The impact of tillage and harvest practices on soil CO_2 emission of sugarcane production areas, southern Brazil

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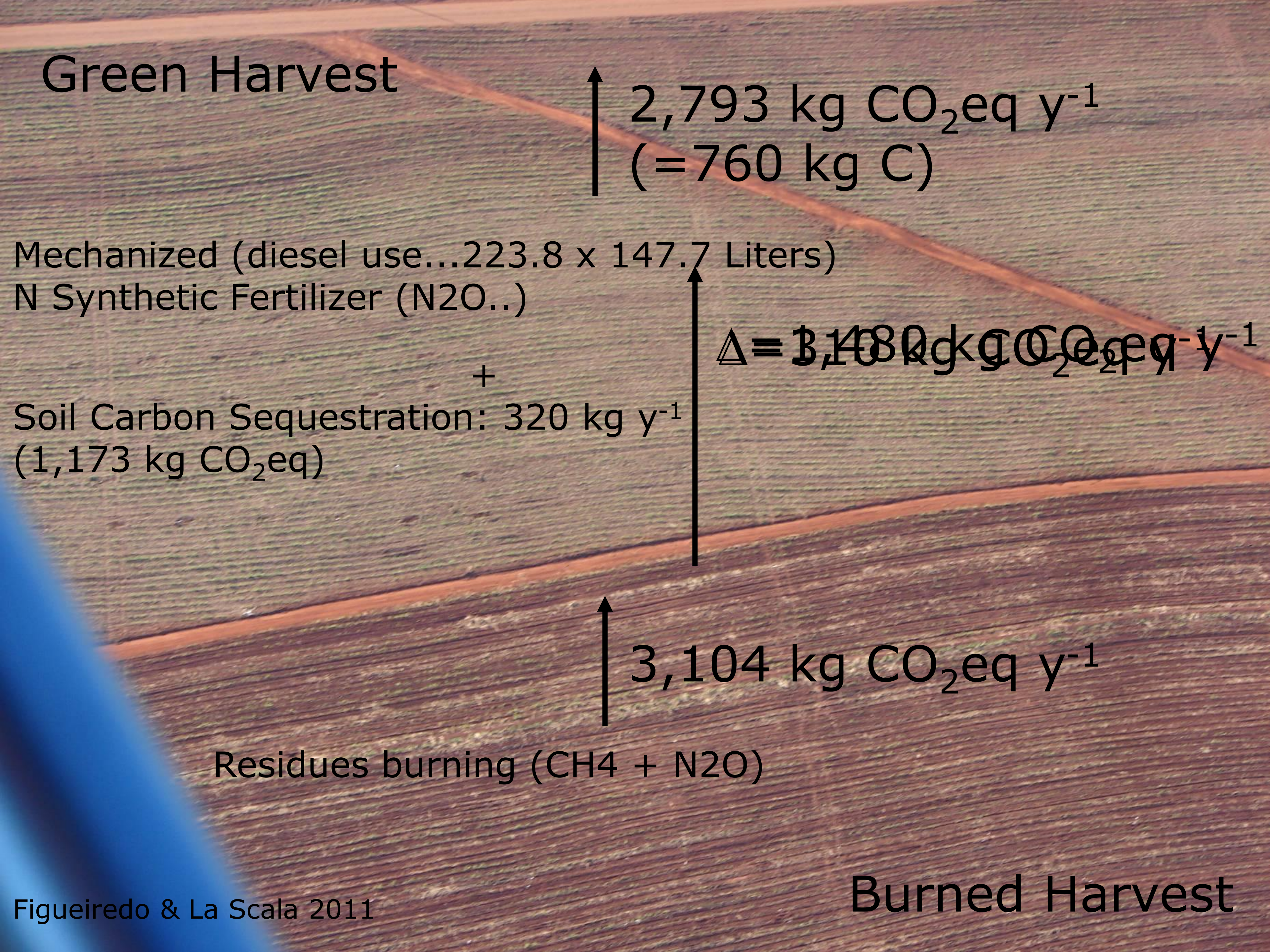
Greenhouse gas balance in the conversion from burned to green harvest


Green Harvest
2,793 kg CO_2eq y^{-1}
(=760 kg C)
Mechanized (diesel use...223.8 x 147.7 Liters)
N Synthetic Fertilizer (N2O..)
+
Soil Carbon Sequestration: 320 kg y^{-1}
(1,173 kg CO_2eq)
Δ=1,480 kg CO_2eq y^{-1}
Δ=311 kg CO_2eq y^{-1}
3,104 kg CO_2eq y^{-1}
Residues burning (CH4 + N2O)
Burned Harvest
Figueiredo & La Scala 2011

Specific aims:

We focus on soil CO_2 emission (FCO2), considering its spatial and temporal variability, studying which management practice would impact most on it, which soil property would be mostly relate to FCO2.

Studies conducted after harvest or tillage

Field Studies (2008-2010):

FCO2 after tillage: 3 studies (with/without crop residues)

FCO2 x soil properties: 3 studies (GH and BH areas)

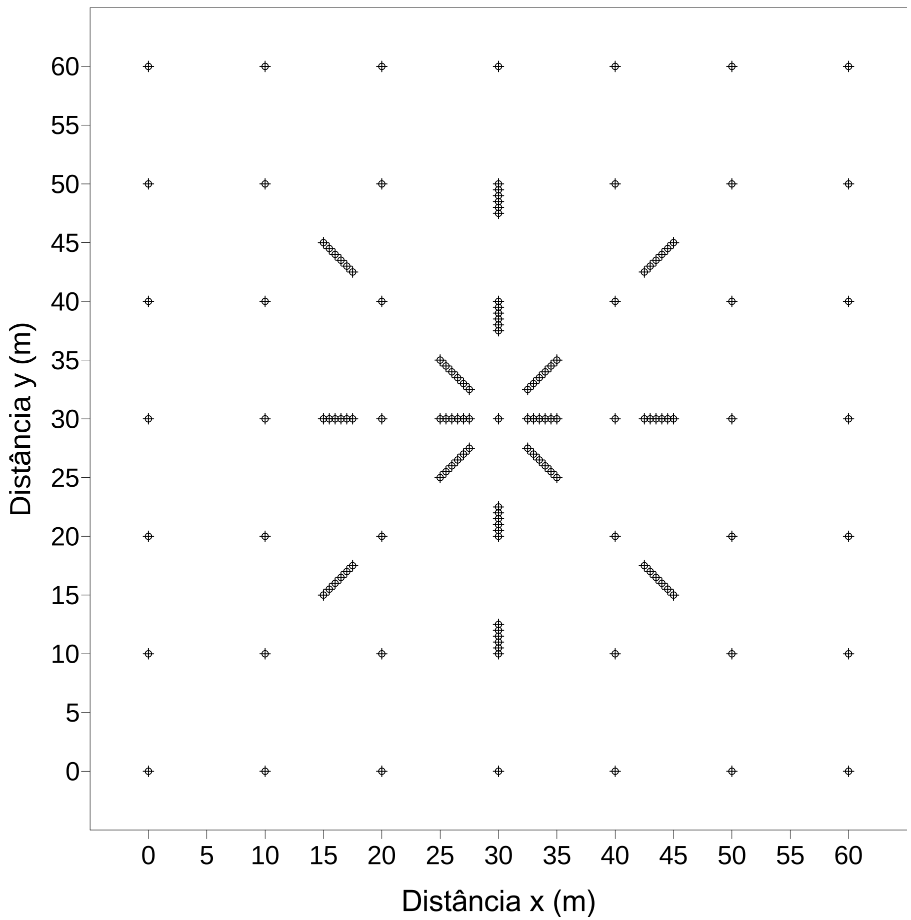
FCO2 Spatial variability (+ anisotropy): 2 studies

Effect of sugarcane crop residues on FCO2: 1 study

Some photos of studied plots from FCO2 after tillage experiment conducted in Mococa city, SP. Usina Ipiranga mill areas, January – February 2010

FCO2 after tillage experiment conducted in Barrinha city, SP, August 2008. Above: NT with and without crop residues on soil surface. Bellow: after Rotary Tillage.

Influence of sugarcane residues on FCO2. Experiment conducted in Guatapará city, São Martinho mill areas, October 2009



Grid layout with 141 points (above). Bellow, some photos showing the soil collar, equipments and the experimental area studied (Guariba city, SP) July 2010.

