Soil Health and Climate Resilience
“Climate-Smart Wines”

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Michigan State University

Greenhouse Gas Emissions from Agriculture (2020)

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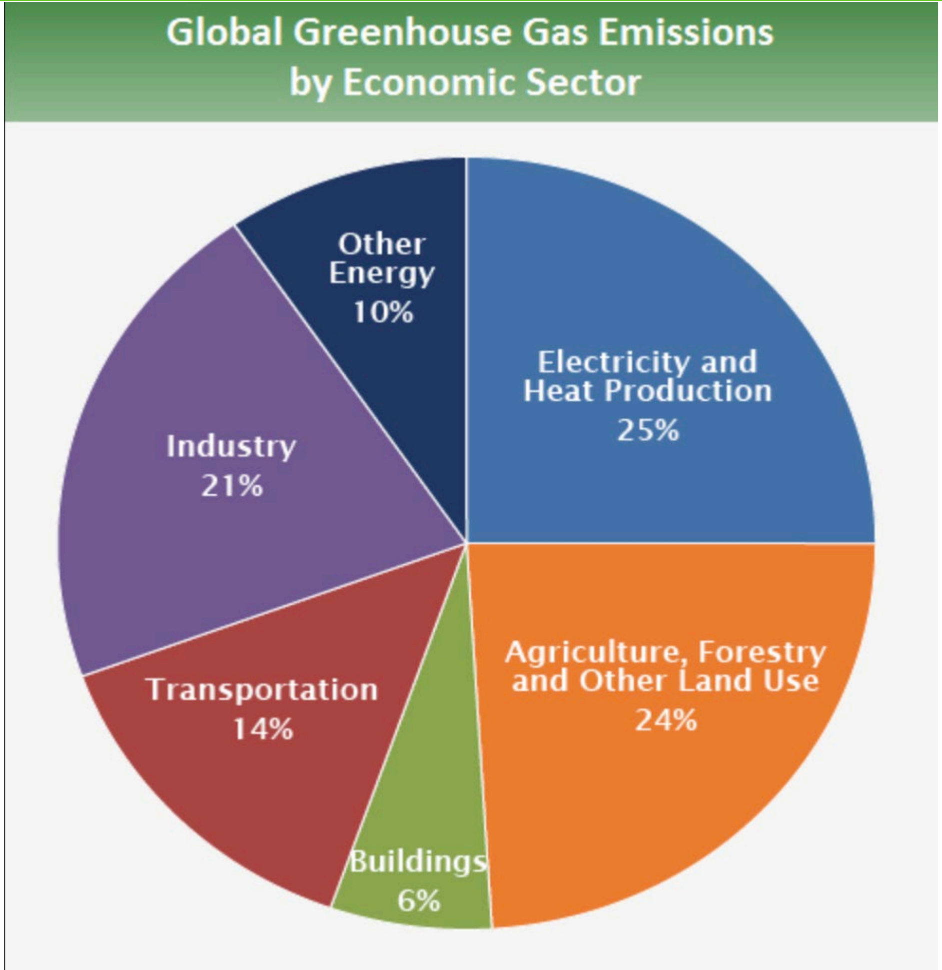

Greenhouse Gas Emissions from Agriculture (2020)

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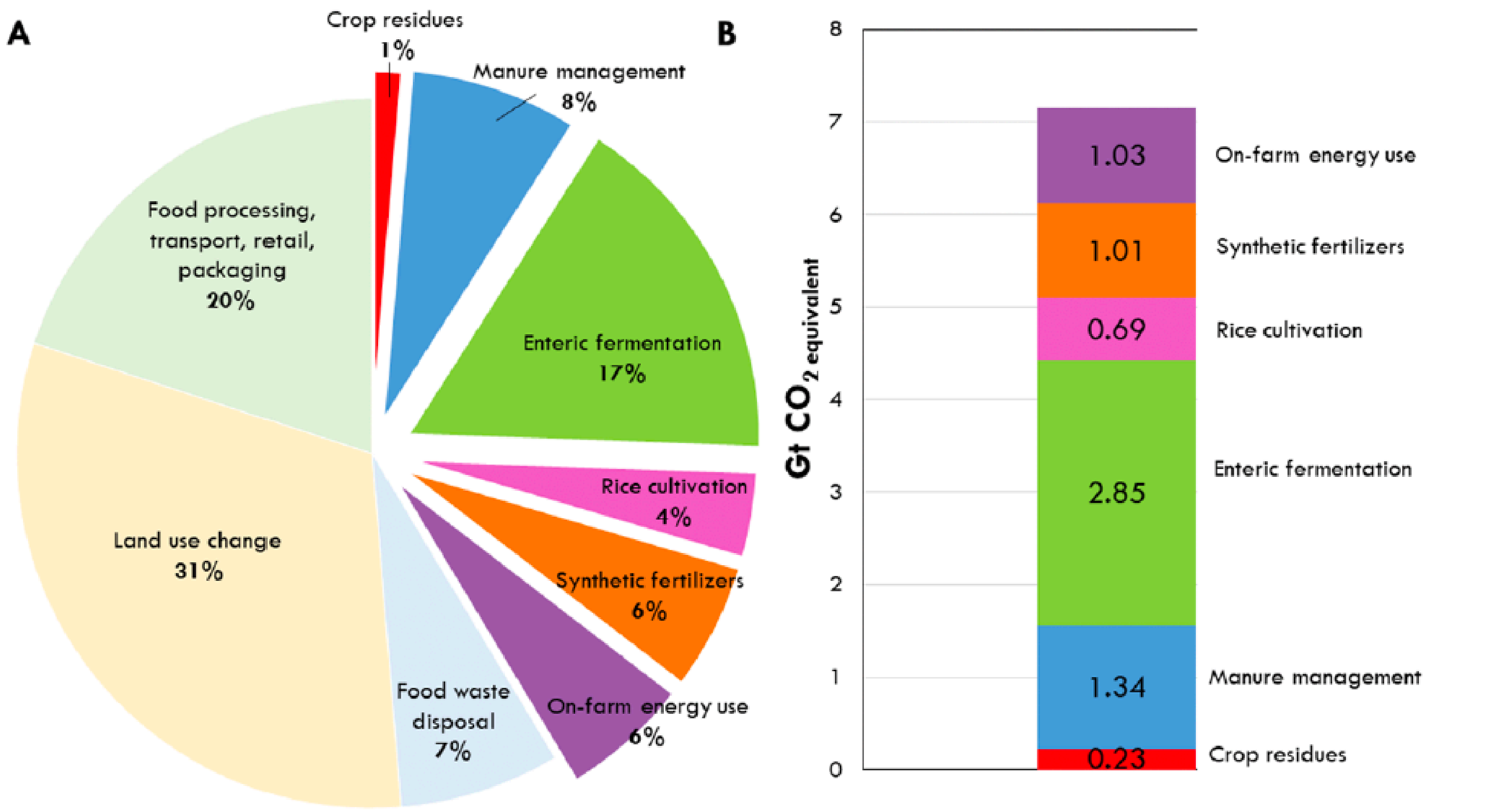

Global emissions from food systems, 2020 (17.3 Gt $CO_{2\ equivalent}$)

Emissions from agricultural systems, 2020 (7.1 Gt $CO_{2\ equivalent}$)

Rosa and Gabrielli (2023)

Temperature changes and increased variability

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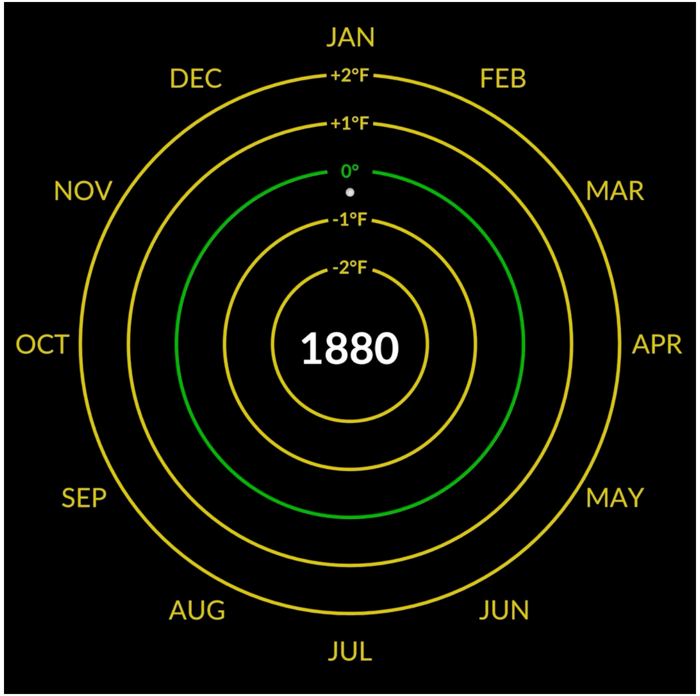

