The Impact of Farming Practices on Agricultural Greenhouse Gas Emissions

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Sarah Barrows, Kamila Kazimierczuk, Dr. Mariefel Olarte, Dr. Nikolla Qafoku, and Corinne Drennan

Pacific Northwest National Laboratory

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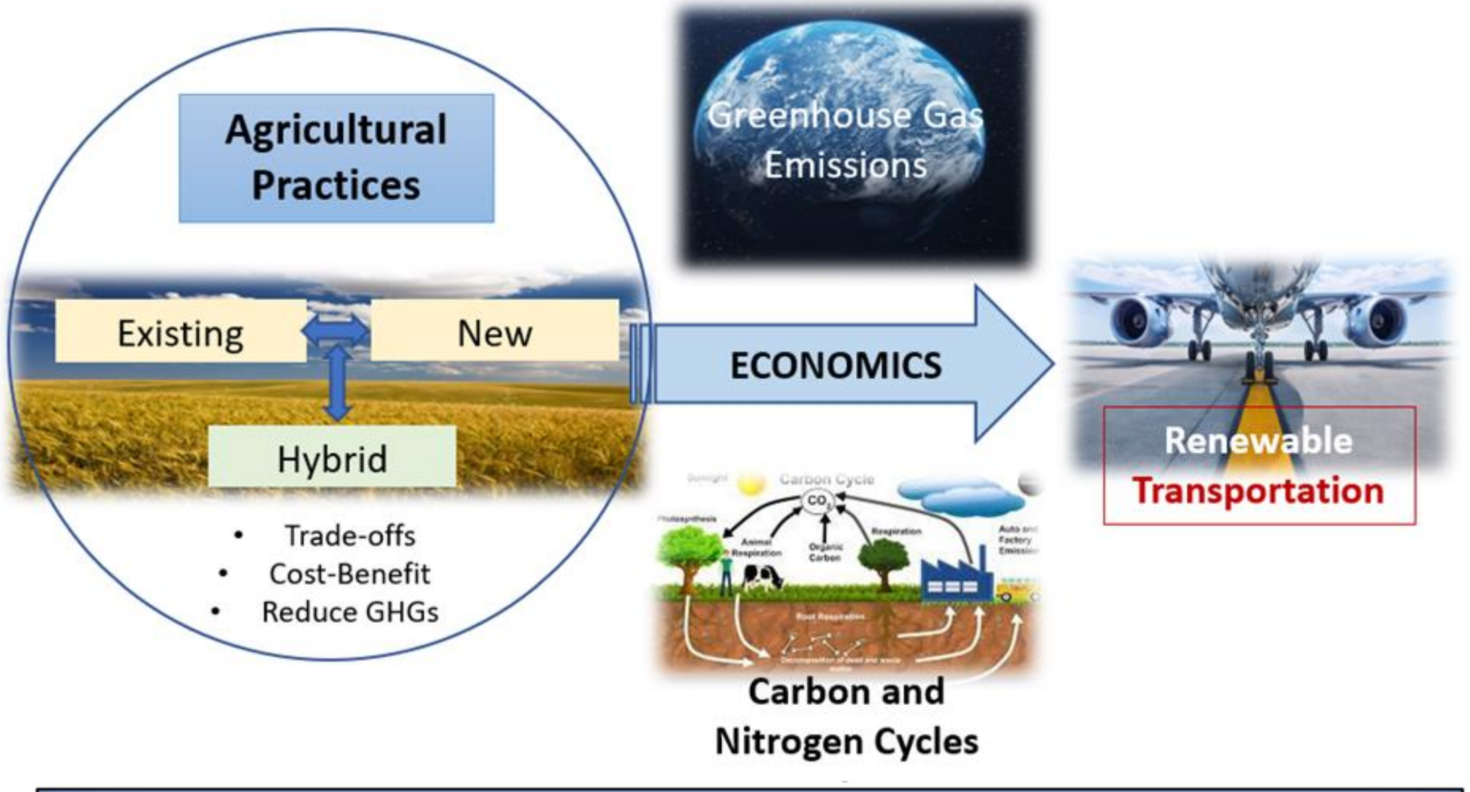
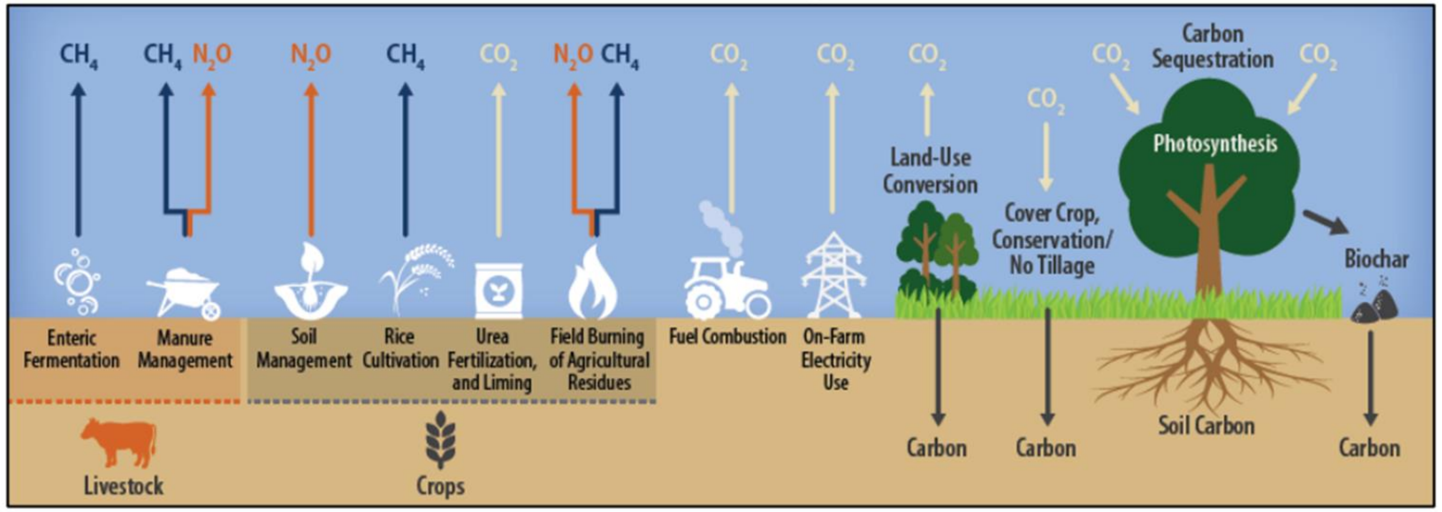
Why do GHG fluxes in agriculture matter?