Conceptual:

$$\frac{dC}{dt} = -kC \qquad \frac{dC}{dt} = -F_{C-CO2}$$

$$\downarrow$$

$$F_{C-CO2} = kC$$

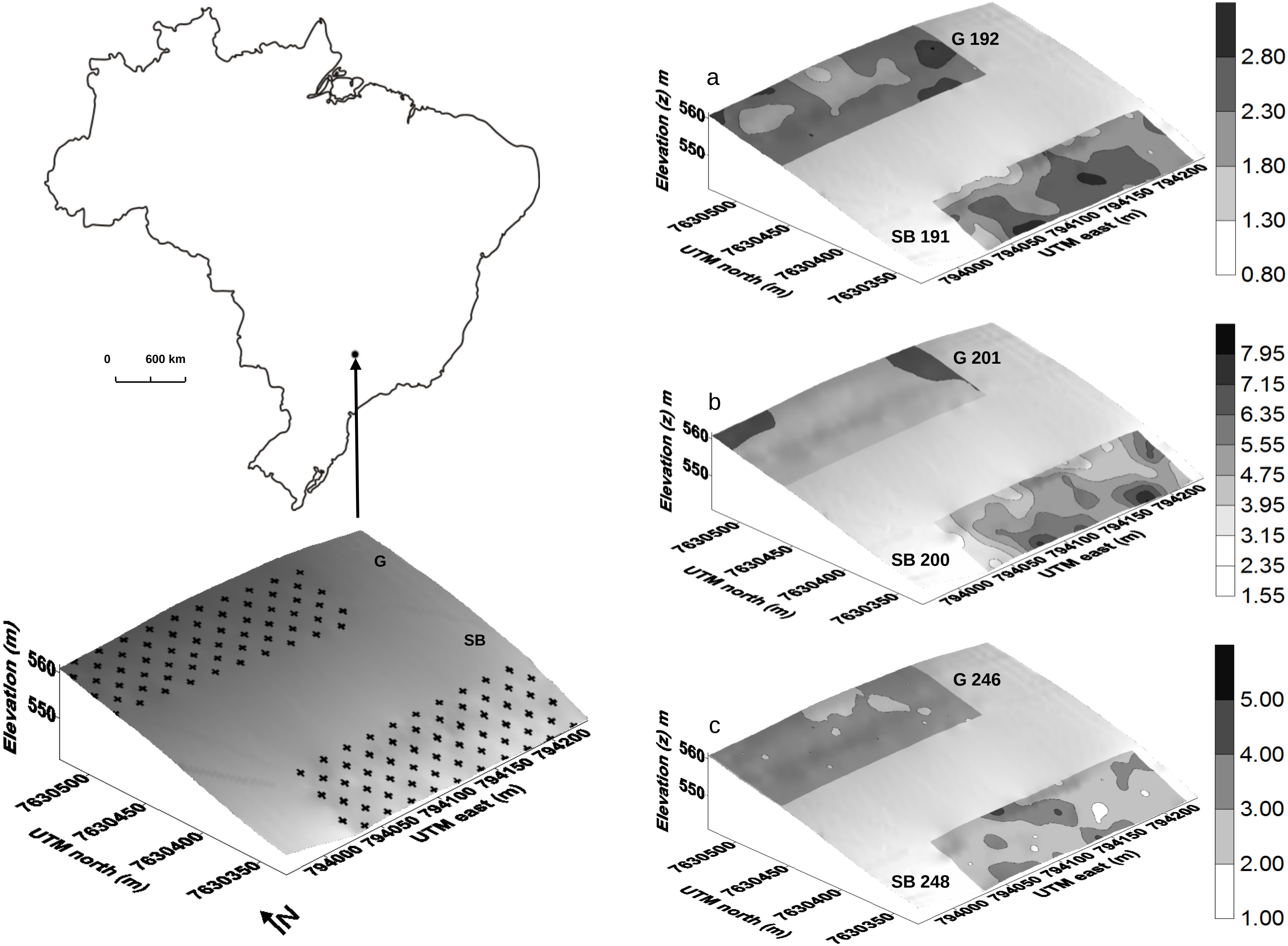
$$C = Carbon\ Stock$$

$$k = k[temp(\vec{r}), moisture(\vec{r},t), O_2(\vec{r},t), Clay(\vec{r}), C/N(\vec{r},t)]$$

$$\underbrace{O_2(\vec{r},t)}$$

$$Free\ Air\ Porosity = Total\ Porosity - Moisture\,(vol.)$$

The influence of sugarcane residues on FCO_2



Panosso et al. 2009

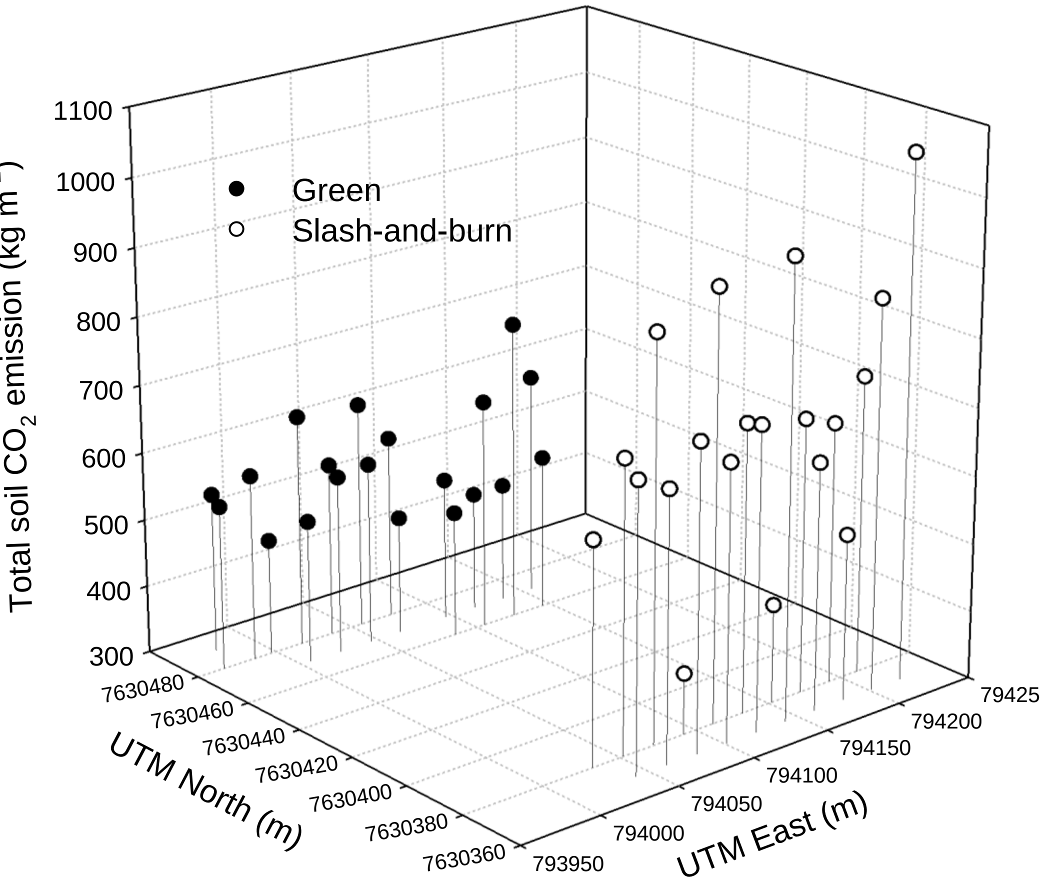


Figure 3. Spatial representation of total soil CO_2 emission during 70 days for each sample points in Green and Slash-and-burn management systems.

<u>Total Emission</u>

G: 557 g CO_2 m^{-2} SB: 729 g CO_2 m^{-2}

<u>Difference:</u>

172 g CO_2 m^{-2},

(X 12/44)

= 46,9 g C-CO_2 m^{-2}

= 469 kg C-CO_2 $hectare^{-1}$

(In 70 days...after harvest...)

