Soil Carbon and Nitrogen Stocks under no-tillage and conventional tillage in the Middle West Vakinankaratra, Madagascar

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INTRODUCTION

Studies of organic matter in terrestrial ecosystems has received greater attention in recent years, both for their contribution for improving soil fertility and for its importance in understanding carbon cycle. Furthermore, the soil organic matter plays important roles in improving soil physical properties and resistance to erosion (Leprun, 1988) and in determining fertility (Feller and Beare, 1997). The organic status of the land can be affected by several factors including agricultural practices that have a major impact on the dynamics of soil organic matter (Wesemael and Brahy, 2006). Therefore, in view of storing carbon for long periods in the soil, carbon must be protected against microbial mineralization.

For the case of the Middle West Vakinankaratra, Madagascar, the aim of the study is to establish a baseline on carbon and nitrogen stocks while comparing the effects of two cropping systems: direct seeding mulch-based cropping system (DMC) and conventional tillage (CT). This comparison was performed on different subgroups of ferralitic soils.

MATERIALS AND METHODS

Soil samples were collected from 100 farmers 'plots, 54 conducted under CT and 46 under DMC, spread evenly throughout the study area that incorporates three municipalities of the district of Betafo. In this area, three subgroups of ferrallitic soils predominate: concretioned ferrallitic soils (SFC); rejuvenated ferrallitic soils with poorly degraded structure (SFPD); and rejuvenated ferrallitic soils with highly degraded structure (SFD). Soil samples were collected from each corner of a 10m x 10m square and at 0-10 cm, 10-20 cm, 20-30 cm, 50-60 cm, 80-90 cm depth. Four samples from each identical horizon were mixed for a composite samples.

Only the 0-30 cm horizons were selected for laboratory analysis. Analyzes were performed on the aliquot of about 20 g of soil finely crushed to 0.2 mm. Total C and N content were determined by dry combustion in an elemental CHN analyzer. Bulk density was determined using undisturbed cylinders. C and N stocks were then calculated.

RESULTS AND DISCUSSION

Soil C stocks declined with depth. It also varied according to the cropping system adopted. The values were higher under DMC than under CT. A difference between carbon stock for the two systems was observed only for the surface horizons (p-value = 0.01), with 23.08 Mg C ha^{-1} under DMC and 19.59 Mg C ha^{-1} under CT. For the two underlying horizons, no difference was observed. Nevertheless, no difference was observed between the two cropping systems for 0-30 cm depth.

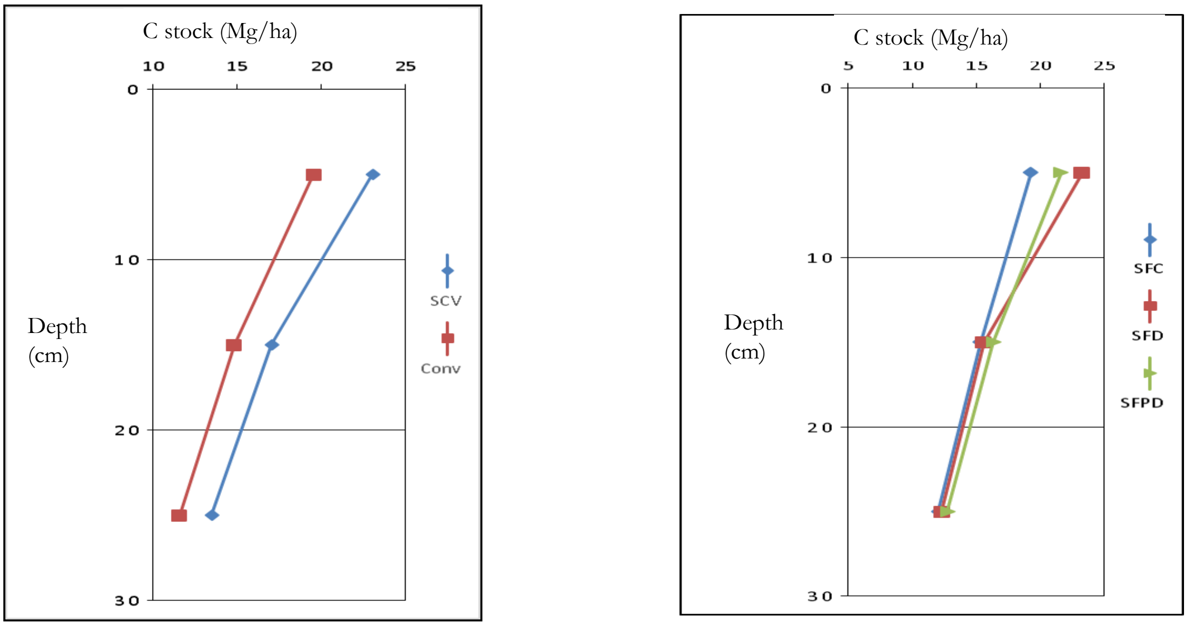

Figure 1: Soil Carbon Stocks for 0-30 cm depth (left: cropping systems, right: soil type)

