Vertical Distribution and Stratification of Organic Carbon Fractions in a Semi-Arid Calcareous Soil

Carlos M. Romero[1], Richard E. Engel[1], Chengci Chen[2], Roseann Wallander[1], Catherine Zabinski[1], Emma Bode[3] and Melissa Marlen[3]

[1]Land Resources and Environmental Sciences – Montana State University, Bozeman, MT;
[2]EARC – Montana State University, Sidney MT;
[3]Undergraduate Program Environmental Sciences- Montana State University, Bozeman, MT.
carlos.romero2@msu.montana.edu

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INTRODUCTION

The study of labile-C stratification and elucidation of interactive relationships with soil organic carbon (SOC) may provide useful information to evaluate the vertical effects of land use on soil quality (Toosi et al., 2012). Relatively few studies have analyzed the combined effects of land use and soil depth on chemically and physically isolated SOC fractions in semi-arid areas. The objectives of this work were: 1) to determine the effect of land use on the concentration and stratification ratio (SR) of SOC fractions (Franzluebbers, 2002) from the topsoil to 40-cm soil depth; 2) to evaluate the relationships among SOC fractions, and 3) to quantify the proportion of soil C fractions to total carbon (TC) as affected by land use.

Figure 1 .

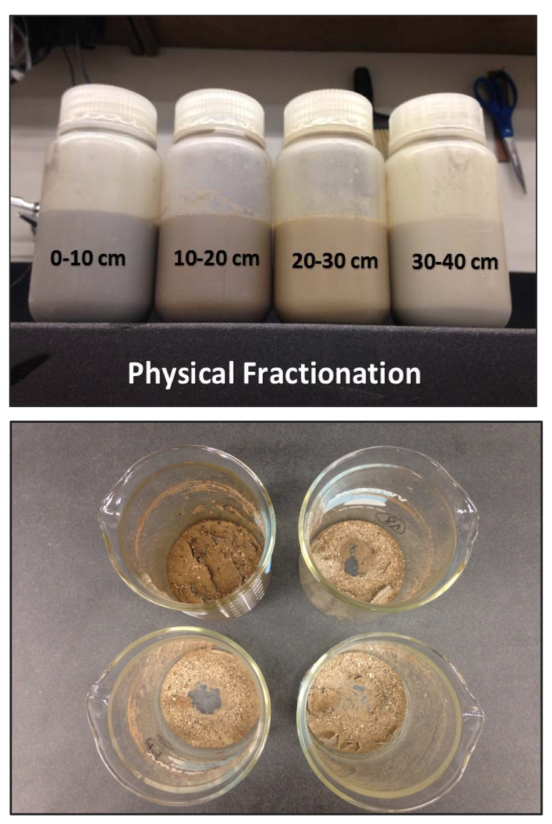

Figure 2.

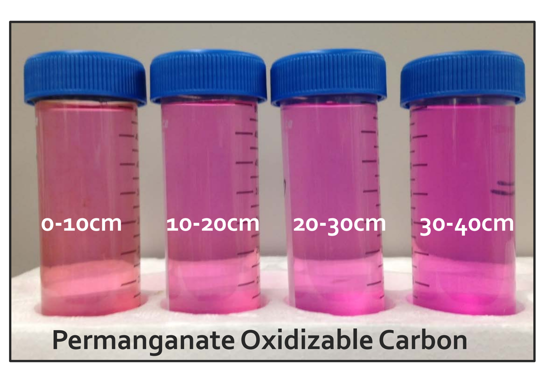

Figure 3.

MATERIALS & METHODS

Soil sampling was conducted on a Judith clay loam (fine-loamy, carbonatic, frigid Typic Calciustolls) (Fig. 1) from central Montana (47°03′ N; 109°57′ W). The experiment comprised four land use types: native vegetation (NV), conservation reserve program (CRP), and wheat (*Triticum aestivum* L.) based cropping systems established in 2004 either under no-till (Ag-NT) or strip-till (Ag-ST) (Fig. 2). Soil samples were taken in September 2014 at 0-10, 10-20, 20-30, and 30-40 cm depths. Air-dried/sieved soil samples were analyzed for TC and total N (TN), and soil inorganic carbon (SIC). SOC was calculated as SOC=TC-SIC. Physical fractions of SOC were measured as particulate- (POC) and mineral- (MOC) organic carbon (Fig. 3). Permanganate oxidizable carbon (POXC) was measured in the whole soil and fine fraction (<53 µm).

