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# EFFECT OF DEFORESTATION AND MANAGEMENT ON SOIL CARBON STOCKS IN THE SOUTH AMERICAN CHACO

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**Abstract**

In the Argentine sub-humid Chaco since the end of the '70 there has been an advance of the agricultural frontier over the native forest. Loss of forest reduces carbon stocks in vegetation and causes significant losses of soil organic carbon. The objective of this study was to determine the organic carbon (OC) stock up to 1-meter deep and to determine its fractions in the surface soil layers under different land uses: agricultural (less than 10 years and more than 20 years under agriculture), pasture and forest in the Chaco region. The OC contents up to 1 m deep expressed in equivalent mass were as follows: forest (119.3 Mg $ha^{-1}$)> pasture (87.9 Mg $ha^{-1}$)> agricultural (71.9 and 77.3 Mg $ha^{-1}$). The most sensitive OC fraction was the coarse fraction (2000 µm -212 µm) in the two depths studied (0-5 cm, 5-20 cm). Resistant carbon (<53 µm) was the main fraction of organic matter for all the studied situations except for the forest. The stock of OC, its quality and its distribution in the profile were sensitive to the change of land use in the studied region. The conversion of the Chaco forests to crops was associated with reductions of OC up to the meter deep and with the decrease of the labile fractions. The loss of such important ecosystem service that helps mitigate global warming could be reduced by appropriate management practices, one of which may be the incorporation of pastures of warm-season grasses.

*Keywords: Carbon sequestration, particulate carbon, land use change*

## Introduction, scope and main objectives

Since the end of the 1970s, the Argentine agricultural frontier has been advancing over natural ecosystems (Gasparri et al., 2009; Viglizzo & Jobbagy, 2010). The sub-humid and semi-arid Chaco has one of the largest areas of native forests and since 1997 there has been a notable increase in the deforested area (Albanesi et al., 2003; Volante et al., 2009).

Loss of forests not only reduces carbon stocks in vegetation but also causes significant losses of soil OC (Neill et al., 1998; Post & Kwon, 2000; Desjardins et al., 2004). Chaco forest has 60% of the carbon accumulated in the aerial biomass and 40% in organic matter in the first meter of soil, and because of the large surface area that occupies in Argentina constitutes a large reservoir of carbon (Gasparri et al., 2008). Due to the introduction of agriculture, up to 50% of soil organic matter can be lost after 20 to 30 years in the forests of tropical America, until reaching a new equilibrium (Eswaran et al., 1993). In the eastern sub-humid Chaco, reductions in the levels of organic matter have been detected in the first centimeters, especially of their labile fraction (Álvarez & Lavado, 1998; Roldán et al., 2000; Albanesi et al., 2003; Sánchez (2006). Agricultural practices not only affect the total amount of OC, but also change the relative proportion of OC fractions (Barbero et al., 2006; Conteh et al., 1998). The main reasons for this decline were deforestation plus soybean and cotton monoculture, increased years of agriculture and inadequate management.

In the mid-1990s the adoption of no-till occurred. This technique was adopted in Argentina due to the low production costs, the possibility to devote less productive areas to agriculture (Satorre, 2005; Derpsch et al., 2010), the save of operation time and to the minimal soil distribution that allows reduce the erosion, recover the stability of the aggregates, conserve water and increase carbon sequestration (Panigatti et al., 2001, Díaz Zorita et al., 2002, Viglizzo et al., In Viglizzo & Jabbagy, 2010).

In the western part of the region, livestock production become important, and in some cases the native forest is replaced by warm-season grasses pastures. This activity produces a lower reduction of the OC contribution to the soil and is expected lower losses of OC than under continuous agriculture (Caruso et al., 2012).

The objective of this study was to determine the organic carbon (OC) stock up to one meter deep and to determine its fractions in the surface soil layers under different land uses: agricultural (less than 10 years and more than 20 years under agriculture), pasture and forest in the Chaco region.