Panosso et al. 2011

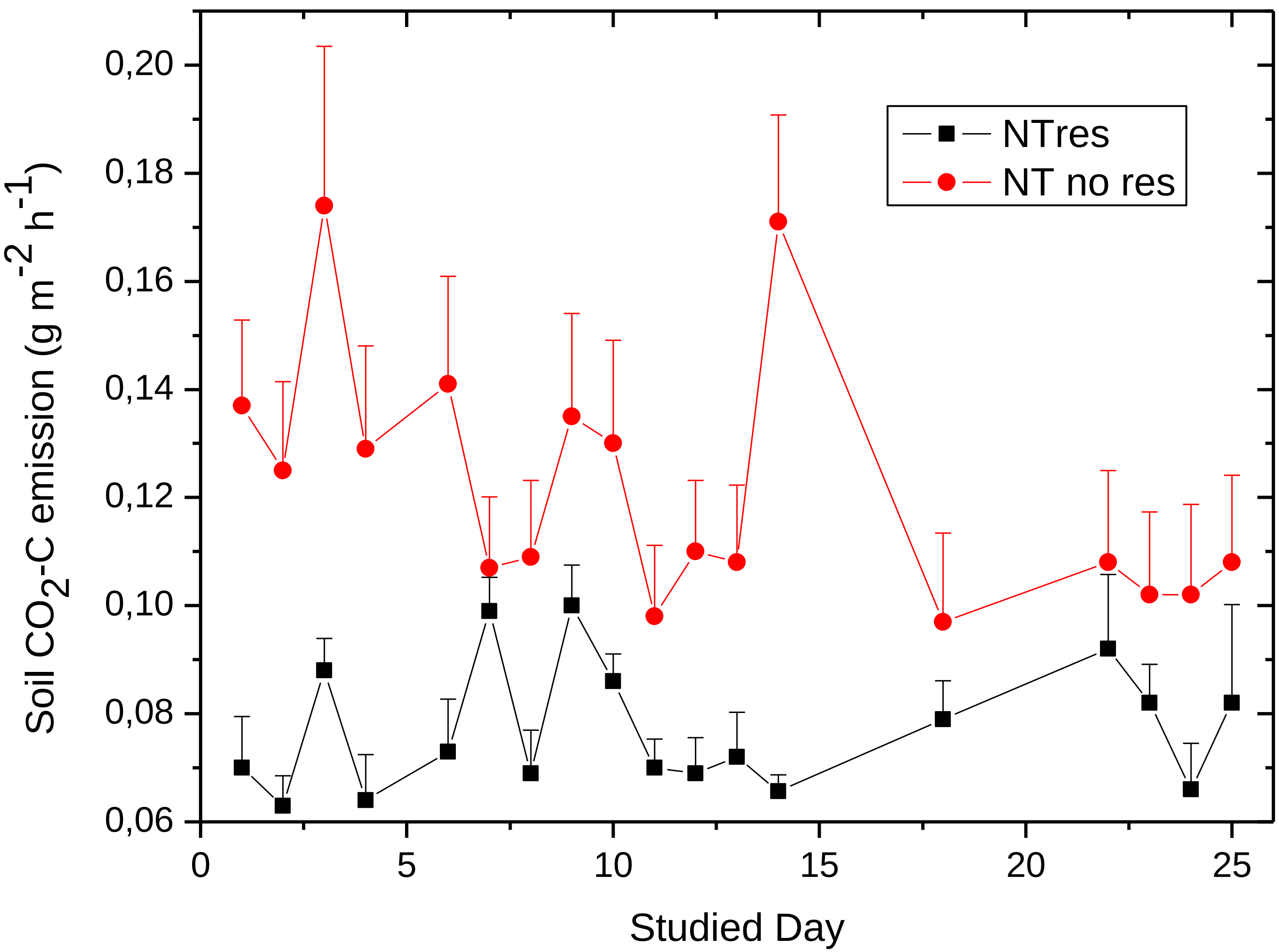


Figure 1. Mean (half of standard error) of CO_2-C emission in the studied days (Mococa, 2010).

Difference: D0 – D100 ~ 252.4 kg C-CO_2 hectare^{-1} (in 25 days...)

Figueiredo et al. 2011

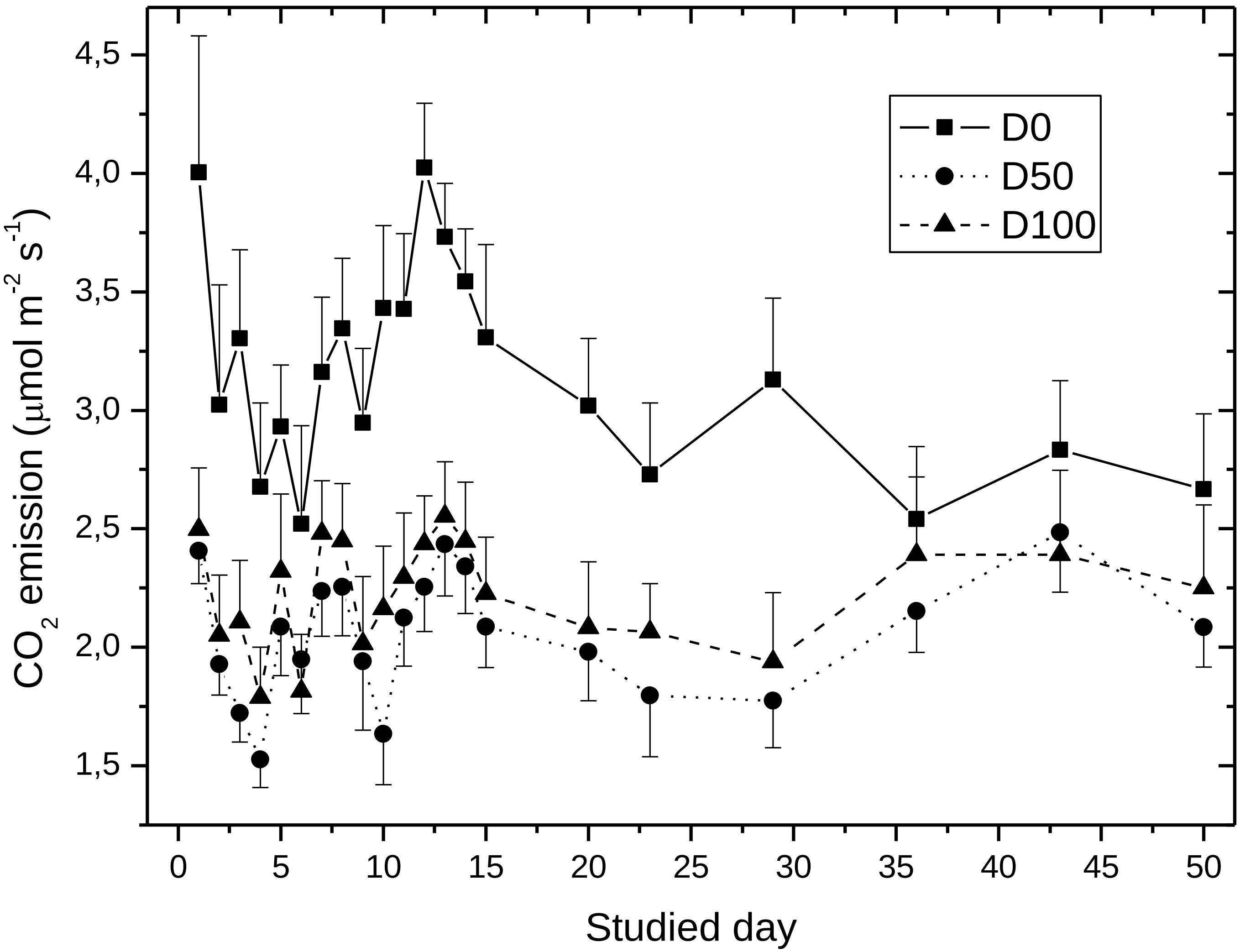


Figure 1. Mean (half of standard error) of CO_2 emission in the studied days.

Difference: D0 – D100 ~ 400 kg C-CO_2 hectare^{-1} (in 50 days...)

