Universidade de São Paulo
Escola Superior de Agricultura “Luiz de Queiroz”
Programa de Solos e Nutrição de Plantas
LSN5820 – Matéria Orgânica do Solo

Considerações experimentais, tratamentos e métodos na determinação das taxas de sequestro de carbono

José Igor Almeida Castro
Felipe Bonini da Luz
Christian Lopes

Maio - 2020

Published March 28, 2014

Review & Analysis–Soil & Water Management & Conservation

Experimental Consideration, Treatments, and Methods in Determining Soil Organic Carbon Sequestration Rates

Kenneth R. Olson*
Dep. of Natural Resources and Environmental Sciences
College of Agricultural, Consumer and Environmental Sciences
Univ. of Illinois
1102 Goodwin Ave
Urbana, IL 61802

Mahdi M. Al-Kaisi
Dep. of Agronomy
College of Agriculture and Life Sciences
Iowa State Univ.
2104 Agronomy Hall
Ames, IA 50011

Rattan Lal
School of Environment and Natural Resources
The Ohio State Univ.
Columbus, OH 43210

Birl Lowery
Dep. of Soil Science
College of Agric. and Life Sciences
Univ. of Wisconsin-Madison
1525 Observatory Dr.
Madison, WI 53706

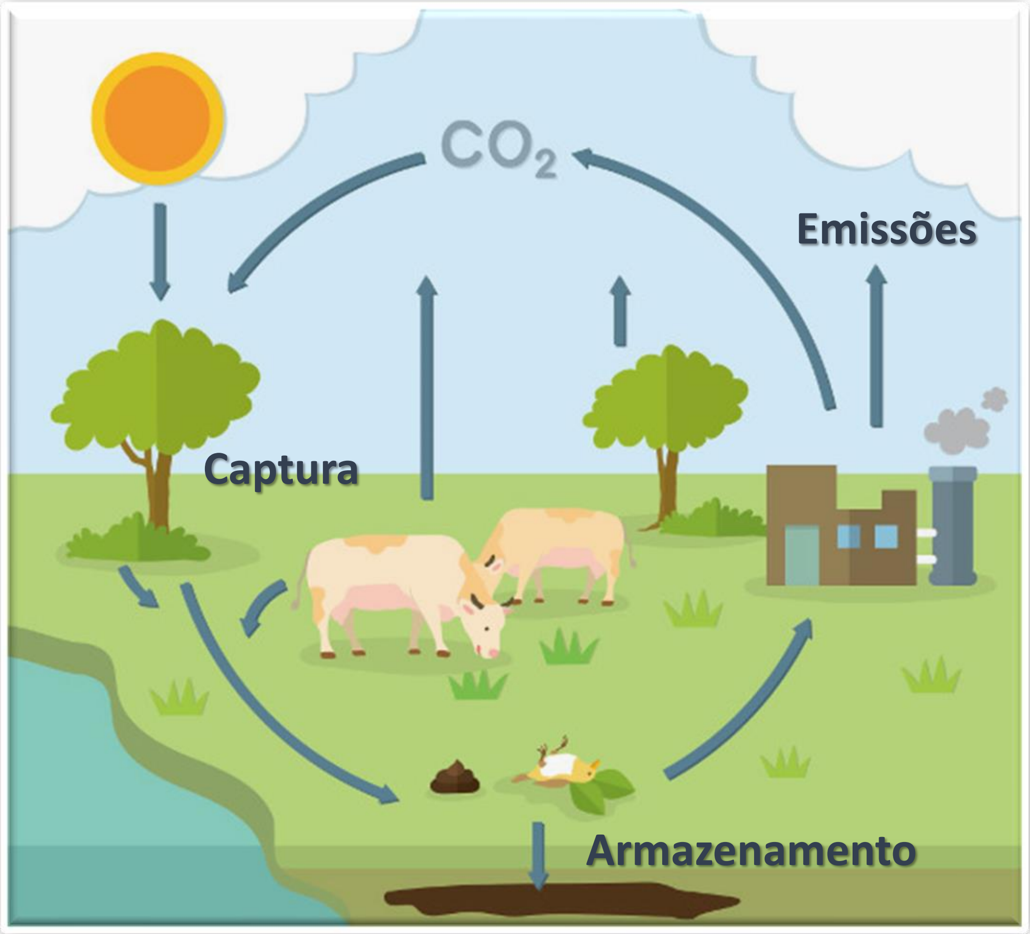
In agricultural land areas, no-tillage (NT) farming systems have been practiced to replace intensive tillage practices such as, moldboard plow (MP), chisel plow (CP), and other systems to improve many soil health indicators, and specifically to increase soil organic carbon (SOC) sequestration and reduce soil erosion. Numerous approaches to estimate the amounts and rates of SOC sequestration as a result of a switch to NT systems have been published, but there is a concern regarding protocol for assessing SOC especially for different tillage systems. Therefore, the objectives of this paper are to: (i) define and understand concepts of SOC sequestration, (ii) quantify SOC distribution and the methodology of measurements, (iii) address soil spatial variability at field- or landscape-scale for potential SOC sequestration, and (iv) consider proper field experimental design, including pretreatments baseline for SOC sequestration determination. For SOC sequestration to occur, as a result of a treatment applied to a land unit, all of the SOC sequestered must originate from the atmospheric CO_2 pool and be transferred into the soil humus through land unit plants, plant residues, and other organic solids. The SOC stock present in soil humus at end of a study must be greater than the pretreatment SOC stock levels in the same land unit. However, one should recognize that a continuity equation showing drawdown in atmospheric concentration of CO_2 may be difficult, if not impossible, to quantify. Therefore, SOC sequestration results of paired comparisons of NT to other conventional tillage systems with no pretreatments SOC baseline, and if the conventional system is not at a steady state, will likely be inaccurate where the potential for SOC loss exists in both systems. To unequivocally demonstrate that the SOC sequestration has occurred at a specific site, a temporal increase must be documented relative to pretreatment SOC content and linked attendant changes in soil properties and ecosystem services and functions with proper consideration given to soil spatial variability. Also, a standardized methodology that includes proper experimental design, pretreatment baseline, root zone soil depth consideration, and consistent method of SOC analysis must be used when determining SOC sequestration.

Introdução

- Definições
- Revisão sobre Estoque e Sequestro de Carbono no solo
- Modelo experimental ideal
- Influência do Manejo do Solo
- Métodos de determinação da taxa de sequestro de C
- Todo Carbono no solo está sequestrado?
- Considerações Finais

Armazenamento de C orgânico no solo

Captura e armazenamento de CO_2 em pools bióticos e pedológicos de C que, de outra forma, seriam emitidos para na atmosfera (Lal, 2007).



