



Short communication

Importance of carbon fractionation for the estimation of carbon sequestration in reclaimed coalmine soils—A case study from Jharia coalfields, Jharkhand, India



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ARTICLE INFO

Article history:

Received 5 February 2015

Received in revised form 6 November 2015

Accepted 26 January 2016

Available online 12 February 2016

Keywords:

Inorganic carbon

Labile carbon

Stable carbon

Coal carbon

Reclaimed and unreclaimed coalmine soils

Carbon sequestration

ABSTRACT

Reclaimed mine soils (RMS) provide an excellent opportunity to sequester Carbon (C) both in mine soils and vegetation, as RMS initially lack biogenic C. Soil C in RMS consists of inorganic Carbon (IC), biogenic Carbon (recent C) and geogenic Carbon (coal C). In Indian mining conditions, estimation of C sequestration of RMS sites are difficult due to presence of substantial amount of coal C contributed during mining and reclamation activities, which overestimates the values of C sequestration. Conventional procedures for estimation of soil organic carbon (SOC) cannot distinguish between biogenic and coal C in the RMS. The objective of this study was to find out relative distribution of inorganic, biogenic and coal C fractions in a 10 year old RMS (tree density 1500 ha⁻¹ with average girth of 43–66 cm) along the soil profile (0–10 cm and 10–20 cm) by chemical fractionation methods and compare with unreclaimed site. Inorganic C constitutes 7–10% and 11–19% of total soil carbon (TSC) in RMS site and unreclaimed site, whereas biogenic C constituted 45–66% and 21–25% of TSC in RMS and unreclaimed site, respectively. Both labile and stable C fractions were found higher in RMS site than unreclaimed site. Coal C contributed higher in unreclaimed site (68–55%) than the RMS site (47–24%). The study concluded that estimation of IC, biogenic C and coal C is essential for estimation of C sequestration potential in RMS for the dry tropical climate.

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1. Introduction

Global warming is one of the major issues today due to increase of anthropogenic contribution of CO₂ into the atmosphere. The Kyoto Protocol strongly affirms the fact that afforestation of degraded land has the potential of acting as major sink of CO₂ through storing soil carbon, plant litter, above ground and root biomass (Pietrzykowski and Daniels, 2014; Tripathi et al., 2014; Maiti and Maiti, 2015; Zhao et al., 2015a). Reclaimed mine soil (RMS) have the capability to recover the soil disturbance and degradation caused by mining activities through accretion of soil organic carbon (SOC) (Maiti, 2013; Kumar et al., 2015). Total soil carbon (TSC) in RMS sites mainly consists of: soil inorganic carbon (IC), geogenic C (i.e., coal carbon) and biogenic C (i.e., plant derived or recent carbon). The biogenic C is further splitted into three major fractions based on their chemical stability, biochemical recalcitrance and turnover rates: (i) active or labile C, (ii) recalcitrant

or stable C, and (iii) slow or intermediate C (Trumbore, 1997; von Lutzow et al., 2007). Labile C consists of easily decomposable plant litter and root exudates, soil microorganisms, polysaccharides, cellulose and hemi-celluloses with fast turnover rates (Fontaine et al., 2007). Stable C fraction consists of lignins, lipid polymers, suberins, resins, fats, waxes other high molecular condensed soil organic matter (SOM) and non hydrolysable SOM with half life varying from years to decades (Stevenson, 1994; Chan et al., 2008). This fraction also contains humified products formed by biological transformation. Humic fraction can be further divided into humic acids, fulvic acids and humin which are most resistant to decomposition. Intermediate C fraction has turnover rates from decades to centuries and consists of charcoal, pyrolysed and black C (Chan et al., 2008). Different types of carbon influencing the estimation of CO₂ sequestration in coalmine soils are presented in Fig. 1.

Sources of “coal C” in minesoils are incorporation of coal particles or coal dust during overburden removal, coal mining and reclamation operations (Ussiri and Lal, 2008; Mukhopadhyay et al., 2013). Microbial decomposition of biogenic C sources (litter) along with different pedogenic process leads to mixing with coal C. Also, the humus and coal particles due to their same dark color cannot be easily distinguishable. Literature suggests that labile fraction

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controls the C flux by rapid changes in residue input to soil, whereas stable fraction is relevant for maintaining long term CO₂ sequestration as it controls the SOC pool (Trumbore, 1997; Fontaine et al., 2007; Mukhopadhyay et al., 2014).

