Digital Technologies to Enhance Agricultural Resilience in a Changing Climate and Society

Bruno Basso

University Distinguished Professor

Dept. Earth and Environmental Sciences

MICHIGAN STATE UNIVERSITY

Challenges agriculture and food system face

Grow nutritious food, animal feed, fiber and fuel/energy with less water and land than we have now in a changing climate

Protect soils, water, air quality and biodiversity

Reach negative GHG emissions

Provide reliable, revenue streams to farmers to incentivize changes


Urbanization


Deforestation

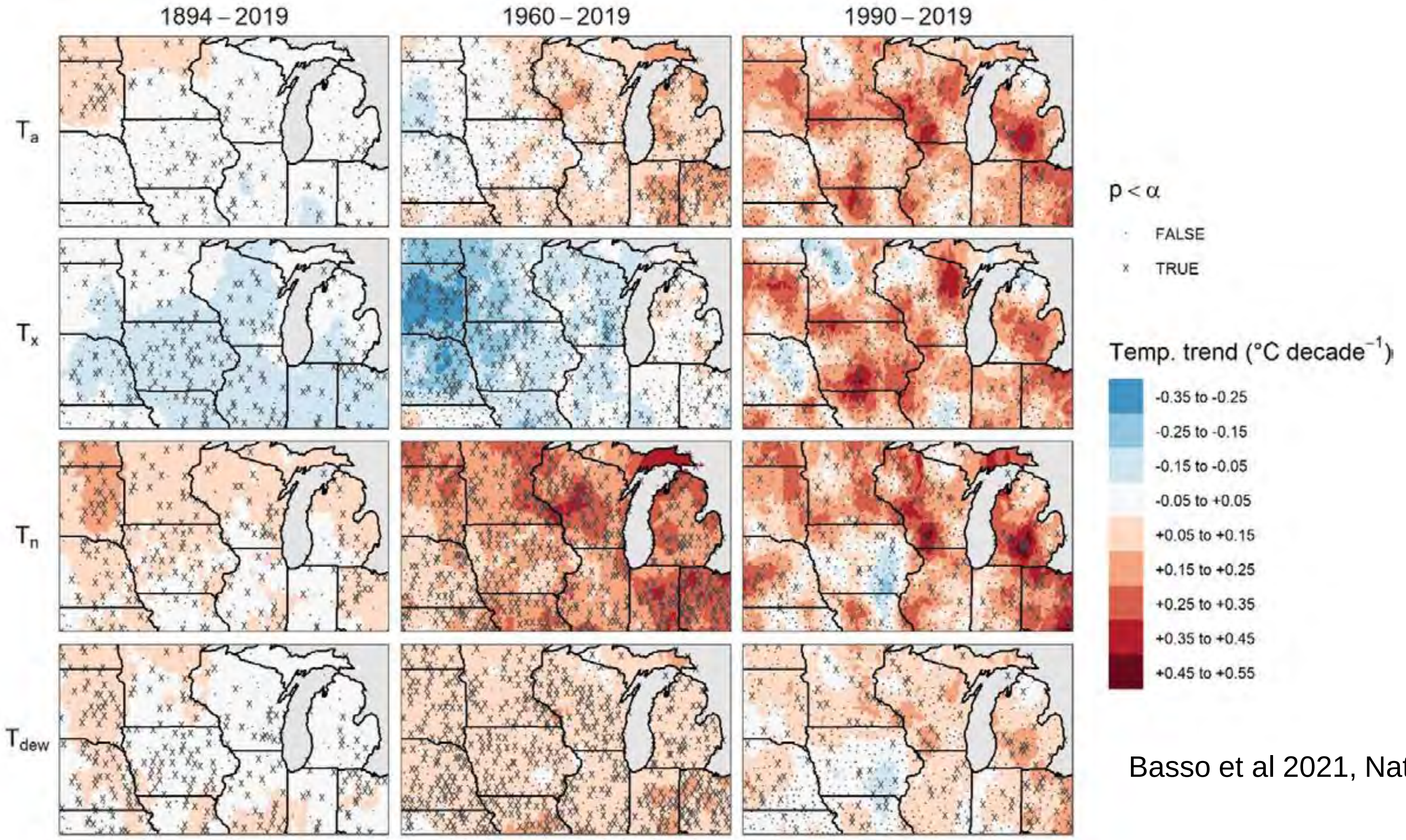

Fires/Land Degradation


Soil Erosion


Water quality

Climate Variability and need for resilience

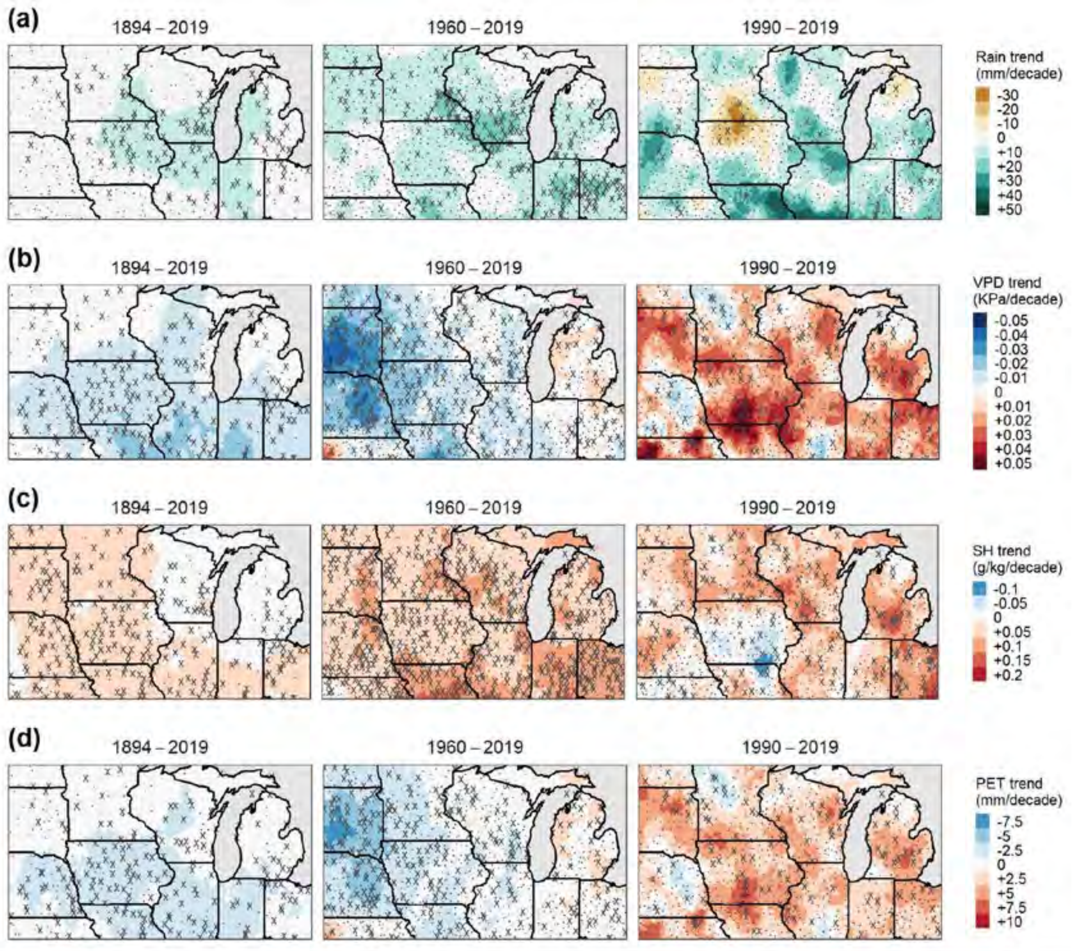
MICHIGAN STATE UNIVERSITY



Basso et al 2021, Nature Communications

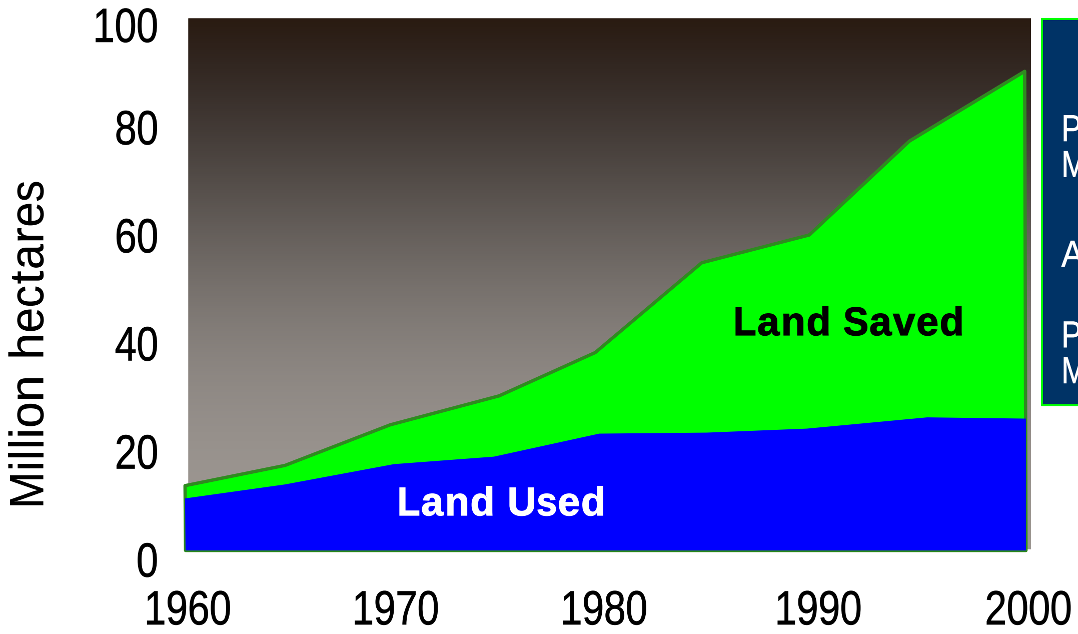
Climate Variability and need for resilience

MICHIGAN STATE UNIVERSITY



Basso et al 2021, Nature Communications

Indian Wheat Production—Area Saved Through Adoption of High-Yield Technology



	1961	2000
Production, Million tonnes	11	76
Av. Yield. t/ha	0.85	2.90
Population, Millions	452	1,016

Source: FAOSTAT

Breakthroughs in Agriculture

MICHIGAN STATE UNIVERSITY

1900s
Mechanization

1950s
Fertilizers and Agrochemicals

1990s
Breeding and Biotechnology

2010s
Data Science and Modeling

AI/ML

Robots

Satellites

Big Data

Drones

Data Analytics

Sensors

Genomics

Microbiomes

Breakthroughs in Agriculture

MICHIGAN STATE UNIVERSITY

1900s

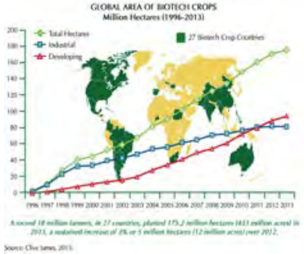
Mechanization

1950s

Fertilizers and Agrochemicals

1990s

Breeding and Biotechnology



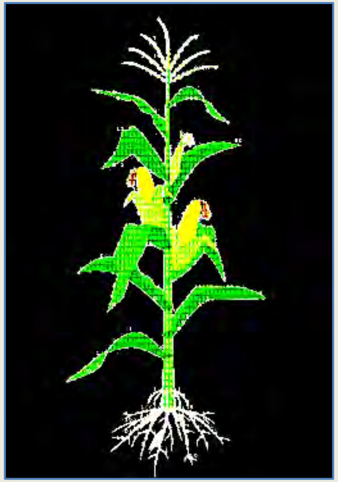
2010s

Data Science and Modeling

Present

Circularity & Sustainability

(Environment, Social and Economic)



A Digital Revolution in Agriculture

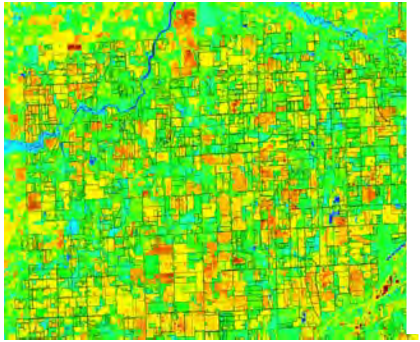
THE FUTURE OF AGRICULTURE

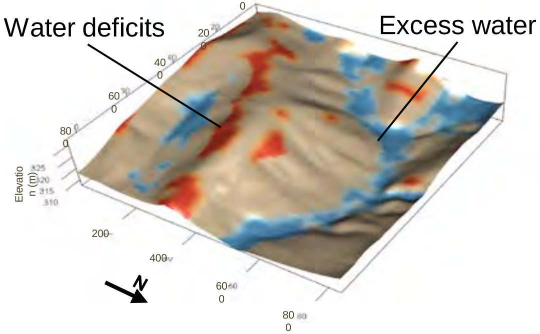
A technological revolution in farming led by advances in robotics and sensing technologies looks set to disrupt modern practice.