- **Net-zero emission** economy by 2050
- Food system accounts for **26-31%** of our total GHG emissions[1,2]
  - On-farm emissions **10%** of U.S. emissions[3]
- U.S. **renewable fuel** lifecycle GHG reduction goals towards 100%
- Farmer **economics** influence adoption
- Growing global **population and changing climate** impacting agricultural production[4]

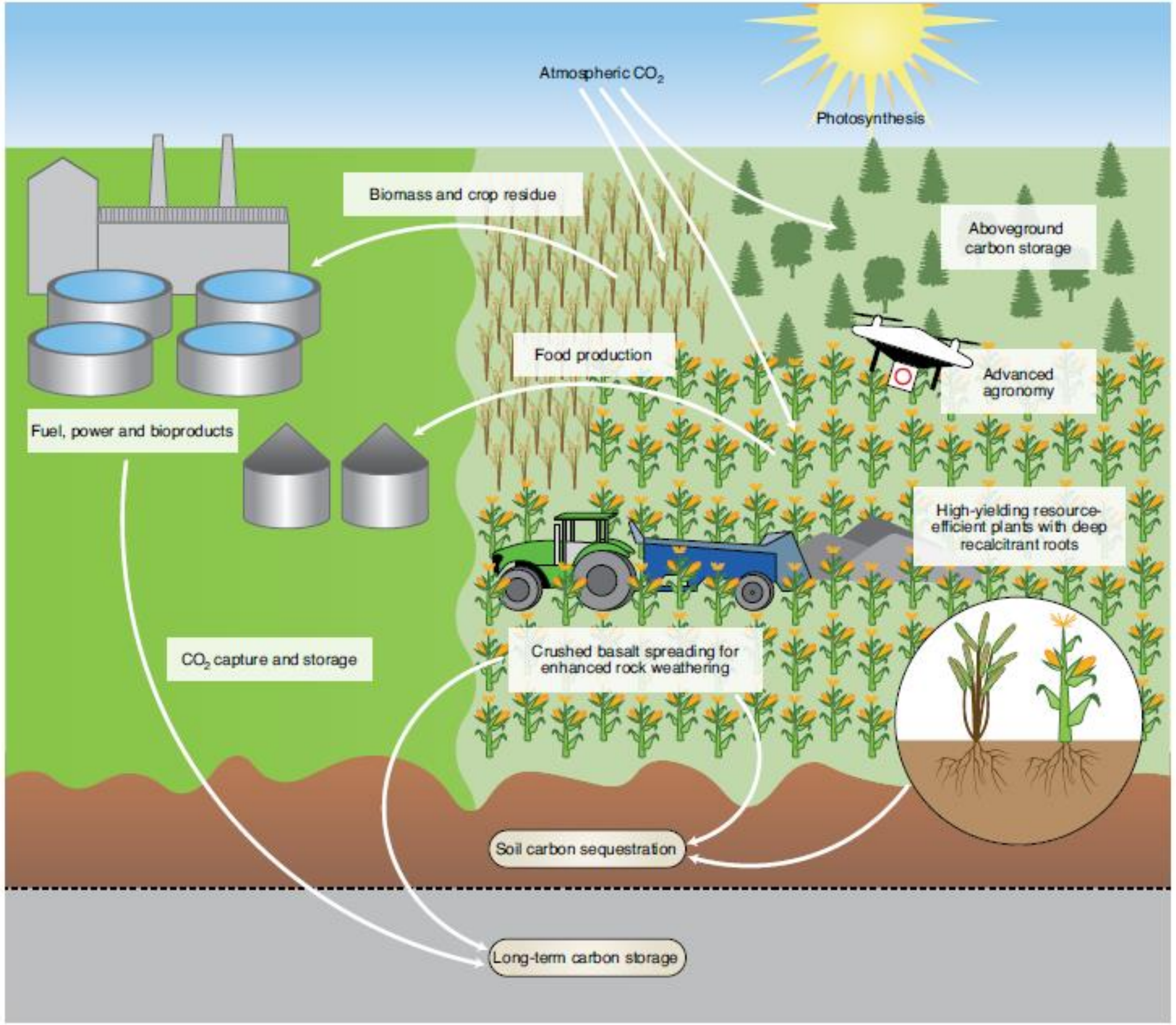




Source: CRS 2021 https://crsreports.congress.gov/

[1] Poore and Nemecek 2018 https://www.science.org/doi/pdf/10.1126/science.aaq0216
[2] Tubiello et al. 2021 https://dx.doi.org/10.5194/essd-2021-389
[3] EPA 2022 Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2020
[4] Jagermeyr et al. 2021 https://doi.org/10.1038/s43016-021-00400-y

Farm of the Future – Agricultural Practices to Mitigate GHG Emissions



Source: Horton et al. 2021 https://doi.org/10.1038/s41477-021-00877-2

Agricultural Practices:

- Regenerative Agriculture
- Digital Agriculture
- Controlled-Environment Agriculture

