Soil organic carbon: a key component of soil health in a changing climate

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Outline

Global C cycle

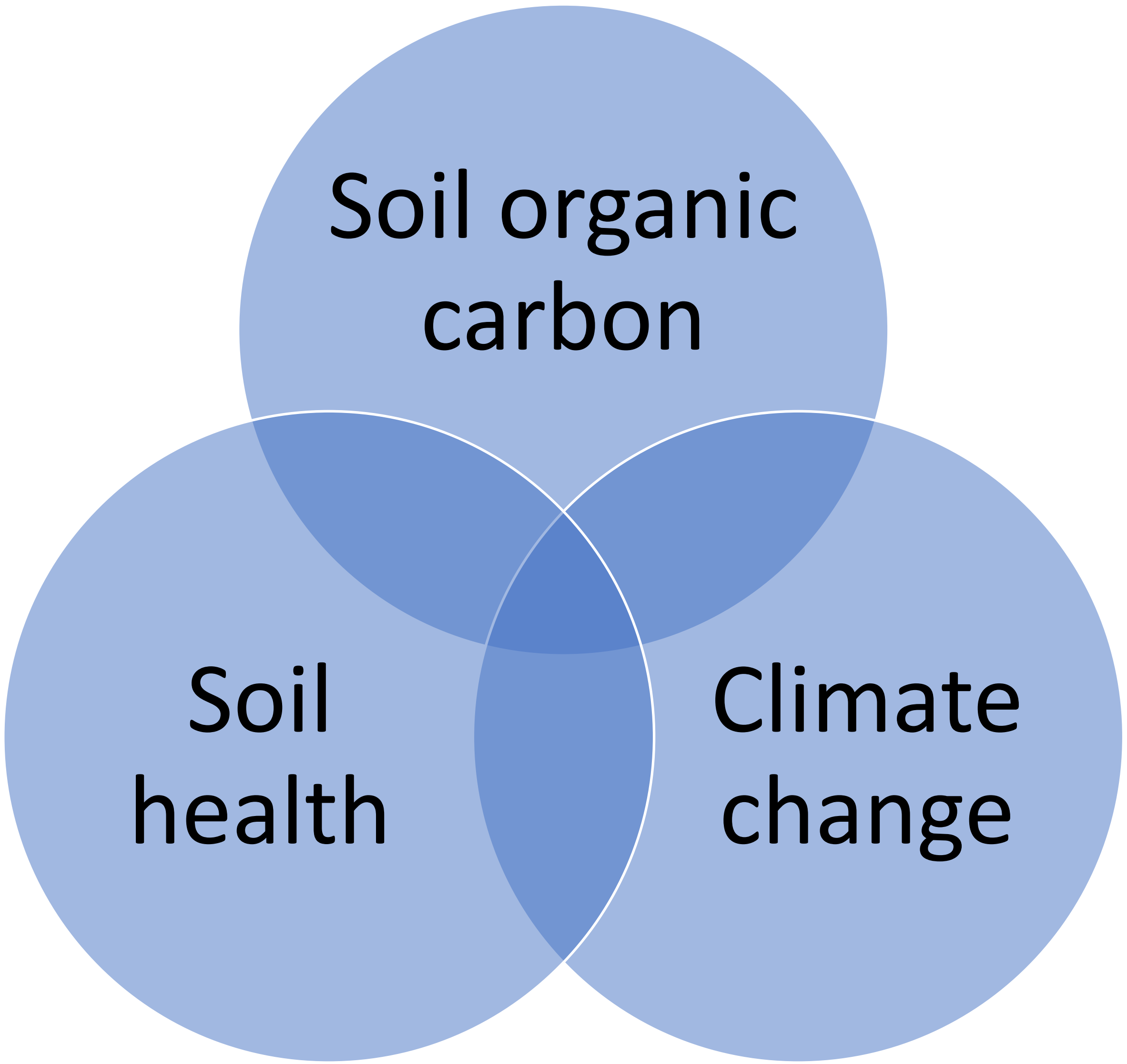
- Natural
- Human activities

Climate change mitigation

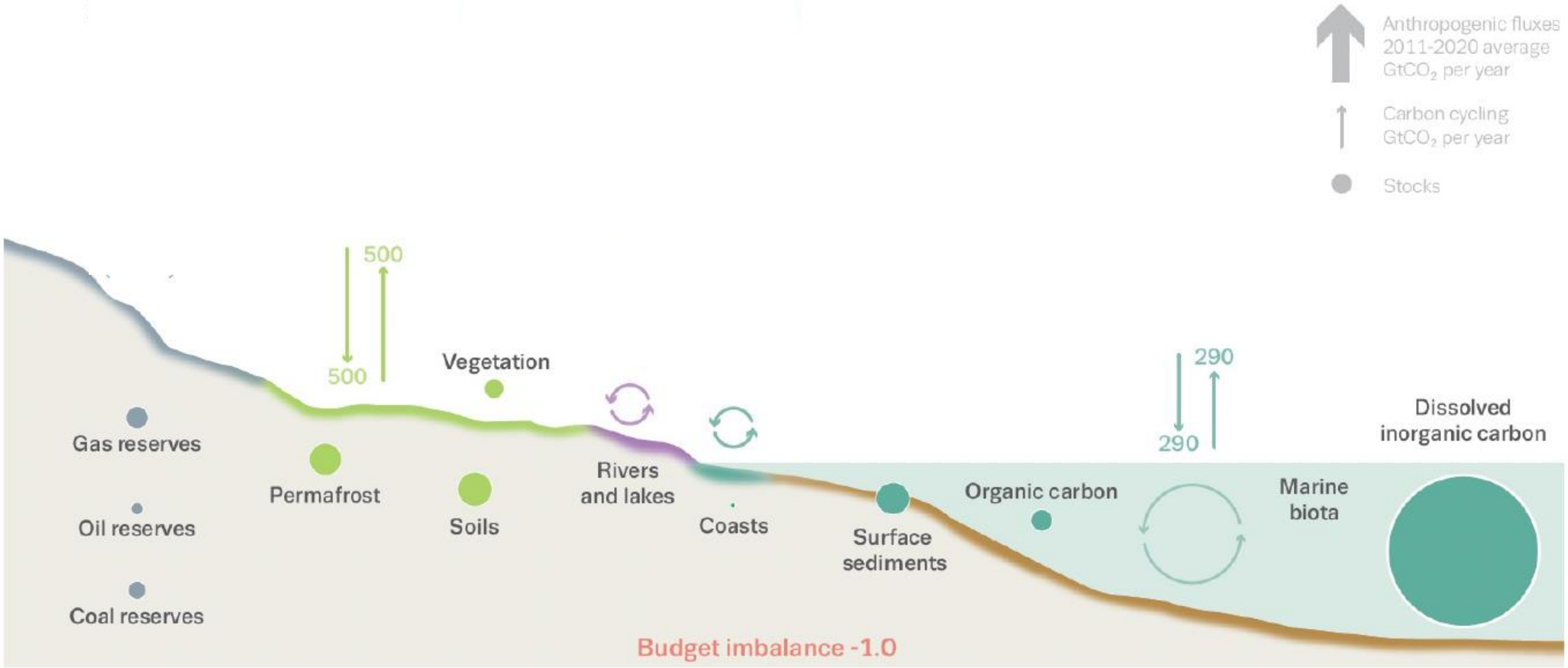
- Natural climate solutions
- Soil C sequestration

