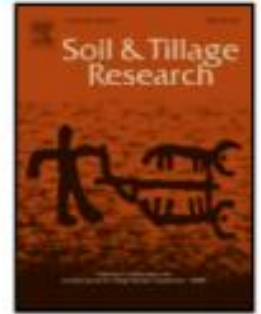




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Mechanical and biological chiseling impacts on soil organic C stocks, root growth, and crop yield in a long-term no-till system

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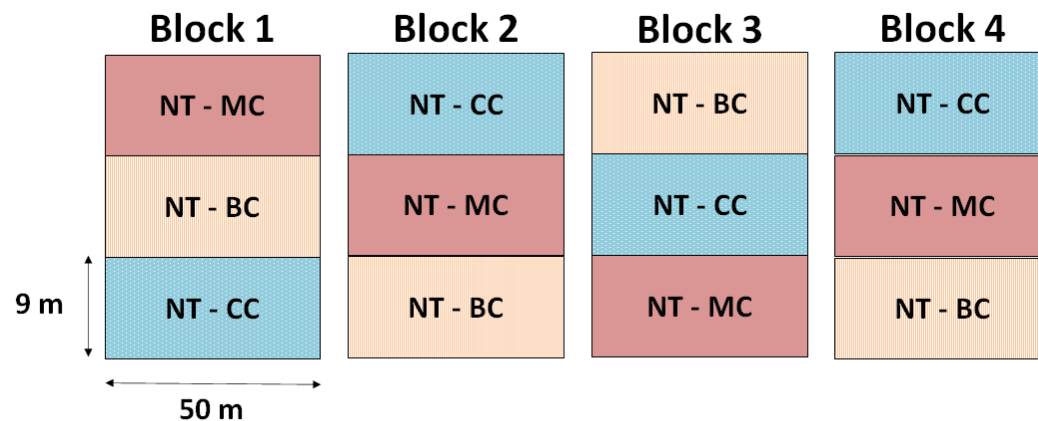
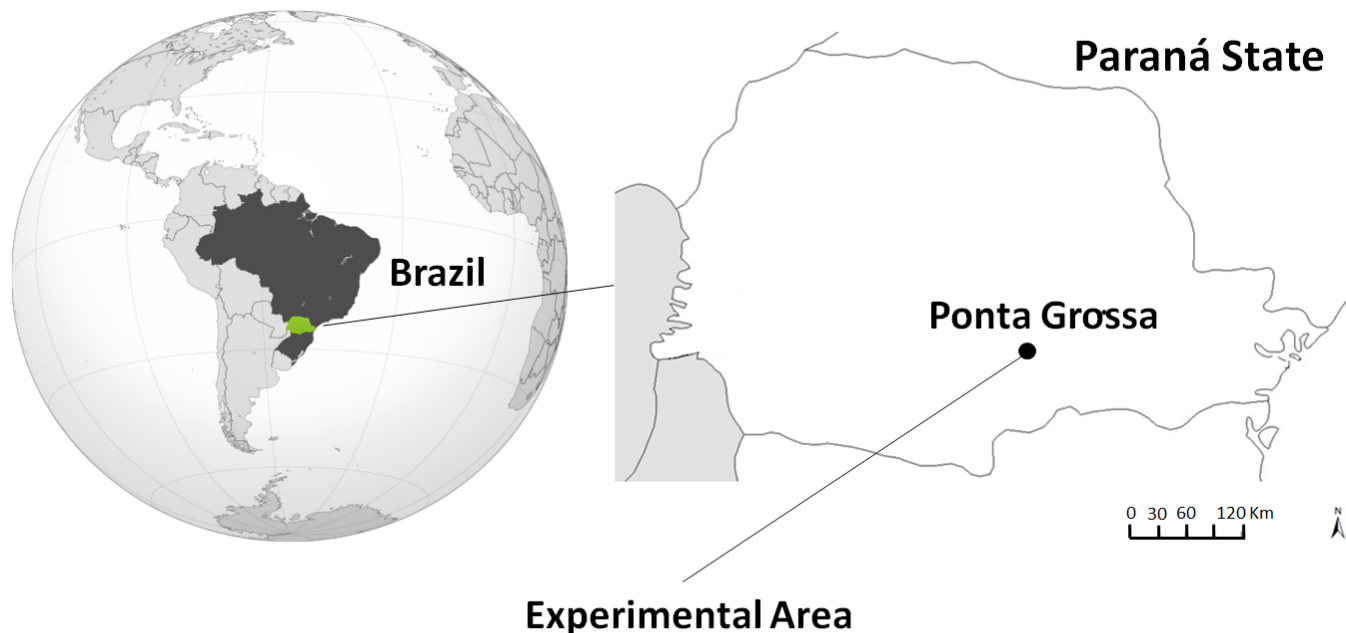
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Localização



Hipótese

Esse estudo foi baseado na premissa de que plantas com sistema radicular agressivo e profundos podem ser uma alternativa para uma escarificação biológica do solo

Objetivo

Avaliar as alterações temporais nos estoques dos reservatórios do C orgânico do solo (COT, POXC, HWEOC) devido a ação da escarificação mecânica e biológica em um experimento de longa duração em plantio direto.

Descrição da área experimental

Coordenadas geográficas: 25° 05' 52" Latitude S; 50 ° 02' 43" Longitude W

Altitude: 970 m; Temp. Média Anual = 18,7°C

Temp. Média Anual = 18,7°C

Classe de solo: Latossolo Vermelho argiloso

Análise granulométrica e química do solo antes da implantação do experimento

Table 1
Soil texture, soil fertility, and soil density at 0-10, 10-20, 20-30 cm depths before experiment establishment in May 2009.

