XXXV Congresso Brasileiro de Ciência do Solo
CENTRO DE CONVENÇÕES - NATAL / RN
O SOLO E SUAS MÚLTIPLAS FUNÇÕES
02 a 07 DE AGOSTO DE 2015

Isotopic composition shifts of soil regarding sugarcane expansion into pastures areas in South-Central Brazil[1]

Dener Márcio da Silva Oliveira[2]; Andressa Gonçalves Cerqueira[3]; Amanda Rocha Fiallos[3]; Amanda Corrêa Capellari[4]; Thalita Pereira Lavorenti[4]; Carlos Eduardo Pellegrino Cerri[5]

[1] Financial support by FAPESP (Process n° 2014/08632-9).
[2] Doctorate student; Luiz de Queiroz College of Agriculture – University of São Paulo; Piracicaba-SP; denermsoliveira@gmail.com. [3] Undergraduate student; Luiz de Queiroz College of Agriculture – University of São Paulo. [4] Undergraduate student; Engineering School of Piracicaba. [5] Professor; Luiz de Queiroz College of Agriculture – University of São Paulo.

ABSTRACT: The most pervasive scenario of sugarcane expansion in Brazil is into areas previously used as pasture. Changes in soil organic matter (SOM) have raised controversies about the environmental sustainability of biofuels crops. To further elucidate changes in C and N dynamics at superficial and deeper soil layers resulting from sugarcane expansion in South-Central Brazil, we examined the effects of land use change (LUC) on C and N isotopic composition of soil. Soil sampling was carried out in three study sites (LAT_17S; LAT_21S and LAT_23S) and isotope composition of C and N were determined using an elemental analyzer and mass spectrometer. The LUC caused shifts on isotopic composition of soil in areas of South-Central Brazil. In areas undergoing the conversion native vegetation - pasture, alterations in $\delta^{15}N$ and $\delta^{13}C$ were more noticeable in shallow layers, while in conversion pasture - sugarcane the shifts extend to deeper soil layers.

Index terms: ^{13}C, ^{15}N, land use change.

INTRODUCTION

The ethanol derived from 1 ha of sugarcane avoids the emission of about 14 Mg CO_2 eq yr^{-1} relative to the use of fossil fuels (Betts, 2011). Besides, when compared to ethanol derived from other feedstock, such as corn, sugarcane is the most effective option to mitigate greenhouse gases (GHG) emissions. In Brazil, the largest producer of sugarcane ethanol, the area currently planted with sugarcane is undergoing significant expansion (Lapola et al., 2014).

The most pervasive scenario of sugarcane expansion in Brazil is into areas previously used as pasture (Lapola et al., 2014). The sugarcane expansion between 2000 and 2010 occurred mostly over pastures (73.04 %) and annual crops (25.08 %), and to a smaller extent over citrus (1.3 %), and native vegetation (0.5 %) (Adami et al., 2012).

The land use change (LUC) induces modifications in biomass production and soil organic matter (SOM), which are the major sources of uncertainty in life cycle assessments of tropical agricultural products (Don et al., 2011). The C stored in the soil, which globally is more than three times the amount of C in the atmosphere (Lal, 2008), plays a key role in the dynamic of GHG (Cotrufo et al., 2011). Thereby, changes in soil C and N stocks have raised controversies about the environmental sustainability of biofuels crops (Mello et al., 2014).

Isotopic techniques have been applied in tropical areas for study of C dynamics, where forests with C3 photosynthetic pathway plants are replaced by C4 plants such as tropical forages and sugarcane (Franco et al., 2015). In these cases, it is possible to infer about the origin and level of stabilization of C stored in soil using the isotopic signature of ^{13}C ($\delta^{13}C$). In addition, despite the complexity to interpretations of isotopic signature of ^{15}N ($\delta^{15}N$) in soils, some generalizations can be made (Lerch et al., 2011). Thus, it is possible that $\delta^{15}N$ values allow inferences about the impacts of LUC in N cycling and SOM dynamics in tropical agroecosystems.

To further elucidate changes in SOM dynamics at superficial and deeper soil layers resulting from sugarcane expansion in South-Central Brazil, we examined the effects of the most common LUC sequence in sugarcane expansion areas, i.e. the conversion from native vegetation to pasture and from pasture to sugarcane, on C and N isotopic composition of soil.

