Geoderma 277 (2016) 41–50

Contents lists available at ScienceDirect

Geoderma

journal homepage: www.elsevier.com/locate/geoderma

Effect of long term land use systems on fractions of glomalin and soil organic carbon in the Indo-Gangetic plain

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ARTICLE INFO

Article history:
Received 29 May 2015
Received in revised form 27 April 2016
Accepted 11 May 2016
Available online 25 May 2016

Keywords:
Land use
Tillage
Glomalin related soil protein
Fractionation
Carbon storage
Physicochemical properties

ABSTRACT

Long-term history of tillage and cropping mediated disturbed and undisturbed use soils effect on glomalin related soil protein (GRSP) and soil organic carbon (SOC) and on their sub fractions were investigated in Indo-Gangetic plain region. In this study, shallow soils were collected from 50-year-old monoculture treatments of undisturbed (*Dendrocalamus calostachyus*, *Mangifera indica* and *Saccharum munja* Roxb.) and disturbed (*Oryza sativa* cultivated field) land use. Our results showed that compared with undisturbed soils, soils under the disturbed use dramatically depleted in SOC, particulate OC (POC), non-particulate OC (NPOC), GRSP, easily extractable GRSP (EE-GRSP) and difficulty extractable GRSP (DE-GRSP). The depletion in labile POC was found to be little higher than physically protected NPOC, and were almost similar among the fractions of GRSP (each decreased by 50%). Further, a linear correlation was found among the fractions of GRSP and SOC, and in turn resulted in the similar relationship with soils bulk density, porosity, pH, available phosphorus, total phosphorus, organic nitrogen's, cations (calcium and potassium), arbuscular mycorrhizal (AM) abundance, and with microbial activity. These results indicate that the factors involve in SOC accumulation simultaneously encourage AM proliferation and in turn GRSP enrichment. Apart from this, the higher contribution of GRSP-C in NPOC (13 to 17%), tended to increase with decreasing soil disturbance, suggesting the role of GRSP in accumulation and stabilization of SOC in this zone. A two component factor structure showed component 1 considerably occupied by fractions of GRSP, SOC and those other variables favouring GRSP and SOC, primarily scored by undisturbed (*M. indica* and *D. calostachyus* treatments) soils. The second component which has fewer influence over soil variables, considerably occupied by microbial activity, electrical conductivity, cations and nutrients (available nitrogen, phosphorus) was also exemplified by undisturbed soils (except *D. calostachyus* treatment). Thus, improving GRSP and SOC stock in disturbed agricultural soil in studied area is of urgent requirement for the long-term goal of C sequestration and sustainable soil health. Our finding should stimulate management plans for degraded lands aimed at recovering the landscape heterogeneity.

1. Introduction

The conversion of undisturbed woody and gross land use systems (LUS) to a disturbed cultivation field is known to cause large losses of both soil organic carbon (SOC) and microbial diversity (Grandy et al., 2009; Alguacil et al., 2014; Ngo-Mbogba et al., 2015). These losses however, seem to be mainly governed by associated tillage and cropping disturbance (Curaqueo et al., 2011; Meyer et al., 2012). Much of the environmental damages in cultivated fields such as loss of soil nutrients, aggregation, erosion and vulnerability to surface compaction may be ascribed to the soil impoverishment due to SOC and microbial activity decline. SOC sequestration in association of vegetation and soil biological activity is a possible way of reducing the concentration of atmospheric CO_2 and to moderate the global climate change. Therefore, it is essential to maintain appropriate concentration of SOC and soil microbes for sustainable soil productivity, profitability and as a reasonable sink of atmospheric CO_2. The SOC concentration in Indo-Gangetic plain (IGP) region is generally <10 g kg^{-1}, which accounts for 13% of the geographic area of India as well as covering large area of Pakistan, Nepal and Bangladesh. Irrespective to low SOC, IGP region has the fertile soils, favourable climate and abundant surface/groundwater making this the largest cereal producer region in the world and backbone of food security in India (Pal et al., 2009). The low SOC in this region might be the result of several decades of old cropping systems that involve the removal of agricultural by-product such as crop residues and cattle dung for fuel and fodder leading to low inputs of organic manure in agriculture fields. The rapid increase in population and food demand in India and specifically in IGP region is adding further pressure on land

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http://dx.doi.org/10.1016/j.geoderma.2016.05.004
0016-7061/

resources. In such circumstances, soil exploitation increased for cereal crop production, resulting in accentuated land degradation, biodiversity losses and reduction of food production. Remediation of these problems requires unconventional strategies facilitating rapid restoration of soil production potential.

