



Soil Organic Carbon Stock as Affected by Different Tillage Practices under Rice-Mustard Cropping System

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Authors' contributions

This work was carried out in collaboration among all authors. Authors RKP and KM designed the study, performed the statistical analysis, wrote the protocol. Author HK wrote the first draft of the manuscript. Authors PKB and PKM managed the analyses of the study. Author RKP managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Management of soil organic matter (SOM) in arable lands has become increasingly important in many areas of the world to combat land degradation, increase food security, reduce carbon emissions and/or mitigate climate change. Soil carbon cycling and composition are essential components of comprehensive agricultural and ecological impacts and forecasting. Soil Organic Matter (SOM) plays keys to developing drought-resistant soils (i.e., water conservation, evaporation and erosion control and soil water infiltration ease) and ensuring sustainable food production. This study was conducted during 2018 (March) after harvesting of mustard at Instructional-cum-

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Research Farm, Assam Agricultural University, Jorhat-13, to determine the temporal effect of different tillage practices on soil carbon stock in Rice (*Oryza sativa*)-Mustard (*Brassica juncea*)-Sesbania (*Sesbania rostrata*) cropping system under conservation agriculture system. The soil was acidic (pH- 5.4), sandy loam in texture with CEC-6.28 cmol(p⁺)/100 g, organic carbon-0.92%, available N-260 kg ha⁻¹, available P-19 kg ha⁻¹, available K-86 kg ha⁻¹. Tillage practices can potentially affect soil organic carbon (SOC) accumulation in agricultural soils. SOC stocks of the 0-15 cm, 15-30 cm and 30-45 cm soil layers for each treatment were calculated by multiplying bulk density (g/cc), organic carbon (%) and depth of the soil (cm). Significantly lower bulk density was observed in CT and the control over the MT. While soil organic carbon was recorded significantly higher in MT over the CT and the control. The SOC stocks in MT were also higher than those under CT and Control ($P < 0.05$). The order of SOC stocks in the 0-45 cm soil layer was MT >CT.

Keywords: Bulk density; soil organic carbon; conventional tillage; minimum tillage; carbon sequestration.

1. INTRODUCTION

Soil organic carbon (SOC) is a dynamic soil property that represents the key component of any terrestrial ecosystem, and any variation in its abundance and composition has important effects on many of the processes that occur within the system [1,2]. Nonetheless, the size and dynamics of the carbon and nitrogen pools in the soils of the world are still poorly known [3,4,5]. Three main reservoirs regulate the carbon cycle on earth [3] the Oceans (~39,000 Peta gram) of C; the atmosphere (~750 Pg C), and terrestrial systems (~2200 Pg C).

Management of soil organic matter (SOM) in arable lands has become increasingly important in many areas of the world to combat land degradation, increase food security, reduce C emissions, and/or mitigate climate change [6]. Soil organic carbon is decreasing slowly due to the tillage intensification, continuous cultivation, use of inorganic fertilizer instead of organic matter. This decline of SOC tends to decreased soil quality and increased the risk of soil degradation. To deal with this situation, conservation agriculture has been recommended as an alternative strategy to invert the soil degradation spiral in many parts of the world. Conservation Agriculture which includes three main components namely No or Minimum tillage [7,8,9], Organic residue incorporation and Suitable crop rotation which has been reported to improve SOM level and ensure carbon accumulation and sequestration in diverse soils from contrasted climate regimes.

Studies have shown the sustainable use of natural resources through adoption and diffusion of Minimum and No-tillage systems improve soil quality and enhance crop productivity vis-versa

climate variability and drought [10]. In other terms, SOM improvement under MT is fundamental for the food system in dry land agriculture. In Spain, [11] Alvaro-Fuentes et al. showed that Minimum Tillage (MT) and No-Tillage (NT) increases soil organic carbon (SOC) stock in the soil profile (0-40cm) as compared to Conventional Tillage [2,12].

Similar results were found in France [13] and Morocco [14, 15,16]. It was also found that, under MT systems, soil can play a role in mitigating CO₂ levels. The continuous harvesting of Plant materials in conventional tillage system was reported by several authors of decreasing carbon levels in soils and harming its fertility and health [17]. SOC stocks depend not only on the tillage system but also on local conditions (soil type and climate) [18]. The effect of conservation tillage on SOC content has been largely investigated throughout the world [19] but studies on the potential storage of SOC under conservation tillage, regarding the effect of soil types, have not been carried out yet.