ACKNOWLEDGEMENTS

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RESULTS

Table 1. Concentrations of total C and N fractions (SOC, and TN) and SOC fractions (POXC, POC, and MOC)†.

ANOVA±						
Factor	SOC	TN	C/N	POXC	POC	MOC
Land Use	<0.0001	<0.0001	<0.0001	0.0001	<0.0001	<0.0001
Depth	<0.0001	<0.0001	<0.0001	<0.0001	0.0021	<0.0001
L*D	0.0496	0.0109	0.5404	0.3510	0.4886	<0.0001

Soil Depth	SOC	TN	C/N	POXC	POC	MOC
	Native Vegetation					
cm	----g kg^{-1}-----			mg kg^{-1}	----g kg^{-1}-----	
0-10	33.03 a¶	2.64 a	12.31 a	962.79 a	10.05 a	22.99 a
10-20	18.94 b	1.89 b	10.01 b	638.37 b	2.89 b	16.05 b
20-30	16.60 b	1.71 b	9.78 b	638.96 b	2.33 b	14.35 b
30-40	12.63 c	1.35 c	9.39 b	501.96 c	2.00 b	10.64 c
	Conservation Reserve Program					
0-10	22.40 a	2.09 a	10.72 a	898.84 a	4.25 a	18.15 a
10-20	18.69 a	1.91 a	9.82 b	654.41 b	2.20 b	16.49 a
20-30	13.75 b	1.57 b	8.71 c	590.52 b	2.11 b	11.64 b
30-40	11.75 b	1.36 c	8.63 c	452.02 c	2.03 b	9.72 b
	Agriculture - NT					
0-10	16.99 a	1.73 a	9.86 a	704.34 a	2.08 a	14.91 ab
10-20	15.87 a	1.76 a	9.00 b	598.37 a	0.70 b	15.17 a
20-30	12.27 b	1.50 b	8.15 c	616.72 a	-	13.06 b
30-40	8.57 c	1.13 c	7.60 c	423.26 b	-	10.83 c
	Agriculture - ST					
0-10	17.85 a	1.73 a	10.32 a	740.28 a	1.74 a	16.11 a
10-20	14.69 ab	1.61 a	9.15 b	579.60 b	0.28 b	14.58 ab
20-30	12.91 b	1.51 a	8.55 b	535.92 b	0.40 ab	13.15 b
30-40	8.72 c	1.15 b	7.61 c	404.53 c	-	10.64 c

Data are mean (n=4). † SOC, soil organic carbon; TN, total nitrogen; POXC, permanganate oxidizable carbon; POC, particulate organic carbon; MOC, mineral organic carbon. ±The values represent the probability value (two-way ANOVA) of the impact of land use, soil depth, and their interactions on the soil C and N fractions. ¶Small letters in a column indicate differences across soil depth based on LSD Fisher test (*P*<0.05).

- **SOC and TN concentrations decreased in the direction NV>CRP>Ag-NT=Ag-ST.**
- **POXC concentration decreased in the direction NV=CRP>Ag-NT=Ag-ST.**
- **C:N ratios decreased with soil depth and became narrower with soil cultivation (i.e. NT, ST).**