Ongoing PNNL research into

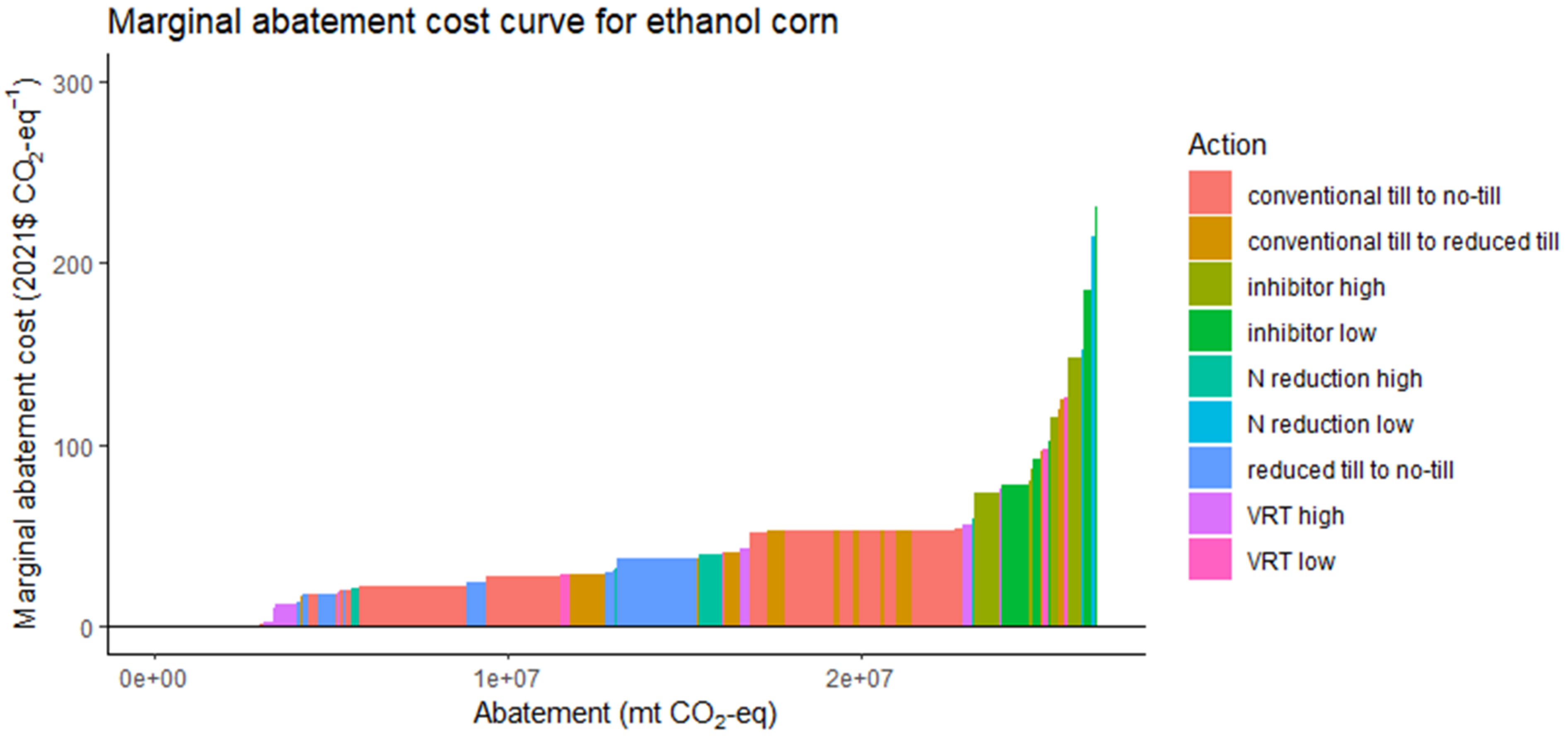
- GHG Emissions
- Economics
- Biofuel Processing Impacts

Regenerative agriculture has the potential to reduce GHG emissions, though impacts vary