Capturar CO2 e armazenar no solo

Reduzir as emissões de CO2

Sequestro de Carbono

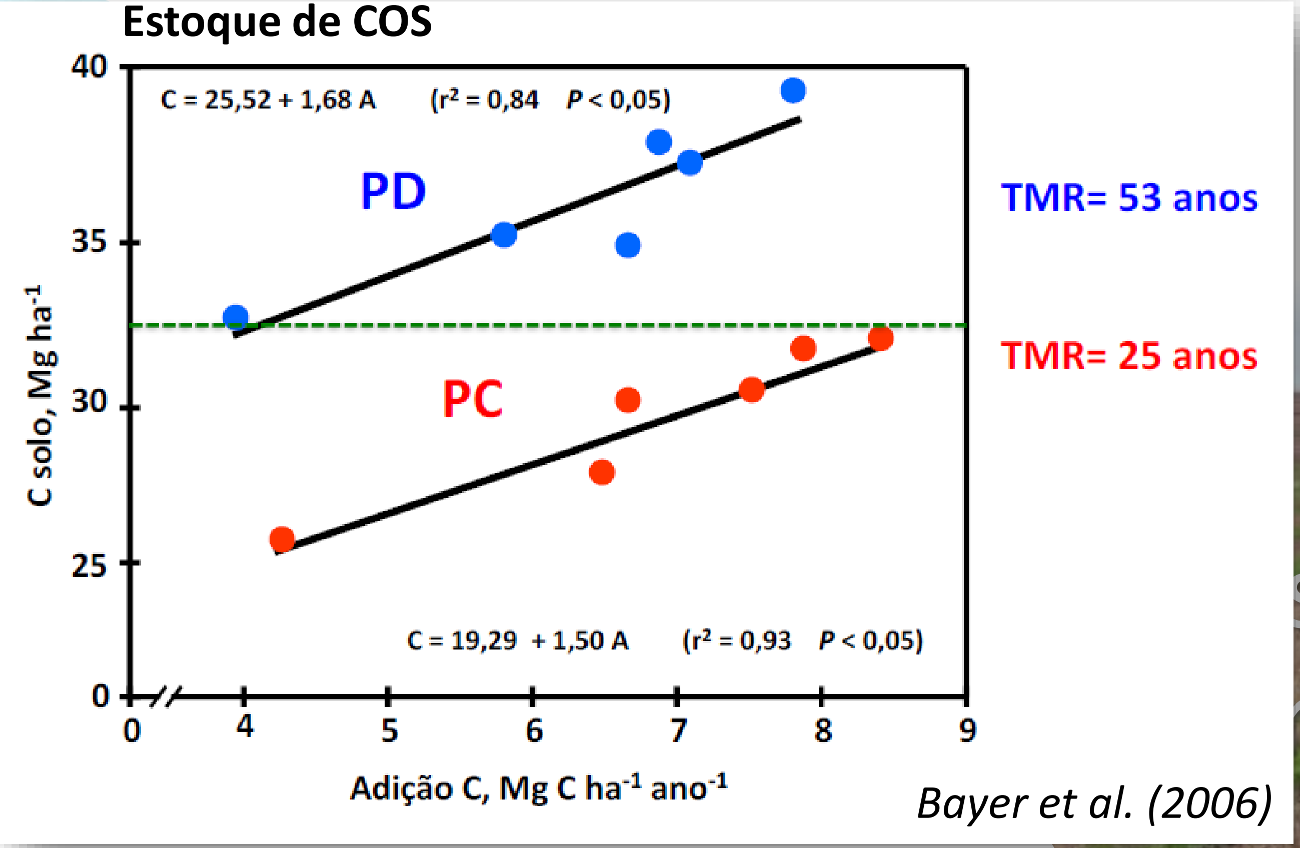
“

- *Processo de transferência de CO_2 da atmosfera para o solo através da decomposição de resíduos vegetais e outros compostos orgânicos, que são armazenados como parte da matéria orgânica do solo.*
- *O tempo de retenção de carbono sequestrado no solo pode variar de curto a longo prazo.*
- *O COS sequestrado é deve aumentar o estoque líquido de COS durante e ao final de um estudo para níveis superiores da linha de base antecedente ao pré-tratamento.*

”

Olson (2013a; p. 203)

Diferenças entre os sistemas



Sequestro de Carbono no solo

Table 1. Published Worldwide and Regional USA soil organic C (SOC) retention rates or rates of net SOC storage change for a switch from conventional till (CT) to no-till (NT).

Region, USA Worldwide	SOC Retention Rate (Mg C ha^{-1} yr^{-1})	Source reference
North Central	0.48 ± 0.59	Johnson et al. (2005)
Northwest	0.27 ± 0.19	Liebig et al. (2005)
South East	0.45 ± 0.04	Franzluebbers (2010)
North East	-0.07 ± 0.27	
South West	0.30 ± 0.21	
USA	0.50	
Worldwide	0.48 ± 0.13	
Humid climates	0.22	
Arid climates	0.10	

Quadro 3. Potencial de sequestro de carbono na camada de 0 a 20 cm, na região da Mata Atlântica (Dados compilados por Mello et al., 2006)

Mudanças de uso da terra	Área total	Taxa de sequestro de C	Potencial de sequestro de C
	M ha	Mg ha^{-1} ano^{-1}	Tg ano^{-1}
Colheita com queima para colheita mecanizada da cana-de-açúcar	3,30	1,62	5,35
Pastagem degradada para cana sem queima	1,93	0,1 a 0,8	0,19 a 1,54
Cana existente sem queima	1,03	1,62	1,67
Cultivo convencional para SPD	6,85	0,2 a 0,8	1,37 a 5,58
Pastagem degradada para SPD	3,80	0 a 0,71	0 a 2,70
SPD	8,02	0,2 a 0,8	1,60 a 6,41
Pastagem degradada para bem manejada	19,65	2,71	53,25
Pastagem bem manejada	28,00	2,71	73,88
Cana-de-açúcar com queima para reflorestamento	1,93	0,66	1,27
Pastagem degradada para reflorestamento	0,78	0 a 1,63	0,08 a 1,27
Reflorestamento	3,10	2,42	7,50
Total			144 a 154

Carvalho et al. (2010)

