Does agricultural practices impact the quantity and the forms of organic carbon stored in cultivated soils of the Senegal groundnut basin? A Rock-Eval approach

SoCa

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Introduction

In West Africa, smallholders integrate crop and livestock. This integration plays an important role in agricultural productivity, increases SOC and improves soil fertility [1]. Carbon sequestration involves increasing the stocks of soil organic carbon (SOC) stable forms, while improvement of agricultural productivity requires labile SOC forms which can release essential nutrients for plant growth [2]. Meeting these two challenges (productivity and mitigation) simultaneously requires documentation of both the quantity and the quality of SOC [3]. Rock-Eval pyrolysis is a simple and fast method for obtaining information on the carbon content and thermal stability of organic matter [4]. In the context of soil science, this technique is recommended for quantitative and qualitative characterization of soil organic matter (SOM).

Study sites

Agro-ecological description of the sites

- Sudano-Sahelian climate (average annual temperature: 30 ° C)
- Short rainy season from July to October (average annual rainfall: 530 mm)

Figure 1: Localisation of the 3 study areas (orange boundaries)

- Arenosol (with sandy fraction > 90%)
- Low SOC in topsoil [1.6 – 19.1 g.kg^{-1} soil; Median: 4 g.kg^{-1} soil]

Materials

Studied samples

- 120 samples (Soil layers 0-10 & 10-30 cm) were selected from a large sample set (1800 plots) that capture diversity in local cropland management according to 4 factors

Field's location
→ House field
→ Out-field

Season
→ Crop season
→ Off crop season

Plot management
→ Cultivated plot
→ Annual fallow

Type of organic inputs
→ No input
→ +Millet residues
→ +Manure
→ +Organic wastes

+

- 10 samples selected from two preserved sites not exploited by humans for 30 years:

→ Tree plantation
→ Protected savannah

Methods

Rock-Eval pyrolysis (RE)

- Thermal analysis method of the organic matter where the fluxes of HC, CO et CO_2 are measured
- Studied signal: S2 thermogram (Figure 2) - Integration between the predefined temperature limits.

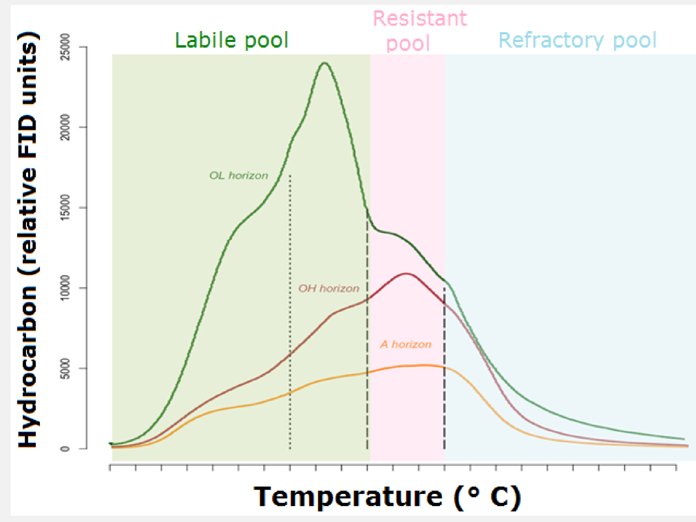

Figure 2: Rock-Eval signal as used in this study

- Pools linked to thermal stability of SOM
  - *-**Labile** pool: A1 et A2 [200-400 °C]*
  - *-Resistant pool: A3 [400-460 °C]*
  - *-Refractory pool: A4 and A5 [460-650 °C]*
  - ***Stable** pool* (Resistant + Refractory)
- I index = (Labile pool of SOM / Resistant pool of SOM) *linked to the decomposition of SOM [4]*
- R index =(Resistant pool of SOM + Refractory pool of SOM/100) *linked to the stabilization of SOM [4]*

→ Comparison of data obtained with a reference dataset on Ferralsols (depth < 30 cm) [4]

