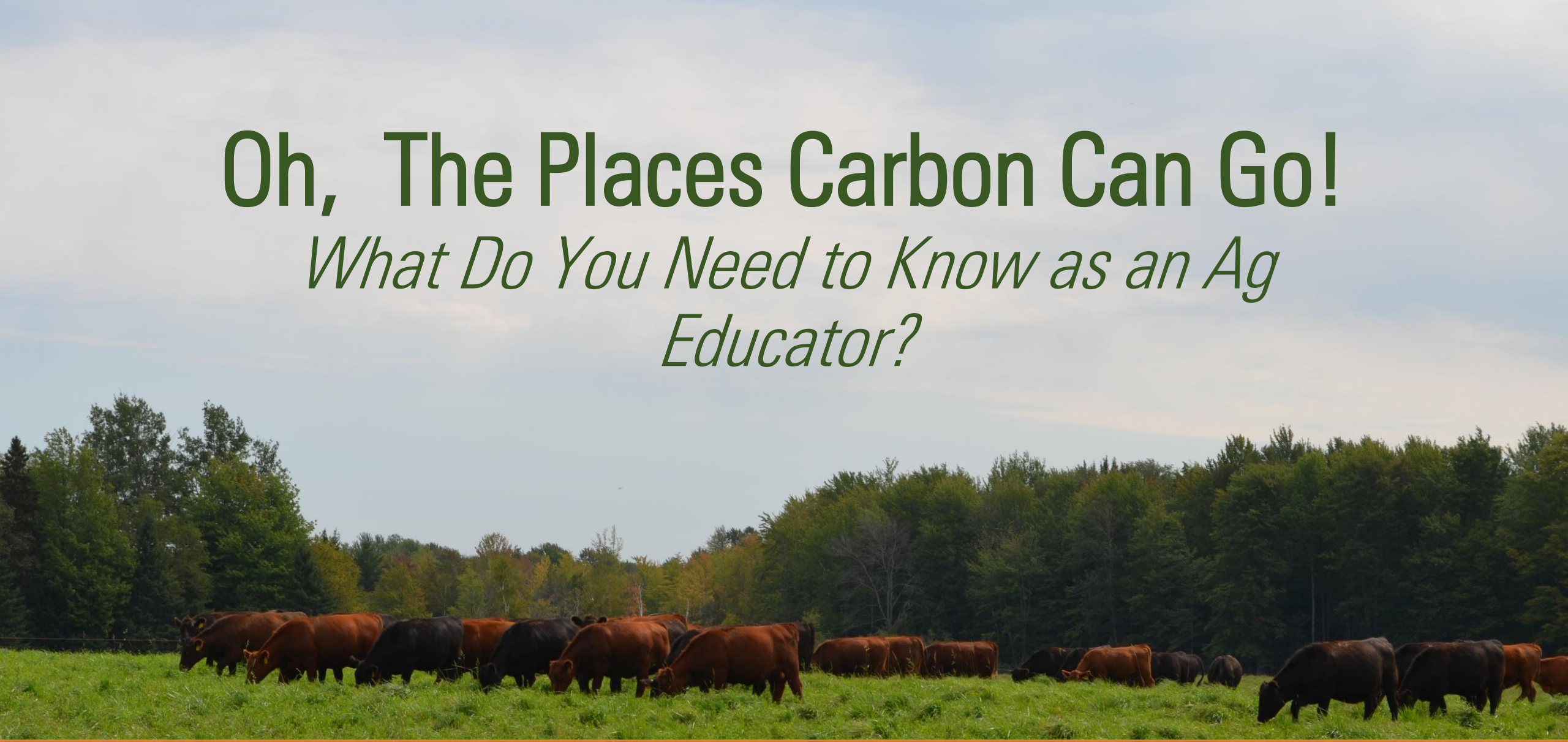
Oh, The Places Carbon Can Go!

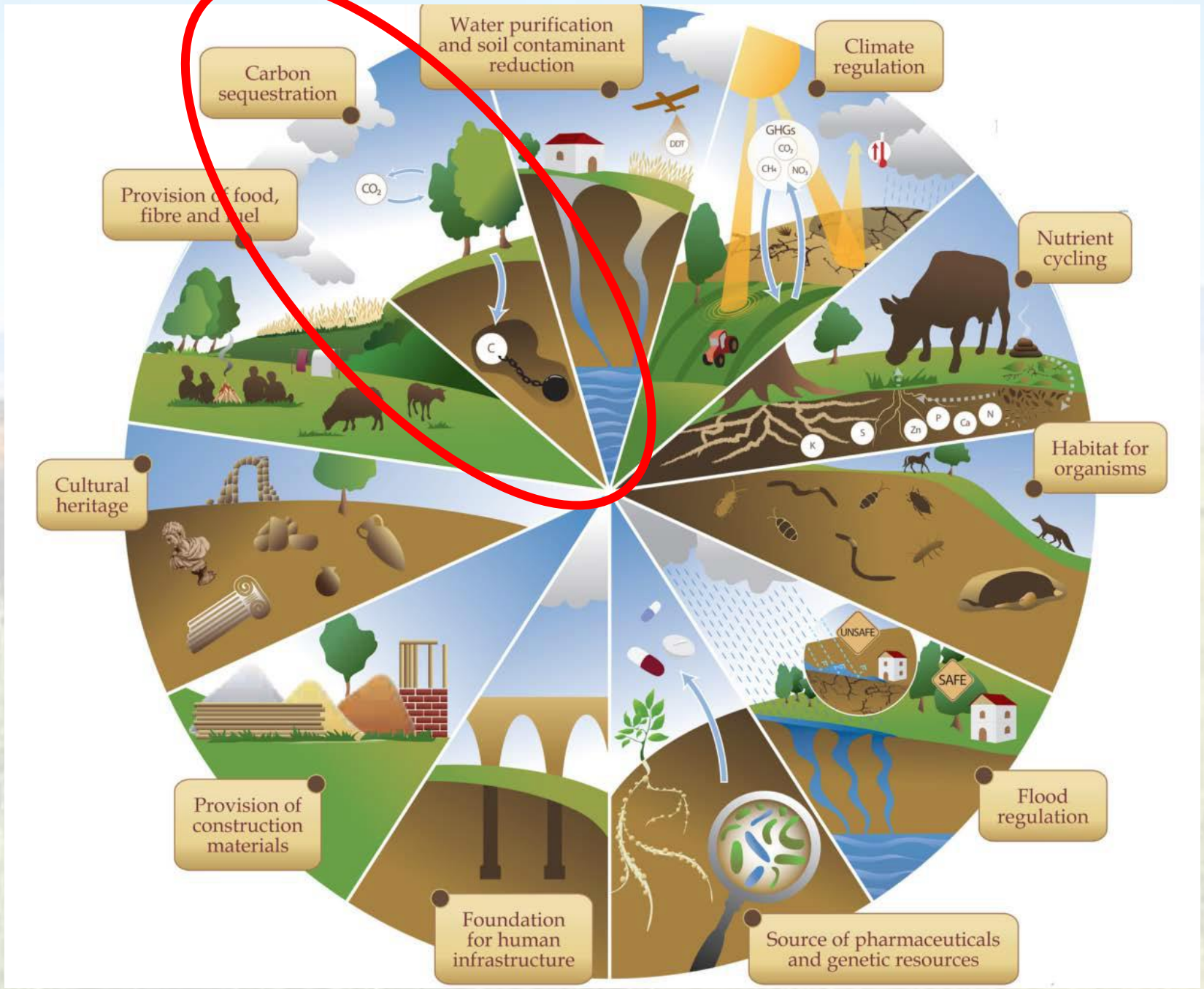
What Do You Need to Know as an Ag Educator?



Dr. Jasmine Dillon Assistant Professor, Department of Animal Sciences, Colorado State University
Dr. Megan Machmuller Research Scientist, Soil & Crop Sciences, Colorado State University

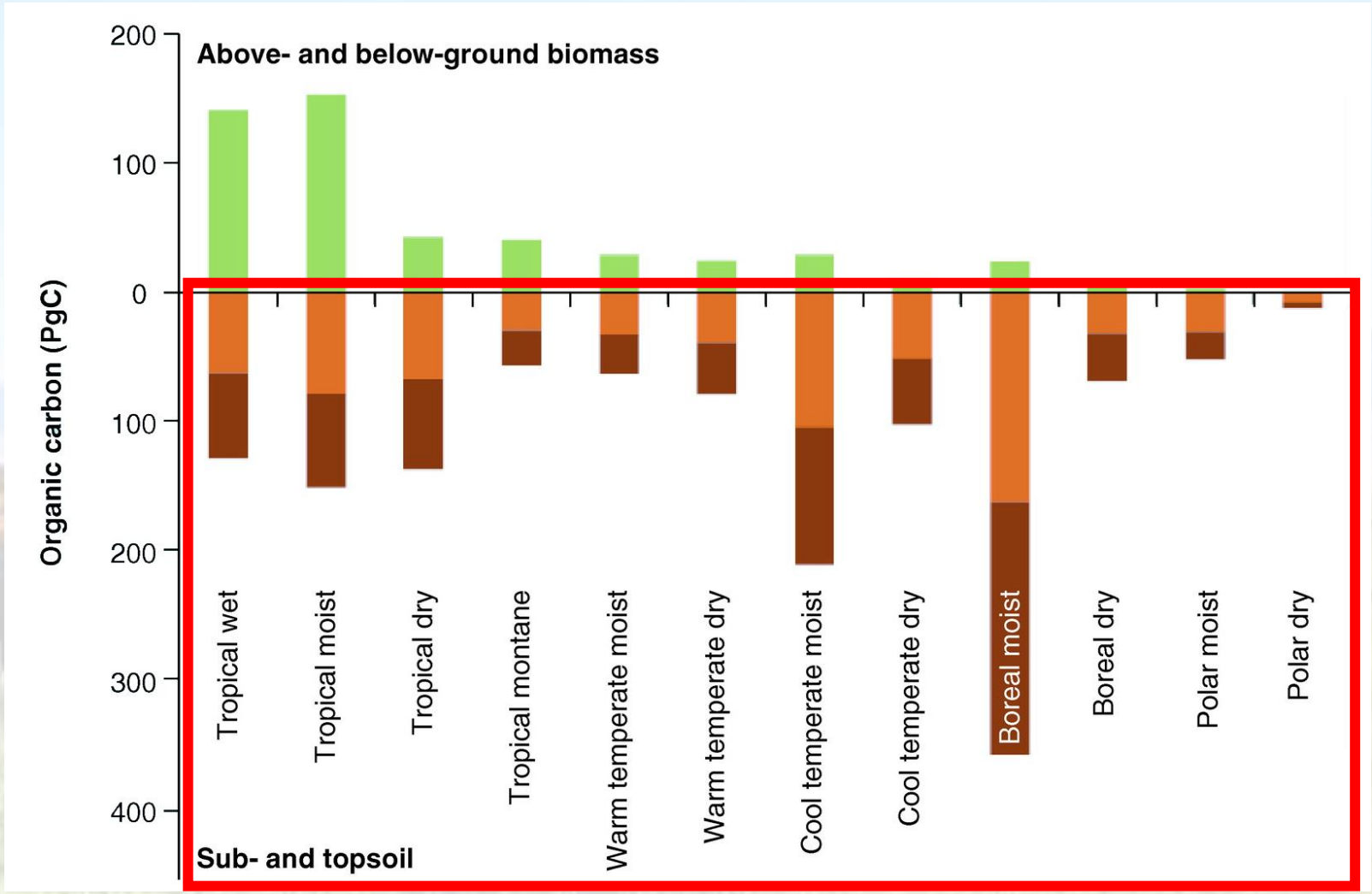
Photo taken by Jesse Bussard at the Michigan State University Lake City Research Center

Soil underpins many ecosystem services, positioning it at the **nexus of our grand challenges**.



Globally, soils contain about 50,400 billion metric tons of carbon.

Soil stores more carbon than vegetation and atmosphere combined.



Soil health is foundational to achieving the sustainable development goals

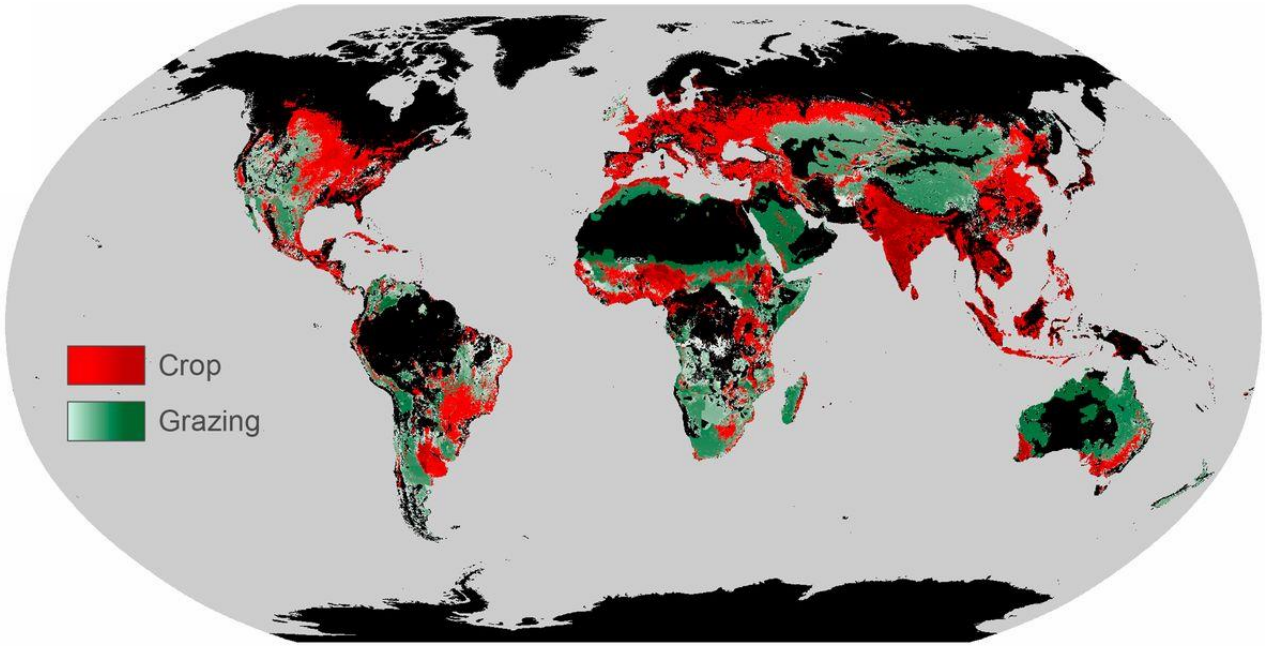
wbcsd

Figure 2:
Soils sit at the center of the UN conventions on desertification, climate change and biodiversity and delivers the key to solutions to many of the SDGs, with four specific relevant targets.