2. MATERIALS AND METHODS

This study was conducted during 2018 (March) after harvesting of mustard at Instructional-cum-Research Farm, Assam Agricultural University, Jorhat-13, India to determine the temporal effect of different tillage practices on soil carbon stock in Rice (*Oryza sativa*)-Mustard (*Brassica juncea*)-Sesbania (*Sesbania rostrata*) cropping system under conservation agriculture system. The experimental site was situated at 26°47' N latitude, 94°12' E longitude and an altitude of 86.6 m from the mean sea level.

In the experiment, there were three treatments i.e. Minimum tillage system (MT) conventional

tillage system (CT) and control (undisturbed soil). The CT plots were ploughed, according to farmers' practice in the region, at 30 cm of depth with a "tractor-drawn Mould Board plough" in June for rice and October for mustard each year. The soil was minimum disturbed under MT and maintained covered with flat and stubble residues at 30% levels. In the control plot, the soil was not disturbed at all. Rice (*Oryza sativa*)-Mustard (*Brassica juncea*)-Sesbania (*Sesbania rostrata*) cropping system was adopted and the crop management was similar in CT and MT treatments. Indeed, direct-seeded ahu rice (Variety-Basundhara) was sown (broadcast) in June 2017 at a seed rate of 110 kg ha⁻¹. The recommended dose of fertilizer was applied i.e. 40-20-20 kgha⁻¹ of N₂-P₂O₅-K₂O respectively. In mid of Oct 2107, mustard (Variety-NRCHB-101) were sown at a seed rate of 6 kg ha⁻¹ and recommended dose of fertilizer was applied i.e. 87-220-25 kgha⁻¹ of N₂-P₂O₅-K₂O respectively.

The climatic condition of Jorhat, as a whole, is sub-tropical and humid summer and cold winter. Normally, monsoon rain starts in June and continues up to the month of September-October. Fig. 1 shows the monthly time-series (2017) of the average rainfall and temperature and those occurring during the studies period.

The soil of the experimental site belongs to the taxonomic class of Aeric Endoaquept with sandy clay loam texture with 49% sand, 24% silt and 27% clay, acidic in reaction having a pH value of 5.4. The soil was with CEC - 8.46 c mol (p⁺)/100

g, organic carbon - 0.68%, available N - 264.74, P₂O₅-20.68, K₂O-76.98 kg/ha respectively.

Soil samples were collected after harvesting of the mustard crop during March of 2018 for determination of bulk density, soil organic carbon and soil carbon stock. Composite soil samples were collected from three depths (0-15, 15-30 and 30-45cm) with seven replicates per treatment. Bulk density (BD) was determined by the gravimetric method using undisturbed soil cores [20] of 10 cm diameter and 7.5 cm height and was expressed as Mg m⁻³. Soil organic carbon was determined by oxidation of organic carbon following the classical method of [21]. The stock of soil organic carbon (SOCs) was determined using the following equation given by M. Bernoux [22].

$$SOCs = BD * SOCc * D * 10^4$$

Where, SOC_s is the soil organic carbon stock (Mgha⁻¹), BD is the Bulk Density (Mg m⁻³), SOCc is the soil organic carbon content (%), D is the layer depth (m), 10⁴ is the conversion factor from m² to the hectare.

The technique of analysis of variance (ANOVA) as described by Panse and Sukhatme [23] was used in RBD for statistical analysis of data obtained from various treatments. The effects of tillage system on the SOCc, SOC_s were tested in the different treatments using SPSS version 17. Analysis of variance (ANOVA) was used to determine the significance of tillage effects in each treatment and Critical Difference (CD) at 5% level of significance and Coefficient of Variance (CV) were calculated.

