How much can soil organic matter realistically be increased with cropping management in California?

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Double Tree Hotel & Fresno Convention Center

In this talk

- Agriculture influence on Soil C loss over time
- Soil C sequestration management
- Reversing soil C loss with crop yield increases
- 4 per mil (4PT) initiative to sequester soil C
  - Soil C sequestration requires N
- Soil C sequestration success: any amount!!

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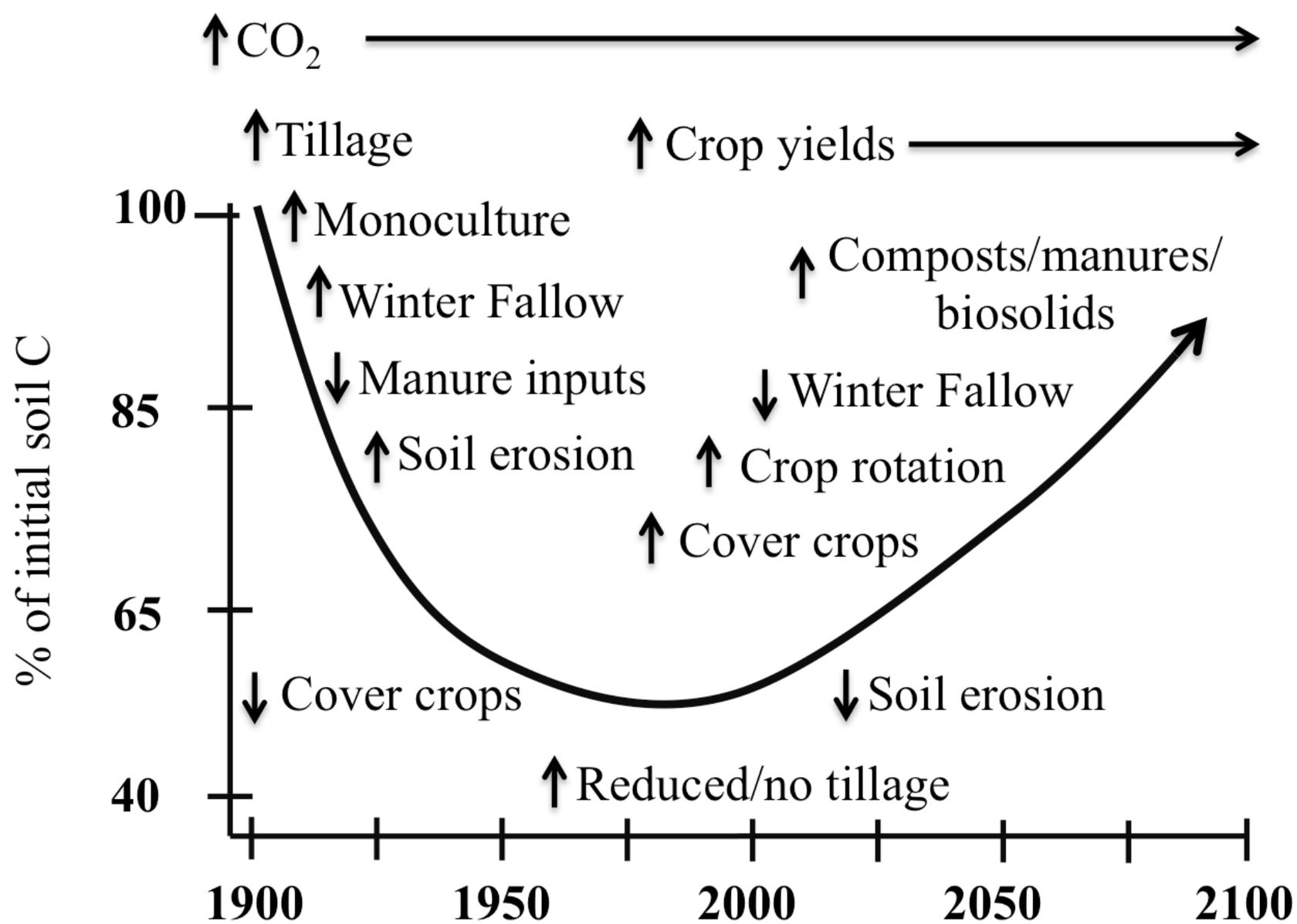
Soil C overtime