BY ANTHONY KING

Forbes

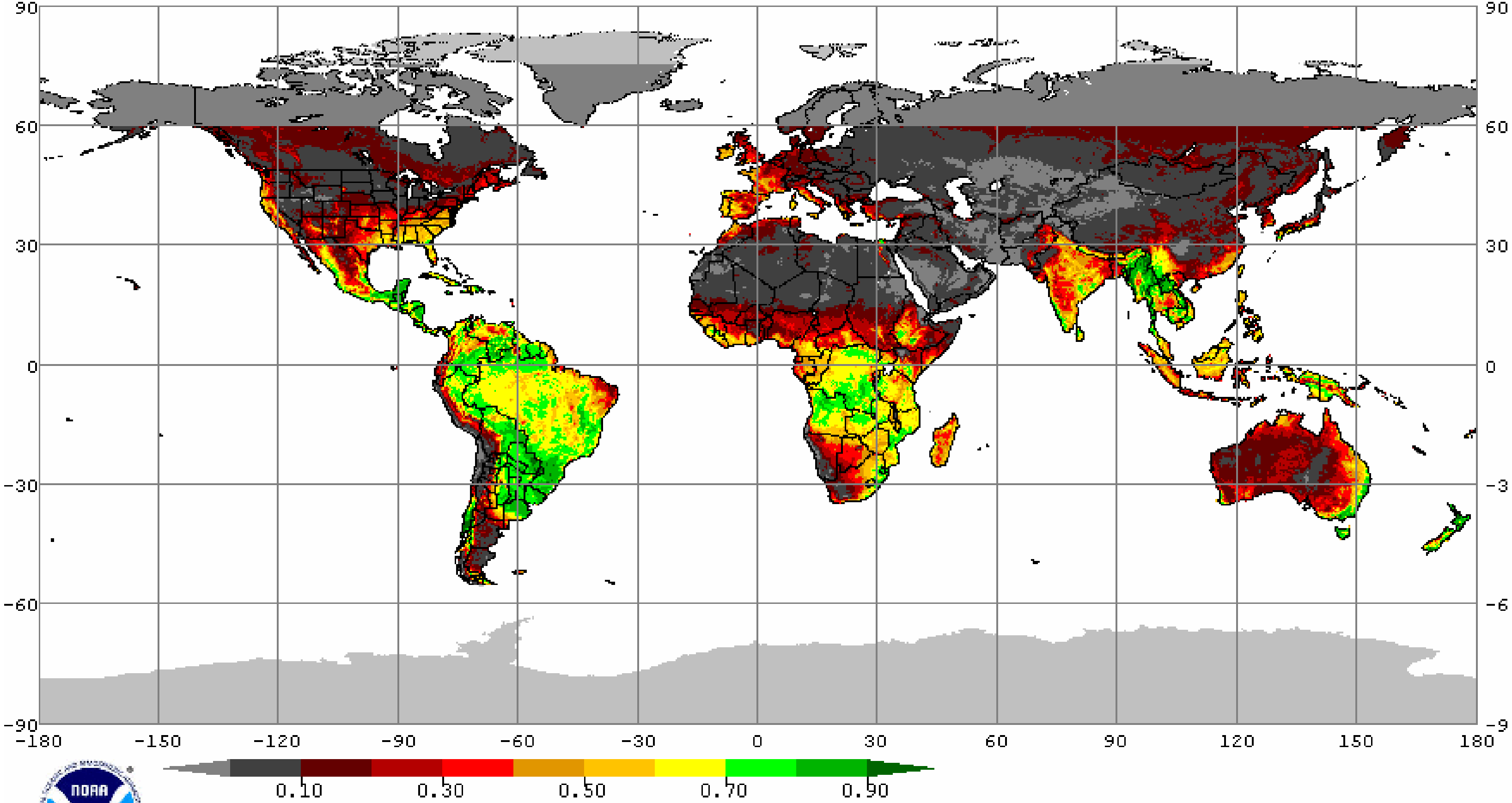
Welcome To The New World Of Digital Agriculture





We can detect mostly everything from the sky

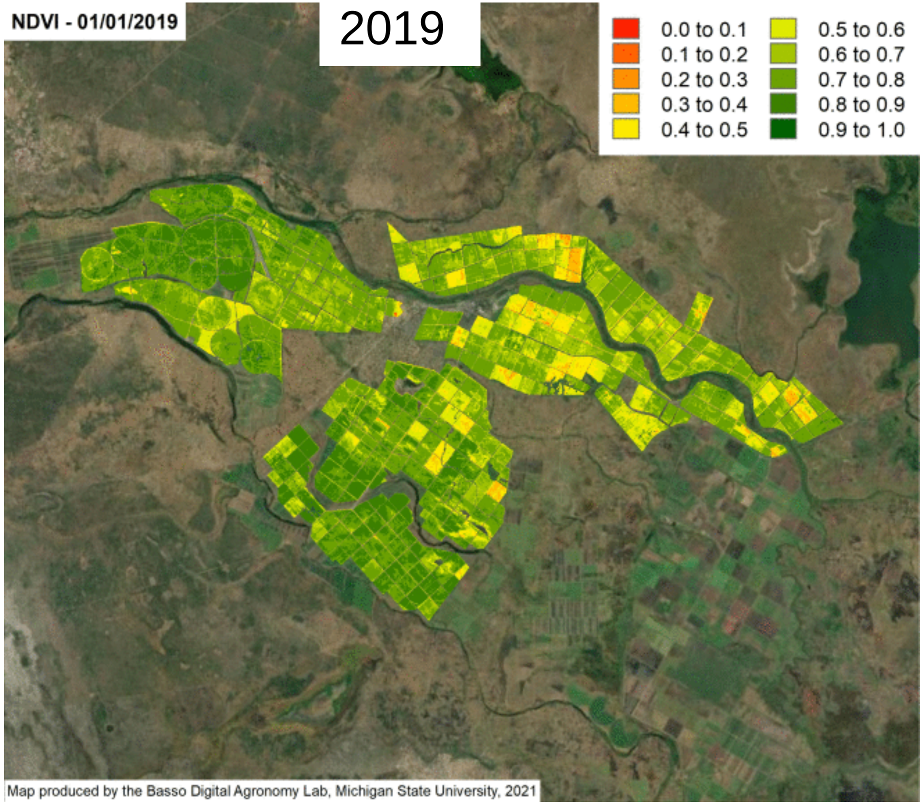
MICHIGAN STATE UNIVERSITY

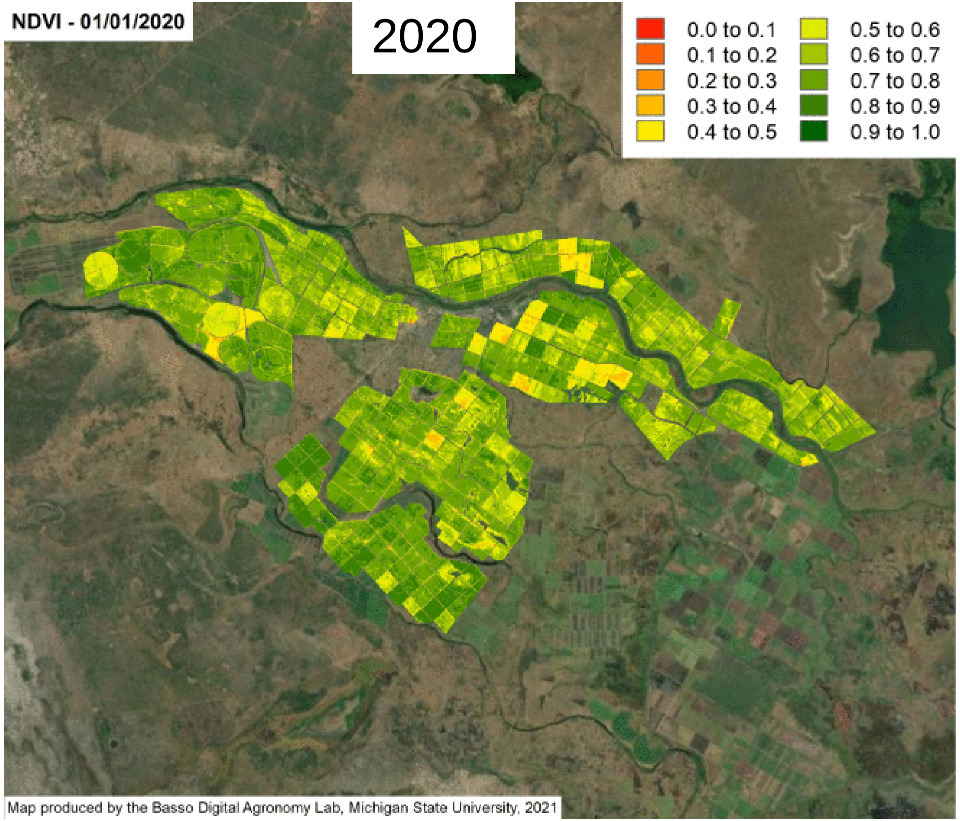


Weekly changes of vegetation

Remote sensing at high spatial and temporal resolution

MICHIGAN STATE UNIVERSITY





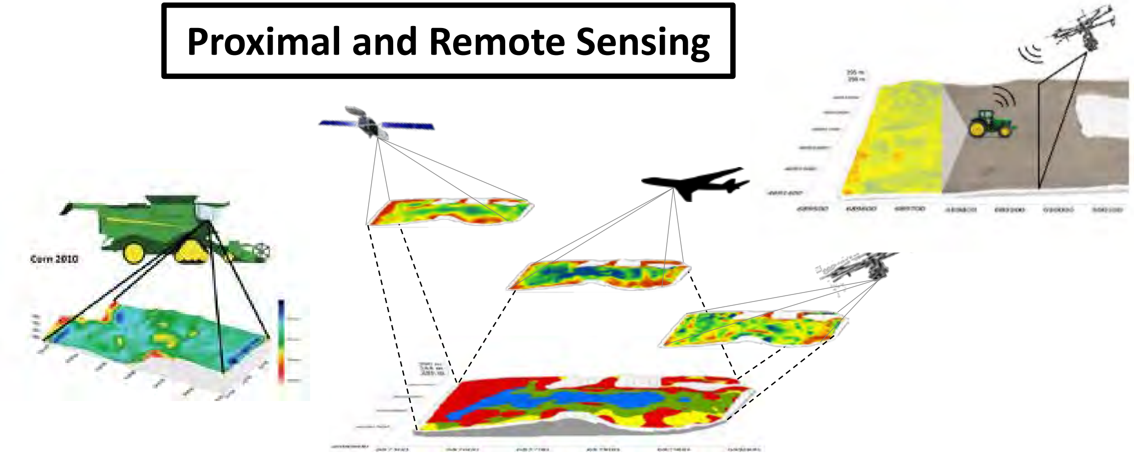
Daily changes of crop vigor and modeling yields in Mozambique sugarcane fields