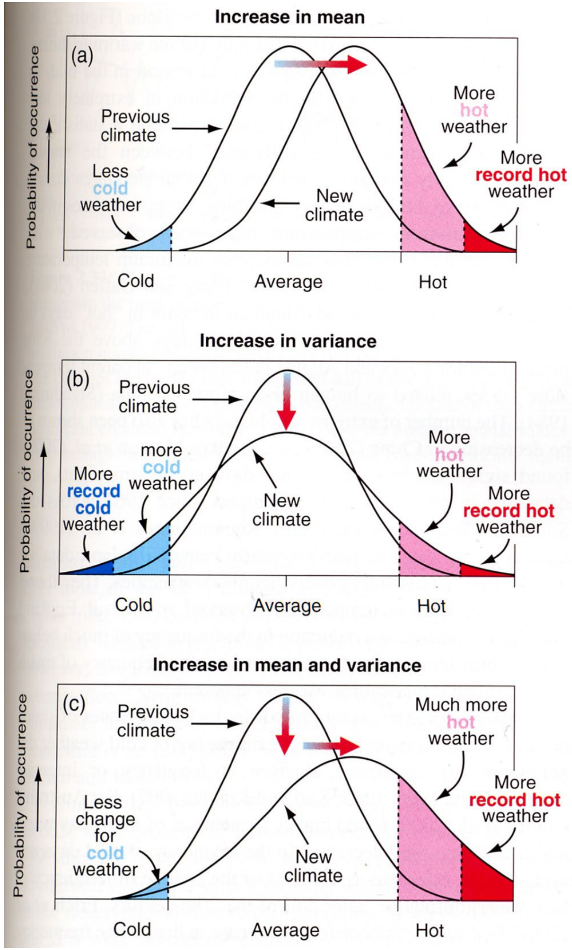

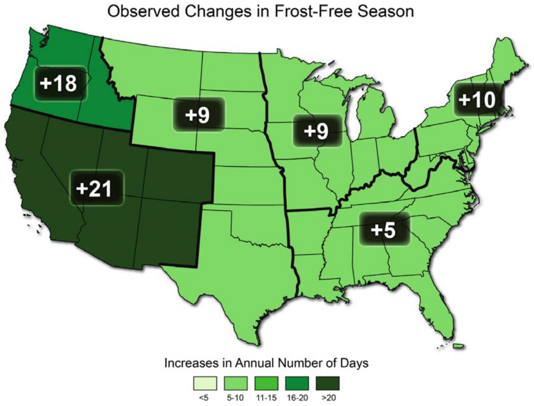

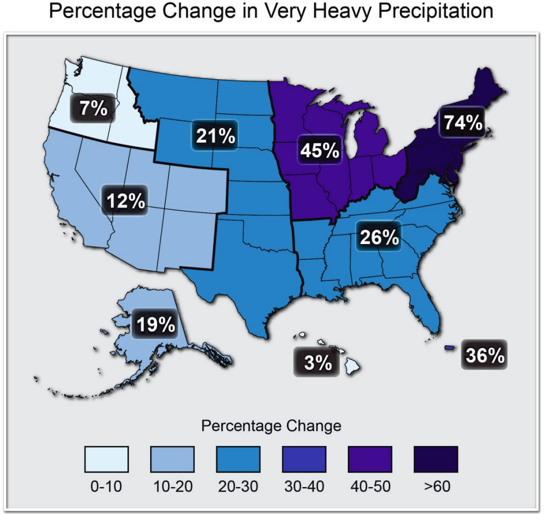

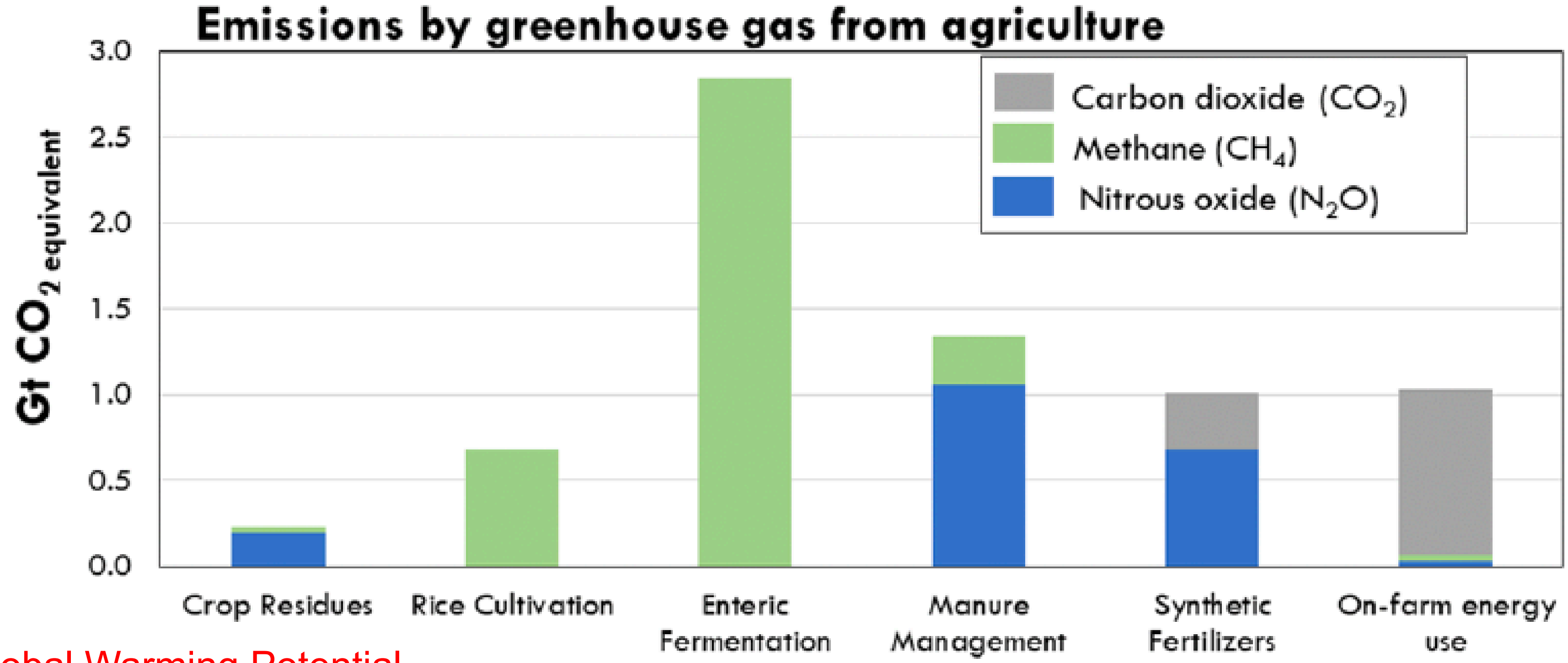

Global Warming Potential

Carbon dioxide (CO_2) = 1

Methane (CH_4) = 21

Nitrous oxide (N_2O) = 296

Rosa and Gabrielli (2023)

We can mitigate current emissions by 100%

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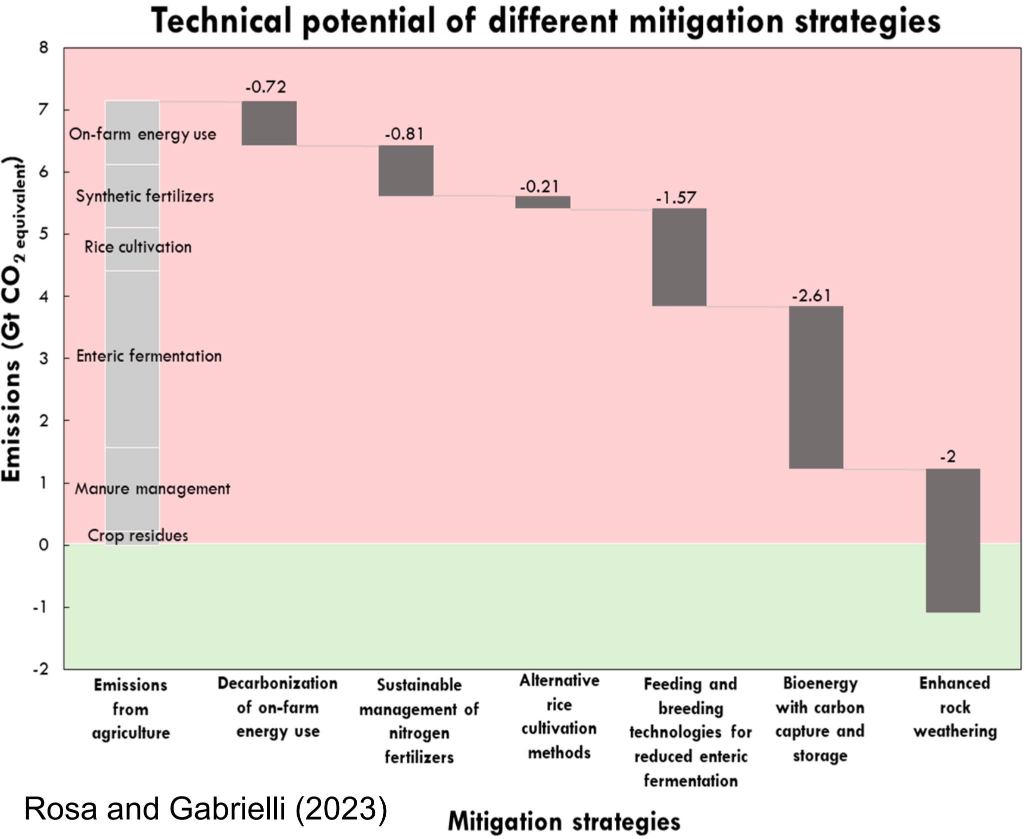
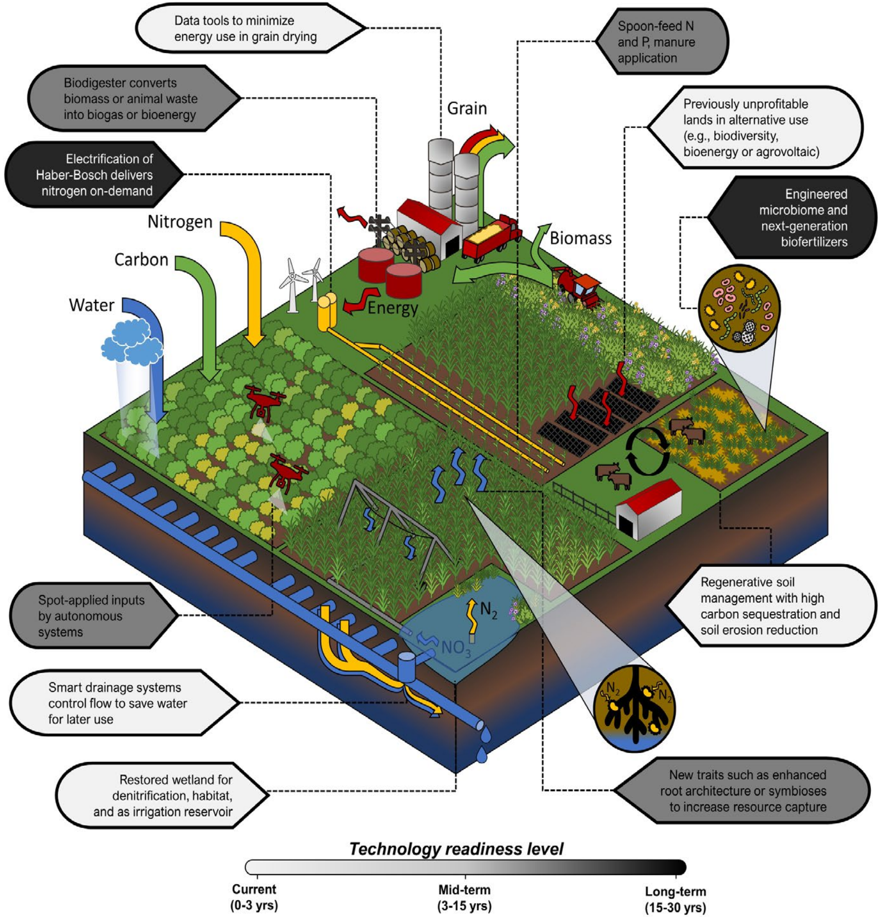