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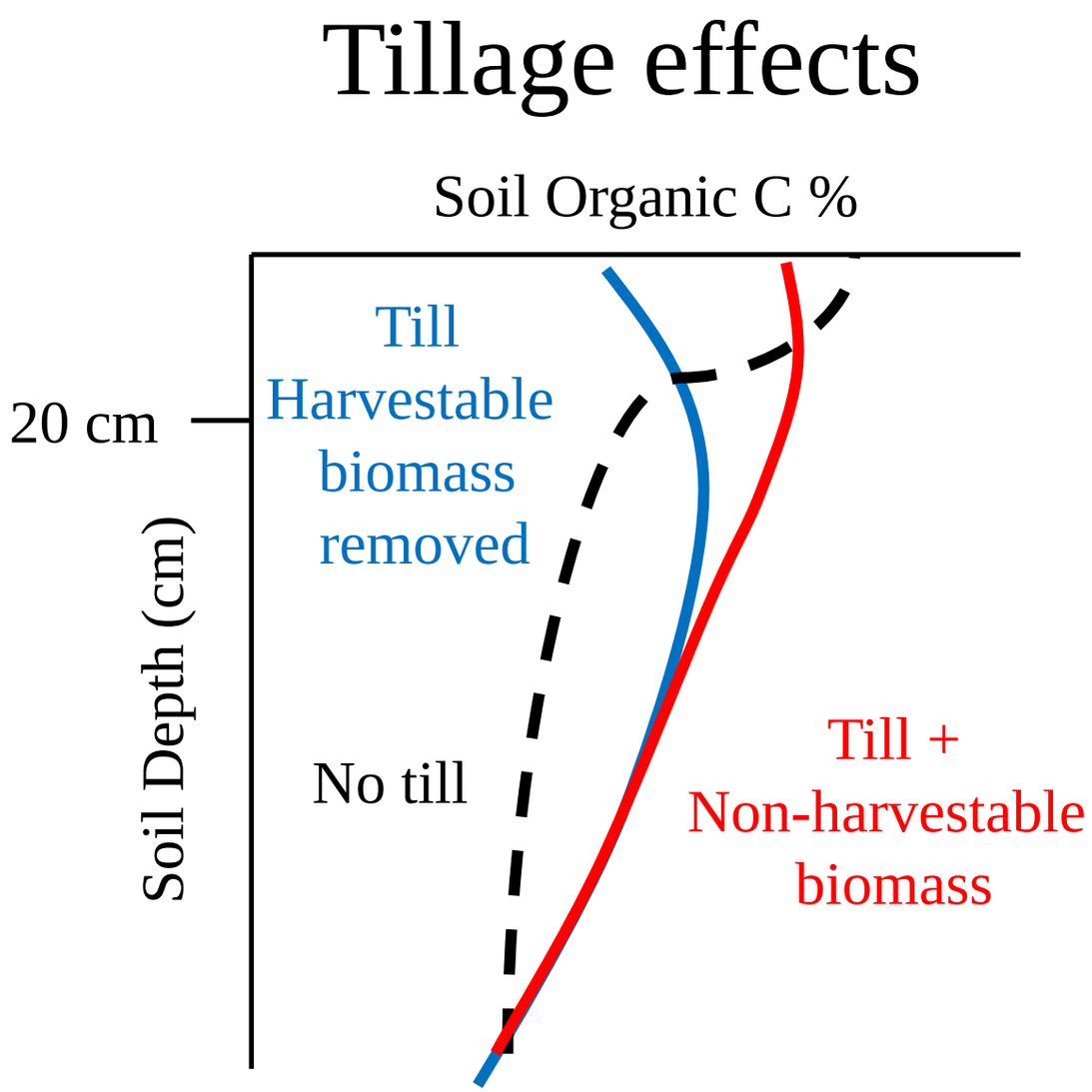
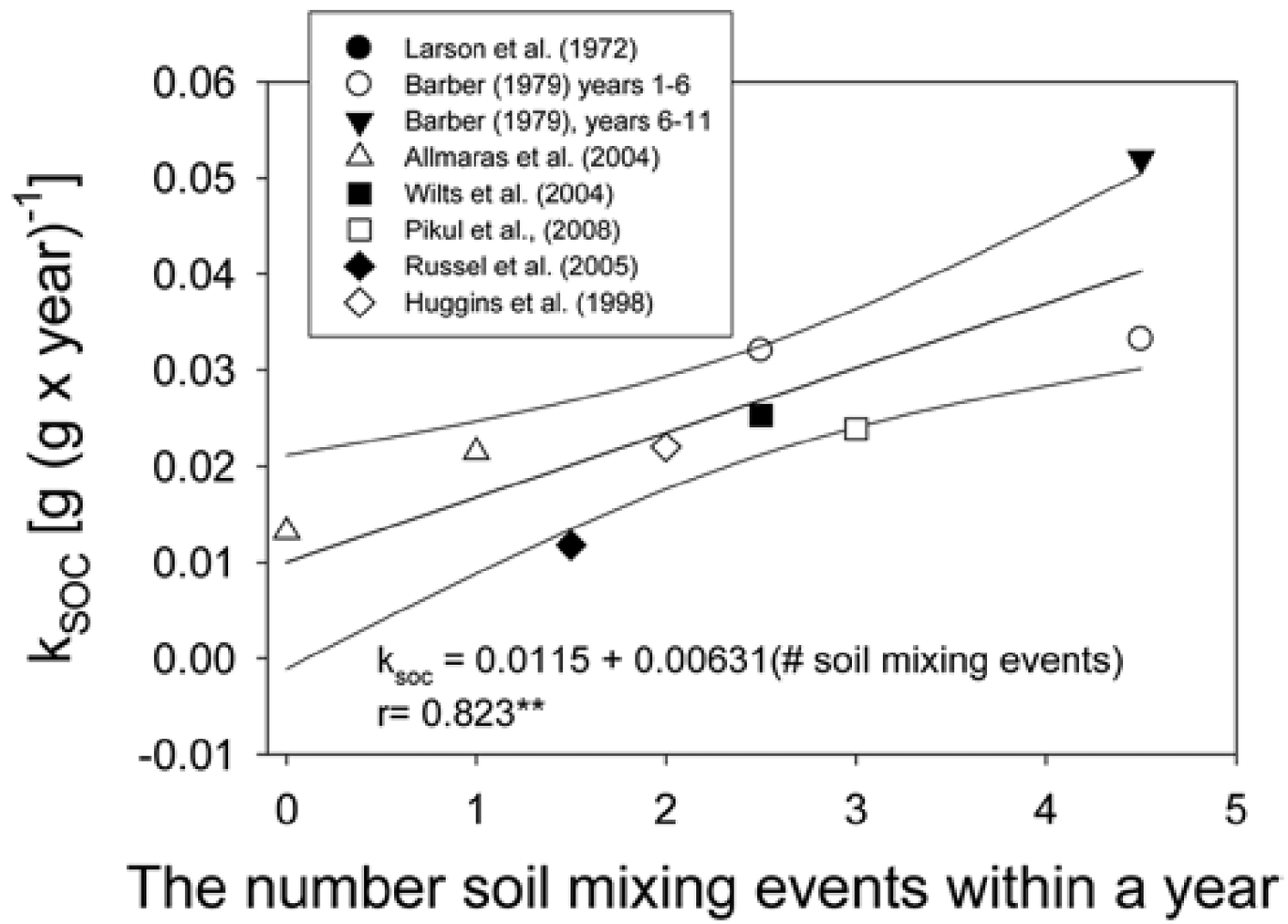
Is no till vs. increasing crop residue return more important





Clay et al., Agron. J. 104:763–770 (2012)

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Tillage and soil C sequestration

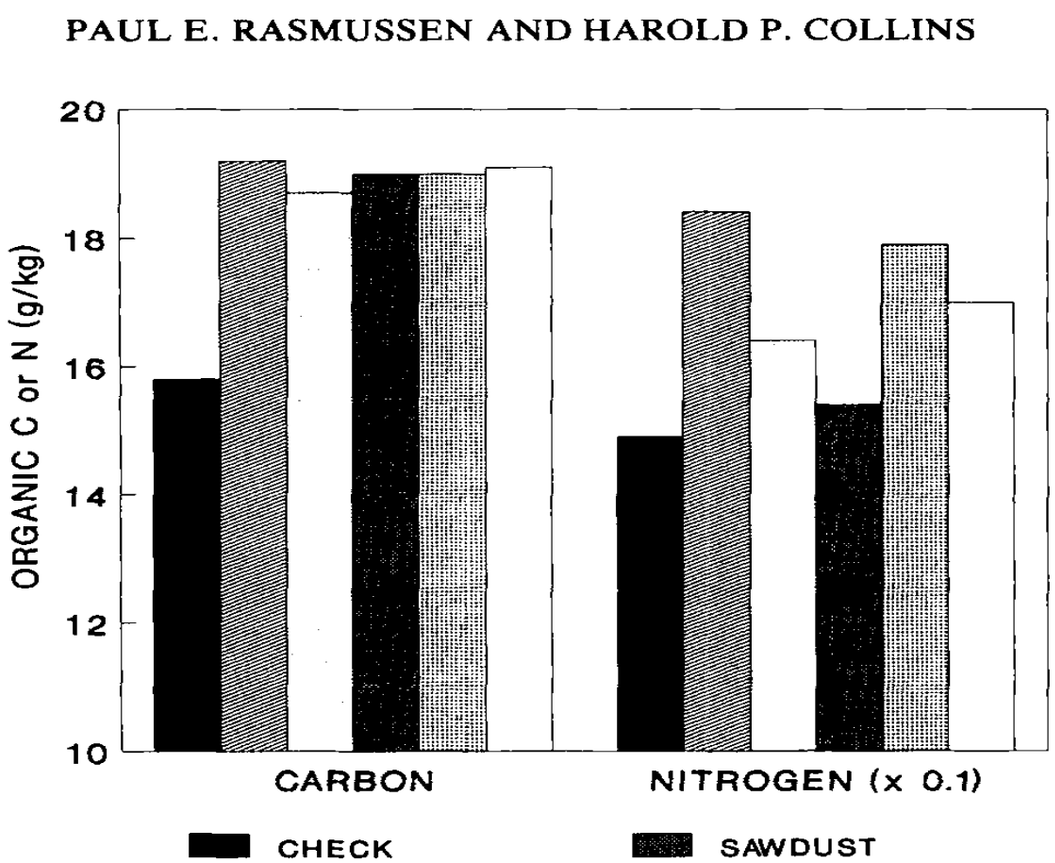
- Palm et al. (2014) found that out of more than 100 studies, half reported SOC sequestration rates greater in tilled than no-tilled systems.
- A meta-analysis found that crop productivity in cool and wet climates is often reduced in no-till systems (Ogle et al. 2012).
- Adoption of no till initially increases nitrous oxide emissions up to 20 y due to soil compaction (Six et al. 2004).
- Powlson et al. (2014), concluded that no-till systems have limited potential for climate change mitigation due to limited SOC sequestration.

