Global-to-Local-to-Global Analysis of Sustainability: An AccelNet Network of Networks

Presented by Thomas Hertel (PI) Purdue University
At the 11th Annual Forestry and Agriculture GHG Modeling Forum

Half of the UN Sustainable Development Goals bear on Land & Water Resources: GLASSNET is a network of networks for addressing these challenges using an integrative approach
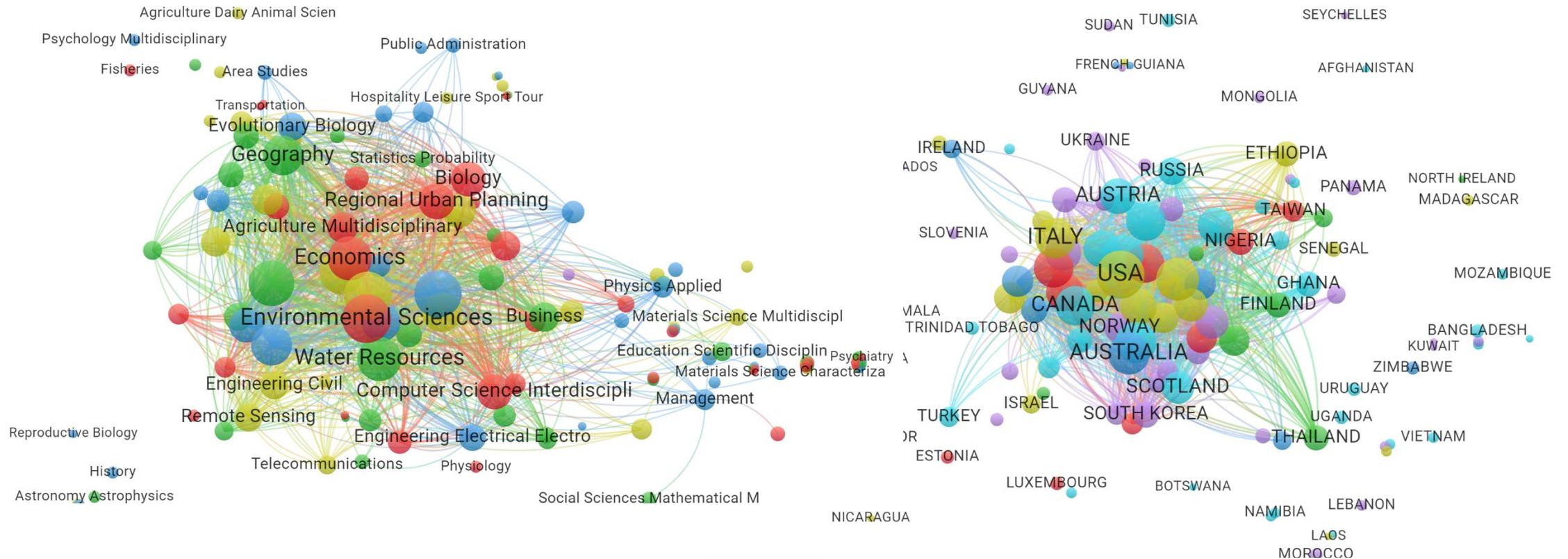

GLASSNET:

- **Enables transformative analysis** to facilitate decision making for sustainable development

- **Develops diverse human capital** for analysis of tradeoffs and synergies among SDGs

- **Engages a network of networks**, facilitating integration across research teams to advance knowledge and identify sustainable pathways
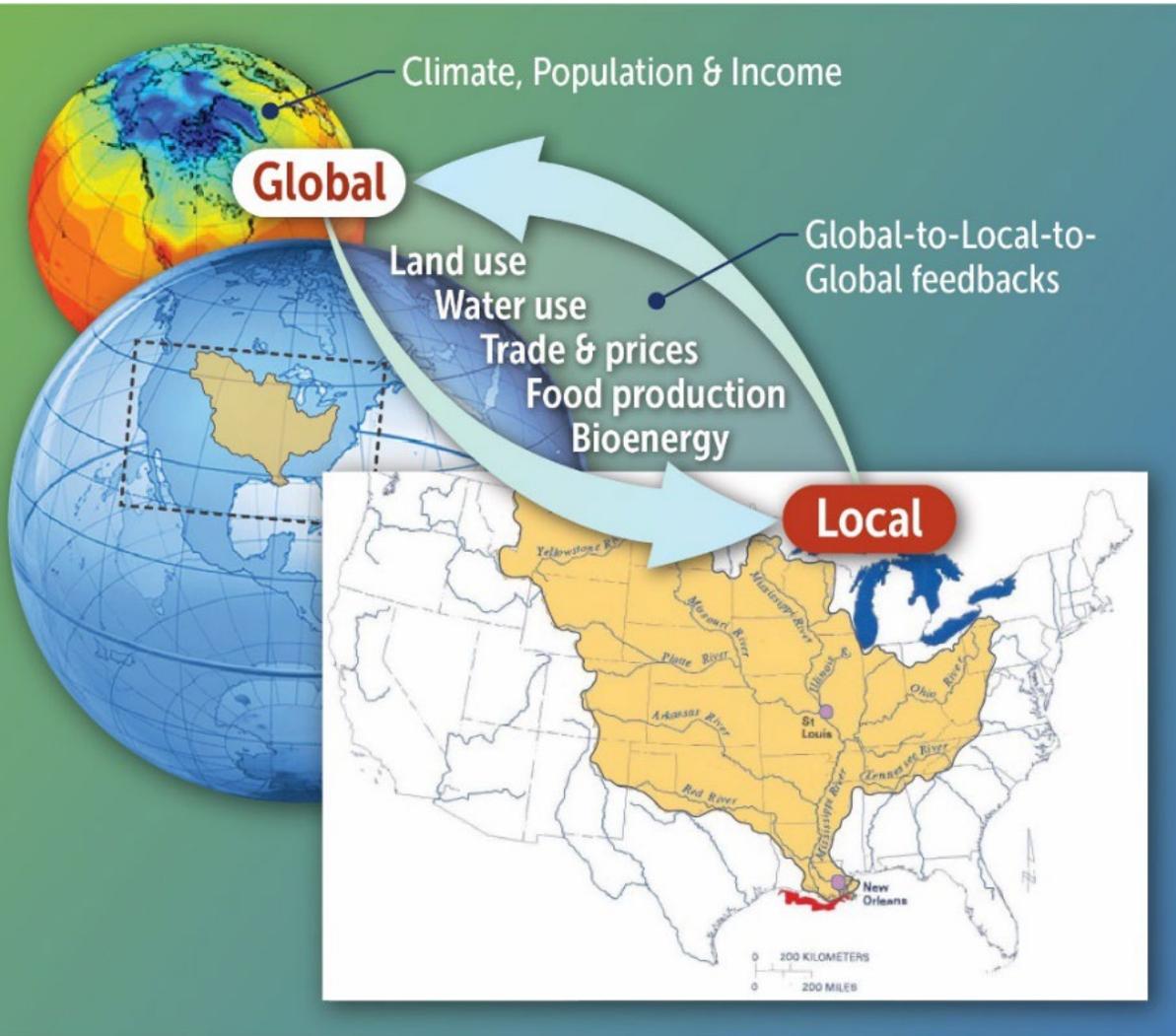
GLASSNET is linking researchers across disciplinary and geographic boundaries

Global-to-Local-to-Global Analysis is central to GLASSNET

- Global forces drive local food-energy-water systems stresses

- Local responses are shaped by specific climatic, biophysical and socio-economic conditions