MATERIAL AND METHODS

The study sites were located in three strategic and representative sites in the South-Central, the main sugarcane producing region in Brazil (Figure 1). The study sites are: 1) Lat_17S: located in Jataí city, Southwestern region of the Goiás state (Lat.: 17º56′16″S; Long.: 51º38′31″W) 2) Lat_21S: located in Valparaíso city, West region of the São Paulo state (Lat.: 21º14′48″S; Long.: 50º47′04″W) 3) Lat_23S: located in Ipaussu city, South-Central region of the São Paulo state (Lat.: 23º05′08″ S; Long.: 49º37′52″ W).

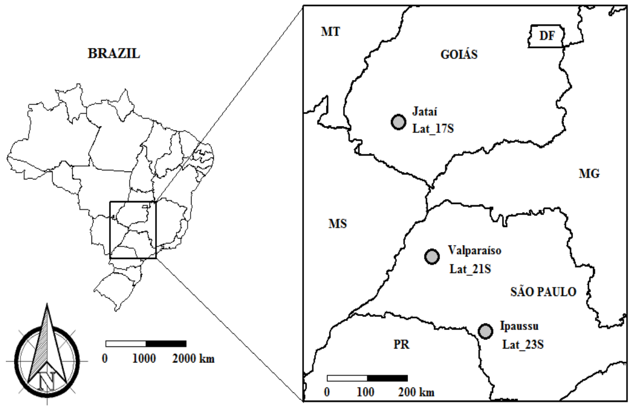

Figure 1 - Geographic location of the study sites across the South-Central sugarcane belt in Brazil.

In this study it was used a synchronic approach (chronosequence) and each one of the three studied sites was composited by three land uses (Figure 2): native vegetation (NV), pasture (PA) and sugarcane (SG), representing the most common land use change sequence in South-Central region of Brazil. The three land uses are located adjacent to each other, minimizing the effects of climatic, topographic and soil variations.

The sampling design in the three land uses (NV, PA and SG) in each study site was composed by a sampling grid with nine points, 50 meters away from each other. The samples (0-0.1 m and 0.9-1.0 m) were collected using a Dutch auger. Isotope composition of C and N were determined using an elemental analyzer and mass spectrometer at the Laboratory of Isotopic Ecology at the Center for Nuclear Energy in Agriculture, (CENA-USP). Results were expressed as $\delta^{13}C$ and $\delta^{15}N$ (‰) using PDB-Vienna as reference for C and air composition for N.

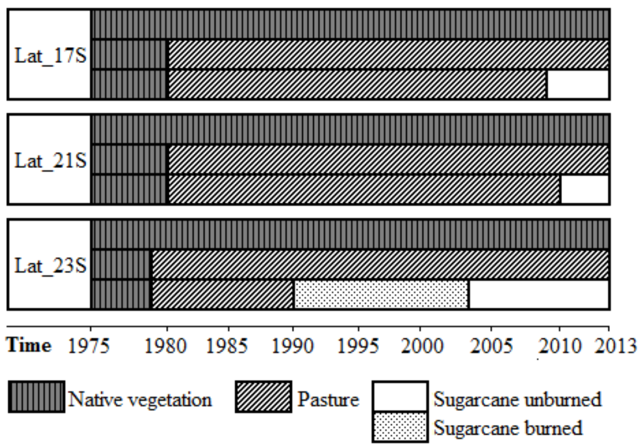

Figure 2 - Schematization of chronosequences in areas undergoing LUC in South-Central Brazil.

RESULTS AND DISCUSSION

The LUC has determined shifts in the isotopic composition of soil in all assessed sites (Figure 3). Soils under NV showed typical values of $\delta^{13}C$ for areas with C3 plants (Figure 3A). The $\delta^{13}C$ at superficial layer (0-0.1 m) were 26.17 (±0.41), 26.40 (±0.41) and 25.23 (±0.47) ‰, in LAT_17S, LAT_21S and LAT_23S, respectively. In this same soil layer, the conversion NV-PA increased $\delta^{13}C$ of SOM in all assessed sites, while the conversion PA-SG did not alter notably the $\delta^{13}C$ values in these areas, showing that, at 0-0.1 m layer, the relative proportion of C4 plants in MOS not changed in areas undergoing this conversion (Figure 3A).

