Musings on Carbon Farming

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Monroe County Climate Change Task Force
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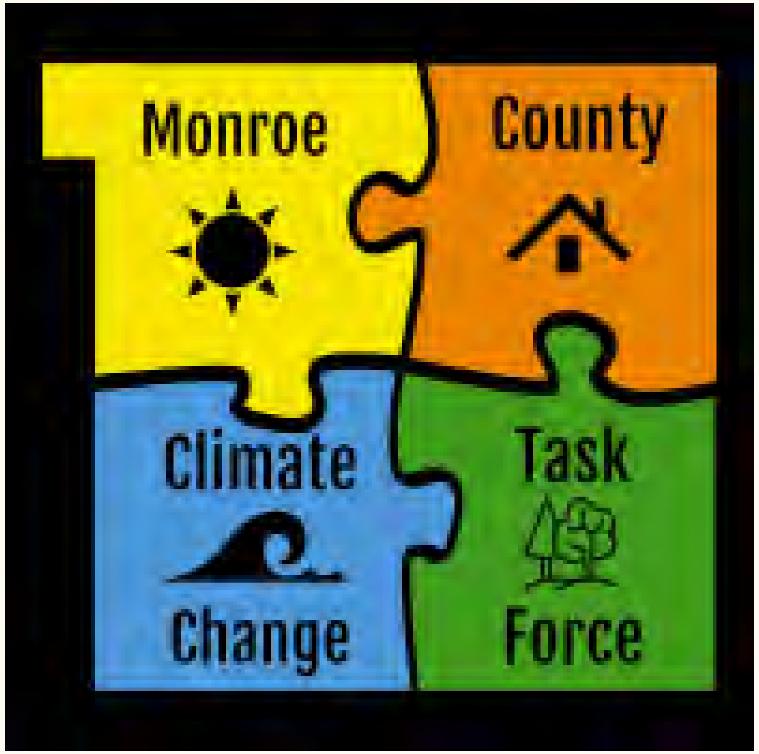
"It ain't what you don't know that gets you into trouble.
It's what you know for sure that just ain't so."

Mark Twain


Ron
Mark
IMBA
JOIN
MOUNTAIN

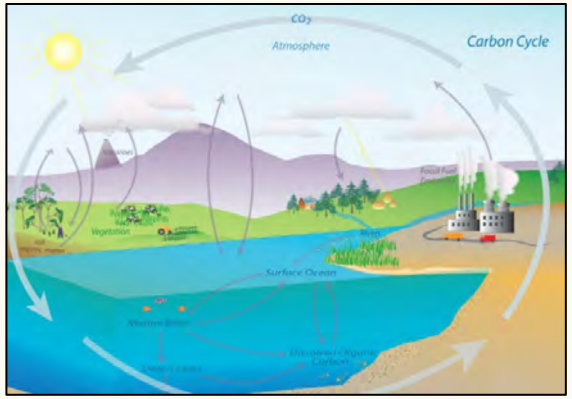
All Agriculture is Defined by Place

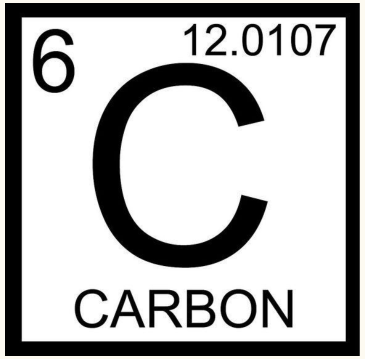


Accordingly, climate mitigation solutions must by tailored to location conditions

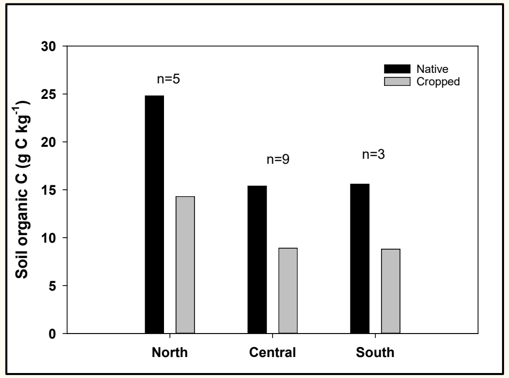
Main Points

- Carbon cycling plays an important role in ecosystem processes.
- For soil carbon to increase, carbon inputs must exceed outputs.
- Most soils have the capacity to store additional carbon, but…
- There are many factors that need to be considered to ensure agriculture is a net GHG sink.





Carbon Inputs > Carbon Outputs



NGPRL Cropping Systems Evaluation

Global warming potential

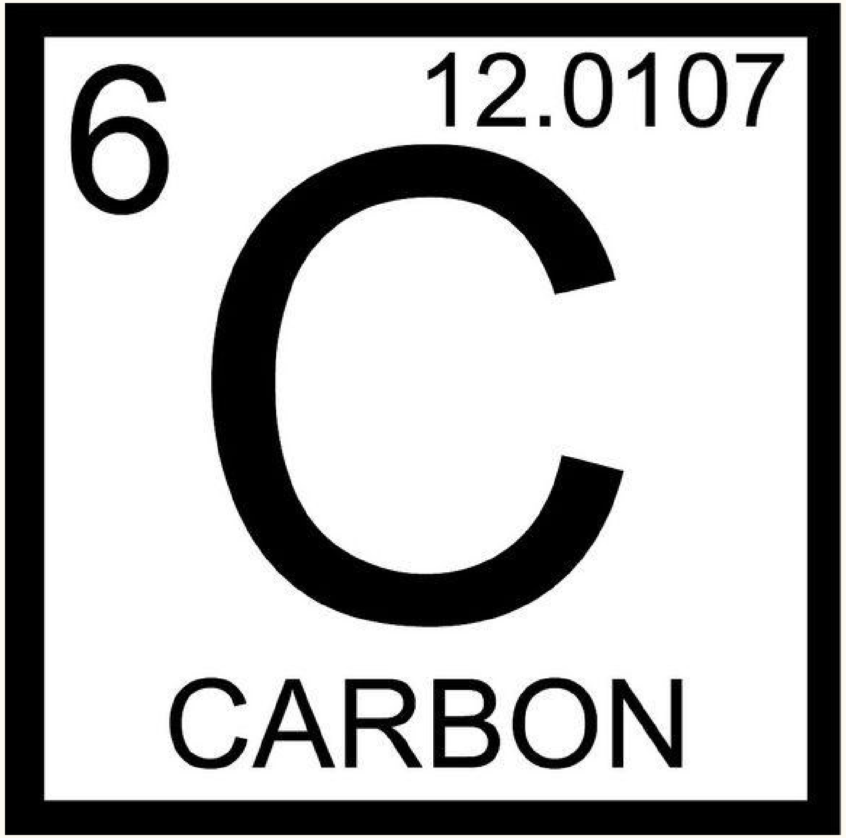
Factor	Spring wheat - Fallow	Continuous spring wheat	Spring wheat - Safflower - Rye
	---------- kg $CO_{2equiv.}$ ha^{-1} yr^{-1} ----------		
Seed production	21 b†	42 a	47 a
Fertilizer production	66 c	238 a	171 b
Pesticide production	112	82	99
Field operations	93 c	143 a	128 b
SOC change	69	-205	-1244
CH_4 flux	-19	-11	-14
N_2O flux	479	1658	799
Net GWP	**822**	**1948**	**-14**