Basso lab

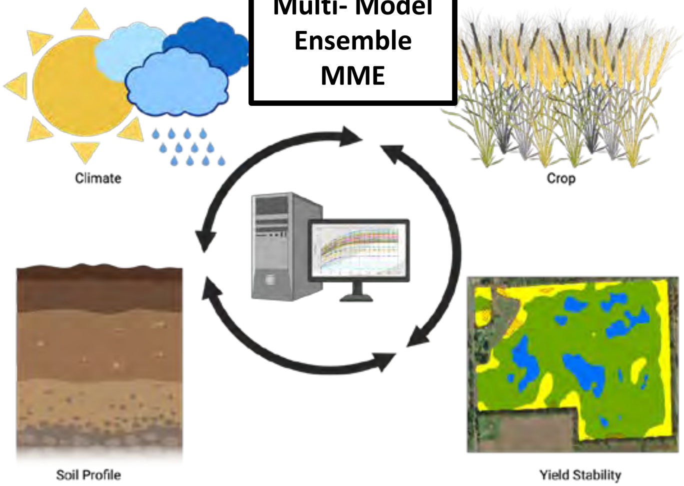
Digital Twins for scaling solutions

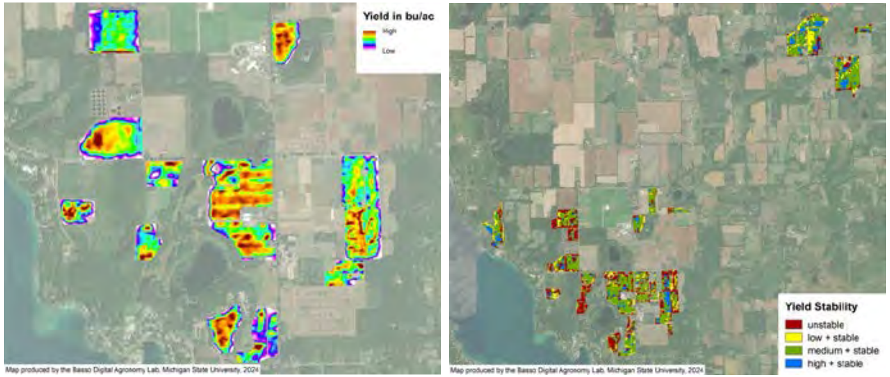
MICHIGAN STATE UNIVERSITY

Proximal and Remote Sensing

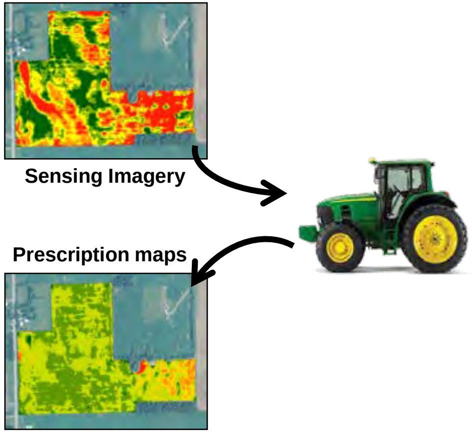


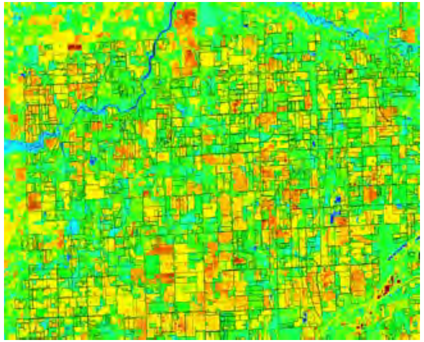
Multi- Model Ensemble MME





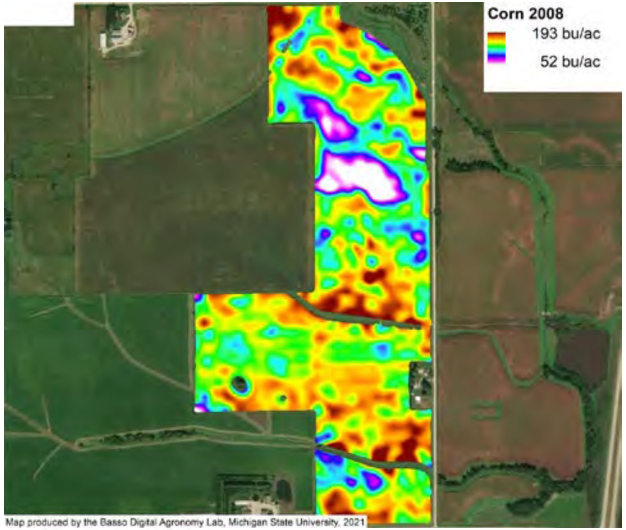
Yield Stability

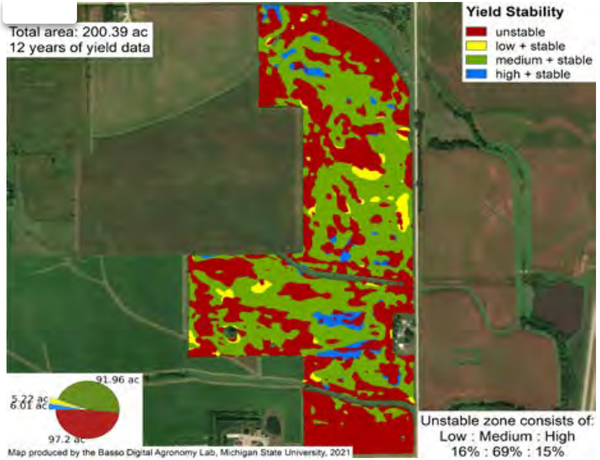




Carbon Intensity

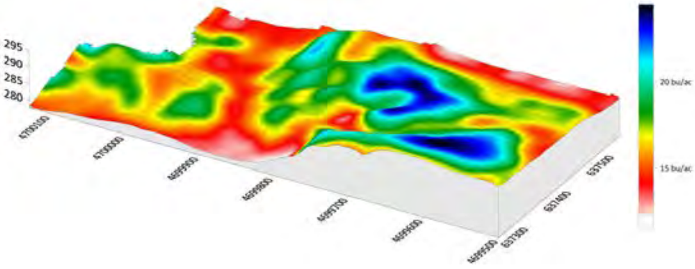
Yield Stability Maps





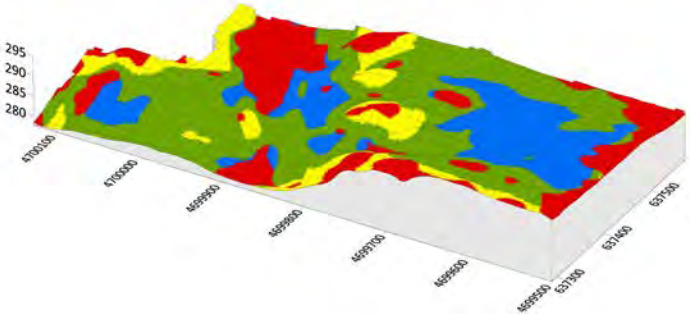
68% of US corn was harvested with combined equipped with yield monitor 45% of the corn area was yield mapped (Lowenberg-DeBoer and Erickson, 2019, *Agron J.*)

Soybeans 2009



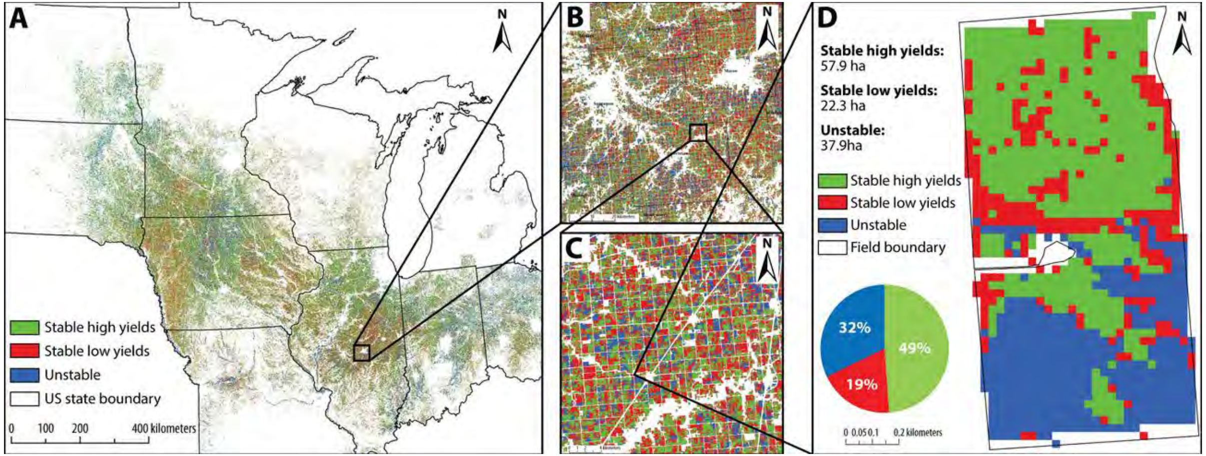
Yield Stability

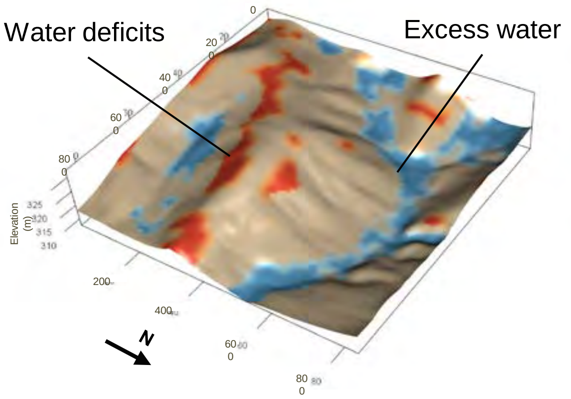
unstable
low + stable
medium + stable
high + stable



Yield Stability scaled up to 80 M acres

MICHIGAN STATE UNIVERSITY





Crop and yield stability maps for (A) 10 Midwest states; (B) 10,000 km2 subregion; (C) 196 km2 subregion; and (D) 118 ha

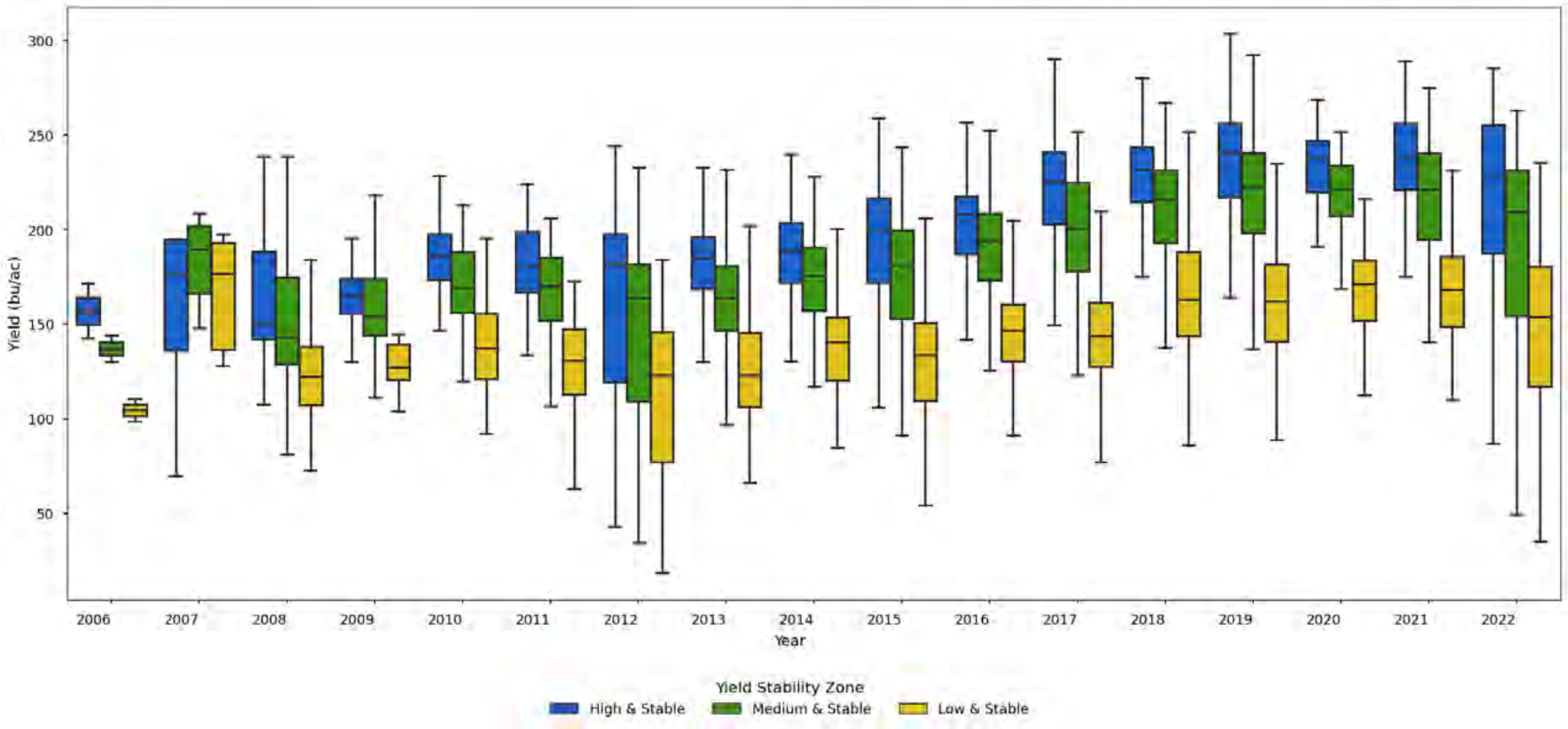
Methods:
- 15 years NASA Landsat images
- Common Land Units (field boundaries)
- Crop data layers (corn and soybeans)
- NASS Arms (Fertilizer rates)

Subfield productivity across 80 Million acres
- 48% stable high productivity (HS); N Use Eff.~75%
- 25% stable low productivity (LS); NUE ~45%
- 27% unstable (U; 64% High yield, 26% Low yield); NUE ~ 58%