Soil depth	Soil texture			Soil fertility								Soil density
	Sand	Silt	Clay	pH	H + Al	Al ³⁺	Ca ²⁺	Mg ²⁺	K ⁺	CTC	P	
	----- g kg ⁻¹ -----			Ca Cl ₂	----- cmol _c dm ⁻³ -----						ppm	
0–10	441	52	506	4.7	7.3	0.2	3.3	1.4	0.6	12.7	14.5	1.19
10–20	428	53	518	4.8	6.8	0.1	3.0	1.2	0.4	11.6	4.7	1.27
20–30	433	54	512	4.8	6.4	0.1	2.8	1.1	0.4	10.9	4.0	1.26

Tratamentos:

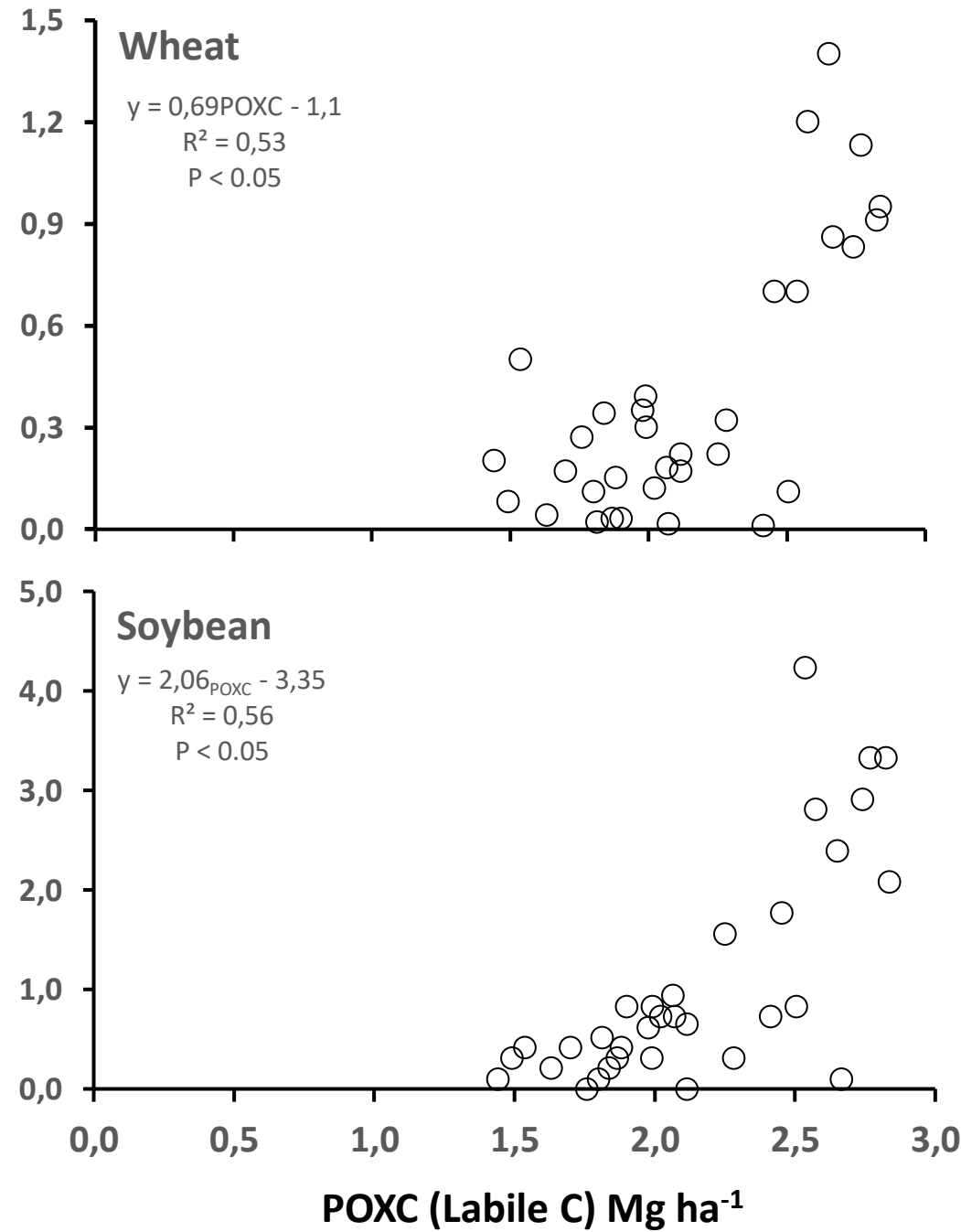
1) NT-CC = No-till cover crop, without any Mechanical or biological chiseling; **2) NT Mechanical Chiseling (NT-MC)**: No-tillage with Mechanical chiseling at 25 cm depth, cultivated with black oat + vetch in winter; and **3) NT biological chiseling (NT-BC)**: No-tillage without any mechanical disturbance, cultivated with black oat + forage radish (Raphanus Sativus L.).

Table 2
Analysis of variance (ANOVA) for cumulative crop yield and biomass-C input, SOC stocks and wheat and soybean's root development.