Soil health

- Role of soil C
- Quantification
- Challenges



Global carbon budget 2011-2020 averages



Mitigating climate change

Reduce

Remove

Protect

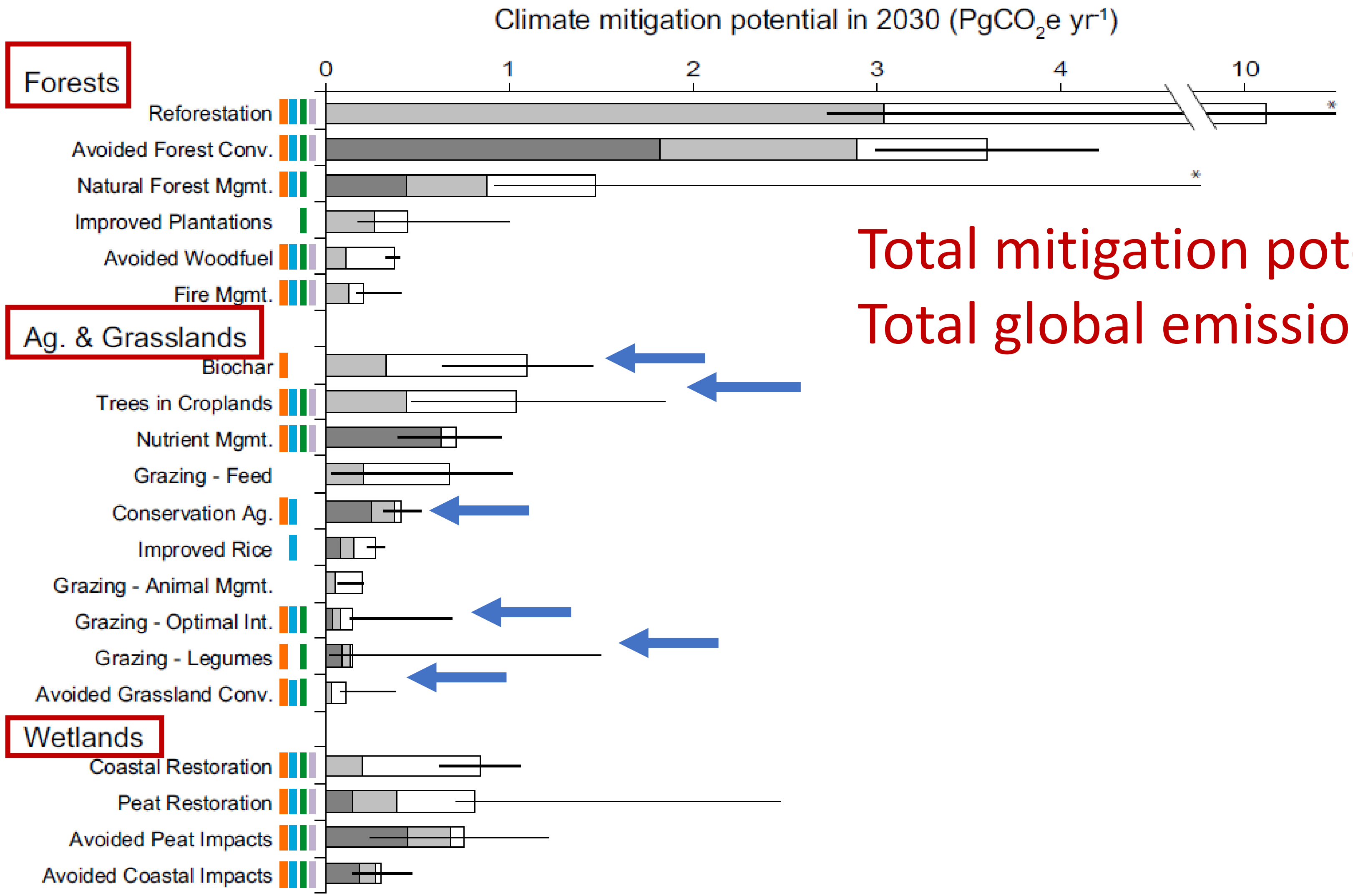
Reduce greenhouse gases release into the atmosphere

Remove greenhouse gases already in the atmosphere

Natural climate solutions
C capture technologies

Protect currently stored C to avoid additional greenhouse gas emissions

Natural climate solutions



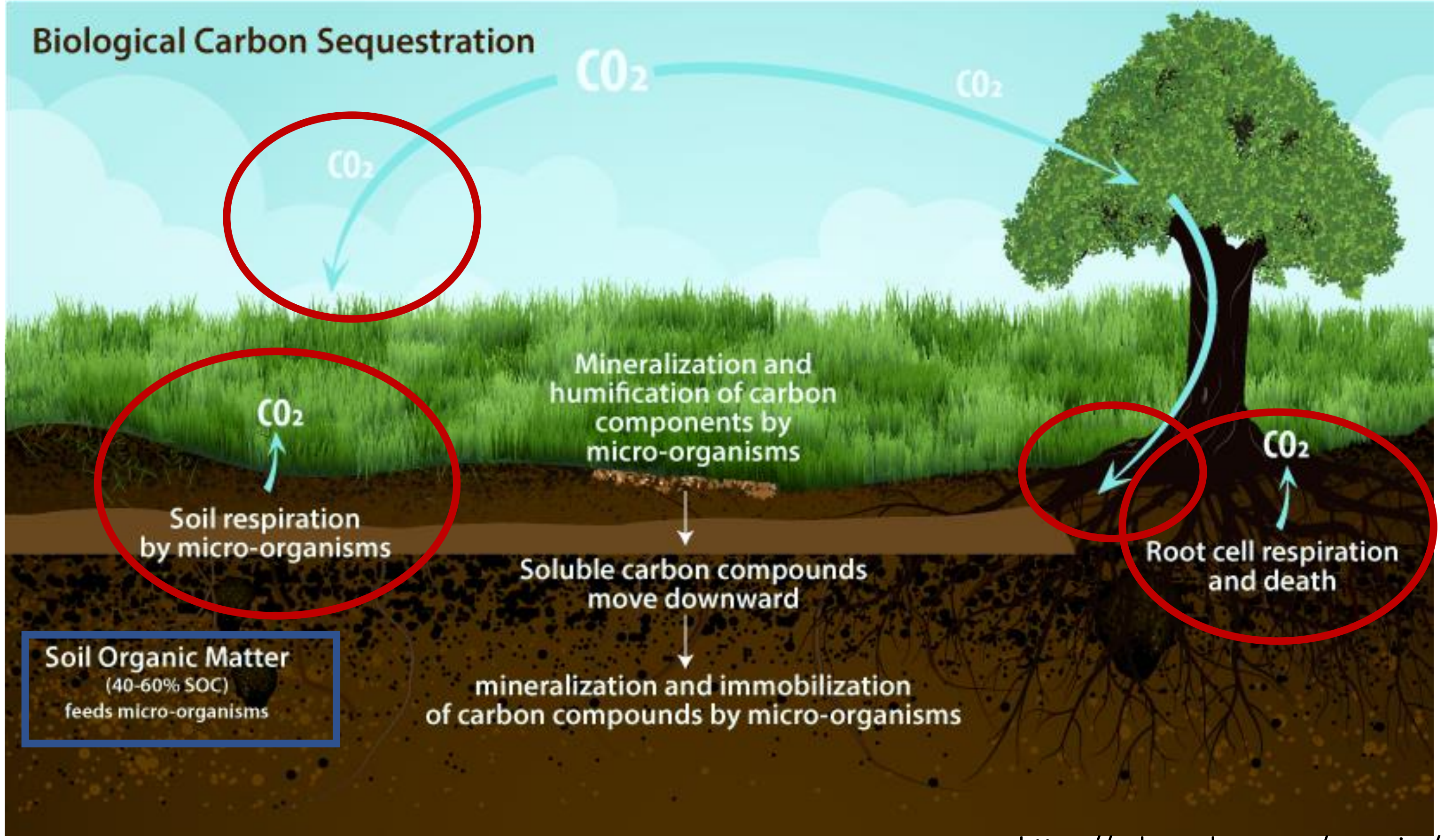
Total mitigation potential 23 $GtCO_2$ per year