Corradi et al. 2011

FCO_2 x soil properties

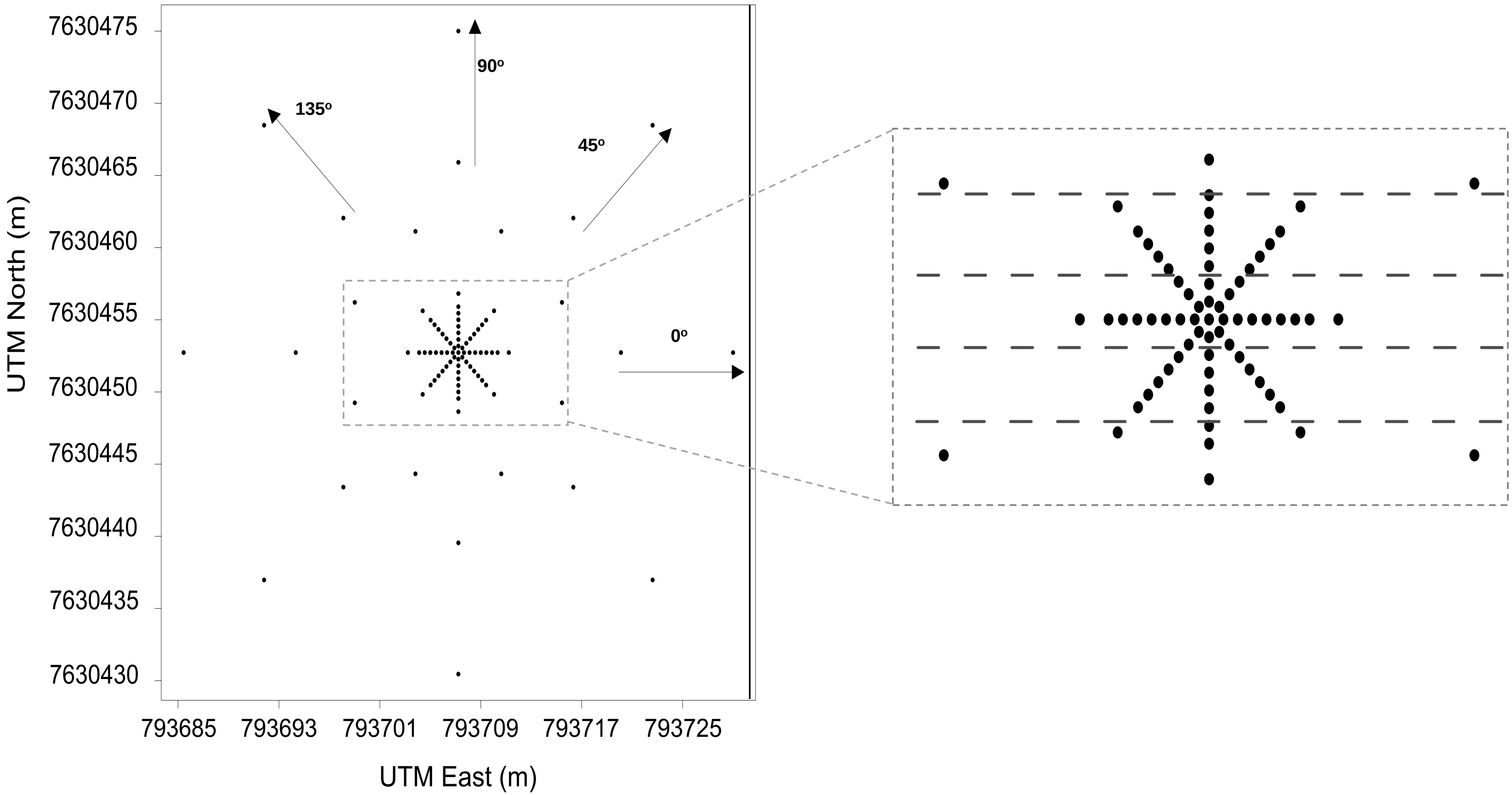


Figure 1. The study area (50 m 50 m) with 89 points and all directions and crop lines position on the field (– – –).

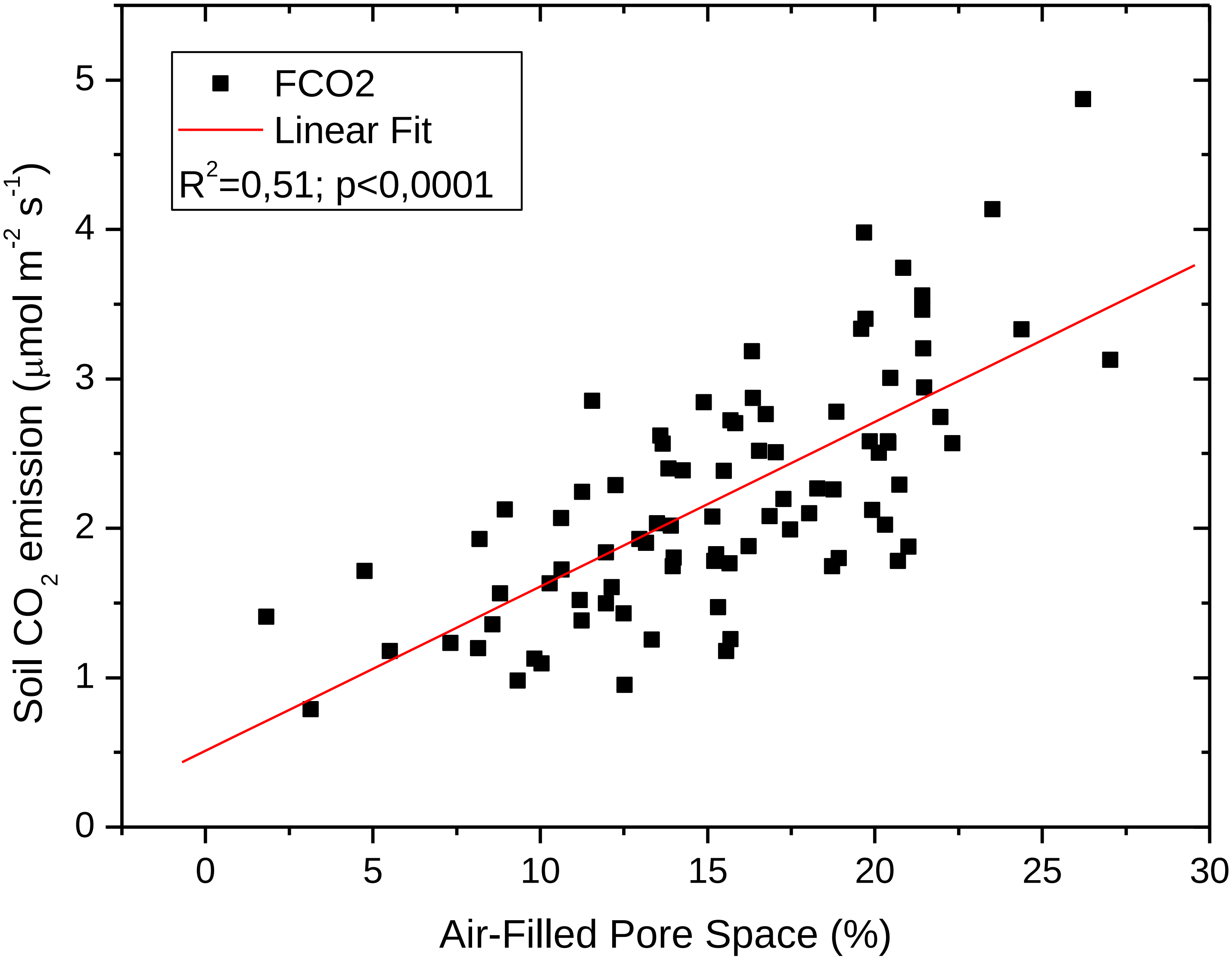
Panosso et al. 2011

Table 2. Means of soil CO_2 emission and the others soil properties with their respective coefficient of variation (CV) for the different directions.