C stocks did not vary according to the sub-groups of ferrallitic soils. However, rejuvenated ferrallitic soils with poorly degraded structure displayed the highest stocks in the horizon surface (23.29 Mg C ha^{-1}). The introduction of cover crops (*Stylosanthes sp*) in DMC system constitutes an additional organic inputs that can affect long-term changes in soil carbon stocks (Scopel *et al.*, 2005) and improve soil organic matter enrichment (Séguy *et al.*, 2001), particularly in the surface (Costantini *et al.*, 1996). In these systems, a part of the organic matter is physically protected from degradation by the microorganisms in aggregates (Six *et al.*, 2002). Conventional tillage decreases aggregate stability and consequently causes a deprotection of the organic material (Balesdent *et al*. 1999). The higher stock under DMC can also be explained by a better control of carbon losses by erosion as vegetation cover and crop residues improve soil protection against erosion (Razafindramanana, 2011).

Nitrogen stocks are significantly different between the two systems for the three depths analyzed. The higher values were determined in the surface horizon under DMC, with approximately 1.77 Mg N ha^{-1} under DMC 1.43 Mg N ha^{-1} under CT. For the 0-30 cm horizon the nitrogen stocks were significantly higher under DMC with 4.16 Mg N ha^{-1} , and 3.27 Mg N ha^{-1} under CT. On the surface horizon, the rejuvenated ferrallitic soils with poorly degraded structure had the highest stock with 1.80 Mg N ha^{-1} while the concretioned ferrallitic soils had the lowest stock with 1.41 Mg N ha^{-1}. However, nitrogen stocks for three groups of soil are not significantly different for the 0-30 cm horizon.

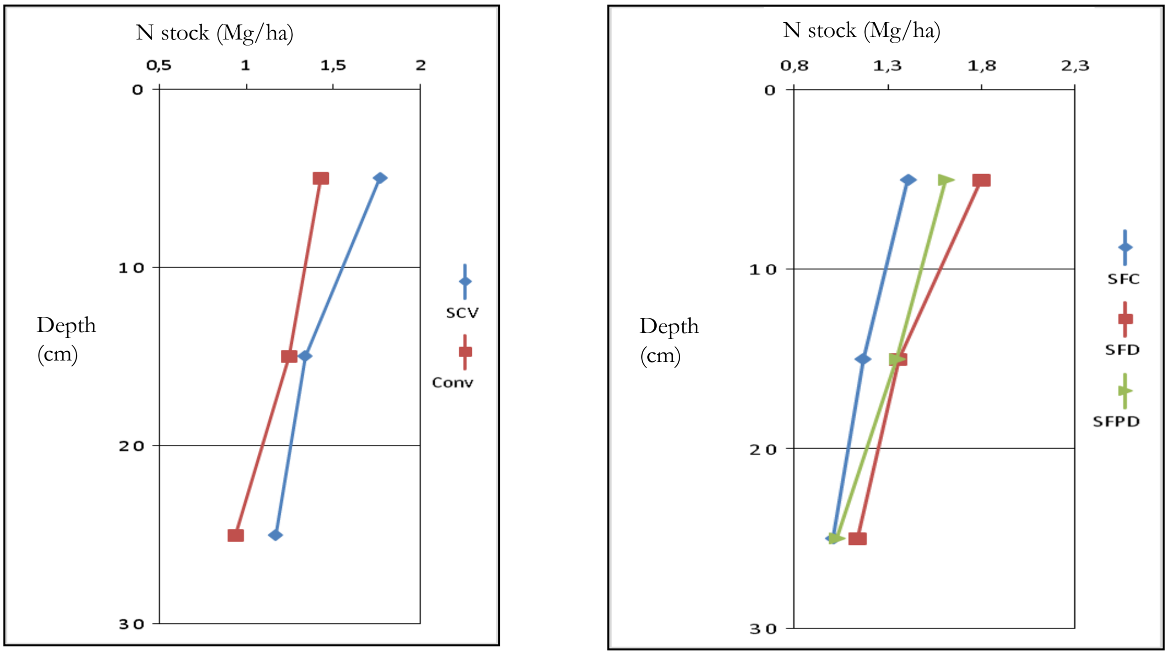

Figure 2: Soil Nitrogen Stocks for 0-30 cm depth (left: cropping systems, right: soil type)

Differences between nitrogen stocks under DMC and under CT were observed for each horizons, with significant higher values under DMC. The use of highly productive cover crops, such as the legume *Stylosanthes sp*, could also explain the increase of the level of nitrogen storage in DMC with regards to CT. The symbiotic fixation of atmospheric nitrogen by legumes may significantly contribute to improve the nitrogen status of the soil in the layer where plants are cropped.

CONCLUSION

This study assessed the effects of two cropping systems, conventional tillage and DMC, on total C and total N storage in the soil. The positive effects of DMC on C storage were found only in the surface horizon, due to a decrease of organic matter content with depth in this system. The same effects have been observed on N stocks for 0-30 cm horizons. This was attributed in particular to the nature of the cover crop used, *Stylosanthes sp*, which is a highly productive nitrogen-fixing legume. From this study, carbon and nitrogen storage in soil does not depend on the soil type, at least for the different groups of ferrallitic soil in the Middle West of Madagascar.

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