Sequestro de Carbono no solo

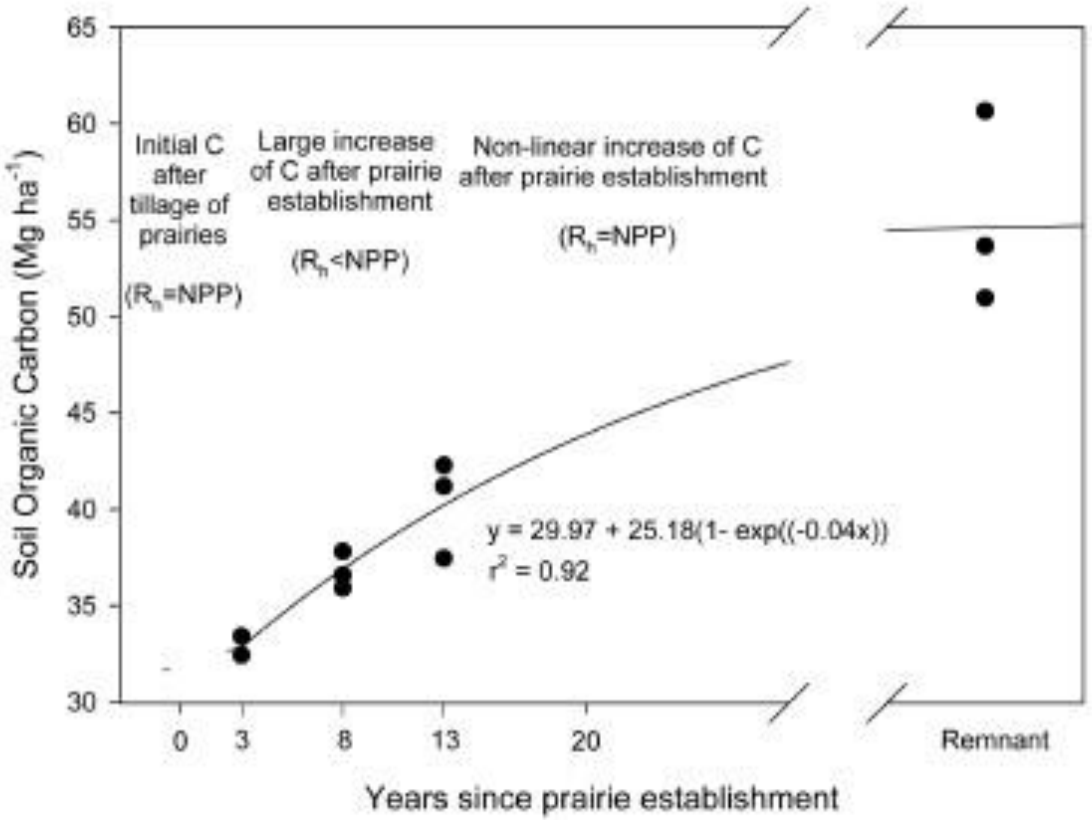
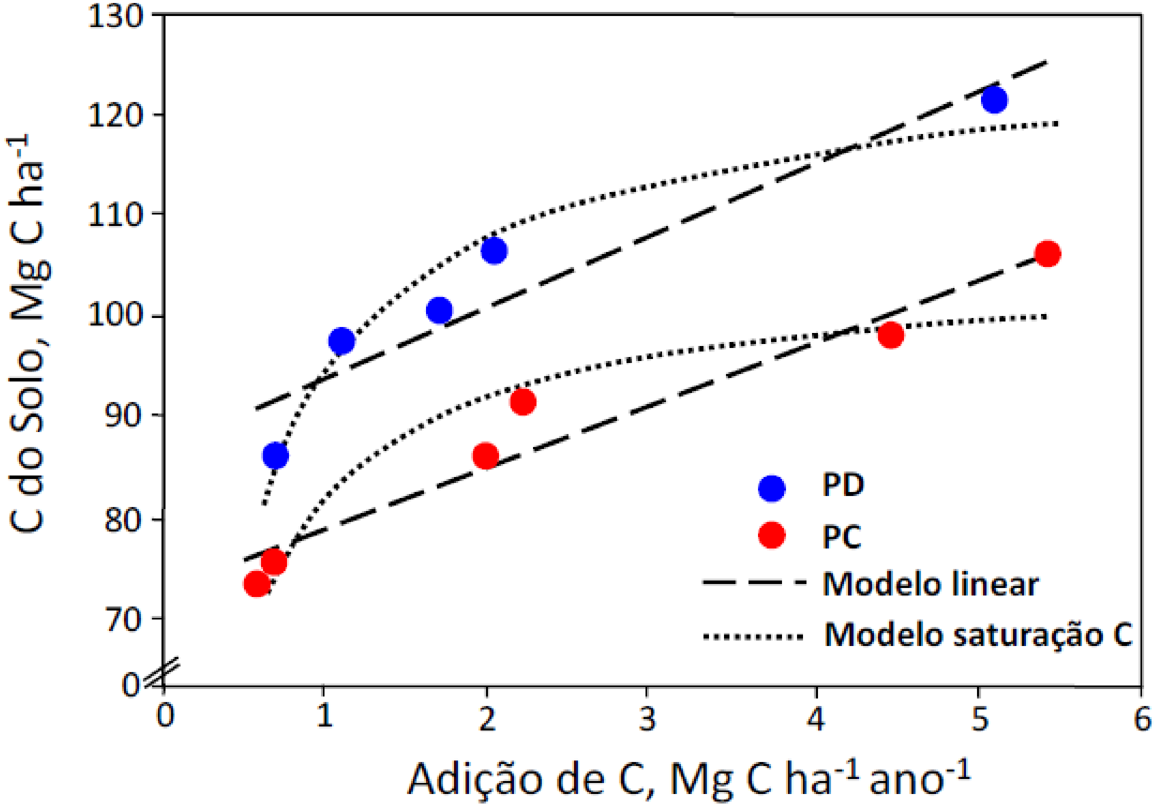
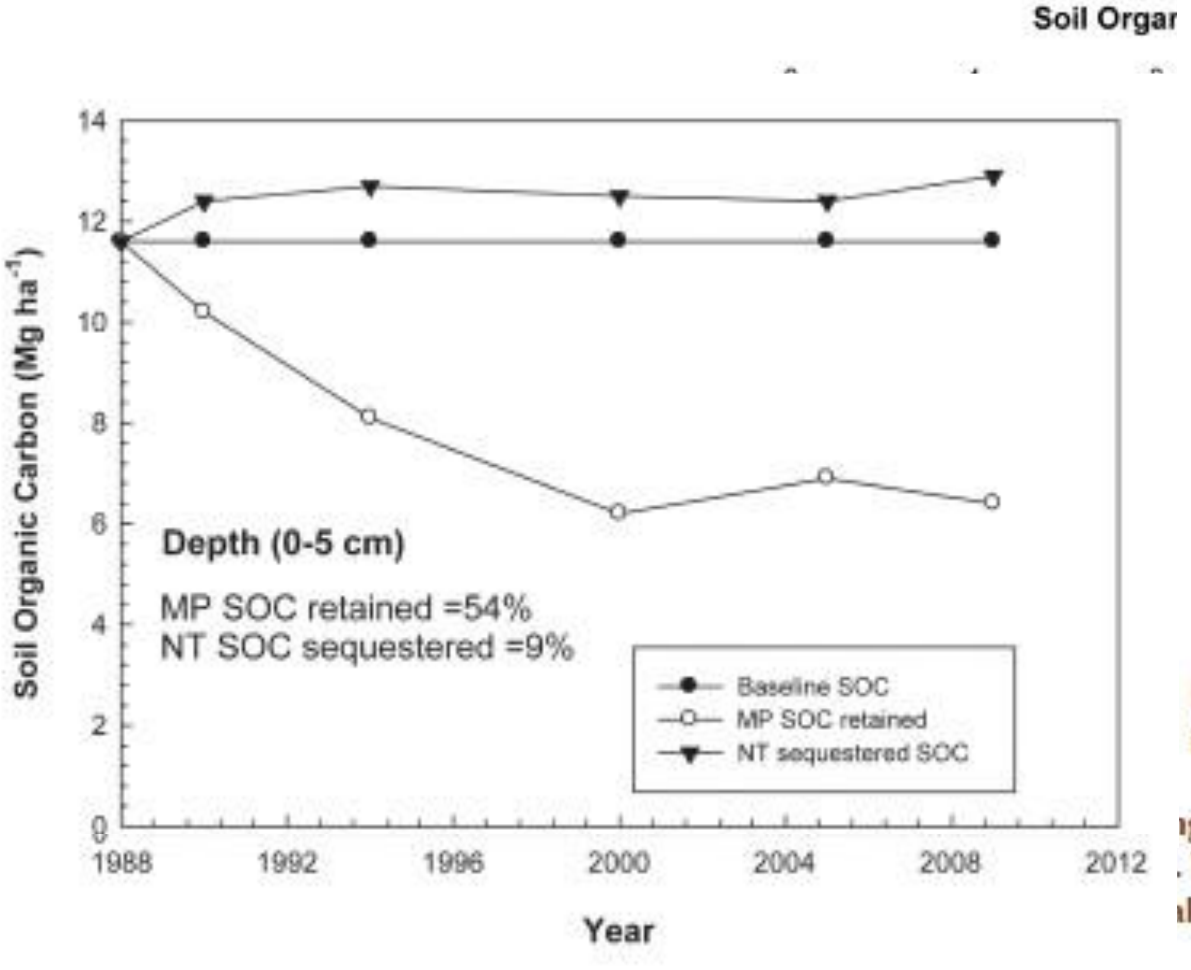


Fig. 1. Soil organic carbon content over a 2- to 14-yr period of reconstructed prairies and potential future increase (Guzman and Al-Kaisi, 2010: J. Environ. Quality 39:136-146).



Stewart et al. (2007)