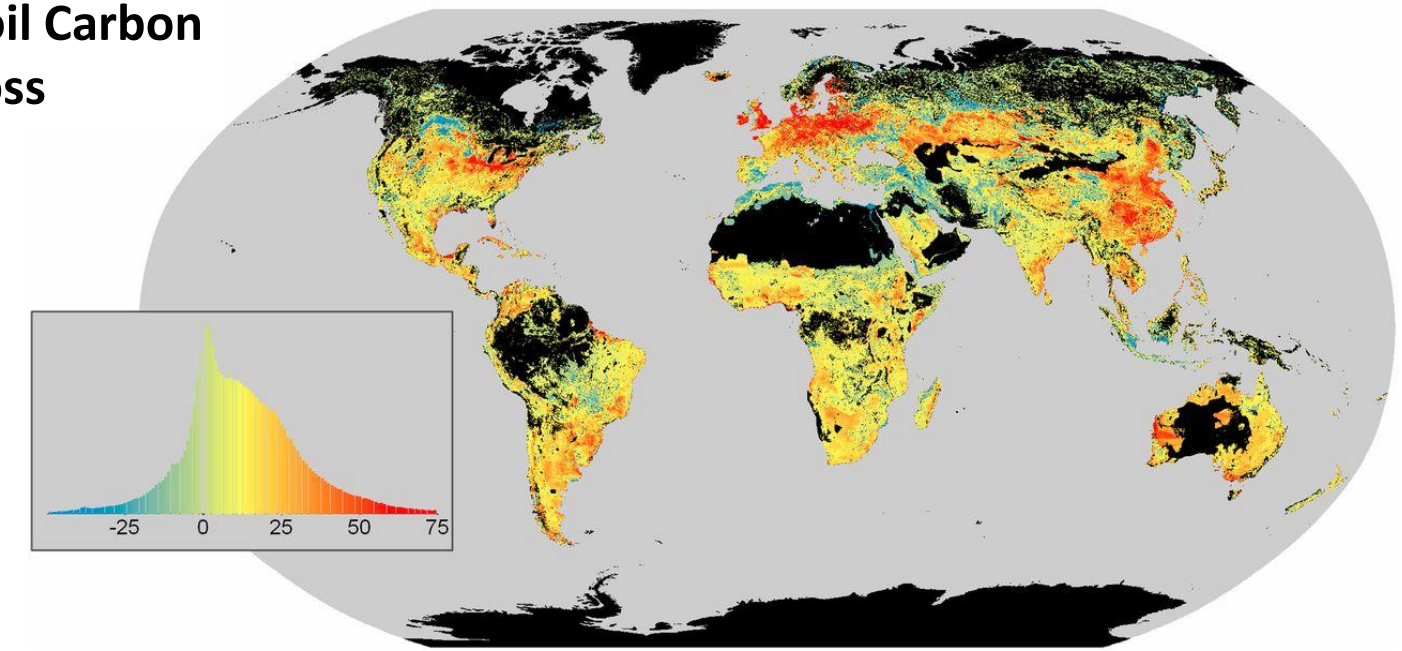
We have lost about 120 billion metric tons of soil!

While tragic, this also presents great opportunity for carbon sequestration.

Global Land Use

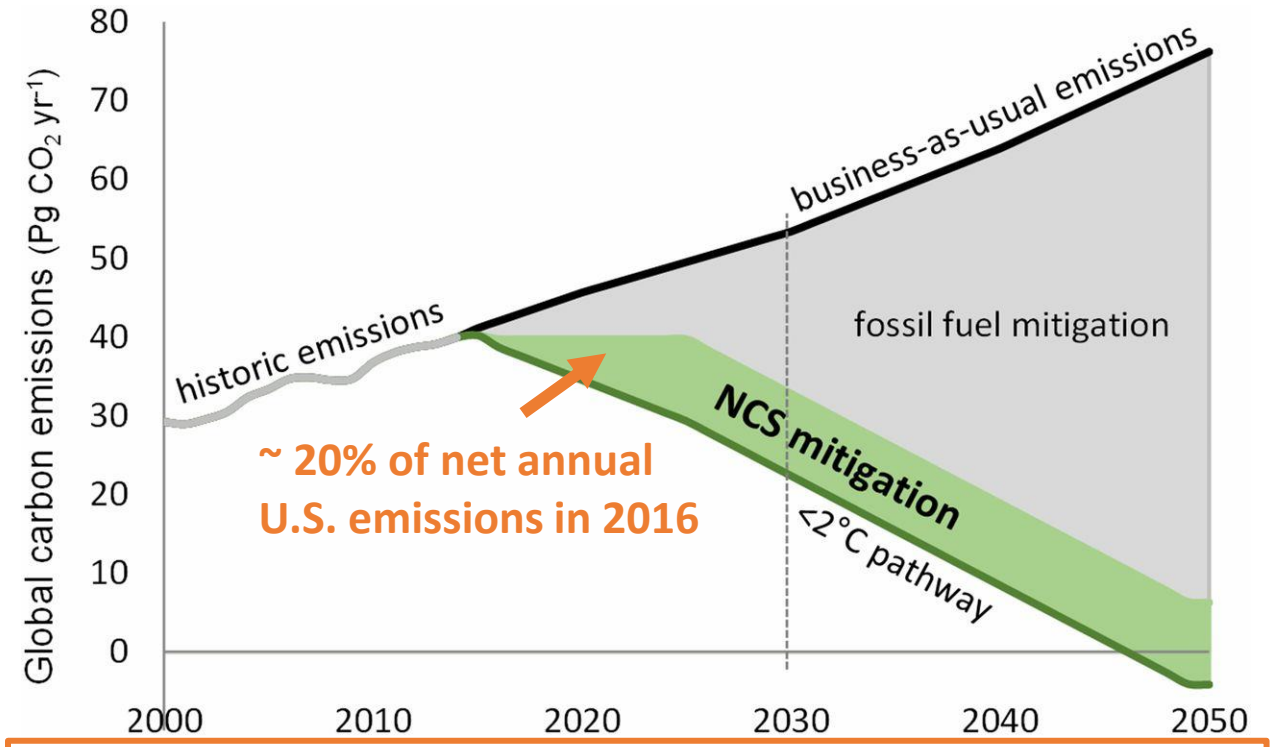


Soil Carbon Loss



Sanderman et al 2017

Soil carbon sequestration potential: A win-win strategy?

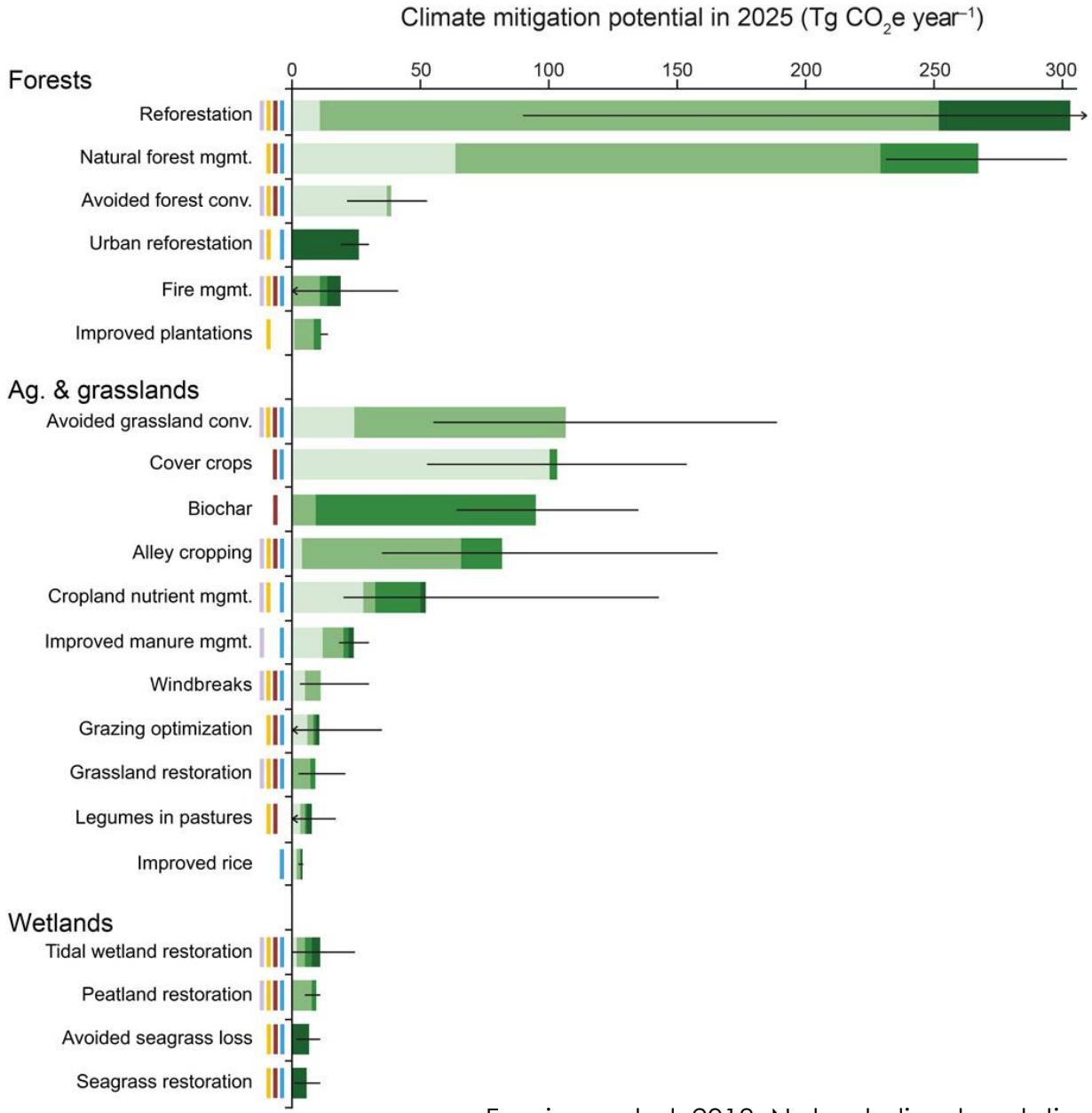


PROS

- Relatively low cost
- Known technology
- Many co-benefits
- No need for new land (in agriculture)