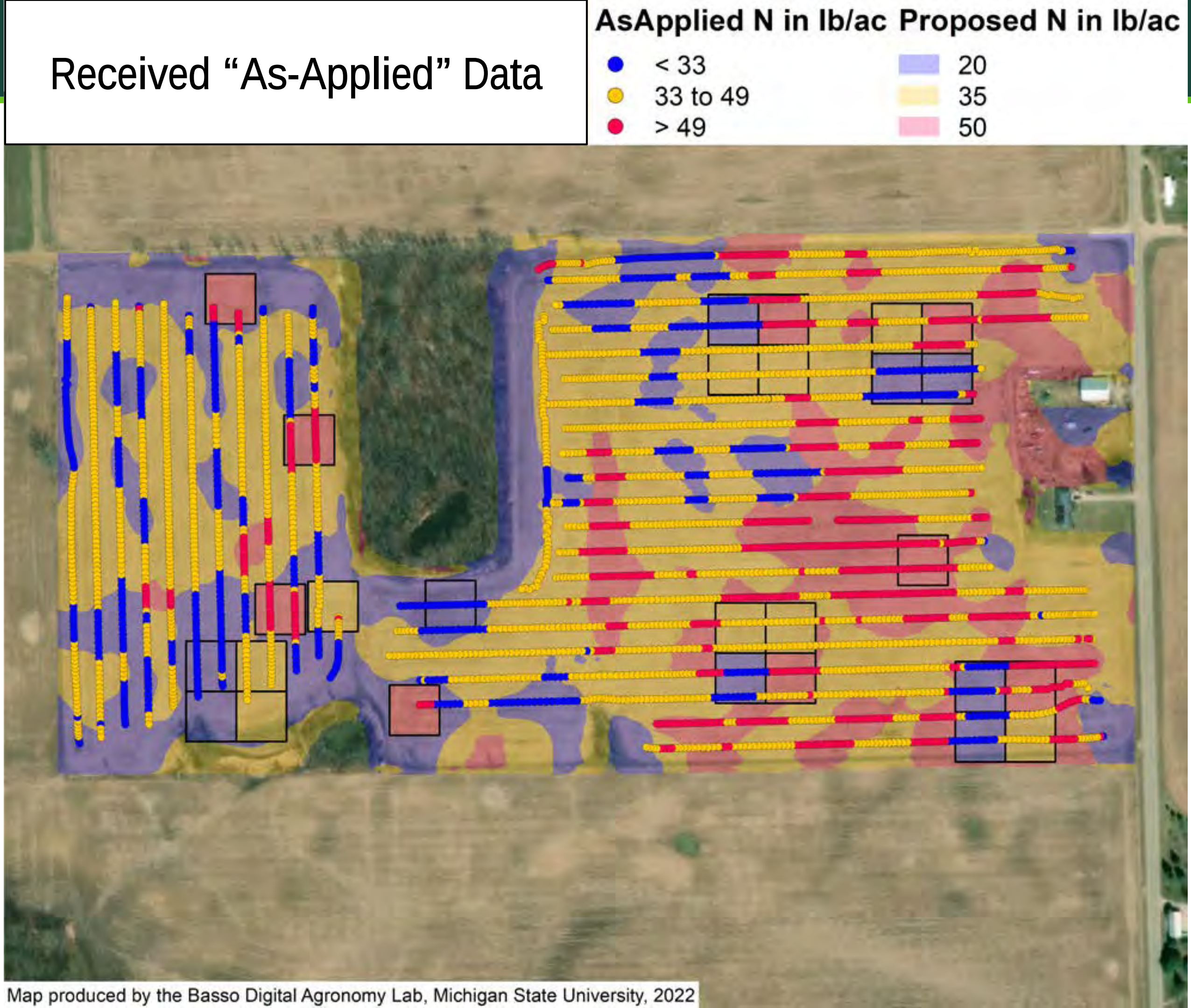
Impacts
- ~ 1.4 Tg N yr $^{-1}$ of N fertilizers is lost to the Gulf of Mexico
- ~ 700 Million US$ yr $^{-1}$ wasted from crop unused fertilizers
- 1.1 Billion Giga Joule of energy lost
- 7 Million tons yr $^{-1}$ CO_2 lost to the atmosphere

Basso et al., 2019; Martinez-Feria and Basso. 2020

Yield under Uniform N Management:
Stable Zones, 526 fields with N application > 150 lb N/ac



Received "As-Applied" Data



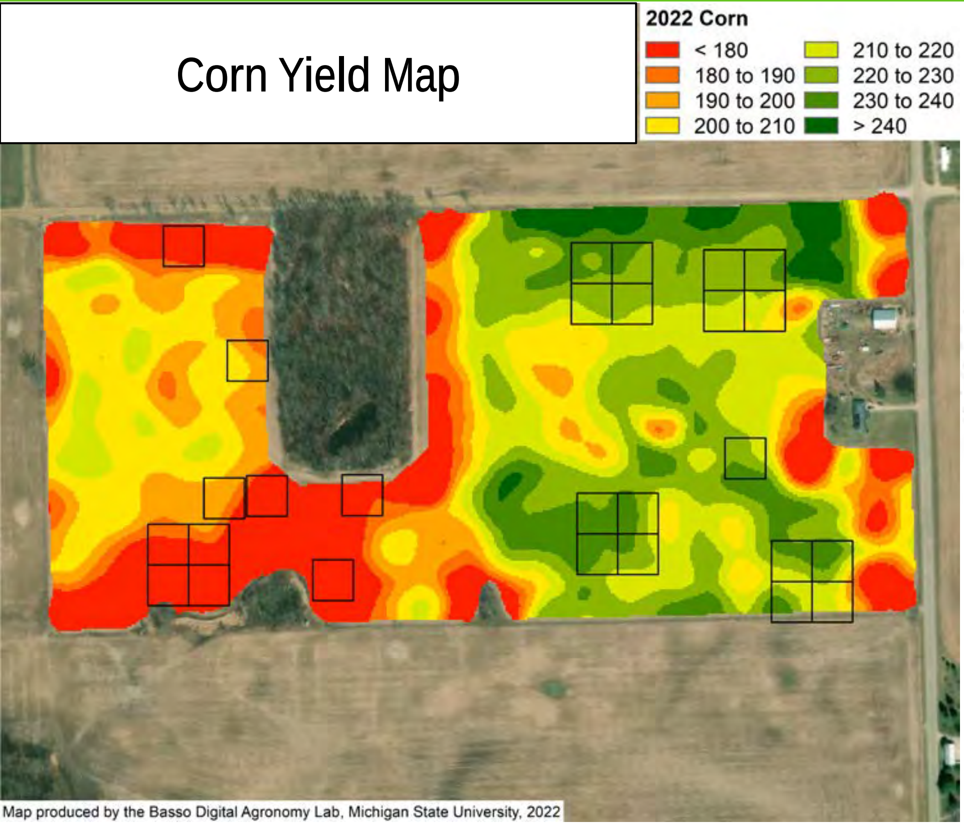
MICHIGAN STATE UNIVERSITY

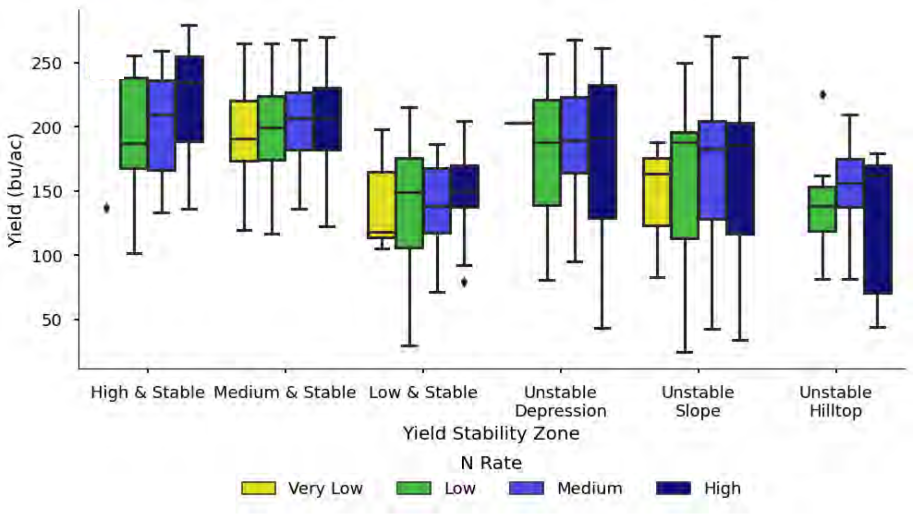
Variable Rate Nitrogen Fertilizer

Prescription Nitrogen and the Field's Response

MICHIGAN STATE UNIVERSITY

Corn Yield Map



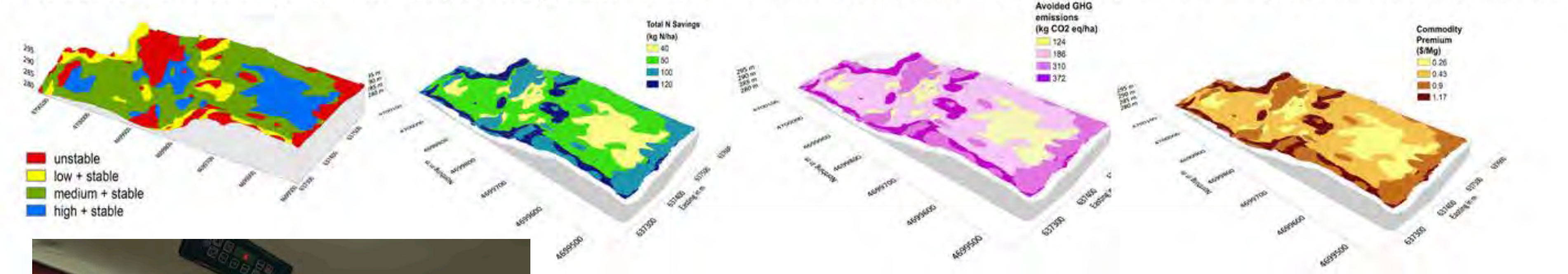


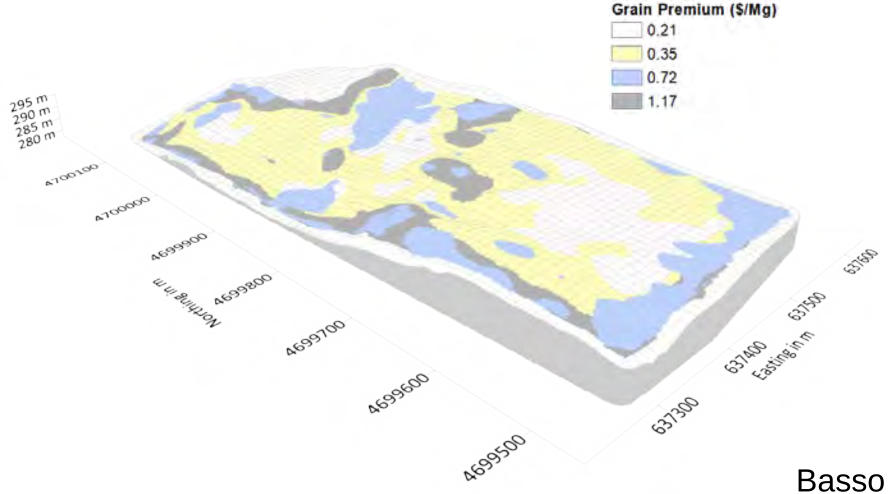
Basso et al. submitted

Climate Smart Commodities

MICHIGAN STATE UNIVERSITY

A. Example of a Yield Stability map **B. Nitrogen saving from the Rx map** **C. Avoided GHG emissions from Rx map** **D. Commodity Premium from GHG reduction**