Total global emissions 47 $GtCO_2$ per year

Griscom et al., 2017

Soil Carbon Sequestration

"transferring CO_2 from the atmosphere into the soil of a land unit, through plants, plant residues and other organic solids which are stored or retained in the unit as part of the soil organic matter"



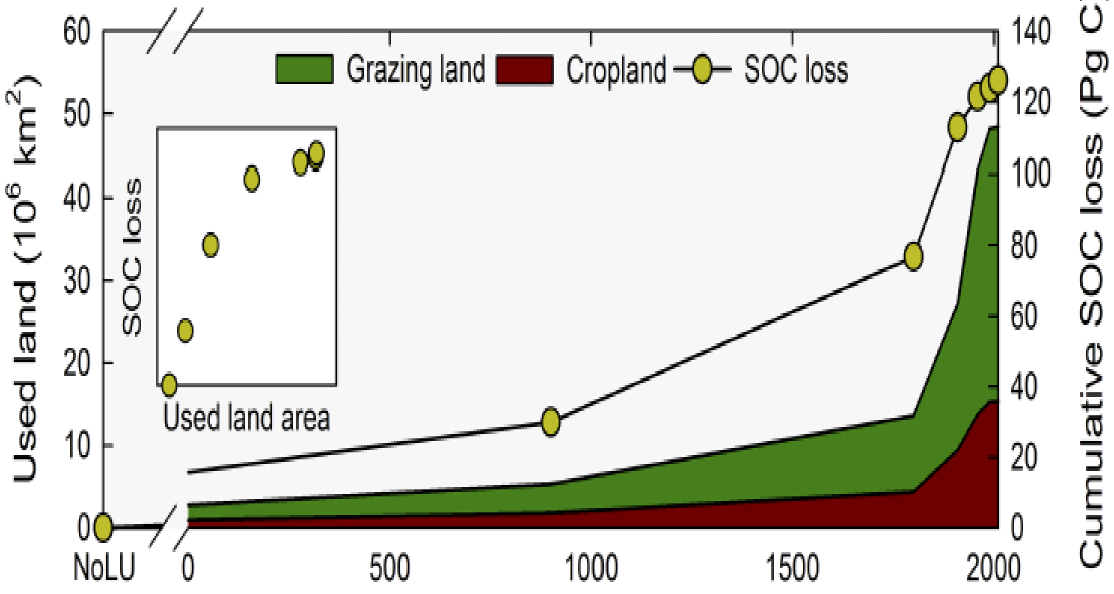
https://calrecycle.ca.gov/organics/compostmulch/toolbox/carbonsequest/

Agricultural soil carbon sequestration

Soil carbon debt of 12,000 years of human land use

Jonathan Sanderman[a,1,2], Tomislav Hengl[b,1], and Gregory J. Fiske[a]

[a]Woods Hole Research Center, Falmouth MA 02540; and [b]The International Soil Resource and Information Center – World Soil Information, 6708 PB Wageningen, The Netherlands



- **Globally, 133 Pg C has been lost due to grazing and cropping**
- **25% of topsoil SOC**
- **Returning <u>ALL</u> lost soil c – equivalent to 10 years of CO_2 emissions**
- **Using best practices 18-37 Pg C could be realistically sequestered**

Are we focusing on the right thing?

Consensus among scientists

- Conservation ag **can** stop C losses and regain some C
- Soil C **is** critical for productivity under global warming
- Achievable soil C sequestration **has** positive impact on soil properties

Debated among scientists

- **What** are the min/max of C sequestration rates?
- **Can** achievable soil C sequestration have impact climate change?
- **Are** we diverting the focus from reducing GHG emissions?