Properties	0°		45°		90°		135°	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV
FCO2 299A ($\mu mol\ m^{-2}\ s^{-1}$)	1.85 b	24.8	2.43 ab	40.1	2.31 ab	26.5	2.64 a	47.0
FCO2 301M ($\mu mol\ m^{-2}\ s^{-1}$)	1.67 b	37.2	2.18 ab	34.4	2.23 ab	35.4	2.31 a	34.0
FCO2 301A($\mu mol\ m^{-2}\ s^{-1}$)	1.70 a	35.0	2.00 a	49.0	2.15 a	27.0	2.32 a	35.4
FCO2 302M ($\mu mol\ m^{-2}\ s^{-1}$)	1.55 b	29.2	2.09 a	37.2	1.96 ab	26.3	2.04 ab	32.6
FCO2 302A ($\mu mol\ m^{-2}\ s^{-1}$)	1.87 a	26.4	2.34 a	42.9	2.35 a	41.5	2.16 a	32.3
FCO2 308M ($\mu mol\ m^{-2}\ s^{-1}$)	1.44 b	42.6	2.47 a	44.9	2.19 a	29.9	2.39 a	36.6
FCO2 313A ($\mu mol\ m^{-2}\ s^{-1}$)	2.01 b	44.9	3.34 a	57.8	2.66 ab	34.6	2.84 ab	39.9
FCO2 322M ($\mu mol\ m^{-2}\ s^{-1}$)	1.63 b	43.3	2.53 a	50.9	2.50 a	32.1	2.68 a	40.4
FCO2 ($\mu mol\ m^{-2}\ s^{-1}$)	1.72 b	32.1	2.42 a	41.1	2.29 ab	24.4	2.42 a	35.2
Ts (°C)	26.24 a	1.6	25.78 a	1.6	25.96 a	2.8	25.96 a	2.4
Ms (%)	31.07 a	21.7	26.68 b	11.1	27.07 b	9.6	26.74 b	14.4
AFPS (%)	9.34 b	68.5	16.75 a	27.2	16.84 a	21.5	17.03 a	29.2
Ds ($g\ cm^{-3}$)	1.22 a	2.7	1.15 b	6.4	1.15 b	4.9	1.15 b	5.8
TPV (%)	40.40 b	2.4	43.43 a	5.2	43.91 a	4.8	43.77 a	4.4
Macro	4.49 b	41.2	6.76 ab	38.3	8.38 a	42.2	6.85 ab	38.4
Sand ($g\ kg^{-1}$)	141.81 a	2.4	142.00 a	3.2	141.55 a	1.9	142.60 a	2.2
Silt ($g\ kg^{-1}$)	244.69 bc	3.3	256.10 ab	7.5	267.60 a	4.3	239.33 c	6.8
Clay ($g\ kg^{-1}$)	613.50 ab	1.2	601.90 bc	3.0	590.85 c	2.2	618.08 a	2.8
pH	4.5 b	6.6	4.6 ab	3.9	4.6 ab	4.1	4.7 a	5.3
SOM ($g\ dm^{-3}$)	24.90 a	8.6	23.50 a	10.0	23.85 a	8.8	23.65 a	8.4
Cstock ($Mg\ ha^{-1}$)	860.16 a	7.7	769.95 b	9.1	774.57 b	7.3	770.86 b	8.3
P ($mg\ dm^{-3}$)	17.76 a	9.8	17.25 a	39.6	20.05 a	61.4	16.20 a	27.2
Bases ($mmol_c\ dm^{-3}$)	43.34 a	25.2	44.47 a	16.1	44.77 a	17.0	45.15 a	27.9
CEC ($mmol_c\ dm^{-3}$)	106.34 a	7.9	102.37 a	5.3	106.87 a	11.2	97.95 a	7.6
V (%)	40.83 a	23.4	43.47 a	15.5	42.09 a	16.6	46.04 a	27.1

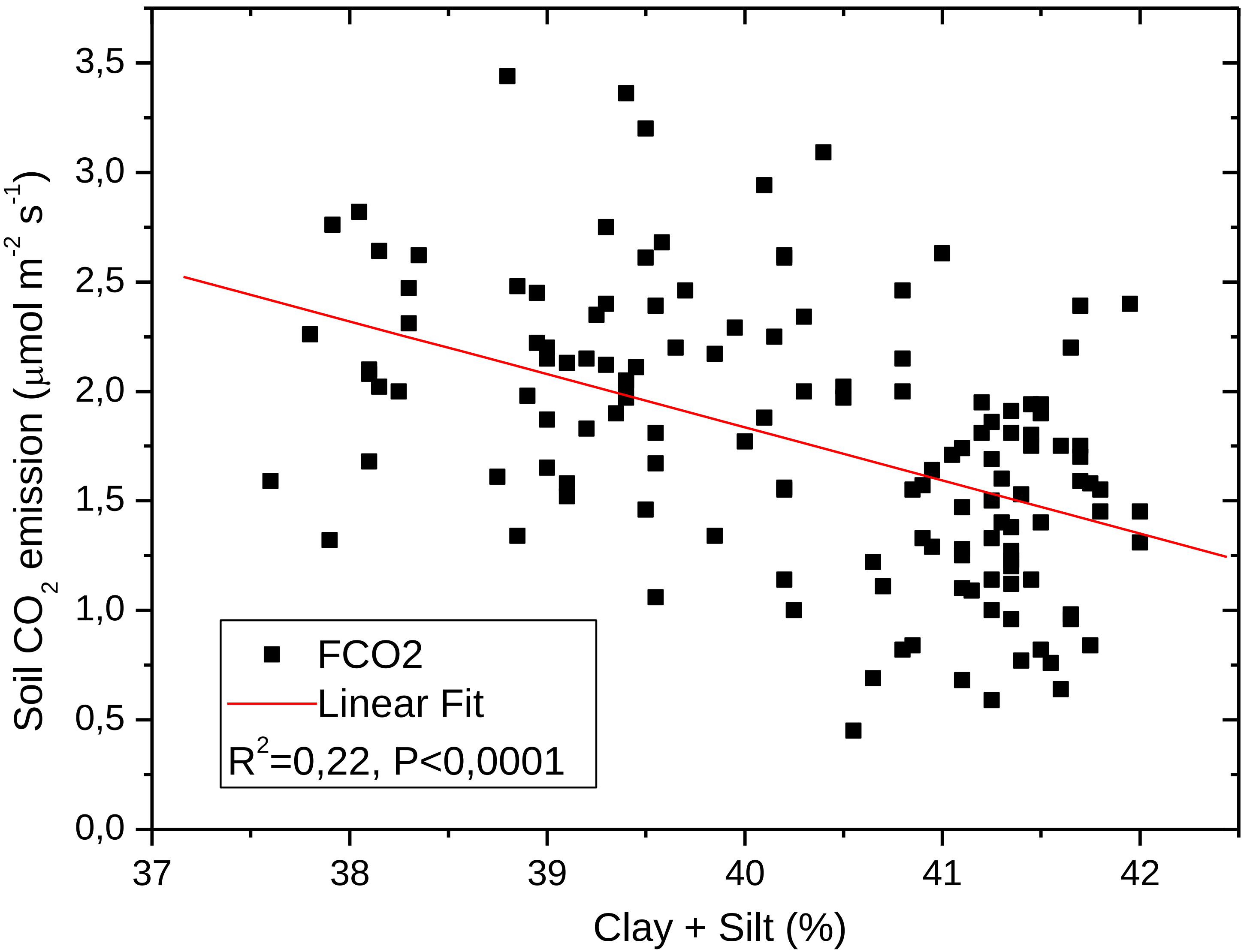
N=89; Means followed by the same letters on rows do not differ (Tukey; $p < 0.05$). FCO2 = soil CO_2 emission; Ts = soil temperature; Ms = soil moisture; AFPS = air-filled pore space; Ds = soil bulk density; TPV = total pore volume; Macro = macroporosity; Sand = sand content; Silt = silt content; Clay = clay content; SOM = soil organic matter; Cstock = carbon stock; P = available phosphorous; Bases = sum of bases; CEC = cations exchange capacity; V= base saturation.