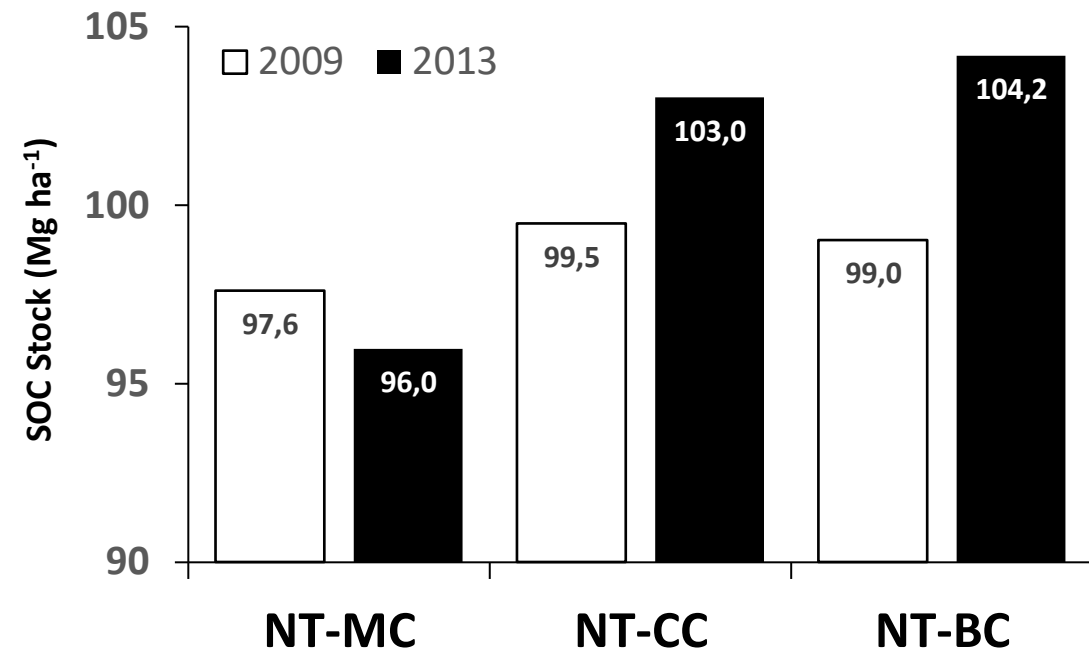
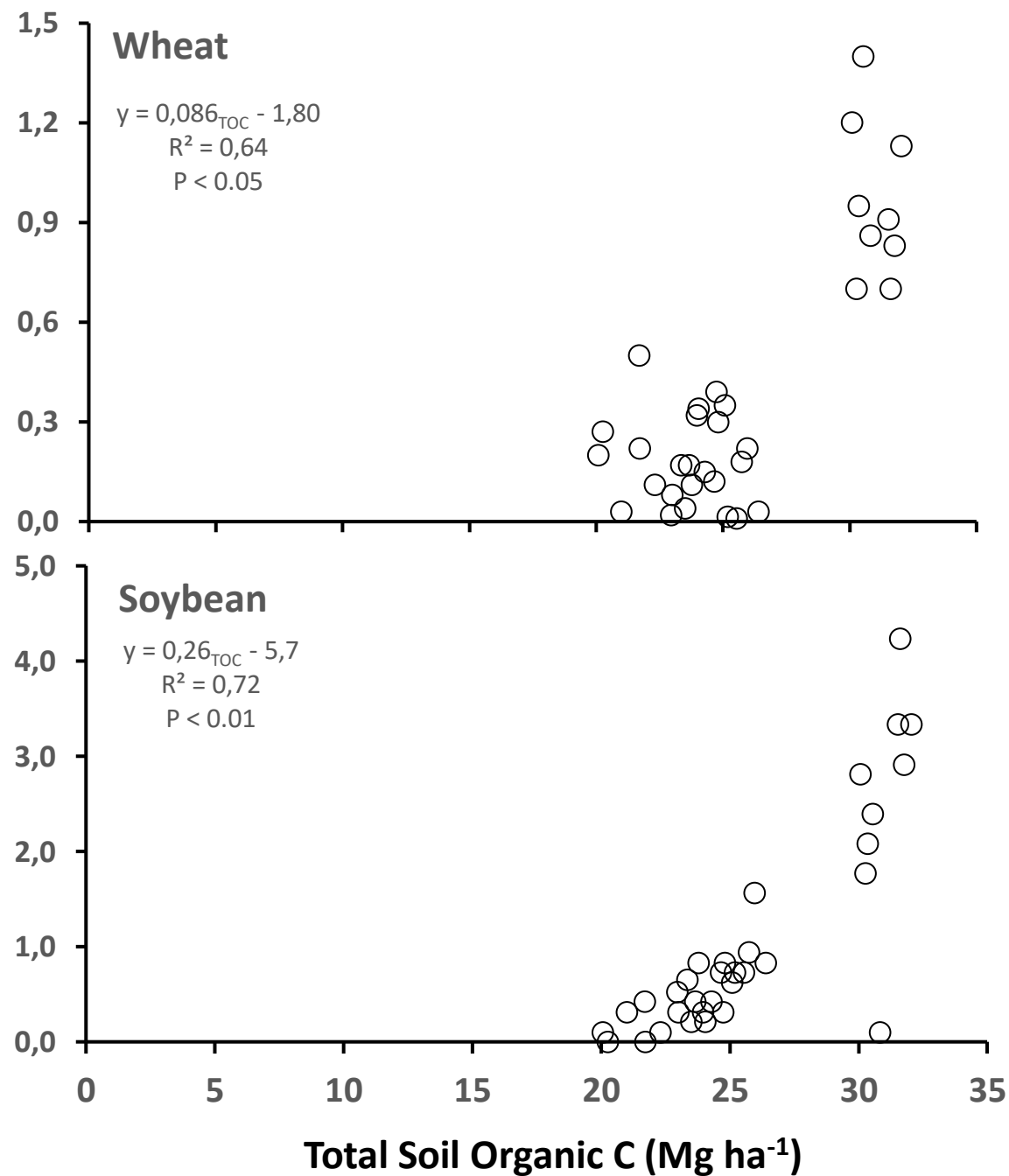
Variable		Variation source		
		Chiseling	Soil depth	Chiseling vs depth
Cumulative crop yield ^a		*	—	
Biomass-C input	Aboveground	*	—	
	Belowground	*		
	Total	*	—	
SOC stocks 2009 [‡]	HWEOC ^b	ns	*	ns
	POXC	ns	*	ns
	SOC	ns	**	ns
SOC stocks 2013 ^{‡‡}	HWEOC	*	**	ns
	POXC	*	**	ns
	SOC	ns	**	ns
SOC stocks (gain or losses)	HWEOC	*	ns	ns
	POXC	**	**	**
	SOC	**	**	*
SOC stocks (Sequestration rates)	HWEOC	**	*	*
	POXC	**	ns	*
	SOC	*	ns	ns
Wheat root development	Mass	ns	**	*
	Length	ns	**	*
Soybean root development	Mass	ns	**	*
	Length	ns	**	*

[‡] 5 months after chiseling.
^{‡‡} 42 months after chiseling; ns = not significant.
** Significant at p < 0.01 .
* Significant at p < 0.01 ; - not applicable.
^a Represents the sum of all grain production for all 4 years experiment.
^b HWEOC: hot-water extractable organic carbon; POXC: permanganate oxidizable organic carbon; SOC: total soil organic carbon.

Root Dry Mass (mg cm⁻³)



Root Dry Mass (g cm⁻³)



Crop sequence, yield, above and below-ground dry matter and biomass-C input during 2009 to 2013 experiment period in a long-term no-till field for soil management systems.