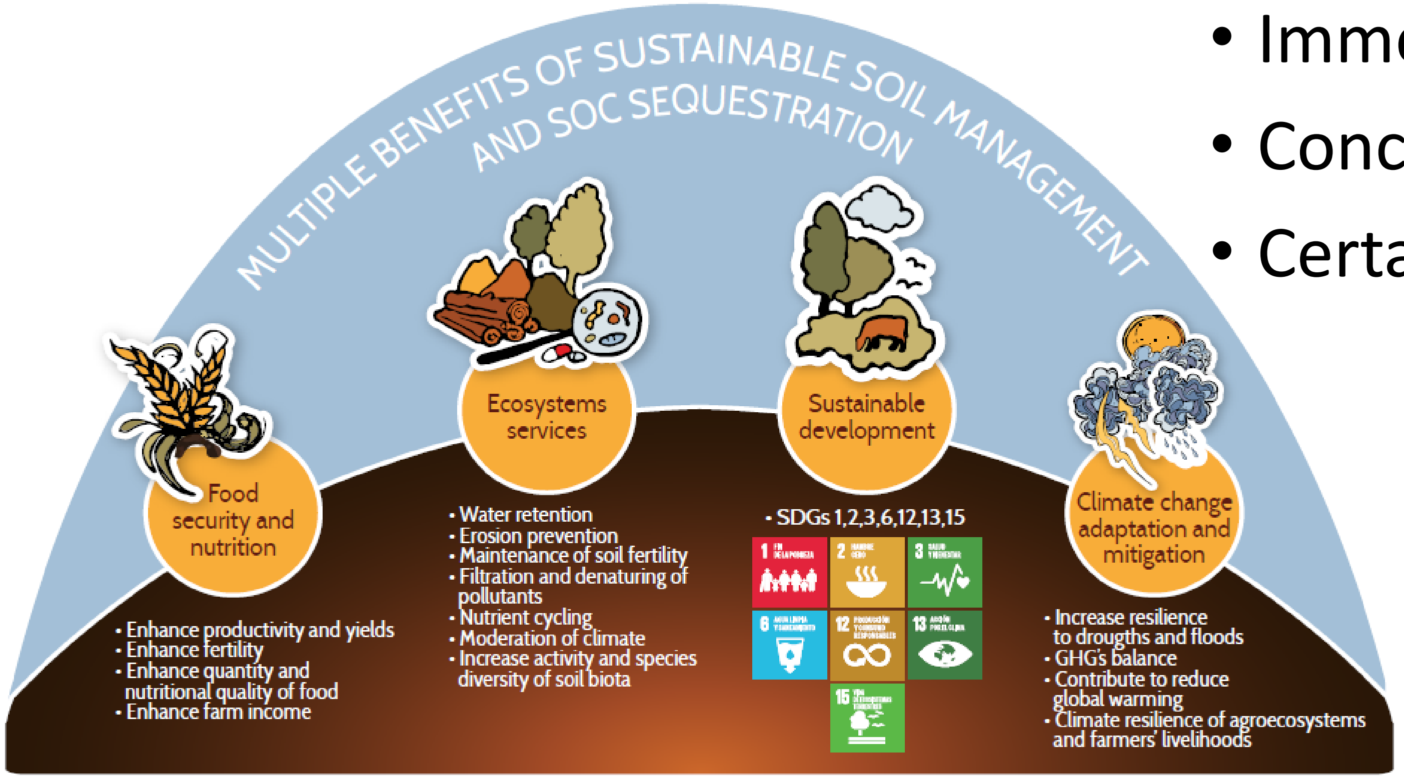
Climate change mitigation vs adaptation

Mitigation – sequester atmospheric CO_2

- Long-term
- Abstract
- Uncertain

Adaptation – increase soil resilience

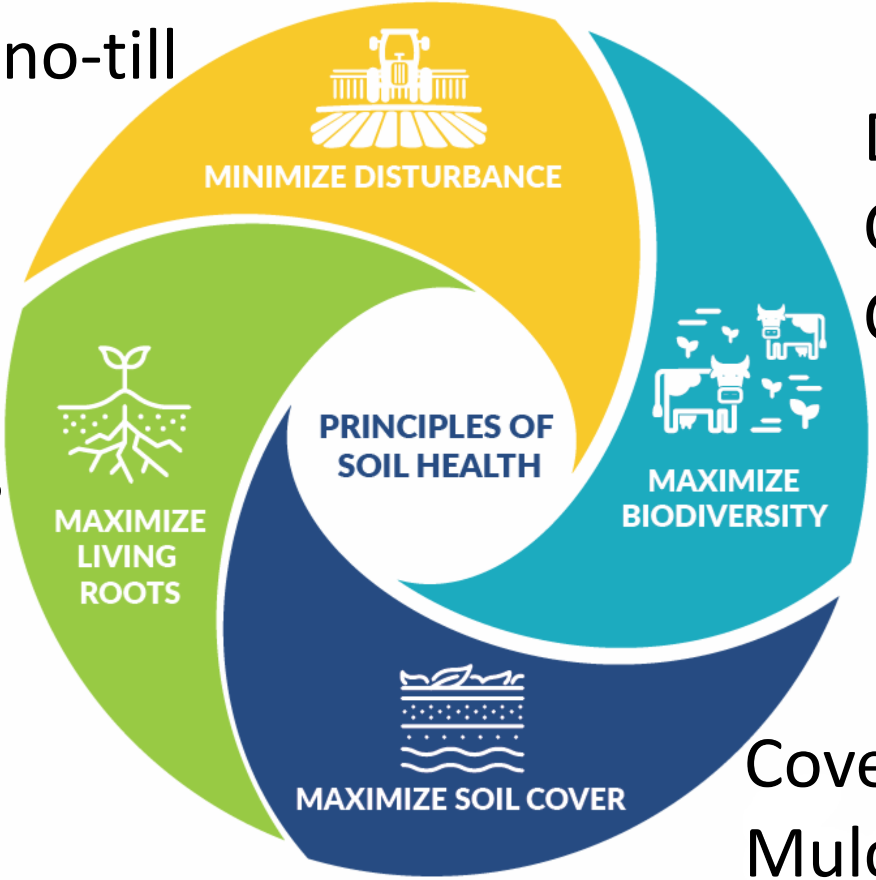
- Immediate
- Concrete
- Certain



FAO, Recarbonization of Global Soils (2019)

How can we increase soil carbon (principles of soil health)

no-till



Diverse cover crops
Crop/grazing integration
Crop rotation

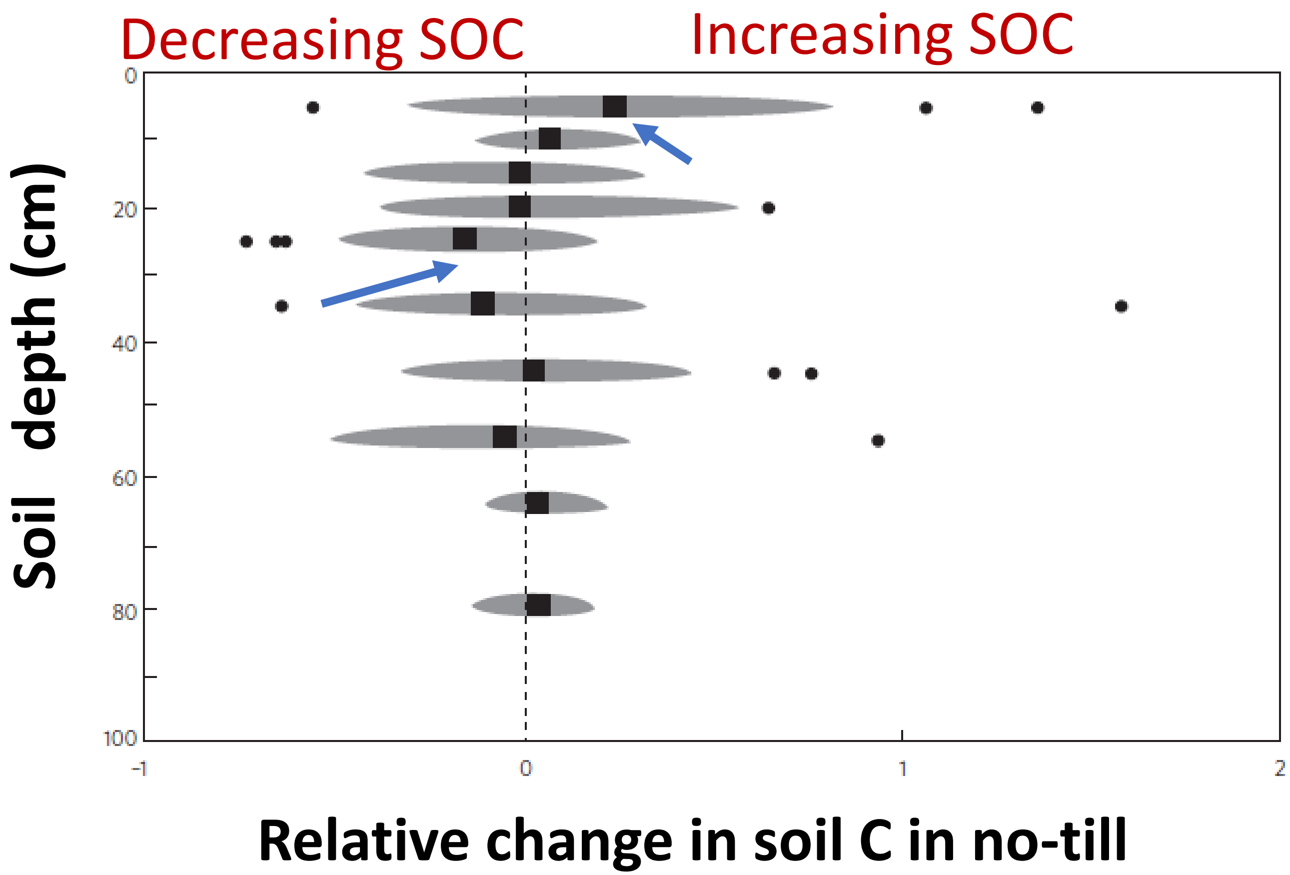
Cover crops
perennials

Cover crops
Mulch
Residue retention

PERSPECTIVE
PUBLISHED ONLINE: 30 JULY 2014 | DOI: 10.1038/NCLIMATE2292
nature climate change

Limited potential of no-till agriculture for climate change mitigation

David S. Powlson[1*], Clare M. Stirling[2], M. L. Jat[3], Bruno G. Gerard[2], Cheryl A. Palm[4], Pedro A. Sanchez[4] and Kenneth G. Cassman[5]