Cover crops, crop rotation and manure

- Cover crops often increase SOC and N availability .
- Cover crops have a positive effect on increasing N use efficiency.
- Crop rotations increase input diversity and reduce fallow similar to cover crops.
- Numerous studies have shown the positive effects of animal manure on SOC sequestration.

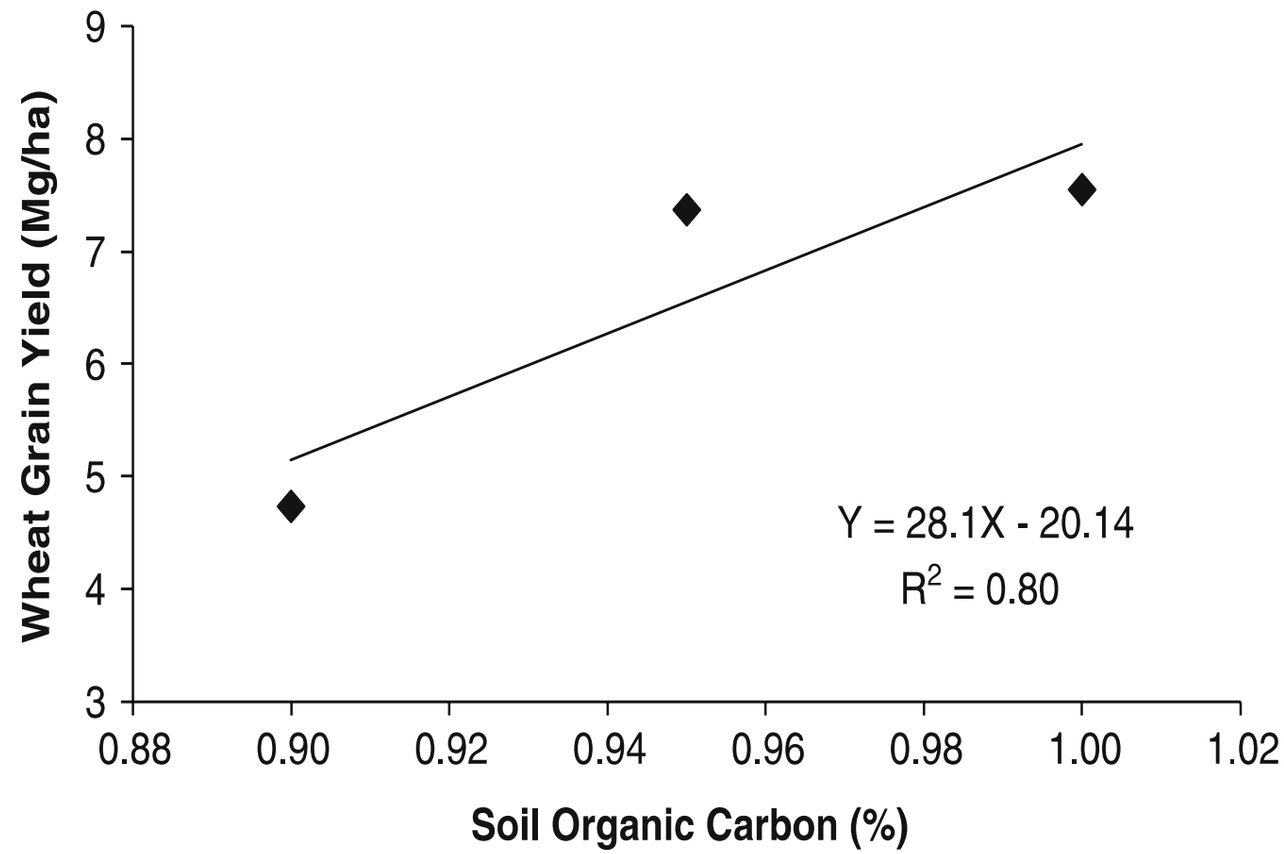
Do quality or mass of C inputs matter?

Soil C independent of input quality



Larsen et al., Agr. J. 64:204-208

C quality or input mass affects crop productivity?