†Negative numbers imply C uptake. Means in a row with unlike letters differ ($P \le 0.05$)

Liebig et al. (2019)

Carbon

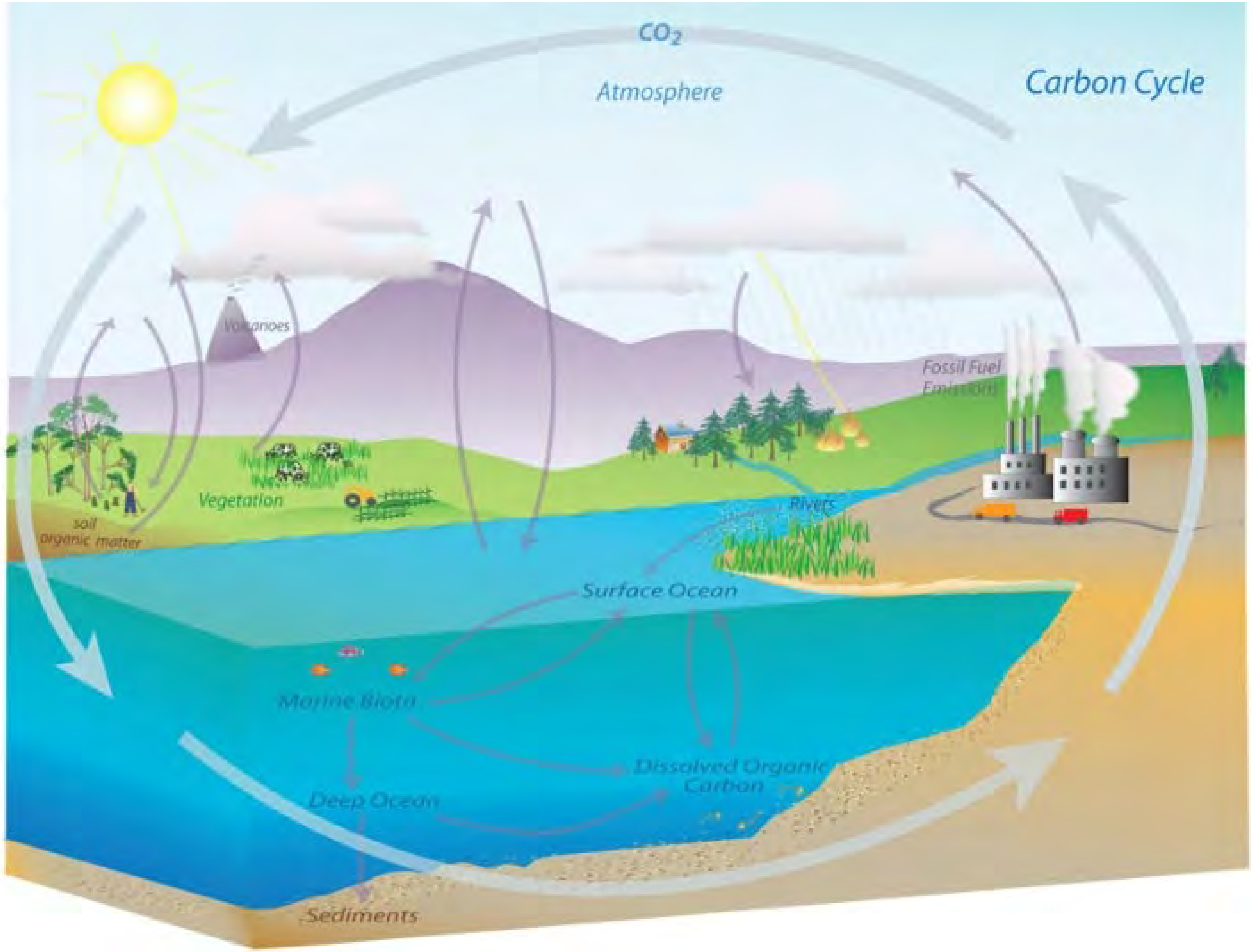
- Foundational element of life
- Binds with oxygen, hydrogen, nitrogen, phosphorus, and sulfur.
- Stocks of carbon include sedimentary rocks, oceans, soils/vegetation, and the atmosphere.