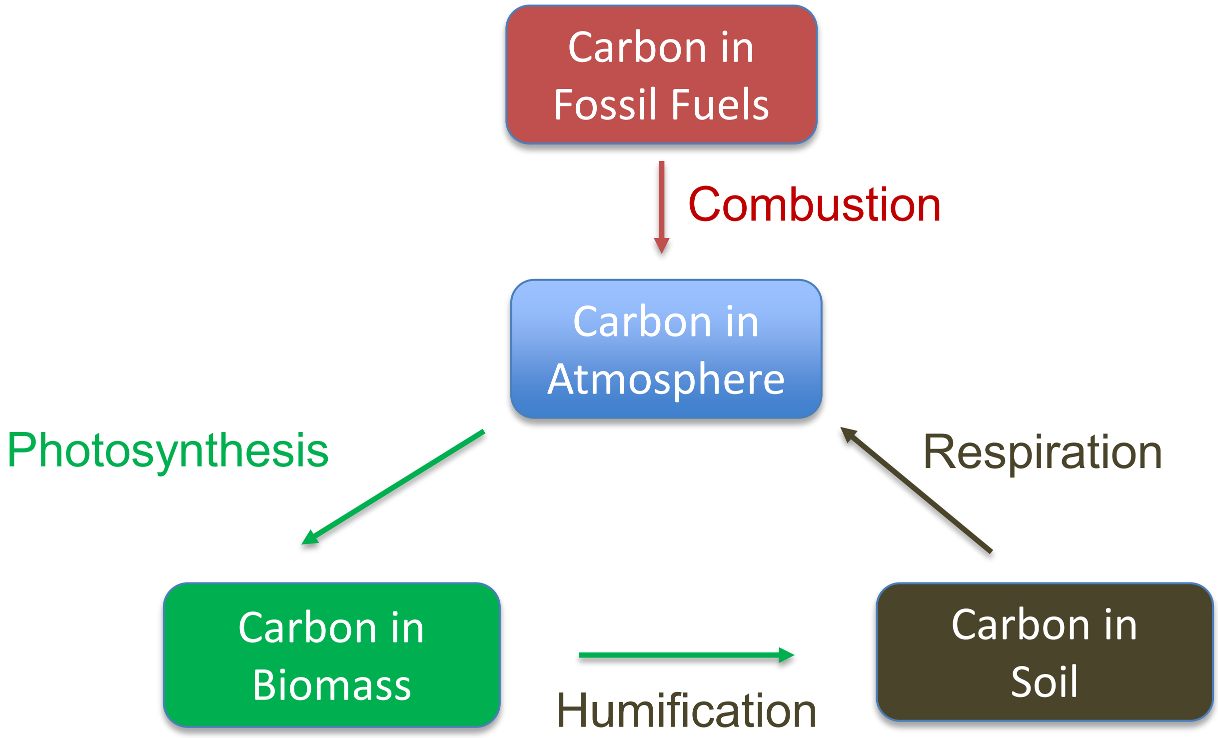
Rosa and Gabrielli (2023)



Basso, et al 2021 Ag Syst

Northup, Basso, et al., 2021, PNAS

Carbon stocks and transformations



Relative impacts for the carbon footprint of wine

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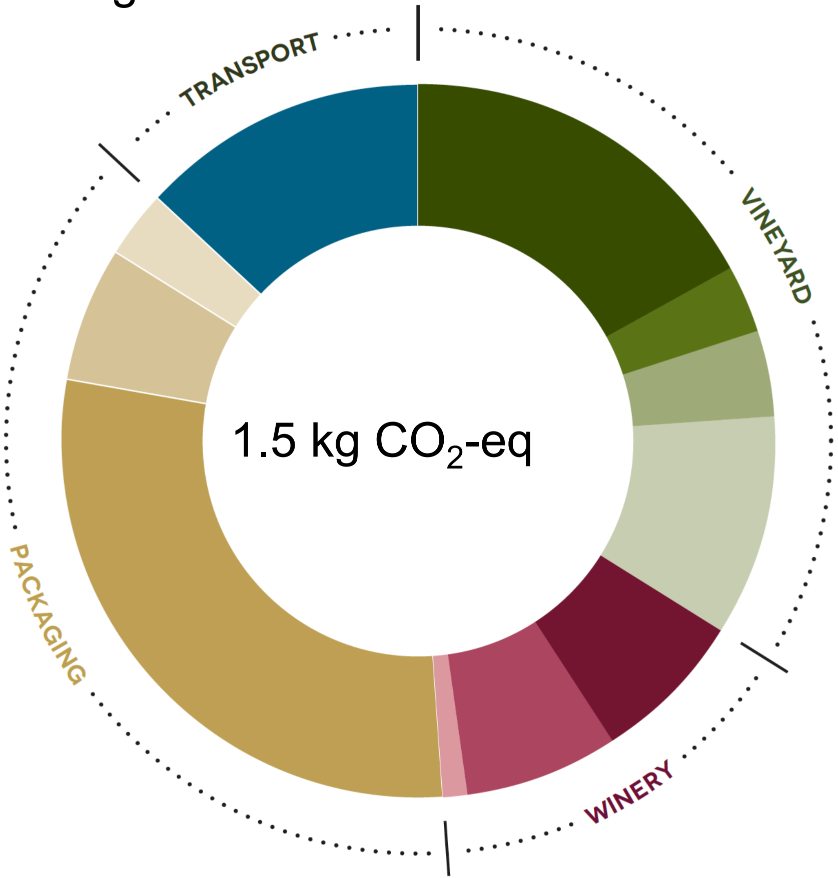
From cradle to retail gate



VINEYARD

- 17% Bio-geochemical field emissions[1]
- 3% Fuel production and combustion
- 4% Electricity consumption
- 10% Raw materials production[2]

WINERY

- 7% Fuel production and combustion
- 7% Electricity consumption
- 1% Other winery[3]

PACKAGING[4]

- 29% Glass bottle
- 6% Corrugate case box
- 3% Other packaging[5]

TRANSPORT

- 13% Transport of bottled wine[6]

Sources and sinks of CO_2e in cropping systems

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Is cropland mitigation even possible?

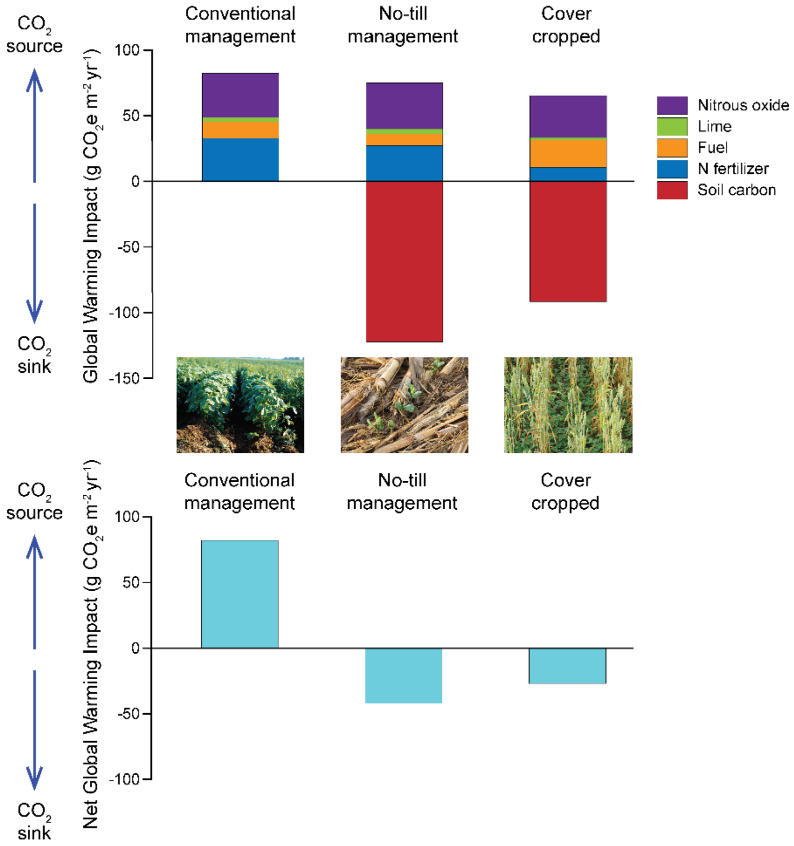
Sources of CO_2e in cropped systems

- Fuel use
- Pesticides, seeds, other inputs
- Nitrogen fertilizer manufacture
- Soil carbon loss
- N_2O emissions
- Lime (carbonate) inputs
- CH_4 emissions
- Powered irrigation

Offset by CO_2e sinks

- Soil carbon gain (no-till, cover crops)
- CH_4 consumption

Global Warming Impacts of c-s-w rotations in Michigan



Source: Robertson et al., 2000 Science; Gelfand et al. 2013 Nature

Advantages of growing cover crops

- Reduce erosion
- Increase porosity
- Increase soil organic matter
- Increase water holing capacity and/or infiltration
- Increase Beneficial Microbes
- Add nitrogen through fixation (legumes)
- Suppress weeds
- Break up compaction
- Break disease cycles
- Potential to increase yield of cash crops
- Prevents runoff into waterways
- Soil carbon sequestration
- Enhance biodiversity
- Reduces leaching
- Creates wildlife habitats
- Attracts pollinators

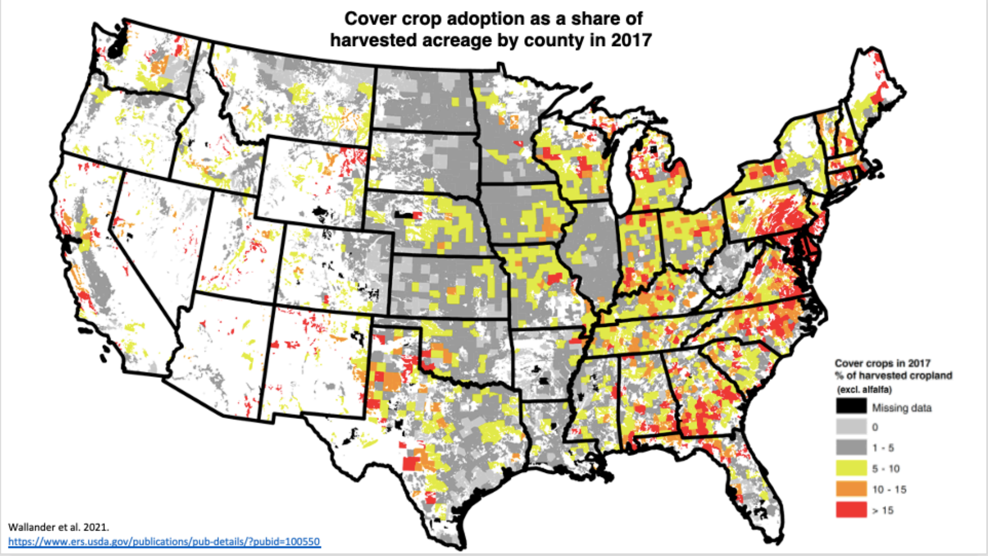
After a few years:

$10-40 per acre savings in corn

$5-10 per acre savings in soybeans

Trends in Cover Crops adoption

- Adoption of cover crops increased 50% from 2012 to 2017 in the U.S with an adoption of 7.2% in 2021
  - Largely to additions to corn grain and soybean fields
  - Michigan had a 1.5x increase in acres in that time which was 10.1% of cropland using cover crops in 2017
  - No till is on ~40% of corn
- Interest in cover crops has peaked due to:
  - Incentive programs
  - Productivity
  - Environmental sustainability



