Soil organic carbon stocks in a Brazilian Oxisol under different pasture systems

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Introduction

Pastures are the main land use systems in the world and in Brazil they occupy 115 Mha. A major part of Brazil´s greenhouse gas emissions is due to land use change and agriculture. Livestock production is responsible for >90% of methane and about 55% of CO_2-equivalent emissions due to agriculture (Cerri et al. 2009). However, productive well-managed pastures can improve degraded soils and increase soil organic carbon (SOC) stocks through humification of grass and root residues. In order to enhance pasture yields and SOC sequestration, nutrient availability in soils must also be improved, especially for N and P. This work aimed to assess how SOC stocks are affected by the combination of grasses and legumes, in comparison with pure grass pastures and other land uses in a clayey Oxisol in southeast Brazil.

Methods

This research was conducted in the campus of the Universidade Federal de Lavras (21º13'42" S, 44º58'13" W; 925 m asl). Five neighboring areas were selected for sampling, comprising: (1) a native, semi-deciduous forest; (2) pure *Brachiaria decumbens* pasture (planted in 1990, under continuous grazing by bovines); (3) mixed *B. brizantha* and *Arachis pintoi* pasture; (4) mixed *B. brizantha* and *Stylosanthes guianensis* pasture; and (5) corn under annual tillage for 25 years. Both pasture + legume plots were planted in 2007 after 15 years under conventional tillage corn, and kept under cyclic bovine grazing. The local soil is a Humic Rhodic Acrudox with clayey (>60% clay) texture and granular structure. Soil sampling for SOC and bulk density (core method) was done in March 2010 using 3 pits per treatment, at depths of 0−5, 5−10, 10−20, 20−40, 40−60 and 60−100 cm. Soil samples were air-dried, sieved (<2 mm) and ground to pass a 100 mesh (0.150 mm) sieve for SOC determination by dry combustion in a Vario Micro Cube (Elementar, Hanau, Germany) apparatus. SOC stocks were calculated using an equivalent mass approach due to soil compaction. The experimental design was completely randomized in triplicate. Treatment means were compared by the Tukey test.

Results and Discussion

Soil bulk density increased significantly in pastures and corn plots in comparison with the native forest (Figure 1); the highest levels were found in areas currently or formerly cultivated with corn. Remarkably, such compaction occurred to a depth of 1 m, due to the very low soil densities and macroporosities in the native forest and the intensity of plowing/harrowing. The opposite occurred for SOC concentration, since the highest values were, as expected, found in the native forest, especially in the top 20 cm (Figure 2). At the 0−5 cm depth, the lowest values were found for the *Brachiaria* + *Stylosanthes* pasture, which can be ascribed to intense organic matter decomposition due to a very low C:N ratio of 7.0 (Pimentel 2012), and in the corn site.

The effect of land use change on SOC stocks occurred for all depths (Table 1). Pure *Brachiaria* pastures had significantly less SOC than native forest for the 0−20 cm (most intensively cultivated layer) and 0−40 cm (maximal arable layer) depths, but not for the 0−60 and 0−100 depths. Since most SOC changes typically occur in the top 20 cm, this trend is primarily due to the decreasing ratio of SOC change:total SOC as increasingly deeper layers are considered for the *Brachiaria* pasture. However, SOC losses for the grass-legume pastures increased from 30 t C/ha for the 0−20 cm depth to

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90 t C/ha for the 0−100 cm layer in comparison with native forest, and even more for the corn. Therefore, the data showed that intense SOC losses can occur with annual cultivation even to very deep layers, contrasting with the typically superficial effect noted for Brazil as a whole (Zinn et al. 2005). It is possible that such heavy losses are also due to originally very high SOC stocks of >200 t/ha for this area, which are not common in Brazilian savanna and Amazonian soils. However, mixed pastures of *Brachiaria* + *Arachis* seem to increase SOC levels in comparison with corn, but this effect was weaker in the case of the *Brachiaria* + *Stylosanthes* pasture. Such difference was probably due to the greater predominance of *Stylosanthes* in this association, which generated residual organic matter with high N content and thus more susceptible to microbial decomposition.