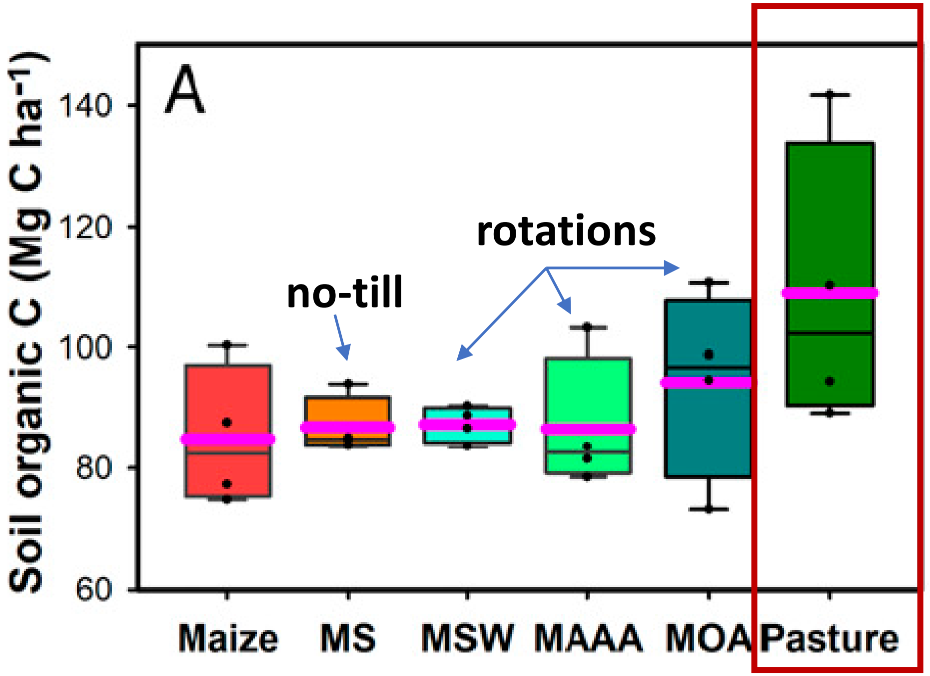


SOC increases at 0-10 cm
SOC decreases at 25 cm depth, net balance of **zero change in soil organic C**

Soil health vs climate change benefits

Persistent soil carbon enhanced in Mollisols by well-managed grasslands but not annual grain or dairy forage cropping systems

Yichao Rui[a,b,1], Randall D. Jackson[c], M. Francesca Cotrufo[d], Gregg R. Sanford[c], Brian J. Spiesman[e], Leonardo Deiss[f], Steven W. Culman[f], Chao Liang[g], and Matthew D. Ruark[a]



In a 29 –year field experiment comparing **continuous maize** with **no-till** maize, organically managed-crop rotations, and **managed pasture**.

…**only managed pasture increased soil organic C**

Contents lists available at ScienceDirect

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Review

Carbon sequestration in agricultural soils via cultivation of cover crops – A meta-analysis

Christopher Poeplau[a,b,*], Axel Don[a]

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[b] Swedish University of Agricultural Sciences (SLU), Department of Ecology, Box 7044, 75007 Uppsala,

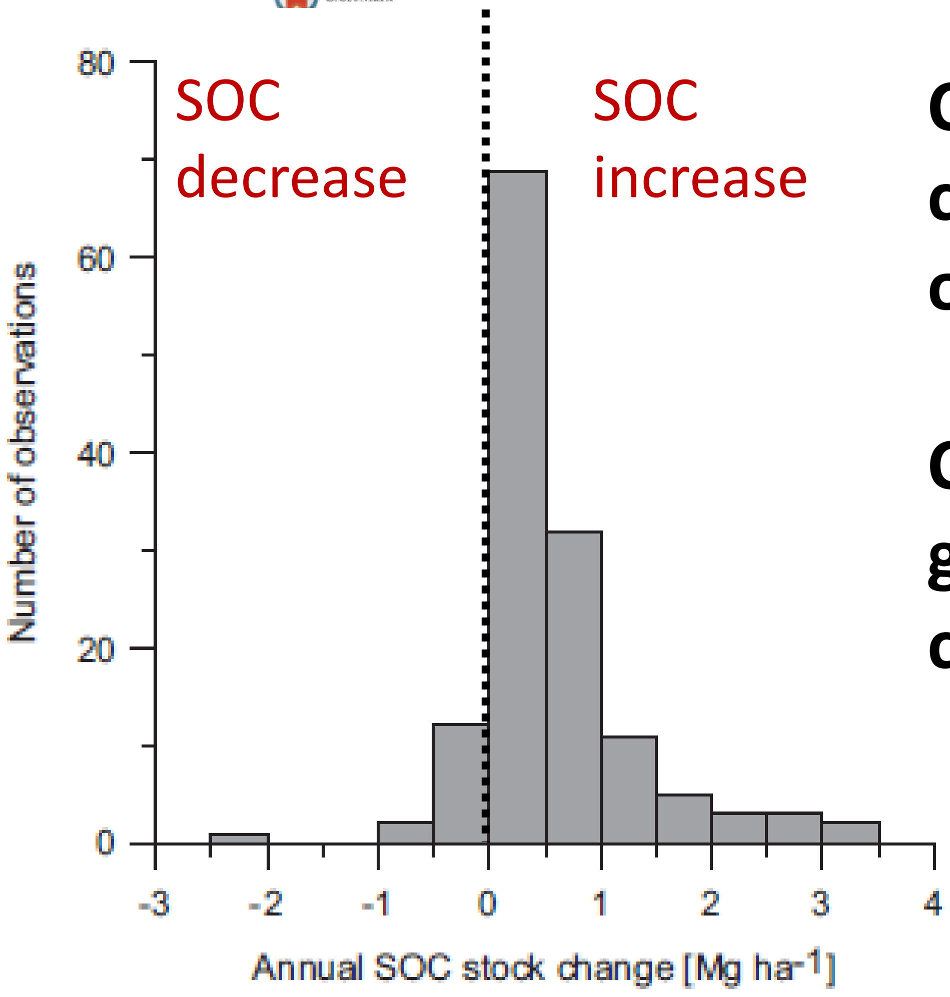


Fig. 3. Histogram of annual change of soil carbon due to cover cropping in comparison to fallow winter.

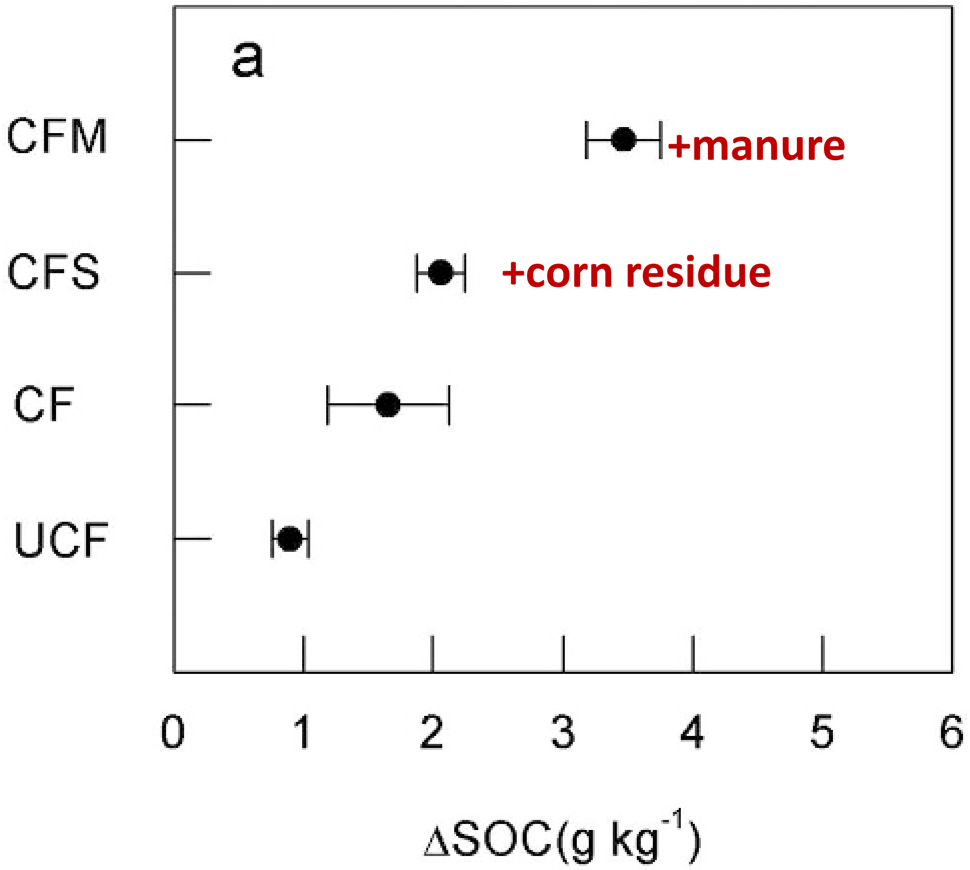
Cover cropping consistently increases soil organic C