## Methodology

Soil sampling was carried out in production fields of Santiago del Estero province (central area of Argentina). This area is located in the subhumid Chaco natural region (Vargas Gil, 1988). Annual rainfall ranges from 700 mm to 1000 mm. The average annual temperature is 21 ° C. The most representative soils are Haplustolls, Argiustolls and Ustifluvents (Vargas Gil, 1988).

Sixteen cropped fields were selected, eight with less than 10 years and eight with more than 20 years under agriculture. The agricultural management consisted in one summer crop per year (alternating between soybean, maize and cotton) under continuous no-till. Additionally eight situations of native forest (forest curtains) and eight situations of warm-season grasses pastures (Panicum maximun cv. Gatton Panic) were selected. In each situation soil was sampled up to one meter deep:  0 to 5 cm, 5 to 20 cm and then every 20 cm. Four subsamples were taken from each soil interval.

The OC was determined by wet combustion using the Walkley-Black method (Nelson & Sommers, 1996) and in the 0-5 and 5-20 cm intervals particulate OC was also measured (Cambardela and Elliot , 1992). Soil carbon contents are expressed at a fixed depth and as constant soil mass (Neill et al., 1997) to isolate the effect of differences in soil bulk density. In the each situation, soil bulk density was determined by the cylinder method,

The analysis of the variance (ANOVA) was performed and the LSD test ($p \leq 0.05$) was used for the comparison of means. The normality of the data was checked by the modified Shapiro Wilks test.

## Results and Discussion

Soil use influenced soil OC up one meter deep unless in the 20 to 40 cm interval where all situations had the same amount (19.5 Mg ha$^{-1}$, Figure 1). There was a significant reduction in the OC in agricultural sites relative to the pristine situation (native forest) in the first 20 cm and from 40 to 80 cm depth. The pastures only presented this reduction in the surface layers. Between 34% and 48% of the total OC was found in the first 20 cm of soil, in the forests the carbon was more stratified (Jobbágy & Jackson, 2000). For 0 to 20 cm the decrease in OC was 45%. The vertical distribution of OC tends to follow the design of the root system (Jobbágy & Jackson, 2000).

The OC contents up to one meter deep expressed in equivalent mass (9885 Mg ha$^{-1}$ of soil) followed this trend: forest ( 19.3 Mg ha$^{-1}$) > pasture ( 87.9 Mg ha$^{-1}$) > agricultural situations (71.9 and 77.3 Mg ha$^{-1}$).

Organic carbon stock in agricultural sites did not differ between years under agricultural so the losses of soil organic carbon occur in the first years of the conversion to agriculture. The soil OC content is related to the carbon input from the vegetation. Net primary production varies between biomes, being higher in forest, intermediate in pastures and lesser in crops (Aber & Melillo, 2001; Follet et al., 2009). In the Pampas region Sainz Rozas et al. (2011) observed that the reduction of OC under agriculture ranges from 36 to 53% relative to the pristine soils. This places our values in the middle of this range of variation. This lost of OC is explained by the lower contribution of crops to the soil (Álvarez, 2006), greater mineralization rate and a greater susceptibility to erosion (Andriulo & Cardone, 1998) in agricultural situations.

Land use has a significant influence on carbon fractions. The most sensitive fraction was the coarse fraction (2000 μm -212 μm) in both studied depths (Figure 2). Resistant carbon (<53 μm) was the main fraction of organic matter for all the studied situations except for the forest, where the more labile and more readily available fractions represented the 65% of the total OC in the surface horizon and 55% in the 5 -20 cm layer (Franzluebbers et al., 1996).

The resistant carbon (<53 μm) content in agricultural sites totalized the 78% of the total OC so there is a redistribution of OC from more labile fractions to more resistant ones, which have a lower nutrient mineralization rate.