The Carbon Cycle

It’s all a matter of scale

Global Scale



NOAA (2019)

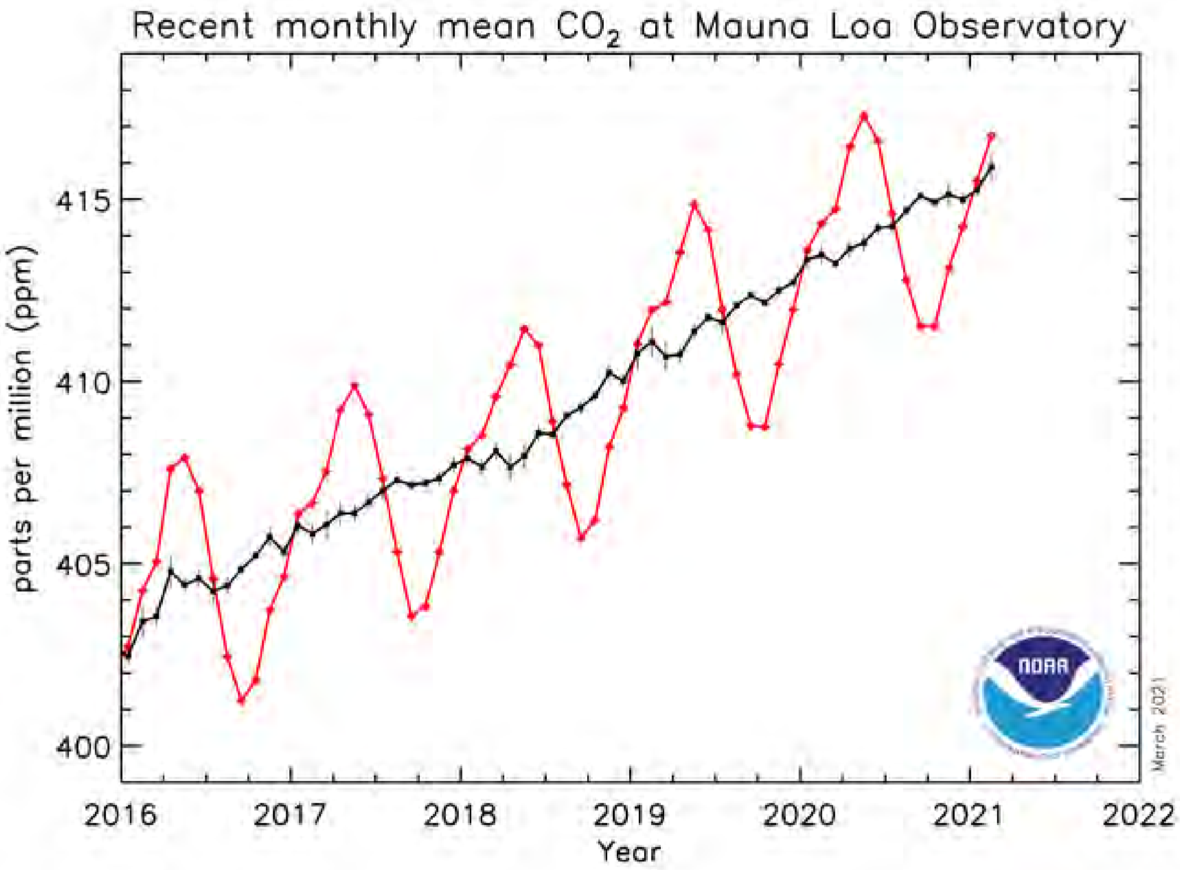
Carbon Stocks

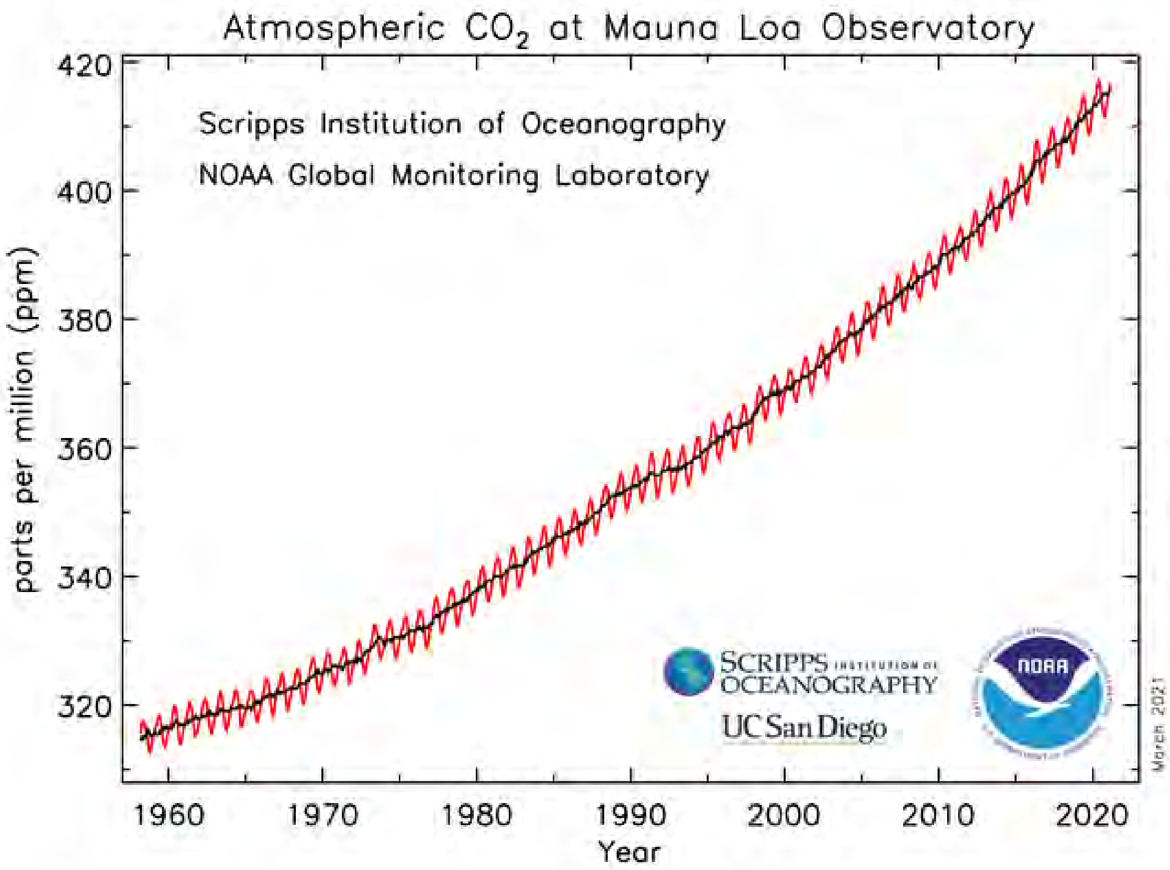
Major categories at global scale

Category	% of total
Water (deep)	80
Soil	5
Permafrost	4
Ocean sediments	4
Oil, gas, coal	3
Water (surface)	2
Atmosphere	2
Vegetation	1