Results & Discussion

Result 1: Specific RE signature of the Arenosols

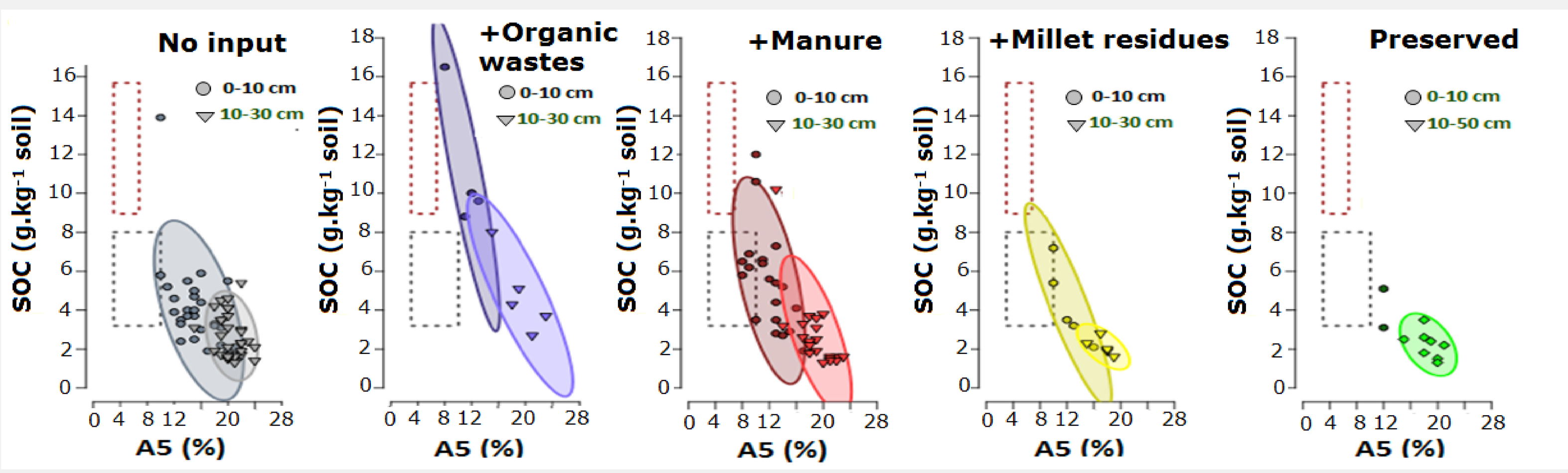

Figure 3: Relationship between soil organic carbon (SOC) and the most refractory pool (A5) determined by the RE method, in different situations. The dotted boxes illustrate the models obtained by depth for the reference dataset [4]

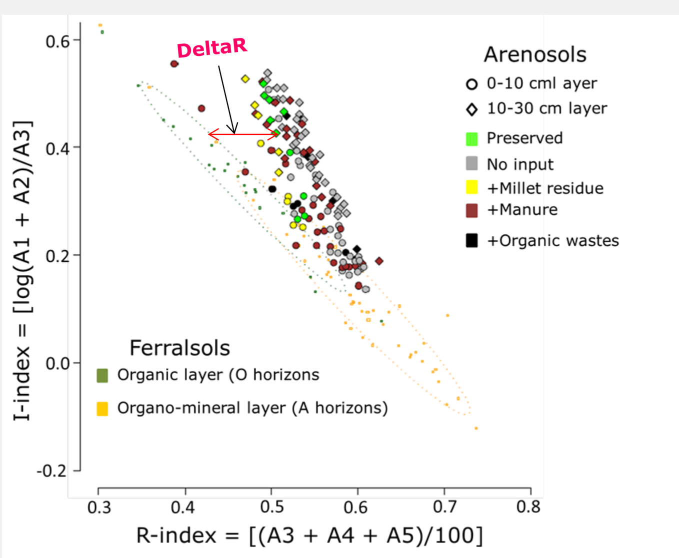

Figure 4: Projection of Senegal's Arenosols on the "Humic trend" constructed with I and R indexes with the reference dataset on Ferralsols from [4]

- Relative enrichment compared to [4] in the most refractory A5 pools in all situations, independently from organic inputs (Figure 3)
- Arenosols of Senegal = R index higher than in the reference Ferralsols' dataset [4]
- Arenosols of Senegal = Specific signature marked by I index more important in deep layer than in the reference data set [4]
- Deviation of the values observed in Senegal compared to the model obtained with a reference data set [4] → calculation of a **DeltaR** (Figure 4)
- DeltaR strongly correlated with A5 and anti correlated with A3 and A4 (Table 1)

Table1: Correlation matrix between C stable pools and DeltaR

DeltaR vs.					
A3 (Resistant pool)		**A4** (Refractory pool)		**A5** (Most refractory pool)	
R²	Equation	R²	Equation	R²	Equation
0.88	y = -0.009x + 0.28	0.49	y = -0.012x + 0.26	0.92	y = 0.0093x + 0.08

Result 2: Organic inputs ensure the link between quantity of SOC and quality of SOM