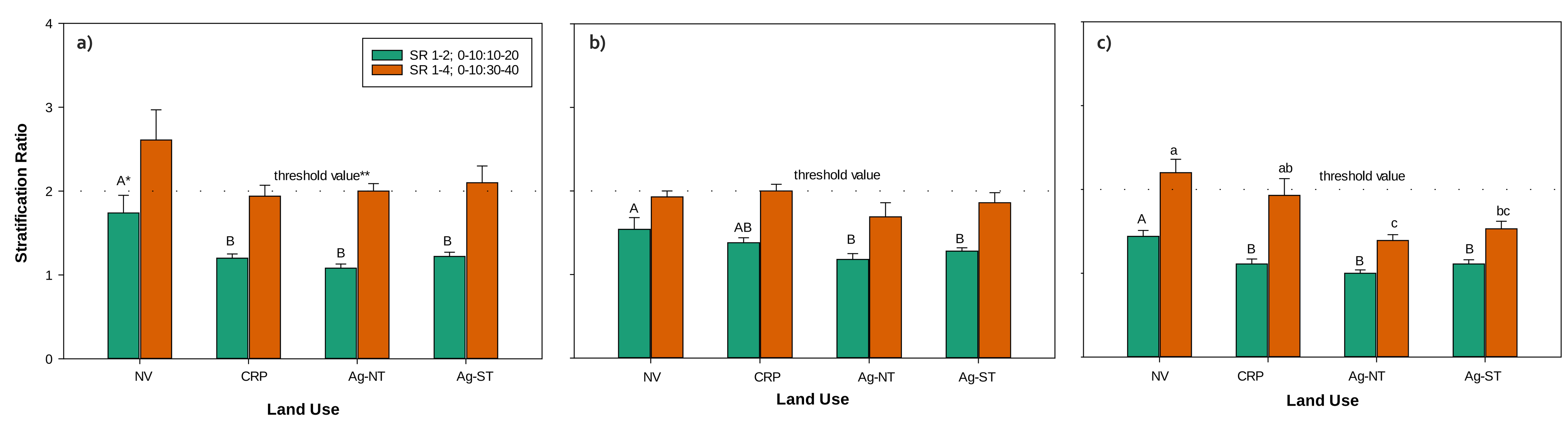


Figure 4. Stratification ratio (SR) of SOC (a), POXC (b), and MOC (c) in native vegetation (NV), conservation reserve program (CRP), and croplands under no-till (Ag-NT) or strip till (Ag-ST). Data are mean (n=4). SOC, soil organic carbon; POXC, permanganate oxidizable carbon; MOC, mineral organic carbon. *Different letters (A-B or a-c) indicate significant differences (*P*<0.05) among land uses within each ratio depth. **values >2 indicate better soil quality (Franzluebbers, 2002).