SOCCR2 Report (2018)

The Carbon Cycle
Dynamics and feedback

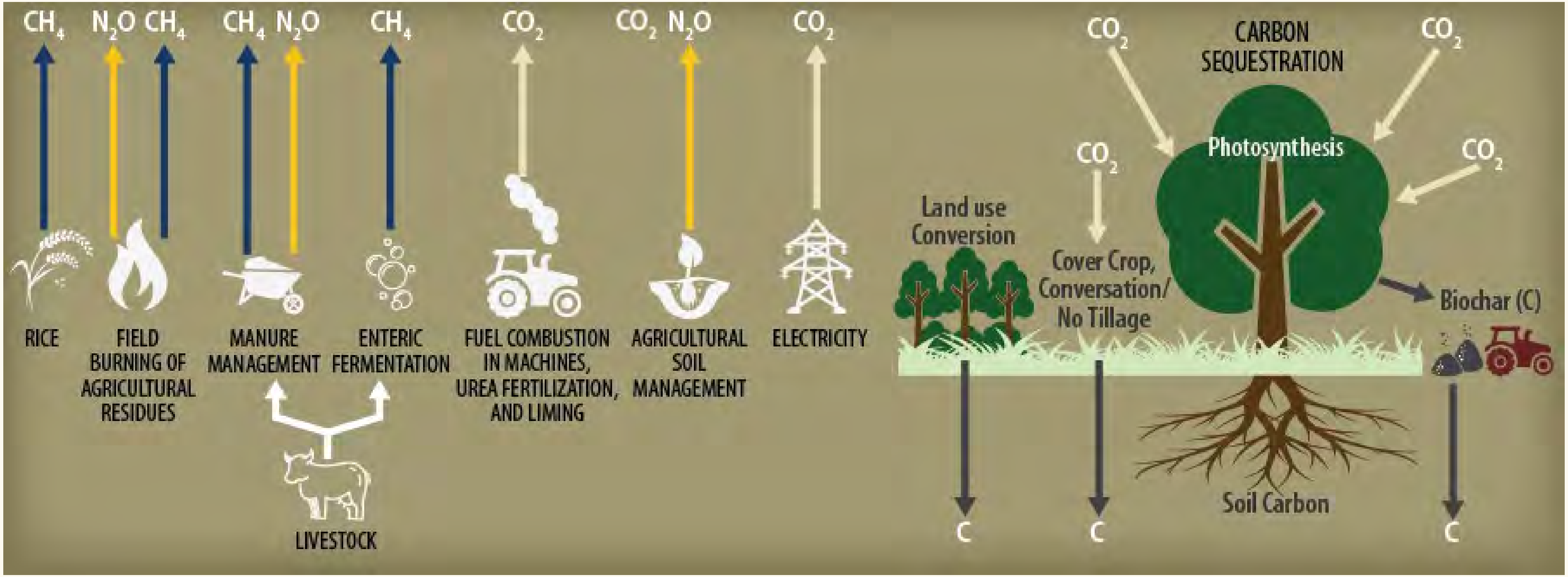




NOAA (2021)

Enterprise Scale

Many sources, a few sinks



CRS (2018)

Enterprise Scale

Are we a source or sink?

Really short answer…

- We're both.

Short answer…

- Across enterprises, we're a carbon sink but a greenhouse gas source.

Long answer…

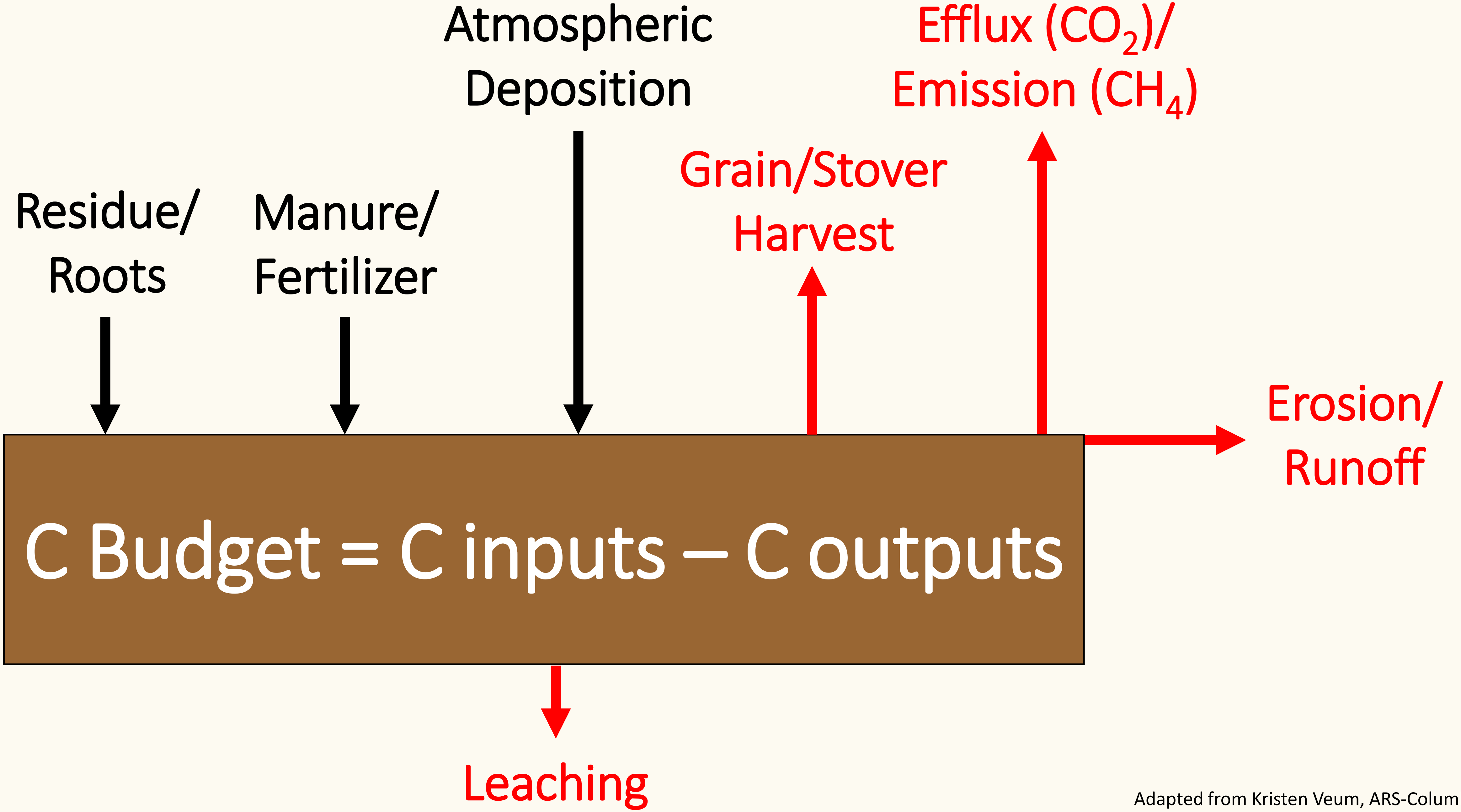
- It's inappropriate to generalize since every enterprise is unique.