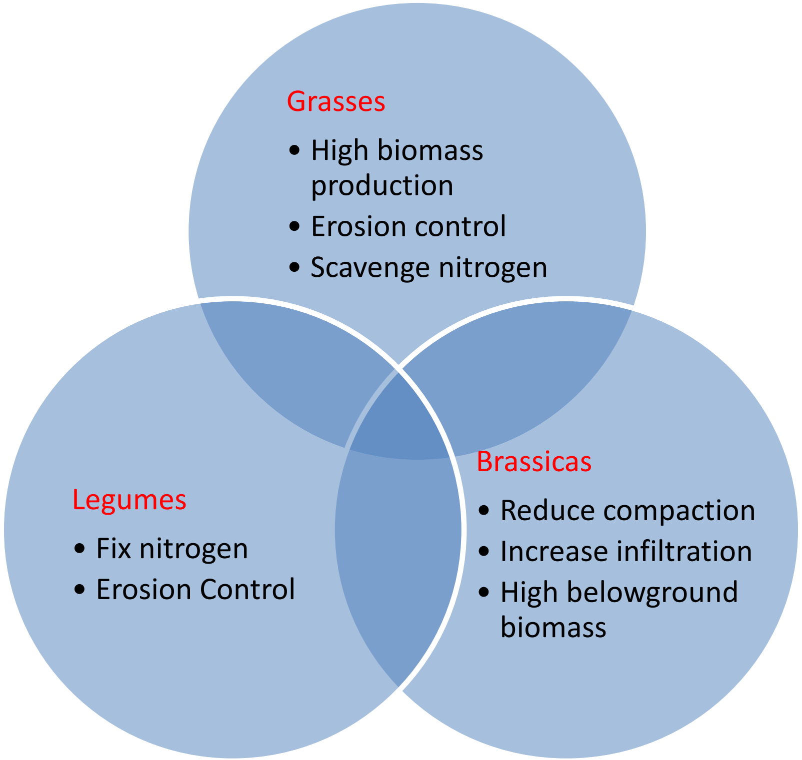
Source: USDA

Disadvantages of growing cover crops

- Increased time and labor
- Cost to plant and terminate
- Can alter soil temperatures prior to planting
- Can become a weed if not terminated properly
  - Trade off between growing to flowering for pollinator services and letting them spread seeds to become potential weeds
- Residues can become habitats to pests
- Harmful insects and diseases can carry on from the cover crop to the cash crop
  - Rotate plant families to prevent this

Plant Family Benefits

Grasses: Annual Ryegrass; Cereal Rye; Barley, Oats, Sorghum-Sudangrass, Triticale, Wheat
Legumes: Alfalfa, Clover (Berseem, Red, Crimson, etc.), Cowpeam, Sunnhemp, Hairy Vetch
Brassica: Mustard, Oilseed Radish, Rapeseed, Turnips, Winter Canola



National Cover Crop Survey Report Highlights

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- **Mixtures:** Most producers used a mix of 3 to 5 species
- **Fertilizer cost:** 52% reported no change while the other 48% reported saving anywhere from $3-$20 per acre
- **Weed control:** 73% said weed control improved even if there wasn't a savings in herbicide costs
- **Yield:**
  - **Soybeans:** 2.07-bushel(3.6%) increase
  - **Corn:** increase of 1.09-bushel (0.5%)
  - Farmers with 10 or more years of experience had gains of 6.3% in soy and 6.27% in corn showing that benefits increase with more years

795 farmers from 49 U.S states surveyed

Source: National Cover Crop Survey Report (2023)

Weed Suppression

- 15 studies from the Midwest corn belt shows that 5 Mg ha^{-1} of grass cover crops can decrease the amount of weeds by 75% (Nichols *et al.* 2020)
- 53 studies (1990-2018) show that fall-sown grass species in a reduced tillage system provide the most weed suppression and that CC biomass is inversely related to weed suppression (Osipitan *et al.* 2019)
  - Increased seeding rate of cereal rye resulted in 67% better weed suppression

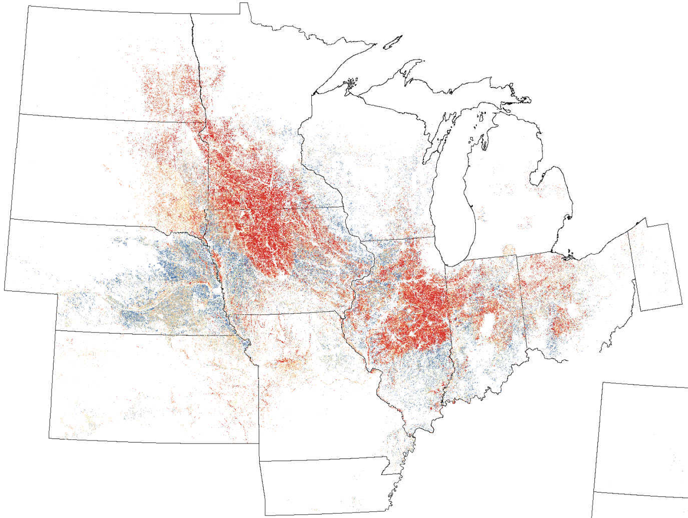
Carbon Sequestration

- 93 studies found that cover crops increased SOC by 12% (Hu *et al.* 2023)
- 61 studies found that cover crops increase SOC by 7.3% and are sequestering 5.5 million Mg of SOC per year in the U.S (Joshi *et al.* 2023)
  - Global potential to sequester 175 million Mg of SOC per year if all corn fields used cover crops
- Similarly, Wooliver and Jagadamma (2023) found that cover crops increase SOC on average by 6.07% over 44 studies

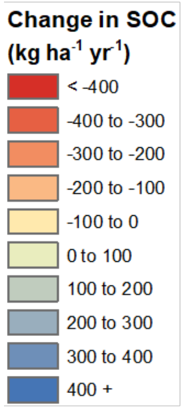
Cover crops increase SOC anywhere from 6-12%

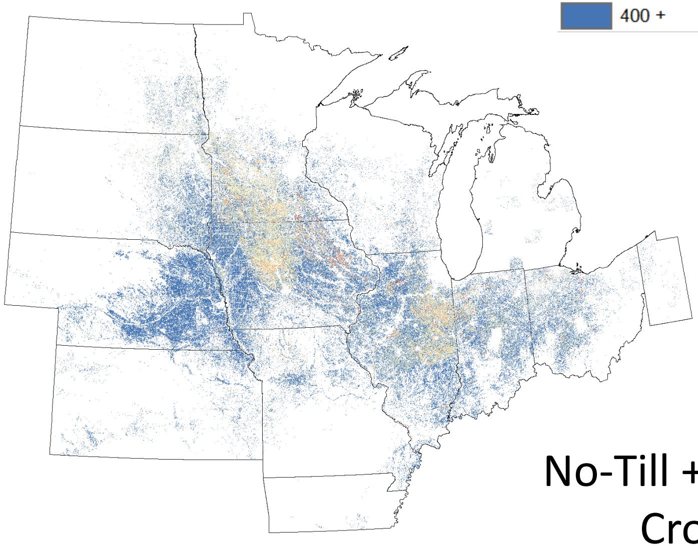
Changes in SOC (kg ha^{-1} $year^{-1}$)

Conventional Tillage



- Change in SOC per year (kg/ha/yr) (1978-2022)





No-Till + Cover Crop

Effects on Nitrogen and Yield

- 41 articles showed that cover crops can reduce nitrate leaching by 69% and up to 75% with species in the Brassicaceae family (Nouri *et al.* 2022)
- Another study showed that leaching was reduced 40% in a legume-based system but relying on them to fix their own nitrogen resulted in a 10% decrease in yield (Tonitto *et al.* 2006)
- The effect on yield is also variable and can be affected based on competition for resources, overly dry or wet years, how many years of CC use, etc.
  - The literatures shows mixed results of decreasing and increasing yield

The hidden cost of cover crops

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. Number of acres plantable from a single acre seed harvested

Cover crop	Low yield	Mean yield	High yield
Hairy vetch	8.41	18.41	28.41
Oats	37.18	43.59	50.00
Cereal rye	22.35	27.93	33.52
Red clover	40.71	57.02	73.33

Planting cover crops for seeds in low yielding areas

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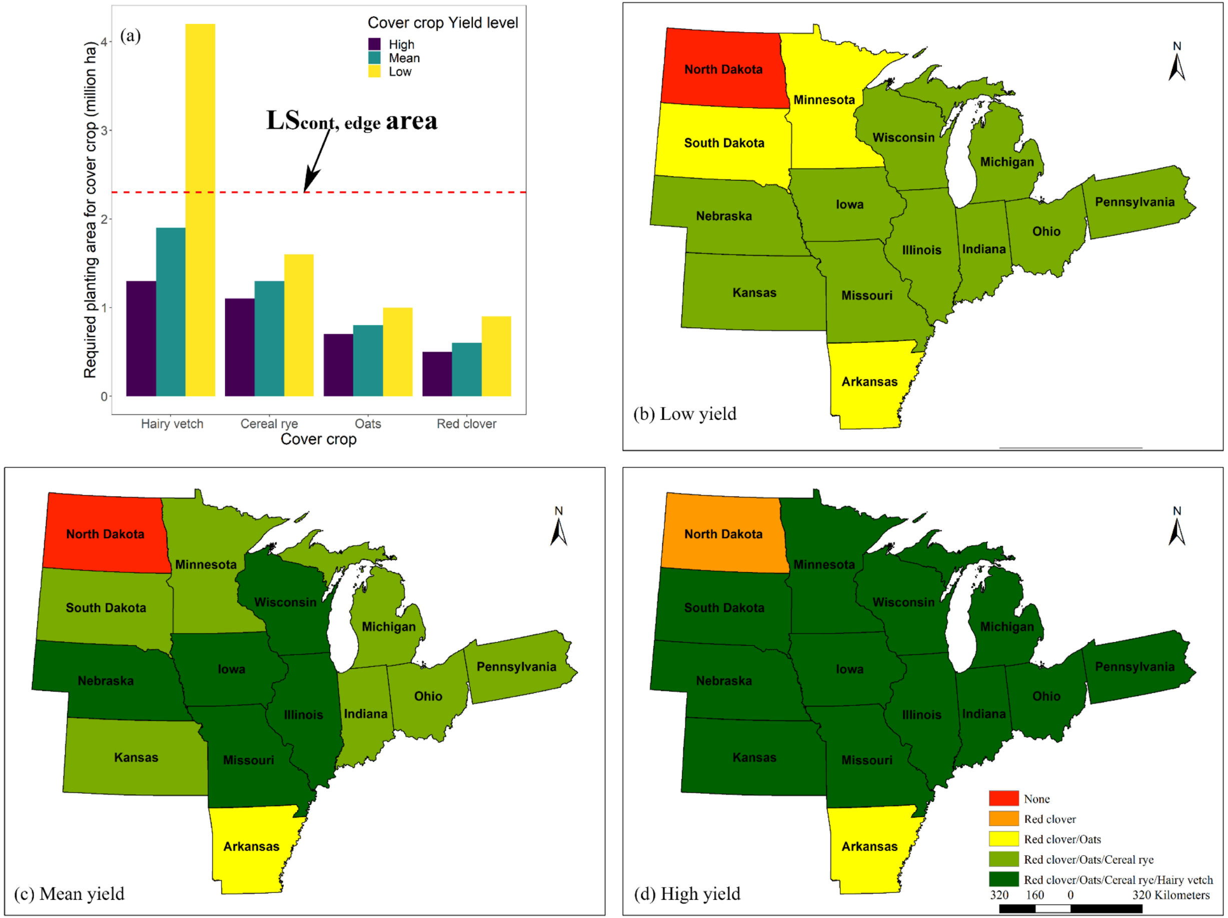
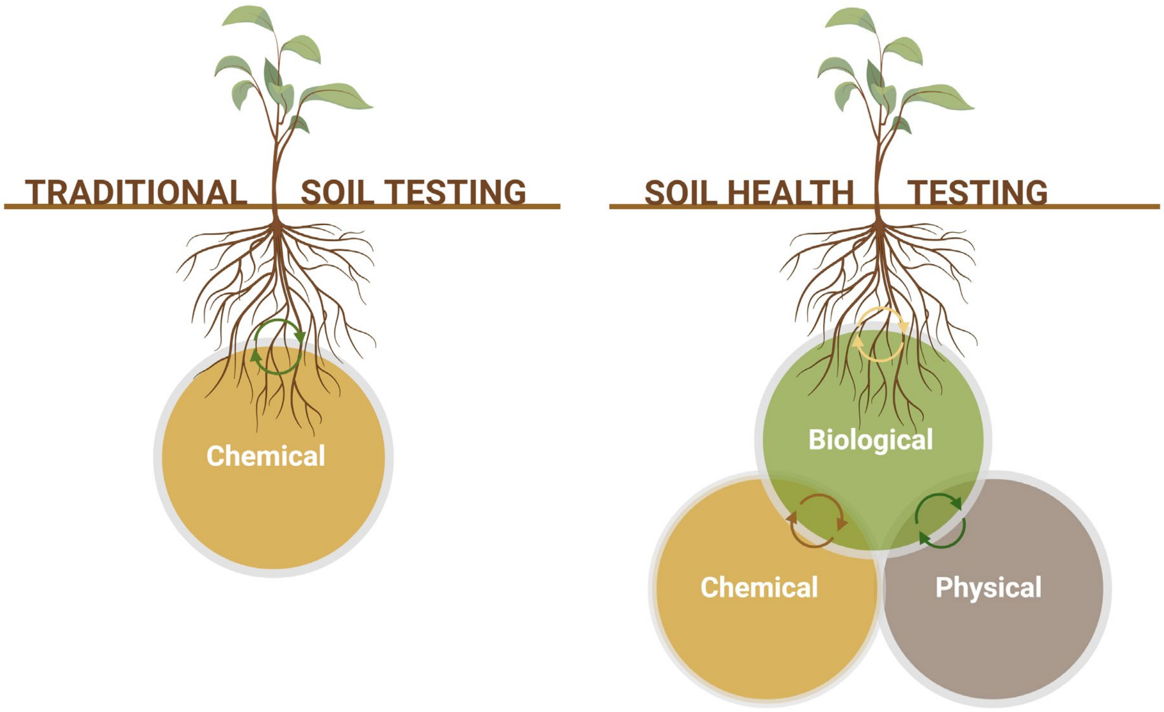


