surface soil (0.98%) was observed more than subsurface (0.57%) and similar trend was found in OB spoil with 0.89 per cent in surface and 0.53 per cent in subsurface soil. In Wani North area native soil had 0.83 and 0.50 per cent and OB spoil had 0.58 and 0.32 per cent SOC in surface and subsurface soil samples respectively (Table 1). Average SOC content in the soil samples collected from 0-30 cm depth was recorded maximum in Chandrapur (0.82%) followed by Wani (0.74%) and Wani North (0.55%) (Fig 4).

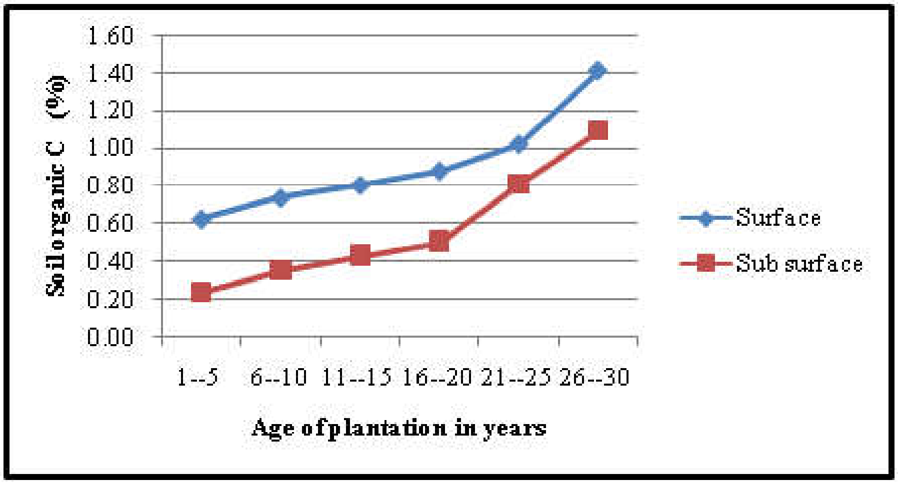

Fig 2. Distribution of soil organic carbon under surface and subsurface soil

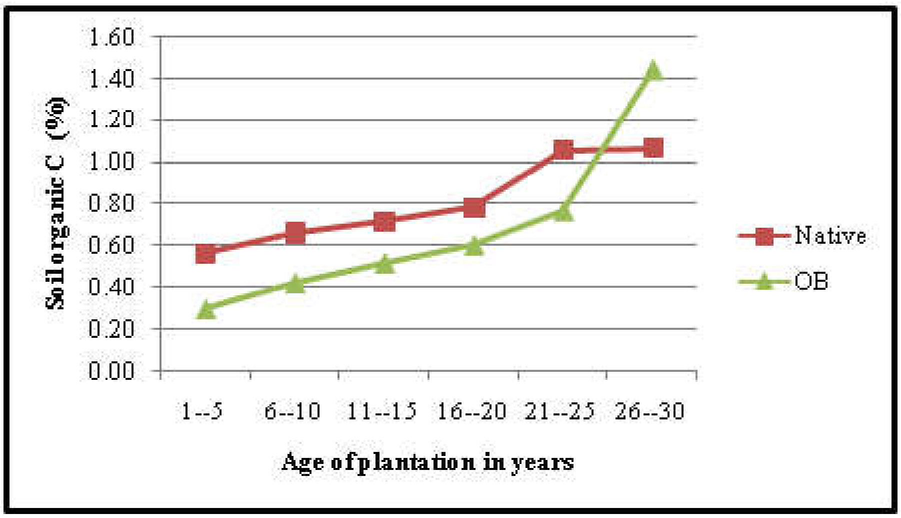

Fig 3. Distribution of soil organic carbon under native and OB plantation

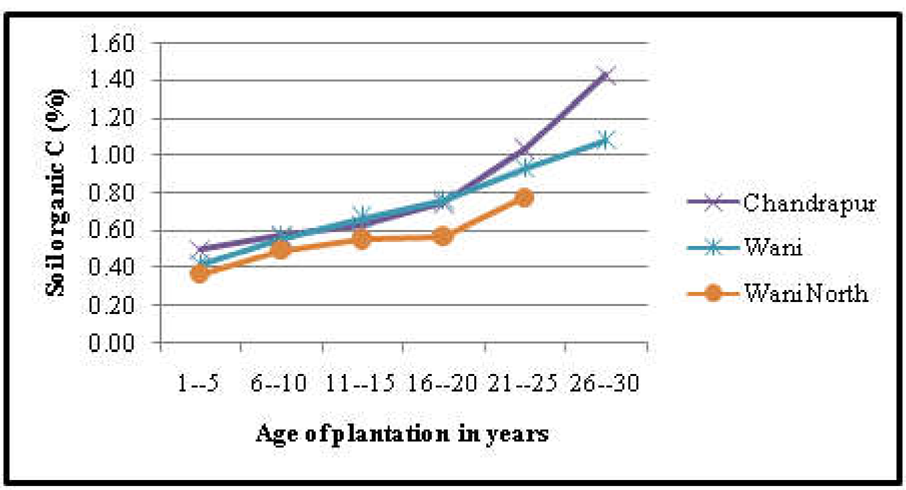

Fig 4. Distribution of SOC under study sites

Soil organic carbon content in the selected study sites under surface and subsurface depth and in native soil and OB spoil was mostly attributed by the slope and aspect of land, micro-climate, density of plants, soil characteristics, degree of erosion, species characteristics, distance of plantation site from the mining area, coal handling place and coal transport road. Terrestrial carbon storage is influenced by many environmental factors (Zhong and Xu 2009). Williamson and Johnson (1990) reported that organic carbon content in native forest soil was very high (1.02%). Arora et al (2014) also observed that SOC increased with age and decreased with soil depth.

Average SOC content in soil varied significantly ($P<0.05$) among different age groups, study sites and substratum. SOC increased from 0.43 to 1.25 per cent over 30 years period showing nearly 3 times more carbon in 25-30 years old OB dump than younger ones of 1-5 years of age. Maximum SOC was recorded in Chandrapur followed by Wani and Wani North. More carbon stock in Chandrapur area could be due to better management of plantations, local climatic factors, soil characteristics, density of trees and less anthropogenic pressure. Quantification of SOC shows that native plantation witnessed higher carbon than OB dumps which could be due to low level of nutrients in OB dump material.

CONCLUSION

The major objective of raising plantations in coal mine area is to promote eco-friendly environment through ecosystem interactions, species diversity and improvement in soil characteristics. The present investigations showed that the plantations on OB mine spoil and native soil changed the soil physico-chemical characteristics to some extent depending on the tree species and their management. Thus plantations of suitable native tree species having higher growth and carbon sequestration potential on OB dumps have great scope in global carbon balance by accumulating carbon in plants and soil. The existing plantations in Wardha coalfield area were in developing stage and would take time to amend soil status at par with nearby natural forests.

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