Panosso et al. 2011

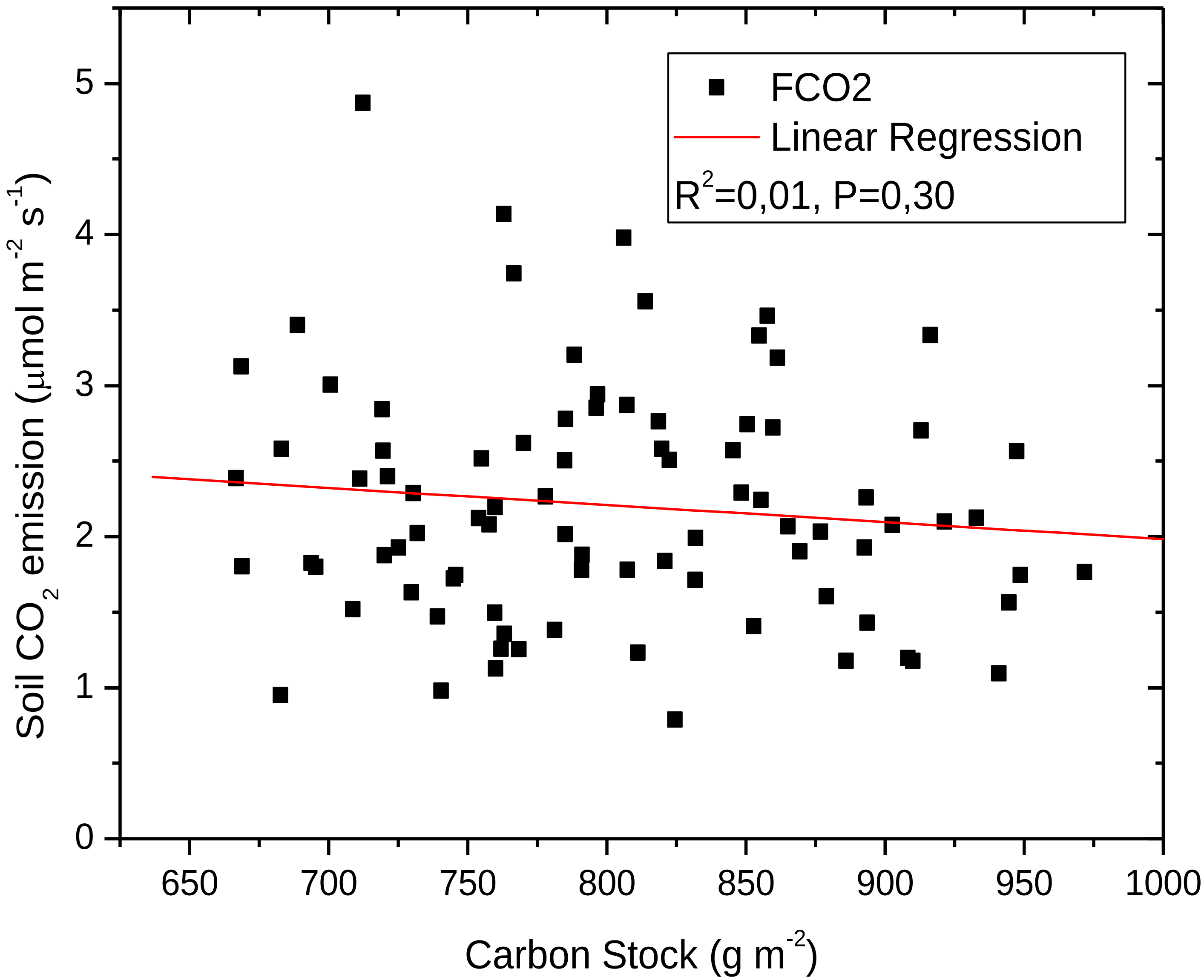


$$\frac{\Delta FCO2}{\Delta AFPS} \sim 0{,}11 \mu mol\ m^{-2}\ s^{-1} (\%AFPS)^{-1} \xrightarrow{\Delta AFPS = -1\%} \Delta F_{C-CO2} = -370 kg\, C\ hect.^{-1}\ year^{-1}$$

Panosso et al. 2011



Brito et al. 2010



$$F_{C-CO2} = kC$$

Panosso et al. 2011

FCO2 induced by tillage

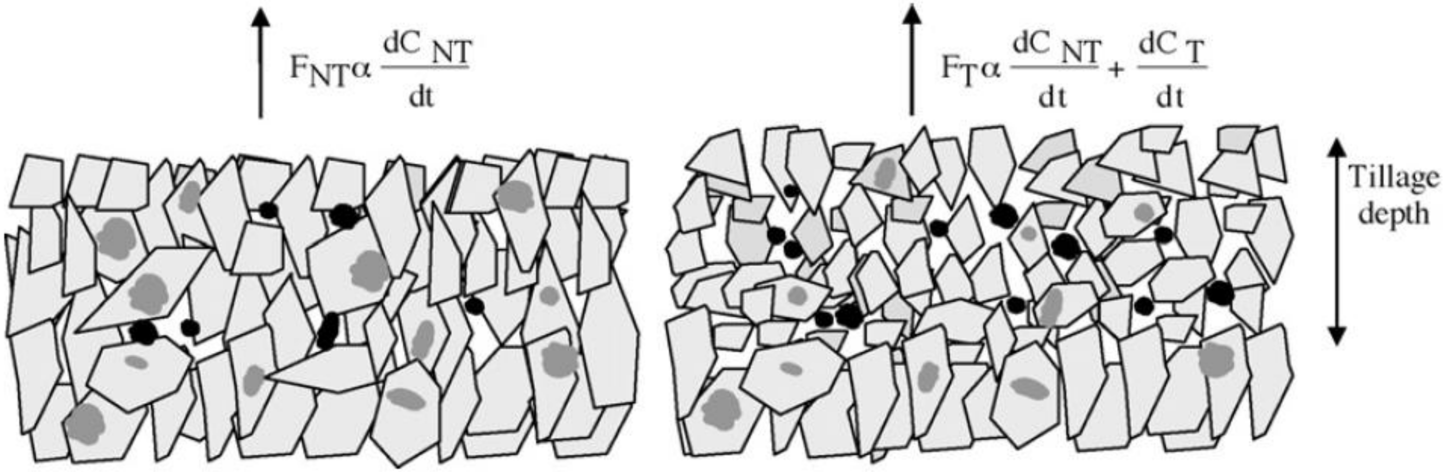


Fig. 1. Schematic representation of free (black) and aggregate protected (grey) labile C in the no-till (left) and tilled (right) plots after tillage. Tillage releases C from aggregates resulting in an increase of labile C available for microbial decay.

$$\frac{dC_{soil}(t)}{dt} = -kC_{soil}(t) \qquad C_{soil}(t) = C_0 e^{-kt} \qquad F(t) = C_0 k e^{-kt}$$

$$C_T(t=0) = C_{0NT} + C_{0T}, \qquad F_T(t) = -\frac{dC_{soil}(t)}{dt} = -\frac{d}{dt}(C_{0NT}e^{-k_T t} + C_{0T}e^{-k_T t})$$