- Accumulation of local responses feeds back to regional and Global systems
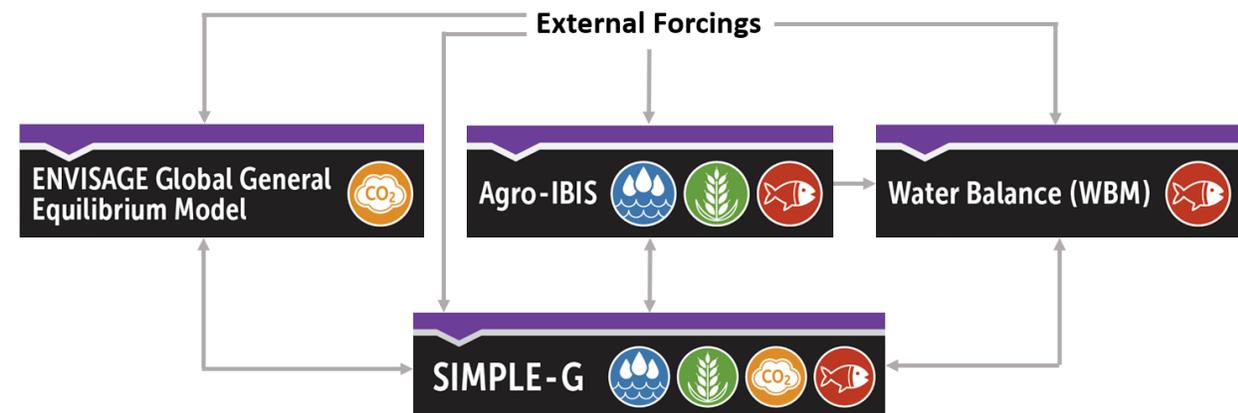
Outline of the talk

- **Climate mitigation scenarios: Implications for US agriculture**
- **Methodology for model linking**
- **Agricultural responses to climate policy**
- **Implications for water quality**
- **Contrast with existing water quality policies**
- **Conclusions**

Mitigation scenarios capture EU carbon pricing and US SCC estimates, CBAM to curtail dirty imports

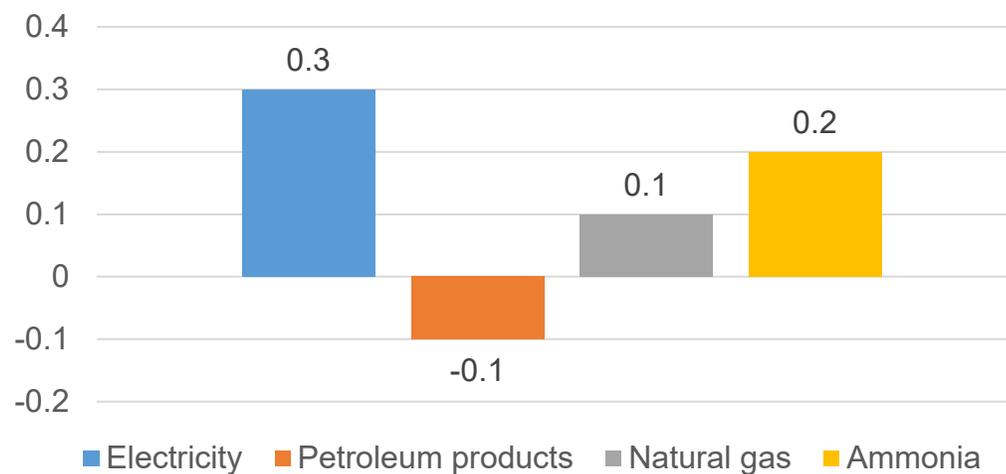**Impacts of EU mitigation on prices in US, percent change**


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Original reference
        ↓
EU climate mitigation policy
EU economy wide carbon price as of April 2022:
89 EUR per ton of CO2 + carbon border adjustment
(CBA)
        ↓
New reference
        ↓
US climate mitigation policy
Three carbon pricing scenarios + CBA
        ↓
Outputs and linking variables
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Table ES-1: Social Cost of CO_2, 2020 – 2050 (in 2020 dollars per metric ton of CO_2)

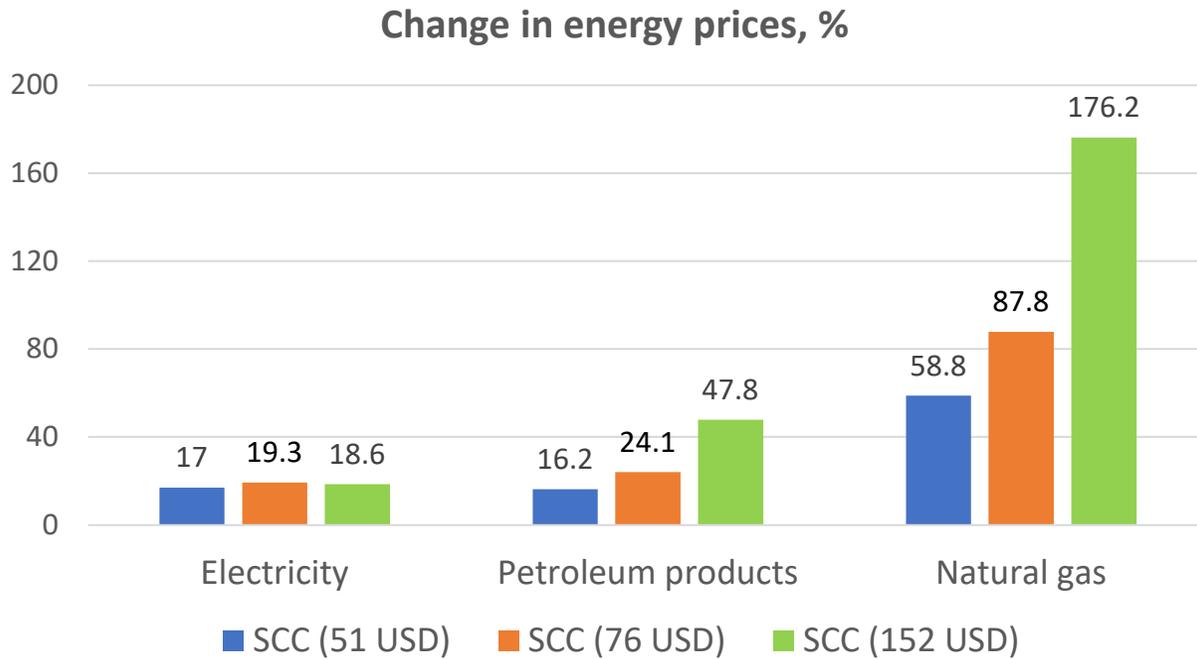| Emissions Year	5% Average	3% Average	2.5% Average	3% 95th Percentile
2020	14	51	76	152
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260

