NATURAL ORGANIC MATTER RESEARCH

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Long term pasture alters carbon stocks and organic matter dynamics in Brazilian Southwestern Amazon

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Introduction

The impact of land use change (LUC) on the soil organic matter (SOM) is well investigated in subtropical areas, but little is known about the LUC effect in the SOM of tropical areas. The State of Acre, Southwestern Brazilian Amazon, presents about 85% of its area still under native vegetation and therefore constitutes an optimal scenario for studies about alterations of SOM dynamics and carbon (C) sequestration promoted by LUC in Amazonian soils. The main objective of this work was to evaluate the impact of pasture introduction on the C stocks and SOM dynamics in Acrisol profiles under long-term pastures in the Brazilian Southwestern Amazon.

Methods

Two farms were selected for this study: Cipoal (CI) and Iquiri (IQ) (09° and 10º S, 67° W), located in the Acre State, Brazil. The climate is tropical humid without a dry season (Af) (Koppen-Geiger), with a mean precipitation of 1,600 to 2,700 mm year^{-1}, and mean annual temperature of 24.5ºC. In each farm, soil samples were collected (4 replicates) in six layers (0-5, 5-10, 10-20, 20-40, 40-70 and 70-100 cm) from 21 years old (P21) and 41years old pastures (P41), and from native forest (NF, C_3 plants). The pasturelands (C_4 plants) were mainly cultivated with *Brachiaria brizantha* and *humidícola*, and intercropping with forage peanuts (only in CI farm). C content was determined by dry combustion and stocks were calculated according to the mass-equivalent approach. The contribution of C_4 plants to the SOM composition was evaluated by isotopic signature $\delta^{13}C$ determination. The proportion of "young" C (derived from pasture), α, was calculated. The SOM chemical composition was investigated by ^{13}C NMR CP/MAS in composite samples (n=4) of the soil (SOM_{soil}) and of the clay fraction (SOM_{clay}) from the 0-5 cm layer, treated previously with 10% HF solution.

Results and discussion

The C/N ratio, varied between 8 to 9.7 in the 0-5cm layer and decreased to around 4.3 to 6.2 at 70-100 cm layer, regardless the soil use. These values are lower than those observed usually for subtropical soils and are indicative of a comparatively more intense humification process in tropical soils.

In the CI farm, only the P41-B area showed a greater soil C stock in the 0-20 cm layer (38 Mg ha^{-1}) than that under NF (Fig. 1a). However, when considered the accumulated C stock within the 100 cm depth, a gradual increase of C stock with time was observed (Fig. 1c) and a value of 120 Mg ha^{-1} was achieved under P41-B. In the IQ farm, accumulated C stocks in the 0-20cm and in the 0-100cm layer under P21 were greater than under NF, whereas the C stock of P41 area did not differ from NF (Figs. 1b, 1d). The soil in the P41 area presented a coarser texture (45 to 77% sand) than the other studied areas. These results evidence the contribution of grassland roots to the SOM accumulation, the potential of soil subsurface as a C sink as well as the importance of organo-mineral in C sequestration in tropical areas.

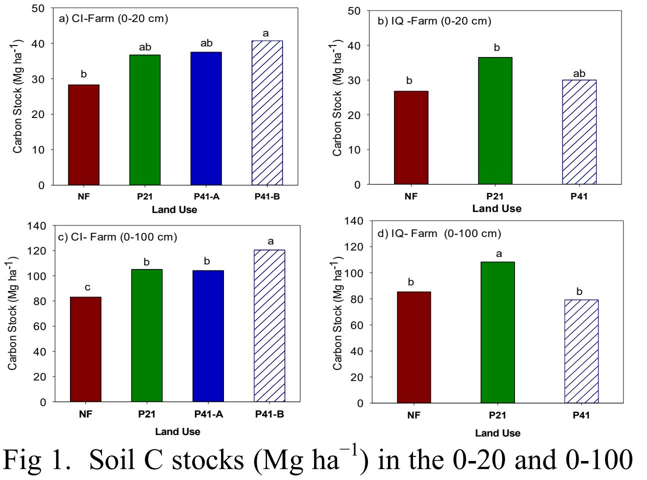

Fig 1. Soil C stocks (Mg ha^{-1}) in the 0-20 and 0-100 cm depth in the CI and IQ. Values followed by the same letters in the layer do not differ by Tukey's test at 5%.

$\delta^{13}C$ was around -27.5 ‰ at the 0-5 cm layer of NF, which is typical for SOM derived from forest (C_3 plants) (Fig. 2). Going down the profile, the values turned less negative (-22 to -24 ‰), and that is assigned to the microbiological discrimination during the humification process that leads to an enrichment of the heavier isotope. The pasturelands in both farms showed an opposite $\delta^{13}C$ variation pattern: the values were greater (less negative) in the surface and turned more negative with depth (Fig. 2). In the CI farm, $\delta^{13}C$ at the 0-10 cm layer under pasture was less negative (-16 to -22 ‰) than in the NF, regardless of the pasture age (Fig 2a), as a result of the input of SOM derived from pasture (C_4 plant). In the case of P41-B the difference reached the

40 cm depth (Fig 2a). These results, together with the C stocks, indicate that three processes occurred after LUC in this farm: mineralization of the endogenous SOM, replacement and addition by the pasture derived SOM. In the IQ farm, $\delta^{13}C$ values in both pasturelands were less negative than in NF at 20 cm depth (Fig. 2b).