Cover crops limited by growing season and added costs

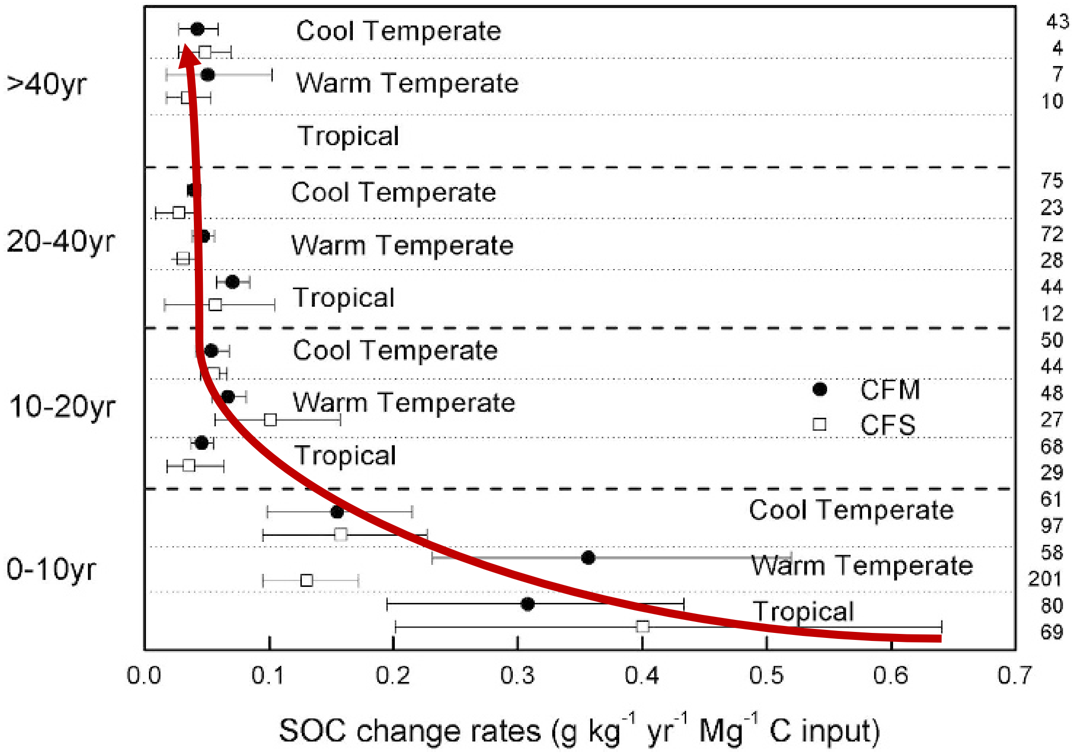
Changes in soil organic carbon in croplands subjected to fertilizer management: a global meta-analysis

Pengfei Han[1,2], Wen Zhang[1], Guocheng Wang[1], Wenjuan Sun[3] & Yao Huang[3]

Organic amendments increase soil C (no big surprise…)



C increase decreases with time
Our ability to increase soil C is limited…

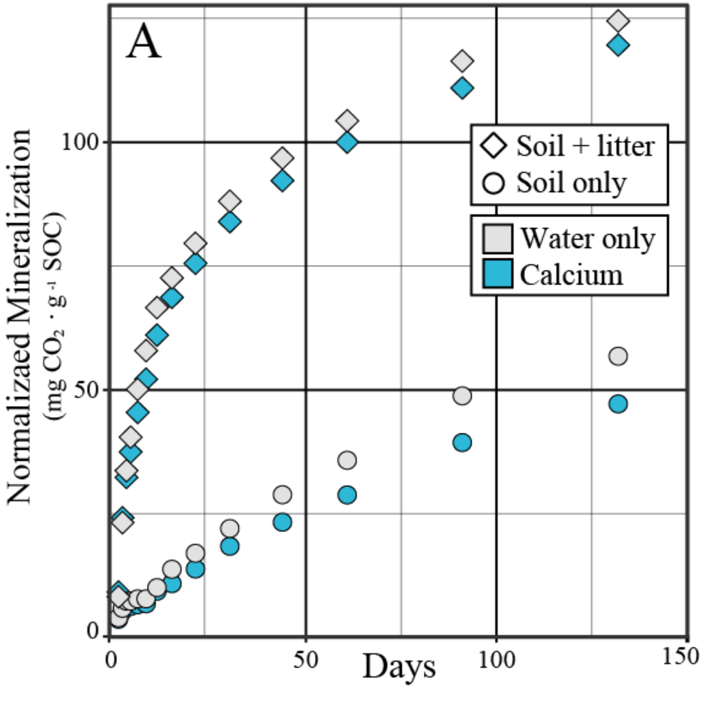


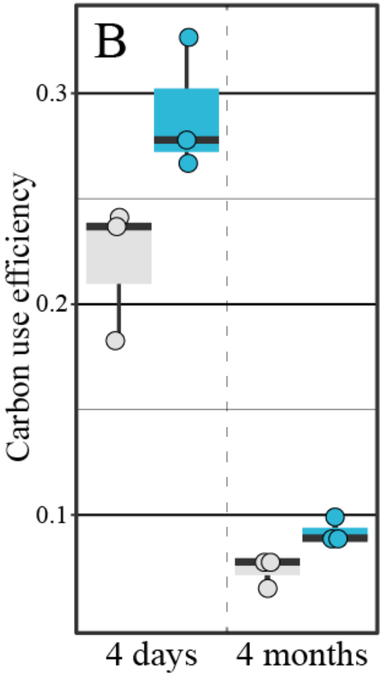
Applying calcium to increase SOC accumulation