In soil, microbial activity play a key role in nutrients cycling, amelioration in plant stresses and are responsible for wide ecological functions of soil (Grover et al., 2011). Arbuscular mycorrhiza fungi (AMF) are one of dominant soil microbial community which is ubiquitously distributed in most of the terrestrial ecosystem and make symbiotic association with plant root. AMF are specifically important soil fungal communities that account for 30% of total microbial population (Olsson et al., 1999). AMF can improve the yield of many crops in various climatic condition by maintaining soil physical properties, alleviate plant from nutrient deficiency as well as abiotic stresses (drought and metal toxicity) and protect plant from pathogen attack (Jeffries et al., 2003; Khan, 2005). Previous studies conducted on the role of AMF in tropical and temperate soil have indicated that higher AMF diversity as well as density appeared in undisturbed forest and grass land than in disturbed agriculture field (Fokom et al., 2012; Alguacil et al., 2014). Tillage along with application of chemical fertilizer and pesticides have been recognized as the most severe threat to AMF diversity and density (Borie et al., 2006; Bedini et al., 2007) therefore, it can merely explain the uneven distribution of these fungi within the various LUS. Furthermore, AMF have been reported to produce glomalin (a glycosylated-protein) as structural component of hyphae and spore wall that is released in soil after their microbial decomposition (Driver et al., 2005; Borie et al., 2006). Though, some questions have been raised by certain authors on the role of AMF on glomalin production (Gillespie et al., 2011), yet glomalin consistently being linked to the AMF traits (Wu et al., 2014). Indeed, higher glomalin concentration is beneficial for both soil (forming soil aggregation, C accumulation and reducing erosion) (Rillig and Steinberg, 2002; Wu et al., 2014) and AMF (increase surface area of soil) (Steinberg and Rillig, 2003). Glomalin deposition generally contributes on an average 5 to 10% of SOC (Rillig et al., 2003) and 5 to 13% of soil N (Lovelock et al., 2004). Glomalin is measured in soil as glomalin related soil proteins (GRSP) and can split into three Bradford reactive fractions that may vary in terms of persistence in soil. The easily extractable GRSP (EE-GRSP) fraction has solubility in relatively less concentrated buffer (20 mM sodium citrate, pH 7), it may be recently produced and it is thought to readily decompose (Rosier et al., 2006), while the difficulty extractable GRSP (DE-GRSP) fraction is considered as recalcitrant and has more persistence in soil (Rosier et al., 2006; Wu et al., 2014). While, the third total- GRSP (T-GRSP) are the sum of both the two fractions (Fig. 1). The variable persistence of GRSP fractions may lead to their unequivocal sensitivity to land use change. Very similar to glomalin, the physical fractionation of soil (Fig. 1) on the basis of particle-size was identified to be an effective tool for evaluating land use dependent changes in SOC (Cambardella and Elliott, 1992; Meyer et al., 2012; Plaza et al., 2013). The rationale behind this fractionation is that the entire SOC are not equally sensitive to change of land use. Some active or labile SOC components are more sensitive, while some slowly cycling components are less sensitive. The particulate organic carbon (POC) mostly consists of plant debris, animal residues, spores, fungal hyphae, etc. (Christensen, 2001) and has short turnover rate, may be more responsive SOC fraction to land use change (Meyer et al., 2012). Conversely, mineral associated or non POC (NPOC) physically protected by the soil minerals (fine silt and clay) and comparatively recalcitrant has longer persistence in soil (Mafın-Spiotta et al., 2008; Torn et al., 2013). These fractions may be less responsive SOC to land use change. Effect of land use change on GRSP and SOC content are well documented in various agroecosystems of tropical and temperate region (Bedini et al., 2007; Gispert et al., 2013; Plaza et al., 2013; Fokom et al., 2012) though, the effect on different GRSP and SOC fractions as well as the interactions among these fractions are poorly understood. However, to the best of our knowledge, there is no data regarding GRSP and SOC fractions in the IGP region.

This work was therefore initiated to measure the AMF spores, the fractions of GRSP and SOC along with soils physicochemical properties of four long-term used (50 yrs old) adjacent agricultural sites under different LUS in the IGP region of India. In all LUS, the three were undisturbed monoculture treatment (*Mangifera indica*, *Dendrocalamus calostachyus* and a *Saccharum munja* Roxb. grown grass land) and a disturbed treatment where *Oryza sativa* L. was under cropping. Our hypothesis was that long-term tillage mediated disturbances result in decrease of GRSP and SOC in soils of *O. sativa* treatment in comparison with soils under undisturbed treatments. However, soil disturbance mediated decrease should be more in labile fractions of GRSP (EE-GRSP) and SOC (POC) than their respective stable fractions (DE-GRSP and NPOC).

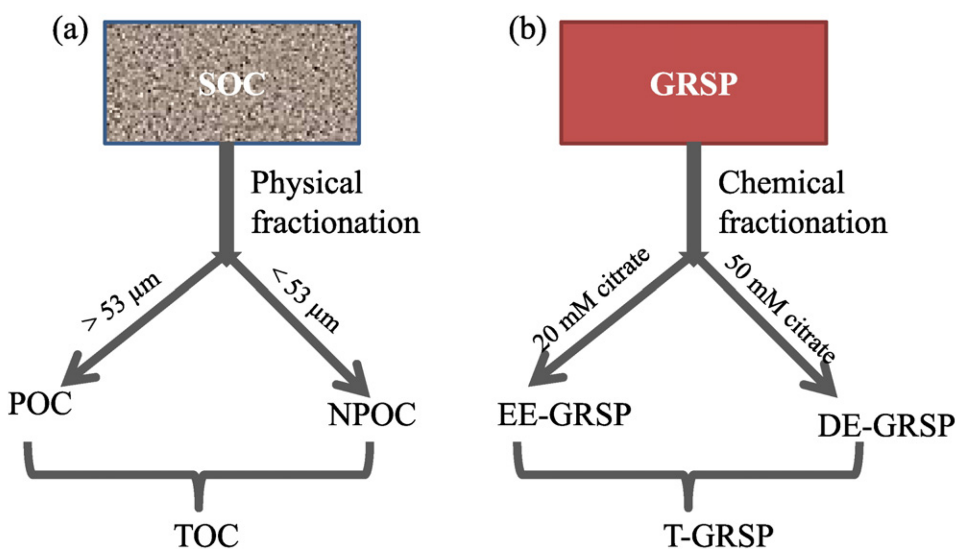

Fig. 1. (a) Fractionation of soil organic carbon (SOC) by wet sieving (physical means) method. POC, particulate organic carbon; NPOC, non-particulate organic carbon; TOC, total organic carbon; (b) fractionation of glomalin related soil protein (GRSP) by citrate buffer (chemical means) method. EE-GRSP, easily extractable GRSP; DE-GRSP, difficulty extractable GRSP; T-GRSP, total GRSP.