R. Lal Food Sec. (2010) 2:169–177

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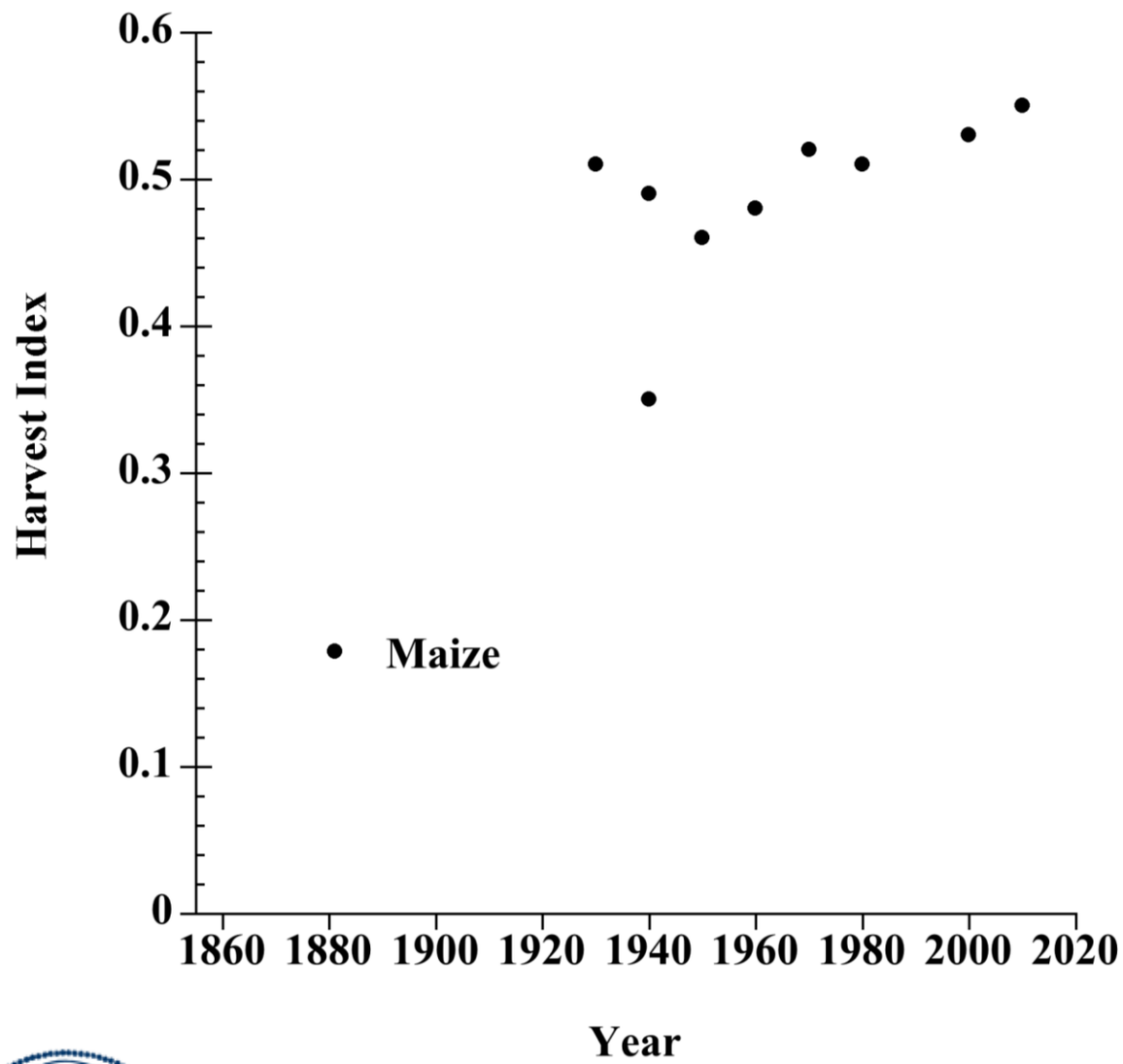
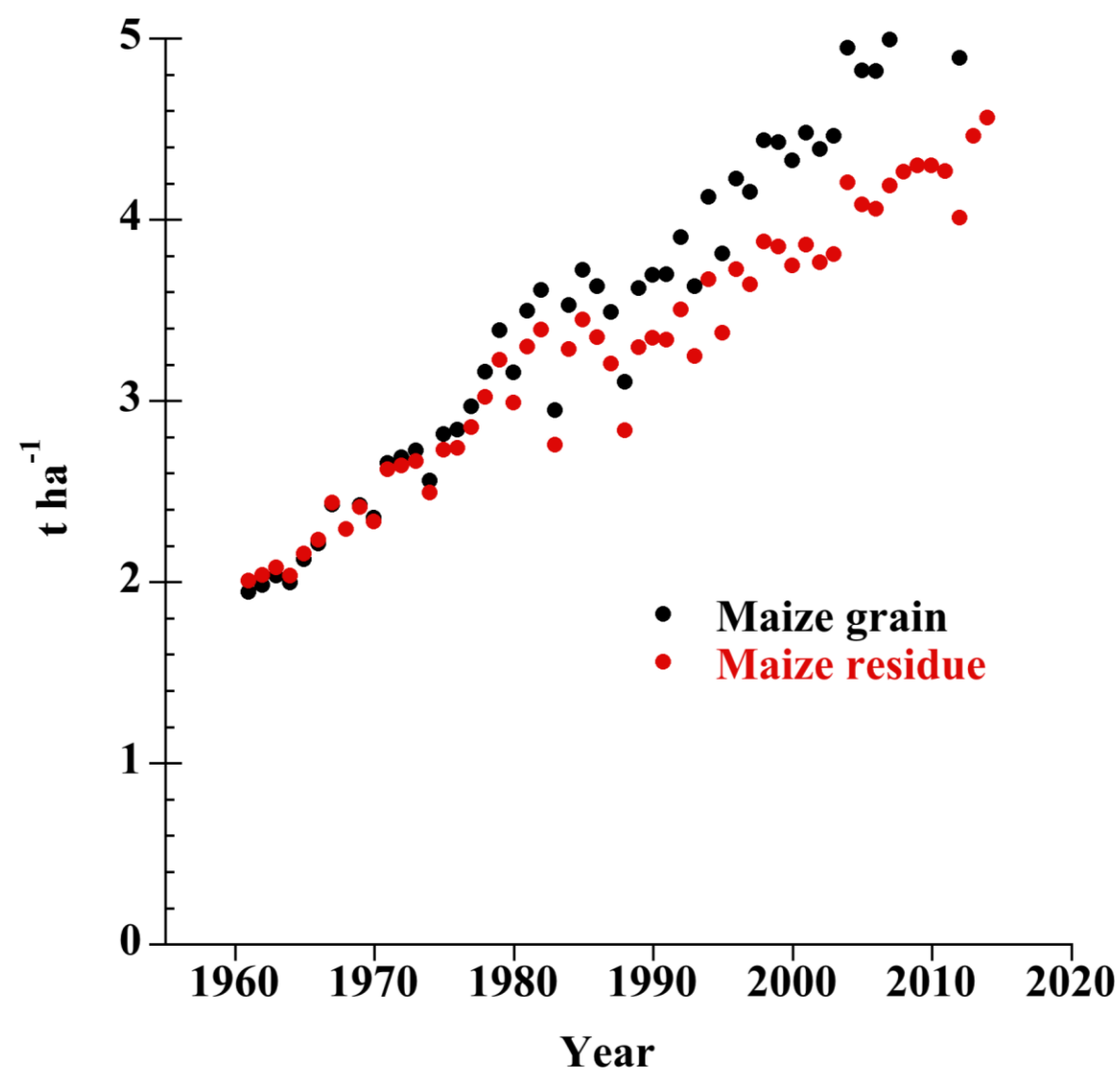
Harvest index & Residue load
Maize

