Effects of Conservation Agriculture and manure application on maize grain yield and soil organic carbon: a comparative analysis

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Introduction

In southern Africa, most farming systems exhibit a close integration of crop and livestock components, with an output of one component being an input of the other. The allocation of crop residues for livestock feed meets two out of three critical objectives; it ensures feed during the dry season (De Leeuw, 1996), improves quantity and quality of manure to restore soil fertility (Murwira et al., 1995) but does not ensure permanent soil cover required under conservation agriculture (CA). Thus under CA, there are strong trade-offs for either allocating crop residues for livestock feed or using the crop residues directly for mulch thereby reducing the amount and quality of manure available and compromising the condition of livestock. The objective of this study is to perform a comparative analysis of maize grain yield and soil organic carbon (SOC) changes in CA systems versus conventional tillage systems with manure application. Crop residue retention and reduced tillage are options that are expected to increase SOC in the long-term, in a similar way to manure application. Therefore, it is necessary to perform a comparative analysis to quantify the differences and to identify the most sustainable system. Crop yield is important for ensuring food security and income, and SOC is an important determinant of soil fertility, productivity and sustainability (Lal, 1997).

Materials and Methods

Data were obtained from two sets of long-term experiments under continuous sole maize (*Zea mays* L.). The experiment on manure application was established in 2002 until 2010 on both clay (Chromic Luvisols) and sandy (Haplic Lixisols) soils (FAO, 2006), and two field types (homefield and outfield) in Murehwa, Zimbabwe. The treatments included a control, 100 kg N ha^{-1}, 100 kg N ha^{-1} + 5 t manure ha^{-1} and 100 kg N ha^{-1} + 15 t manure ha^{-1}. The tillage experiment was established in 1988 to 1999 at three sites, Domboshawa (sandy soils, Haplic Lixisols), Makoholi (sandy soils, Ferralic Arenosols) and Institute of Agricultural Engineering (IAE) (red clay soils, Chromic Luvisols) (FAO, 2006). Conventional mouldboard ploughing was carried out to a depth of about 23 cm. Mulch ripping (MR), was achieved by ripping to a depth of 20 – 25 cm while maintaining the crop residues on the soil surface. Mulch cover at the beginning of the season ranged between 40 and 60 %. All treatments received annual fertiliser additions of 114 kg N ha^{-1}, 22 kg P ha^{-1} and 25 kg K ha^{-1}, the full experimental details are found in Moyo (2003).

Results and Discussion

The addition of 5 t ha^{-1} manure more than doubled maize grain yield of the control (Figure 1) while the effect of mulch and reduced tillage on yield was marginal with a yield gain of only 0.2 t ha^{-1} over a nine year period (Figure 2). Results of Larbi et al., (2002) showed that the effects of mulch on maize grain yield were site specific and generally depended on the amount of mulch retained. Applying too much mulch causes waterlogging and induces immobilization of soil nutrients (Burrows and Larson, 1962). Manure application (5 t ha^{-1}) under conventional tillage increased SOC by 0.13% and 0.09% per year on clay and sandy soils respectively (Figure 3) while the CA practice led to an increase of 0.02% per year for both sandy and clay soils (Figure 4). However, the quantities of manure applied are not achievable under smallholder farming systems. The quantity of manure produced from stover is a function of digestibility and feed intake. Given the low productivity of maize on smallholder farms of 1 t ha^{-1} and assuming that all is available for livestock feed with a digestibility of 56% (Tubei and Saidi, 1981), the amount of manure produced will be 440 kg i.e. ((100-56)/100) $\times$ 1000 kg. Assuming a 50% loss due collection and handling, about 200 kg of manure will be produced per ton of maize stover, hardly enough to contribute significantly to the improvement of soil organic carbon and nutrient supply. However, the opportunity cost of losing mulch is offset by gains in animal productivity given that communal grazing is not adequate during the dry season. The results suggest that the decision by farmers to allocate crop residues to animals as feed is most suitable for their circumstances because manure application in combination with fertilizer provides calcium, magnesium and micronutrients that ensure high yields especially on degraded soils. An optimal procedure for retaining adequate crop residues while providing sufficient feed for livestock is thus required to facilitate the adoption of CA on smallholder farms.

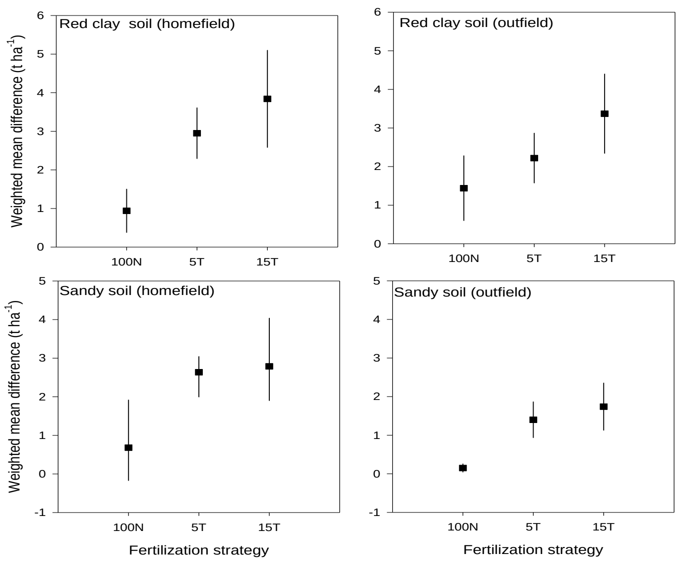

Figure 1 Weighted mean difference in maize grain yield between control and fertilizer as well as different rates of manure application in combination with fertilizer after nine years in different soils and fields at Murewa, Zimbabwe.