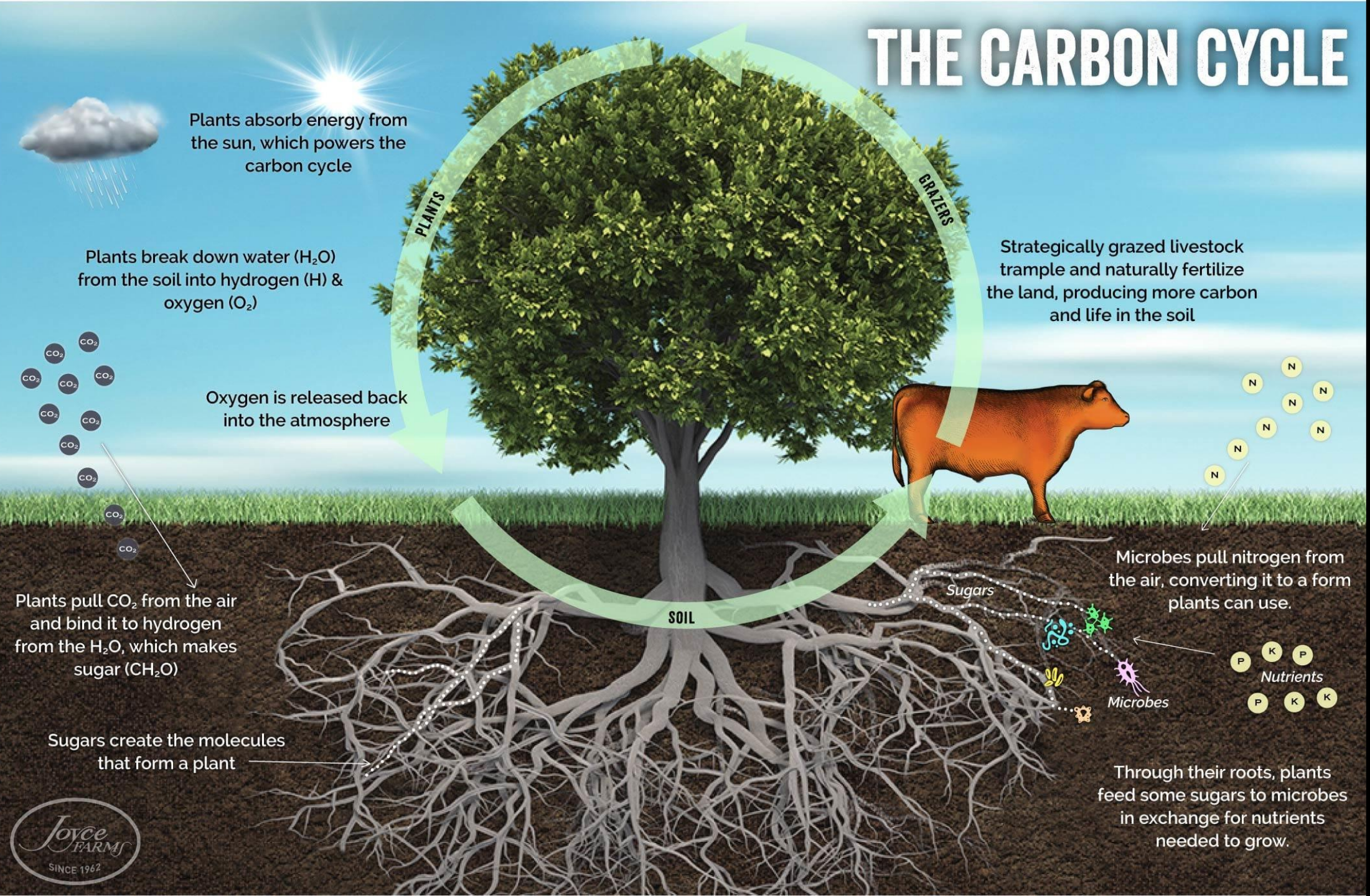
CONS

- Hard to quantify
- Uncertain longevity

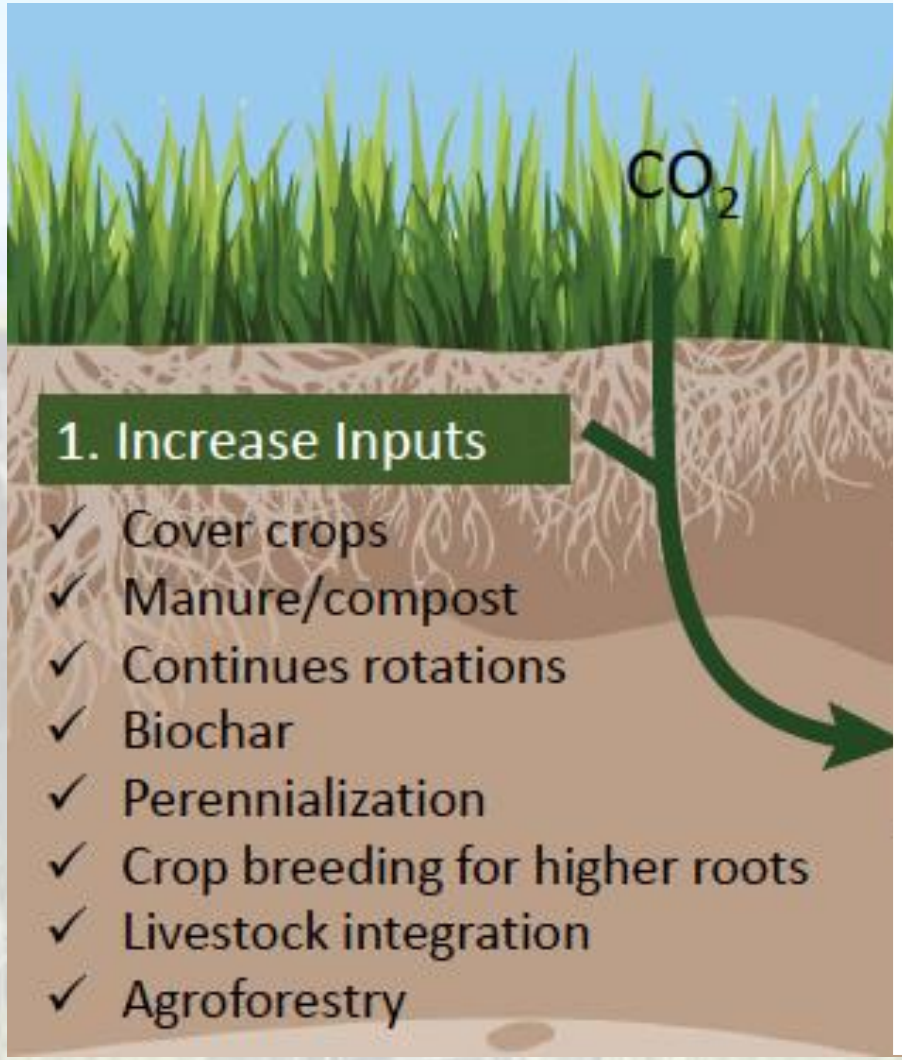


Fargione et al. 2018. Natural climate solutions.

Carbon Cycles on the Farm



The simple biophysics of soil carbon sequestration



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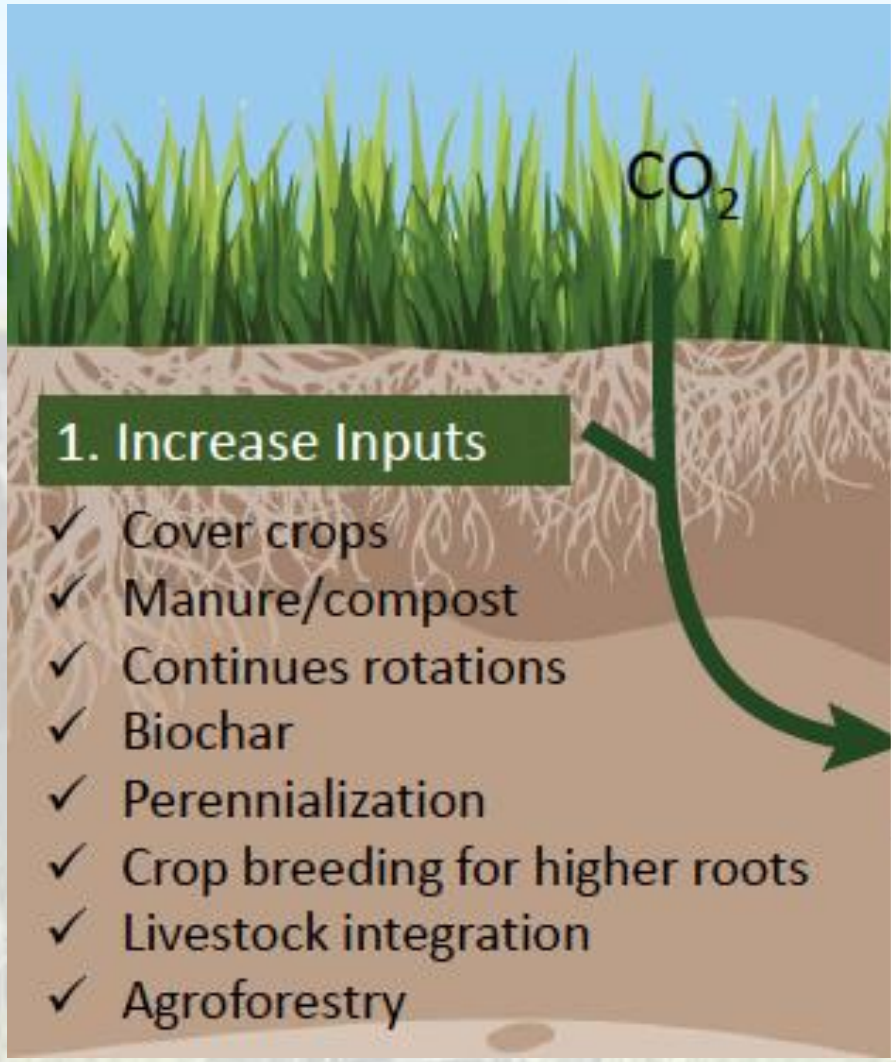

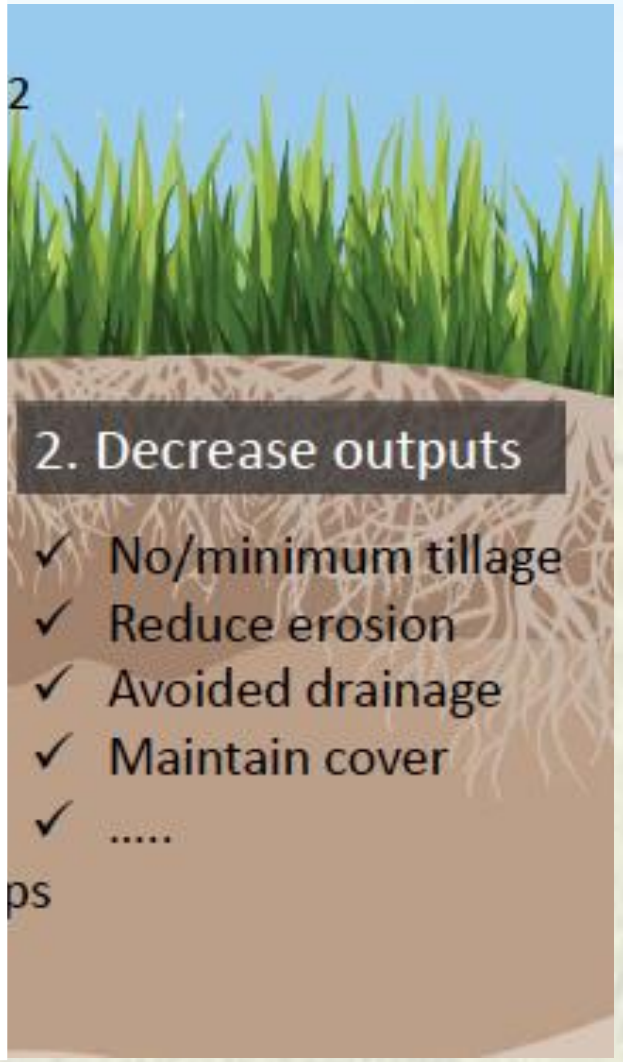

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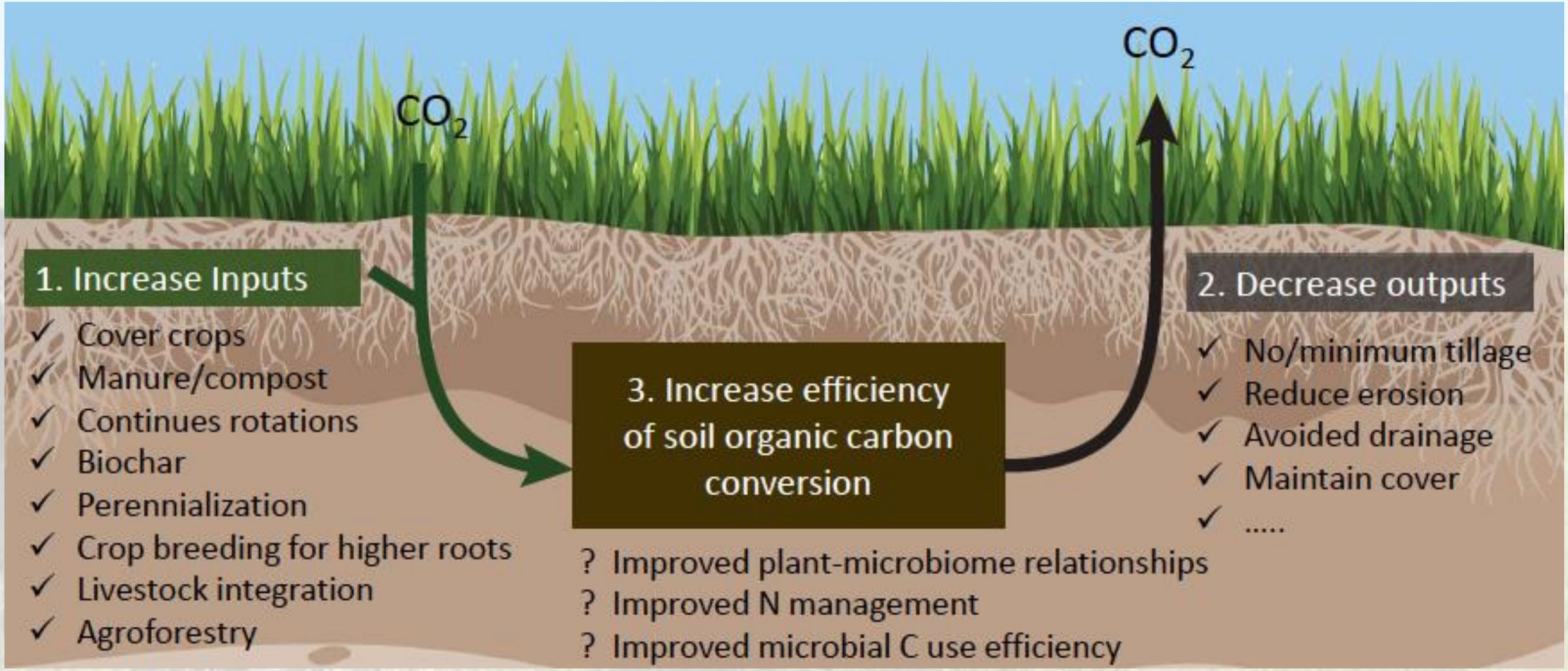
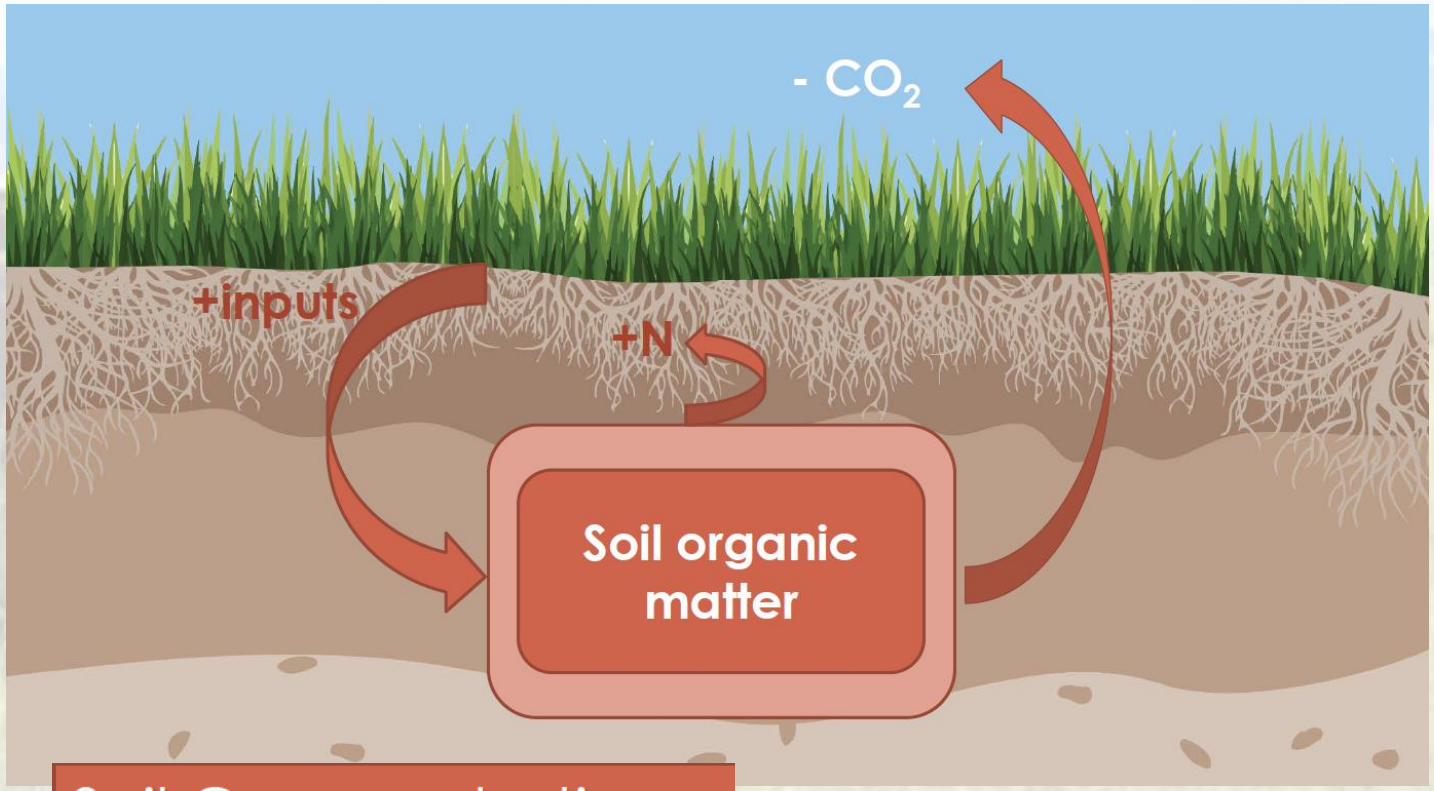


The soil carbon dilemma:

Accrual vs turnover to regenerate fertility

Can we increase soil carbon storage while also increasing nutrient mineralization and natural provision of fertility?