HI



Grain and Residue



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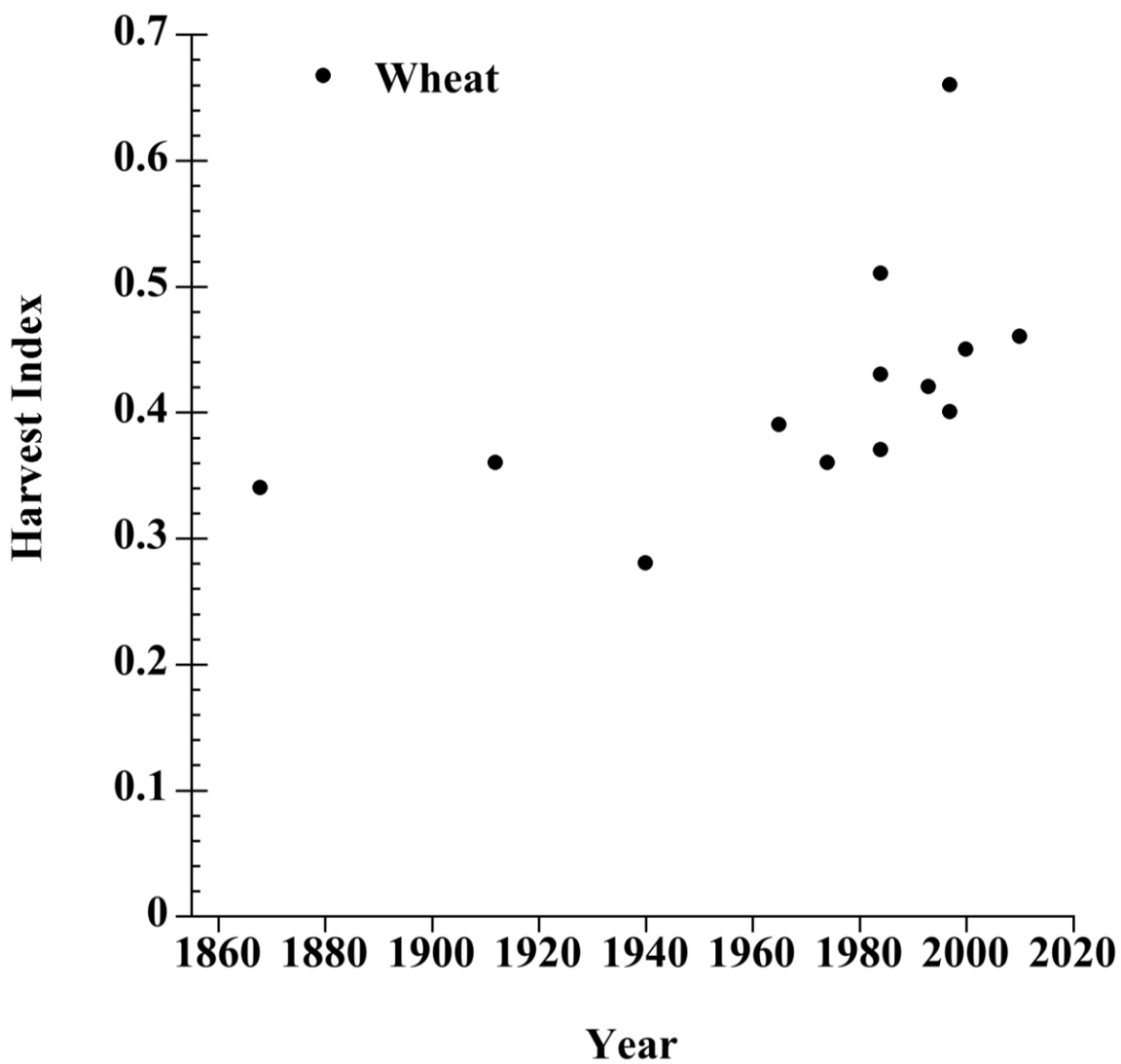
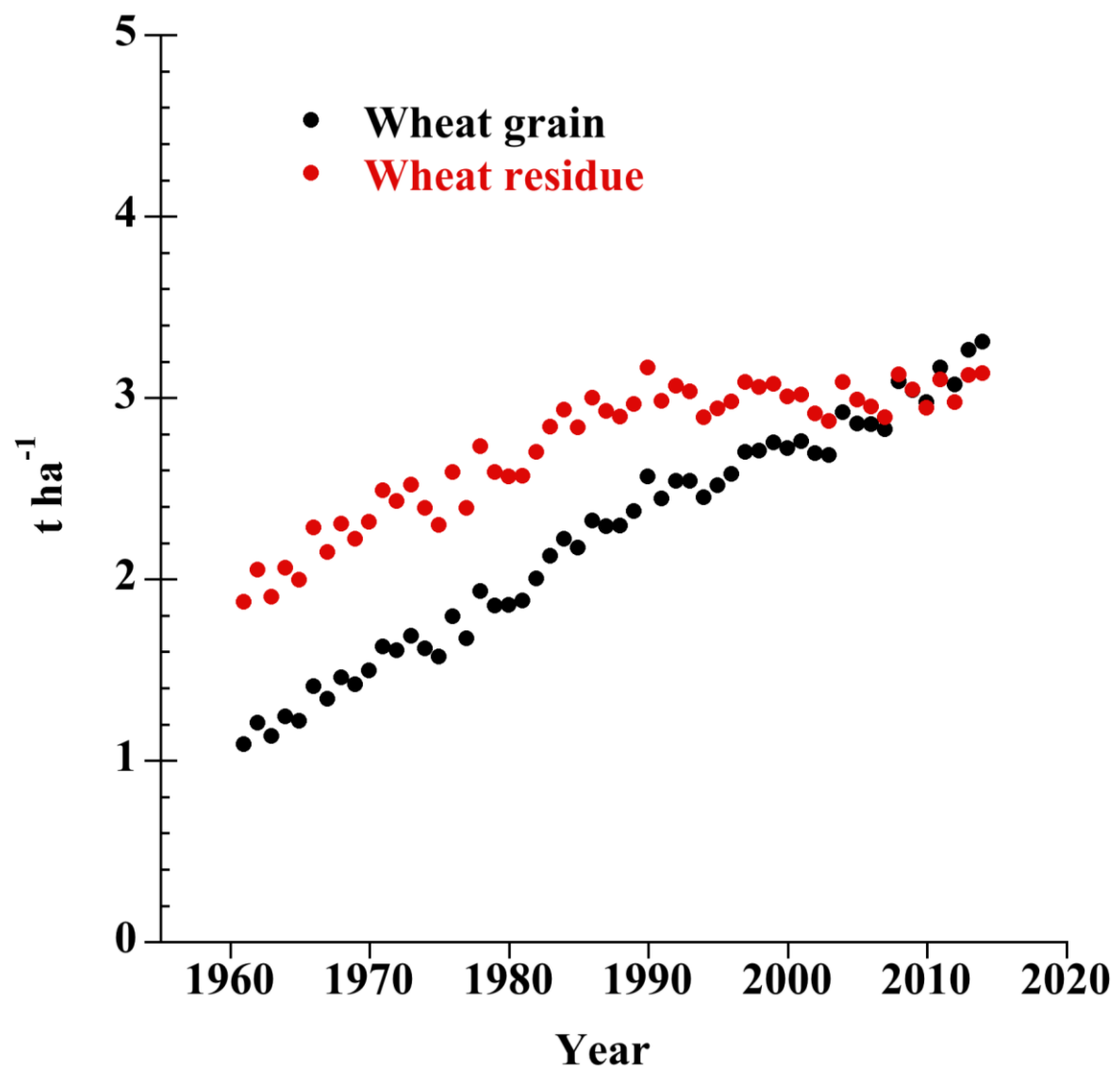
Harvest index & Residue load
Wheat