Influência da profundidade



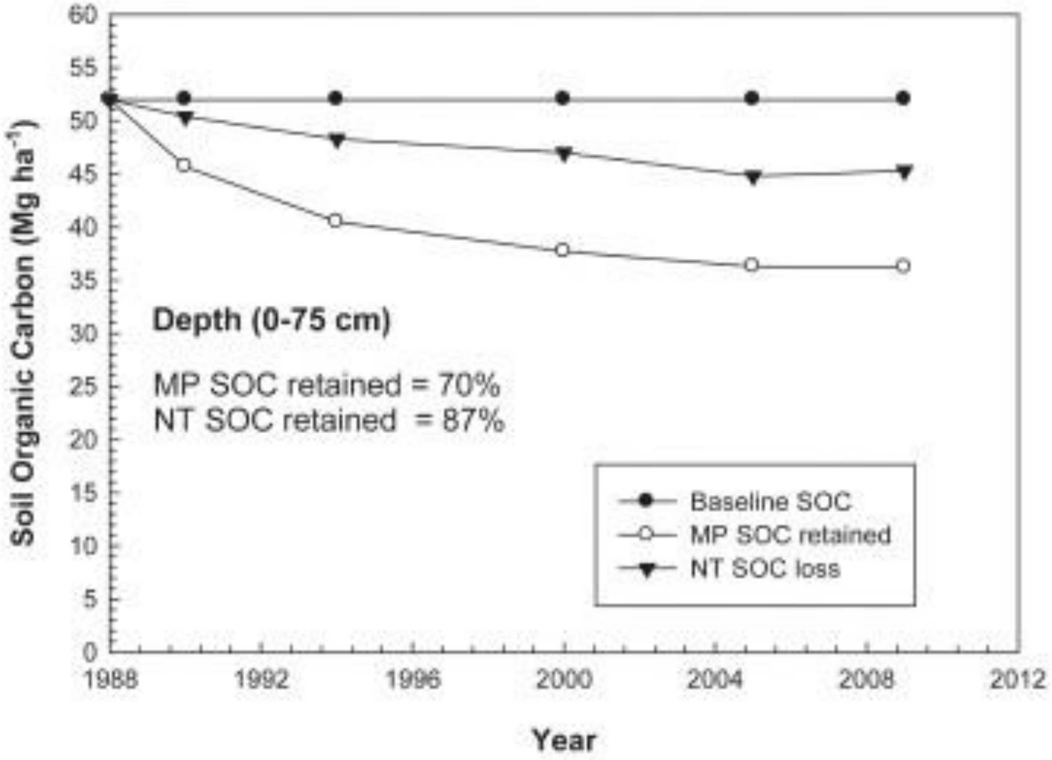
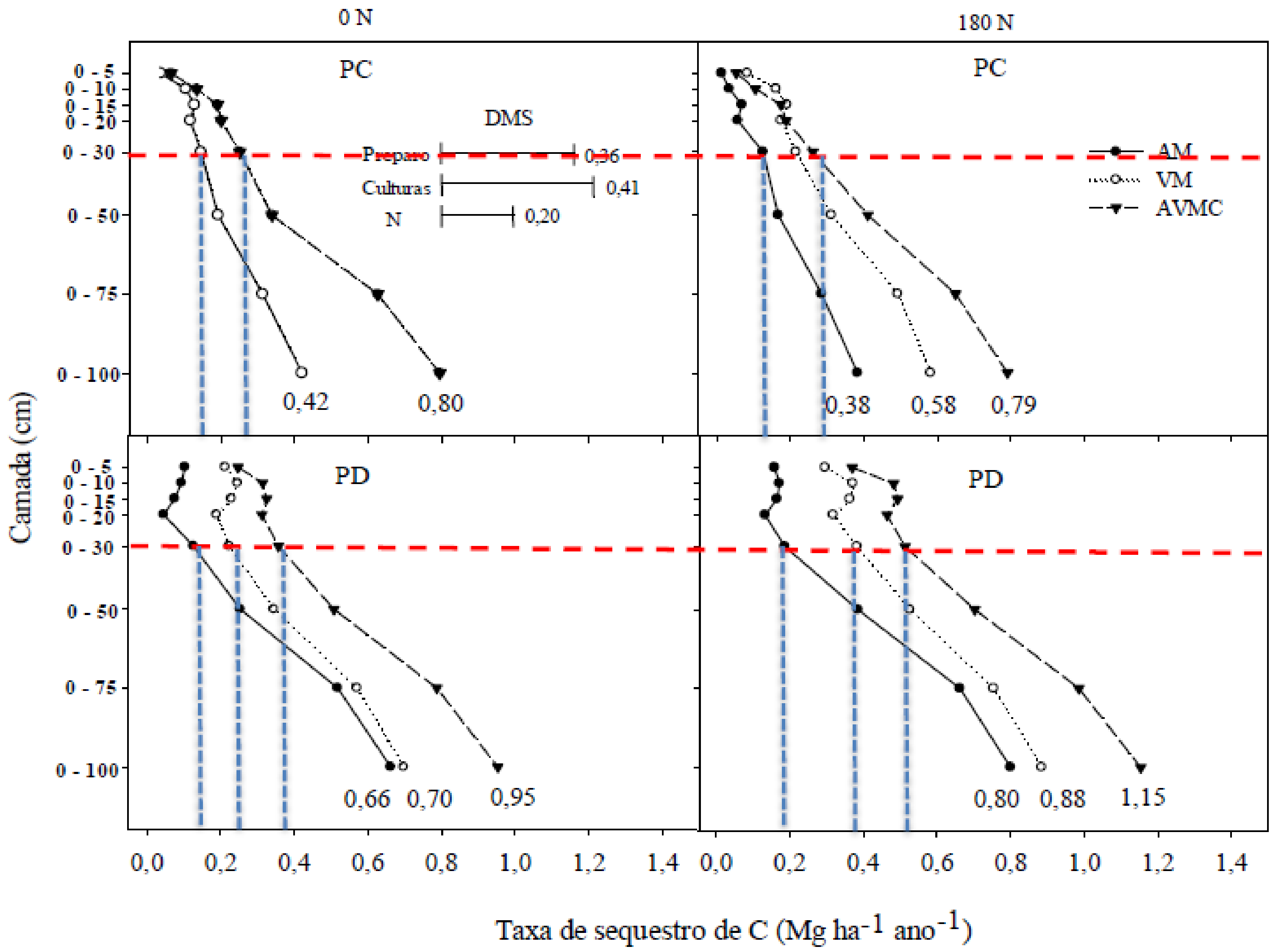


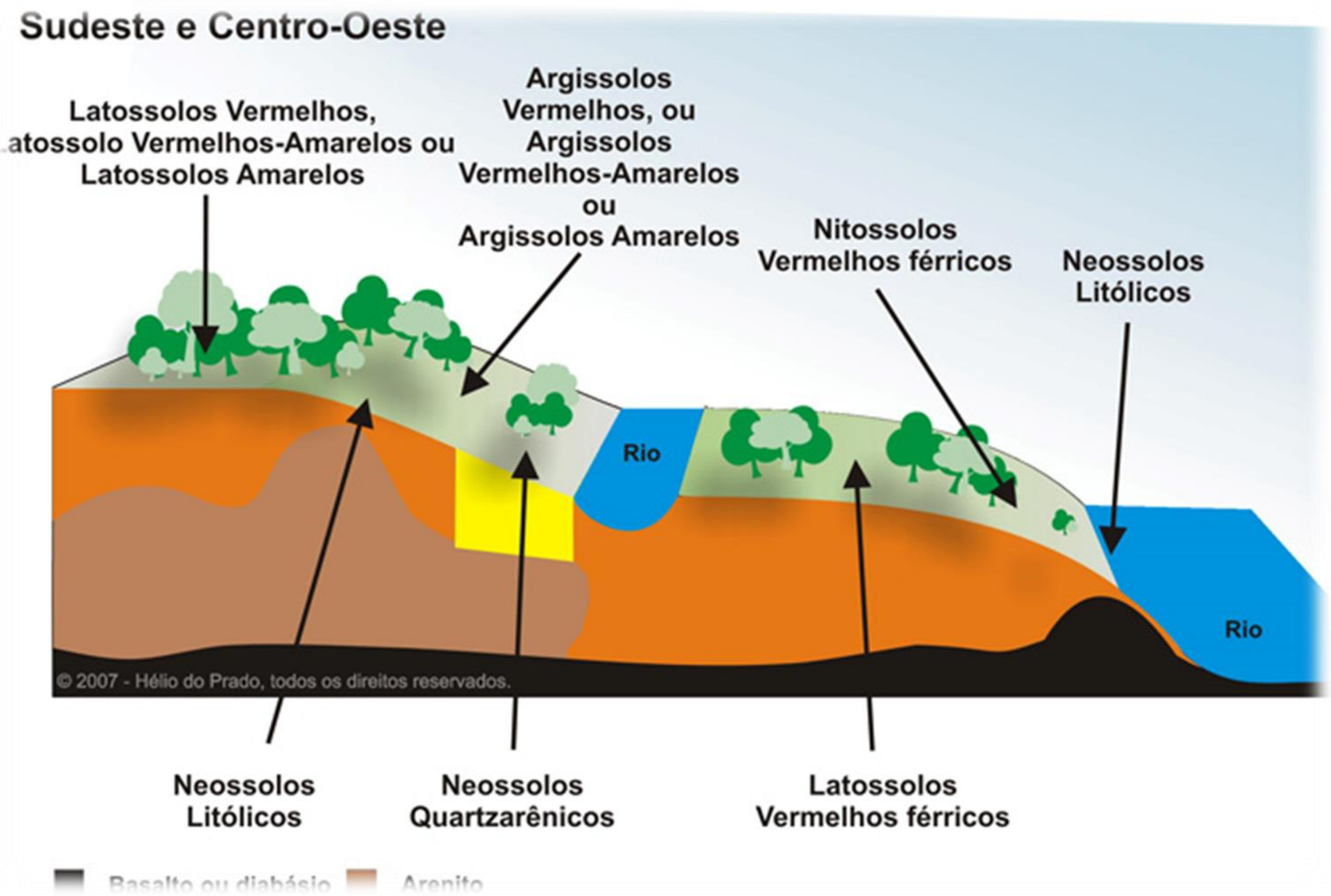
Fig. 2. Soil organic carbon levels in 0- to 5-cm and 0- to 75-cm layers in Grantsburg soils during a 20-yr tillage experiment.