Discount Rate and Statistic
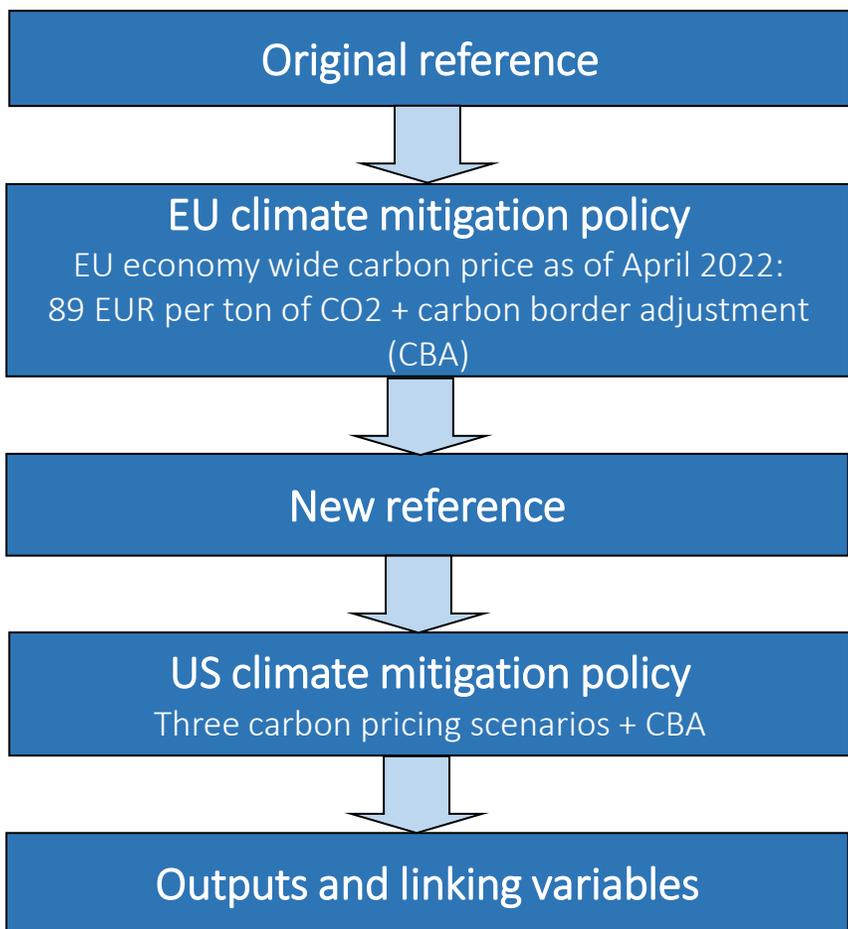
Source: Interagency Working Group on Social Cost of Greenhouse Gases, United States Government, February 2021 (https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf)

# Mitigation policies increase US costs of energy and ammonia fertilizer

Change in energy prices, %

Legend:
- SCC (51 USD)
- SCC (76 USD)
- SCC (152 USD)

Electricity: 17, 19.3, 18.6
Petroleum products: 16.2, 24.1, 47.8
Natural gas: 58.8, 87.8, 176.2

Cost structure of Ammonia production, %

- Capital
- Natural gas
- Electricity
- O&M cost

Capital, 38%
Natural gas, 51%
Electricity, 2%
O&M cost, 9%

ENVISAGE Global General Equilibrium Model CO₂

Prices of energy, fertilizer, land, labor,

SIMPLE-G

Change in ammonia prices, %

30.4, 45.3, 90.6

- SCC (51 USD)
- SCC (76 USD)
- SCC (152 USD)

Water quality challenge

- Nitrogen fertilizer dependent agriculture

- Nitrate loss from the Corn Belt mostly attributed to corn production

- "Dead zone" in the Gulf of Mexico (hypoxia)

- US EPA Hypoxia Task Force has suggested a 45% reduction in N load to gulf by 2035 to reduce the dead zone size to a more acceptable level

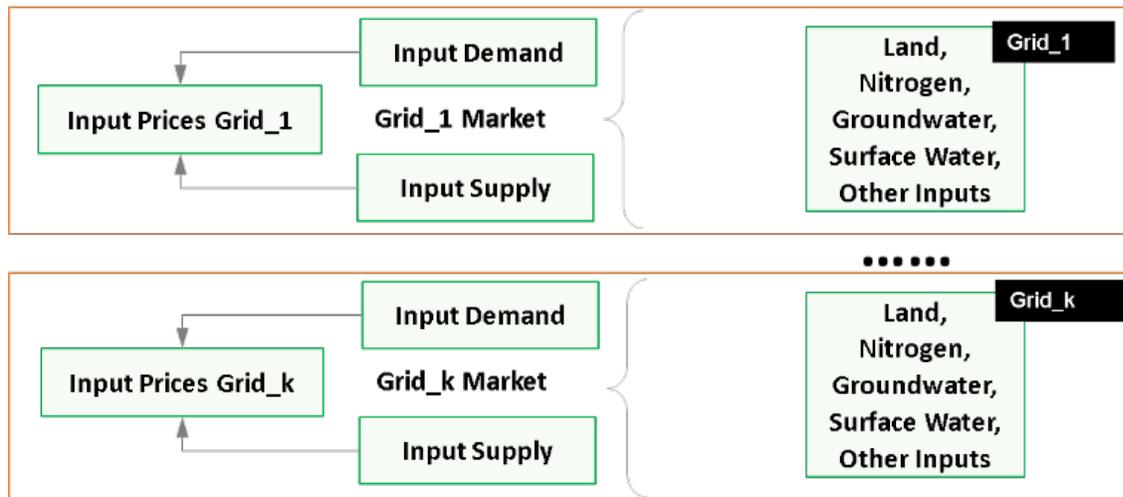- **How are we going to get there?**
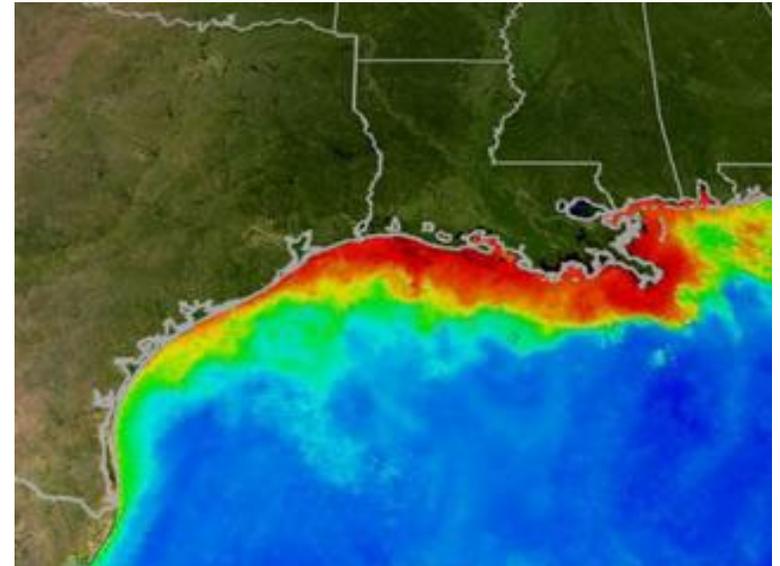
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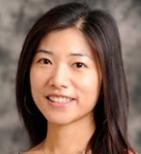
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SIMPLE-G Modeling Framework