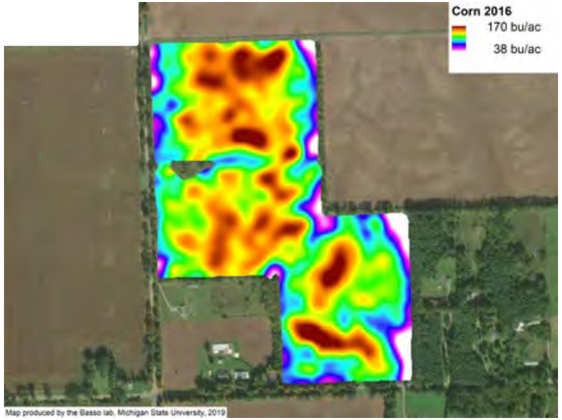


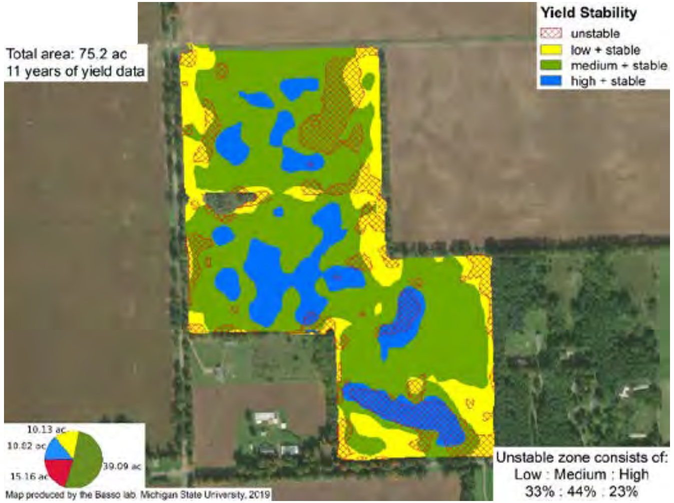


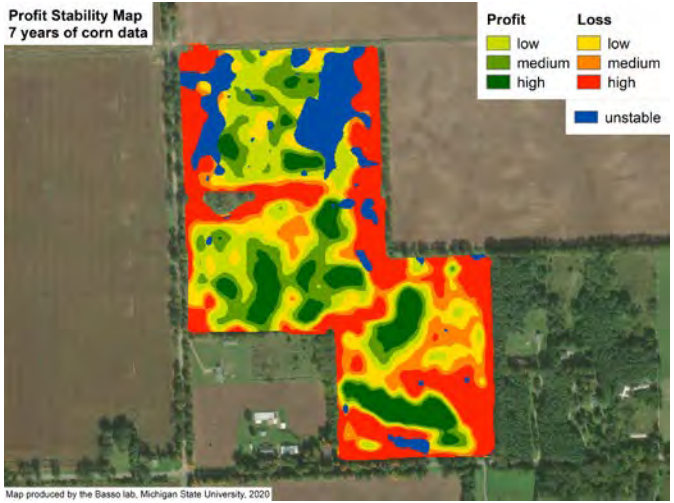
Basso et al, 2022

Carbon credits kg/ha CO2e avoided emissions

Profit Stability

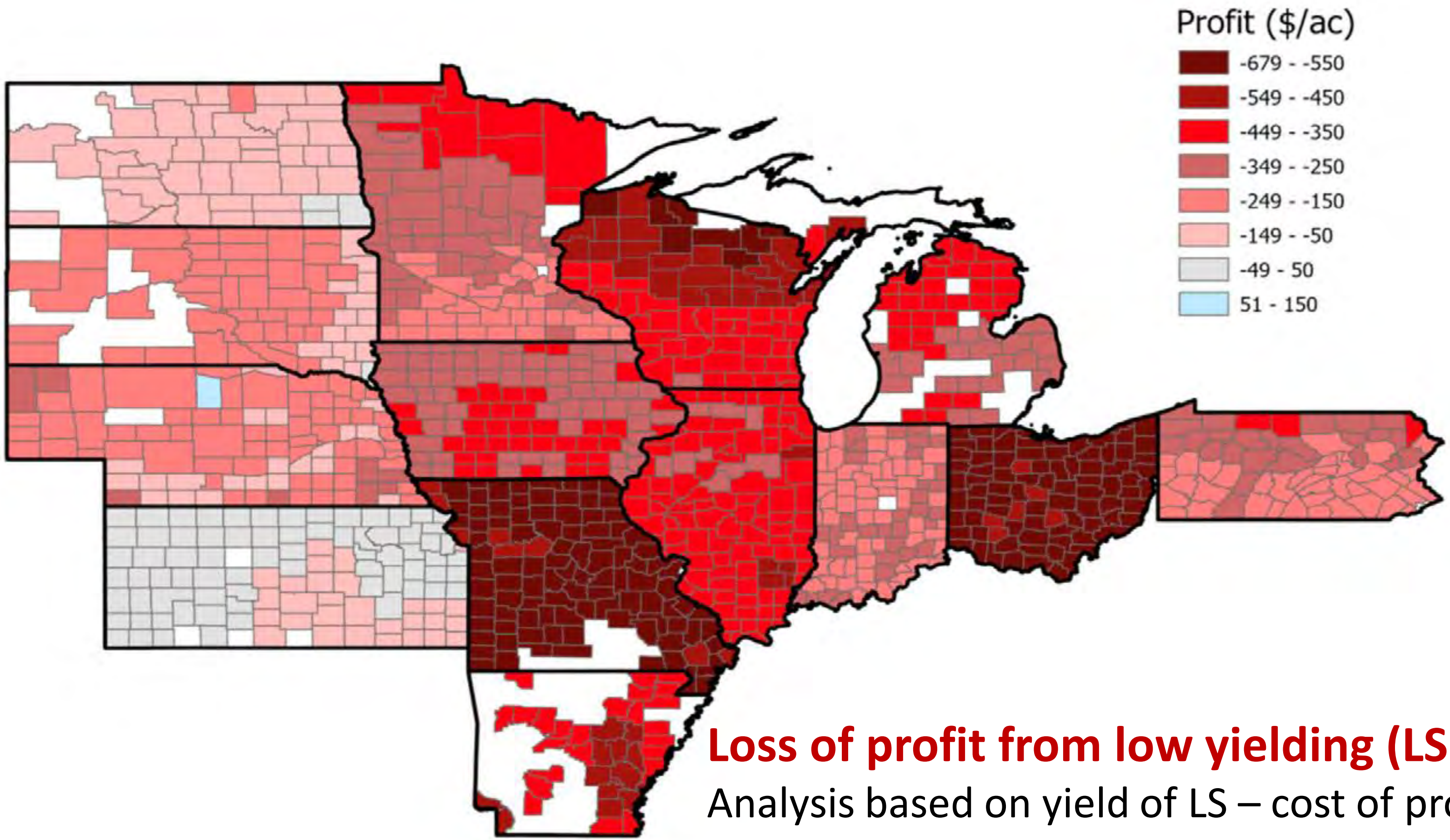






Low $50
Med. $100
High $200

Low yielding areas across 80M acres

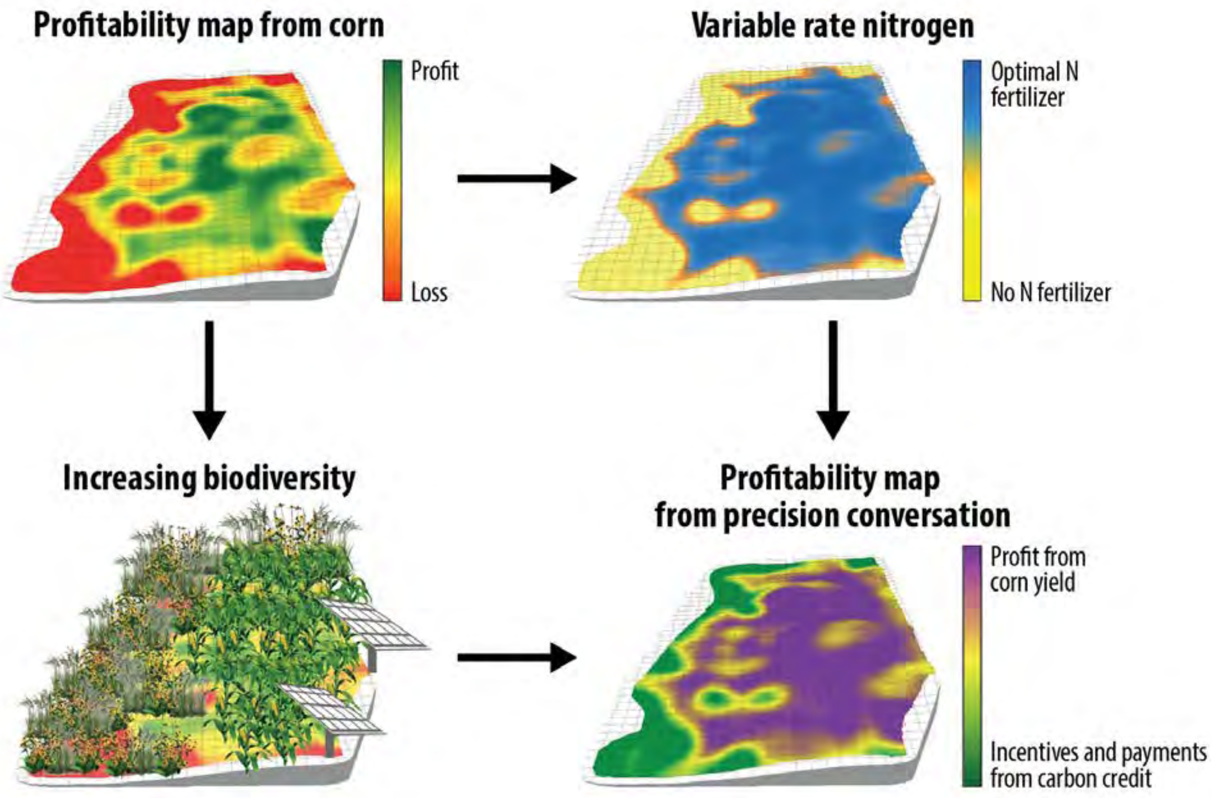


Loss of profit from low yielding (LS) areas

Analysis based on yield of LS – cost of production

Precision Conservation

MICHIGAN STATE UNIVERSITY



Benefits of Precision Conservation

- Nitrate leaching reduction
- Mitigation of GHG emissions
- Soil carbon accrual
- Biodiversity associated benefits
- Economic benefits

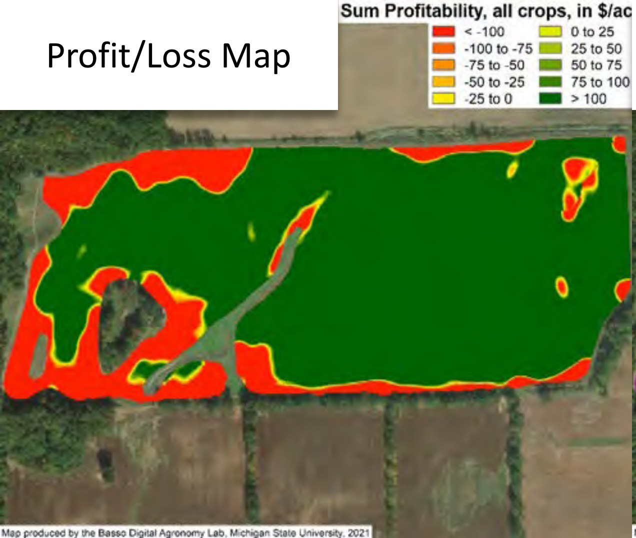
Basso, 2021, Nature Food

Basso and Antle, 2020 Nature Sustainability

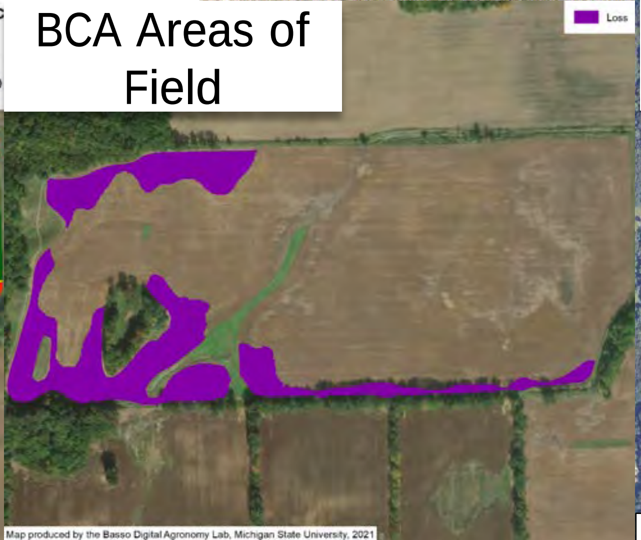
Experience with Digital Ag

On-farm data becomes actionable changes that benefit the environment, local ecosystem, and the farmers profitability

