Land Use Change, Organic Matter Storage and Composition in an Arid Soil of Argentina

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INTRODUCTION

Dry forests of central-western Argentina (i.e. Arid Chaco) are xerophytic ecosystems with a significant role in preserving soil organic matter (SOM) storage and reducing CO_2 emissions through land use and land cover change. However, deforestation, overgrazing, and irrigated agriculture have intensified degradation processes and SOM losses in the Arid Chaco region. Dynamic soil properties (i.e. SOM) are critical parameters to indicate the capacity of a soil to function and recover from anthropogenic and non-anthropogenic disturbances (i.e. fire, drought). The study of SOM fractions with different turnover periods and functional group chemistry can be used to help explain soil responses to land use change and climate variability.

OBJECTIVES

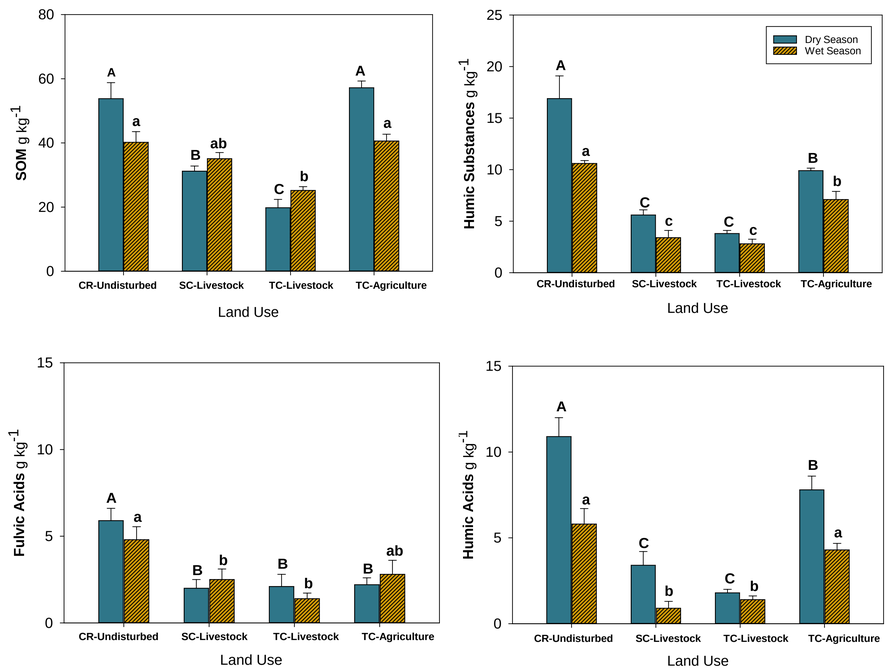
The objectives of this work were to: i) quantify the effects of land use change and seasonality on the surface concentration of SOM and related labile and recalcitrant pools, and ii) examine SOM functional group composition and its relationship to land use and seasonality.

MATERIALS & METHODS

We compared an undisturbed forest (Chancaní Reserve - CR) to three productive sites with different levels of land-use intensity and external inputs: a) TC-livestock, total clearing with extensive livestock, b) SC-livestock, selective clearing (30% of tree cover) with extensive livestock and, c) TC-agriculture, total clearing with irrigated agriculture and fertilization (wheat/maize/potato crop sequence). During August 2011 and February 2012, dry (D) and wet (W) season, respectively, composite soil samples were taken to a depth of 20 cm. Air dried-sieved soil was analyzed for total SOM, humic substances (HS), humic acids (HA), fulvic acids (FA), dissolved organic carbon (DOC) and hot-water extractable carbon (HWC) content. Aliquots of HS in solution were air-dried and FTIR spectra were recorded on KBr pellets. The FT-IR spectra of each sample (adquired between 4000 and 400 cm^{-1} range) were registered using a FT-IR Bruker IFS 28 spectrophotomer. A Shimadzu UV-240 equipment was used to obtain E_4/E_6 ratio (absorbance to 465 and 665 nm of the visible spectra) of each sample.

RESULTS

Figure 1. SOM and SOM recalcitrant fractions concentration (0-20 cm).



Each value is the mean of 3 composite samples, different letters (a-c or A-C) indicate significant differences among sites. LSD test (n=3; p≤0.05). Note: scale on y-axis differs with soil organic matter (SOM) fractions.

Table 1. IR band intensities[a] of HS from dry (D) and wet (W) seasons.