Janzen, 2006



Soil C sequestration and soil health goals need to merge!

Not all soil carbon is made equal

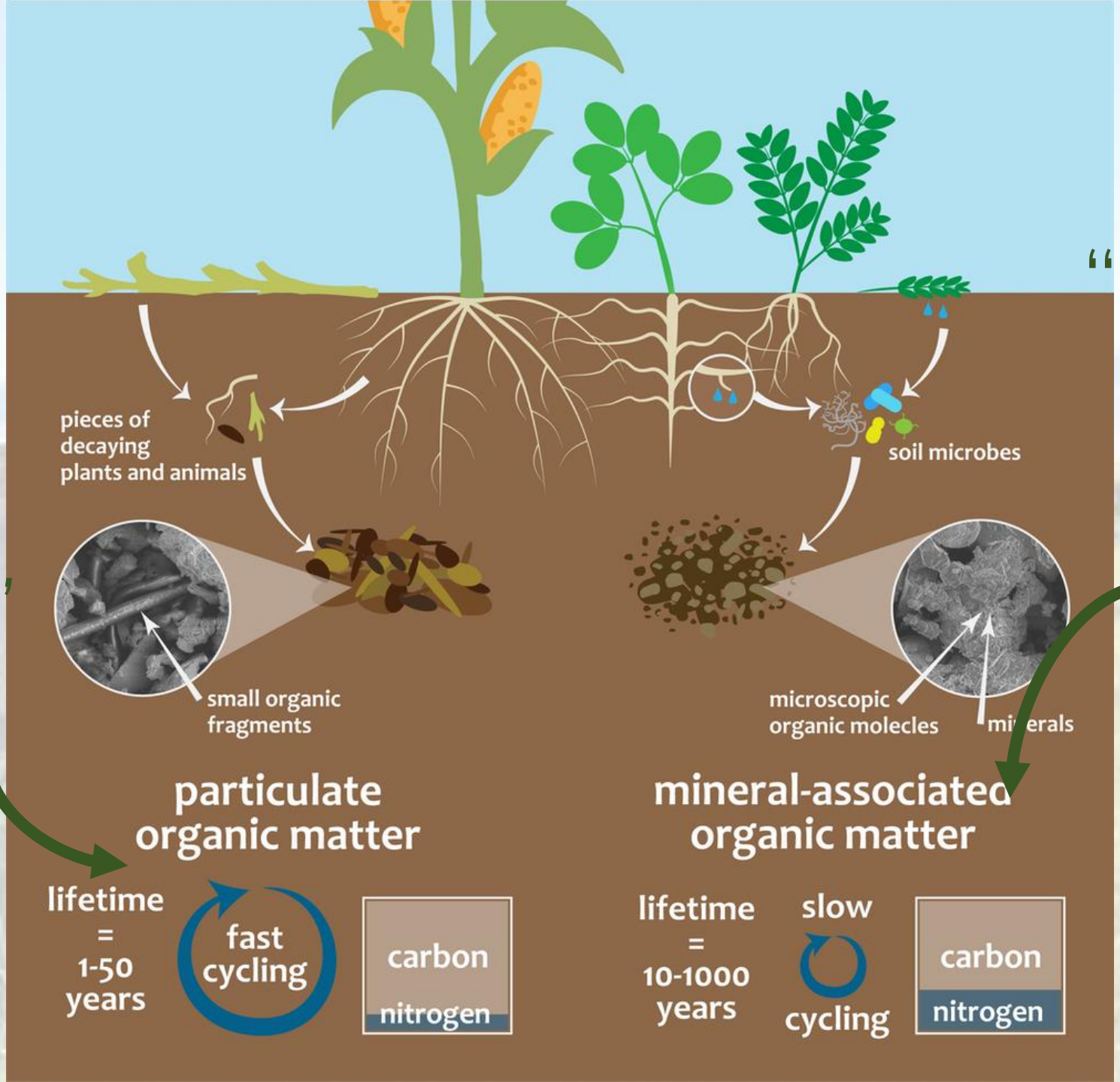
Particulate
Organic **M**atter

Mineral-**A**ssociated
Organic **M**atter

Soil Carbon

MAOM
=
"Protected"

POM
=
"Vulnerable"



Source:
Dr. Jocelyn Lavallee
https://source.colostate.edu/soil-carbon-is-a-valuable-resource-but-all-soil-carbon-is-not-created-equal/

Accounting of Soil Carbon

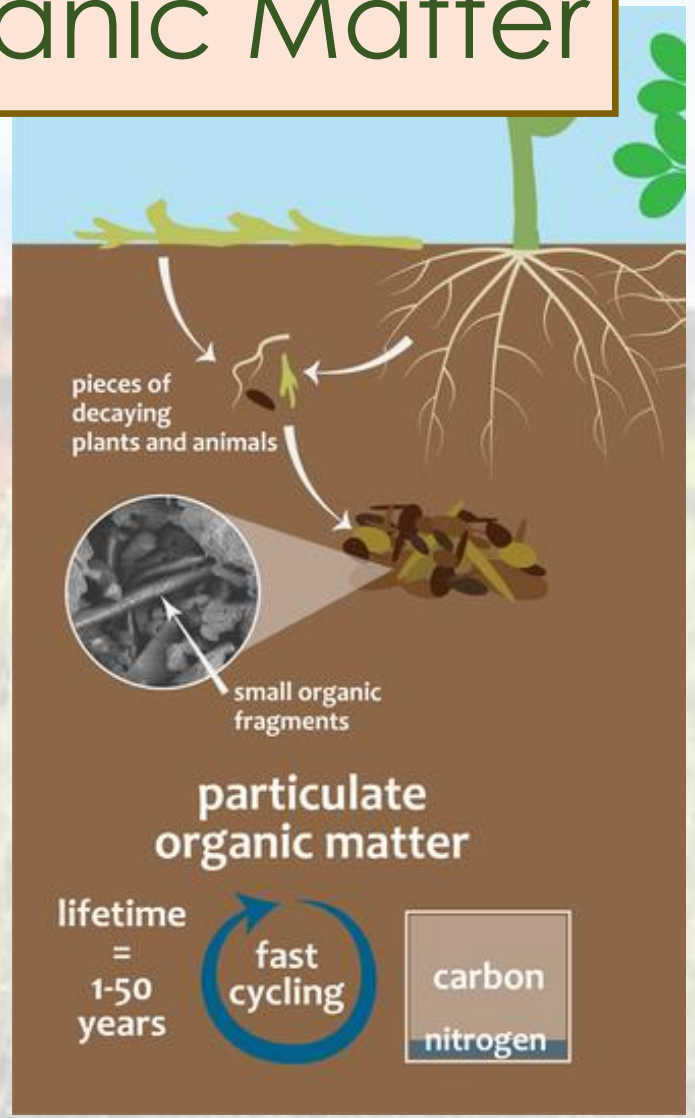
Soil Organic Matter

checking account

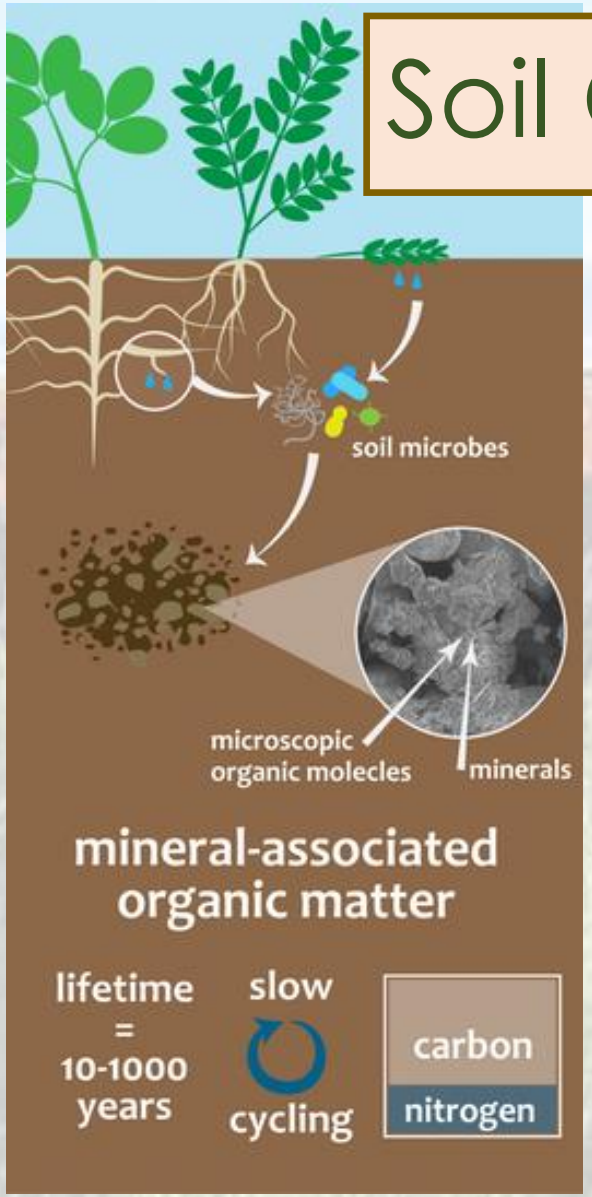
Particulate Organic Matter (POM)

"Vulnerable"

- Quickly replenished, but also quickly used
- Deposits: leaves, roots, and other decaying materials.
- Withdrawals: easily accessible to soil organisms, decomposed and returned to atmosphere within decade or so



Accounting of Soil Carbon



Soil Organic Matter

savings account

Mineral-Associated Organic Matter (MAOM)

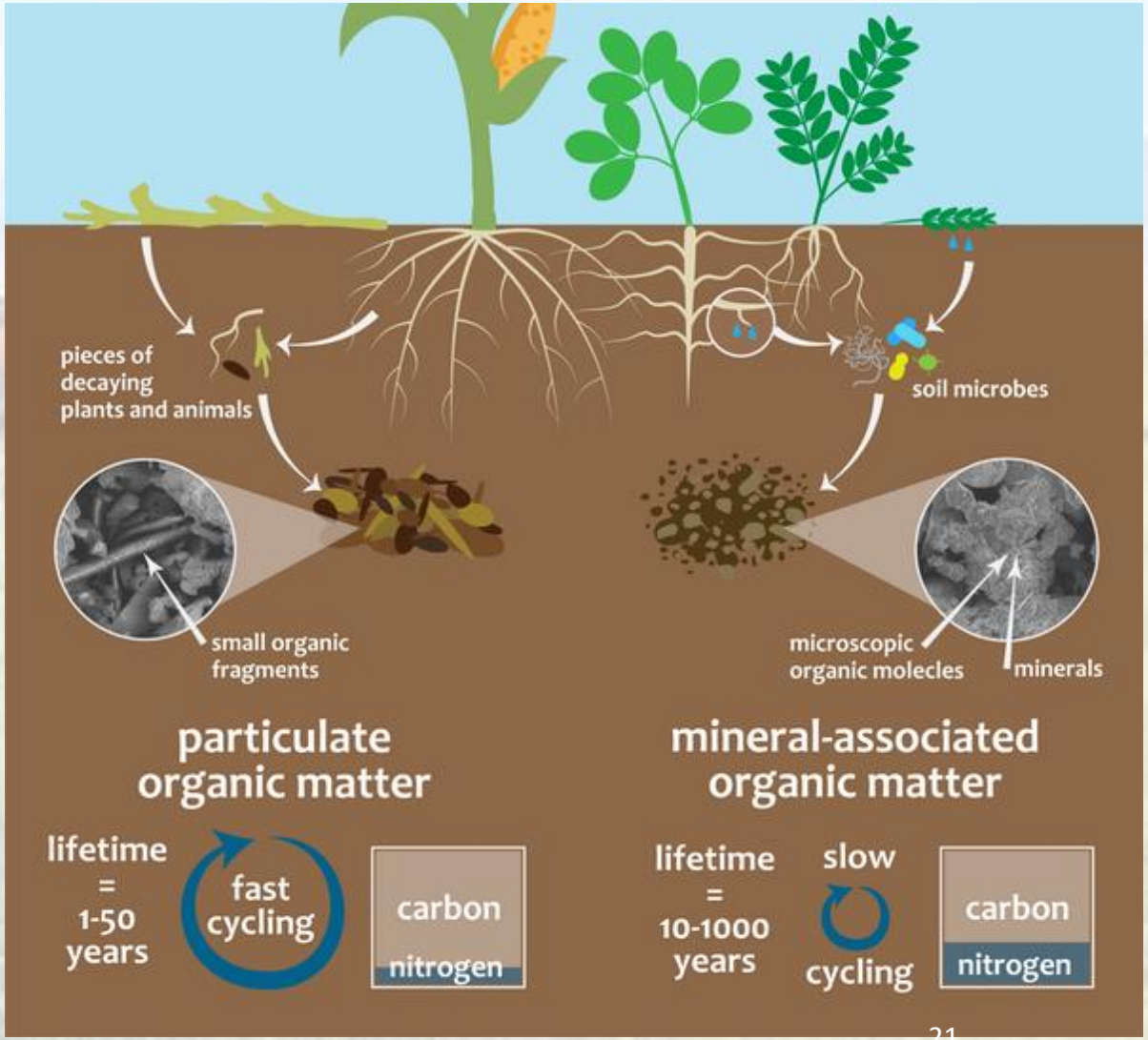
"Protected"