Practice	GHG Impact		
	CO_2	N_2O	CH_4
Reduced or no-tillage	↑↓ Can improve SOC but uncertainties are large. CO_2 emissions increase for rainfed systems.	↑↓ Emissions increase for rainfed systems, slightly reduces in irrigated systems. Soil type affects emissions.	↑↓ Depends on water-use: Reduces CH_4 for paddy crops but increases for dryland crops.
Cover cropping	↓ Improves SOC, though retention horizons tend to plateau over time.	↑↓ Increases direct emissions, reduces indirect emissions. Depends on incorporation of residues, crop type.	? Inconclusive, but appears to potentially increase emissions in some crop systems.
Organic amendments	↓ Improves SOC, especially with biochar amendments. Retention horizons tend to plateau over time.	↑↓ Contrasting results. Dependent on soil moisture content and texture. Biochar tends to reduce N_2O emissions.	↑↓ Residues can increase CH_4 emissions. Biochar reduces CH_4, but water management and soil pH affect this.
Enhanced weathering	↓ Sequesters atmospheric CO_2 as carbonate minerals in soils.	? Can potentially increase plant uptake of N, potentially reducing N_2O emissions.	? Basalt application to rice has potential to abate CH_4 emissions. More research needed.

Economics of Regenerative Agriculture

Farming practices can mitigate GHG emissions of corn for ethanol -
Tillage management and variable rate application of N are relatively low cost with large abatement potential



Barrows, et al., manuscript in preparation

- Economic benefits tied to **ecosystem services**
- **Profits can increase** due to reduced use of pesticides and fertilizers, even with lower yields [5,6]
- **Adoption rates** still low
- **Barriers** include adoption costs, insufficient technical assistance, misalignment of renter/owner incentives

[5] Guenet et al. 2021 https://doi.org/10.1111/gcb.15342
[6] Beerling & Long 2018 Carbon Brief https://tinyurl.com/583j6fur

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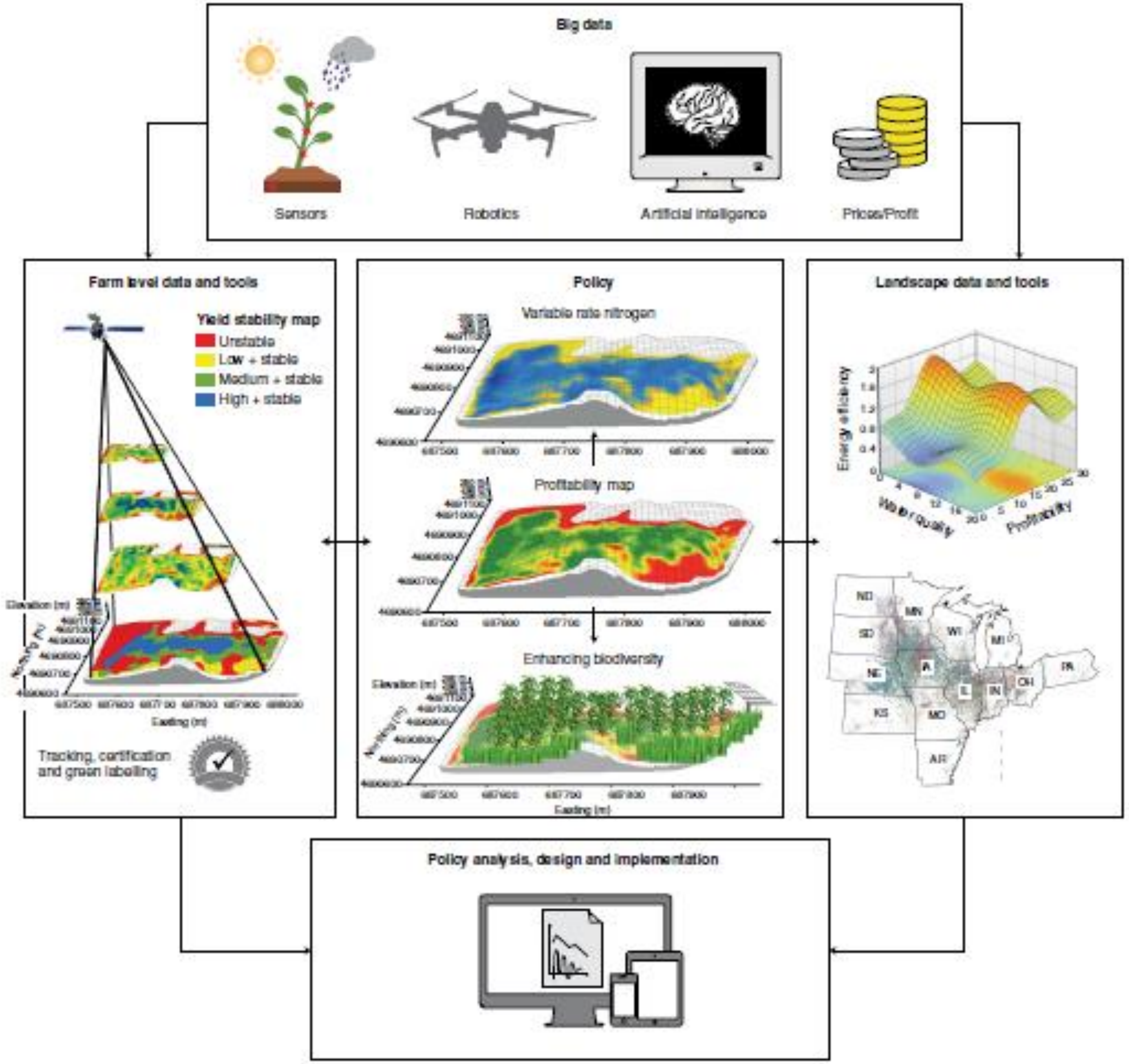
Digital Agriculture