Table 1. Emissions and Net Total Sequestration

Source	1990	2016	Avg. 2012-16
	($MMTCO_2$-Eq)		
GHG Emissions			
U.S. total, all sources	6,355.6	6,511.3	6,630.1
Agricultural activities	556.9	650.7	638.6
Direct emissions	522.0	611.8	596.9
Electricity-related	34.8	38.9	41.8
% agriculture, total	8.8%	10.0%	9.6%
Carbon Uptake			
U.S. net total, LULUCF	(819.6)	(716.8)	(728.3)
Cropland remaining cropland	(40.9)	(9.9)	(12.2)
% Cropland, net total	5.0%	1.4%	1.7%

Source: CRS from *EPA's Inventory* (Tables 2-12, 5-1, and 6-4). May not add due to rounding.

Field Scale



Adapted from Kristen Veum, ARS-Columbia

Field Scale (a mostly fictional example from Mandan, ND; 1994-2012)

AREA 4 SCD Cooperative Research Farm

Spring wheat-Fallow, No Tillage

	Variable	kg C/ha/yr
INPUTS	Stover	855
	Roots	265
	Manure/Fertilizer	0
	Deposition	19
	∑ C INPUTS	1139
OUTPUTS	Grain	554
	C Efflux/Emission	595
	Erosion/Runoff	10
	Leaching	0
	∑ C OUTPUTS	1159
	C INPUTS – C OUTPUTS	(20)

Spring wheat-Safflower-Rye, No Tillage

	Variable	kg C/ha/yr
INPUTS	Stover	1418
	Roots	375
	Manure/Fertilizer	0
	Deposition	19
	∑ C INPUTS	1812
OUTPUTS	Grain	537
	C Efflux/Emission	935
	Erosion/Runoff	0
	Leaching	0
	∑ C OUTPUTS	1472
	C INPUTS – C OUTPUTS	340

Unpublished data, ARS-Mandan [adapted from Liebig et al. (2019), Nash et al. (2018), Veum et al. (2018)]

Field Scale

Carbon Inputs > Carbon Outputs

- Roots/Rhizodeposits
- Residue
- Amendments
- Deposition

- Grain
- Residue
- Erosion
- Efflux/Emission (CO_2, CH_4)
- Leaching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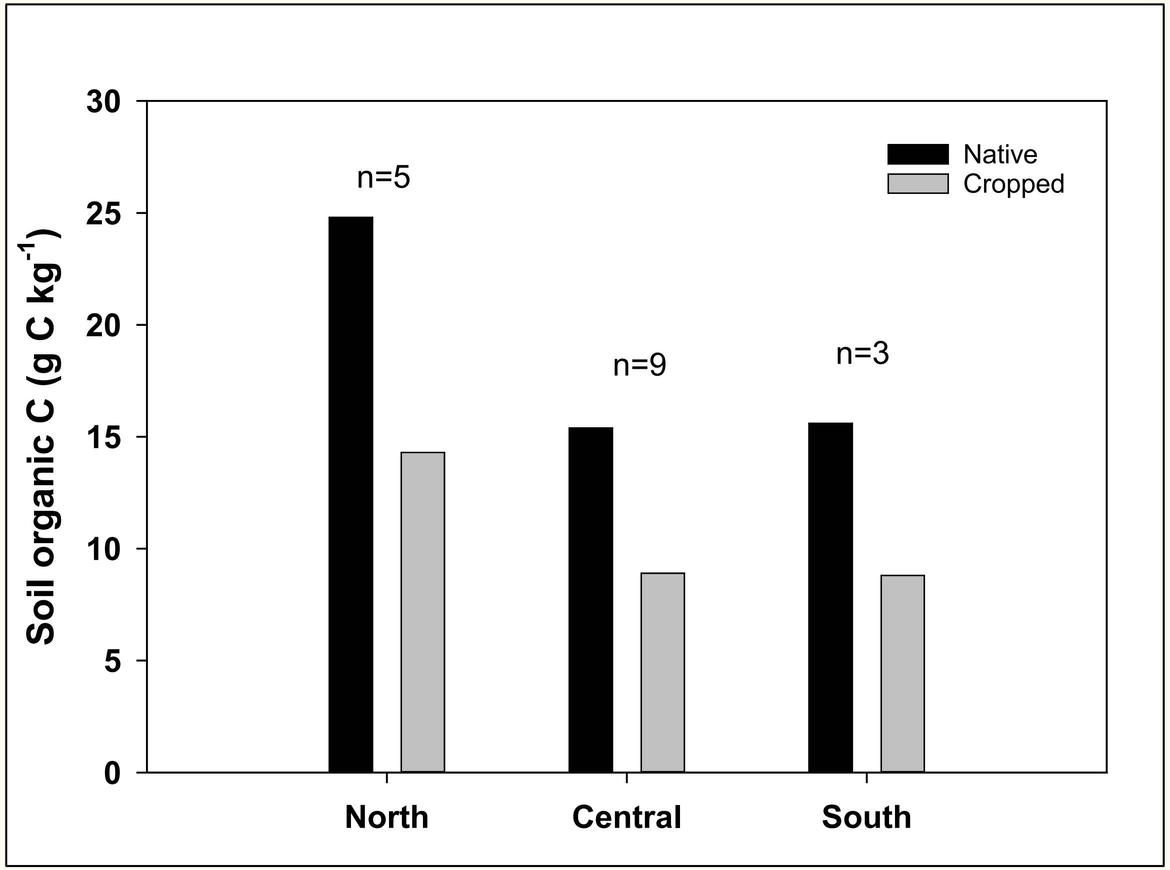
A354426
20-30

Cropping Effects on Soil Carbon

There's room for improvement

- 42% loss of soil organic C in cropland across Great Plains
- Represents approximately 1/5th of estimated soil organic C loss from cropland in US.