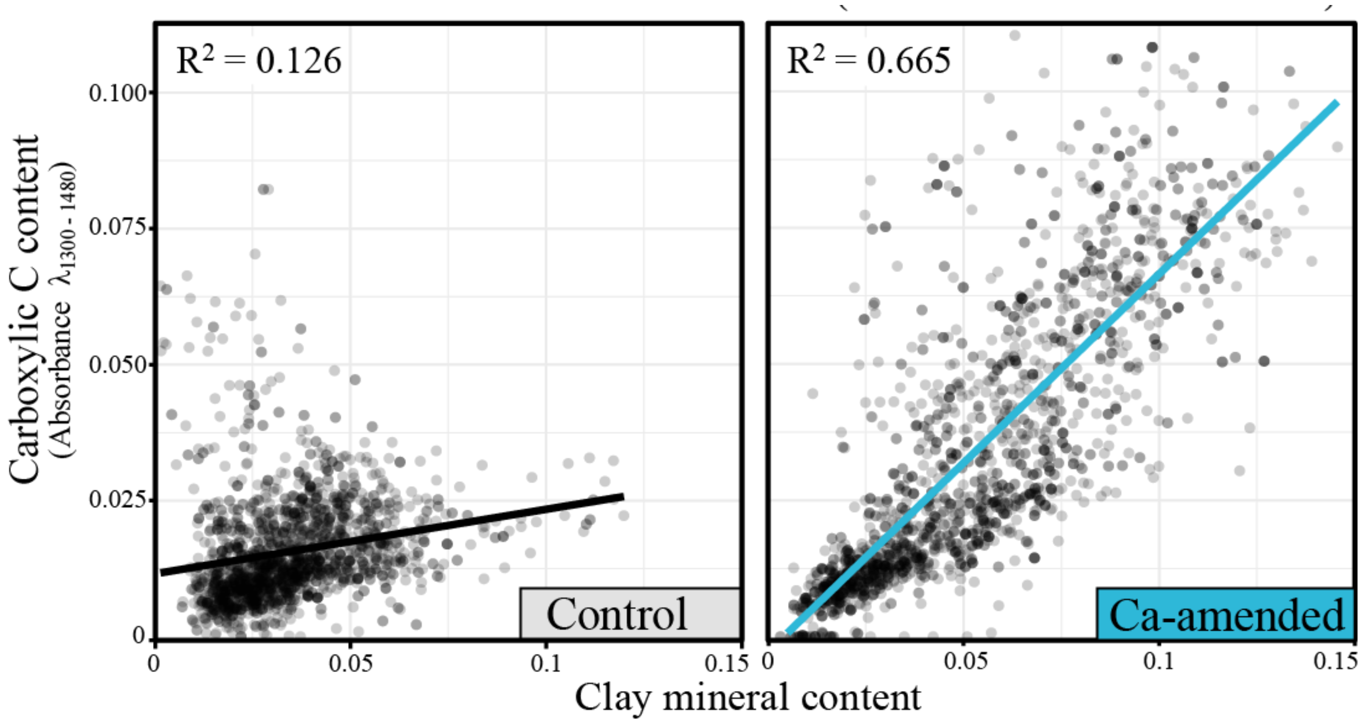
reduced CO_2 release from soil

increased microbial efficiency

Enhanced SOC stabilization via interactions with minerals







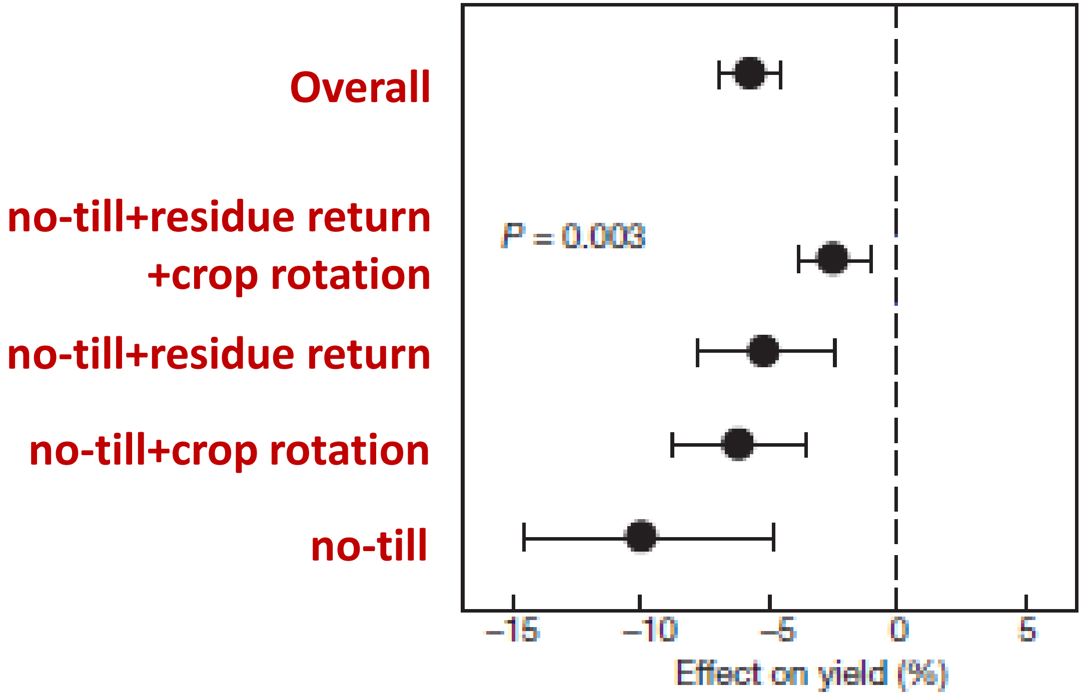
Shabtai, I.A., et al. *in prep*

LETTER

doi:10.1038/nature13809

Productivity limits and potentials of the principles of conservation agriculture

Cameron M. Pittelkow[1]*†, Xinqiang Liang[2]*, Bruce A. Linquist[1], Kees Jan van Groenigen[3], Juhwan Lee[4], Mark E. Lundy[1], Natasja van Gestel[3], Johan Six[4], Rodney T. Venterea[5,6] & Chris van Kessel[1]



Synthesizing 5463 observations from 610 studies on 480 crop in 63 countries…

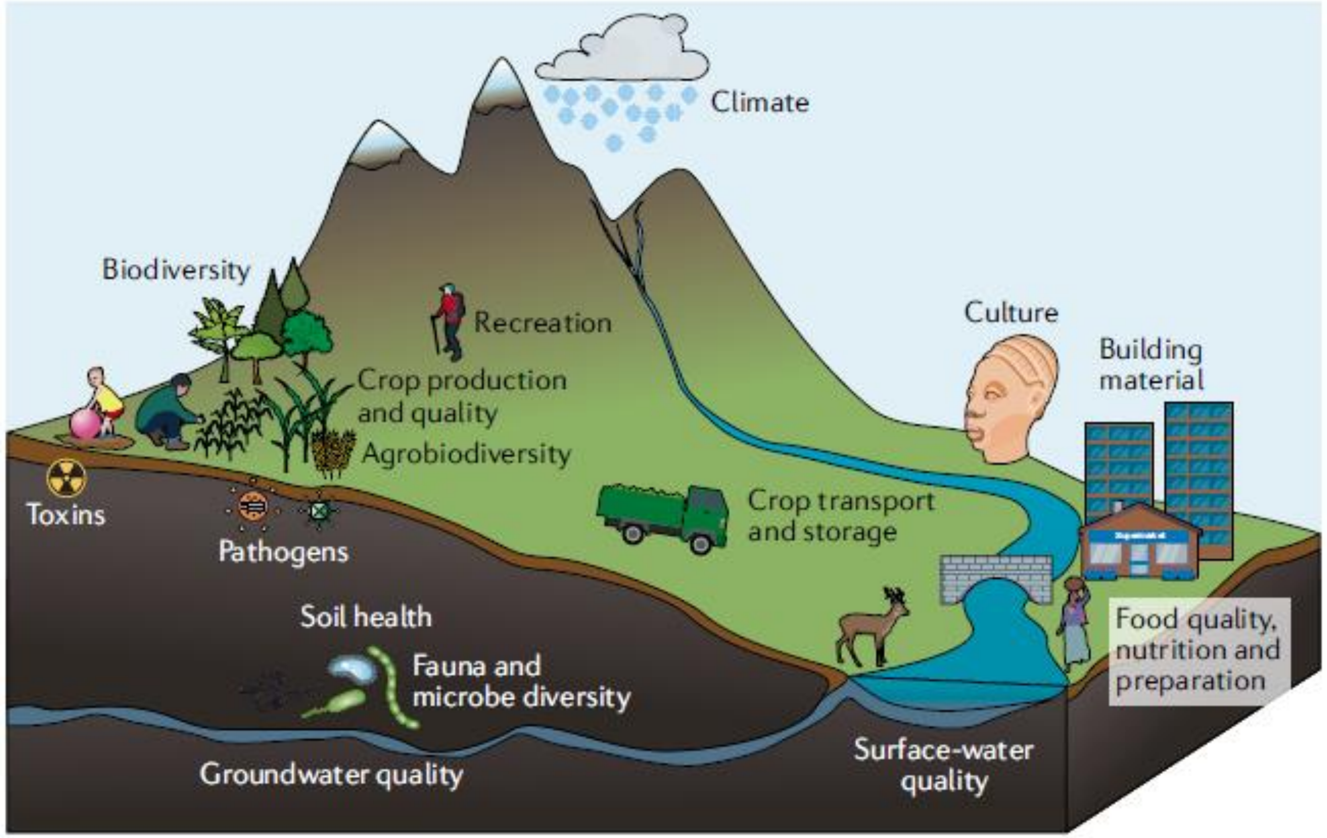
Conservation agriculture practices **decreased yield relative to conventional practices**

In dry climates some yield increases were observed.