Treatments	Corn	Wheat	Soybean	Black Oat	Soybean	Black Oat	Corn	Biomass input	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Cumulative	Annual
	2009/10	2010	2010/11	2011 [§]	2011/12	2012 [§]	2012/13		
----- Grain Yield, Kg ha ⁻¹ -----									
NT-Mechanical Chiseling	10844 ns	3469 ns	3286 ns	0 [‡]	3336 ns	0	10347 b	31282 b	-
NT-Cover Crop	11392	3492	3212	0	3260	0	11618 a	32974 ab	-
NT-Biological Chiseling	11179	3796	3521	0	3820	0	12028 a	34344 a	-
----- Above-ground dry matter, Kg ha ⁻¹ -----									
NT-Mechanical Chiseling	11929 ns	3295 ns	2925 ns	3758 b	2969 ns	3770 b	11382 b	40027 b	10007 b
NT-Cover Crop	12532	3317	2859	4070 ab	2901	4148 ab	12780 a	42606 a	10651 a
NT-Biological Chiseling	12297	3606	3134	4323 a	3400	4410 a	13230 a	44400 a	11100 a
----- Below-ground dry mater, Kg ha ⁻¹ -----									
NT-Mechanical Chiseling	2711 ns	494 ns	585 ns	864 b	680 ns	867 b	2587 b	8789 b	2197 b
NT Cover Crop	2848	498	572	936 ab	665	954 ab	2904 a	9377 a	2344 a
NT Biological Chiseling	2795	541	627	994 a	779	1014 a	3007 a	9757 a	2439 a
----- Total Biomass-C input (Above + Below-ground), Kg ha ⁻¹ -----									
NT-Mechanical Chiseling	6559 ns	1705 ns	1239 ns	1997 b	1288 ns	2003 b	6258 b	21049 b	5262 b
NT-Cover Crop	6890	1717	1211	2163 ab	1259	2204 ab	7027 a	22469 a	5617 a
NT-Biological Chiseling	6761	1866	1327	2297 a	1475	2343 a	7274 a	23344 a	5836 a

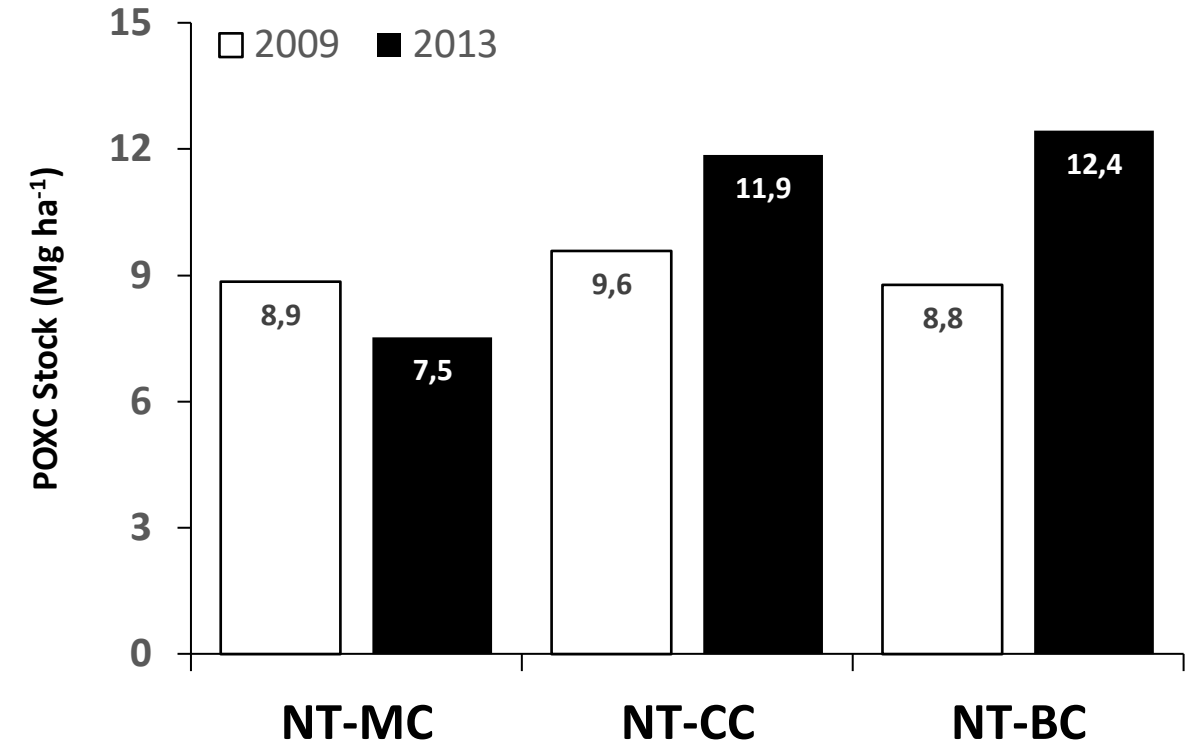
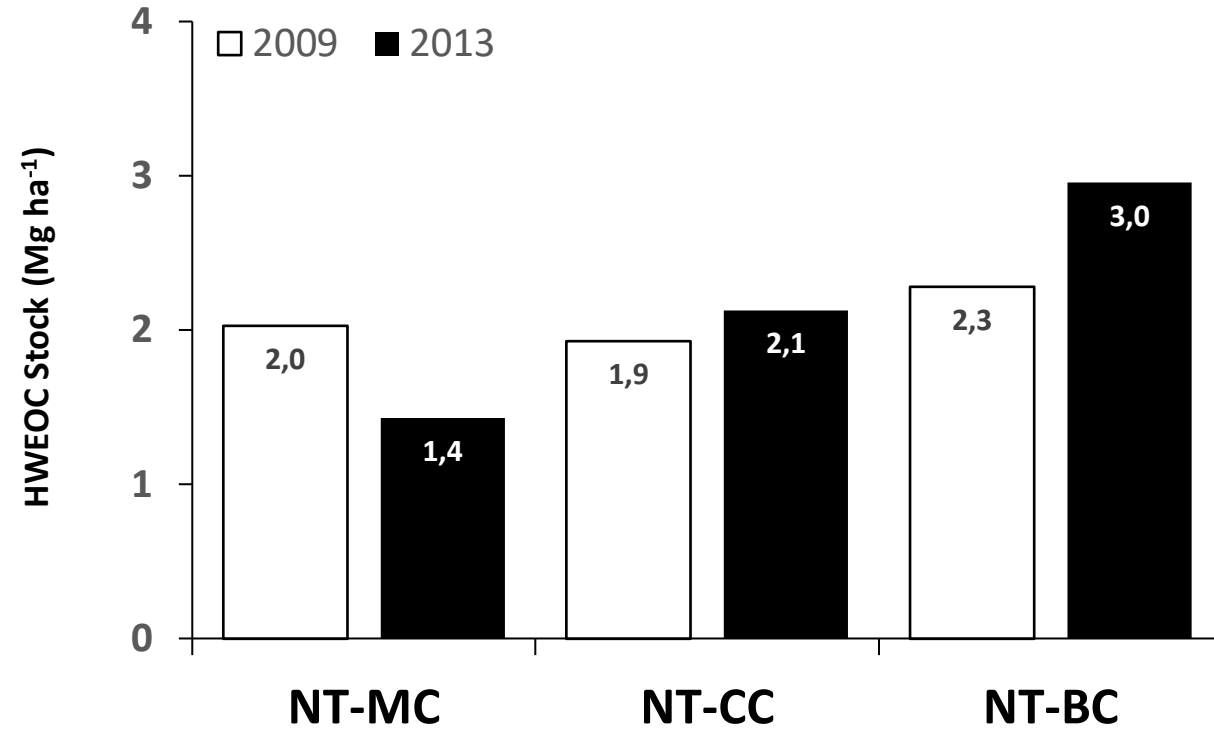
Soil organic carbon pools (SOC, HWEOC, POXC)[§] stock (2009 and 2013), C gain or losses and C sequestration rate for each soil management systems (NT-MC, NT-CC, NT-BC) at each depth sampled. For a given variable, different lowercase letters indicate significant difference between treatments by the LSD test at p < 0.05 using four block replicates