Soil C Loss from Conversion: U.S. Great Plains



Liebig et al. (2009)

Strategies to Increase Soil Carbon

Increase Inputs

- Increase biomass production
- Maintain soil cover
- Apply organic amendments

Reduce Losses

- Minimize soil disturbance
- Don’t burn crop residue
- Avoid draining organic soils

Soil health principles as ‘levers of influence’ on C balance

- **Soil Armor** (residue, erosion)
- **Minimal soil disturbance** (efflux, erosion)
- **Plant diversity** (roots/rhizodeposits, residue)
- **Continual live plant/root** (roots/ rhizodeposits, residue)
- **Livestock integration** (amendments)

Menoken Farm

Burleigh County Soil Conservation District

Value of Soil Organic Matter

- Soil structure stabilization
- Improved water retention
- Increased heat capacity

Physical

- Improved nutrient retention
- Increased buffering capacity

Chemical

- Increased mineralization
- Increased biodegradation

Biological

Franzluebbers (2005)


Carbon
Farming
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Global Warming Potential (GWP)

Putting carbon sequestration in a climate context

Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere up to a specific time horizon, relative to carbon dioxide.

For example...

- 1 CO_2 = 1 $CO_{2\ equiv.}$
- 1 CH_4 = 28 $CO_{2\ equiv.}$
- 1 N_2O = 265 $CO_{2\ equiv.}$

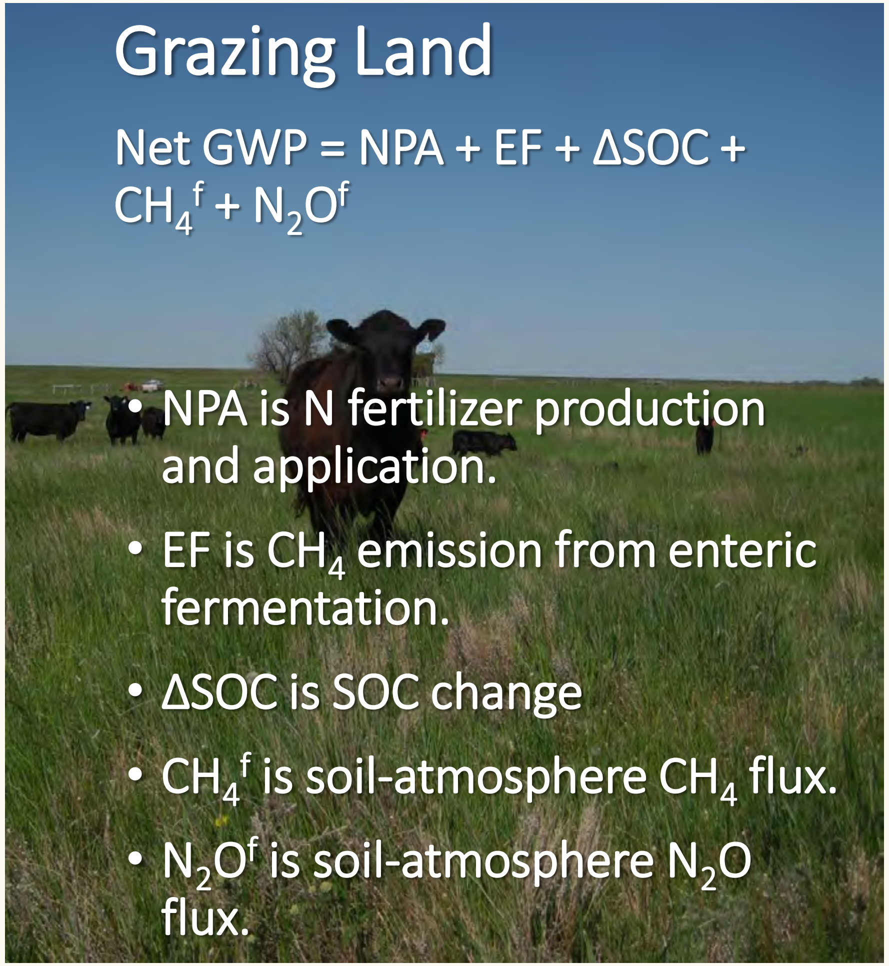
Placing variables on a level playing field

Unit = CO_2 'equivalent'

Myhre et al. (2013)

Global Warming Potential (GWP)

