Carbon and nitrogen stocks in integrated crop livestock

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Introduction

Soil organic matter (SOM) is recognized as an important characteristic of sustainable agricultural systems in the tropics and temperate regions. It is considered an integrated characteristic of physical, chemical and biological soil conditions and has been used as a soil quality index in different land uses and management practices (Lal 2011). Environmental, social, and financial imbalances have occurred, requiring producers to become more efficient. A system of intercropping grain crops with forages can provide enough forage in the dry season to maintain nutritional quality of livestock and even promote weight gain (Castro Filho *et al*. 1991). An integrated crop-livestock system (ICLS) that includes a crop phase and a pasture phase in rotation has strong potential for sustainable beef and grain crop production (Salton *et al*. 2011). Perennial pastures can contribute to soil C sequestration. Several studies have shown significant soil organic C accumulation with well-managed grazing of pastures (Maia *et al*. 2009; Salton *et al*. 2011). However, there are few studies that compare the efficiency of different grasses to maintain productivity and promote an increase in soil organic C and stocks. We hypothesized that an ICLS with maize cultivated under no-tillage in rotation with grazed pasture (*Urochloa* P. Beauv. spp. (syn. *Brachiaria* (Trin.) Griseb. spp.) would result in accumulation of soil organic C and N compared with continuously grazed, degraded pasture or with conventionally tilled monoculture production of maize. Our objective was to evaluate the stocks of soil organic C and N under alternative land uses from the prevailing degraded pasture condition in Sao Paulo state of Brazil.

Methods

The study was located at the Institute of Animal Science (22º46'28.8"S; 47º17'38,2"W) in the municipality of Nova Odessa, São Paulo state (Brazil). The soil, a typical Acrudox, presented amounts of clay, silt and sand of 550, 160 and 290 g/kg, respectively. A continuously grazed pasture area cultivated with *Urochloa brizantha* cv. Marandu was selected as the base condition for this study. The pasture had low productivity and high degradation from the original condition. In August 2003 initial management upon conversion of a portion of the land area to ICLS consisted of surface application of 1.2 Mg/ha of lime. In November 2004, the first planting of maize (*Zea mays* L.) was made with no-tillage in a mulch of grassy residues, using a chisel plow with cutting discs and winged tips. Maize was fertilized with 350 kg/ha of 8-26-16 (NPK) applied in the groove planting and 360 kg/ha of 5-20-20 (NPK) as top dressing with incorporation into soil mechanical incorporation to the soil with a trencher at 5 cm depth.

Five land use systems were compared: (1) integrated crop-livestock with maize and *Urochloa brizantha* cv. Marandu (ICL- Ub- Marandu); (2) integrated crop-livestock with maize and *U. ruziziensis* (ICL- Ruz); (3) integrated crop-livestock with maize and *U. brizantha* cv. Piata (ICL- Ub- Piata); (4) long-term (25-yr-old) pasture with *U. brizantha* (Cont - Pas); and (5) conventional-tillage cropping with– maize only (CT-maize). The experimental design was a completely randomized block with five replications; experimental units were paddocks of 0.8 ha. For the present purposes, soil evaluations were performed from sampling made in May 2010, after seven years of the experiment establishment. Soil carbon and nitrogen content and stocks were evaluated at depths of 0-10, 10-20, 20-30 and 30-40 cm. Total C and N concentrations were determined by dry combustion using an autoanalyzer LECO CN-2000 model. The Soil C and N stocks were calculated based on equivalent soil masses (Ellert and Bettany 1996), taking the soil mass of the native forest as a reference value (woodland Atlantic Forest). Analysis of variance was used to detect significant differences among treatments. Means were statistically separated using the Student Newman-Keuls test ($P<0.05$). Analyses were performed using SAS (2010).