- Created slowly, but also slow to decompose
- Deposits: simple plant compounds and microbial waste
- Withdrawals: unless there is a disturbance (e.g. tillage, plowing) this carbon will take centuries or longer to decompose

Not all soil carbon is made equal

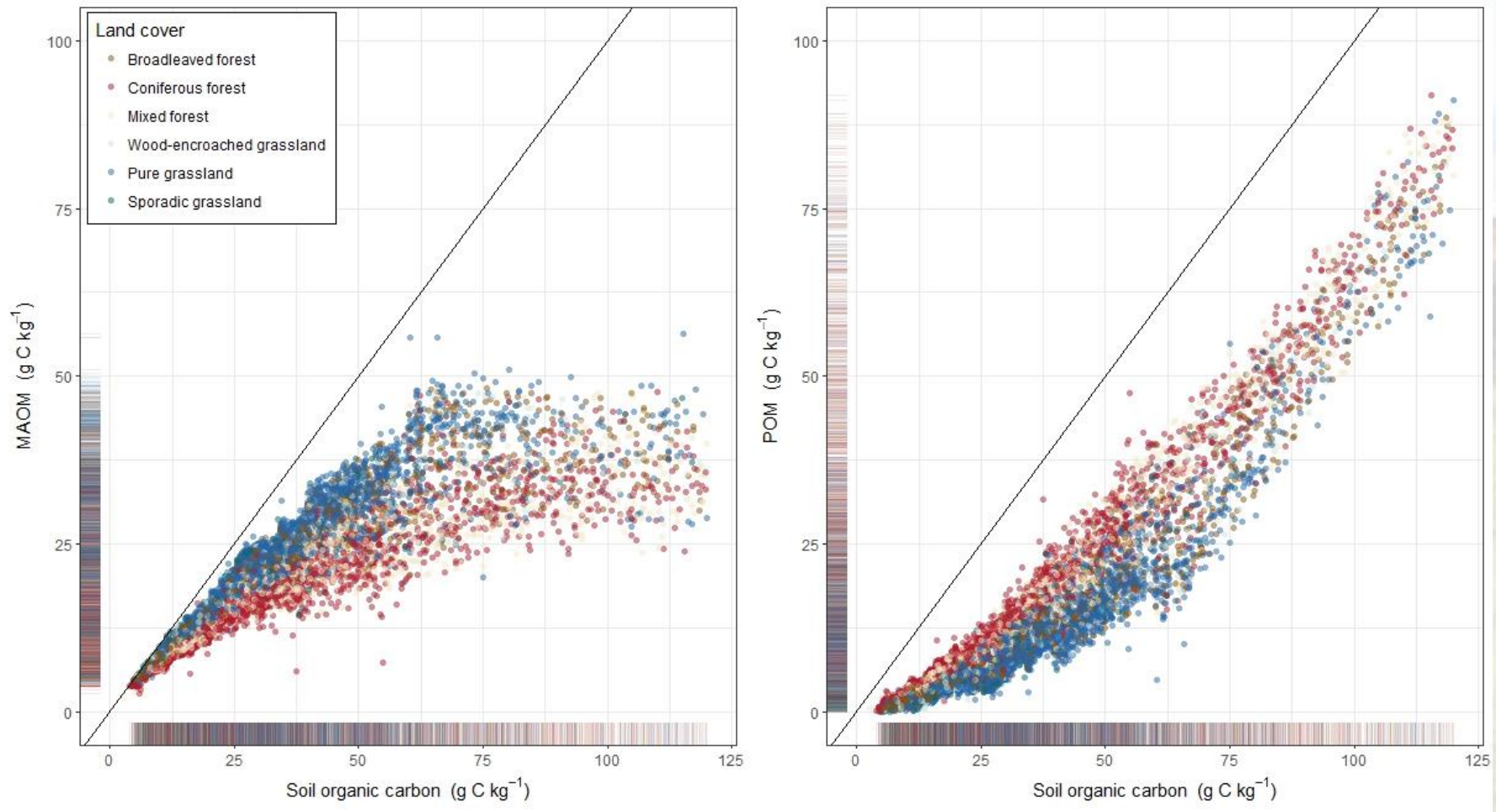
Separating carbon in POM from MAOM is important to assess:

- ✓ Vulnerability to disturbance
- ✓ Potentials for C sequestration
- ✓ Management strategies to accrue more and persistent carbon



Lavallee et al 2020
Cotrufo et al 2019

Soils do not have the same potential to sequester C



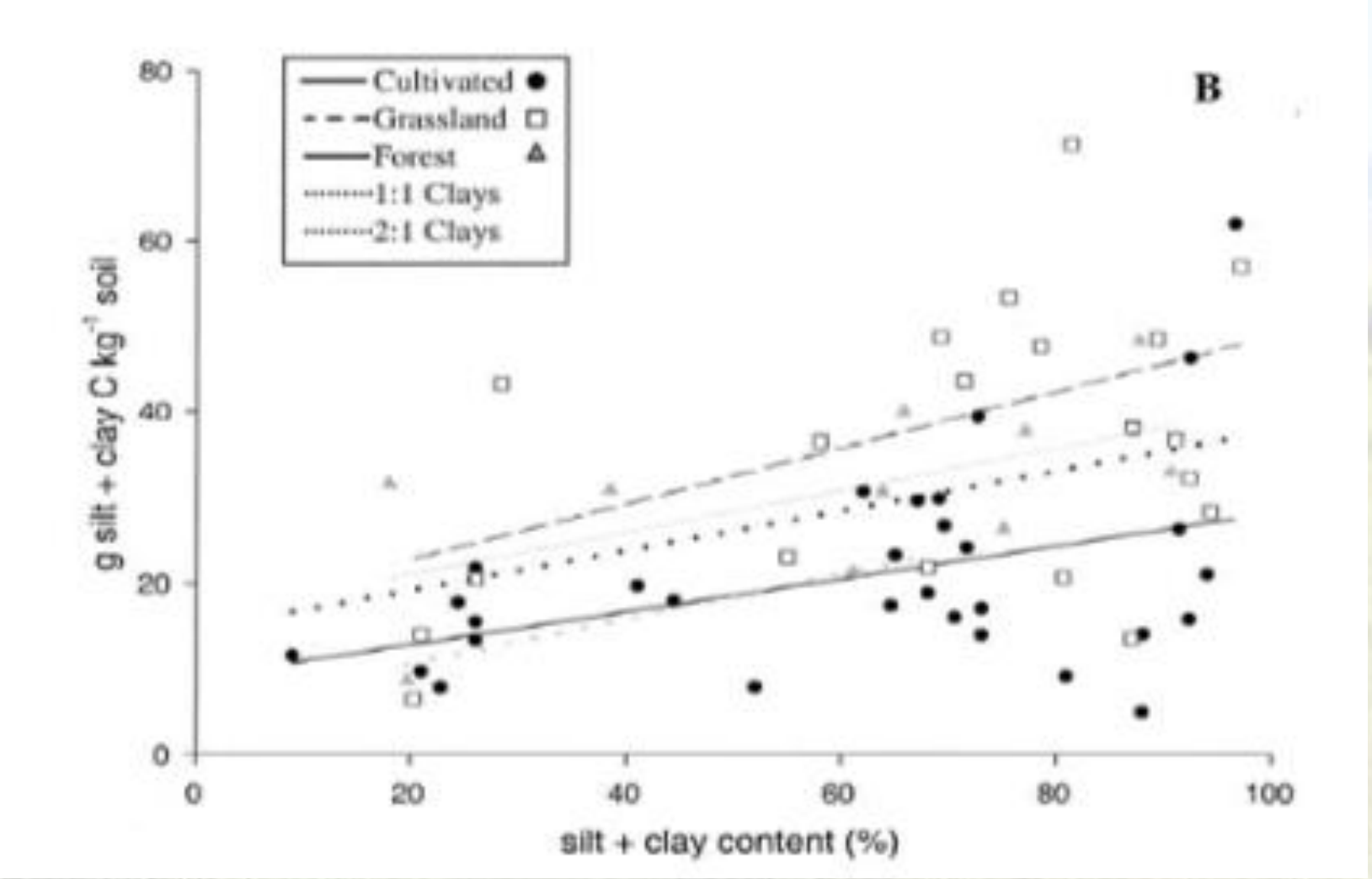
MAOM saturates while POM does not

Most soils are below saturation, especially in deeper horizons.