Profit/Loss Map



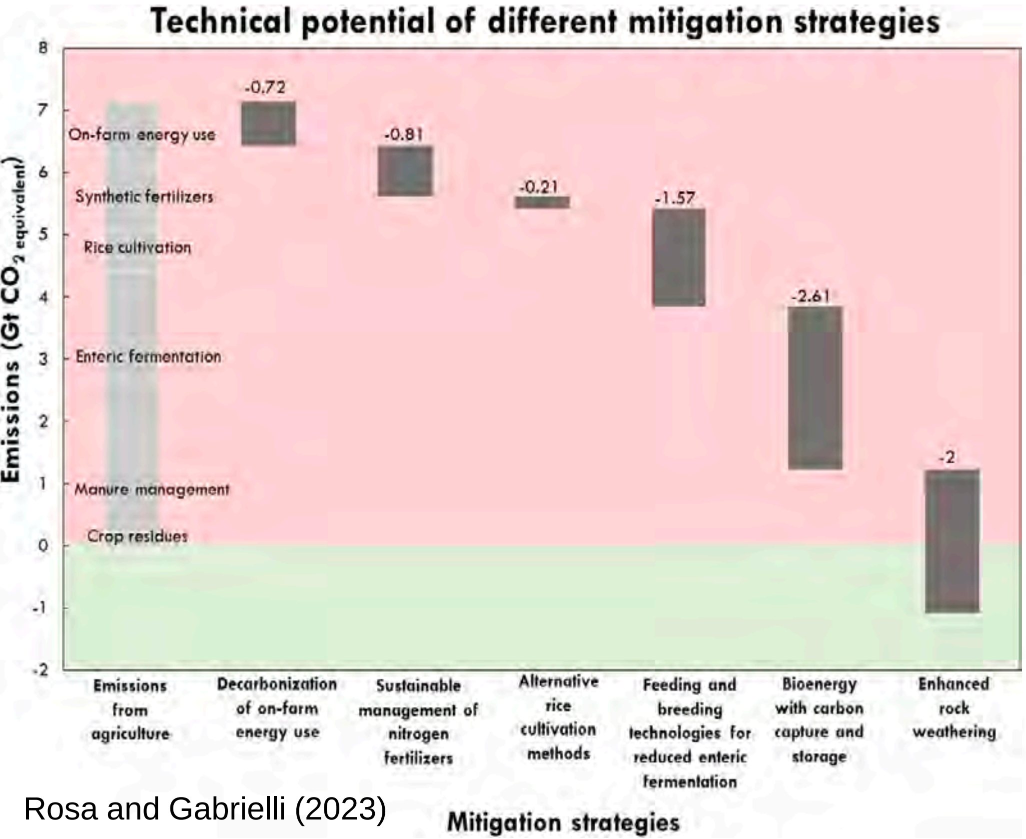
BCA Areas of Field



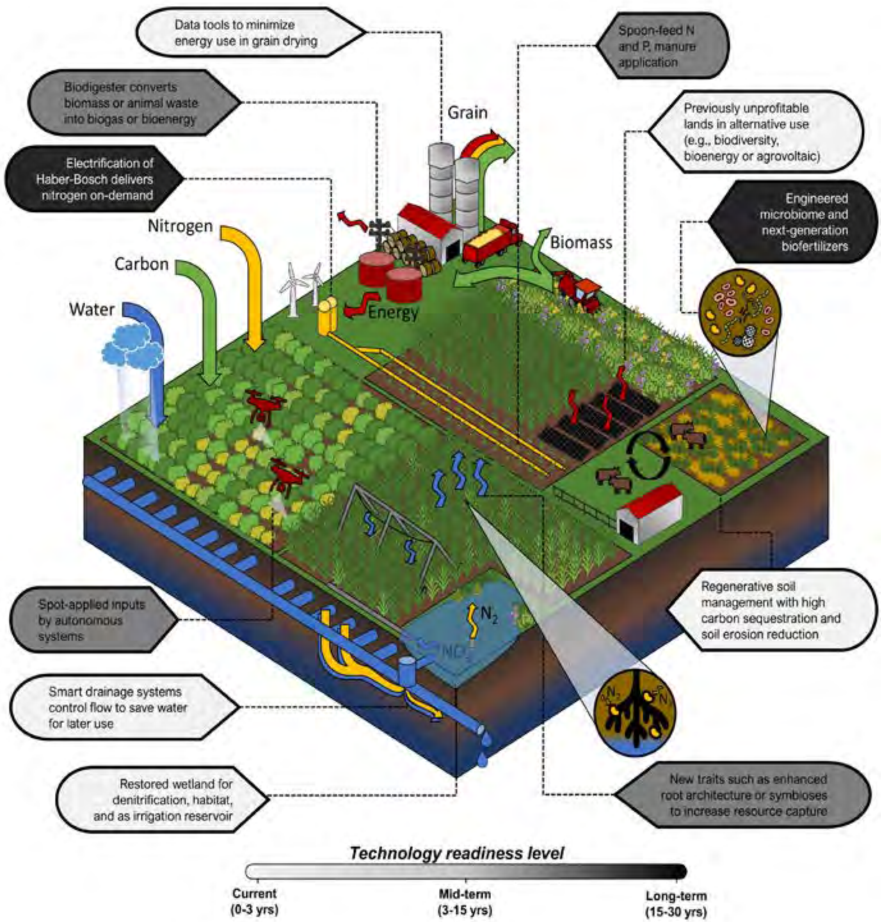
Aerial Image

We can mitigate current emissions by 50-70%

MICHIGAN STATE UNIVERSITY



Rosa and Gabrielli (2023)



Basso, et al 2021 Ag Syst

Northup, Basso, et al., 2021, PNAS

Sources and sinks of CO_2e in cropping systems

MICHIGAN STATE UNIVERSITY

Is cropland mitigation even possible?

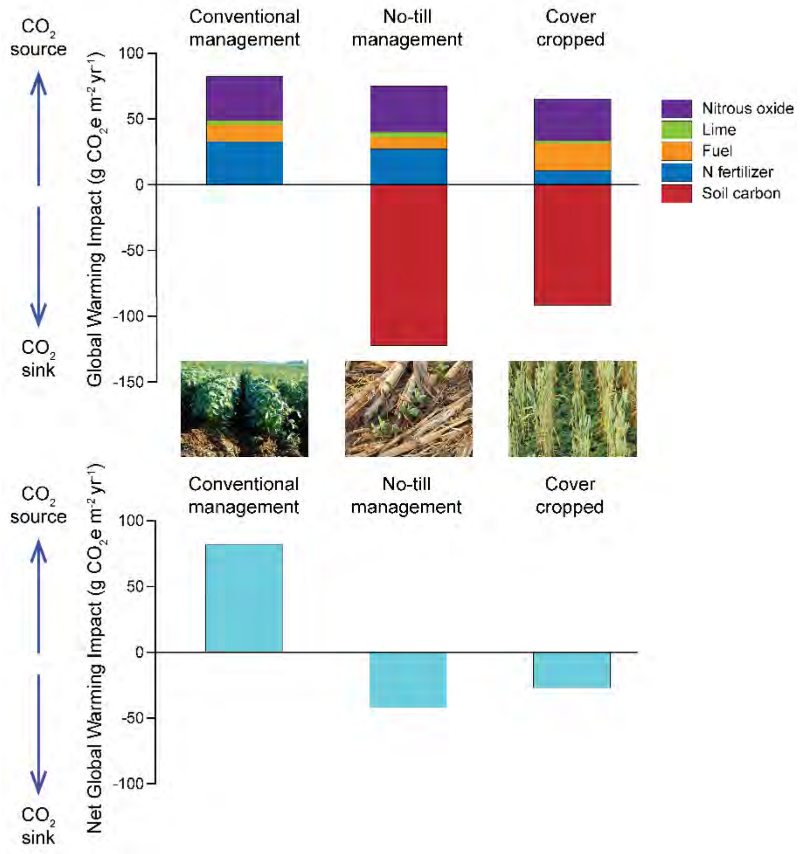
Sources of CO_2e in cropped systems

- 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

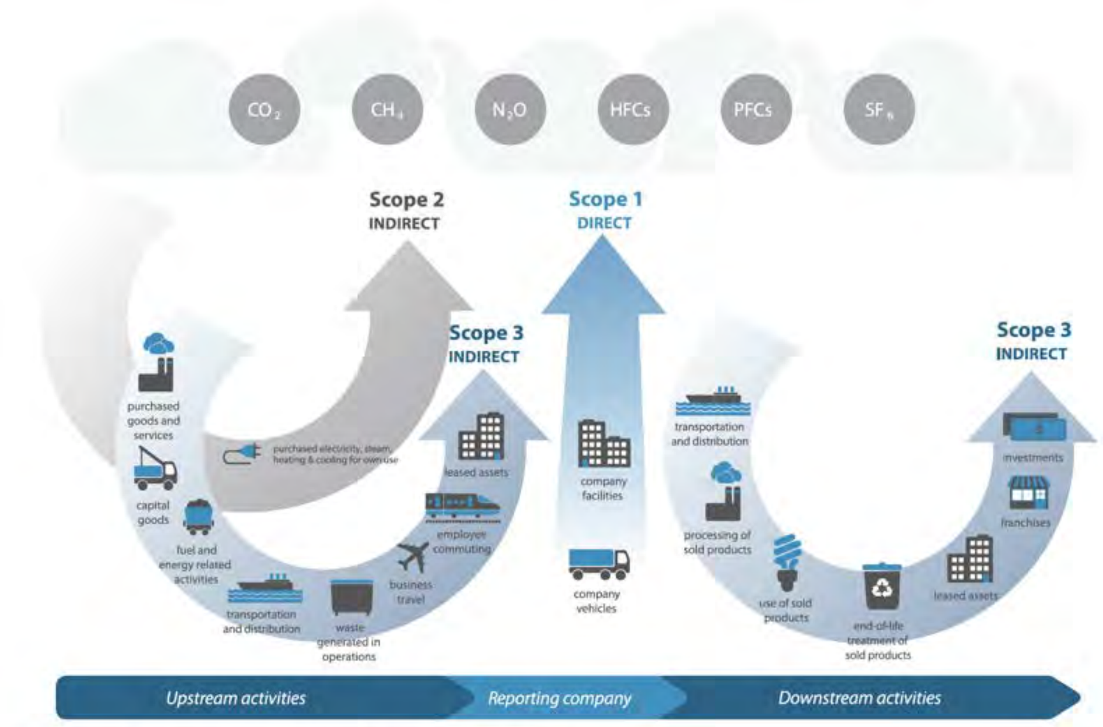
Global Warming Impacts of c-s-w rotations in Michigan



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

kbs lter
Kellogg Biological Station Long-Term Agroecosystem Research

Increasing soil organic carbon (SOC) storage and reducing Greenhouse Gas (GHG) emissions can play a critical role in mitigating climate change. Climate-smart practices offer a viable pathway to achieve this.

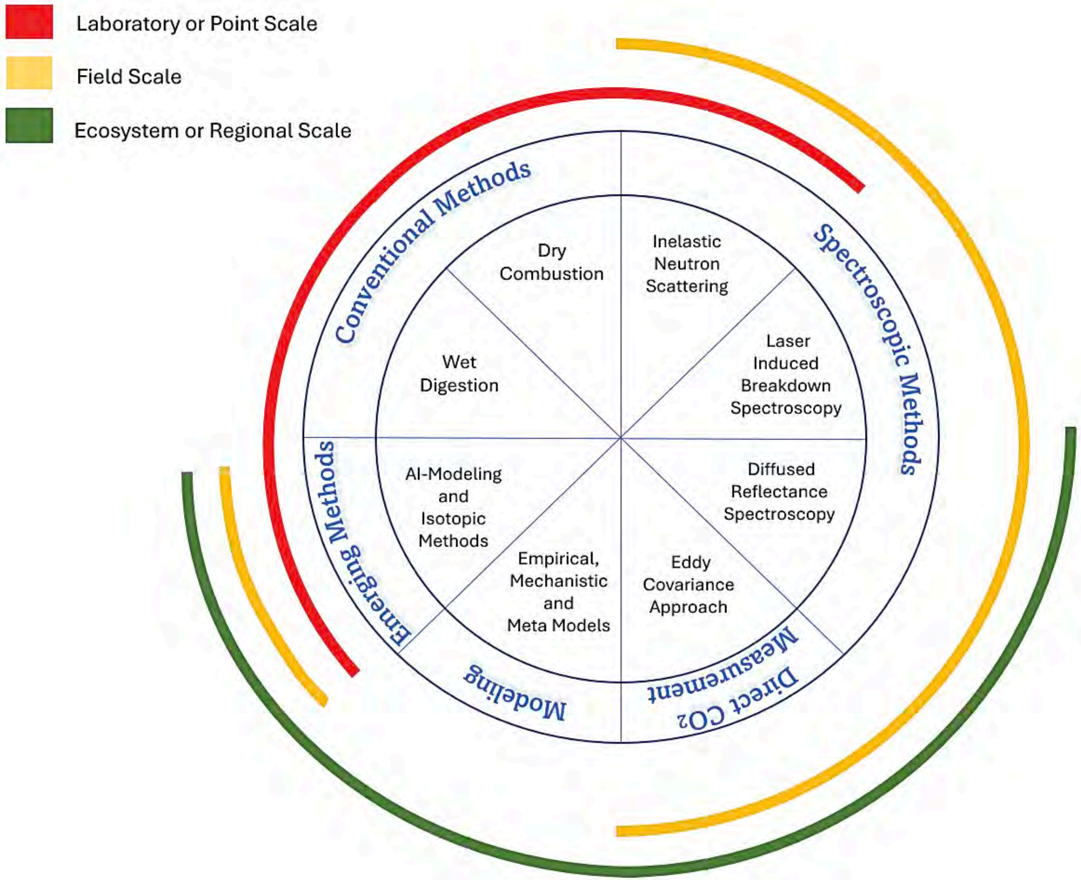


Source: *The Greenhouse Gas Protocol (WRI and WBCSD, 2001).*

Uncertainties in measuring and modeling SOC

MICHIGAN STATE UNIVERSITY

- Laboratory procedures
- Spatial variability
- Bulk density
- Remote Sensing
- Spectroscopy
- Process-based models
- Hydrid models (ML+ Process Based Models



Melkani et al., 2023

Carbon Border Adjustment Mechanism

In Solidarity for a Green World

The 29th session of the Conference of the Parties to the United Nations Framework Convention on Climate Change

Climate change is a **global** problem that needs **global** solutions. As the EU raises its own climate ambition, and as long as less stringent climate policies prevail in many non-EU countries, there is a risk of so-called '**carbon leakage**'. Carbon leakage occurs when companies based in the EU move carbon-intensive production abroad to countries where less stringent climate policies are in place than in the EU, or when EU products get replaced by more carbon-intensive imports.

SUSTAINABLE DEVELOPMENT GOALS
KNOWLEDGE PLATFORM

English ICAO Store

ICAO ENVIRONMENT

Search...