What are the barriers that exist for farmers



- The absence of metrics that predict meaningful early trajectories of regenerative agriculture and soil health outcomes

- Farmers have limited access to meaningful soil health metrics

Farmers in the Midwest are interested in soil health!

- 96% of farmers believe that soil health is important
- 46% of farmers are taking steps to improve soil health

Source: Panel Farmer Survey (PFS). Courtesy of C. Sprunger

Do soil health test match farmer experiences?

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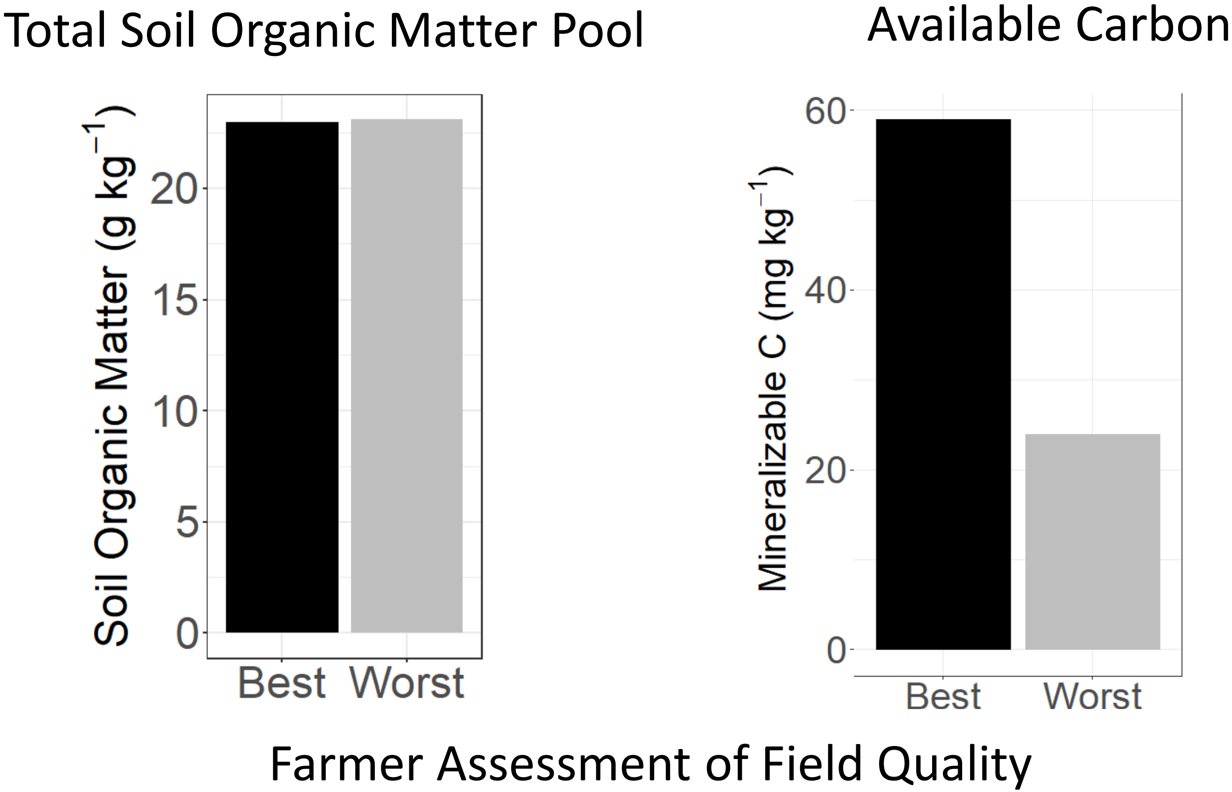

O’Neil et al., 2021

SOC Sampling across stability zones

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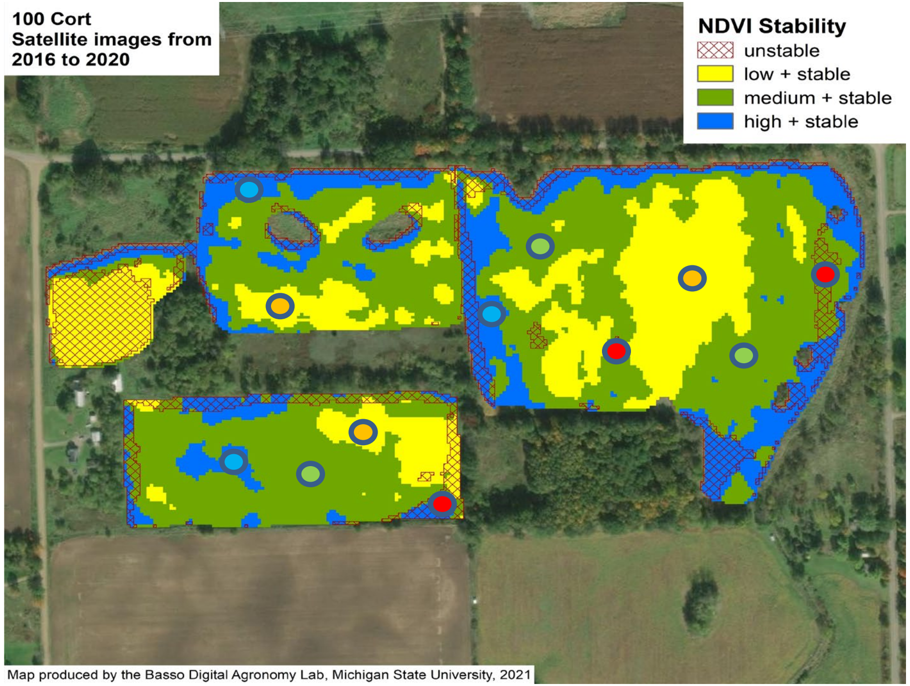

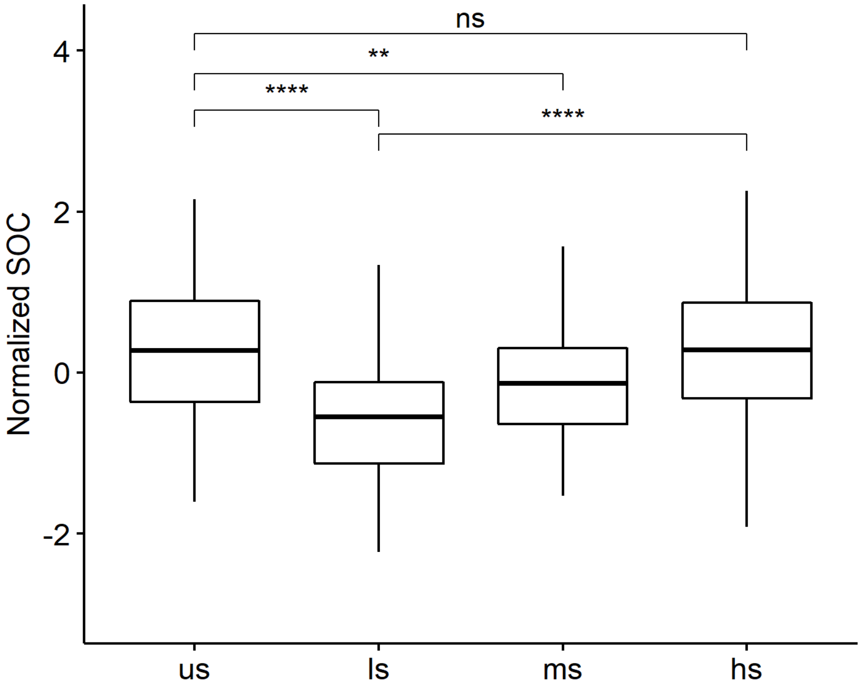

240 samples across a transect from MI to IL

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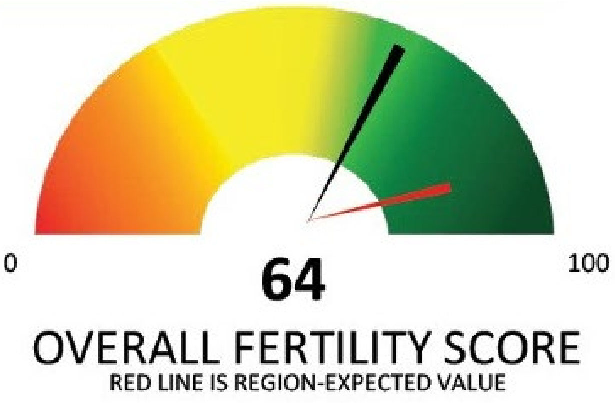
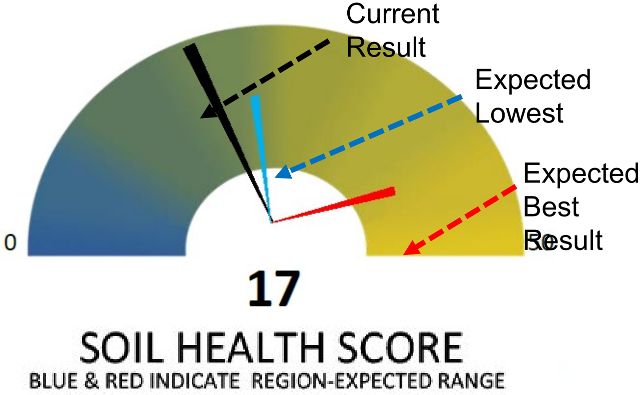
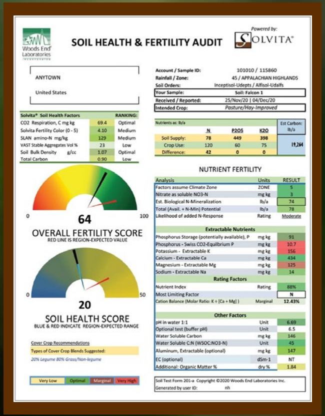
SOLVITA®

a soil test integrating aggregate stability, Amino-N and CO_2 evolution since 1984







woodsend.com/soil-health-test

Solvita® Nexus is a Soil Health and Fertility Audit that accounts for:

- Climate Zones
- Rainfall Zones
- Soil Orders/ Suborders

SOLVITA results for LS (Low Stable) to HS (High Stable) Zones

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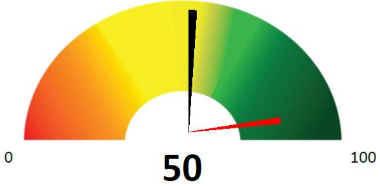
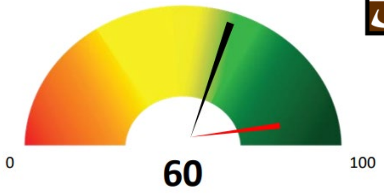
SOLVITA®
Soil Quality Audit

LS | **HS**

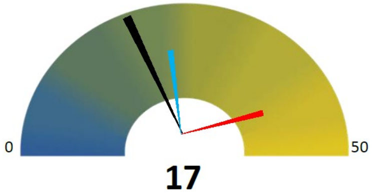
Location:
Michigan-1
S. Central MI

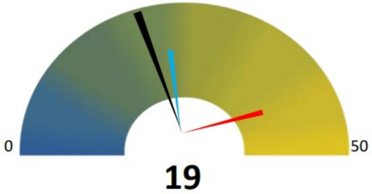
Alfisols-Udalfs





< Overall Fertility Score >
$p < 0.001$

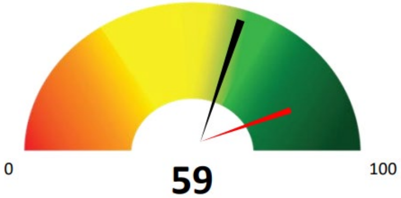


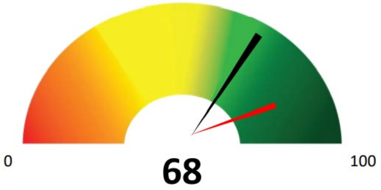


< Soil Health Score >
$p < 0.001$

Location:
Michigan-5
N. Central MI

Inceptisol-Aquepts
Alfisol-Udalfs





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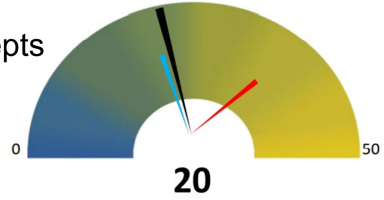

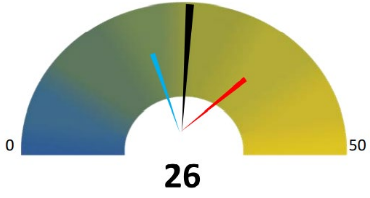

< Soil Health Score >
$p < 0.001$

How can predict carbon dynamics in soils?

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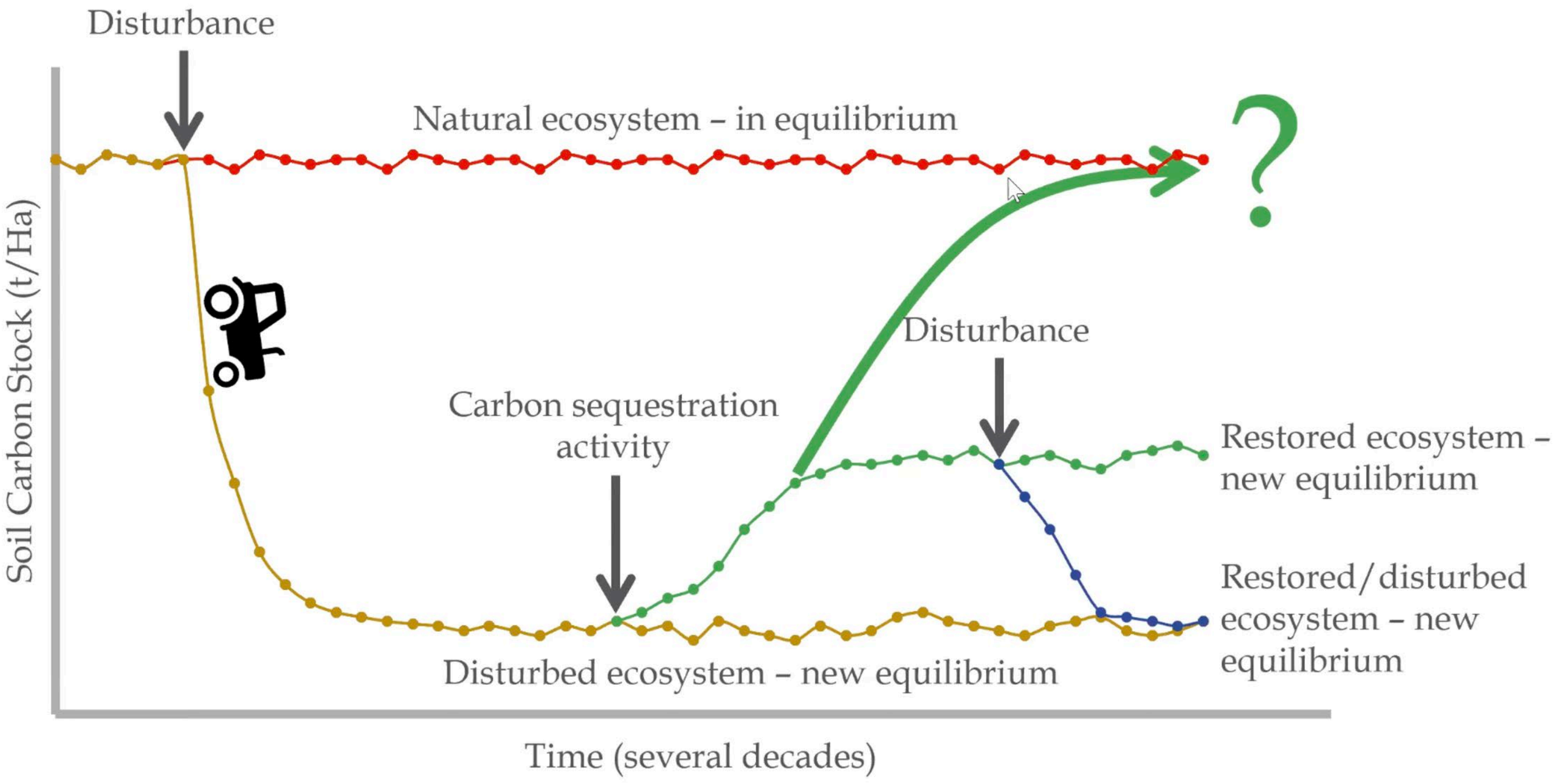

Modeling soil-plant-climate-management

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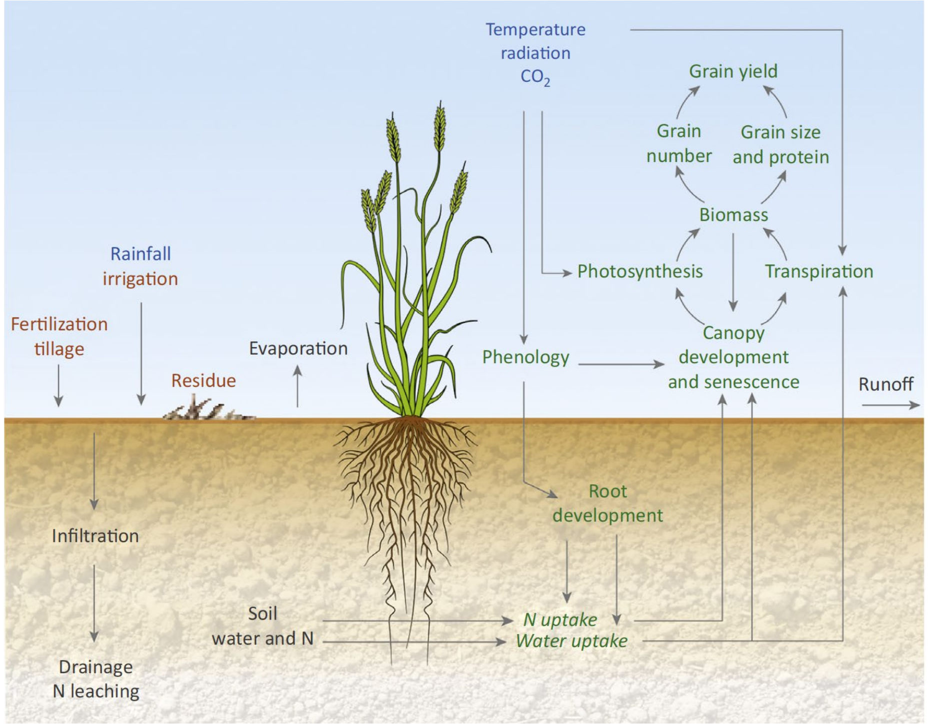
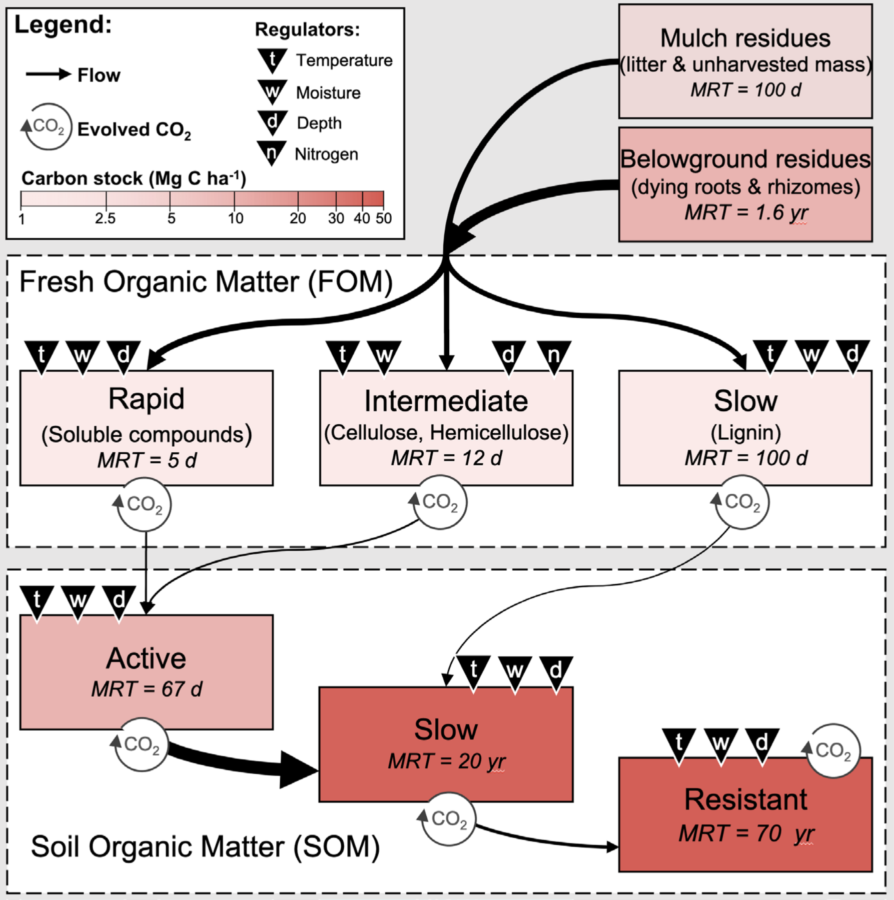