Saturation not a significant constraint to C accrual

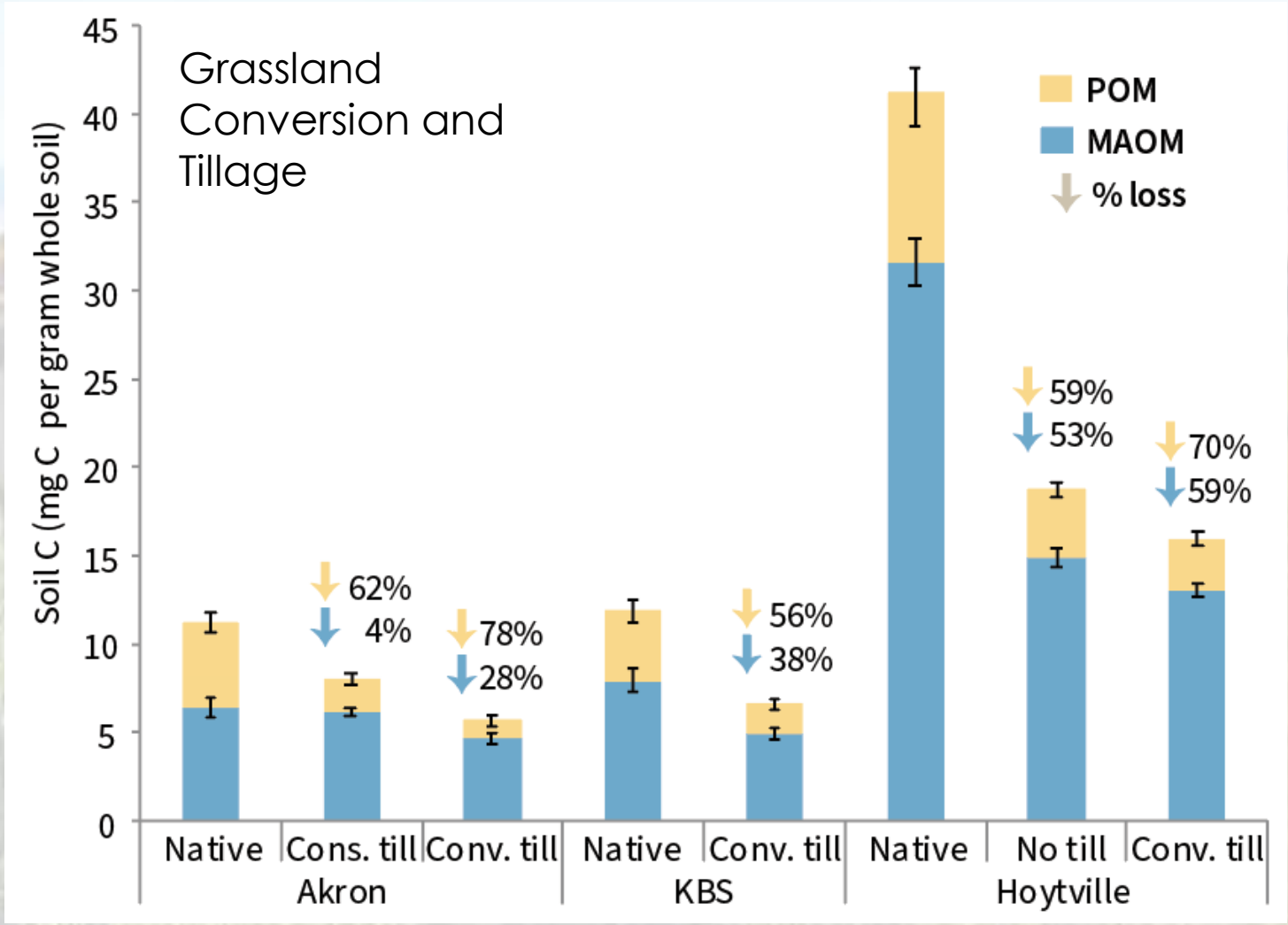
Cotrufo et al 2019

Carbon in MAOM dependent on soil texture



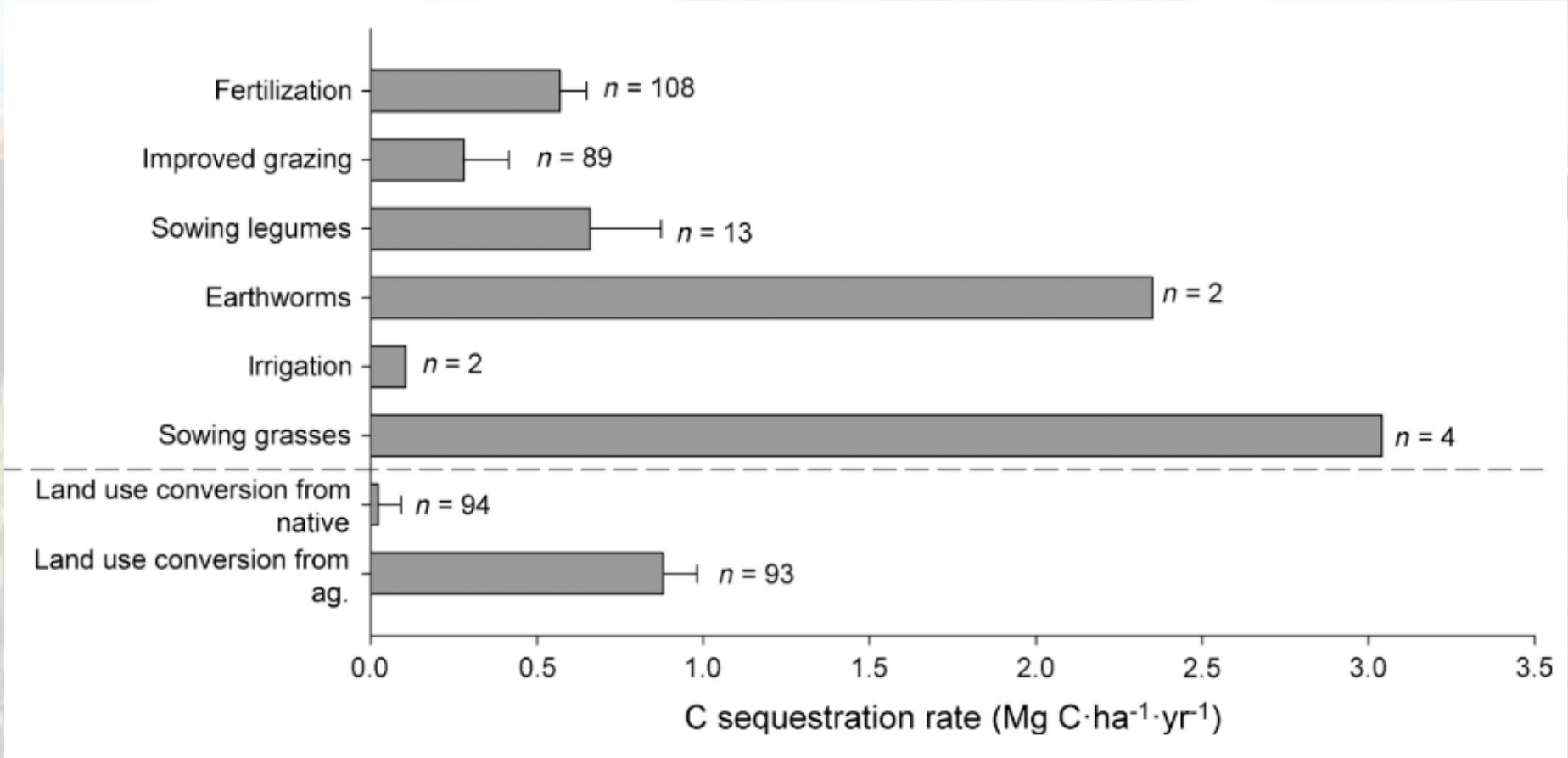
Six et al., 2002

Carbon is more vulnerable in POM than in MAOM



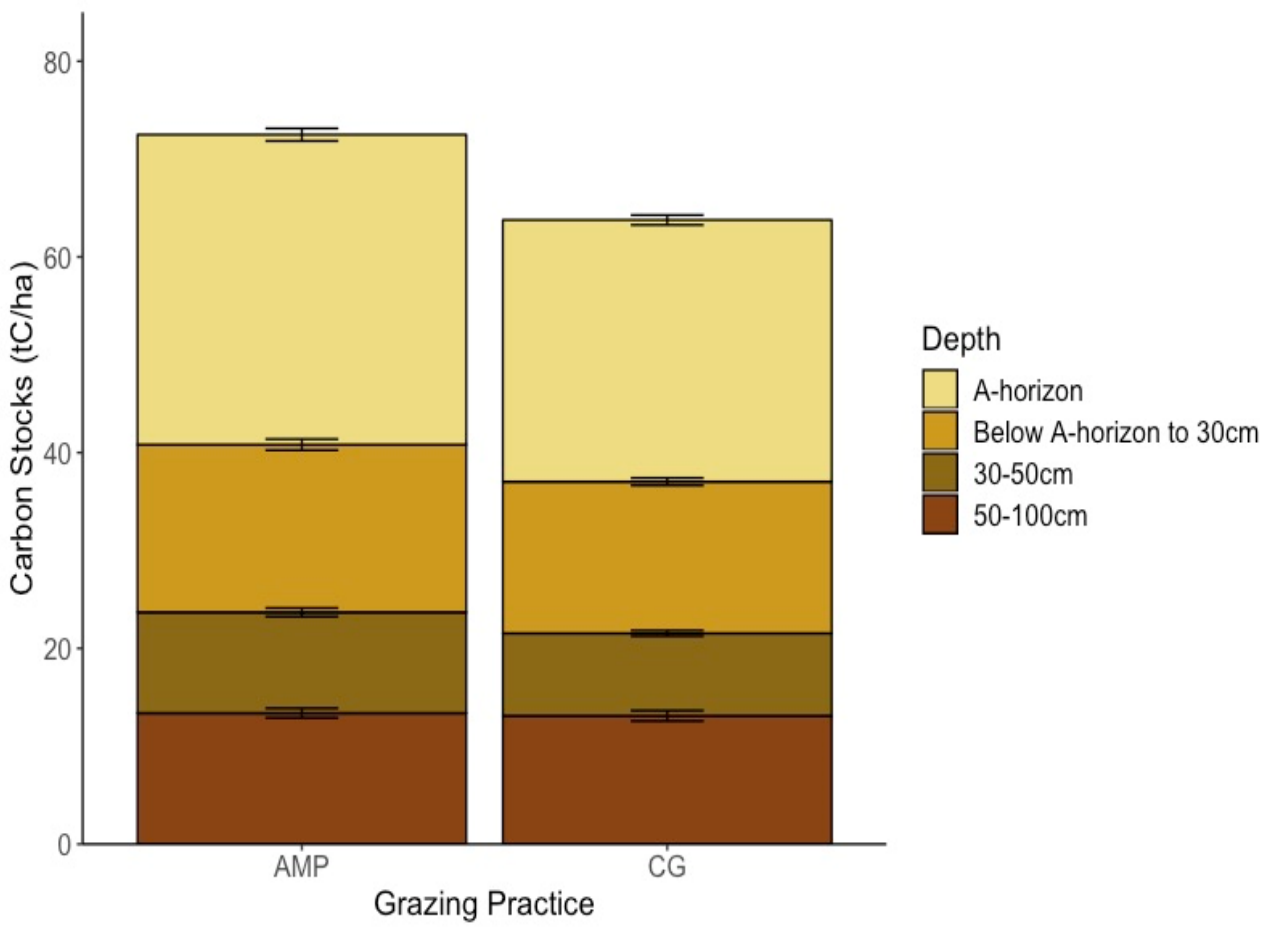
Lavallee et al 2019

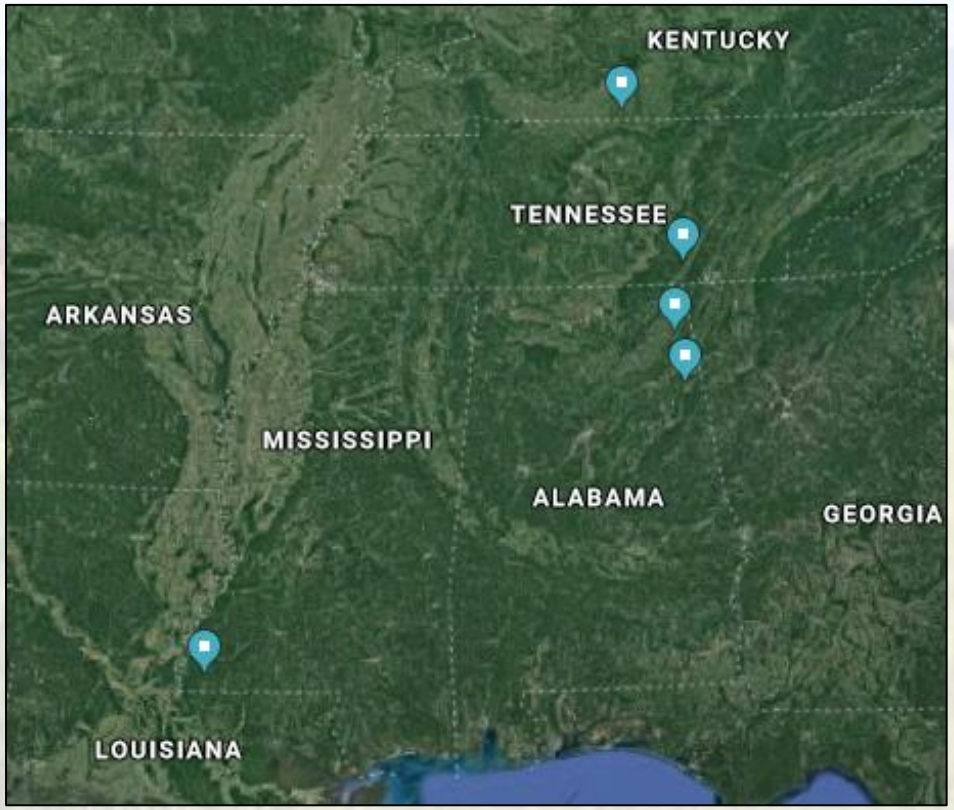
Improving grassland management has high potentials for soil C sequestration



Conant et al 2017

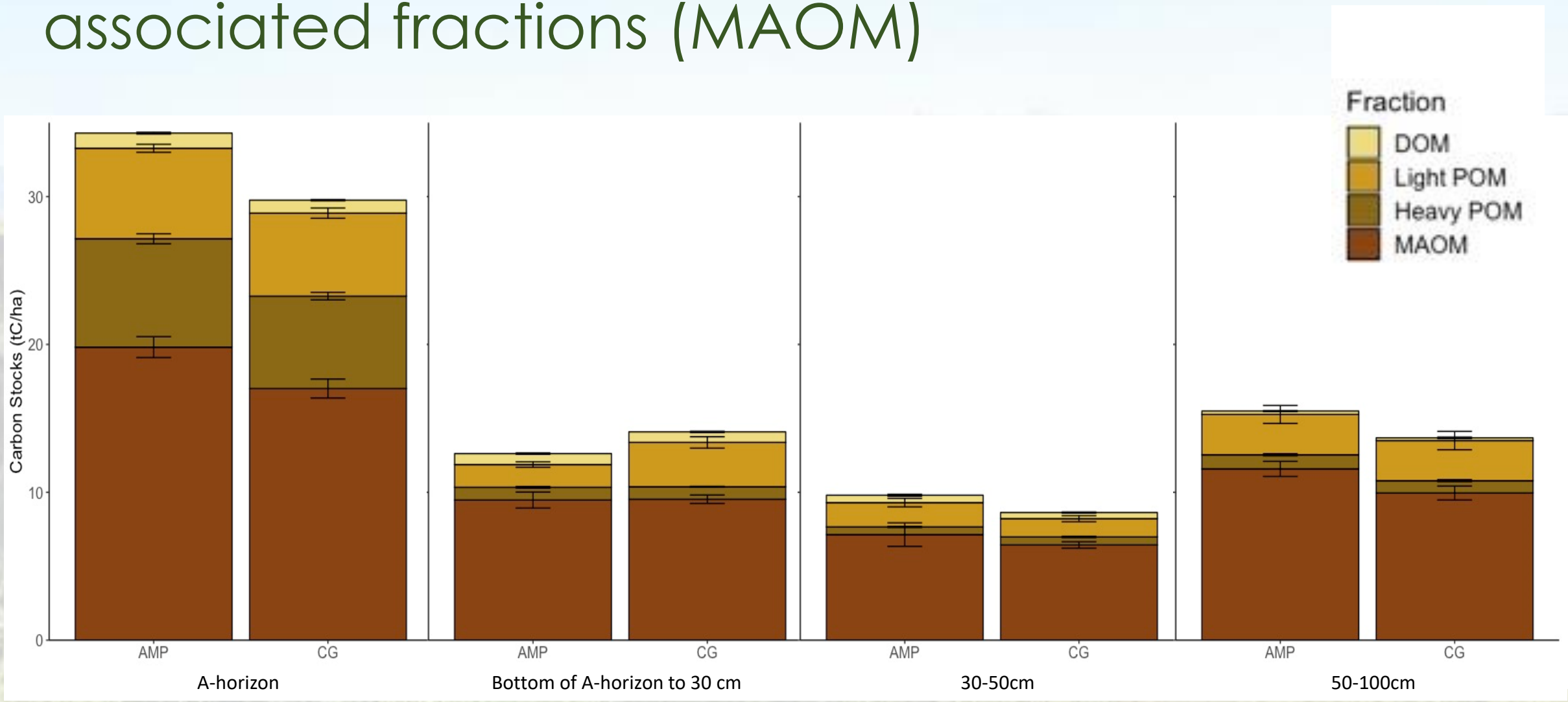
AMP grazing increases soil carbon and nitrogen stocks relative to continuous grazing along 1 meter depth profile





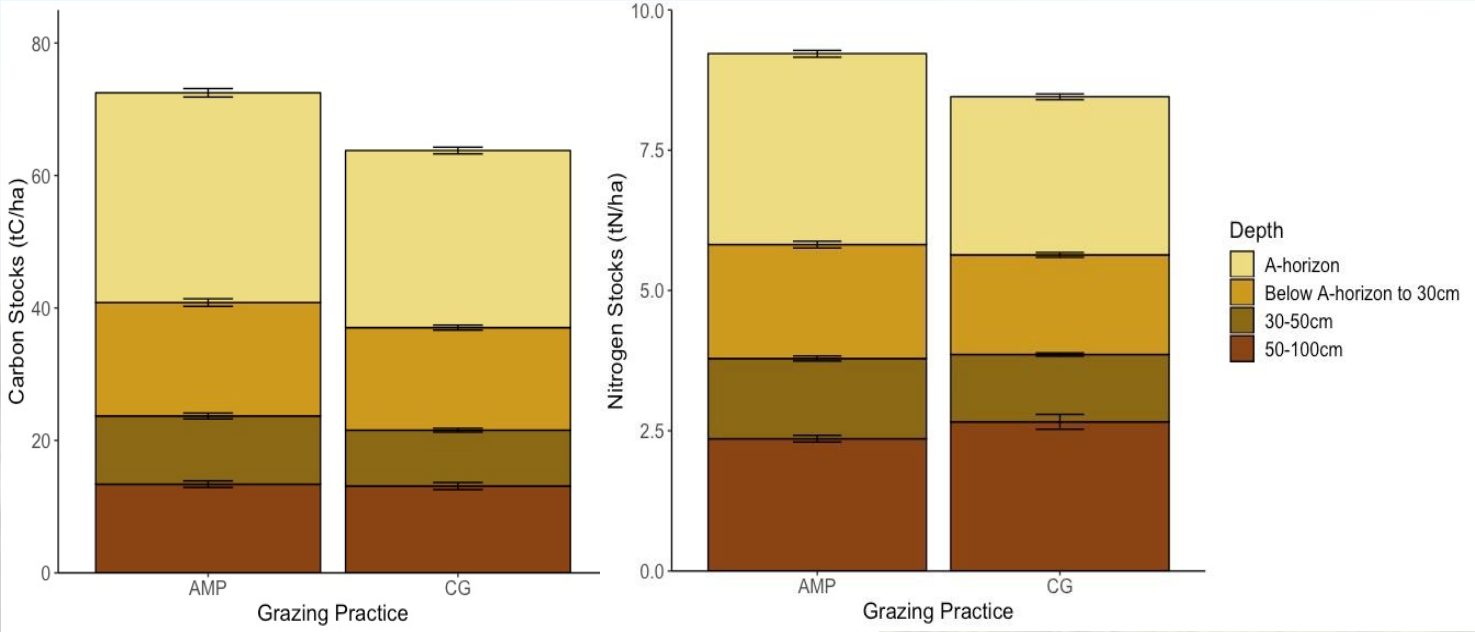
Mosier et al, in review

AMP increased distribution of C toward more persistent and less vulnerable minerally associated fractions (MAOM)