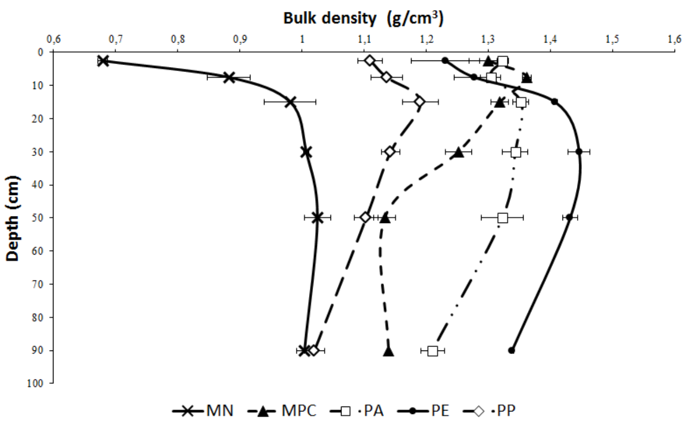

Figure 1. Means of soil bulk density (g/cm^3) to a depth of 100 cm. Bars show standard error of the mean. Land use systems are native forest (MN), corn (MPC), *Brachiaria* + *Arachis* pasture (PA), *Brachiaria* + *Stylosanthes* pasture (PE), and pure grass pasture (PP).

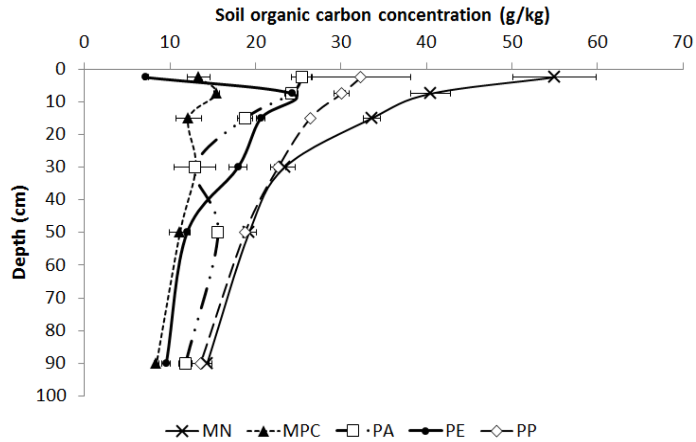

Figure 2. Means of soil organic carbon concentration (g/kg) to a depth of 100 cm. Bars show standard error of the mean. Land use systems are native forest (MN), corn (MPC), *Brachiaria* + *Arachis* pasture (PA), *Brachiaria* + *Stylosanthes* pasture (PE) and pure grass pasture (PP).

Conclusion

Replacing native forests with pastures, where inherent SOC stocks are high, apparently leads to heavy SOC losses, even when pastures are well managed and productive. However, SOC is preserved better under pastures than under annual crops with conventional tillage, and pastures can sequester SOC after croplands are turned into grazing lands. Nevertheless, this study also indicates that excessive N inputs through biological fixation in legume-grass mixtures can unexpectedly accelerate organic matter decomposition and delay or preclude SOC sequestration on degraded or over-exploited land.

Table 1. Soil organic carbon stocks for different standardized depths. Means within columns followed by the same letter do not differ by the Tukey test at P<0.05.

Land use	Soil organic C stocks (t/ha)			
	0−20 cm	0−40 cm	0−60 cm	0−100 cm
Native forest	71.8 A	128.5 A	171.8 A	239.9 A
Brachiaria	50.7 B	100.2 B	142.2 A	207.8 A
Brachiaria + *Arachis*	39.4 BC	71.3 C	100.3 B	155.9 B
Brachiaria + *Stylosanthes*	33.2 CD	71.8 C	102.2 B	145.9 BC
Corn	24.1 D	49.5 C	74.0 B	113.7 C

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