The conversion of natural ecosystems to agricultural uses affects significantly the $\delta^{13}C$ values in Brazilian soils (Assad et al., 2013; Franco et al., 2015). This is a further indication that the C losses (native-C) in areas undergoing LUC are partially offset by the C input from the current land uses (modern-C), especially in the upper soil layers. The C from PA and SG has a higher $\delta^{13}C$ value, which determines that PA and SG soils showed intermediate values between these sources (Bernoux et al., 1998).

The conversion PA-SG in these sites revealed a tendency of increase of $\delta^{15}N$ in upper soil layers (Figure 3A). Different environmental changes can be associated with shifts in $\delta^{15}N$ of SOM. In this case, it is suggested that tillage and addition of N fertilizers in SG areas were associated with $\delta^{15}N$ enrichment in these areas by increasing N losses by nitrification, denitrification and NH_3 volatilization (Hogberg et al., 1997).

The $\delta^{15}N$ value in LAT_17S was 4.27 ‰ (±0.65), remarkably lower than others under NV in the 0-0.1 m layer (Figure 3A). Such a discrepancy made it hard to infer about changes associated to NV-PA conversion using $\delta^{15}N$. These lower $\delta^{15}N$ values in soils under native vegetation in LAT_17S were promoted by the high content of legume species in Cerrado Biome, which fix atmospheric N depleted (Bustamante et al., 2004).

Even to deeper soil layers, the LUC was associated with changes in isotopic composition of SOM (Figure 3B). However, areas under NV and PA are close in the Figure 3B, allowing inferring that more noticeable alterations on SOM dynamics regarding NV-PA conversion occurred on shallow layers. Under these two land uses, the high $\delta^{15}N$ observed at 0.9-1.0 m soil layer suggest advanced stage of SOM decomposition. The successive microbial decomposition of N-containing substrates results in the progressive increase in $\delta^{15}N$ (Hogberg et al., 1997).

