Long-term impact of reduced tillage and residue management on soil carbon stabilization in tropical agroecosystems.

P. Chivenge[1,2]*, H. Murwira[2], K. Giller[3], P. Mapfumo[4] and J. Six[1]

[1]Department of Plant Sciences, University of California, Davis, USA [2]TSBF- CIAT, Harare, Zimbabwe, [3]Plant Production Systems, Wageningen University, Netherlands, [4]Department of Soil Science, University of Zimbabwe, Zimbabwe.

Introduction

- Soil organic matter (SOM) is crucial in tropical agricultural systems where nutrient poor, highly weathered soils with low CEC are managed with minimum external inputs.
- Soil organic carbon (SOC) dynamics are influenced by agricultural management practices such as tillage, mulching, removal of crop residues and application of organic and mineral fertilizers.
- Type and length of tillage, and soil texture influence the amount of SOC present in the soil, the rate of SOC turnover, and its distribution among size fractions.
- Tillage disrupts macroaggregates thereby inducing rapid decomposition of SOM with subsequent loss of C from the system.
- Crop residue removal enhances SOC decline, especially when coupled with conventional tillage (CT).

Objective

❖ To assess the effects of disturbance (i.e. tillage) and C input (i.e. crop residue return) on SOC content and its distribution across size fractions in two soils differing in texture.

Hypotheses

❖ SOC content will increase with decreasing tillage intensity in the order tied ridging (TR) > clean ripping (CR) > CT.

❖ Returning crop residues will result in greater SOC than removing residues.

❖ SOC dynamics are more responsive to tillage disturbance in the clay soil as aggregates are disrupted to release protected SOC, while in the sandy soil C input differences would result in bigger differences in SOC content.

Methods

✓Established in 1988/89 cropping season in Zimbabwe at 2 sites (Table 1).

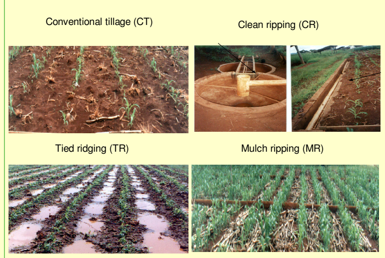
Table 1: Selected characteristics of the sites

Site	*% sand*	*% clay*	*Texture*	*Parent material*	*Soil classification*
IAE	21	59	clay	gabbro	Rhodic Paleustalf
DTC	83	4	sand	granite	Udic Kandiustalf

✓Mean annual rainfall for both sites: 800-1000 mm; mean annual temperature: 22ºC.

✓ Soil samples were collected in June 1998 (0-30 cm depth).

Treatments



SOM Fractionation

✓ Dispersion was done by shaking soil in 5 g L^{-1} Na hexametaphosphate for 16 hr.

✓ Wet sieved to separate 212-2000 µm (coarse sand), 53-212 µm (fine sand) and 20-53 µm (coarse silt).

✓ Smaller fractions, 0-5 µm (clay) and 5-53 µm (fine silt) separated by sedimentation method.

✓Organic C in whole soil and fractions analyzed using LECO C analyzer.

Results and Discussion

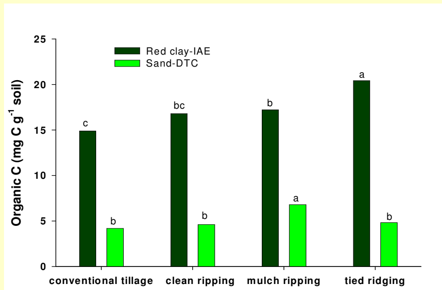


Figure 1. Management effects on SOC of a clay and a sandy soil. Within a soil type bars with a different lowercase letter are significantly different ($p<0.05$).

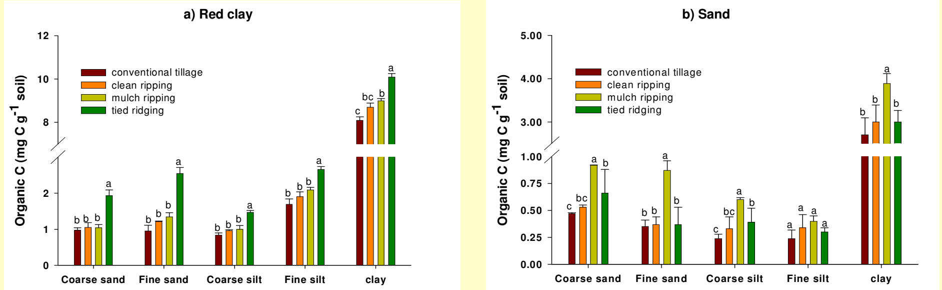


Figure 2. Management effects on SOC in the different size fractions of, a) a clay, and b) sandy soil. Bars are means ± standard error. Within a fraction bars with a different lowercase letter are significantly different ($p<0.05$). NB different scales were used for the two graphs.