Baldos et al. (2020), Environmental Modelling and Software
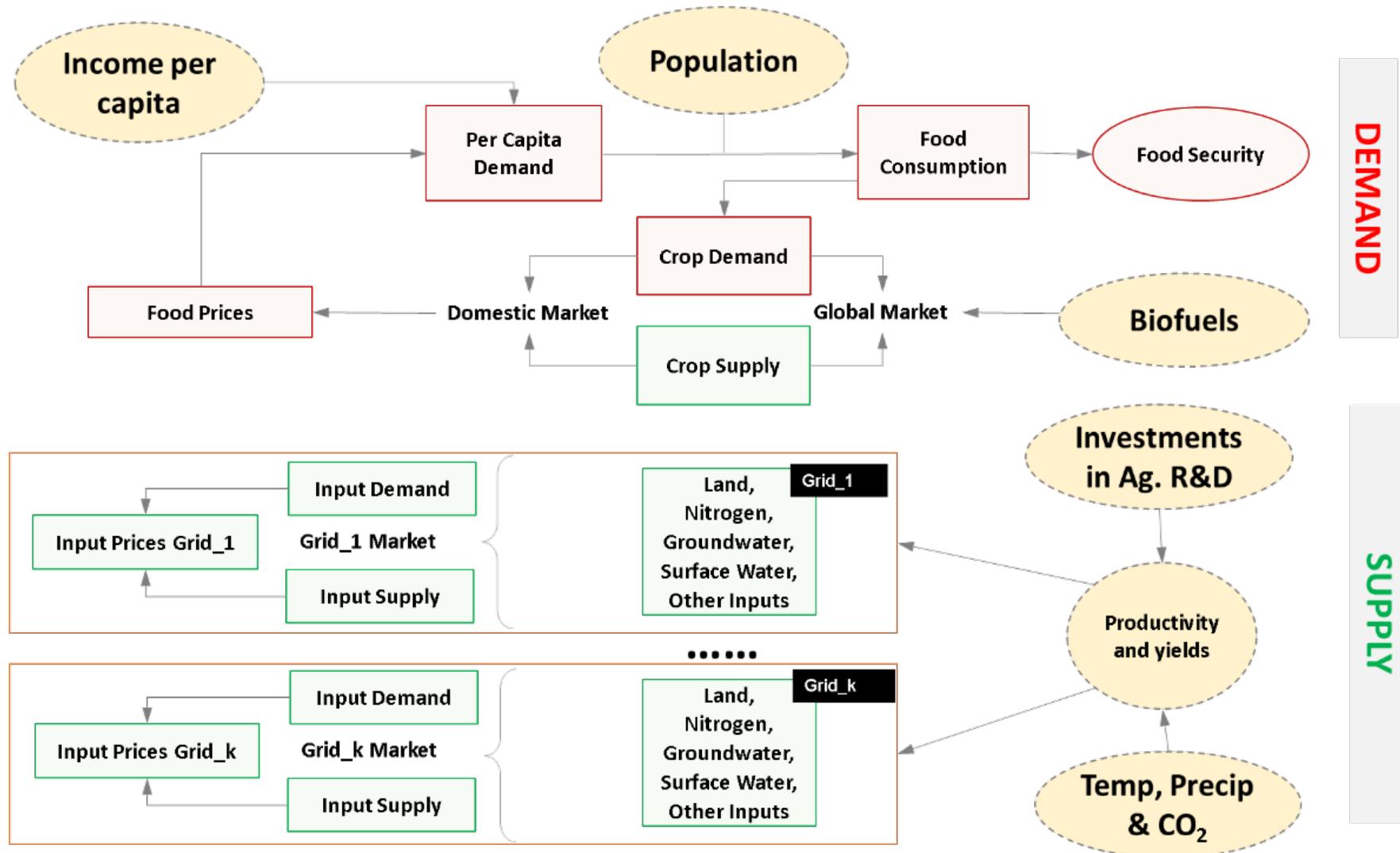
Linking ENVISAGE to SIMPLE-G

Farm level demand shift
determined by ENVISAGE model
in presence of perfectly elastic
supply in ENVISAGE

Grid_1

| Input Demand | Grid_1 Market | Input Supply |

Input Prices Grid_1

Land, Nitrogen, Groundwater, Surface Water, Other Inputs

Grid_k

Input Prices Grid_k

Grid_k Market

Input Demand

Input Supply

Land, Nitrogen, Groundwater, Surface Water, Other Inputs

Variable input
price changes
determined by
ENVISAGE
model; result
in supply shift
in SIMPLE-G

Grid cell activity in SIMPLE-G (5-arc-min)