SOC Pools	Depth (cm)	Soil management systems [†]											
		NT-MC	NT-CC	NT-BC	NT-MC	NT-CC	NT-BC	NT-MC	NT-CC	NT-BC	NT-MC	NT-CC	NT-BC
		2009 Stocks			2013 Stocks			C stock gain or losses [‡]			C sequestration rate		
		----- Mg ha ⁻¹ -----									----- Mg ha ⁻¹ yr ⁻¹ -----		
SOC	0-10	34.94 ns	37.08	37.07	32.92 c	37.78 b	39.90 a	-2.03 b	0.71 a	2.83 a	-0.51 b	0.18 a	0.71 a
	10-20	34.04 ns	32.74	33.03	34.36 ns	34.39	35.58	0.32 ns	1.65	2.55	0.08 ns	0.41	0.64
	20-30	28.62 ns	29.67	28.93	28.71 ns	30.85	28.70	0.08 ns	1.18	-0.22	0.02 ns	0.29	-0.06
	0-30	97.6 ns	99.5	99.0	96.0 c	103.0 b	104.2 b	-1.62 b	3.53 ab	5.16 a	-0.41 b	0.88 ab	1.29 a
HWEOC	0-10	0.51 ns	0.51	0.79	0.46 c	0.67 a	0.99 b	-0.05 ns	0.16	0.20	-0.01 ns	0.04	0.05
	10-20	0.60 ns	0.56	0.64	0.49 c	0.76 a	0.95 b	-0.11 b	0.21 ab	0.31 a	-0.03 b	0.05 ab	0.08 a
	20-30	0.92 ns	0.87	0.85	0.48 c	0.70 a	1.02 b	-0.43 b	-0.17 ab	0.16 ab	-0.11 b	-0.04 ab	0.04 ab
	0-30	2.03 ns	1.93	2.28	1.43 c	2.13 a	2.96 b	-0.60 c	0.20 b	0.67 a	-0.15 c	0.05 b	0.17 a
POXC	0-10	3.88 ns	3.92	3.71	3.04 c	4.68 b	5.05 a	-0.84 c	0.77 b	1.35 a	-0.21 c	0.19 b	0.34 a
	10-20	2.89 b	3.29 a	2.91 b	2.38 b	4.39 a	3.80 a	-0.52 b	1.10 a	0.81 a	-0.13 b	0.27 a	0.22 a
	20-30	2.08 b	2.37 a	2.15 b	2.11 b	2.78 b	3.59 a	0.03 b	0.41 a	1.43 a	-0.01 b	0.10 a	0.36 a
	0-30	8.85 b	9.58 ab	8.78 b	7.53	11.86	12.44	-1.33 c	2.28 b	3.66 a	-0.33 c	0.57 b	0.92 a