Basso et al 2010



Basso et al., 2016 Adv in Agronomy

Modeling climate resilience

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Climate variability and change scenarios

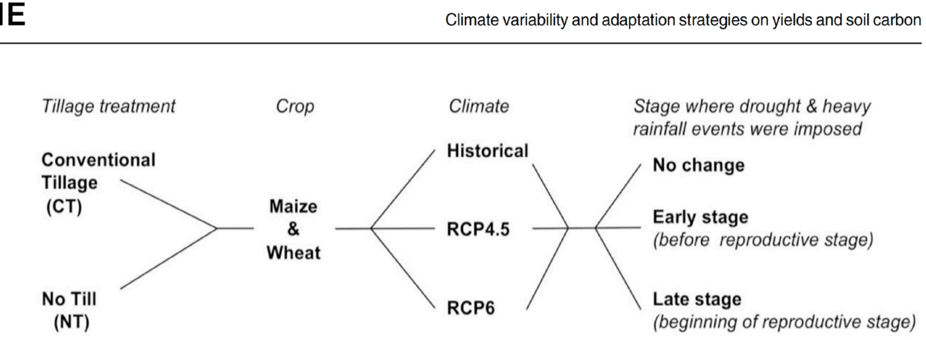

Fig 2. Illustration of the simulation experiments studying the impact of tillage treatments and climate change, considering climate scenarios and precipitation variability at crops' early and late stages, on the yields of maize and wheat and SOC of the maize-soybean-wheat rotational cropping system.

https://doi.org/10.1371/journal.pone.0225433.g002

Model validation

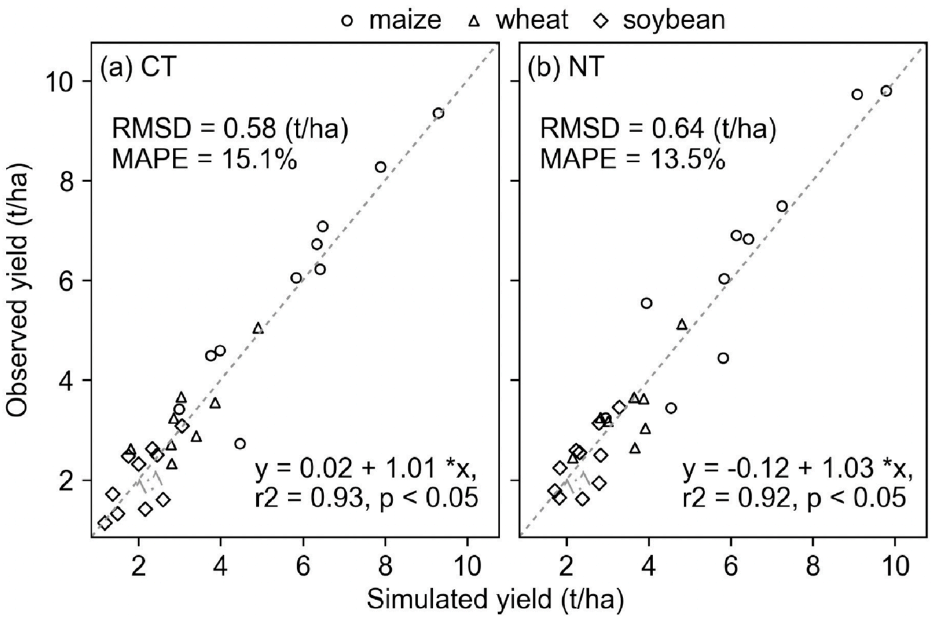

Fig 3. Comparisons between the simulated and the observed grain yield in the maize-soybean-wheat rotation system under (a) conventional (CT) and (b) no-till (NT) treatments at the Kellogg Biological Station in 1989–2016.

https://doi.org/10.1371/journal.pone.0225433.g003

Liu and Basso, 2020 Plos One

How do we model resilience in drought and excess water

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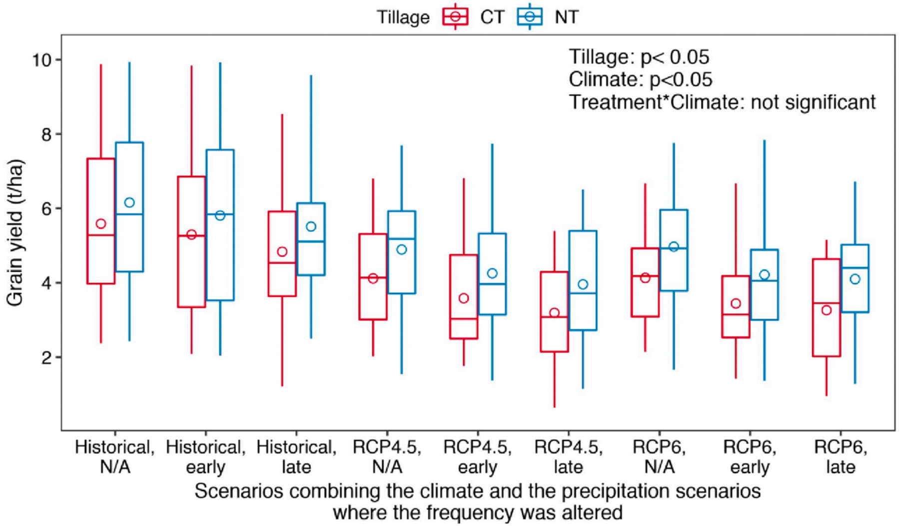

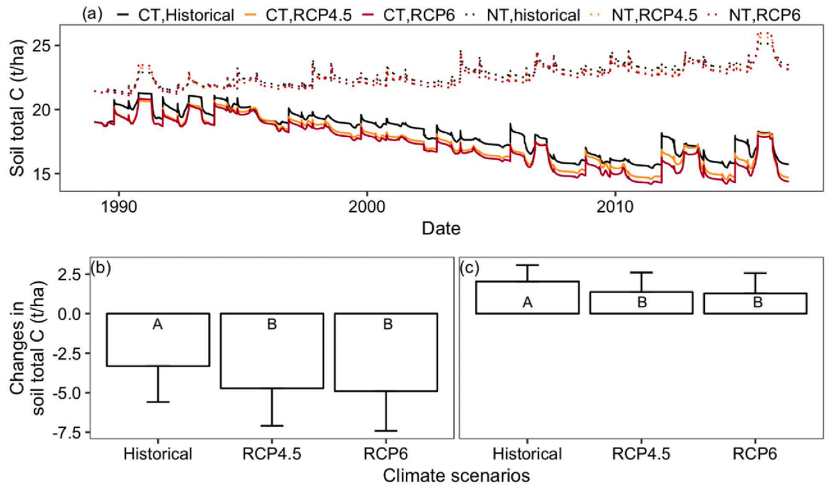

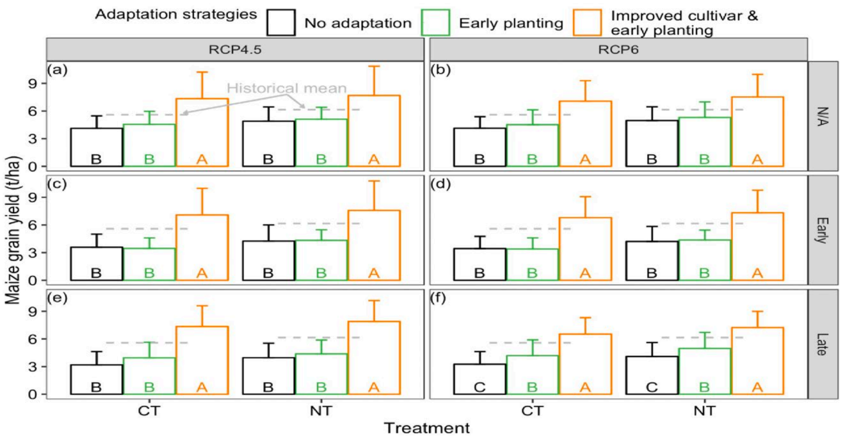

Carbon and Ecosystems Services Markets

Carbon Credits Payments $ to farmers through **offsets and insets**

Carbon Sequestration

Regenerative practices for ecosystems services

Greenhouse Gas (GHG) emission reductions

Carbon offsets/insets:

1) join a program;
2) sample for soil carbon,
3) soil carbon modeling,
4) re-sample for soil carbon,
5) reporting and verifications of carbon sequestered or GHG emission reductions

$ practice adoption (payments for cover crops)

$ for scope 3 emissions reduction by food companies (reduction of N2O emissions)

Insets and labeling

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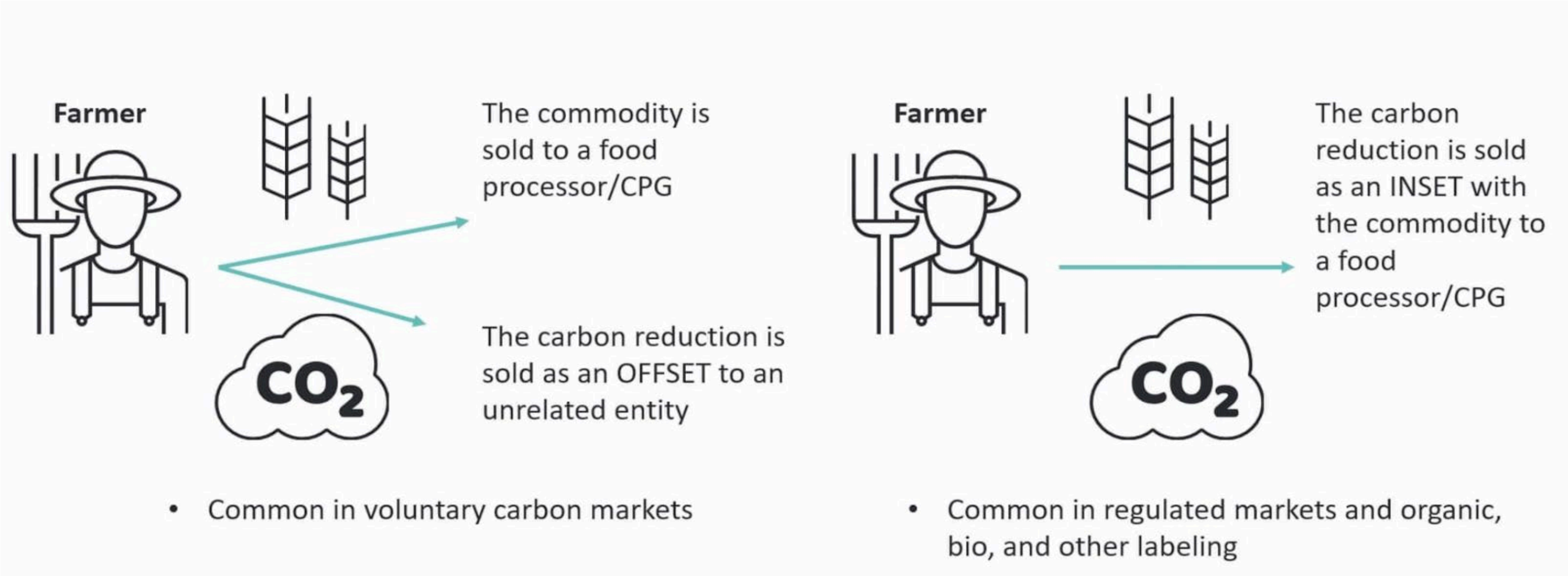