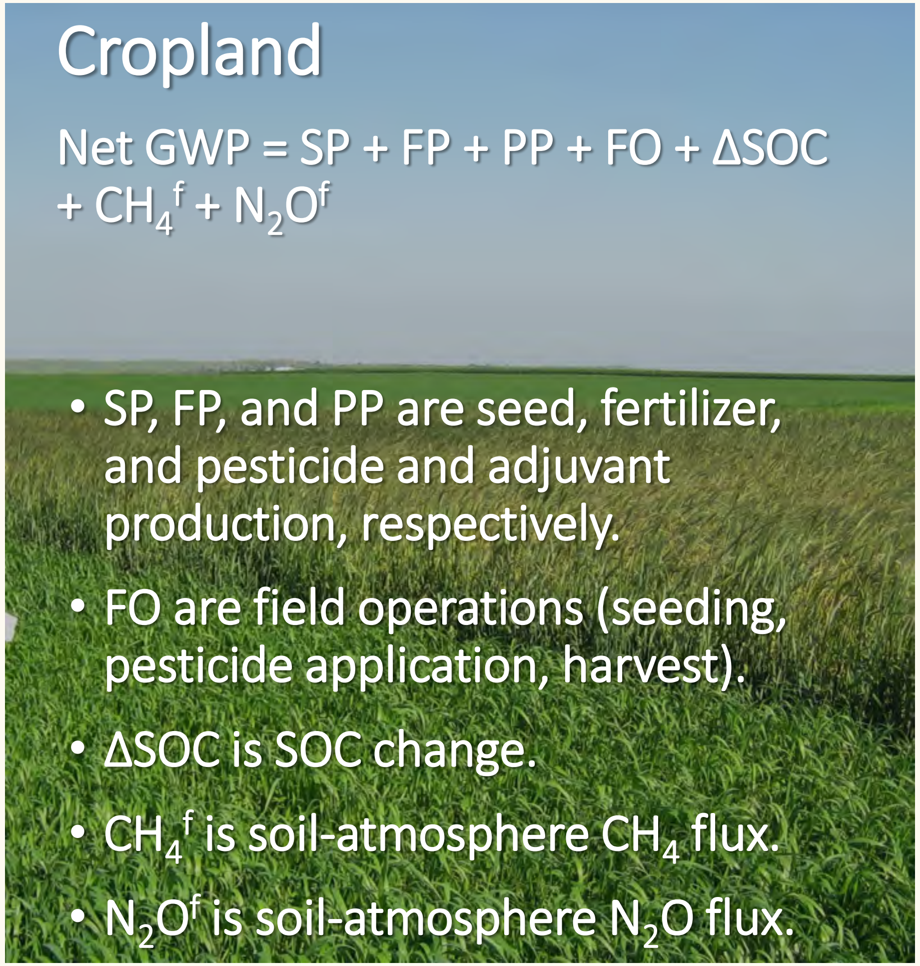
Common contributing variables



Grazing Land

Net GWP = NPA + EF + ΔSOC + CH_4^f + N_2O^f

- NPA is N fertilizer production and application.
- EF is CH_4 emission from enteric fermentation.
- ΔSOC is SOC change
- CH_4^f is soil-atmosphere CH_4 flux.
- N_2O^f is soil-atmosphere N_2O flux.



Cropland

Net GWP = SP + FP + PP + FO + ΔSOC + CH_4^f + N_2O^f

- SP, FP, and PP are seed, fertilizer, and pesticide and adjuvant production, respectively.
- FO are field operations (seeding, pesticide application, harvest).
- ΔSOC is SOC change.
- CH_4^f is soil-atmosphere CH_4 flux.
- N_2O^f is soil-atmosphere N_2O flux.

NGPRL Grazing Systems Evaluation

Overview

Timeframe

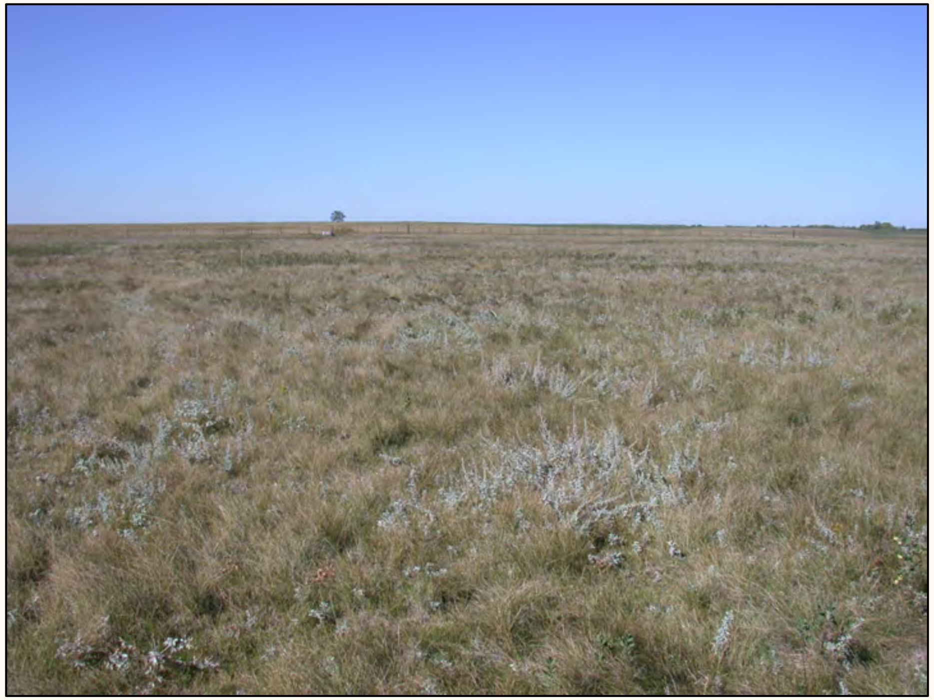
- 2003-2006

Treatments

- Moderately grazed, Heavily grazed, and Crested wheatgrass pastures

Methods

- Static chamber method for gas fluxes
- Soil archive (1959) and contemporary samples (2003) for change in soil organic C



NGPRL Grazing Systems Evaluation

Global warming potential

Variable	Moderately grazed	Heavily grazed	Crested wheatgrass
	- - - - - - - - - - - - kg $CO_{2equiv.}$ ha^{-1} yr^{-1} - - - - - - - - - - - -		
N fertilizer	0 b	0 b	259 (0) a
Ent. Ferment.	176 (28)	484 (76)	563 (227)
SOC change	-1416 (193)	-1517 (187)	-1700 (114)
CH_4 uptake	-63 (9)	-62 (6)	-61 (4)
N_2O emission	520 (85) b	477 (39)	1336 (260) a
NET GWP	**-783 (28) b**	**-618 (76) b**	**397 (227) a**

† Negative numbers imply C uptake. Means in a row with unlike letters differ ($P \leq 0.05$).