HI



Grain and Residue



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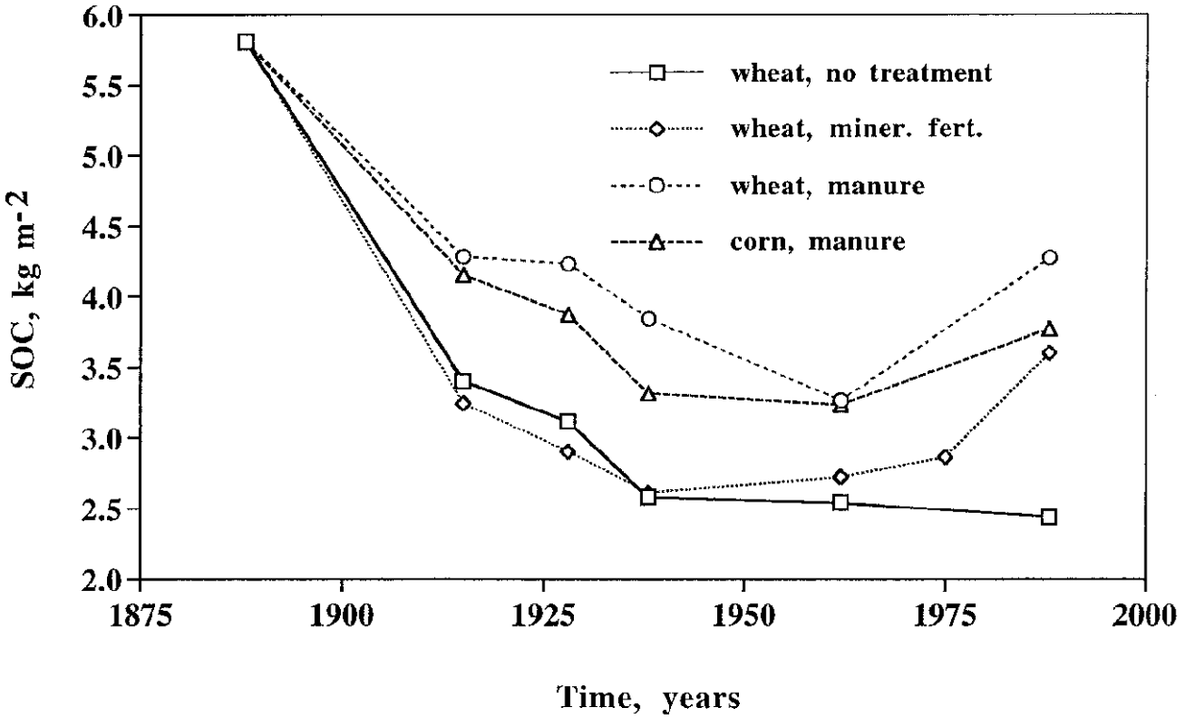
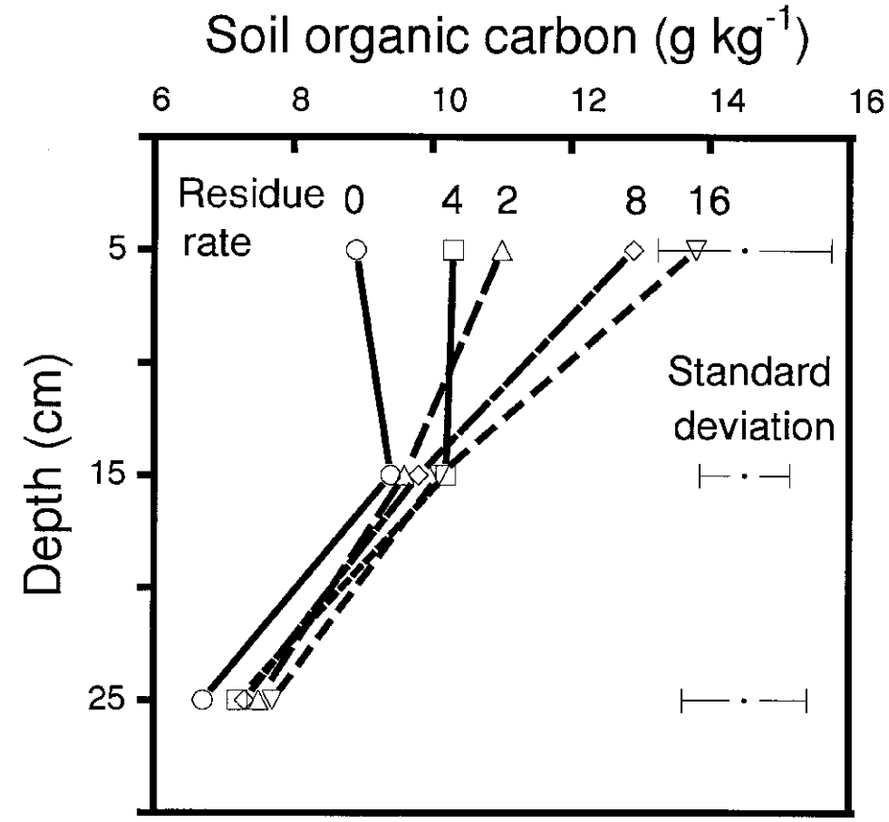
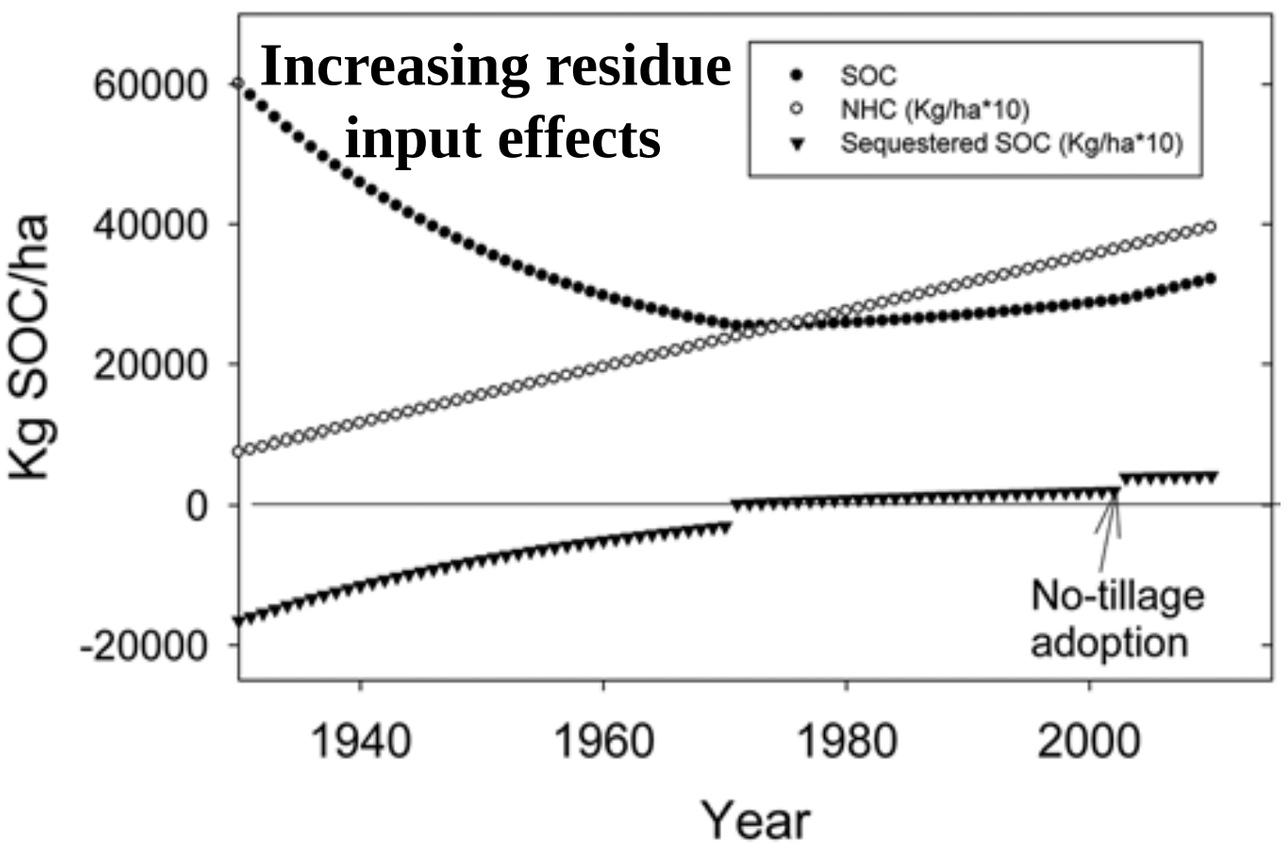
Manure effects



Buyanovsky and WagnerBiol Fertil Soils (1998) 27:242–245



Duiker and Lal / Soil & Tillage Res. 52 (1999) 73-81



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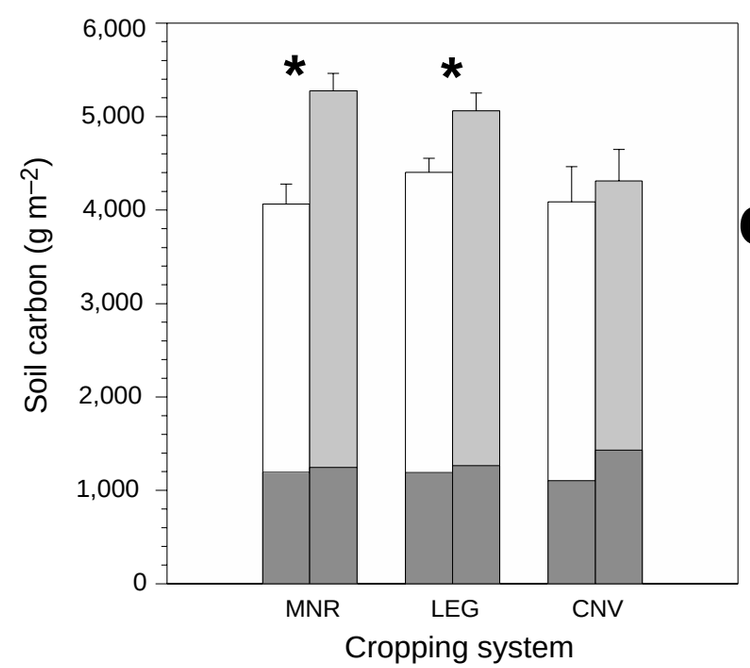