Baldos et al. (2020), *Environmental Modelling and Software*
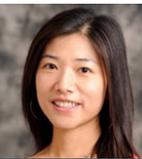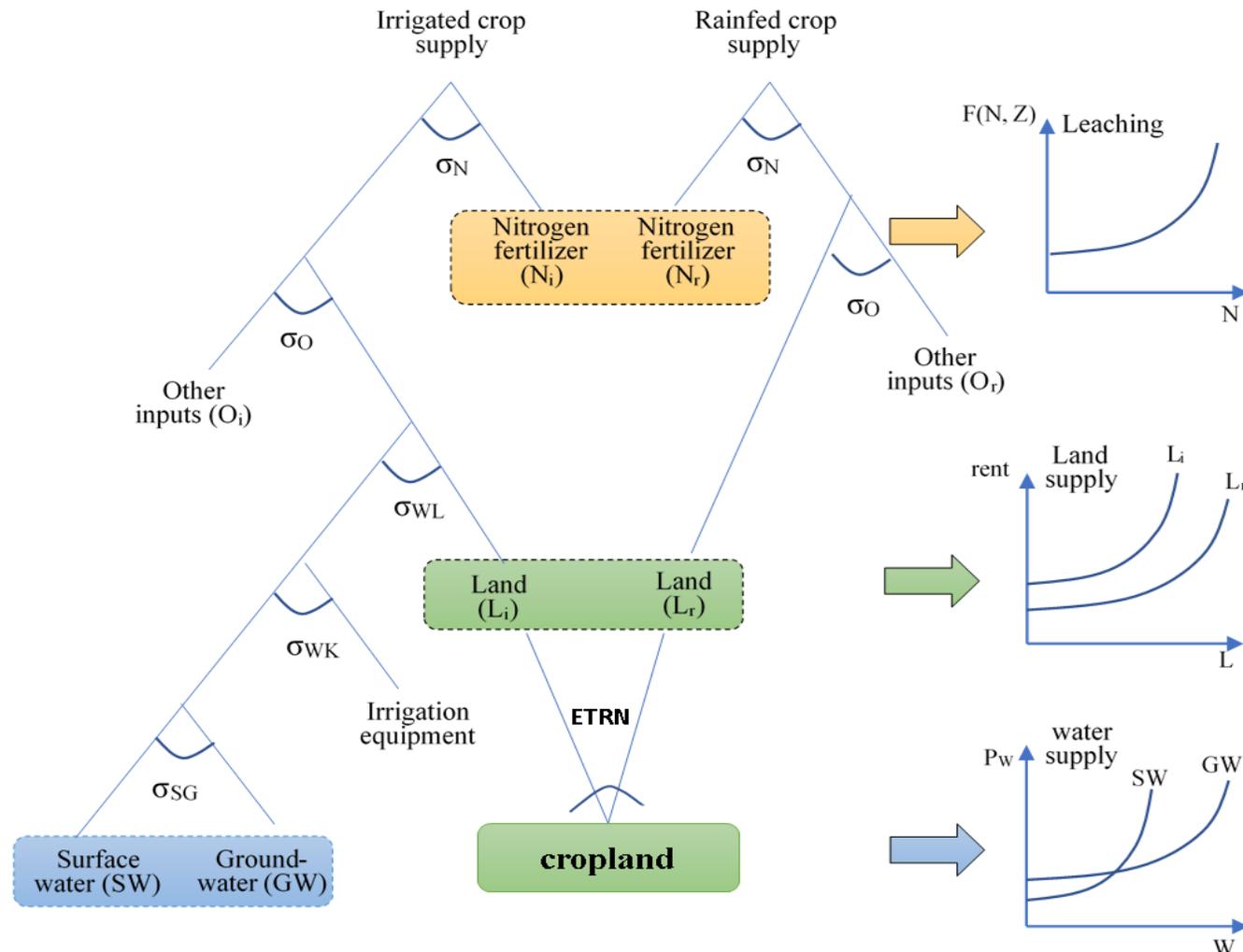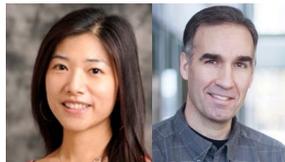
# Agro-ecosystem model provides key grid cell parameterization of SIMPLE-G
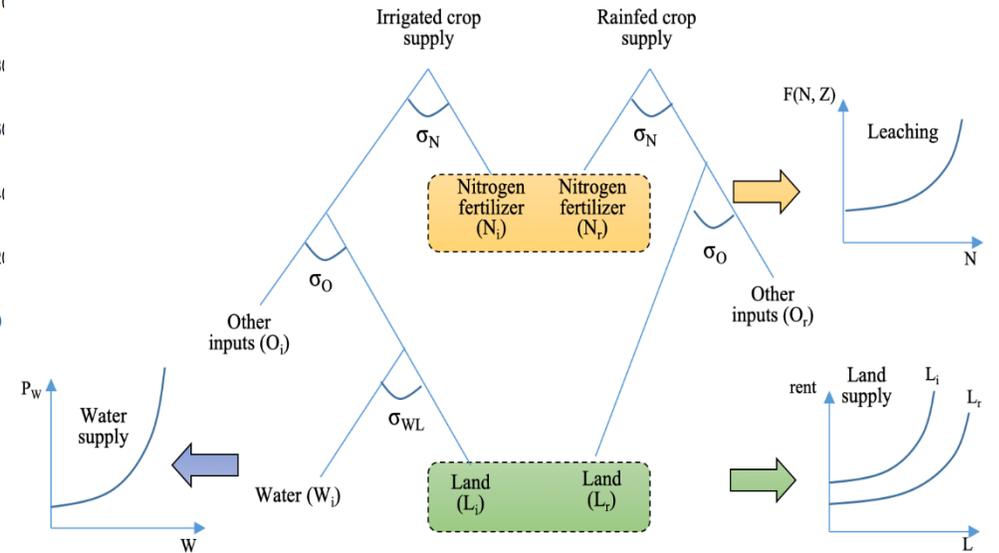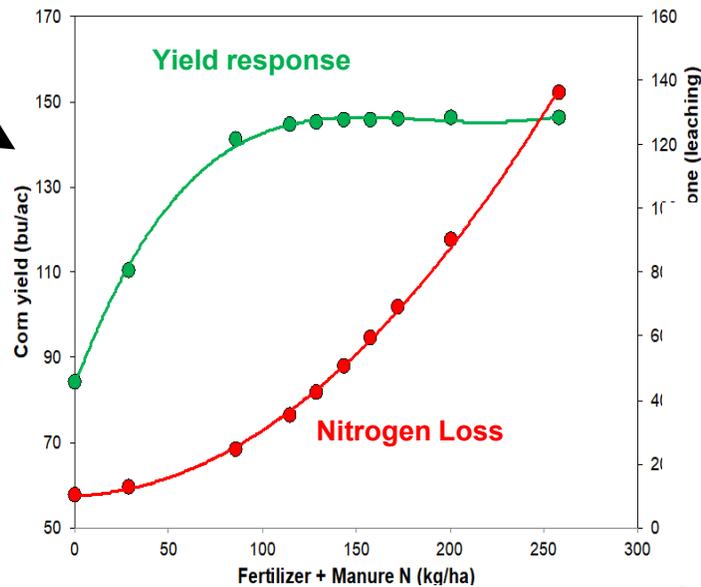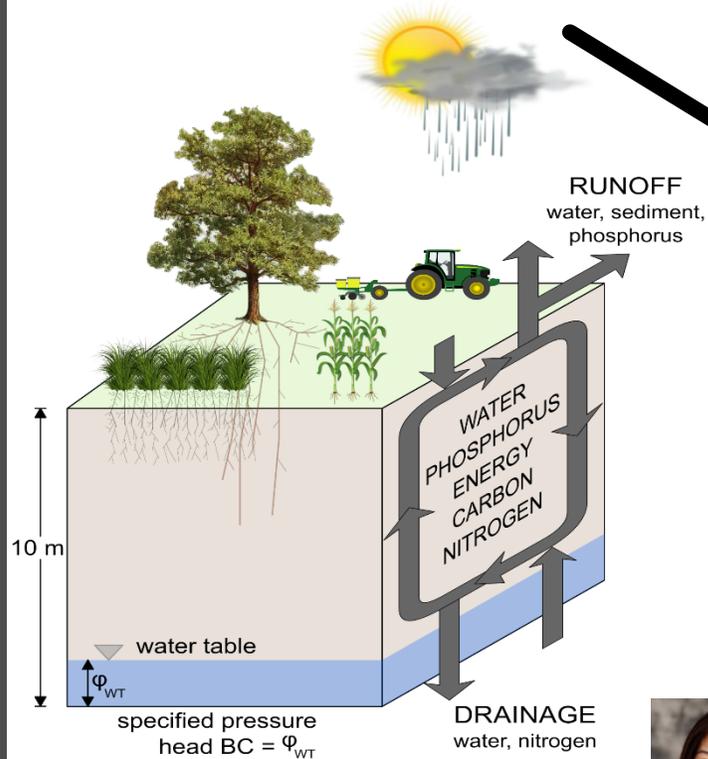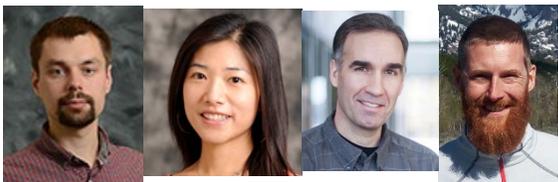

Liu et al. (in review)

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- Contrast with existing water quality policies
- Conclusions