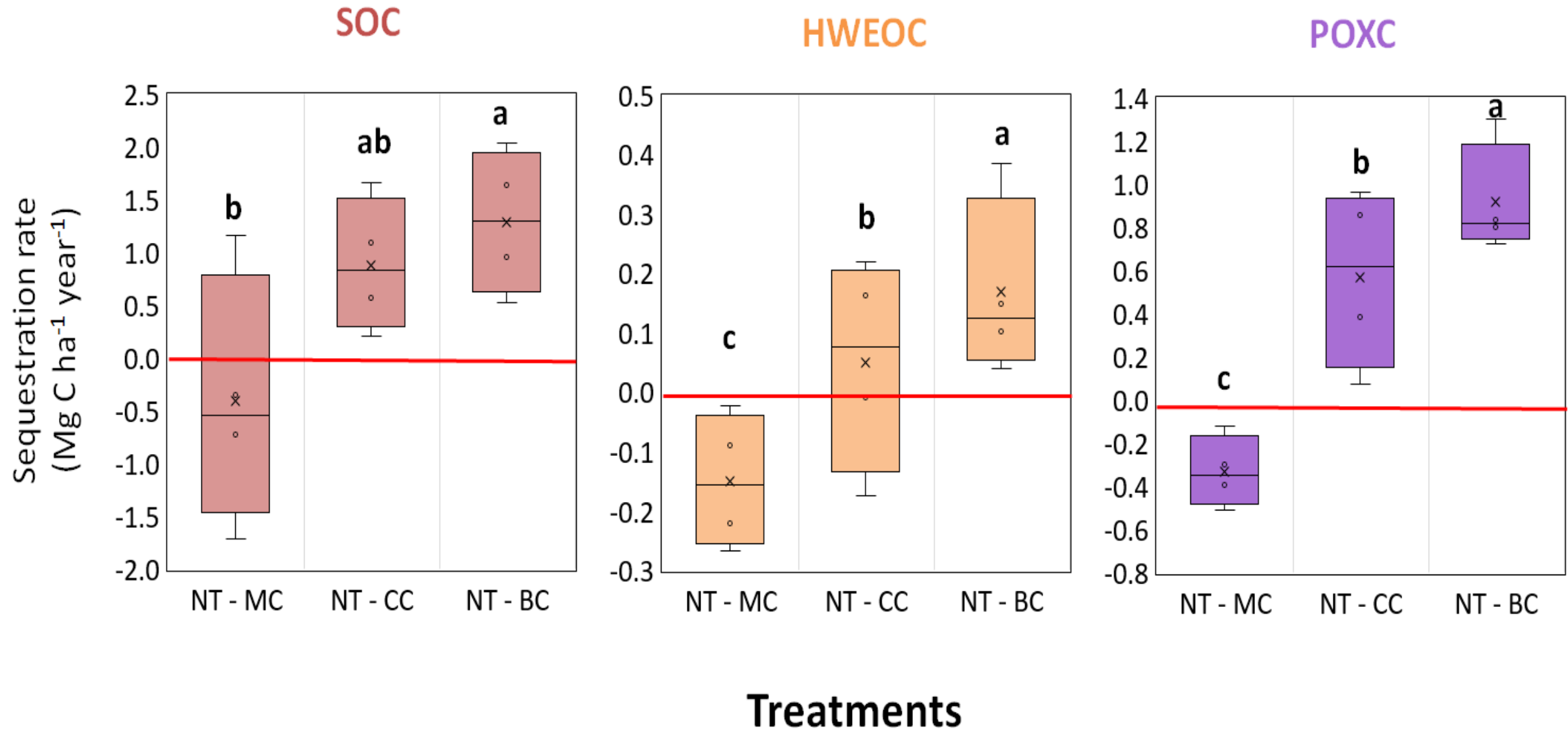
POXC
71,3%

[§] SOC = Soil organic carbon, HWEOC = Hot water extractable organic carbon, POXC = Permanganate oxidizable carbon; [†] Soil management systems: NT-MC = No-till mechanical chiseling, NT-CC = No-till cover crop, NT-BC = No-till biological chiseling; [‡] C Stock gain or losses = difference between C Stock at 2013 - C stock at 2009

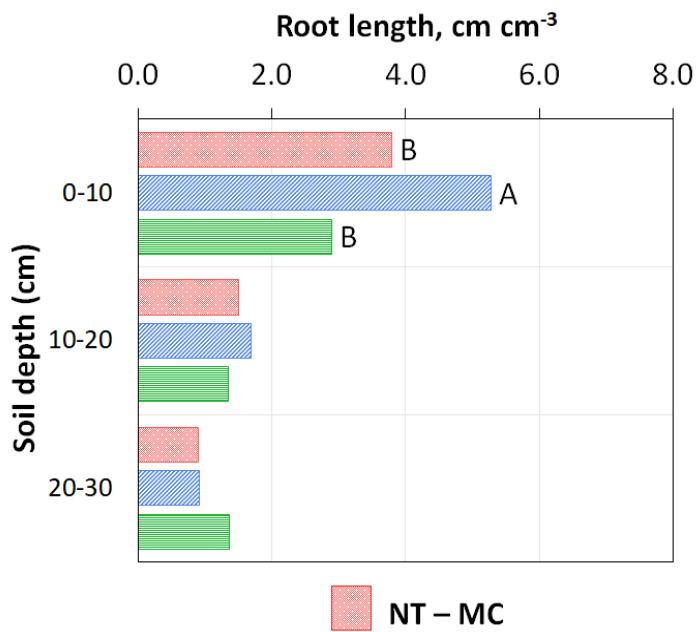
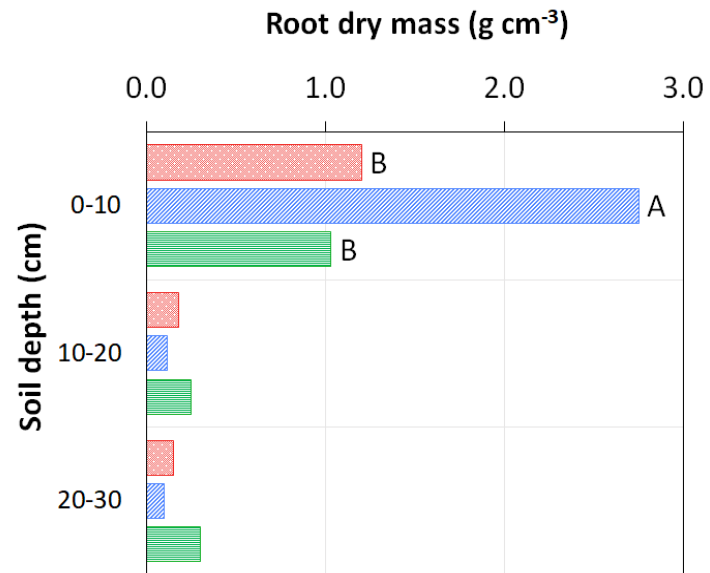
SOC Pools Stock