	Infrared band (wavenumber cm^{-1})									
Sites	I_{3400}		I_{2920}		I_{1720}		I_{1460}		I_{1030}	
	D	W	D	W	D	W	D	W	D	W
CR-Undisturbed	1.16 (0.31)	0.38 (0.08)	0.52 (0.12)	0.20 (0.05)	1.38 (0.14)	0.00	0.89 (0.23)	1.98 (0.40)	0.70 (0.06)	0.96 (0.32)
SC-Livestock	1.32 (0.56)	1.83 (0.34)	0.55 (0.09)	0.83 (0.20)	1.29 (0.19)	0.00	0.90 (0.10)	1.99 (0.35)	0.67 (0.12)	0.45 (0.07)
TC-Livestock	1.14 (0.44)	0.65 (0.10)	1.08 (0.39)	0.73 (0.23)	1.42 (0.11)	0.00	0.75 (0.17)	1.98 (0.55)	0.34 (0.05)	0.39 (0.09)
TC-Agriculture	1.12 (0.25)	1.02 (0.15)	0.62 (0.15)	1.07 (0.45)	1.40 (0.22)	0.00	0.75 (0.08)	1.99 (0.25)	1.59 (0.85)	0.85 (0.21)

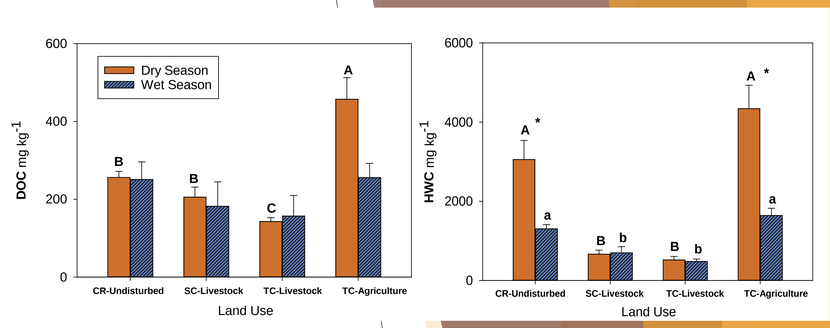
Each value is the mean of n=3. [a] Absorption units in full-scale normalized spectra. Standard error determined for n= 3 (in parentheses). I_{3400}: relative intensity of the band at 3400^{-1}. I_{2920}: relative intensity of the band at 2920^{-1}. I_{1720}: relative intensity of the band at 1720^{-1}. I_{1590}: relative intensity of the band at 1590^{-1}. I_{1460}: relative intensity of the band at 1460^{-1}. I_{1030}: relative intensity of the band at 1030^{-1}.

Table 2. UV-Vis spectroscopic properties of HS.

Site	E_4/E_6[a]		Δ log K[b]	
	D	W	D	W
CR-Undisturbed	3.81 b	2.98 c	0.57	0.54
SC-Livestock	4.75 a	4.76 b	0.68	0.65
TC-Livestock	5.94 a	6.85 a	0.75	0.72
TC-Agriculture	4.12 a	4.60 b	0.70	0.70

Each value is the mean of n=3, different letters indicate significant differences between sites. LSD test (n=3; p≤0.05). [a] E_4/E_6=Abs_{465nm}/Abs_{665nm} [b] Δ log K= log Abs_{465nm} / log Abs_{665nm}.

Figure 2. SOM labile fractions concentration (0-20 cm).



Each value is the mean of 3 composite samples, different letters (a-c or A-C) indicate significant differences among sites, LSD test (p≤0.05). *indicates significant differences between seasons for each sampling site (p < 0.05). Note: scale on y-axis differs with SOM fractions. DOC, dissolved organic carbon; HWC, hot-water extractable carbon.

HIGHLIGHTS

SOM content was higher in CR and TC-agriculture relative to livestock clearing (TC and SC) sites (Fig.1).

The concentrations of HS, HA, and FA were all reduced substantially by land use change (Fig. 1).

The type of clearing (TC and SC) did not affect HS concentration nor E_4/E_6 ratios among livestock systems.

Seasonality only affected the concentration of labile SOM with a general decrease of active-C pools during the wet season (Fig. 2).

The band 1720 cm^{-1}, attributed to the presence of carboxylic groups (stretching of C=O bonds), was only detected during the dry season (Table 1).

Polysaccharides (C-O stretching, 1030 cm^{-1} band) was 4.0 times higher in TC-agriculture than in TC-livestock during dry season (Table 1).

Comparatively, all productive sites presented high values for E_4/E_6 ratio, indicating a lower degree of aromaticity and condensation of SOM and a relatively high presence of aliphatic structures (Table 2).

CONCLUSIONS

SOM components have undergone moderate to strong degradation after the conversion of native woodlands to livestock systems. Higher labile-C concentration observed in TC-agriculture may reflect greater residue accumulation at the soil surface, but not necessarily long-term SOM storage and stabilization as HS were highly impacted. Changes in the original SOM composition of CR-undisturbed soil as an effect of land use change were clearly shown in the soil studied at 0-20 cm depth. FT-IR is a sensitive method to evaluate how management practices affect the storage and chemical characteristics of HS.

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