Soil health – quantifying soil improvement

"the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans"

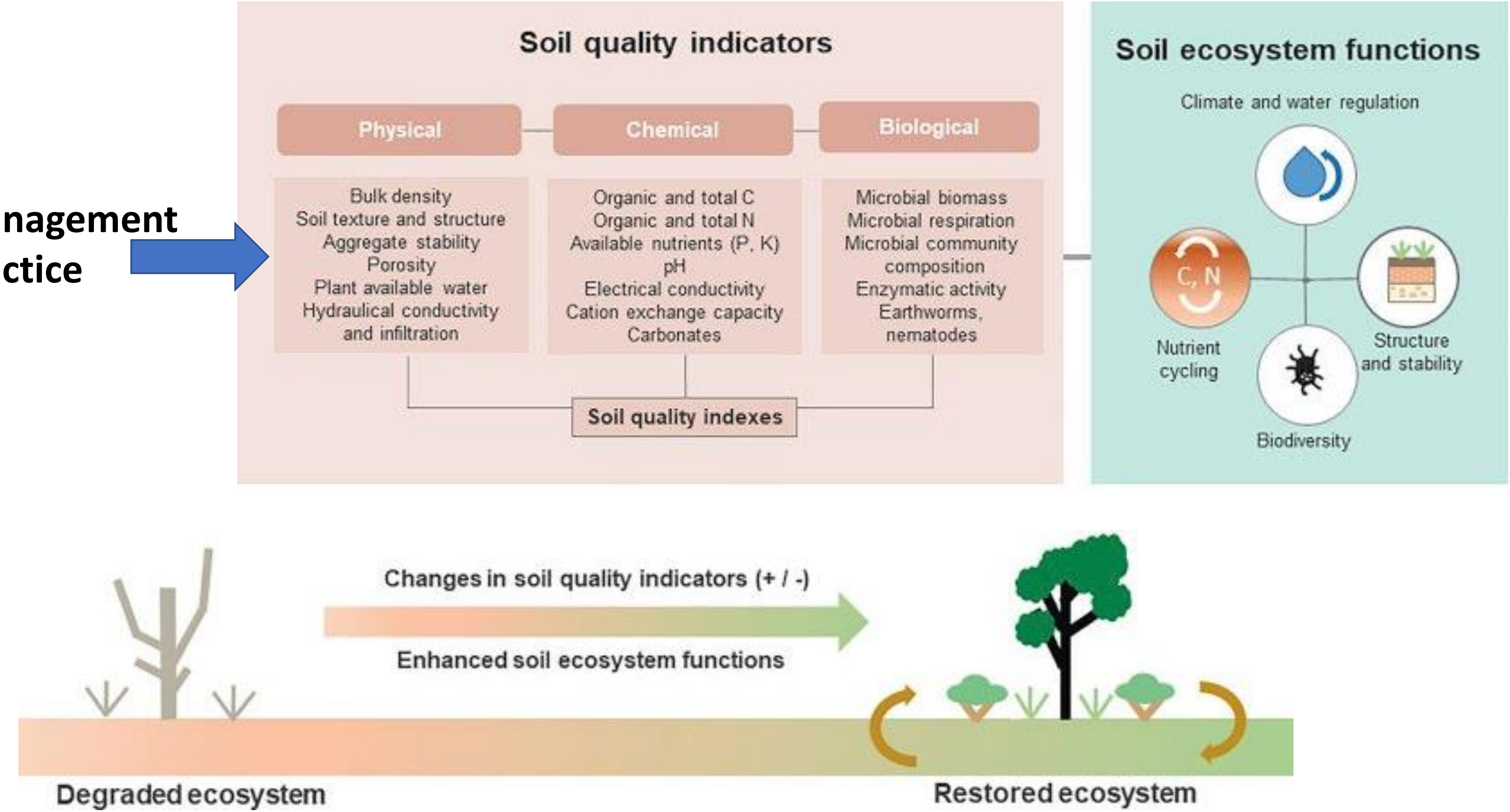
Formerly known as "soil fertility and quality"…



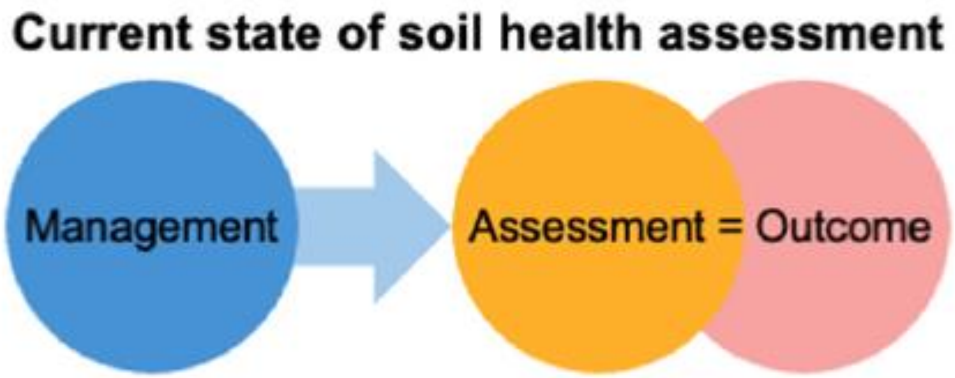
Lehmann et al., 2020

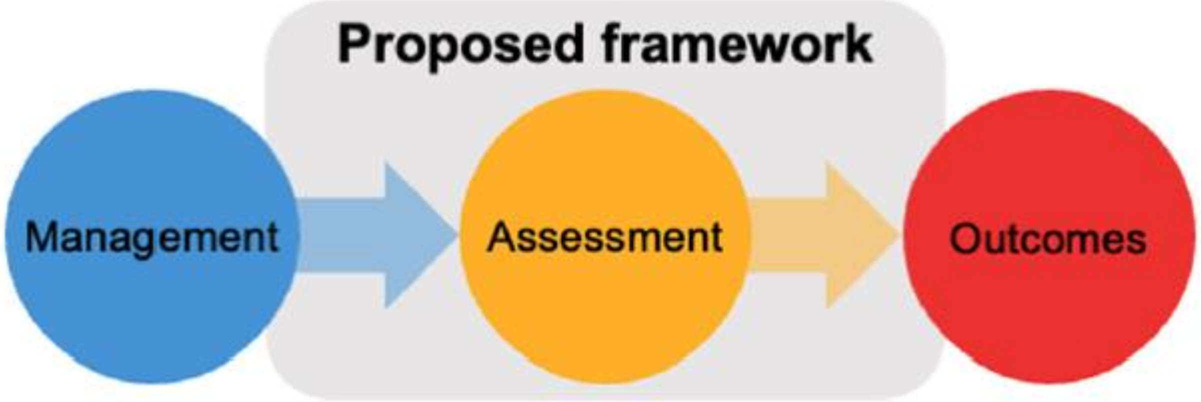
Soil health assessment

Management practice



What do soil indicators really indicate?





Soil health indicators detect management change and **imply outcome** (yield, erosion, water storage) based on assessment scores

Soil health indicators still **cannot quantify outcomes** (yield, erosion, water storage) based on scores.

Wade et al., SBB, 2022

Conclusions

- Soil carbon sequestration likely provides limited climate change mitigation potential
- Soil carbon is critical for adapting to climate change
- Soil conservation practices should be selected carefully
- Soil health framework has room for improvement

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