Liebig et al. (2010)

NGPRL Cropping Systems Evaluation

Overview

Timeframe

- 2006-2009

Treatments

- SW-F, Cont. SW, SW-S-R (est. 1993)

Methods

- Static chamber method for gas fluxes
- 1994 to 2012 change in soil organic C

NGPRL Cropping Systems Evaluation

Global warming potential

Factor	Spring wheat - Fallow	Continuous spring wheat	Spring wheat - Safflower - Rye
	- - - - - - - - - - $kg\ CO_{2equiv.}\ ha^{-1}\ yr^{-1}$	- - - - - - - - - -	
Seed production	21 b†	42 a	47 a
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Liebig et al. (2019)

NGPRL Integrated Systems Evaluation

Overview

Timeframe

- 2016-2019

Treatments

- Grazed and ungrazed crop and pasture

Methods

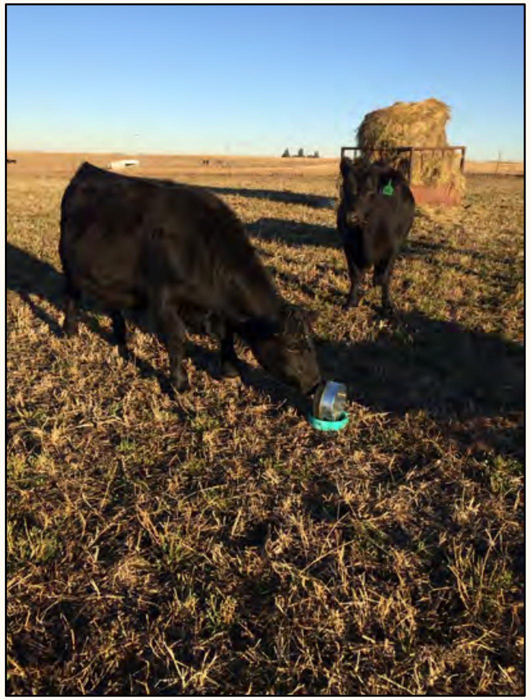
- Static chamber method for gas fluxes
- 1999 to 2014 change in soil organic C

NGPRL Integrated Systems Evaluation

Global warming potential

In review at *Nutrient Cycling in Agroecosystems*, but…

- Both grazed and ungrazed cropland were large soil carbon sinks
- N_2O emissions from the treatments negated 90-99% of accrued soil carbon when expressed on a $CO_{2equiv.}$ basis
- After factoring in other GHG sources and sinks, grazed and ungrazed cropland were net GHG sources



Liebig et al. (in review)

Climate Change / Carbon Sequestration

Carbon farming is the hot (and overhyped) tool to fight climate change

Using farms to capture and store more carbon in soil is becoming trendy, but the science is still not settled on how much it can help to address climate change.

by James Temple Jun 21, 2019

https://www.technologyreview.com/

A growing number of farmers are exploring the potential of capturing and storing greater amounts of carbon dioxide in soil as a way to combat climate change.

Soil naturally stores some amount of carbon, much of it from decaying plants and animal matter. The National Academy of Sciences estimated in a study last year that global farmland could capture and store as much as 3 billion tons of additional carbon dioxide if farmers adopted a number of improved practices, including adding organic matter like manure or compost, shifting cultivation to favor crops that contribute more of their carbon to the soil, or using off seasons to plant cover crops that will then break down. (See "One man's two-decade quest to suck greenhouse gas out of the sky.")

California has started providing small grants from the state's carbon cap-

Do we need reconcile carbon farming's contributions to climate mitigation vs. climate adaptation?

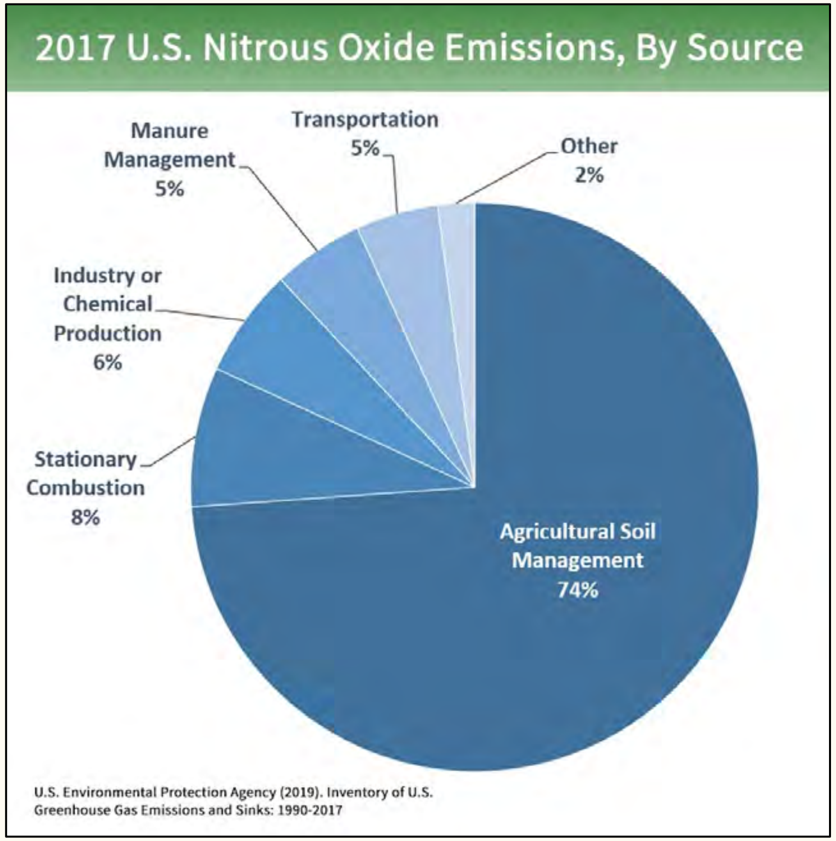
Are there unexplored opportunities to increase carbon sequestration on agricultural lands?

Take a closer look at N_2O

Scale and major sources

Major sources of N_2O are agriculture, industrial activities, and transportation

- <u>Agricultural soil management</u> is by far the largest source
  - 74% total (comprising 95% of all agricultural sources)



EPA (2019)

For N_2O, consider 'flipping the script'…

1 lb N_2O ac^{-1} avoided ≈ 265 lb CO_2 ac^{-1} sequestered

Avoided N_2O emissions are permanent, while most forms of soil carbon sequestration are temporary

Where do we go from here?

- We have the knowledge and tools to use agricultural lands for climate change mitigation
- Landowner incentives need to be truthful about GHG balance
- Capitalize on practices that provide co-benefits
- Effective education is paramount!

Thank you for your attention

Northern Great Plains Research Laboratory

USDA-ARS, Mandan, ND

https://www.ars.usda.gov/plains-area/mandan-nd/ngprl/