However, under P41, whose C stocks did not differ from that of NF (Fig. 1), $\delta^{13}C$ value was less negative than both NF and P21 until 40 cm depth (Fig 2b). It follows that in the IQ farm, under 41 years of pasture, the mineralized endogenous SOM was replaced by the pasture derived SOM, but not surpassed.

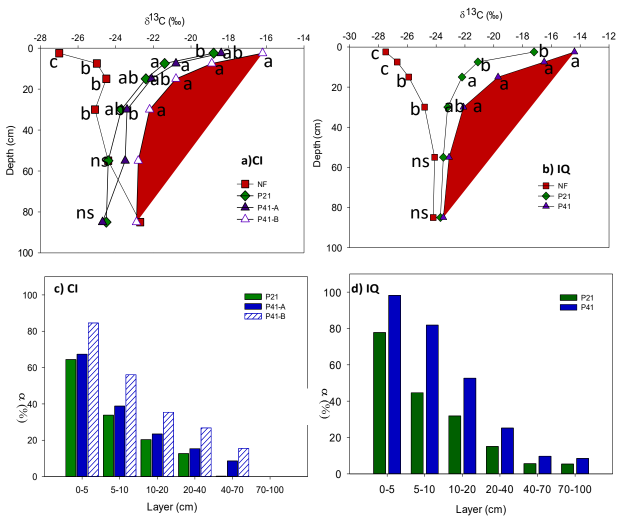

Fig 2. $\delta^{13}C$ (‰) values and proportion of young C (α) in profiles of CI and IQ farms**.** Values followed by the same letters in the layer do not differ by Tukey's test at 5%.

The proportion of young C (α) (C_4 plant derived) in the pasture areas of CI farm varied between 64 to 84% in the 0-5cm layer and decreased gradually with depth, reaching 0.2 to 15% at the 40-70 cm layer (Fig 2c). At the deeper layer (70-100cm) no contribution of pasture residue to the SOM was detected. In all layers, α increased in the order P21< P41A<P41B, clearly indicating the effect of pasture age on the addition/replacement by pasture derived SOM. In the IQ farm, a similar behavior was observed, but the contribution of the young C was always greater than in the CI farm: 77 to 98 % of the SOM in the 0-5 cm layer, decreasing to 35 and 55% in the 10- 20 cm layer (Fig 2d). Furthermore, in this farm, an addition of young C was detected down to 100 cm. In all layers α was greater under P41 in comparison to P21, confirming that replacement of endogenous SOM was stronger under the older pasture.

In the CI farm, the SOM_{soil} chemical composition was dominated by O-alkyl (49 to 55 %), followed by alkyl (21 to 27 %), aromatic (13 to 16 %) and carboxyl groups (8 to 10 %) (Table 1). In the IQ farm a similar trend was observed, however, the alkyl and O-alkyl variation ranges were broader: 24 to 42 % and 31 to 54%, respectively. In both farms, the SOM_{soil} from pasturelands showed a greater O-alkyl and smaller alkyl proportion than the respective NF area. In general, the SOM_{clay} showed a greater proportion of alkyl and a smaller proportion of O-alkyl groups than its respective SOM_{soil}. It follows that SOM_{clay} is comparatively more decomposed than the whole SOM, thus confirming that the humified SOM tends to concentrate in this smaller fraction.

Table 1. Distribution (%) of C groups in the chemical shift regions (^{13}C NMR CP/MAS spectra) of the SOM_{soil} and SOM_{clay} of the 0-5 cm layer.

Land Use	Alkyl	O-alkyl	Aromatic	Carboxyl
	Chemical Shift (ppm)/ proportion (%)			
	0-45	45-110	140-160	160-220
		SOM_{soil}		
Cipoal				
NF	27.6	49.2	13.3	9.7
P21	21.3	51.4	16.6	10.4
P41-A	25.5	52.3	13.3	8.7
P41-B	21.8	55.9	13.5	8.5
Iquiri				
NF	41.8	31.4	12.6	13.8
P21	25.0	51.0	14.0	9.8
P41	24.4	53.7	12.9	8.3
		SOM_{clay}		
Cipoal				
NF	35.0	34.7	15.6	14.4
P21	31.5	36.1	19.2	12.0
P41-A	34.1	30.5	21.2	12.6
P41-B	31.0	36.5	21.1	12.4
Iquiri				
NF	36.5	39.7	9.5	9.9
P21	27.0	43.5	17.0	10.5
P41	26.5	38.9	19.3	12.4

Interestingly, the introduction of pasture promoted an increase of aromatic C in the clay fraction in comparison to the NF, and that can be attributed to the concentration of pyrogenic C in this fraction and/or the intensification of humification process after LUC.

Conclusion

The introduction of pasture in Acrisols in the Southwestern Amazon promoted an increase of soil C stocks. However, the magnitude of the increment depends on the soil granulometry, due to the fact that organo-mineral interactions contribute relevantly to SOM stabilization in tropical climate. The LUC promoted the mineralization of the endogenous SOM that increased with the pasture age, regardless of the change on the C stocks. Also, the SOM chemical composition was altered by the introduction of pasture: whereas an increase of more biochemically labile structures (O-alkyl) occurred in the whole SOM, an increment of the aromaticity occurred in SOM_{clay}.

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