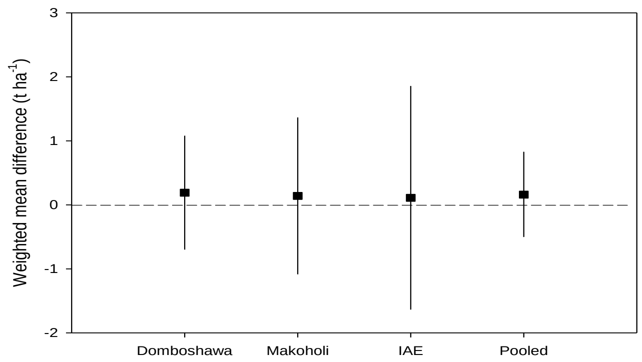

Figure 2 Weighted mean difference in yield between conservation agriculture and conventional tillage at three sites (Domboshawa, Makoholi and IAE) in Zimbabwe (Moyo, 2003).

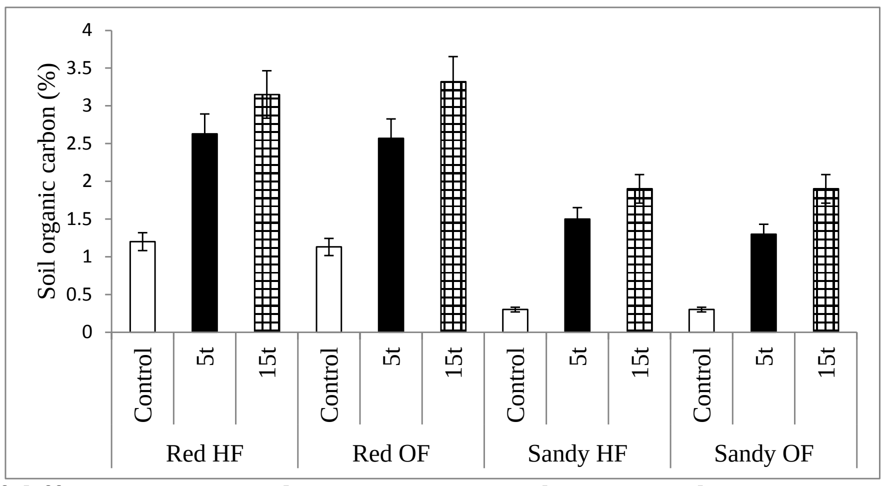

Figure 3 The long-term effect of different manure application rates in combination with ammonium nitrate on SOC (%) on home and outfields in clay and sandy soils after seven years.

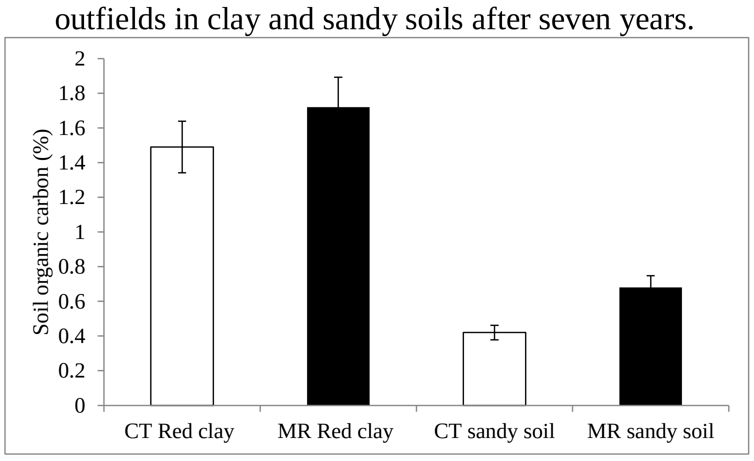

Figure 4 The long-term effect of conventional tillage (CT) and mulch ripping (MR) and on SOC (%) after nine years at IAE (red clay soils) and Domboshawa (sandy soils).

References

Burrows WC, Larson WE (1962). Effect of amount of mulch on soil temperature and early growth of corn, Agronomy Journal, 54**,** 19-23.

De Leeuw PN (1996). Crop residues in tropical Africa: trends in supply demand and use. *In:* Renard C (ed.) Crop Residues in Sustainable Mixed Crop/Livestock Systems. CABI Publishing, Wallingford, UK

FAO (2006). World reference base for soil resources: a framework for international classification, correlation and communication. World Soil Resources Report 103. Pp.128. FAO, Rome.

Lal R (1997). Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO_2-enrichment, Soil and Tillage Research 43, 81-107.

Larbi A, Smith JW, Adekunle IO, Agyare WA, Gbaraneh LD, Tanko RJ, Akinlade J, Omokaye AT, Karbo N, Aboh A (2002). Crop residues for mulch and feed in crop livestock systems: impact on maize grain yield and soil properties in the West African humid forest and savanna zone, Experimental Agriculture, 38**,** 253-264.

Moyo A (2003). Assessment of the effect of soil erosion on nutrient loss from granite-derived sandy soils under different tillage systems in Zimbabwe. Ph.D. Thesis, University of Zimbabwe, Harare, Zimbabwe.

Murwira HK, Swift MJ, Frost PGH (1995) Manure as a key resource in sustainable agriculture: a case study of communal area farming systems in Zimbabwe. *In:* Powell JM, Fernandez-Rivera S, Williams TO, Renard C (Eds.) Livestock and sustainable nutrient cycling in farming systems of sub-Saharan Africa, 1995 Addis Ababa, Ethiopia. ILCA.

Tubei SK, Saidi AN (1981). Sodium hydroxide and ammonia treated maize stover as a roughage supplement to sheep and beef feedlot cattle. *In:* Kategile JA, Said AN, Sundstol F(eds.) Utilization of low quality roughages in Africa. Arusha, Tanzania. Agricultural University of Norway, AAS.