$$F_T(t) = F_{NT}(t) + C_{0T} k_T e^{-k_T t}$$

$$F_T(t) - F_{NT}(t) = a_1 e^{-a_2 t}$$

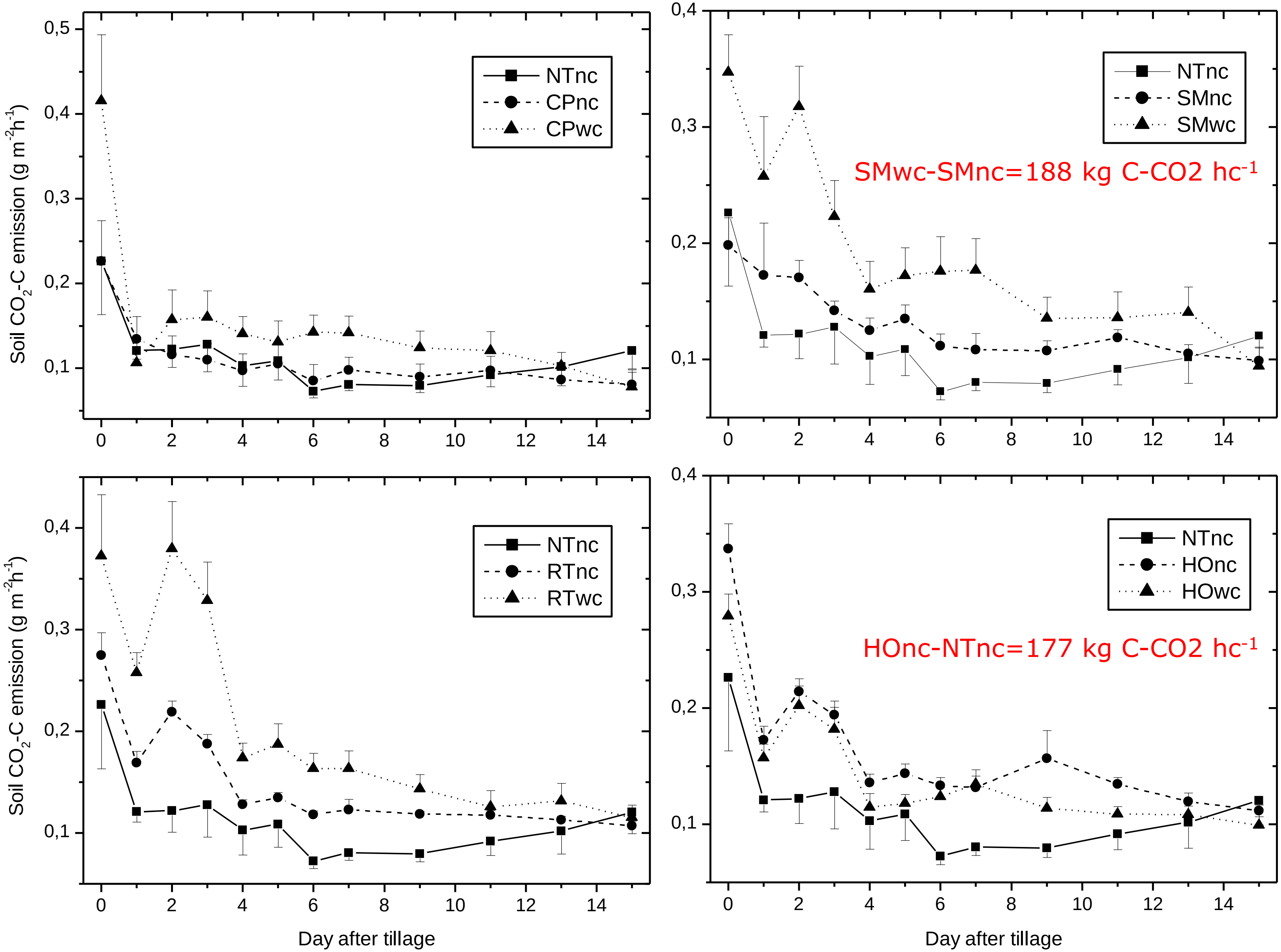
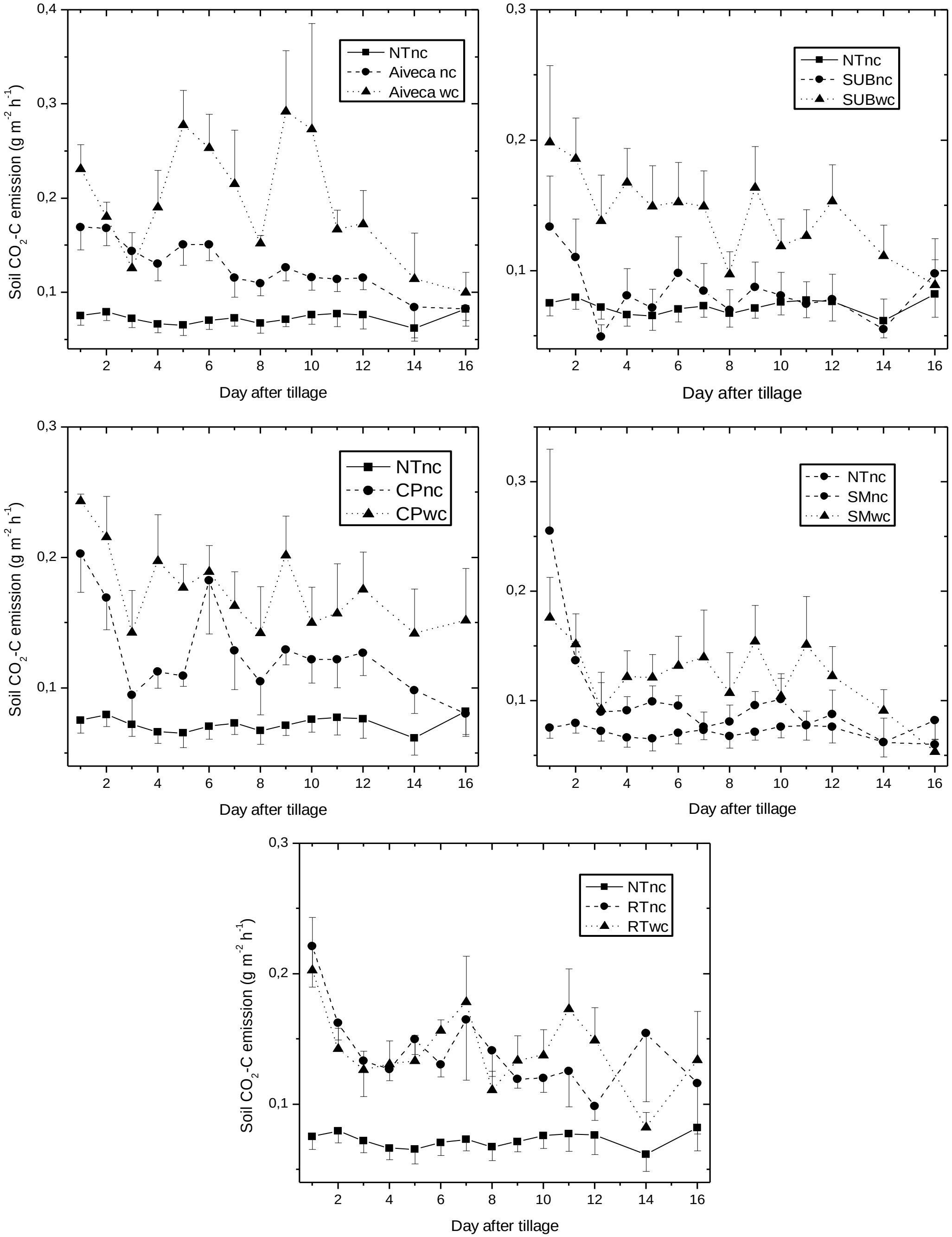


Figure 1. Soil CO_2–C emission after tillage on plots with and without sugarcane residues on soil surface. No till emission in included in all graphs.

Teixeira 2010

La Scala et al. 2011



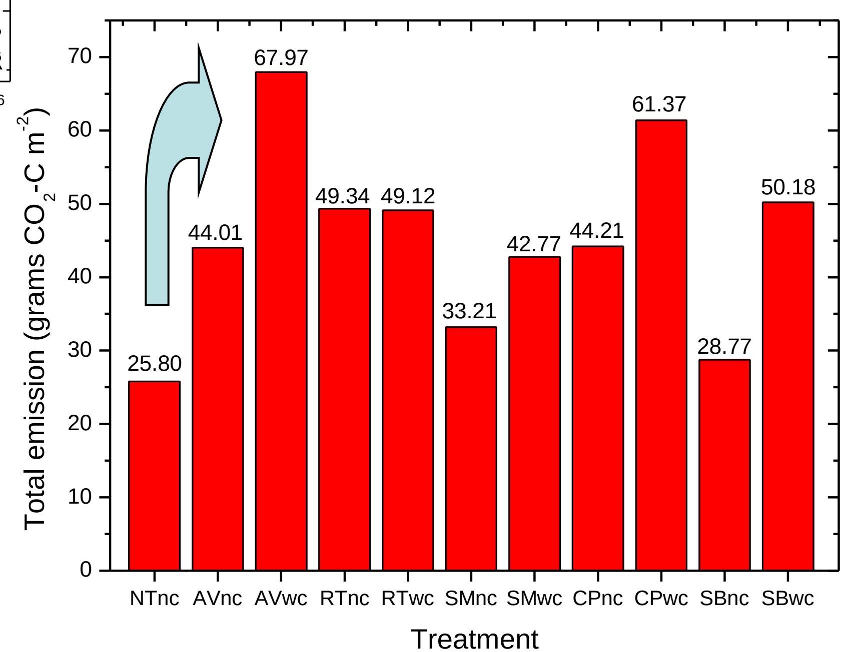
Soil C Losses (15 days after tillage):