Cover crop effects

Drinkwater et al., NATURE 396:262-265 (1998)

TECHNICAL POTENTIAL OF SOIL

Land Use		Technical Potential (Gt C/yr)
I. Soil	• Cropland	0.1-1.2
	• Grasslands/Grazing lands	0.3-0.5
	• Restoration of eroded desertified soils	0.2-0.7
	• Restoration of salt-affected soils	0.3-0.7
	Sub-Total	1.2-3.1 (2.15)
II. Afforestation	• Afforestation, Forest Succession, Agroforestry, Peatland Restoration	1.2-1.4
	• Forest Plantations	0.2-0.5
	Sub-Total	1.4-1.9 (1.65)
Grand Total		**2.6-5.0 (3.80)**

Soil C sequestration potential in California irrigated agriculture

Study	System	Total C T ha^{-1}	Δ Total C T ha^{-1}	C seq T ha^{-1} Y^{-1}
UC Davis 1989-2002				
	Std till/conventional	17.8	-	-
Poudel, Horwath , 2001	Std till/cover crop	20.1	2.3	0.18
	Std till/organic	21.8	4.0	0.31
Five Points, CA 1999-2014				
	Std till/no cover crop	13.9	-	-
Mitchell, Horwath , 2016	Std till/ cover crop	16.9	3.0	0.20
	No till/no cover crop	21.6	7.7	0.51
	No till/cover crop	25.5	11.6	0.77

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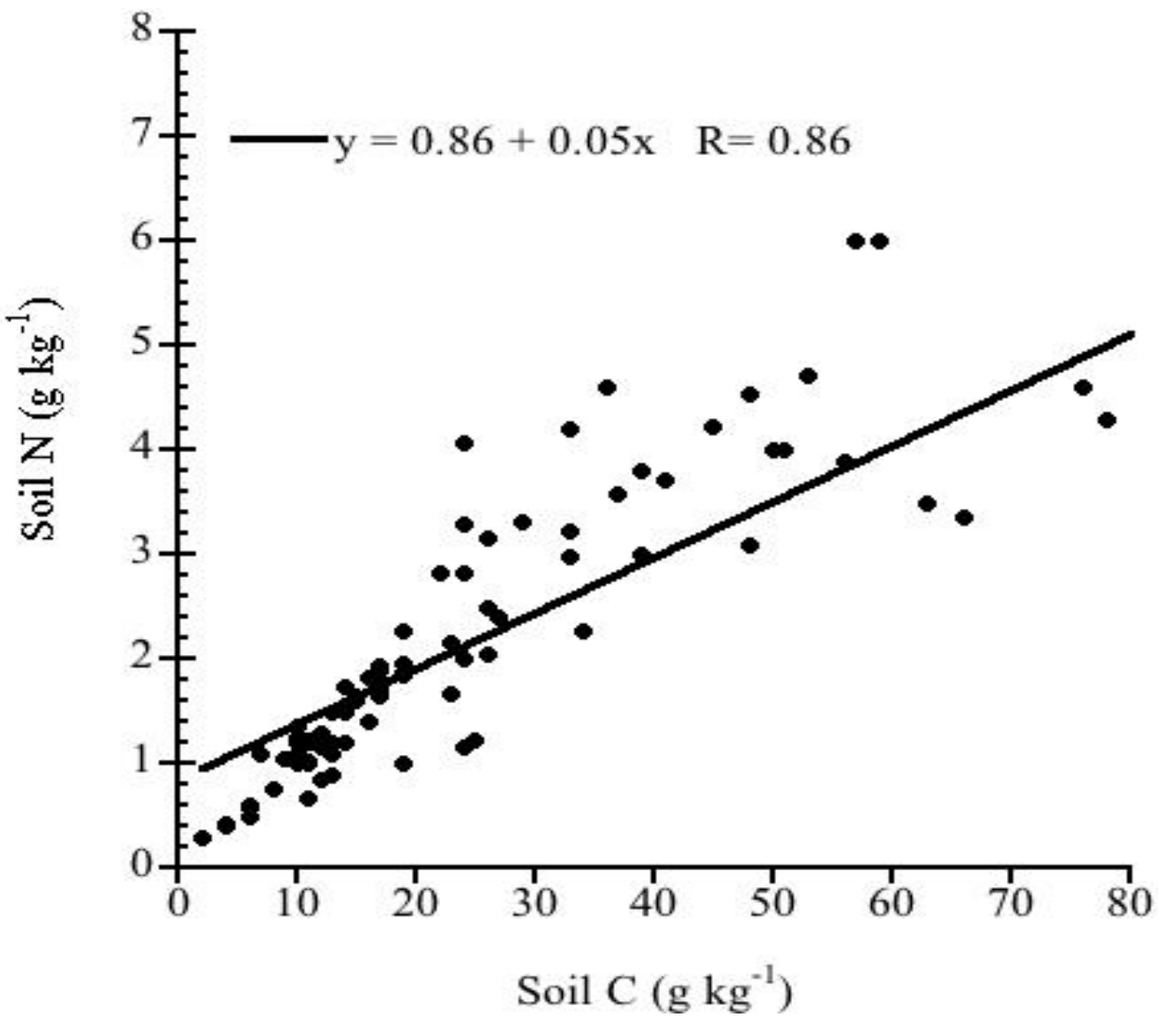
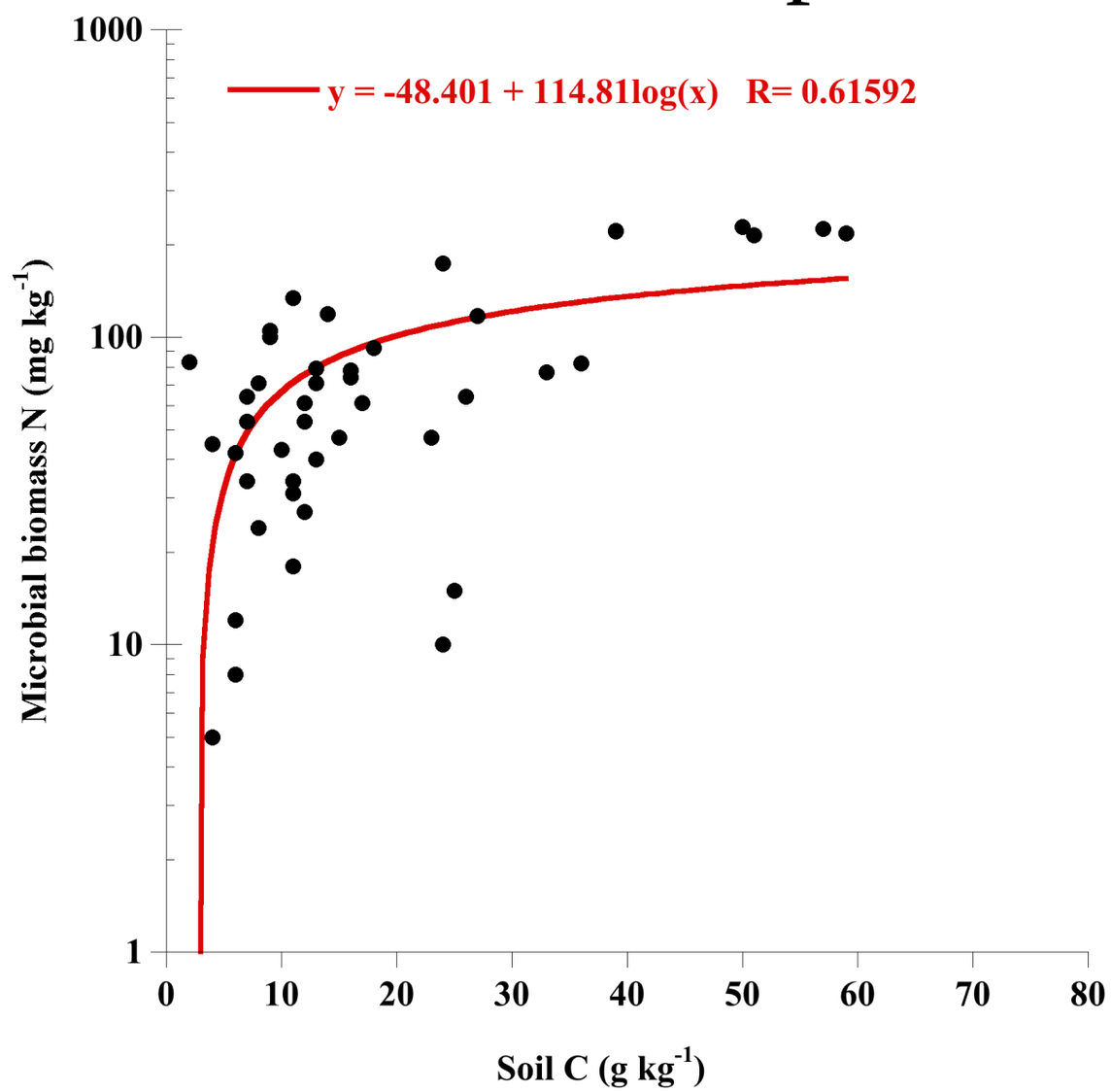
Other constraints on sequestering soil C