- **Land use change disrupted SR values of undisturbed NV soil.**

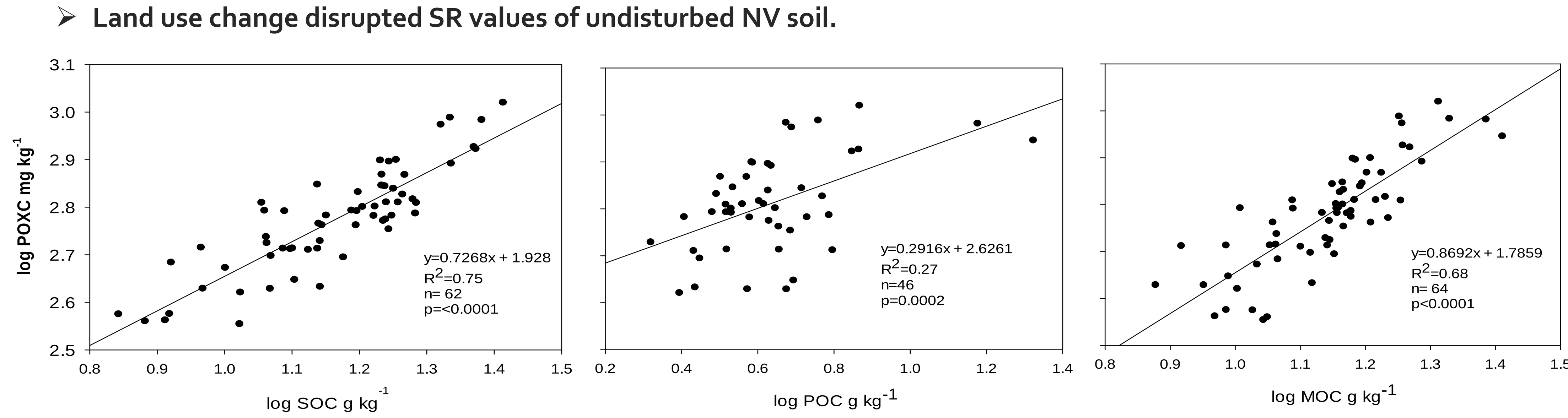
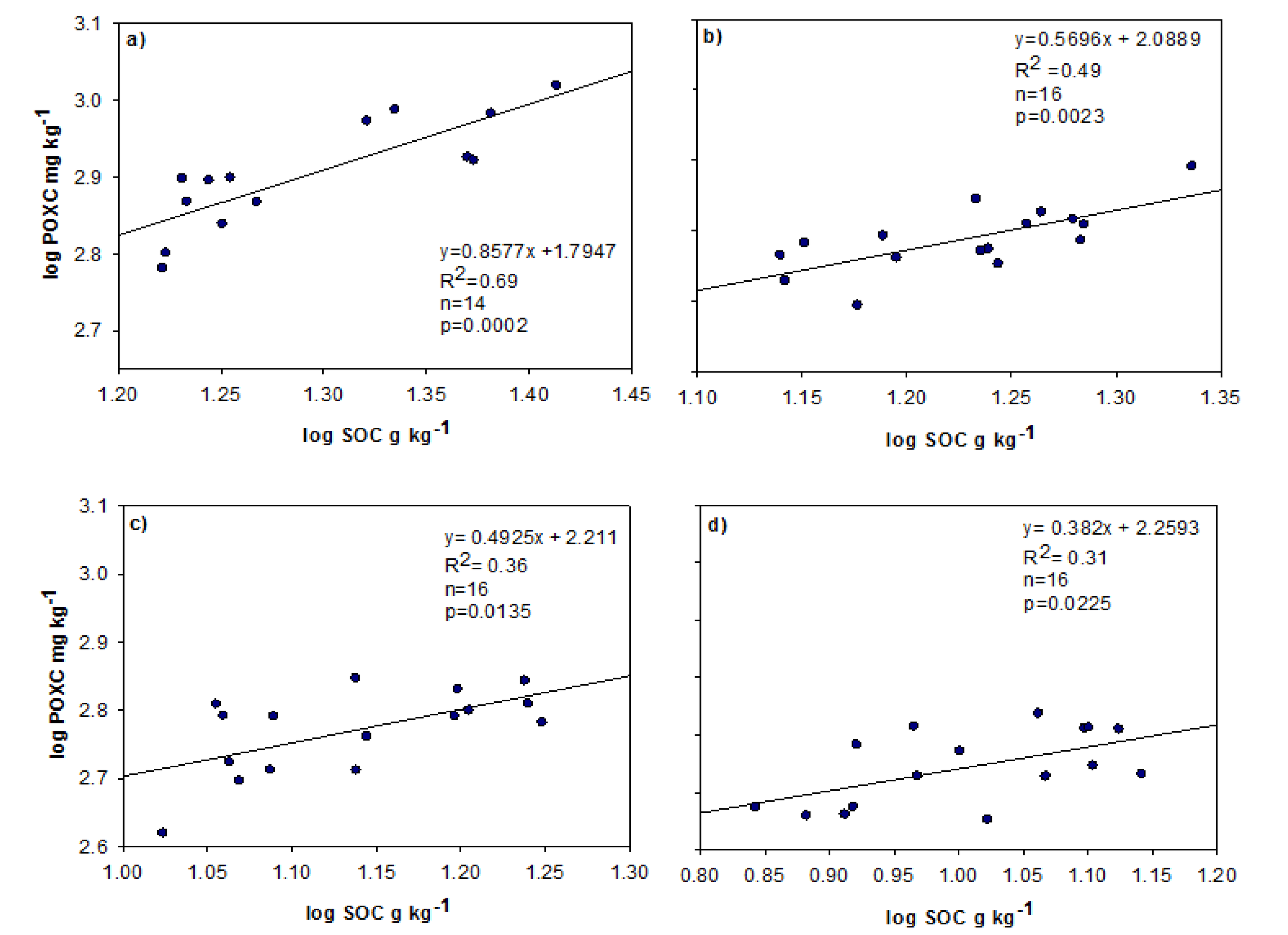


Figure 5. Relationship between permanganate oxidizable carbon (POXC) and soil organic carbon (SOC), and soil C fractions [particulate organic carbon (POC), and mineral organic carbon (MOC)]; (0-40 cm) soil depth. Note: scale on *x*-axis differs with SOC fraction.