About ICAO | Global Priorities | Events | Information Resources | Careers | Featured articles | ICAO TV | Subscribe

ICAO / Environmental Protection / CORSIA / CORSIA Eligible Fuels

- ENV Homepage
- CORSIA Homepage
- CORSIA IMPLEMENTATION
- ACT CORSIA

CORSIA Eligible Fuels

Latest updates

European Review of Agricultural Economics Vol **50 (4)** (2023) pp. 1310–1337
doi:https://doi.org/10.1093/erae/jbad018
Advance Access Publication 2 August 2023

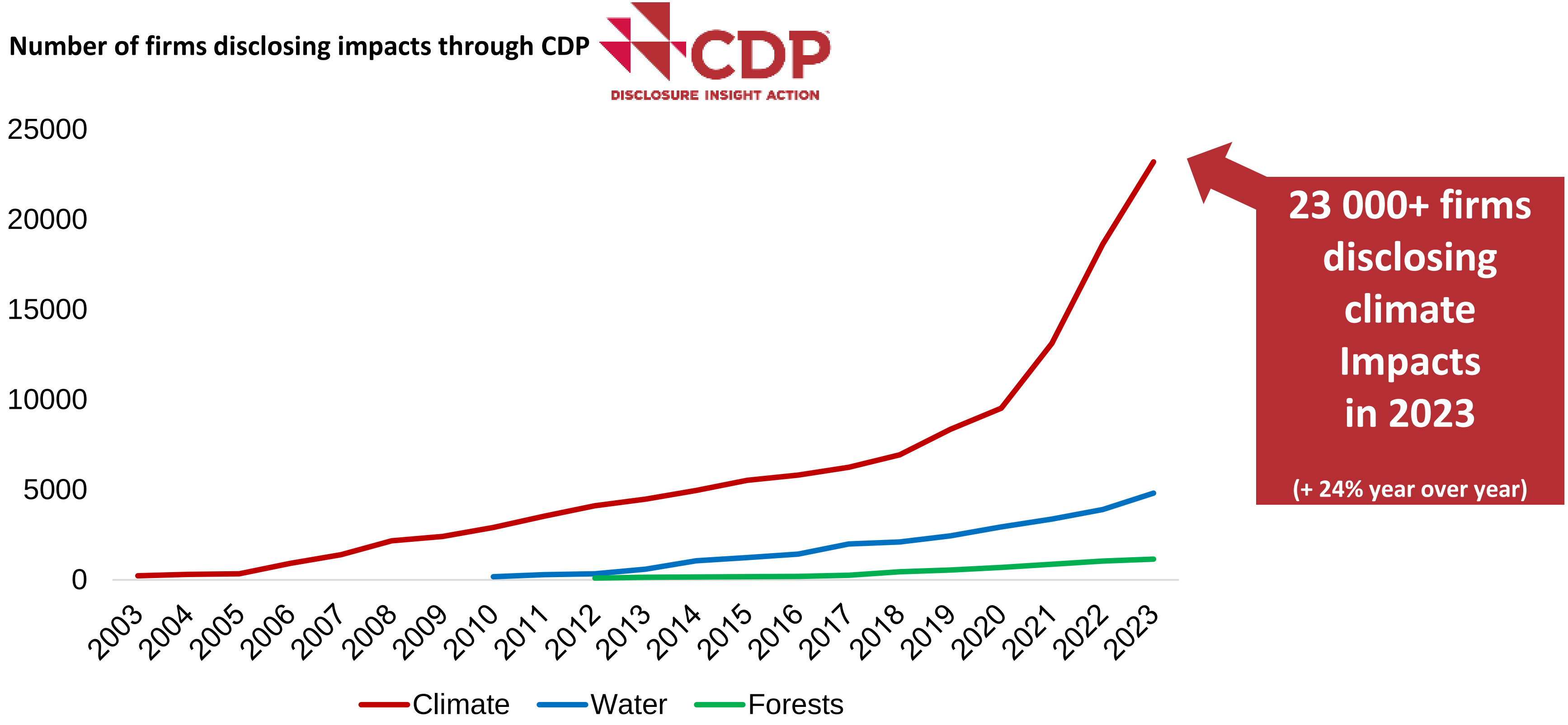
Fast and furious: the rise of environmental impact reporting in food systems

Koen Deconinck*, Marion Jansen and Carla Barisone

All authors are at the Trade and Agriculture Directorate of the Organisation for Economic Co-operation and Development, Paris, France

Received January 2023; final version accepted May 2023

Firms are increasingly disclosing their environmental impact information



Courtesy of Koen Deconinck

Leading retailers are setting **Scope 3 targets**

MICHIGAN STATE UNIVERSITY

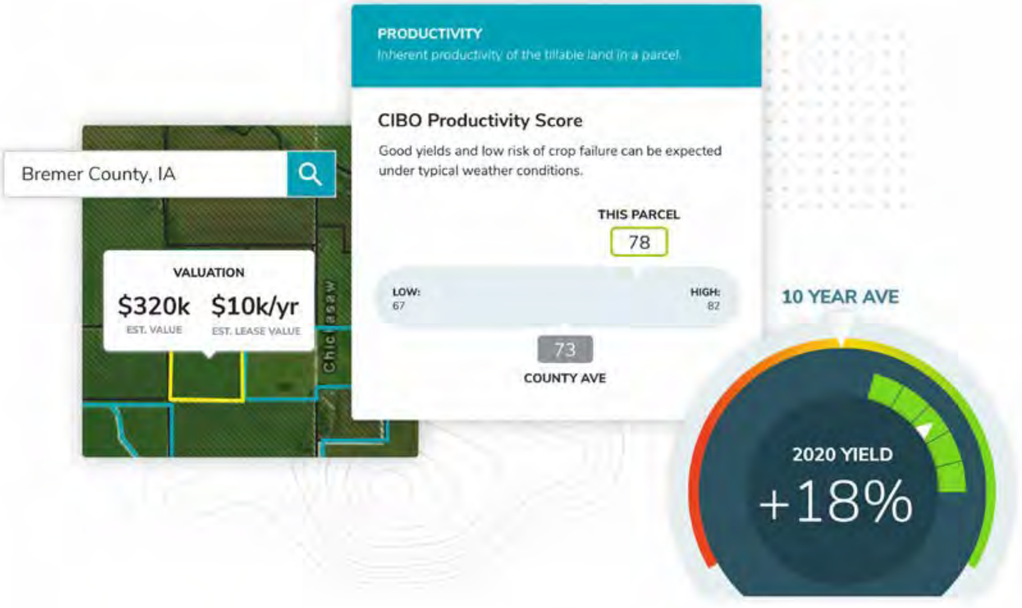
Direct impact ag/food suppliers; This is not just about carbon footprints

SCIENCE BASED TARGETS

Aeon (Japan)	80% of suppliers (by emissions) will set science-based targets
Ahold Delhaize (Belgium, Netherlands, USA)	**Reduce Scope 3 emissions by 37%** (2030 vs 2018)
Aldi (N & S) (Europe, USA)	75% of suppliers (by emissions) will have science-based targets by 2024
Carrefour (Europe, LatAm, MENA)	**Reduce Scope 3 emissions by 29%** (2030 vs 2019)
ICA (Sweden, Norway, Baltics)	70% of suppliers (by emissions) will set science-based targets by 2025
Kesko (Scandinavia, Baltics)	67% of suppliers (by spend) will have science-based targets by 2026
Migros (Switzerland)	67% of suppliers (by emissions) will have science-based targets by 2026
Tesco (UK, EU)	**Reduce Scope 3 emissions to net zero by 2050**
Walmart (US, Canada, LatAm, Asia)	Reduce Scope 3 emissions by one billion tonnes (2030 vs 2015)
Woolworths (Australia)	Reduce Scope 3 emissions by **19%** (2030 vs 2015)

Source: https://sciencebasedtargets.org/companies-taking-action
and https://www.aholddelhaize.com/news/ahold-delhaize-sets-updated-co2-emissions-reductions-targets-for-its-entire-value-chain-in-line-with-un-goal-of-keeping-global-warming-below-1-5-c/

Scores for productivity and land value



Powerful search

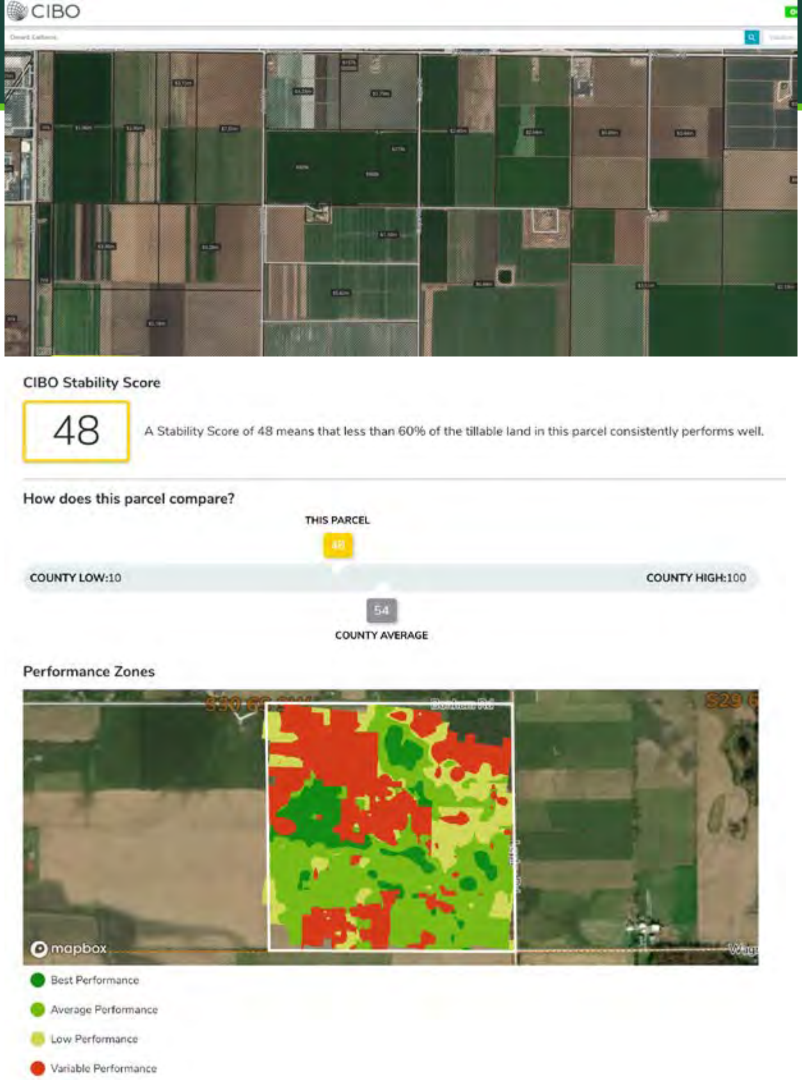
Quickly explore millions of parcels using advanced search criteria like owner, productivity, size, value, and more.

Objective insights

Understand the true potential of a field via exclusive, science-driven insights and proprietary land data.

Simple, intuitive access

Easily access public land data like soil maps, weather, and ownership combined with CIBO insights—for every parcel.

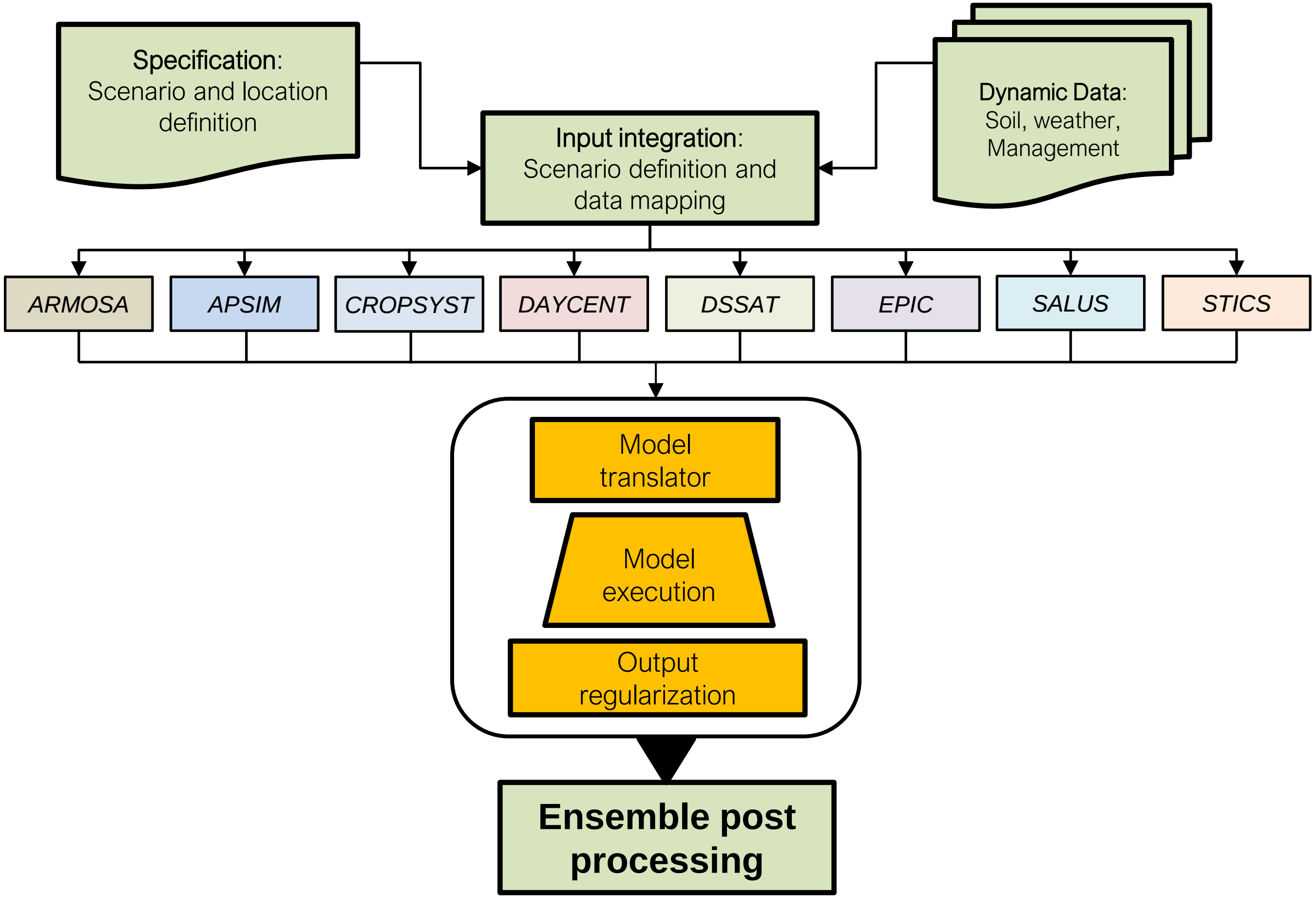


CIBO Technologies Recognized by TIME as one of America's Top GreenTech Companies of 2024