ıges with depth in Grantsburg soils . The baseline for the no tillage and ılly similar and mean was used as

Influência da profundidade



Influência da variabilidade



Variabilidade X Textura do Solo

Textura X Conteúdo de C

Influência da biomassa microbiana

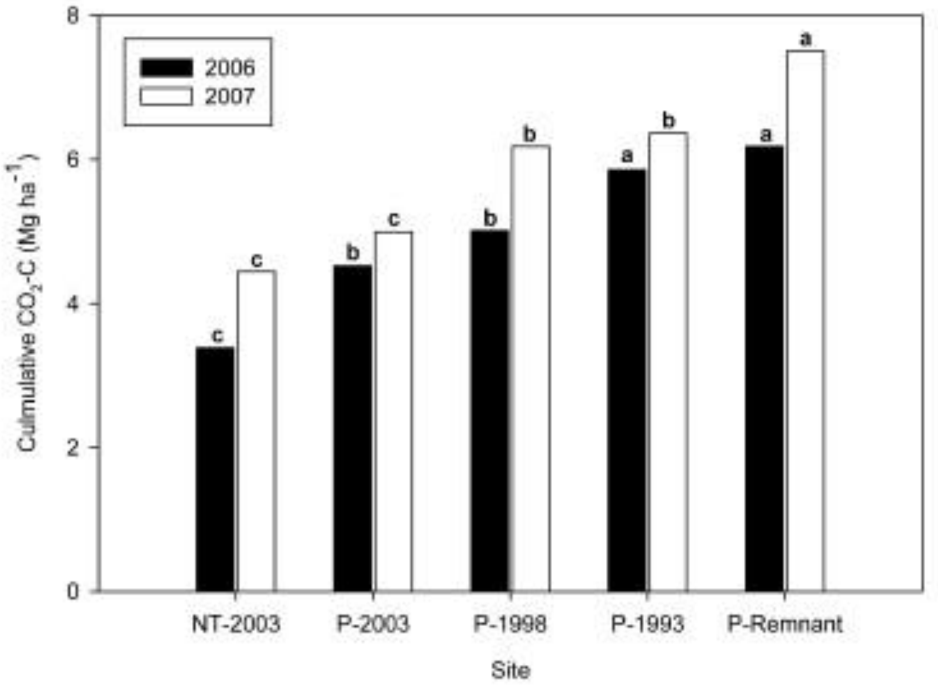
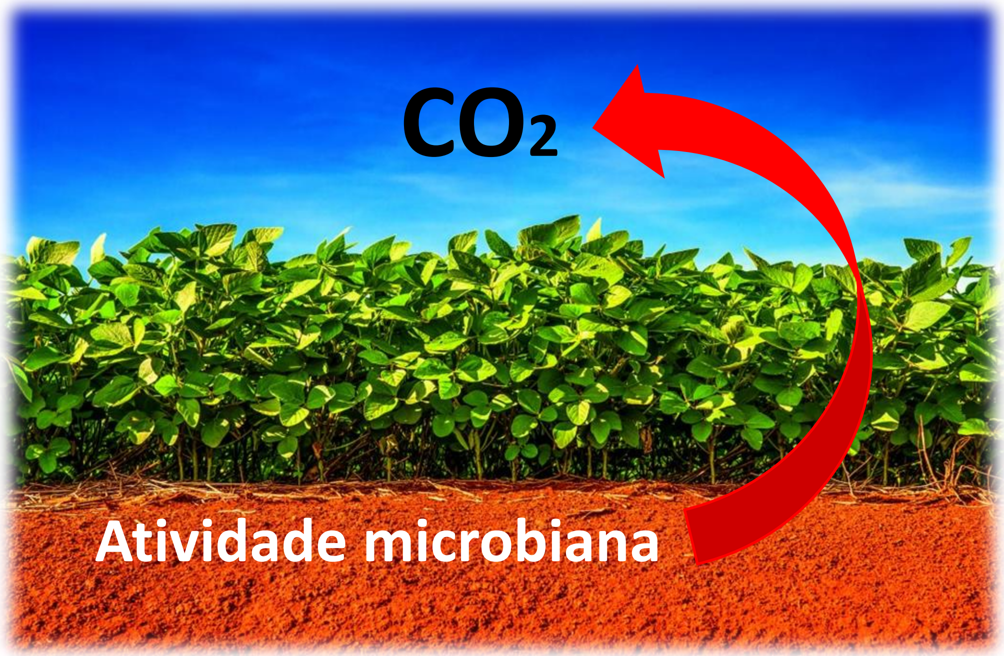
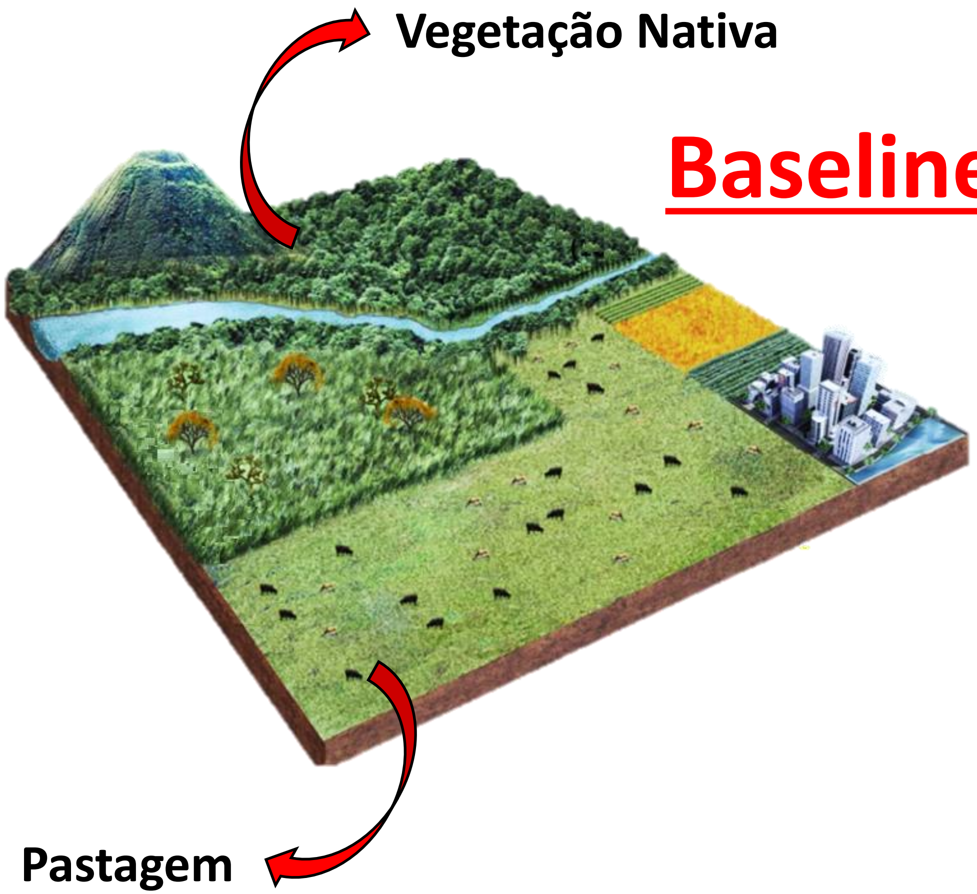


Fig. 4. Cumulative soil CO_2–C effluxes for each site for 2006 and 2007 growing seasons (Guzman and Al-Kaisi, 2010: J. Environ. Quality 39:136-146).