# Heterogeneous impacts of carbon pricing across Mississippi River Basin
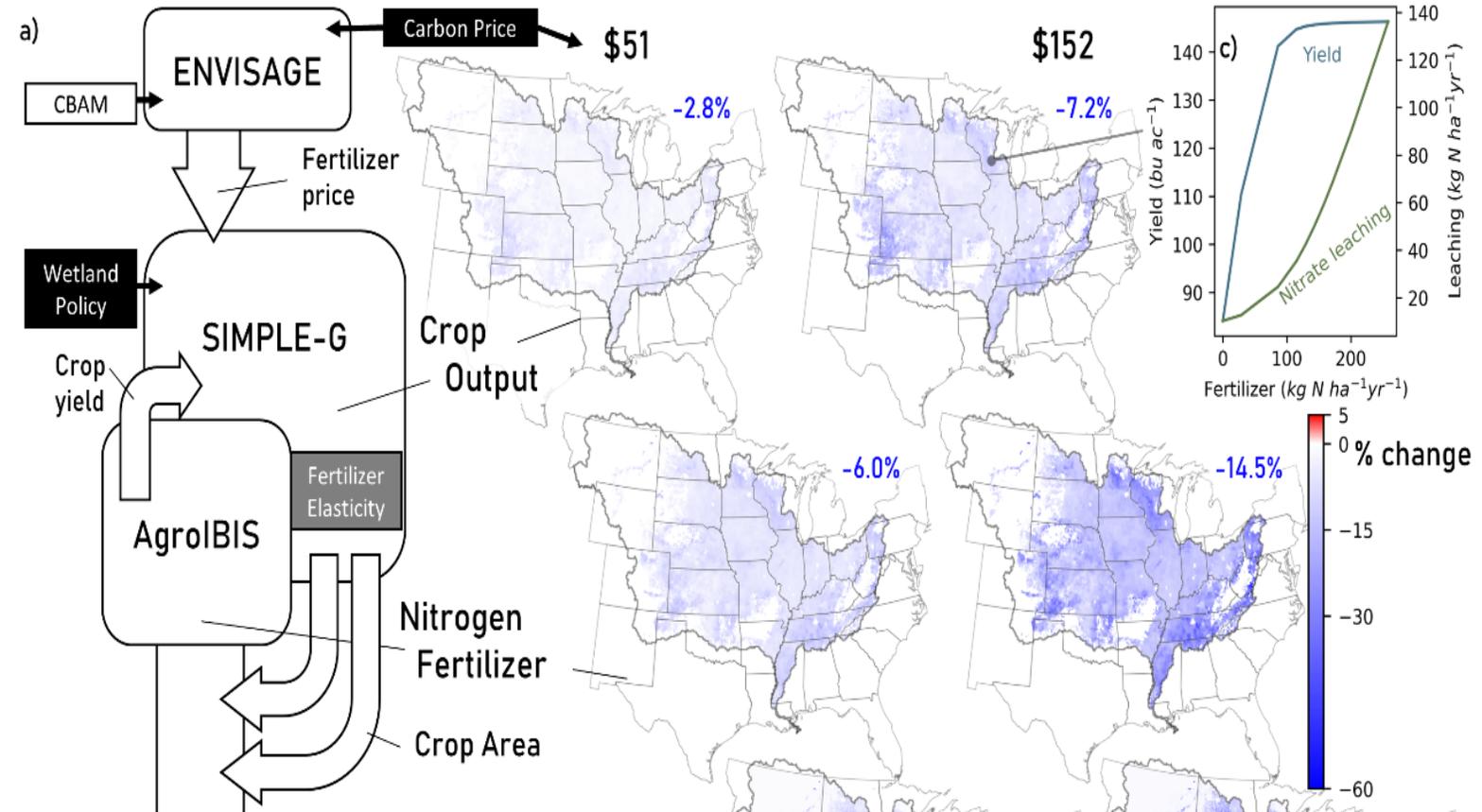
Reduced fertilizer use due to *rate reduction* as well as *reduction in planted area*
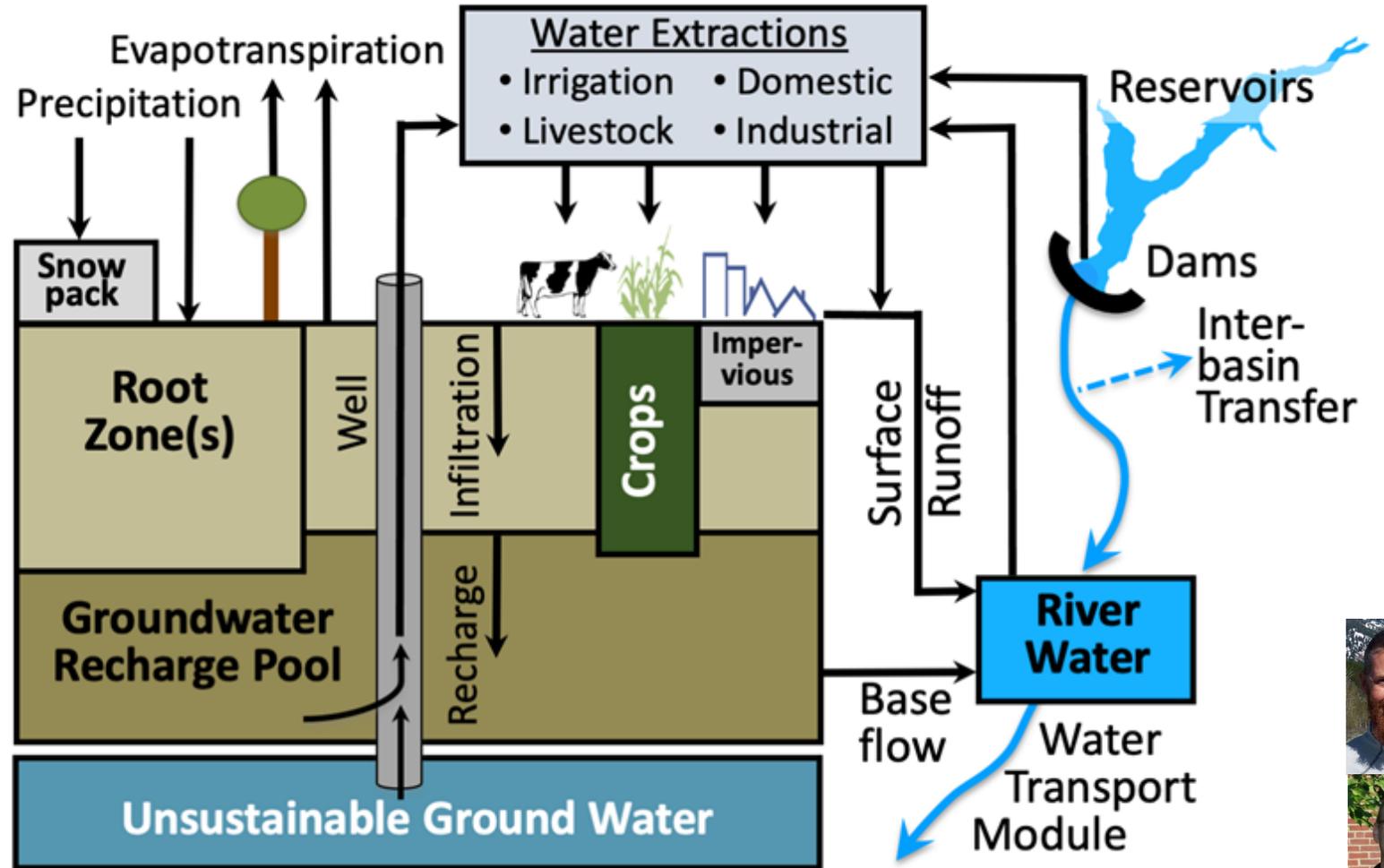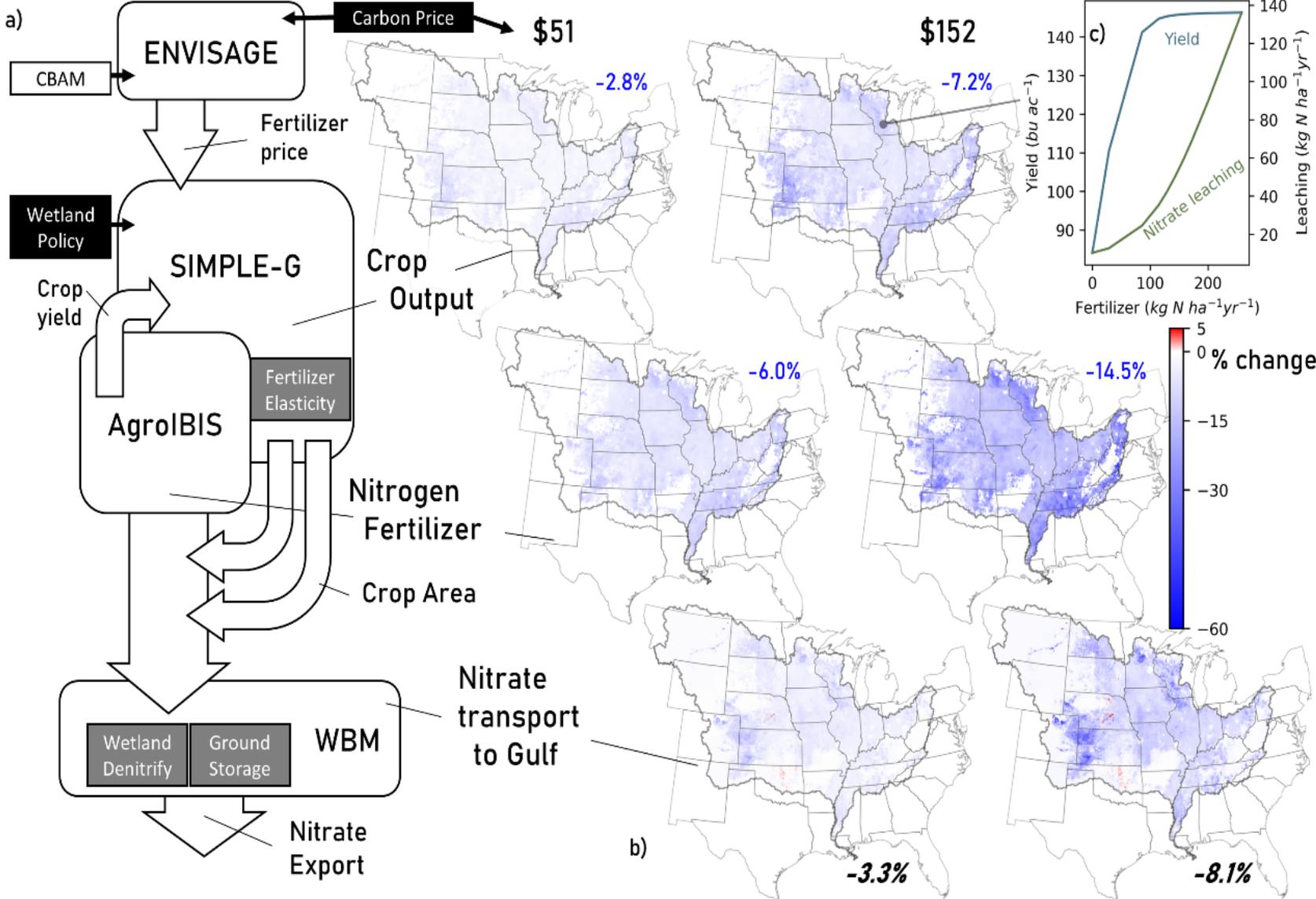
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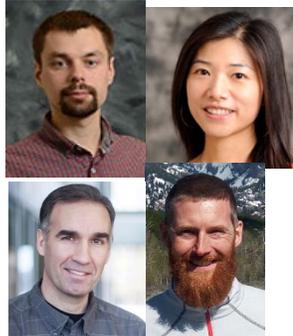- Contrast with existing water quality policies
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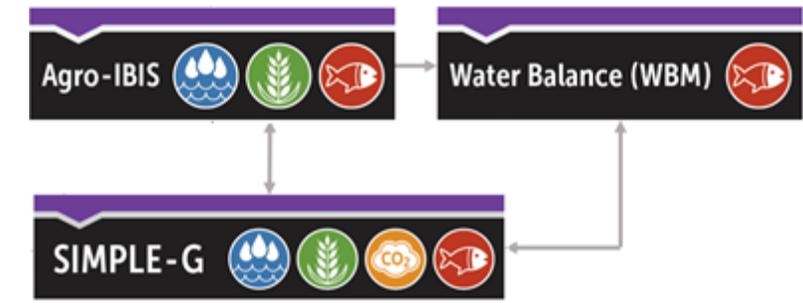
Water Balance Model tracks nutrient transport to streams and groundwater recharge