Mosier et al, in review

NITROGEN



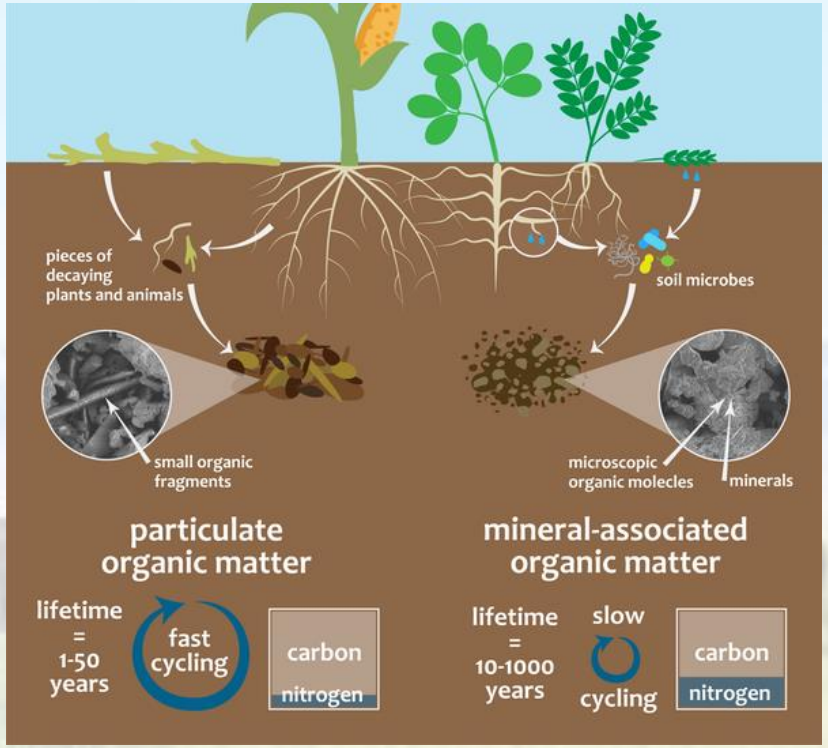
More N in these systems

More efficient SOM use

More persistent MAOM

NITROGEN

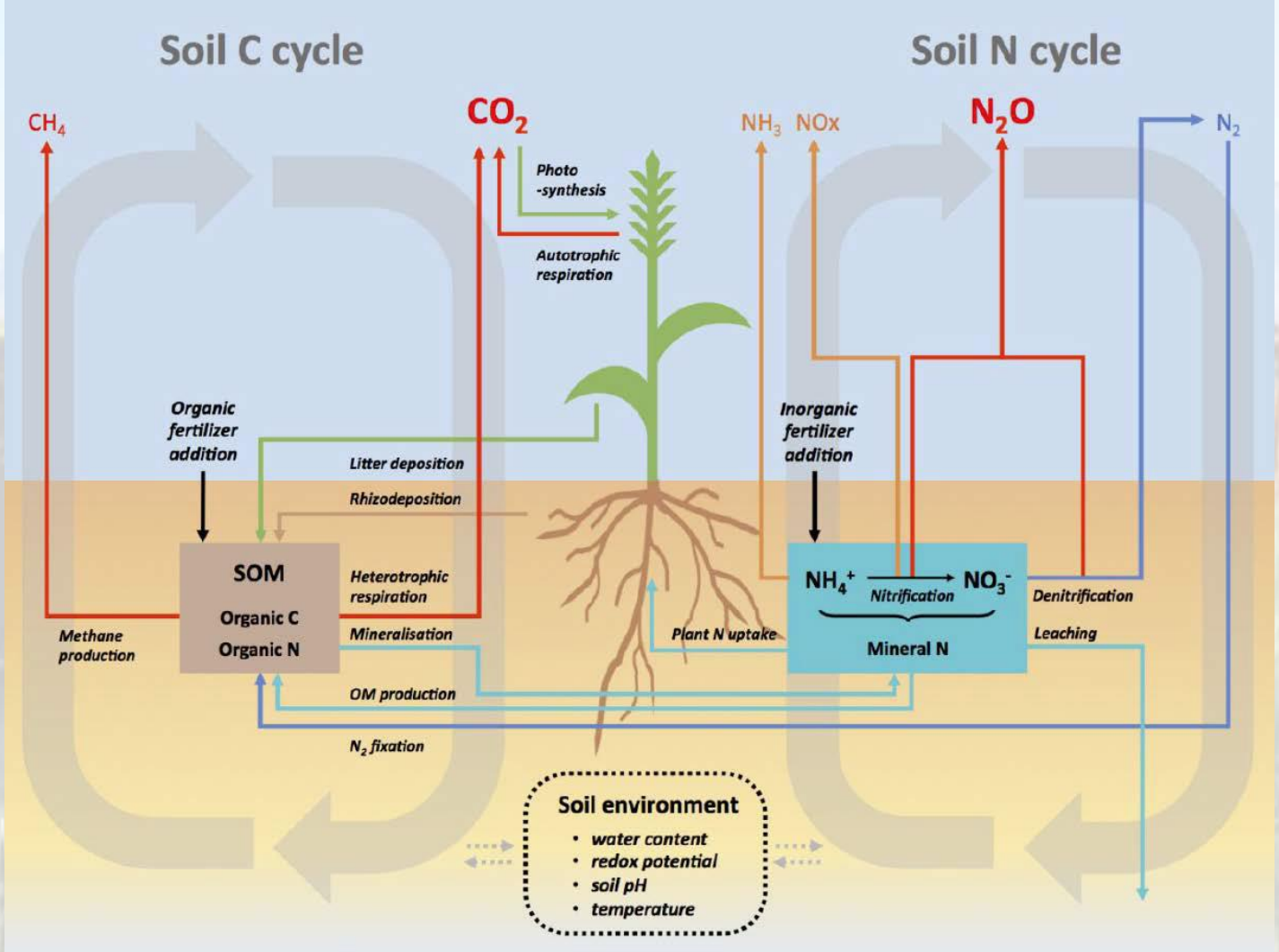
- Nitrogen is essential to sequester more C
  - We must quantify N in order to understand C sequestration potentials



MAOM C:N < POM C:N

More N in these systems → More efficient SOM use → More persistent MAOM

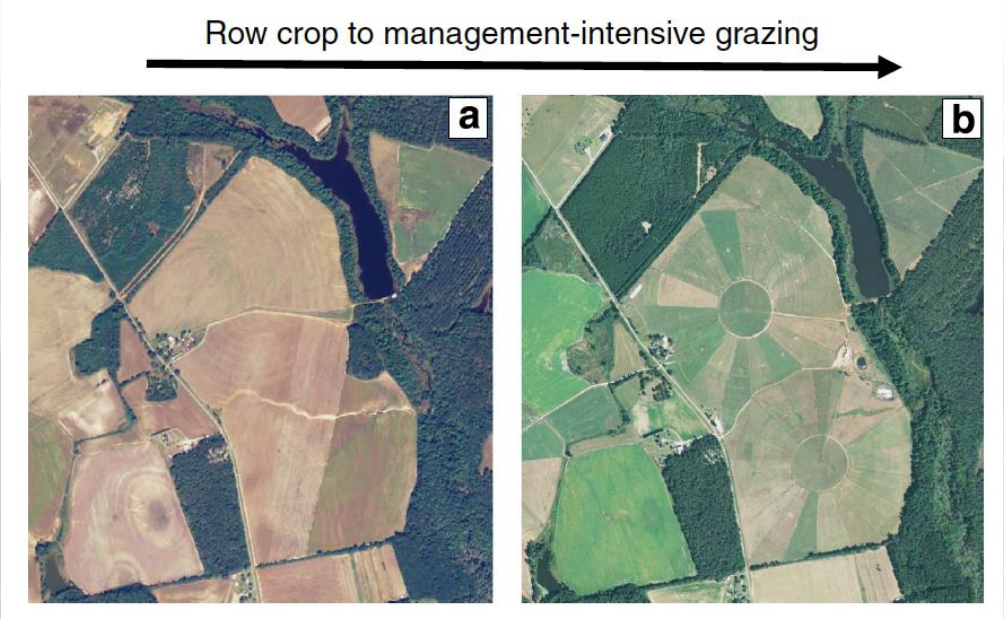
NITROGEN



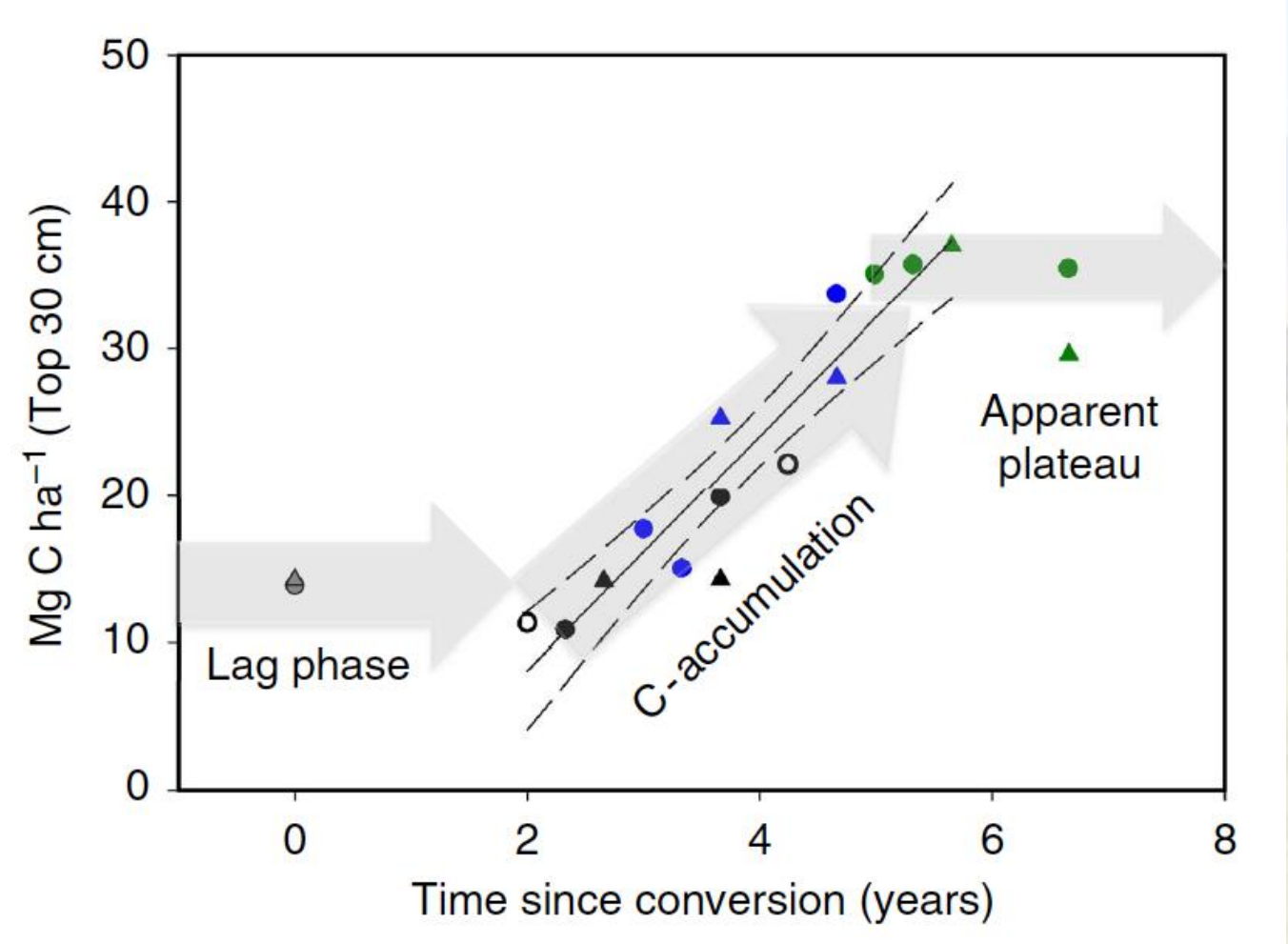
Carbon removal practices may result in N_2O emissions

Guenet et al 2020, Global Change Biology

Soil carbon rapidly increases with conversion from row crop to intensive grazing



Dairy Farms in Southeastern US (Georgia)



Machmuller et al 2015

Impacts of soil carbon sequestration on life cycle greenhouse gas emissions in Midwestern USA beef finishing systems

Paige L. Stanley[a,1], Jason E. Rowntree[a,*], David K. Beede[a], Marcia S. DeLonge[b], Michael W. Hamm[c]

Agricultural Systems 162 (2018) 249–258

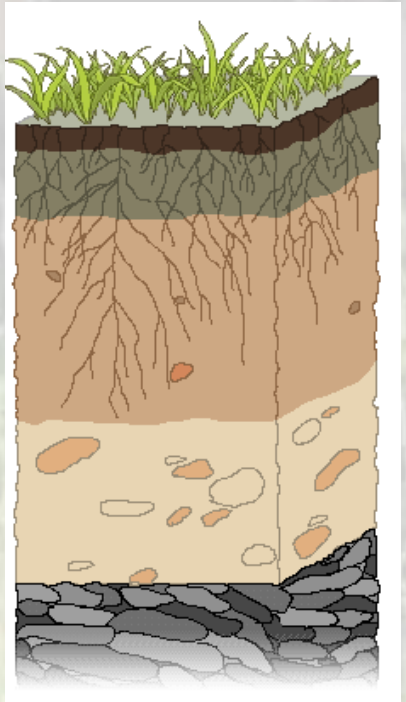
Soil type	Soil C sequestration (Mg C ha^{-1})			
	4-year increase	Mean annual increase	Mean	Std. error
Sandy	8.16	2.04	–	–
Sandy loam	15.18	3.79	–	–
Clay loam	19.75	4.94	–	–
All	14.36	**3.59**	3.59	0.84