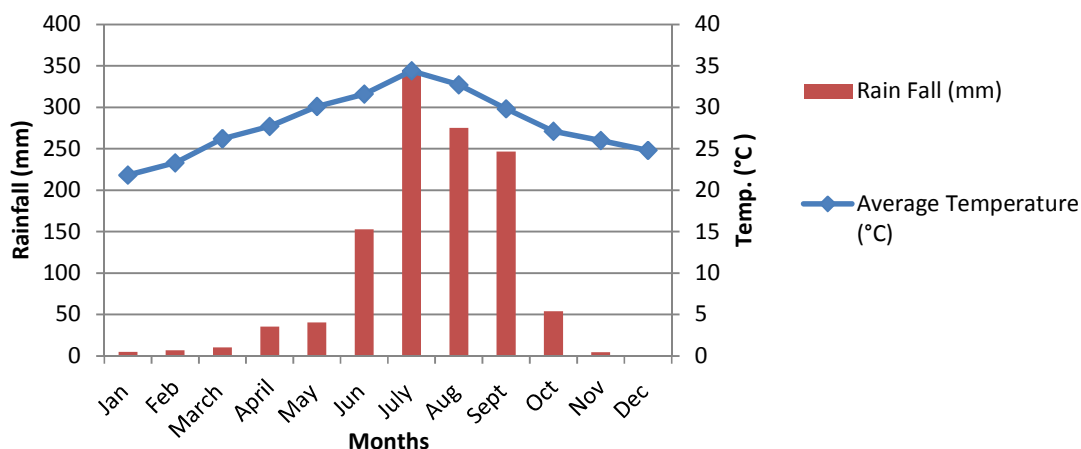


Fig. 1. Monthly average of rainfall and temperature (2017) at Jorhat

3. RESULTS AND DISCUSSION

Data revealed that bulk density at surface and subsurface soil was significantly lower under treatment T₂ with CT over the treatment T₃ with MT as shown in Fig. 2. Confirming the results obtained by other authors Moussadek et al. [24]. Moreover, the treatment T₁ i.e. the undisturbed soil exhibited highest bulk density throughout the depth. Generally, the soils disturbed by tillage or blended with straws had lower BD (e.g., for the 0–5 cm depth under MT) over the CT [25]. The more compactness and with less organic matter content of the subsurface soil showed increased bulk density with less soil aggregation and less root penetration [26,27].

Significantly higher SOC content was observed on surface soils over the subsurface soil with all the treatments as shown in Fig. 3. The minimum

tillage with significantly higher organic carbon over the conventional tillage confirming the results obtained by other authors [11,28,29]. The reduction of SOC_c in conventionally tilled soil could be explained by the excessive removal of biomass after harvest and higher decomposition rate due to increased microbial activity at the soil surface [30]. However, in the lower subsurface horizon, no significant difference of SOC_c had been observed between the CT and MT systems [31,32].

The average SOC_c (0-15 cm) was 17.54 and 16.001 Mgha⁻¹ with MT and CT respectively. Higher soil bulk density with MT over CT, especially in the sub-surface soil confirmed with similar results as reported by the various author that bulk density increases in the few years after the introduction of MT [33]. On the contrary, many authors also suggested that the increase in

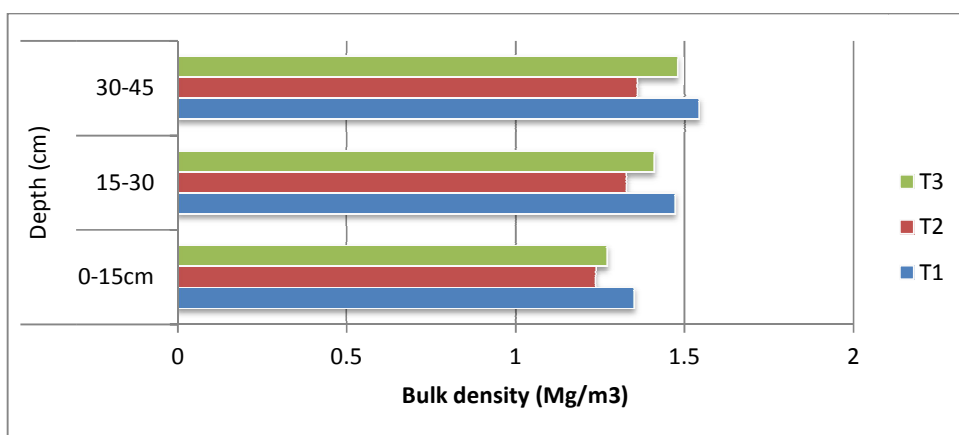


Fig. 2. Bulk density (Mg m⁻³) of soil under various treatments
 T1: Control (Undisturbed soil), T2: Conventional Tillage, T3: Minimum Tillage