- **GHG impacts:**
  - Lower CO_2 and N_2O emissions possible
- **Economics:**
  - Easier for large farms to adopt digital agriculture
  - Profits increased through optimized farm efficiencies
  - Profit margins depend on crop type and conditions



Source: Basso and Antle. *Nature Sustainability*. 2020. 3: 254 - 256

Controlled-Environment Agriculture (CEA)

- **GHG impacts:**
  - High energy usage
  - Carbon footprint higher or lower than traditional growing, depending on CEA location, crop, setup[7]
- **Economics:**
  - More economically, environmentally viable in extreme environments with large populations[8]
  - Upfront costs can be prohibitive
  - Land use can be more efficient
  - Food quality and safety can be more closely controlled[8]

Source: https://zipgrow.com/zipfarm/

Source: https://agincotech.com/

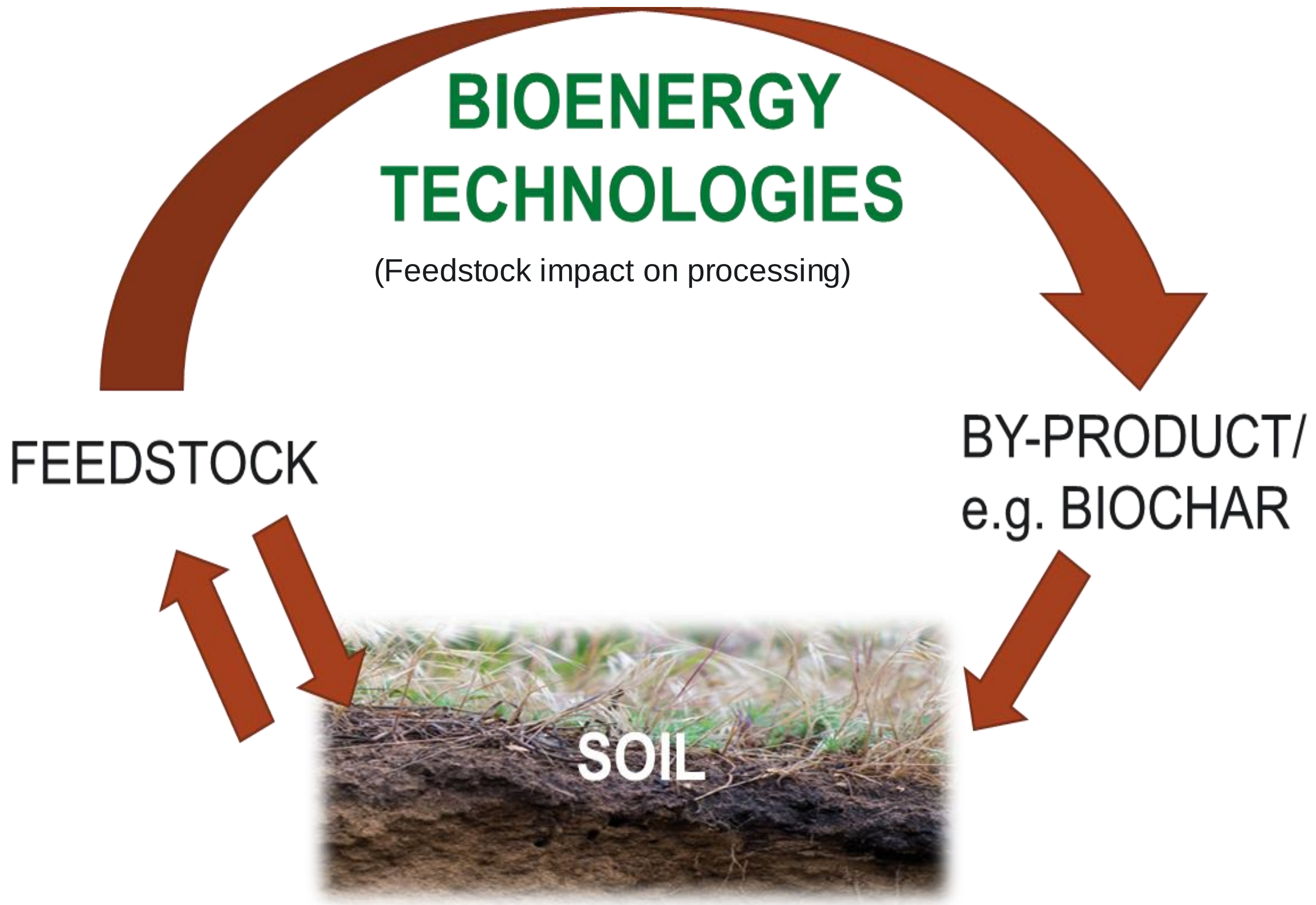
[7] Benis et al. 2017 https://tinyurl.com/mu8axsmf

[8] Barbosa et al 2015 https://www.mdpi.com/1660-4601/12/6/6879

Bioenergy's relationship with agriculture

Agricultural innovations –
Potential interactions with bioenergy

- Regenerative agriculture (cover crops) for **biofuel feedstocks**
- Digital agriculture to **spectrally quantify** plant components to improve yields
- **Algal biomass** can be incorporated into CEA schemes



Many research gaps remain

- To name a few…
  - **How long carbon remains in soils.** Organic and inorganic carbon cycling as function of climate change variables and management practices
  - Accurate and affordable **measurement of carbon sequestration** in agricultural soils for carbon offsetting
    - ✓ **Sensors** and **data processing** needs
  - Application of **digital agriculture** to biofuel crops for optimized fuel production
  - **Regional aspect** of agricultural GHG impacts as function of climate and soil type
  - Farmers' **financial impacts** of adopting sustainable agricultural practices. Reduction of soft costs and other barriers

What PNNL Is Building

- Three-pillar approach: **soils, economics, technology**
- Internally funded literature review on **agricultural GHG emissions** and **economic analysis** of sustainable agricultural practices
- Ongoing collaborations with Microsoft and Boeing on **remote sensing** and **AI/ML** for sustainable agriculture
- Focused research groups with **Washington State University, Montana State University, and the Ohio State University** on agricultural GHG emissions and biofuel impacts on a regional basis

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Thank you

sarah.barrows@pnnl.gov

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