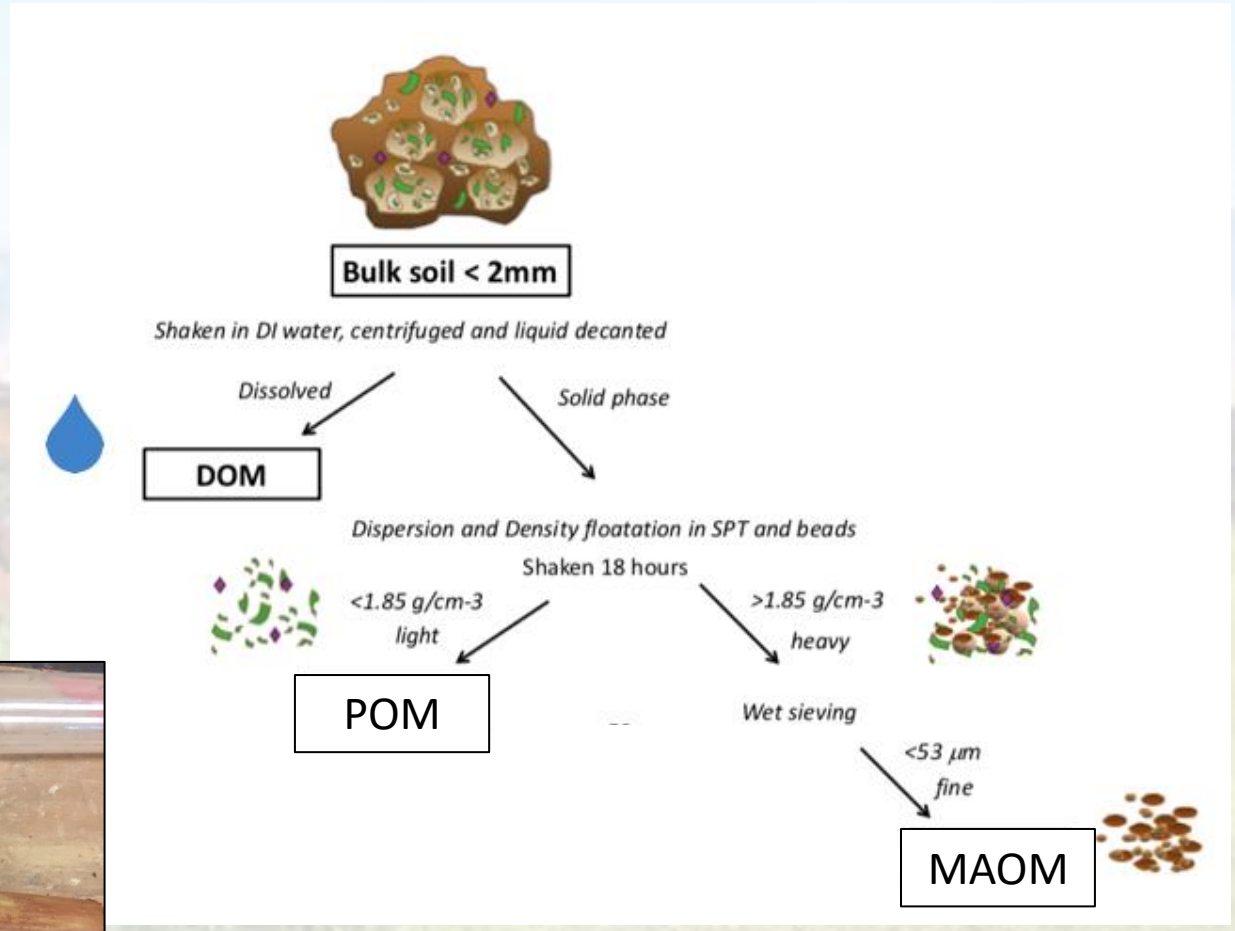
AMP Grazing in Upper Midwest (Michigan)

Found a 4-year C sequestration rate of 3.59 Mg C ha^{-1} yr^{-1} in AMP grazed pastures

Measuring POM and MAOM

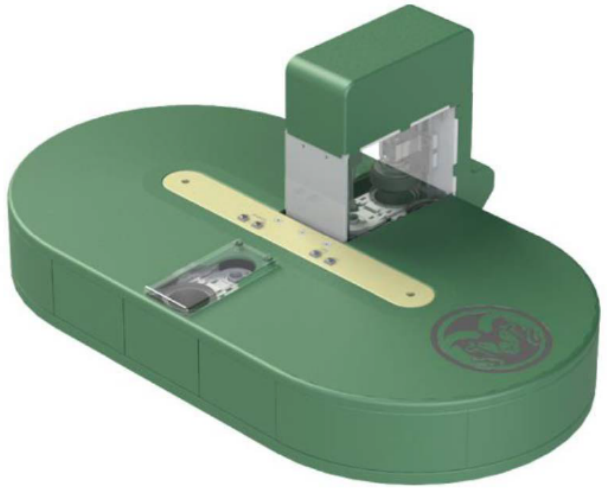
- Collect soil cores
- Split cores by horizon & depth
  - For A horizon (separate shallow from deeper)
- Separate fractions by size and/or density



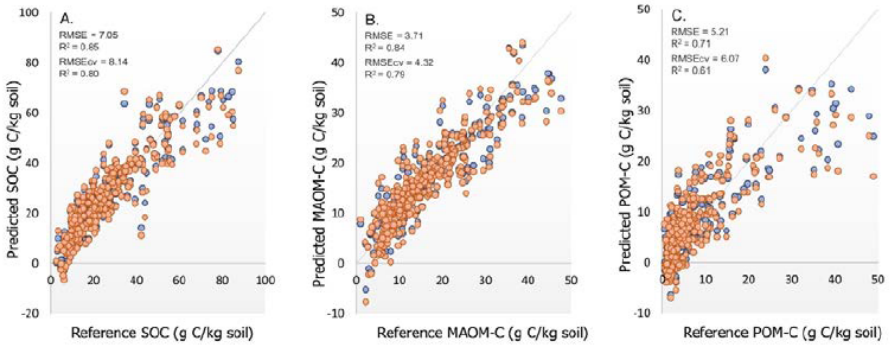


CSU Soil Testing Facility to offer POM & MAOM Analyses

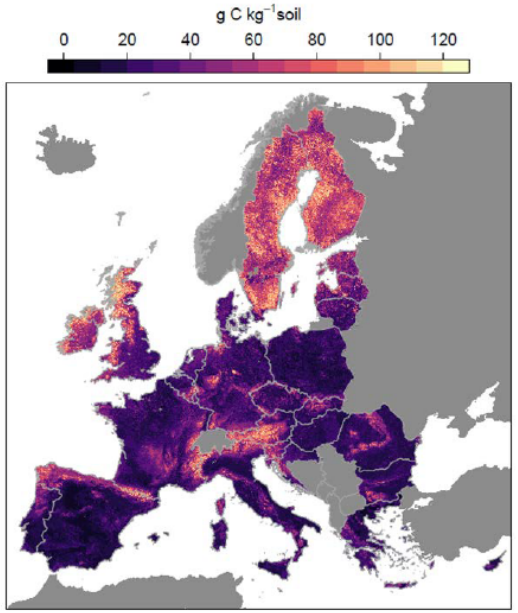
Need for high throughput soil C measurements in POM and MAOM



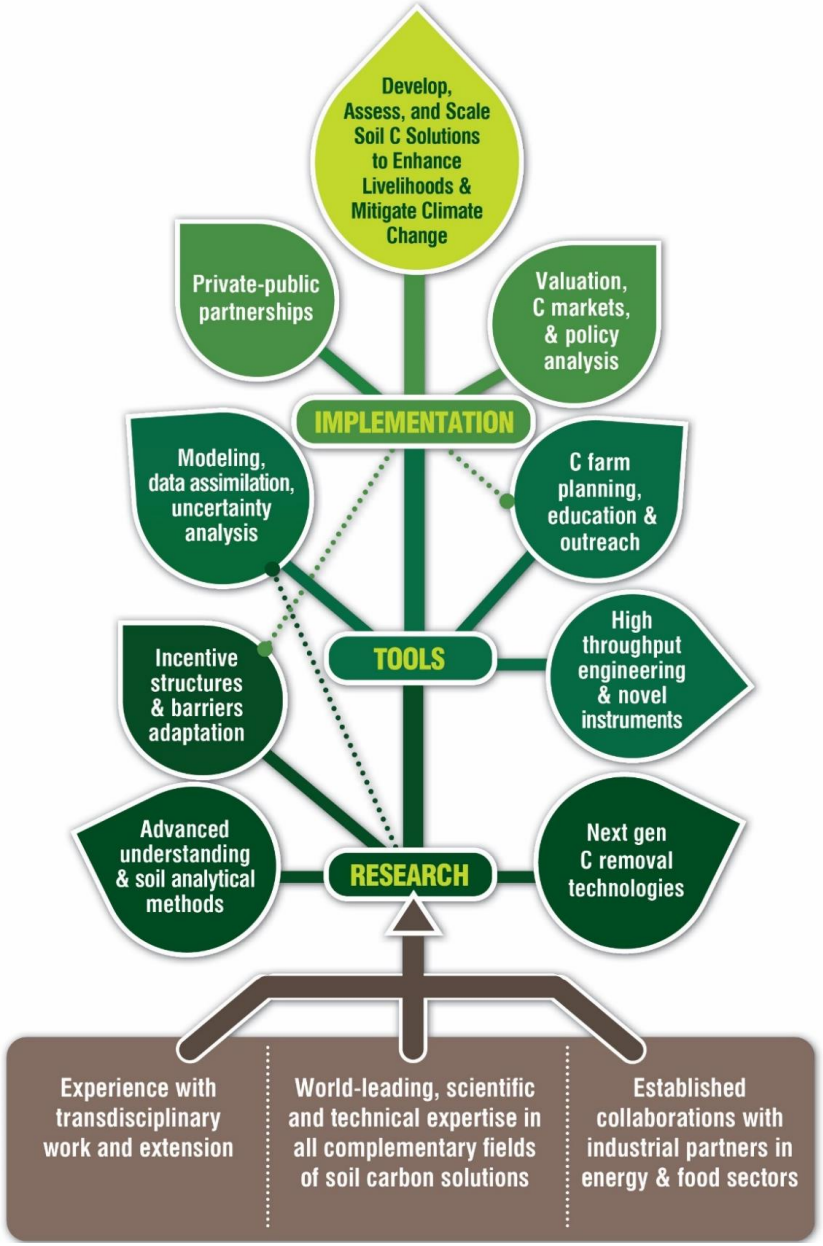
We are developing instruments for automatic processing of soil samples currently done manually



Use high-throughput soil C analytical approaches, such as FTIR (Ramirez et al.,in review)



AI techniques to estimate C and fractions at large scale



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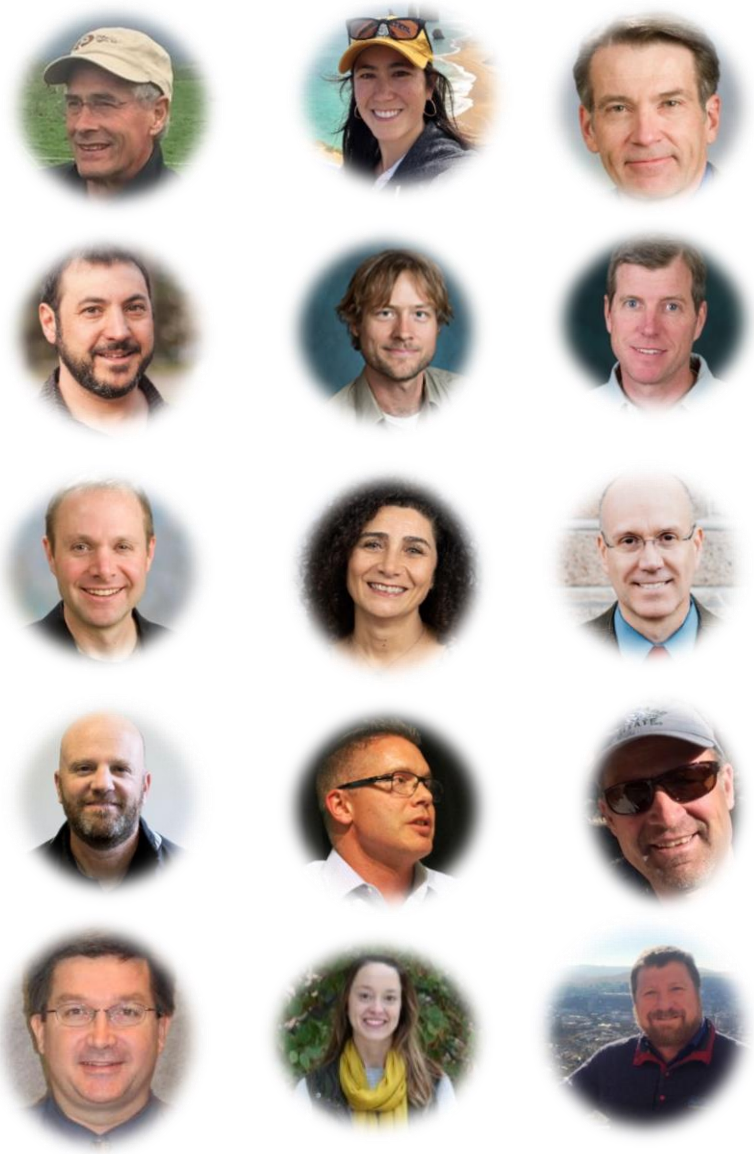

The Soil Carbon Solutions Center:

Enhancing livelihoods and mitigating climate change through cutting-edge research, tools, and implementation

Colorado State University

Key Takeaways

1. Grazing management has the potential to enhance soil carbon sequestration

2. Soil carbon is partitioned into two pools: MAOM *(the savings account)* and POM *(the checking account)*

3. Grasslands accumulate more of their organic matter as MAOM, while forests accumulate more of their organic matter as POM

4. While MAOM saturates because of physical constraints (*e.g.*, amount of clay in soil), POM can continue to accumulate carbon

Questions?

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