- **POXC was more closely related to the mineral fraction MOC (<53 µm) than the coarse fraction POC (>53 µm).**



- **The relationship between POXC and SOC was more strongly correlated in the topsoil than sub-soil layers.**

Figure 6. Relationship between permanganate oxidizable carbon (POXC) and soil organic carbon (SOC) at 0-10 (a), 10-20 (b), 20-30 (c), and 30-40 cm (d). Note: scale on *x*-axis differs with soil depth interval.

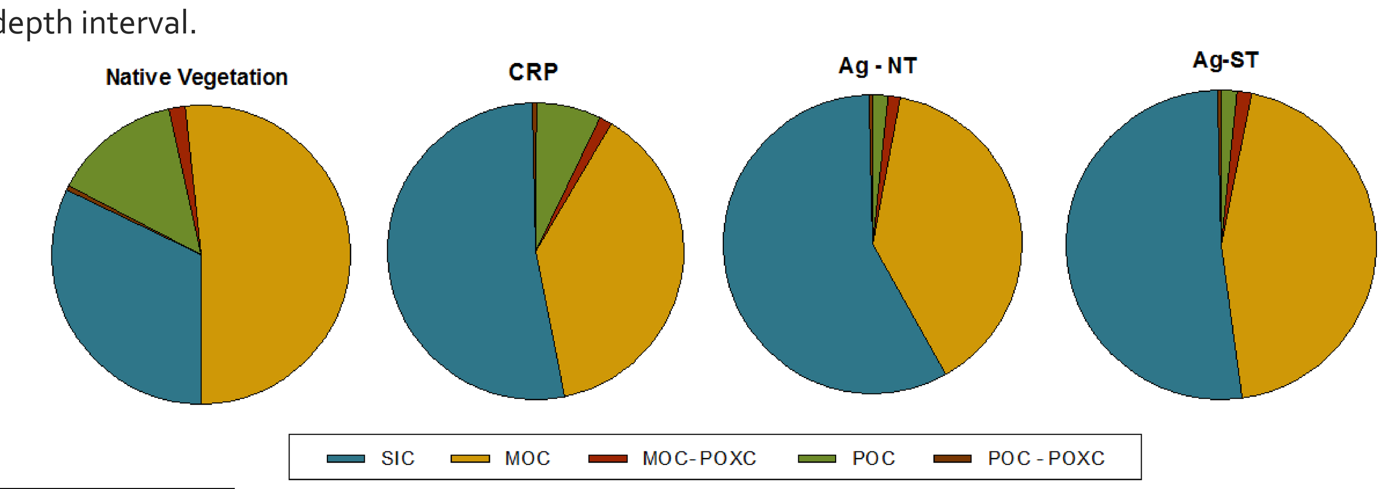


Figure 7. Proportion of soil C fractions to total carbon (TC) as affected by land use (0-40 cm). Data are mean (n=4). SIC, soil inorganic carbon; MOC, mineral organic carbon; MOC-POXC, permanganate oxidizable carbon in the mineral fraction (<53 µm); POC, particulate organic carbon; POC—POXC, permanganate oxidizable carbon in the coarse fraction (>53 µm).

- **Proportion of different soil C fractions to TC (0-40 cm) was affected by land use.**
- **Conversion from croplands to CRP restored SOC fractions (i.e. POXC, POC) relative to NV.**

CONCLUSIONS

Land use change primarily altered the amount and distribution of labile (POXC and POC) and also some of the stable (MOC) soil carbon pools. The SR of SOC, POXC, and MOC were minimally and variably affected by land management (i.e. NT, ST, or CRP).
Mineral associated SOC, MOC (<53 µm), was a principal source of POXC. Croplands under NT or ST exhibited a similar SOC gradient from surface to sub-soil layers. In contrast, CRP offers great potential to restore SOC fractions previously depleted by agriculture.

REFERENCES

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