Standard procedures for quantifying SOC cannot distinguish coal C from biogenic C in RMS, leading to overestimation of SOC pools and sequestration rates (Ussiri et al., 2014). In Indian coal mining scenario, deposition of coal dust in the RMS is comparatively much higher than other countries (like USA, China, Australia, New Zealand, South Africa, etc.) due to its prevalent dry tropical climate, poor reclamation measures and large mechanized open cast mines (more than 90% of coal is produced by opencast mining methods) (Maiti, 2013). Thus, it is essential to separate and quantify these fractions for understanding SOC dynamics and accurate estimation of SOC pools and sequestration rates. To differentiate labile C from stable C, several researchers have been using chemical oxidation methods; like degree of oxidation by KMnO₄ (Blair et al., 1995; Orgill et al., 2014); two steps H₂SO₄ hydrolysis (Rovira and Vallejo, 2002; Xu et al., 2015); oxidation with Na₂S₂O₈ followed by dissolution with HF (Eusterhues et al., 2003). But, most of the studies are limited only to agricultural soils or forest soils, where SOC made up of biogenic C. Adequate information is not available on the quantification of geogenic carbon in tropical climate. The methods applied by Ussiri and Lal (2008) and Chaudhuri et al. (2013) in USA mines to distinguish biogenic C and coal C were used in the present study. The main objective of this study is to quantify and compare inorganic C, biogenic C (labile C and stable C) and coal C between RMS and unreclaimed minesites in surface (0–10 cm) and sub-surface layer (10–20 cm).

2. Materials and methods

2.1. Study area

The present study was conducted on reclaimed coalmine dump of Bastacolla open cast project located in the eastern flank of Jharia coalfields, Dhanbad district of Jharkhand (India), situated within latitude 23°39'N to 23°48'N and longitudes 86°11'E to 86°27'E. Jharia coalfields cover an area of 450 km² and is known to be the most important storehouse of coaking coal in India. The average



Photo 1. View of reclaimed coalmining areas from where soil samples were collected.

height of the dump was about 30 m and afforested with various fast growing tree species (Table 1). Randomly, three quadrats (10 m × 10 m) were laid down in the reclaimed dump and stem density was estimated as 1500 trees per hectare. Out of 5 tree species, *Cassia siamea* constituted approximately 70% of the tree population. The view of reclaimed dump is shown in Photo 1. The girth of tree species, (i.e., DBH) was measured at the height of 1.37 m above the ground level and relative density of different tree species were calculated (Maiti, 2013).

A nearby unreclaimed coalmine overburden dump of same age with no tree cover was taken as reference site (control site) to compare the effects of reclamation on accumulation of different C fractions at surface (0–10 cm) and sub-surface depth (10–20 cm). Natural vegetation of the unreclaimed site comprised scanty growth of grasses and invasive shrubs such as *Lantana camara*, *Hyptis suaveolens*, *Eupatorium odoratum* (syn. *Chromolaena odorata*), *Croton bonplandianus* and grasses—*Pennisetum pedicellatum* and *Andropogon*.

2.2. Collection and analysis of minesoil samples

Seven replicate soil samples were collected from the rhizosphere of 5 tree species along the profiles of 0–10 and 10–20 cm in RMS site. Equal number of soil samples was also collected from unreclaimed site. The soil samples were air dried for 48 h, ground and passed through <2 mm sieve before analysis. Soil fractions (<2 mm size) and maximum water holding capacity (WHC) were determined gravimetrically (Maiti, 2013). Soil pH and electrical conductivity (EC) were determined in soil:water (w/v; 1:2.5) suspension with a pH meter and a conductivity meter, respectively (McLean, 1982). Soil organic carbon (SOC) was determined by K₂Cr₂O₇–H₂SO₄ rapid oxidation method of Nelson and Sommers (1996), available nitrogen by the alkaline potassium permanganate method (Subbiah and Asija, 1956), and available phosphorous by Bray's method (Bray and Kurtz, 1966). Exchangeable potassium (K) was extracted by 1 N ammonium acetate solution (w:v; 1:10) and determined by flame photometer (Jackson, 1973).

2.3. Determination of inorganic carbon, SOC fractions and coal carbon

The sequential fractionation was performed according to the method of Ussiri and Lal (2008) and Chaudhuri et al. (2013). Broadly, this sequential extraction method involved chemical fractionation of soil C into various fractions using set of different

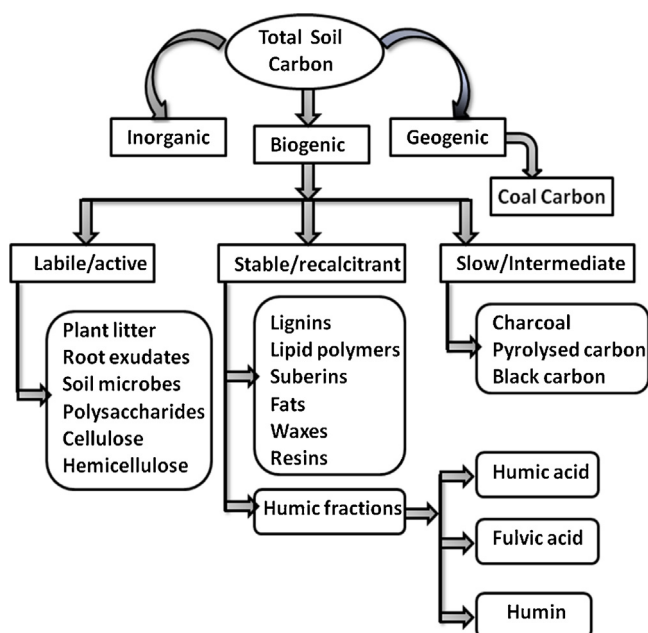


Fig. 1. Types of soil carbon in coal minesoils.

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