March 19, 2024 **Awards, News Release**

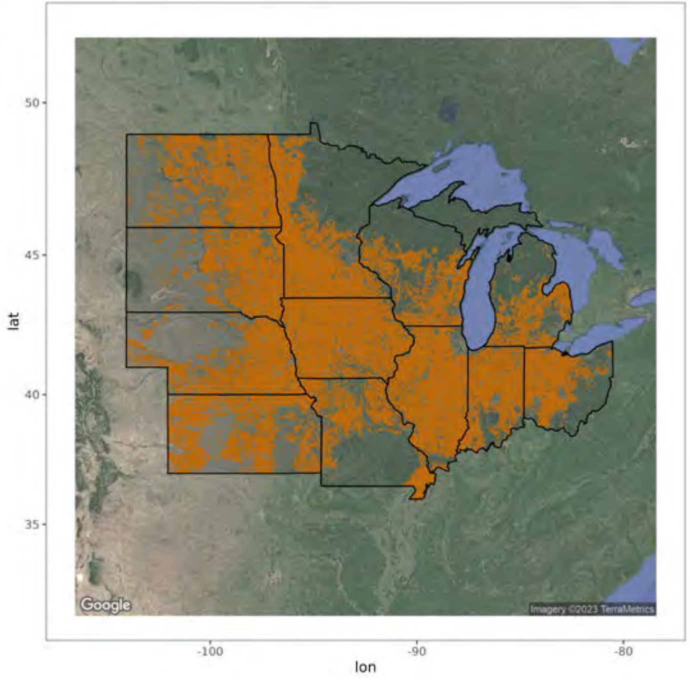
Multi-model ensemble (MME)

Multiple process-based models are executed with the same inputs to assess uncertainty in SOC, GHG and Yield dynamics



Basso et al., 2025

Multi-model ensemble (MME)

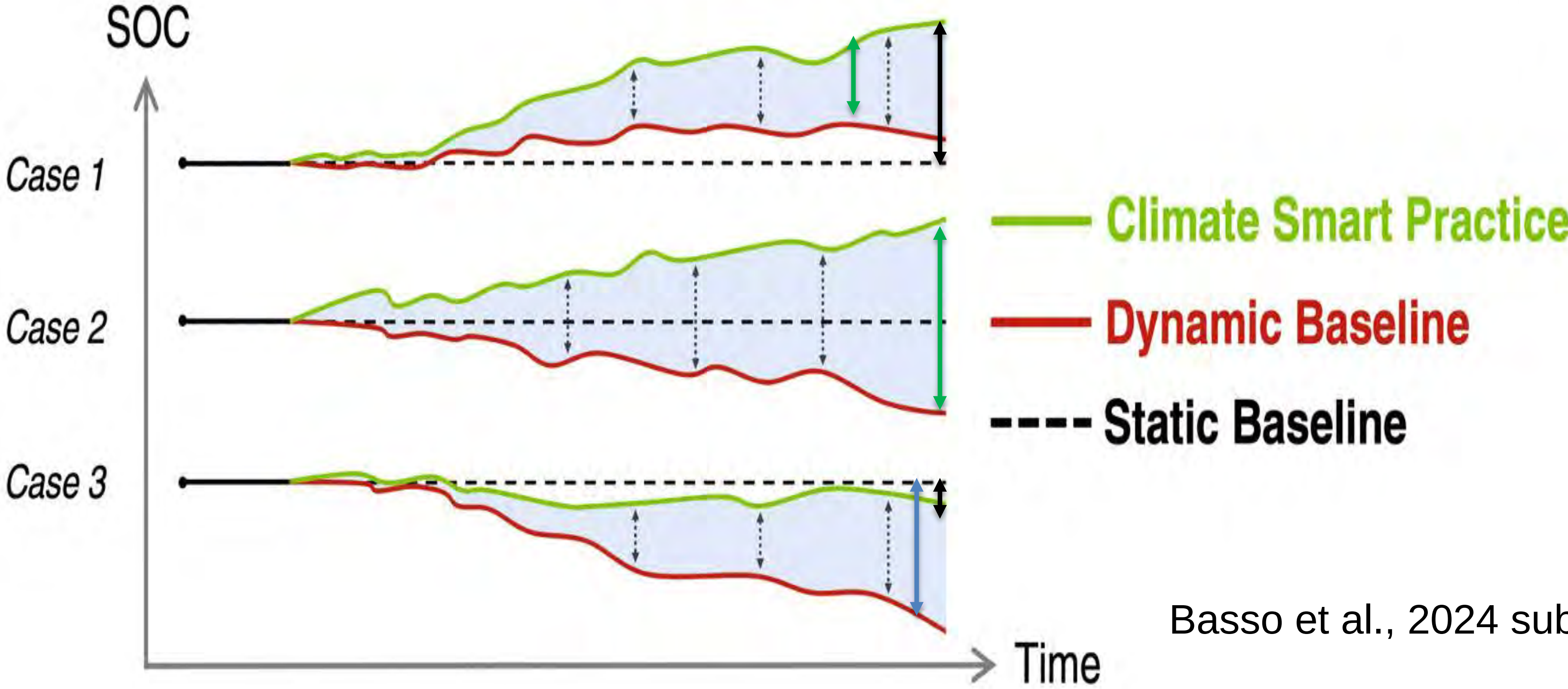


Scenario ID	Tillage	Crop rotation	N amount (%)	Cover crop	Acronym
1	Conventional	Two years (maize - soybean)	100 %		CT
2				Rye	CT CC
3	No till				NT
4				Rye	NT CC

Scenario ID	Tillage	Crop rotation	N amount (%)	Cover crop	Acronym
5	Conventional	maize - soybean	75 %		CT RN
6				Rye	CT RN CC
7	No till				NT RN
8				Rye	NT RN CC

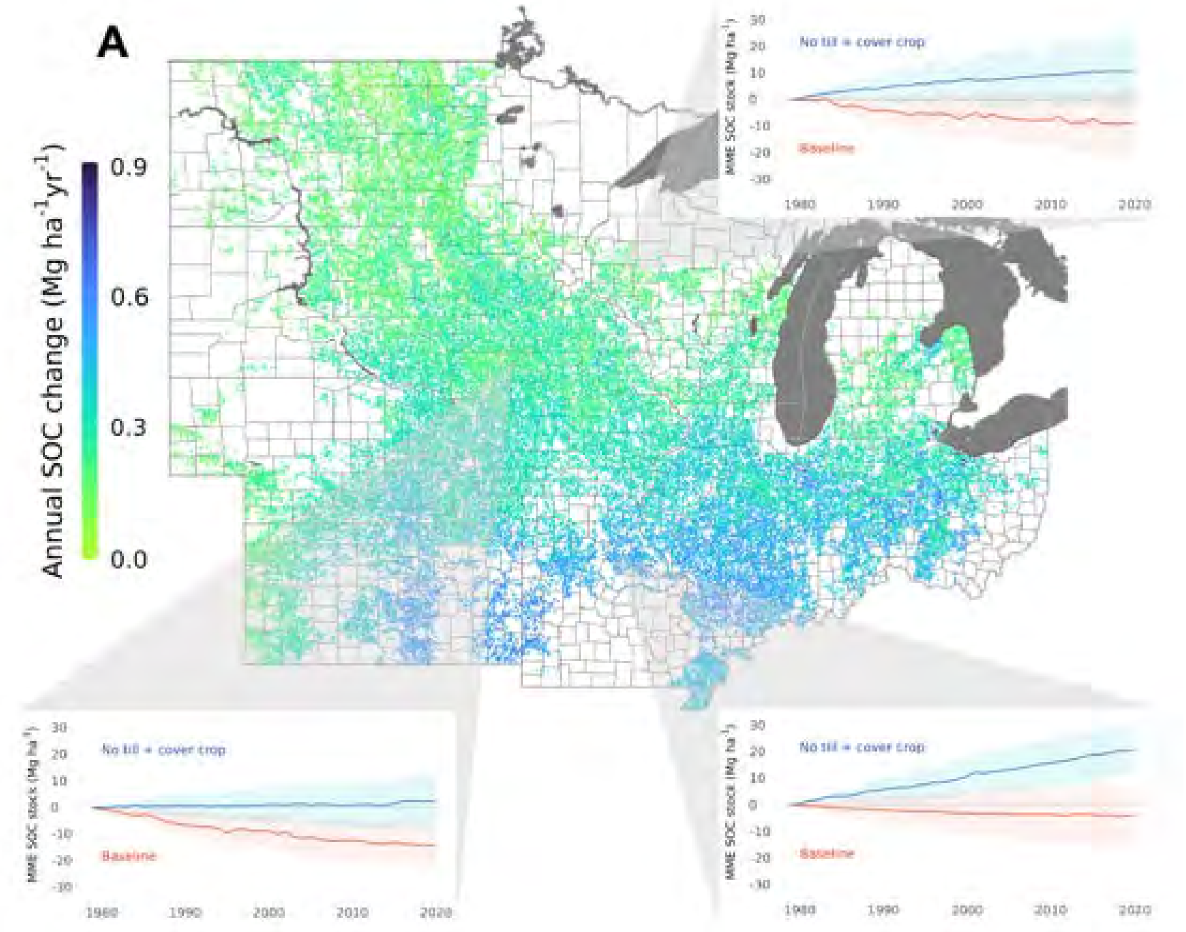
Dynamic baselines are critical

MICHIGAN STATE UNIVERSITY



Basso et al., 2024 sub

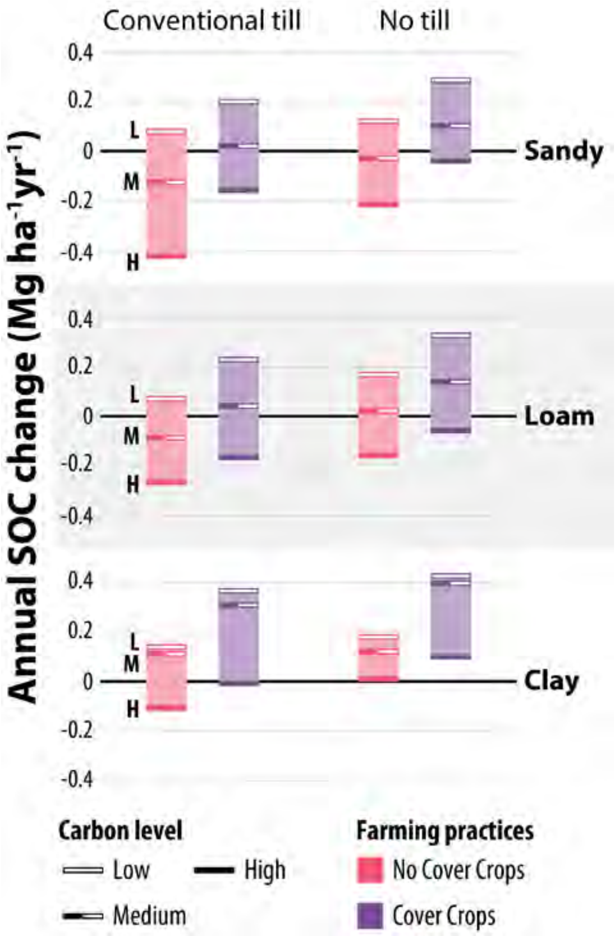
SOC changes under regenerative practices using MME



Basso et al., 2025

Baseline and impact of practices on SOC change

MICHIGAN STATE UNIVERSITY



Conclusions

- Regenerative practices adoption needs to increase for major co-benefits
- We can’t measure everywhere – we need models
- Models can be over-calibrated to cover biases – not useful
- Models need to be tested by independent datasets of good quality
- **Multi-models ensemble (MME) provides an opportunity to benchmark models; to develop dynamic baselines; to reduce uncertainty analysis; to develop better models**
- **Digital Agriculture and Precision Conservation are critical tools to understand and improve farm resilience, profitability and long-term sustainability**

Basso Digital Agriculture Systems Modeling Lab

MICHIGAN STATE UNIVERSITY

Department of Earth and Environmental Sciences
MICHIGAN STATE UNIVERSITY

Follow @BassoLabMSU

@brunobasso1

MICHIGAN STATE UNIVERSITY
AgBioResearch

GREAT LAKES BIOENERGY

USDA United States Department of Agriculture
National Institute of Food and Agriculture

USDA Natural Resources Conservation Service
United States Department of Agriculture

GLISA
A NOAA RISA TEAM

CMPM

ESMC
Ecosystem Services Market Consortium

NASA

Michigan Wheat Program

MICHIGAN POTATOES

NSF

BILL & MELINDA GATES foundation

CLIMATE TRACE

Food and Agriculture Organization of the United Nations