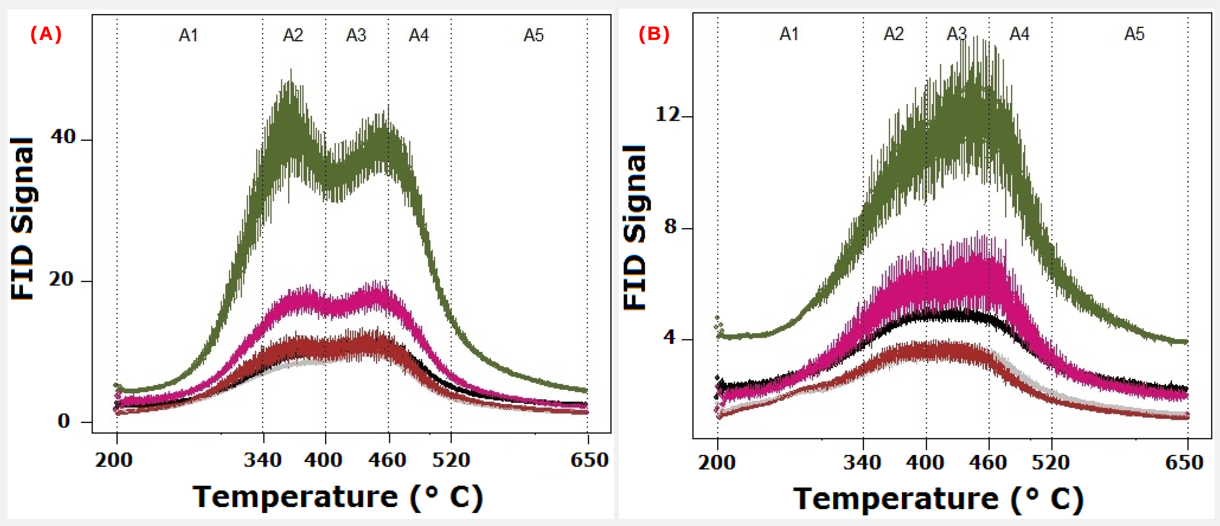

Figure 5: S2 thermograms in 0-10 cm (A) and in 10-30 cm soil layers (B) for the different situations: preserved (grey), No input (black), +Millet residues (brown), +Manure (deeppink) and +Organic wastes (dark green).

- → Quality of SOM in 0-10 cm differs from quality of SOM in 10-30 cm
- → + Manure and + Organic wastes have similar S2 thermograms, as bi-modal in 0-10 cm
- → Important labile pool and stable pools in 0-10 cm soil layer
- → Relative enrichment of A3 and A4 in 10-30 cm soil layer

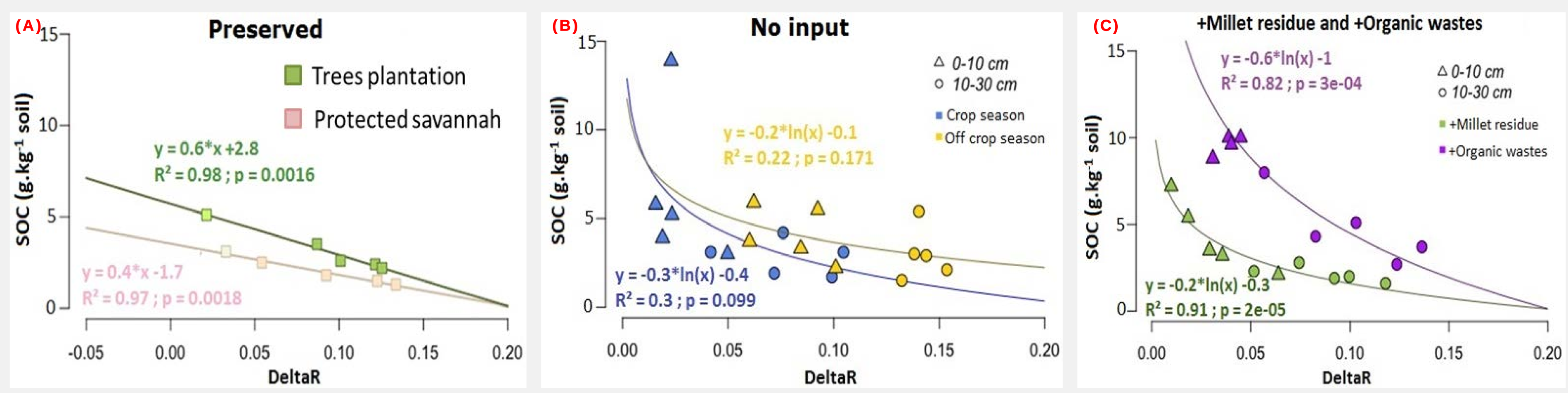

Figure 7: Relationship between SOC and DeltaR in (A) preserved, (B) in No input and (C) in +Millet residue and +Organic wastes situations

→ Strong linear correlations (Figure 7A)

=> **biophysical process** leading to a dilution phenomenon from surface to depth

→ Weak/not significant relationship (Figure 7B)

=> **Quality of SOM independent of the quantity of SOC**, when no organic input

→ Strong logarithmic correlations (Figure 7C)

=> **Organic inputs as a main factor controlling Quantity of SOC and Quality of SOM**

Conclusion

The Arenosols of the Senegal groundnut basin have a specific thermal signature in the Rock-Eval's I/R diagram. In these soils a probably higher mineralization of labile but also of more resistant thermal pools benefits to food security but not to climate change mitigation. Our results show that the quantity of SOC and the quality of SOM are linked in preserved, +Millet residues and +Organic wastes situations. However, they are not correlated in the No-input situations. This result shows that the organic contribution, whether natural or exogenous, guarantee the link between the quantity of SOC and the quality of SOM. Ultimately, this study highlights the importance of maintaining regular organic inputs to these arenosols to maintain soil fertility.

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Poster presented at EGU General Assembly, Vienna, Austria, 4-8 May 2020
[Manuscript currently under review for publication in *Agriculture, Ecosystems and Environment*]

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