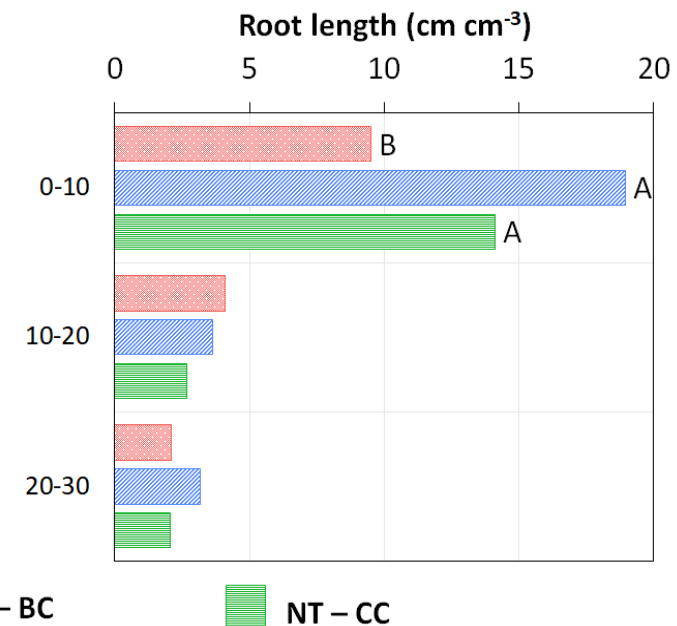
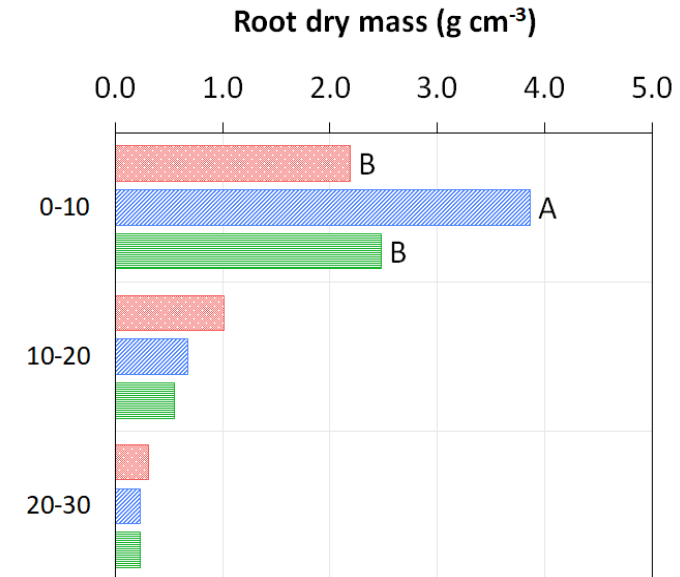
C sequestration rates from October 2009 to March 2013 of total soil organic carbon (SOC), hot water extractable organic carbon (HWEOC), and permanganate oxidizable organic carbon (POXC) at the 0-30 cm layer.

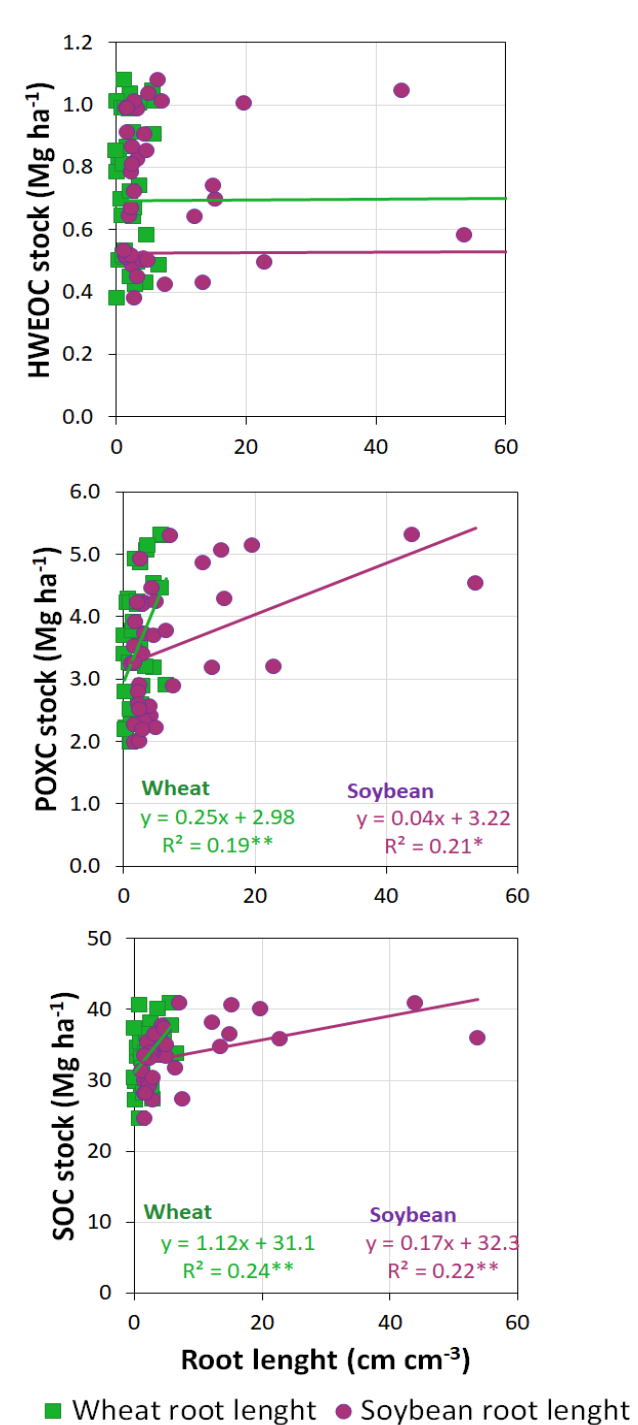
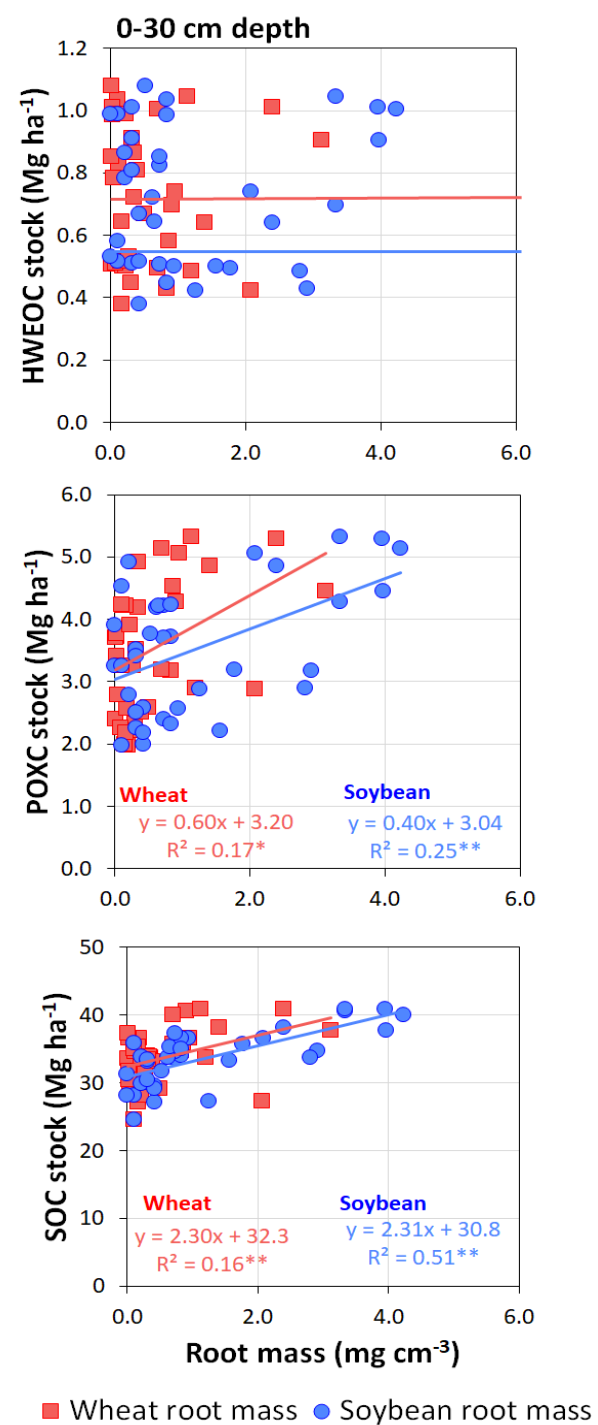