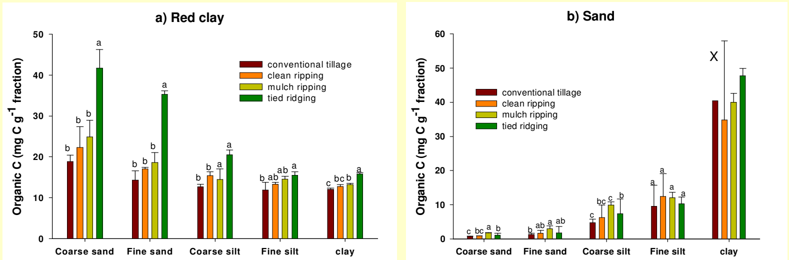


Figure 3. Management effects on SOC in the different size fractions expressed per unit of fraction, for a) a clay, and b) a sandy soil. Bars are means ± standard error. Within a fraction bars with a different lowercase letter are significantly different ($p<0.05$). NB different scales were used for the two graphs. X- the other two replicates could not be analyzed.

Tillage effects of SOC

(Tillage effects are described by comparing CT, CR and TR)

Red clay soil (IAE)

- SOC increased with a decrease in soil disturbance with CT having the least organic C and TR having the greatest amounts of C (Fig. 1).
- Organic C in the size fractions consistently increased with decrease in soil disruption but the gradient was steeper in the coarser fractions (Fig. 2).

Sandy soil (DTC)

- There were no significant differences in SOC and C in the size fractions due to tillage (Figs.2 and 3).
- When organic C in the fractions was expressed per unit of fraction there was a decrease in C with decrease in fraction size for the red clay soil but in the sandy soil, organic C increased with decrease in fraction size (Fig. 3).

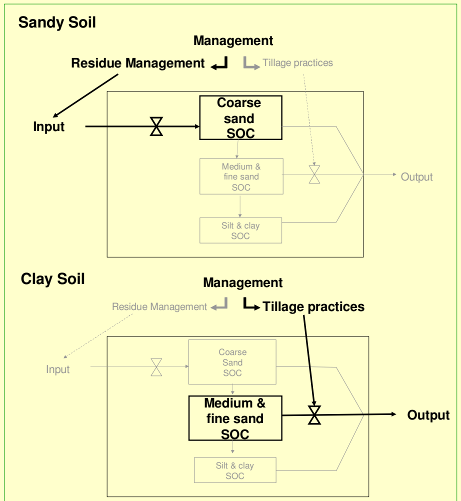


Figure 4. Conceptual representation of the interactive effects between management and soil texture on SOC stabilization, a) In sandy soils organic matter inputs improve SOC content and especially increase SOC in the coarse sand fraction. b) In clay soils, soil disturbance regulates SOC storage where high tillage intensity results in greater loss of SOM.

Residue management effects on SOC

(Effects of C inputs are described by comparing MR and CR which were subjected to the same degree of disturbance but differed in residue return)

- Total SOC and C in the size fractions was higher under MR than CR in the sandy soil (Figs. 1, 2 and 3).
- The magnitude of differences in C in the size fractions between CR and MR decreased with decreasing fraction size; with greatest differences in the coarse sand fraction.
- There were no differences in total SOC and across size fractions of the red clay soil.
- There were no interactive effects between tillage and residue management.

Interactive effects of soil texture and management on SOM

- There were greater tillage effects with the greatest (CT) and least (TR) degree of disturbance in the red clay soil while there were no significant differences in the sandy soil.
- In the sandy soil, MR had greater SOC contents than CR. Consequently, residue management is of greater importance for increasing SOC in coarse textured soils and tillage plays a lesser role (Fig. 4).
- C input predominantly controls SOC by influencing the size of the coarse sand fraction.
- In contrast, tillage influences SOC accumulation in fine textured soils, particularly by disrupting aggregates and exposing coarse sand fraction to decomposition thus limiting the transfer of C from the coarse sand to the fine sand pool.
- Thus, the fine sand fraction is mostly affected by tillage disturbances and determines SOM accumulation *versus* losses in clay soils.

Conclusions

❖Conversion of current management practices in Zimbabwe from CT to reduced tillage on clay soils can improve SOM storage and long-term sustainability.

❖In clay soils, SOC accumulation, primarily within the fine sand fraction can be enhanced by reducing soil disturbance.

❖In contrast, SOC accumulation build-up in sandy soils can only be accomplished by manipulating coarse sand fraction through additions of organic inputs.

***Corresponding author: ppnhamo@ucdavis.edu**

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