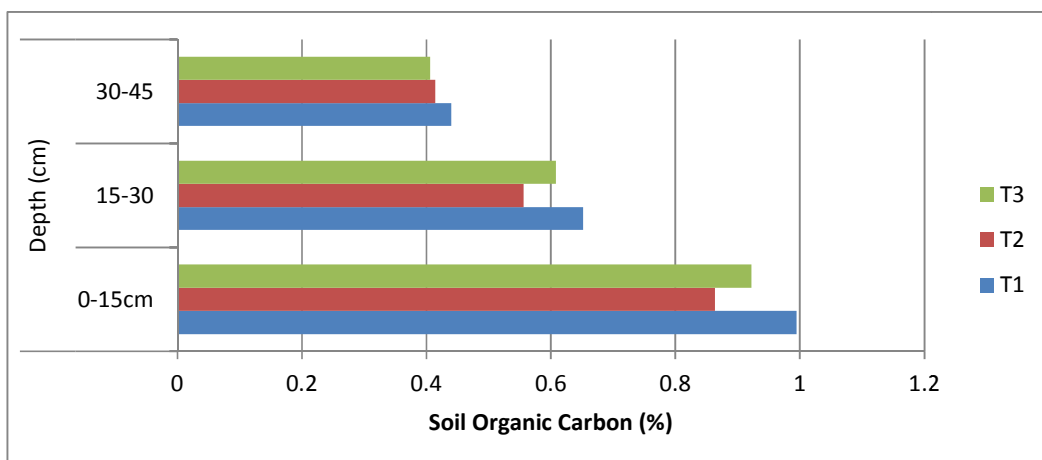


Fig. 3. Soil organic carbon content (%) of soil under various treatments
 T1: Control (Undisturbed soil), T2: Conventional Tillage, T3: Minimum Tillage

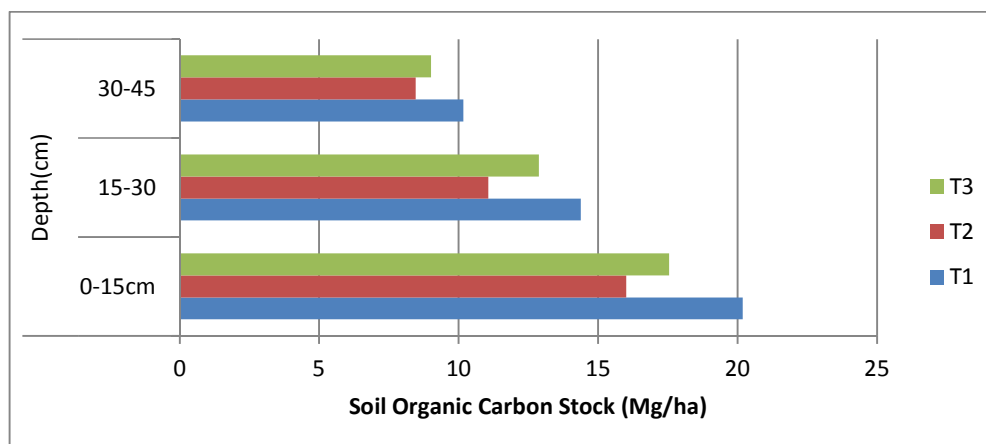


Fig. 4. Soil organic carbon content (%) of soil under various treatments
 T1: Control (Undisturbed soil), T2: Conventional Tillage, T3: Minimum Tillage

bulk density under minimum tillage will be reduced with time following increased in soil biological activity [34,35]. Fig. 4 shows the SOCs in all layers for all the three tillage systems. The analysis of variance indicated significantly higher SOCs with MT compared to CT with all depths i.e. 0-15 cm and 15-30 cm and 30-45 cm and highest was observed with treatment 1, the undisturbed soil. Considering the average SOCs at 0-15 cm depth, MT had significantly higher SOCs over CT at this depth.

4. CONCLUSION

The practice of conservation agriculture with different tillage practices in place of conventional agriculture has the potential to improve the soil physicochemical properties and to sequester more carbon in the soil. After the experiment, we observed that there is a significant increase in soil organic carbon (SOC) in soil with minimum tillage as compared to the soil in which CT was practised. As the soil organic carbon plays a very important role in maintaining the physicochemical and biological properties like aggregation, water holding capacity, nutrient availability, microbial activity etc. This accumulation of organic carbon also results in increased levels of humic and fulvic acid. So the obtained result shows that MT can contribute to the improvement of soil quality and fertility status.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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