# Carbon pricing reduces nitrate export to Gulf of Mexico

Zuidema et al. PNAS, 2023.

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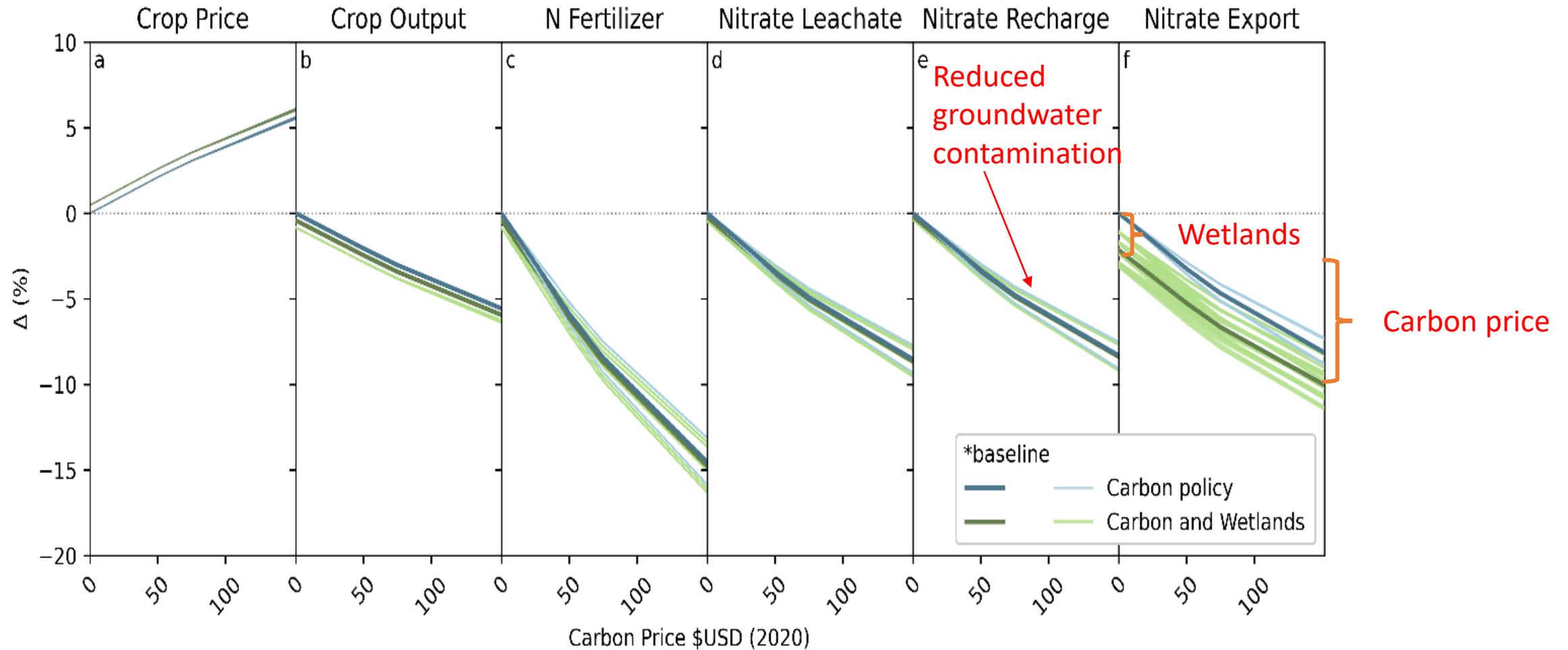- Conclusions

Non-point source water pollution has proven to be an intractable problem in US agriculture