Results and Discussion

Soil organic C and N concentrations were greatest near the surface. In the surface layer (0-10 cm), C concentration ranged between 14.9 and 16.8 g/kg for ICL-Ub-Piata and ICL-Ub-Marandu, respectively; while N concentration ranged between 1.2 and 1.4 g/kg for CT-maize and ICL-Ub-Marandu, respectively. Soil organic C and N concentrations were typical, *i.e.* higher concentrations at the surface and lower concentrations with increasing depth. With depth, soil organic C and N concentrations became more similar among treatments due to the decreasing influence of surface deposition of organic matter inputs. Surface soil organic C accumulation can occur due to deposition of leaves, stems and roots. Highest soil organic C stocks were obtained under ICL-Ub-Marandu and ICL-Ruz followed

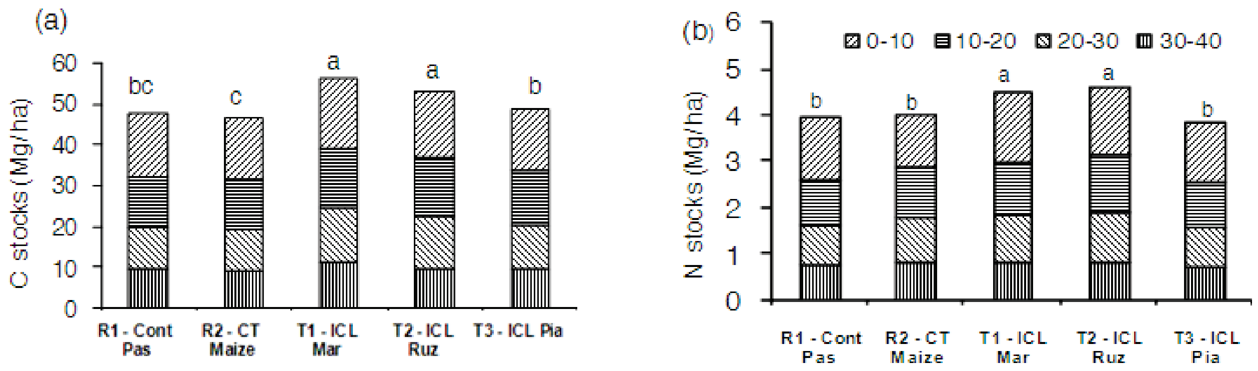

Figure 1. Soil organic C (a) and N (b) stocks in different depths (0-10, 10-20, 20-30 and 30-40 cm) under long- term pasture (R1 – cont pas), conventionally tilled maize silage (CT-maize), integrated crop-livestock systems with maize and *Urochloa brizantha* cv. Marandu (ICL Mar), with *U. ruziziensis* (ICL Ruz), and with *U. brizantha* cv. Piata (ICL Pia). Means (n = 5) with different letters at a depth 0–40 cm differ significantly at *P*< 0.05.

by ICL-Ub-Piata, long-term pasture, and CT maize (Fig. 1a). Similarly, soil N stock was greater in the ICL-Ub-Marandu and ICL-Ruz than other systems (Fig. 1b). No differences occurred among ICL-Ub-Piata and the two references areas.

Annual plowing and harrowing of maize leads to organic matter mineralization and, consequently, lowest soil organic C stock. Productive pastures can maintain soil organic C stock. The initial condition of soil physical and chemical limitations for cultivation resulted in low organic carbon contents. The amounts of N added and / or present in the soil were deficient and limited the addition of C in systems constituted mainly by grasses. This is showed as the difference in soil organic C and N between ICL and CT- maize was not so large in this soil. The C:N ratio of SOM was similar among depths sampled and valueswere similar to those recognized for stable SOM in the tropics. This gives a hint that the high C input from plant residues were being offset by additional N from somewhere in the system. Additional N could be due to fertilizer input in ICL (although there is high N demand by maize that is subsequently exported in grainharvest), or due to biological N fixation by diazotrophic communities present in the rhizosphere of grasses or as endophytic mutualists (Boddey *et al.* 2001). Paul and Clark (1989) attributed soil organic C accumu-lation under conservation tillage systems to two main factors: (1) physical protection of organic com-pounds against microbial decomposition, favored by the C occlusion in soil aggregates; and (2) chemical protection of organic compounds through their inter-action with minerals and cations hindering their decomposition.

Conclusion

Integrated crop-livestock systems have a great potential to increase SOM, represented in this study in the form of C and N stock accumulation. It was the combination of crops and pastures that improved soil organic C and N accumulation compared with continu-ation of long-term continuously grazed pasture or mono-culture cultivation of maize alone. We found larger accumulation rates of soil organic C and N with *U. brizantha* cv. Marandu and *U. ruziziensis* than with *U. brizantha* cv. Piata and with the reference conditions of long-term pasture or conventional tillage cultivation of maize.

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