Soil C requires N



Microbial C plateaus



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Sequestering SOC requires N

- Conference of Parties, Paris 2015, 4PT initiative to achieve an average global rate of 0.6 t C ha^{-1} y^{-1} to offset 8.9 Gt of annual CO_2-C emissions (Minasny et al., 2014).
- The SOC sequestration rate promoted in the 4PT initiative would require 100 Tg N y^{-1} assuming a soil C to N ratio of 12 (van Groenigen et al. 2017).
- This increased N amounts 50 kg N ha^{-1} y^{-1}.

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4 PER THOUSAND INITIATIVE

COP21

Global Soil Organic Carbon Pool 0-40cm Depth

Total Pool = 825 Gt .... *Batjes (1996)*

= 850 × 0.4%= 3.6 Gt C/yr

What is possible on agricultural land:

Soil C sequestration potential (t ha^{-1} 10 y^{-1})	Gt soil carbon (globally)
1	2.7
3	8.0
5	13.4
10	26.8
15	40.2
20	53.6

Likely outcome

4 per thousand in 10 years is 36 Gt C/ 10 yr

Assume:

- 2,682 million hectares agricultural land globally in 2030 (FAO)
- assume consistent indefinite management to sequester soil C
- Including rangeland/pastures (5x ag area and plantation forests 20% of ag area) would help in achieving goal

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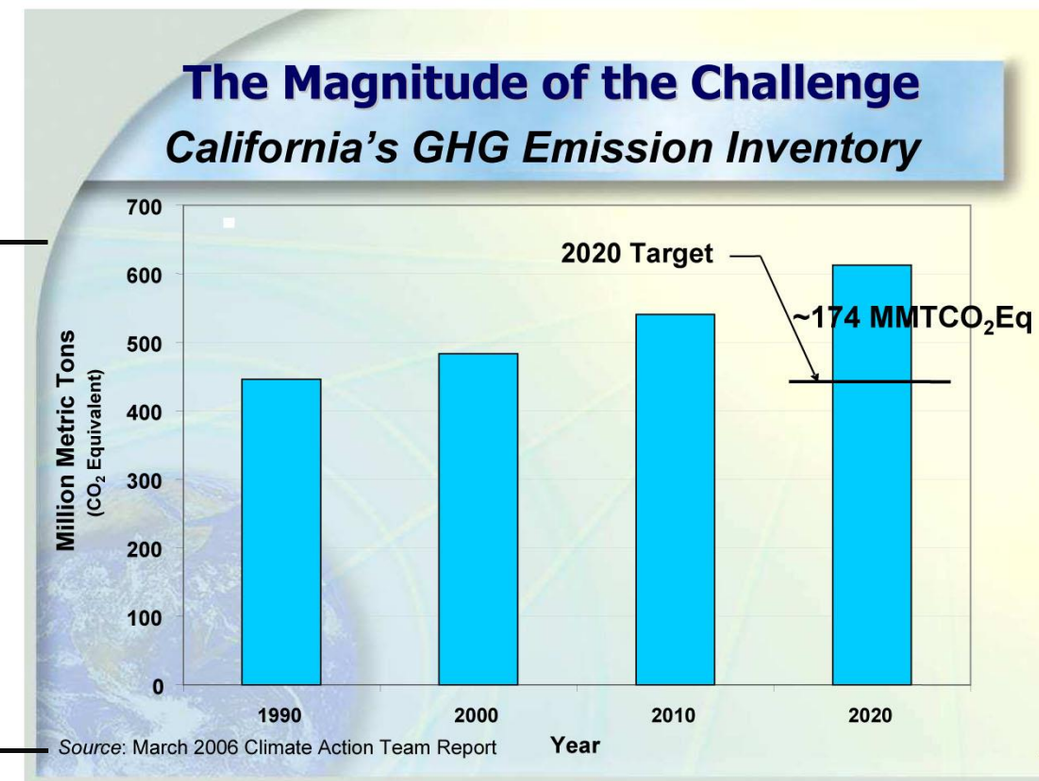
California's Climate Change law AB 32 requires Greenhouse Gas Emission Reduction

Range of soil C sequestration will depend on consistent (annual) management (i.e., cover crops at 3 tons C/ha; Harvestable irrigated land; 3,527,288 ha)

% sequestration potential C	Total Soil C sequestration (total tons)	MMT CO_2 eq	Total C ha^{-1}
5	529,093	2	0.2
25	2,645,466	10	0.8
50	5,290,932	20	1.6
75	7,936,398	29	2.3
100	10,581,864	39	3.0
125	13,227,330	49	3.8



- **Consistent indefinite management to increase soil C is unlikely.**
- **The addition of organic waste would help greatly but supply is limited.**

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Thoughts

- As crops yield potential increases soil C increases.
- Soil C sequestration requires inputs.
- No-till may not increase total soil C
  - It does stratify SOC at the surface and provides a positive ecosystem service.
- Soil C sequestration requires N.
- Bottom line: any amount of soil C sequestration is a positive outcome to improve soil health.

Questions Regarding Response of SOC Pool to Global Warming

- The temperature-sensitivity of SOC pool, especially the old SOC-pool
- Other effects of global warming in SOC dynamics (e.g., H_2O cycle, atmospheric CO_2 pool) interaction with land use change and soil/crop/animal management
- Changes in soil fauna and the attendant rhizosphere process
- Wide spread uses of organic wastes, i.e., composts, biosolids to maintain and or increase SOC
- Targeted soil amendments to influence microbial processes

Thank you!

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