Wheat

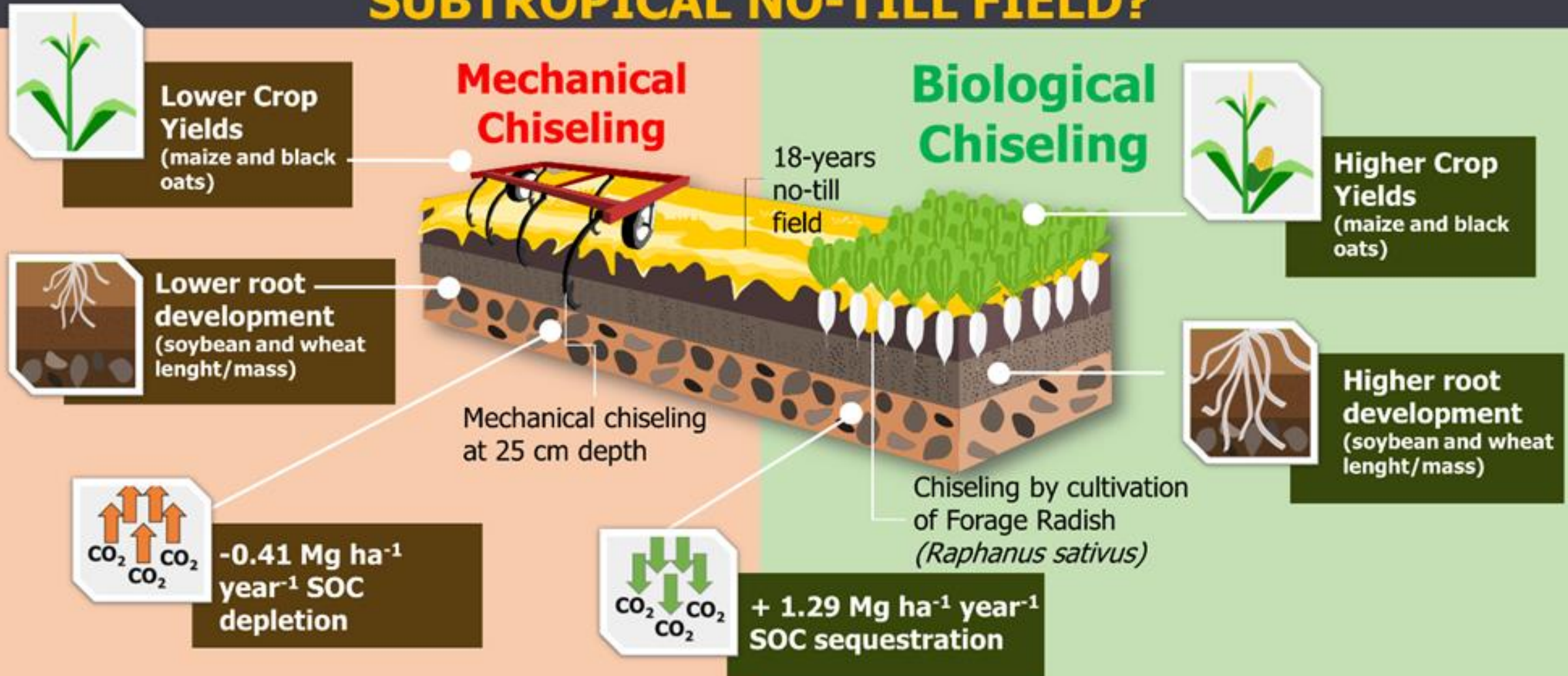


Soybean





WHAT DOES SOIL CHISELING DO IN A SUBTROPICAL NO-TILL FIELD?



Biological Chiseling



**Root
growth**

**Crop
yield**

**SOC
stocks**

**Equilíbrio dinâmico
3.2 a 4.0 Mg C ha⁻¹ ano⁻¹**

Mechanical Chiseling



**Root
growth**

**Crop
yield**

**SOC
stocks**

Conclusions

Here we demonstrate in side-by-side treatments that the use of forage radish (*Raphanus Sativus* L.) (NT-BC) without soil disturbance was a suitable option to replace mechanical chiseling (NT-MC) in this long-term no-till field.

The biological chiseling significantly increased SOC stocks, soybean, and wheat root development (length and mass), and cumulative crop yield and biomass-C inputs in comparison to the NT-MC.

The biological chiseling significantly increased SOC stocks, soybean, and wheat root development (length and mass), and cumulative crop yield and biomass-C inputs in comparison to the NT-MC.

In comparison to the control treatment without any chiseling, the NT-BC significantly increased proxies of microbial related organic matter pools (hot-water and permanganate extractable C), and soybean and wheat root development.

On the other hand, NTMC decreased these variables over time. Since the proxies of microbial related organic matter of HWEOC and POXC acted as sensors for soil management, we recommend the use of these and other more sensitive parameters to evaluate changes in soil health in addition to total SOC and **do not need to disturb the soil with mechanical chiseling**