Modelo experimental ideal



Baseline

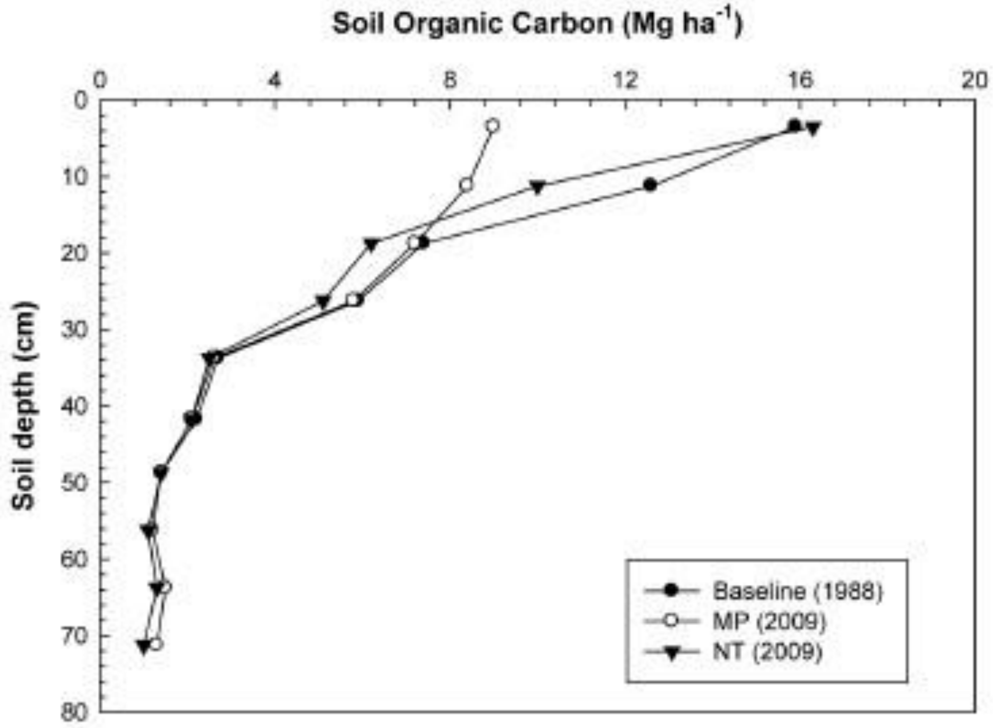
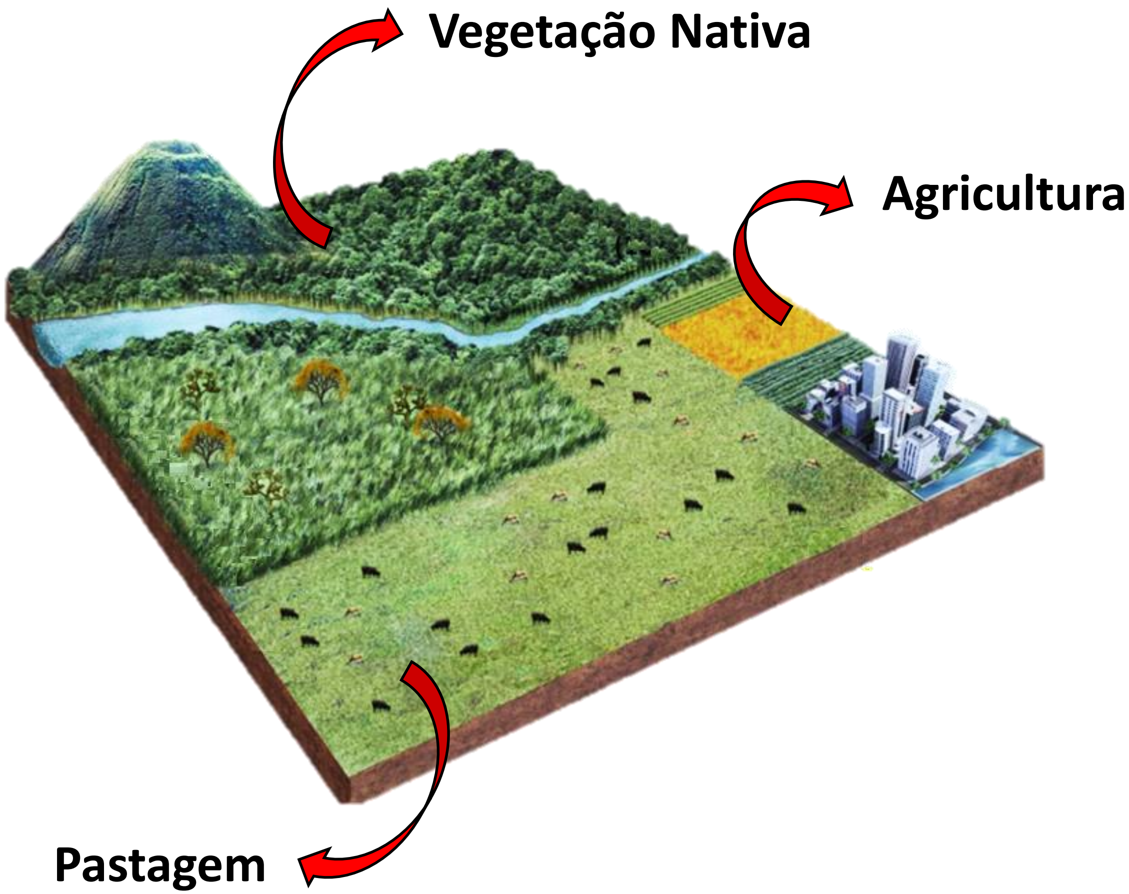


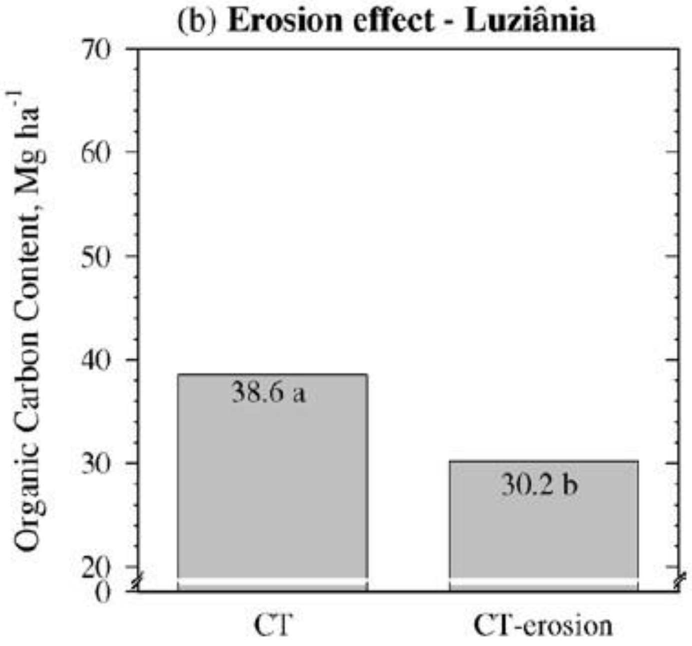
Fig. 3. Soil organic carbon changes with depth in Grantsburg soils after 20-yr of tillage treatments. The baseline for the no tillage and moldboard plots were statistically similar and mean was used as baseline for both treatments.

Modelo experimental ideal



Plantio Direto
Preparo Reduzido
Plantio Convencional

O cultivo convencional é um sistema estável?



Adaptado de Bayer et al. (2006)

Influência do manejo do solo

Table 2. Twenty-year effects of tillage treatments (six replications) on soil organic C (SOC; Mg C ha^{-1} $layer^{-1}$) of the Grantsburg soil. Paired comparison with 2009 MP baseline and pretreatment 1988 baseline methods (Olson, 2010).

Tillage treatment†	Depth	September 1988 (pretreatment baseline)	June 2009	Pretreatment 1988 baseline method 20-yr SOC loss (below pretreatment 1988 baseline)	Paired comparison method with MP as baseline NT vs. MP 20-yr SOC retention rate difference (NT above 2009 MP baseline)
	cm	Mg C ha^{-1} $layer^{-1}$		Mg C ha^{-1} $layer^{-1}$	
NT	0–15	28.5a**	25.2a**	-0.17a	+0.40
	15–75	23.6a	20.1a	-0.18a	+0.06
	0–75 (all)	52.1a	45.3a	-0.35a	+0.46
MP	0–15	28.3a	17.3b	-0.55b	
	15–75	23.1a	18.9a	-0.21a	
	0–75	51.4a	36.2b	-0.76b	

** Mean of six replications with the same letter and in the same year and depth with a different tillage treatment are not significantly different at $P = 0.05$.
† NT, no-till; MP, moldboard plow tillage.