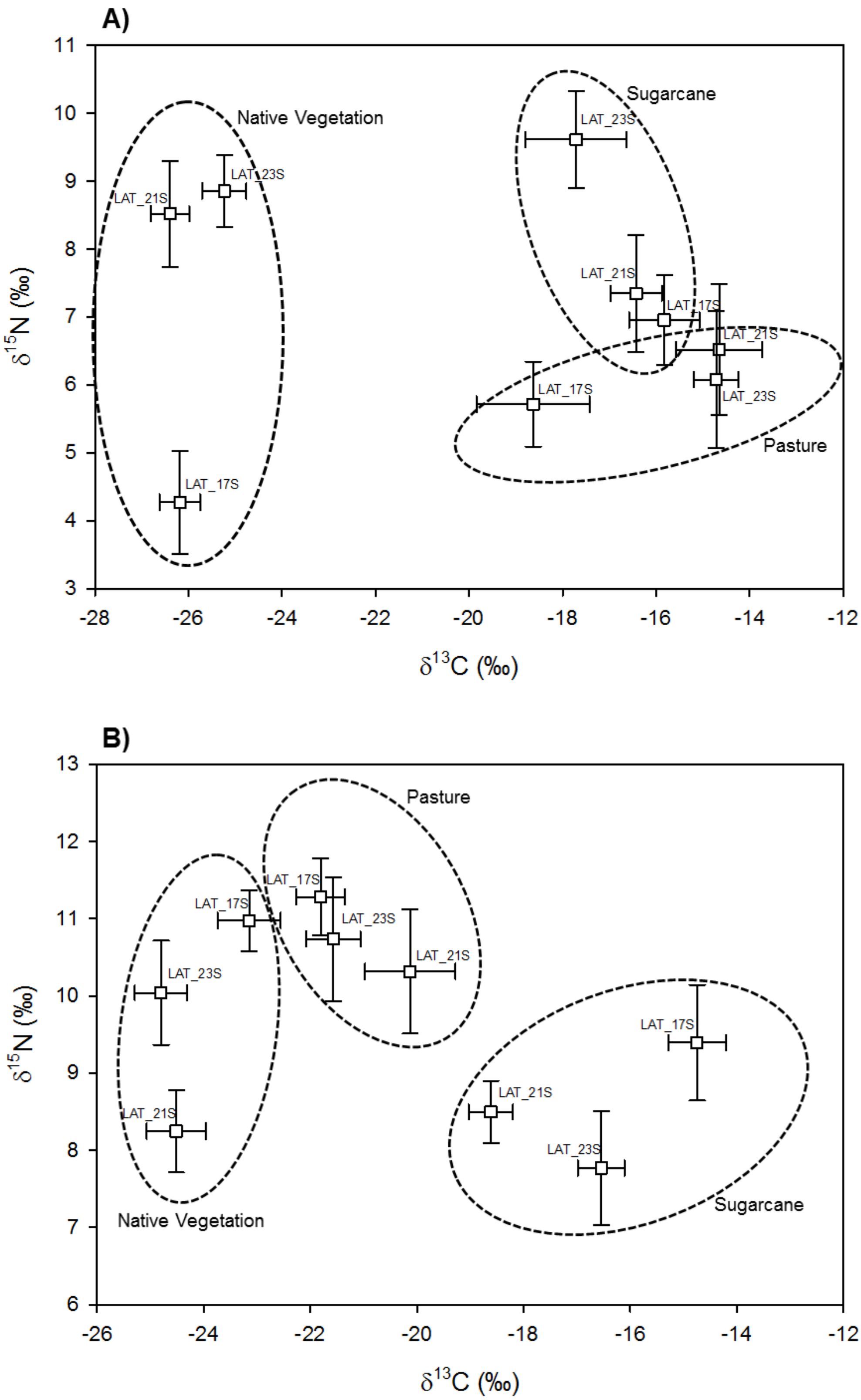

Figure 3 - Isotopic composition ($\delta^{13}C$ e $\delta^{15}N$) of soil at A) 0-0.1 m and B) 0.9-1.0 m in areas under different land uses in South-Central Brazil. Bars represent the standard deviation from the mean values. n = 9.

At 0.9-1.0 m soil layer, the values of isotopic composition of SOM in SG areas were clearly clustered and distinguishable from $\delta^{13}C$ and $\delta^{15}N$ values obtained in areas under NV and PA (Figure 3B). The higher $\delta^{13}C$ in areas under SG indicates greater contribution of C from C4 plants in SOM of these areas, even in deeper layers. In addition, the trend of lower $\delta^{15}N$ values in relation to NV and PA suggest a possible fresh litter input on depth in soils of areas cultivated with SG (De Clercq et al., 2015). Besides, root material tends to be more $\delta^{15}N$ depleted compared to other plant components (Liao et al., 2006). These transitions highlighted the potential of sugarcane to supply C to soil, even in the deeper layers.

In addition, under the same land use, samples from different sites exhibited isotopic signatures close, which allowed the clustering of values according land use. Thus, it is suggested that the vegetation type and aspects related to land use and management were more influential in the isotopic composition of SOM than, e.g. climate conditions or soil attributes, in areas of South-Central Brazil (Figure 3). Recently, De Clercq et al. (2015) discriminated different land uses (grassland *vs* cropland) and management practices (till *vs* no till) using $\delta^{13}C$ e $\delta^{15}N$ of SOM in areas of Belgium and Austria. Besides feasible, this approach is useful to access some generic impacts of LUC and soil management in SOM dynamics. Finally, we highlighted the lack of this kind of research in tropical conditions, where the application of isotopic tools in SOM studies has tended to use only the C partitioning approach.

CONCLUSION

The land use change causes shifts on isotopic composition of soil in areas of South-Central Brazil. In areas undergoing the conversion native vegetation - pasture, alterations in $\delta^{15}N$ and $\delta^{13}C$ are more noticeable in shallow layers, while in conversion pasture-sugarcane the shifts extend to deeper soil layers.

AKNOWLEDGEMENTS

The author gratefully the São Paulo Research Foundation (Process FAPESP n° 2014/08632-9) for the scholarship granted while this research was carried out. Raizen Company is acknowledged for allowing the sampling in its farms and provides logistical support.

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