Making the right claim increases shareholder support (sustainable finance)
Sustainability claims must have relevance and resonate with consumer values
Claims are reported on a product label, and follow accepted data standards and LCA

Climate Smart Commodities

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Measuring, Monitoring, Reporting and Verifying (MMRV)

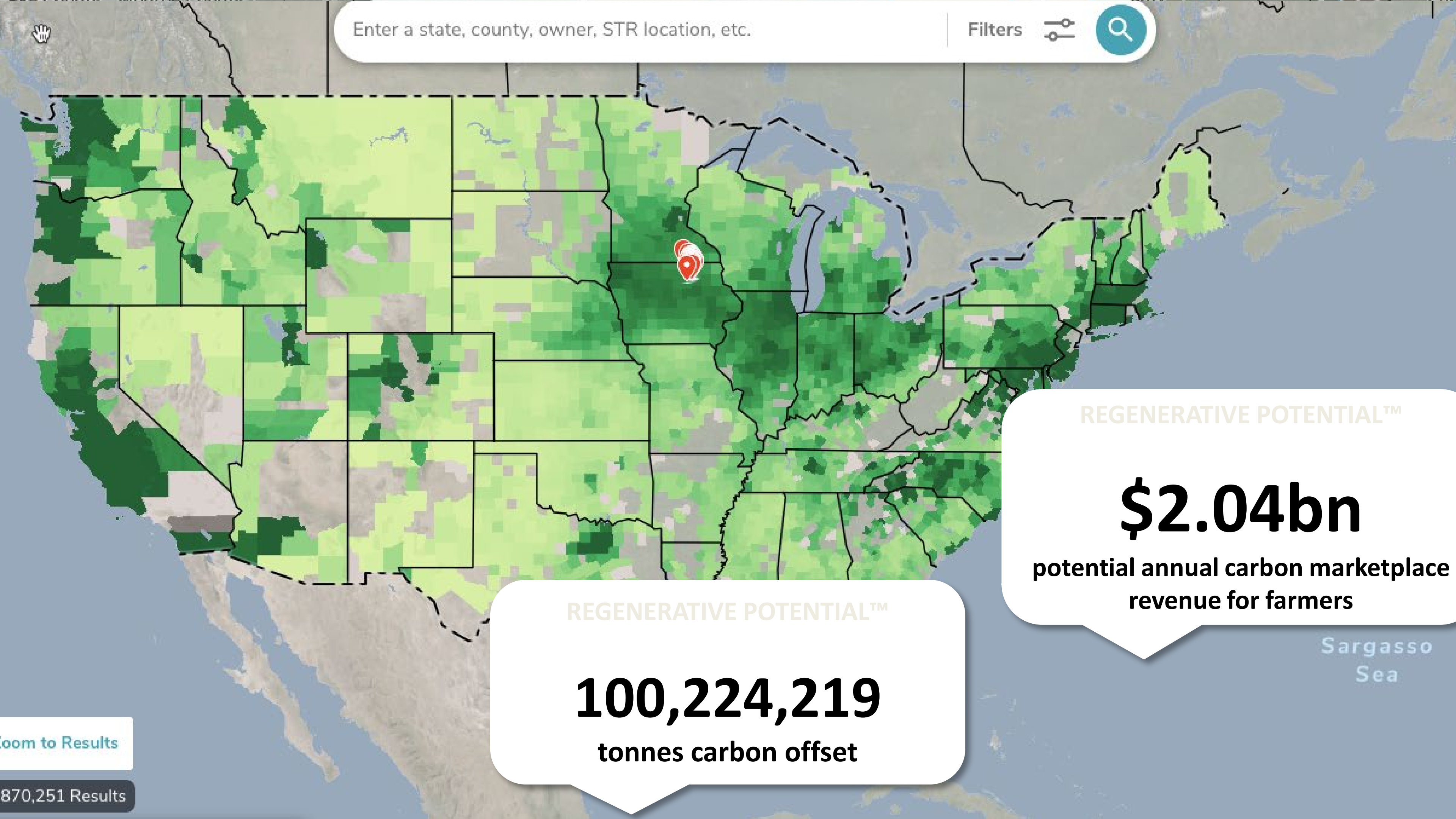
Remotely sense practices using computer vision and satellite imagery

Combine practice data with soil, weather, and other data to model carbon footprint

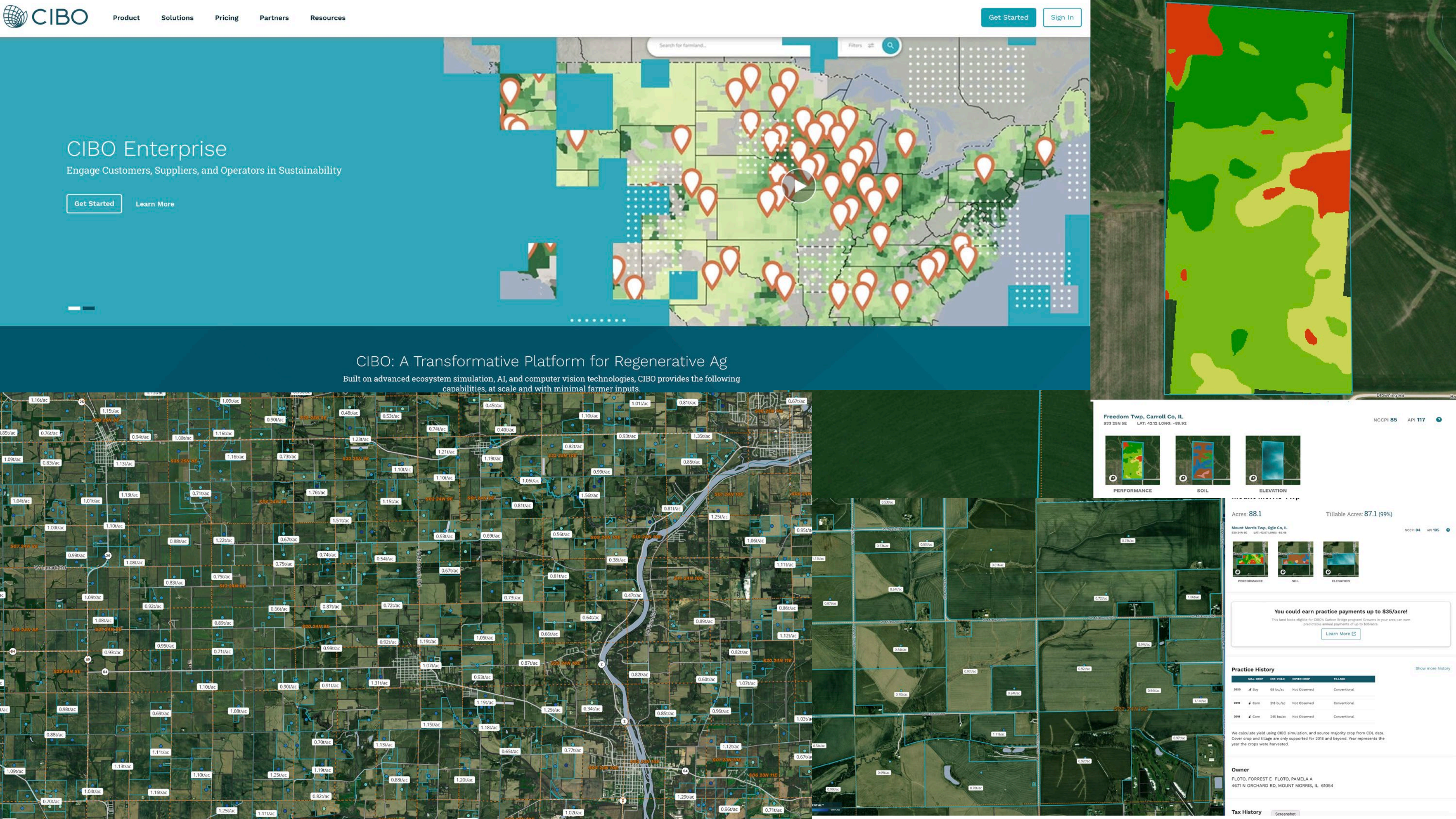
Verify practice changes

Model change in carbon footprint from practice changes

Reward farmers



Enter a state, county, owner, STR location, etc.
Filters
REGENERATIVE POTENTIAL™
$2.04bn
potential annual carbon marketplace revenue for farmers
REGENERATIVE POTENTIAL™
100,224,219
tonnes carbon offset
Sargasso Sea
oom to Results
870,251 Results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CIBO: A Transformative Platform for Regenerative Ag
Built on advanced ecosystem simulation, AI, and computer vision technologies, CIBO provides the following capabilities, at scale and with minimal farmer inputs.
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NCCPI 85
API 117
PERFORMANCE
SOIL
ELEVATION
Acres: 88.1
Tillable Acres: 87.1 (99%)
Mount Morris Twp, Ogle Co, IL
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SOIL
ELEVATION
You could earn practice payments up to $35/acre!
Learn More
Practice History
Owner
FLOTO, FORREST E FLOTO, PAMELA A
4671 N ORCHARD RD, MOUNT MORRIS, IL 61054
Tax History

What are the major barriers?

Paradigm shifts in science…
don't lead to translation

Identified general principles…
How to move to practices?

Innovative systems…
adoption is low

Transdisciplinary partnership and a systems approach can overcome these barriers to get ahead of, direct, and enable change towards sustainability

Basso Computational Agronomy Lab

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NASA

USAID
UNITED STATES AGENCY INTERNATIONAL DEVELOPMENT

NSF

BILL & MELINDA GATES foundation

CLIMATE TRACE

Food and Agriculture Organization of the United Nations

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AgBioResearch

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National Institute of Food and Agriculture

GREAT LAKES BIOENERGY RESEARCH CENTER

USDA Natural Resources Conservation Service
United States Department of Agriculture

CORN MARKETING PROGRAM CMPM OF MICHIGAN

MICHIGAN WHEAT PROGRAM

CiBO TECHNOLOGIES

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GLISA A NOAA RISA TEAM

ESMC Ecosystem Services Market Consortium

NATIONAL WILDLIFE FEDERATION

MICHIGAN POTATOES
MICHIGAN POTATO INDUSTRY COMMISSION