C NT – C MP / 20 anos

NT * MP

45,3– 36,2/ 20 anos = **0,46 Mg C ha ano**

NT * NT

45,3– 52,1/ 20 anos = **- 0,35 Mg C ha ano**

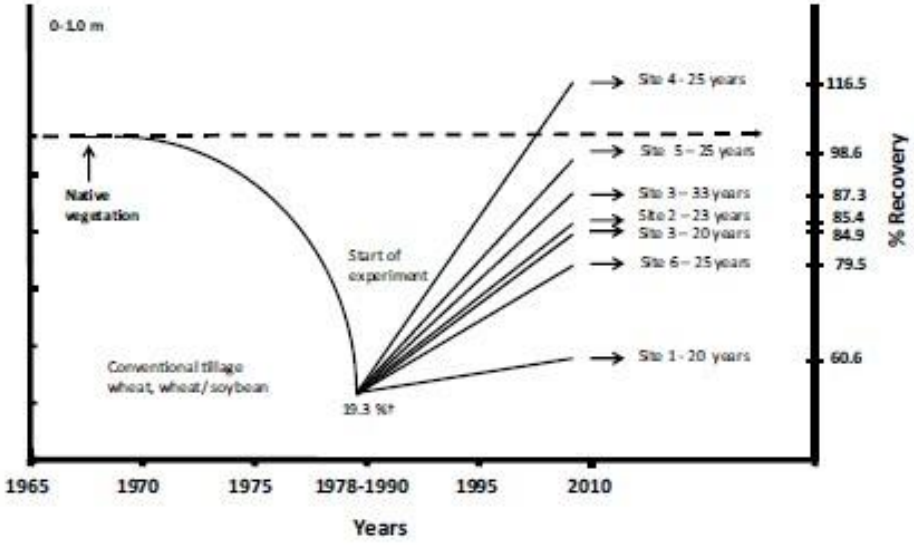
Influência do manejo do solo

Carbon sequestration rates in Brazilian tropical and subtropical no-till soils

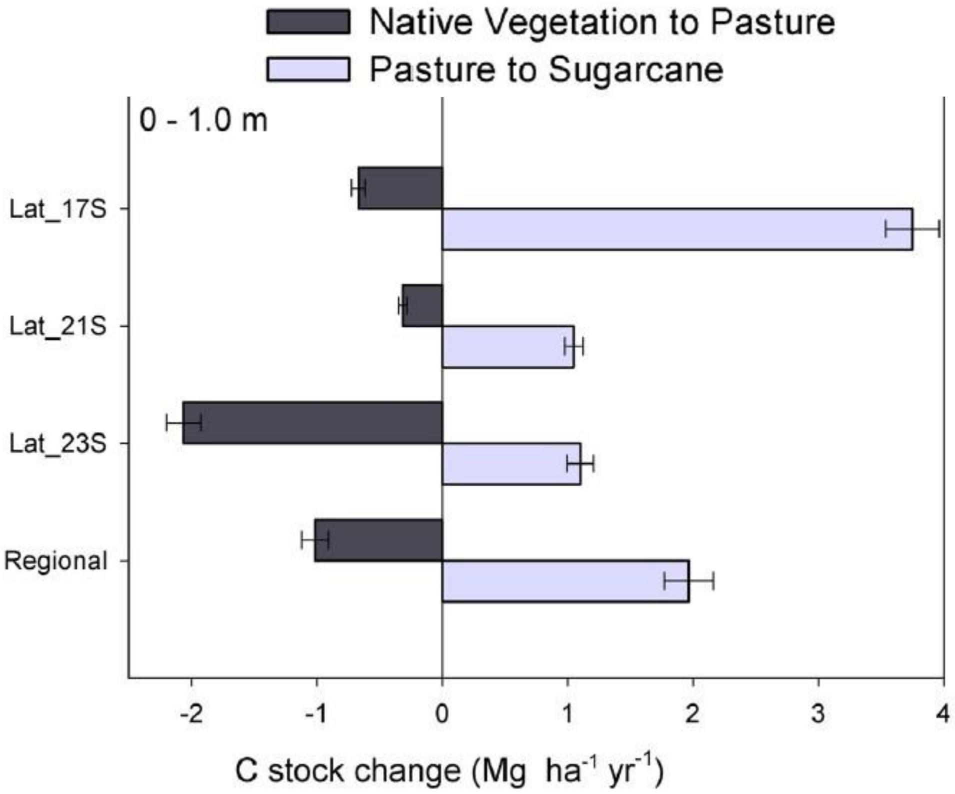
Site	Soil	Climate[a]	Cropping system[b]	Depth (cm)	C stock (Mg ha^{-1}) CT	C stock (Mg ha^{-1}) NT	Time (year)	Rate (Mg ha^{-1}year^{-1})	Reference
Tropical				0–20				0.35	
Embrapa CPAC	Oxisol	–	Win: F	0–20	37.34	47.35	16	0.63	Corazza et al. (1999)
Planaltina DF	41% clay	–	Sum: R, S, P, F and M		37.00	47.50	20	0.52, 0.58[c]	Oliveira et al. (2004)
Agropec. SLC Luziânia GO	Oxisol 35% clay	23.8 1581	Win: F Sum: S and M	0–20	38.60	41.00	8	0.30	Bayer et al. (this study)
Emater-GO Sen. Canedo GO	Oxisol 50% clay	23.0 1500	Win: F Sum: M and B	0–20	48.60	49.60	4	0.25	Freitas et al. (2000)
Agropec. SLC Costa Rica MS	Oxisol 65% clay	24.8 1929	Win: F Sum: S and M	0–20	54.30	57.30	5	0.60	Bayer et al. (this study)
Embrapa CNPMS Sete Lagoas MG	Oxisol 80% clay	22.1 1340	Win: F Sum: M and B	0–20	50.33[d]	50.00[d]	10	−0.03	Roscoe and Buurman (2003)
UFV	Acrisol	19.5	Winter: F	0–20	31.23	38.54	15	0.49	Leite et al. (2004)

Adaptado de Bayer et al. (2006)

Influência do manejo do solo

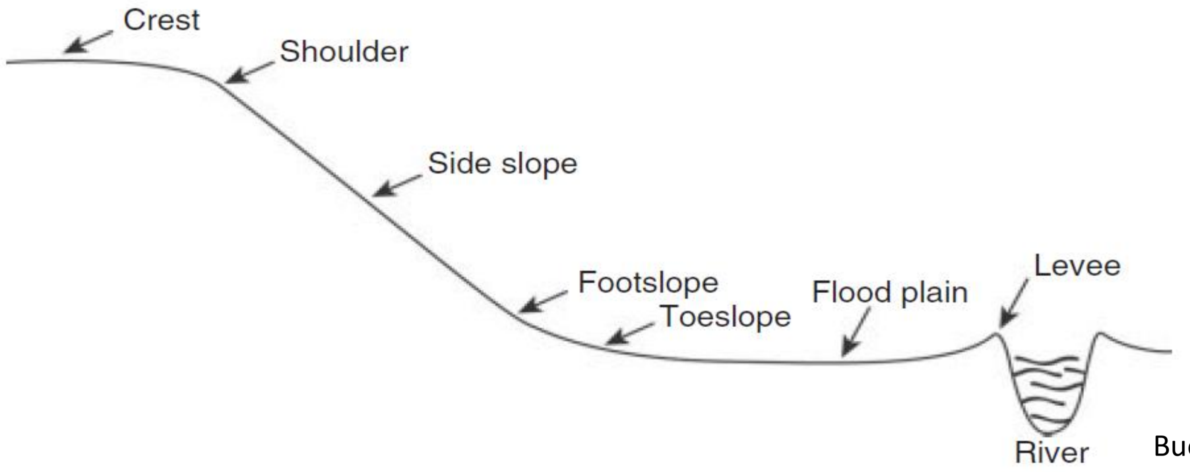


Adaptado de Oliveira et al. (2016)



Adaptado de Oliveira et al. (2016)

Carbono do solo – Adição externa, translocação = Sequestro?