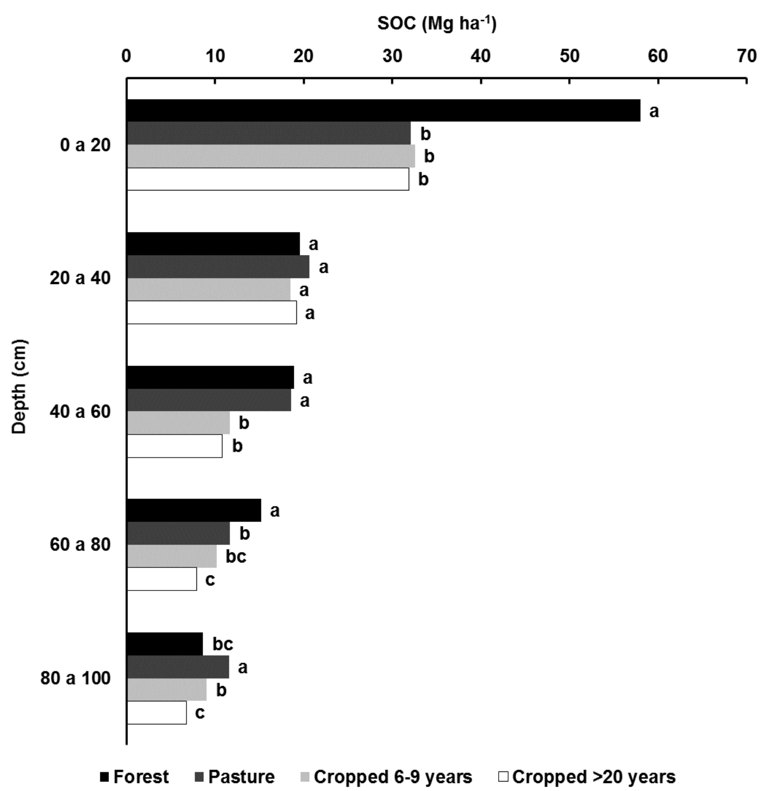


**Figura 1. Soil organic carbon (SOC) distribution in depth under different land uses. Different letters indicate significant differences between land uses for a same depth.**

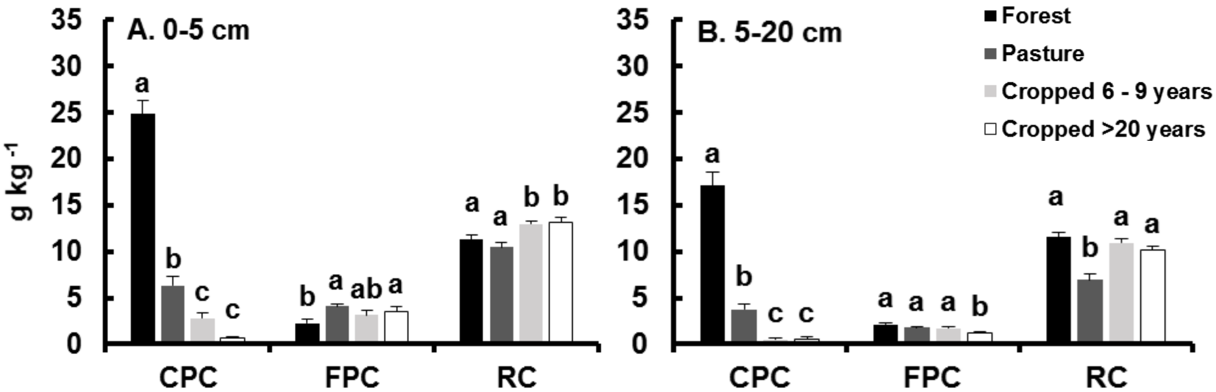


**Figure 2: Coarse particulate carbon 2000 µm - 212µm (CPC), fine particulate carbon 212µm - 53µm (FPC) and resistant carbon <53µm (RC) variations associated with land use .A: Depth 0-5 cm. B: Depth 5-20 cm. Different letters indicate significant differences between landñ uses for a same depth interval.**

## Conclusions

The OC stock, its quality and its distribution in the profile is sensitive to the change of land use occurred in the studied region. The conversion of the Chaco forest to agriculture produced substantial reductions of OC up to the meter deep and a decrease of the labile fractions in surface layers. The loss of such important ecosystem service that helps mitigate global warming could be mitigated by appropriate management practices, one of which may be the incorporation of pastures.

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