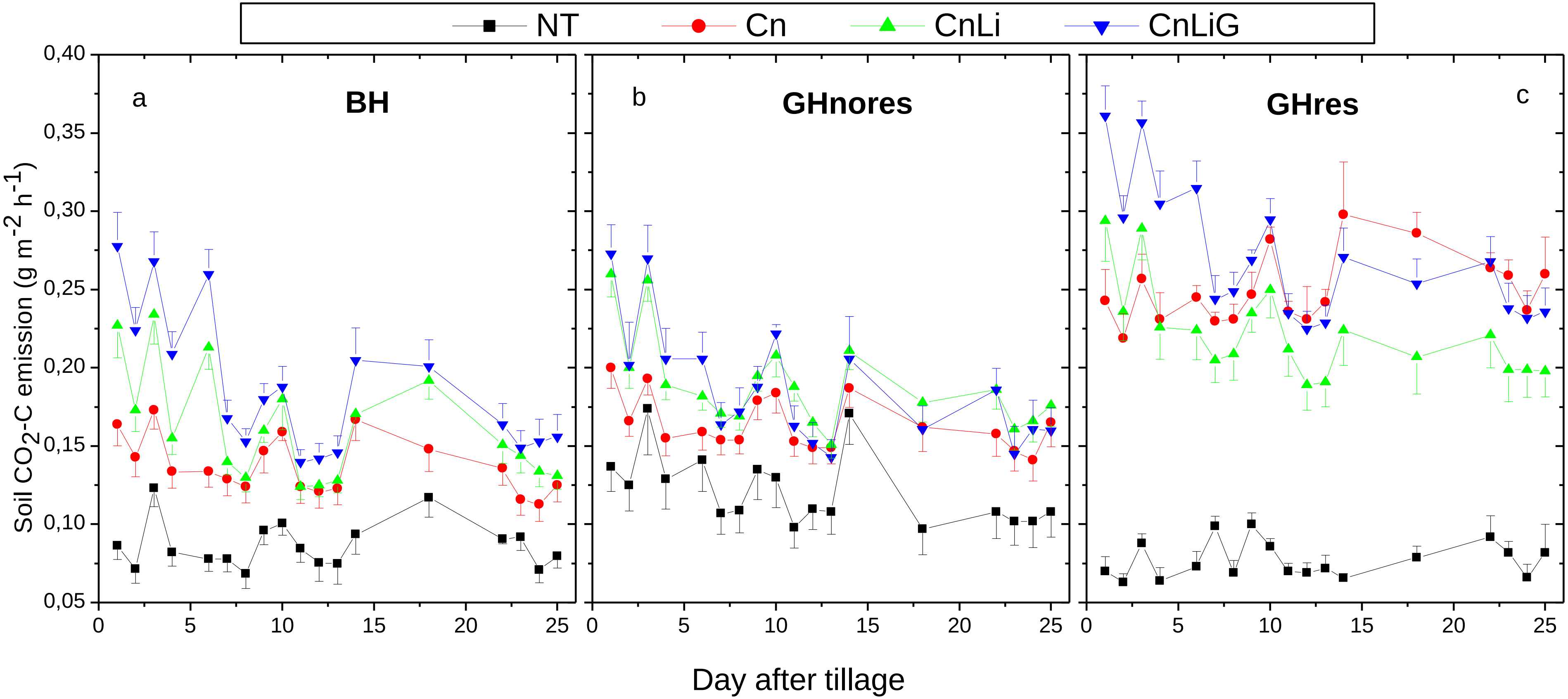
RTnc – NTnc = 235 kg C-CO_2 hec^{-1}

AVnc – NTnc = 182kg C-CO2 hec^{-1}

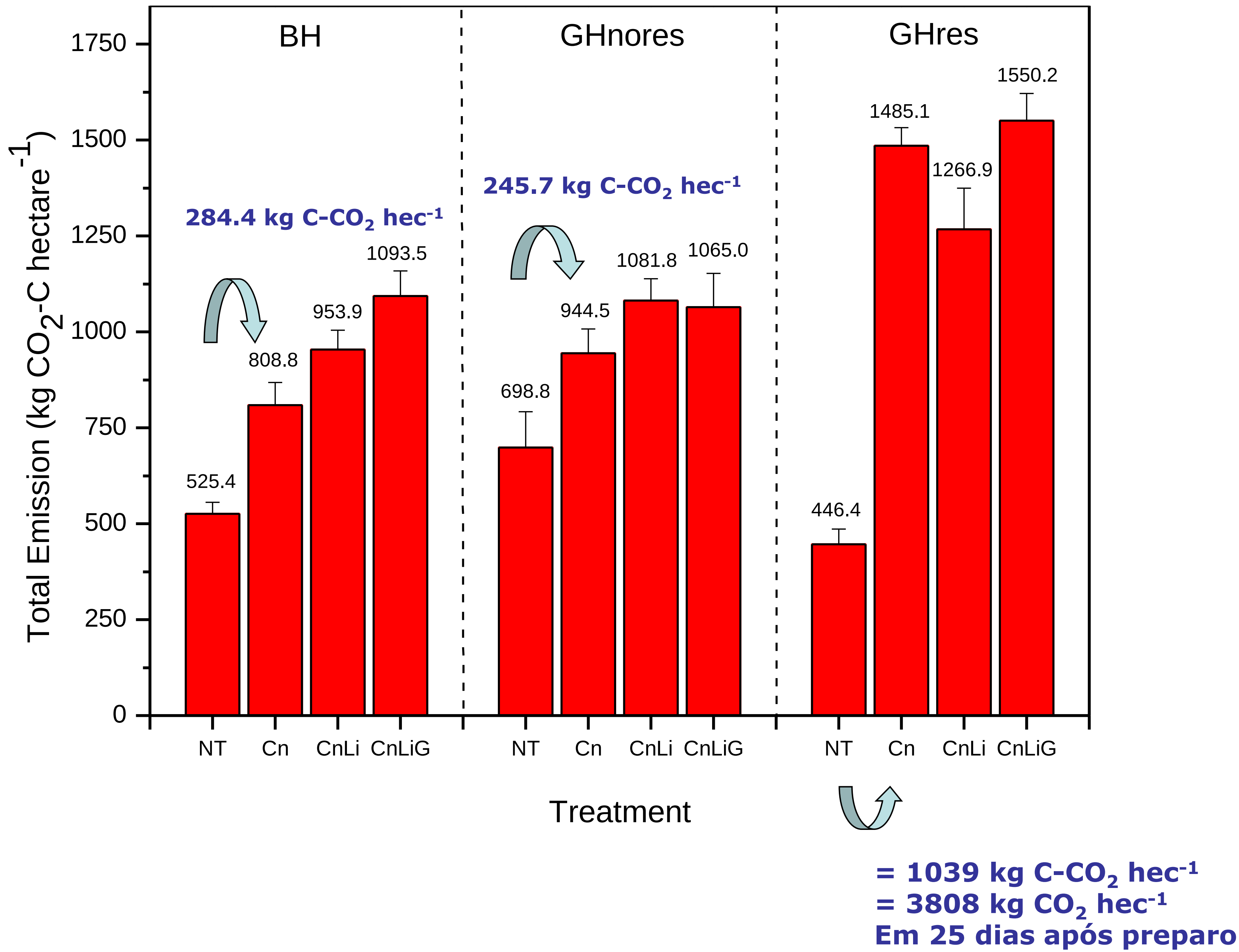
Subnc – NTnc = 29 kg C-CO_2 hec^{-1}

421.7 kg C-CO_2 hec^{-1}





NT
Cn
CnLi
CnLiG
a
BH
b
GHnores
GHres
c
Soil CO2-C emission (g m-2 h-1)
0,05
0,10
0,15
0,20
0,25
0,30
0,35
0,40
0
5
10
15
20
25
Day after tillage



BH
GHnores
GHres
284.4 kg C-CO2 hec-1
245.7 kg C-CO2 hec-1
525.4
808.8
953.9
1093.5
698.8
944.5
1081.8
1065.0
446.4
1485.1
1266.9
1550.2
Total Emission (kg CO2-C hectare-1)
0
250
500
750
1000
1250
1500
1750
NT
Cn
CnLi
CnLiG
NT
Cn
CnLi
CnLiG
NT
Cn
CnLi
CnLiG
Treatment
= 1039 kg C-CO2 hec-1
= 3808 kg CO2 hec-1
Em 25 dias após preparo

Main Conclusions:

1. No burning: keep sugarcane residues on soil.

2. Avoid soil tillage as much as possible (increase ratoon cycles).

3. Pay attention to soil properties which would cause further soil carbon losses (total porosity).