Buol et al. (2011)

> *Processo de transferência de CO2 da atmosfera para o solo através da decomposição de resíduos vegetais e outros compostos orgânicos, que são armazenados como parte da matéria orgânica do solo.*

- Adição externa – erosão e transporte de sedimentos ricos em C
- Aplicação de compostos orgânicos
- Biochar

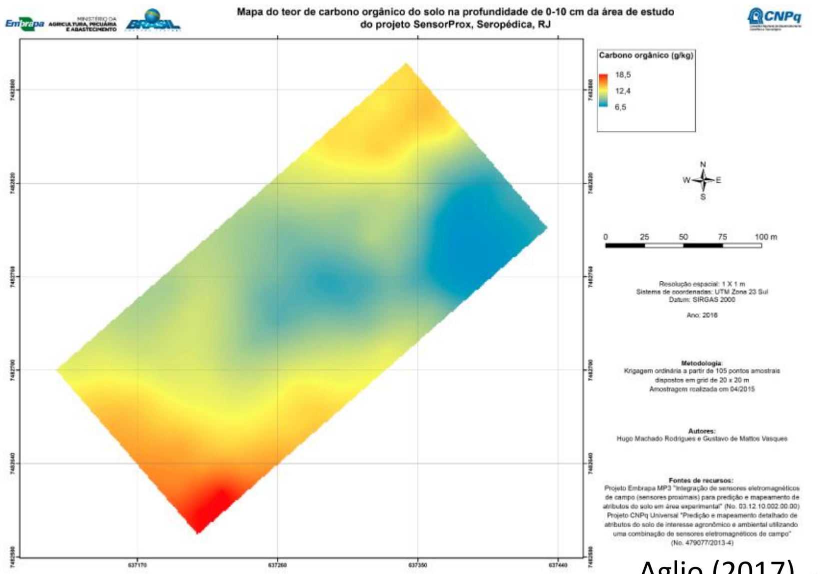
Duvernoy (2016)

Extrapolando escala:
Campo – regional / Global

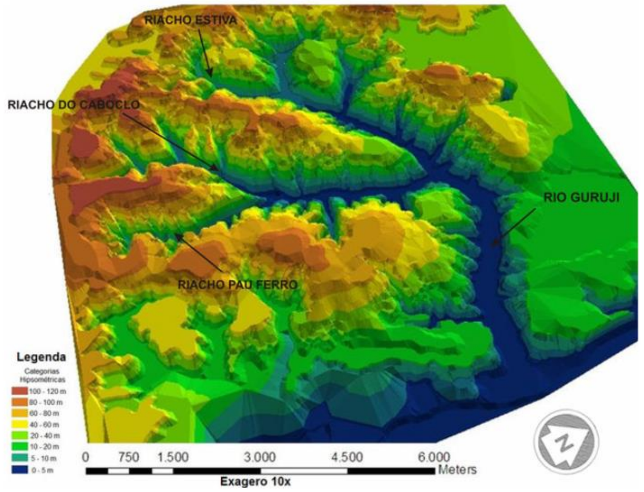
Ponto específico (estudos) → Regional → Nacional → Global

Requisitos para transpor escala:

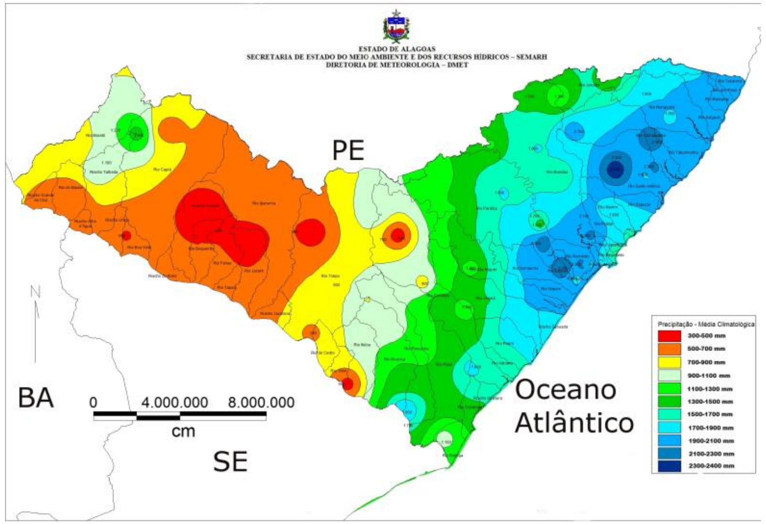
- Escolha parâmetros principais
- Métodos de dimensionamento



Aglio (2017)



Barbosa e Furrier (2012)

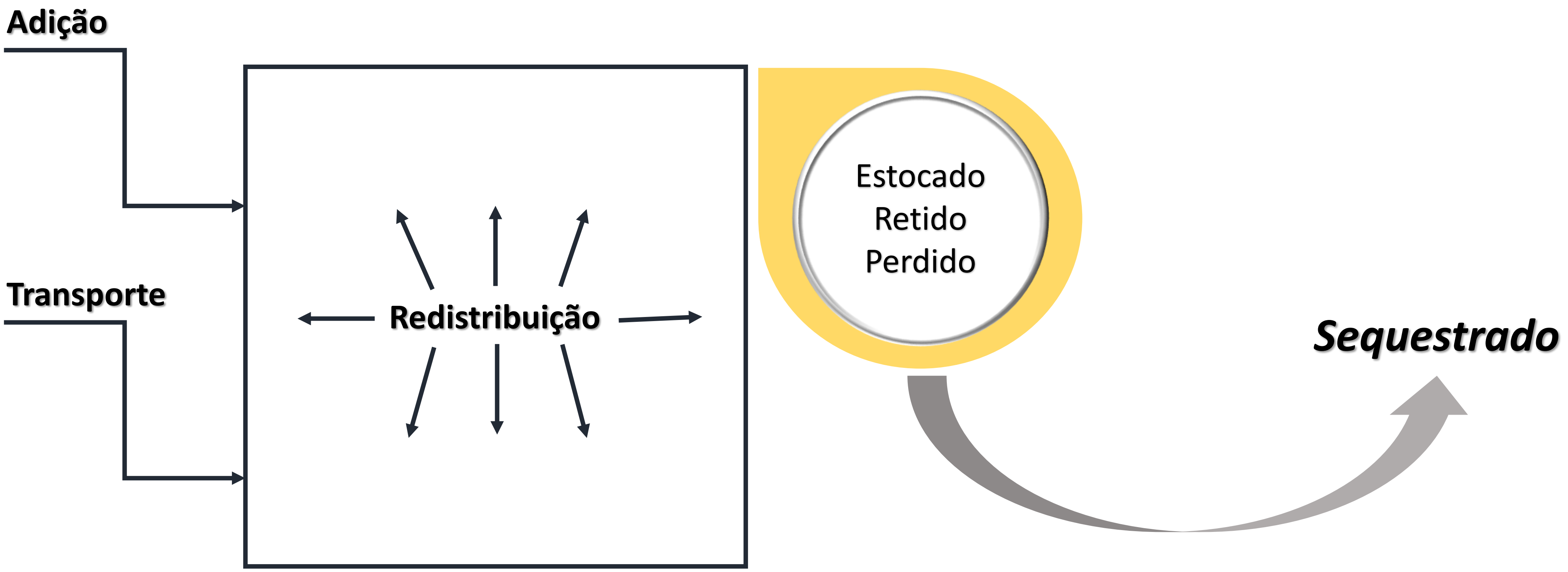


Barneoud (2015)

Molecular → Bacia hidrográfica   Nanosegundos → Milênios

Críticas e Desafios

- Delineamento experimental uniforme;
- Uso do mesmo método de determinação de COS;
- Profundidade além dos 30 cm;
- Densidade do solo (amostragem local).



Conclusões

- **Inconsistências** no entendimento e aplicação do conceito e delineamento experimental;
- Avaliação do carbono presente desde a atmosfera até seu armazenamento no solo;
- Realizar uma avaliação de **balanço líquido** do COS;
- Grandes vantagens de estudos para **mitigação** das mudanças climáticas;
- Incentivos à pesquisas envolvendo o sequestro de carbono no solo por práticas agrícolas.