Managed Wetlands at ACRE

subsurface drainage in

28% reduction in nitrate load

streamflow out
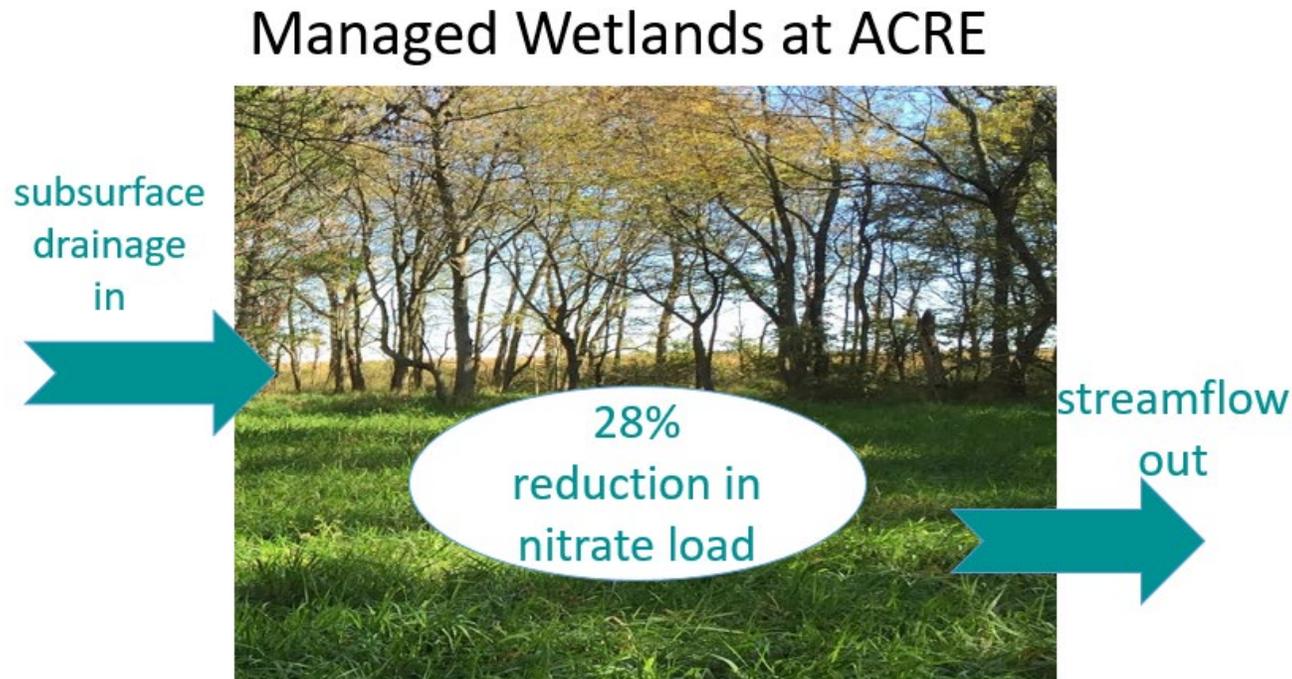
- Wetland restoration at edge of field allows for denitrification
- A favored policy by many environmental groups
- However, despite financial incentives, adoption across the US has been limited
- We limit wetlands to feasible tile-drained fields

Carbon pricing can generate even greater gains than limited wetland restoration for *improvement of groundwater quality* and *nitrate export to the Gulf of Mexico*

Zuidema et al. PNAS, 2023.

Added benefit of carbon pricing is that it *curtails negative spillovers* arising from a spatially limited policy

Wetlands only   Wetlands & $51/ton CO2   Wetlands & $152/ton CO2
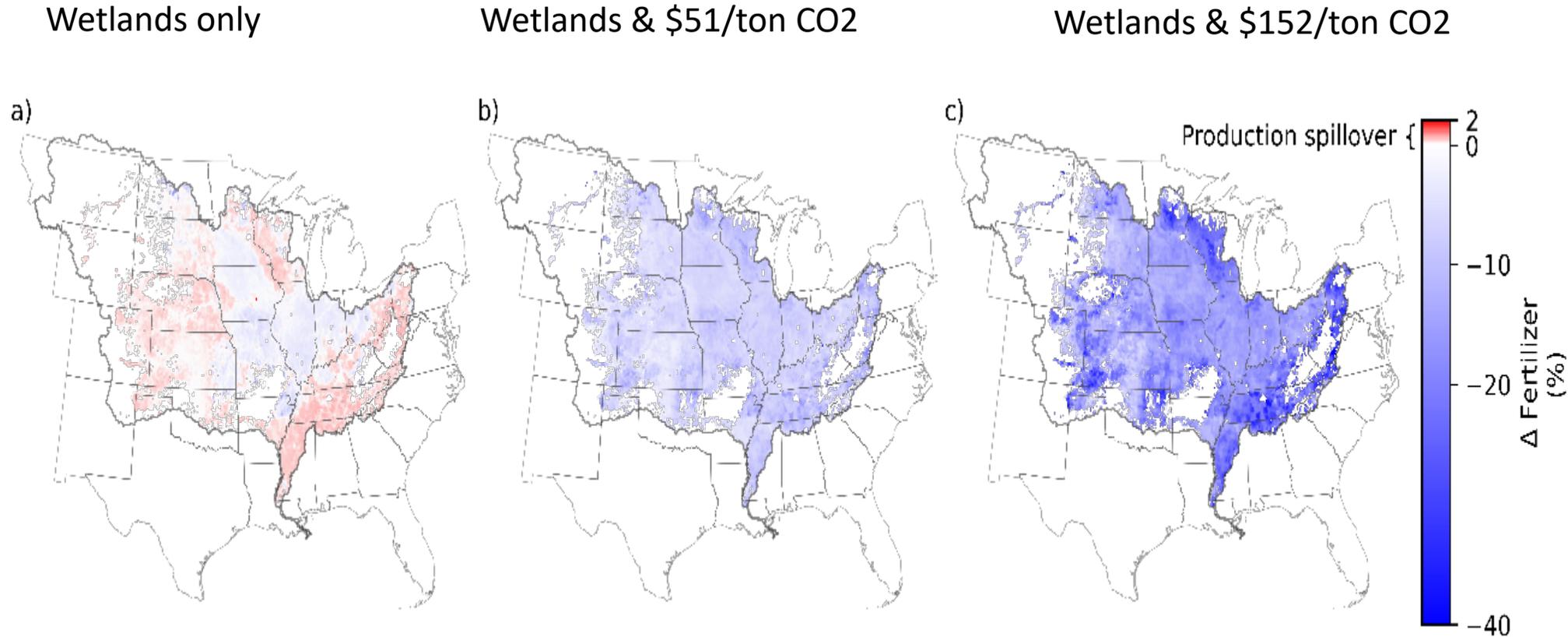
Effect on nitrogen fertilizer applications of coupling wetland restoration with carbon pricing

Zuidema et al. PNAS, 2023.
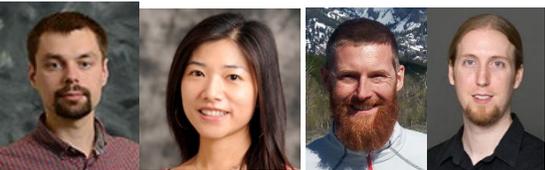
Conclusions

- **Potentially significant water quality *co-benefits from carbon pricing***
- ***Global-local-global* analysis facilitated by linking of economic and biophysical models**
- ***Gridded resolution of economic model key* to successful linkage**
- **Allows for consideration of a wide range of environmental policies**
- **Future work could also consider non-CO2 GHG emissions policies; more complex configurations of climate policy**

GLASSNET is providing an intellectual foundation for Global-Local-Global analysis of land and water sustainability

- **Provost-sponsored GLASSNET conference in April 2022 at Purdue University: 50 scientists and stakeholders exploring GLG analysis**

- **13 papers published in 2023 special issue of _Environmental Research Letters_**

- **Overview by guest editors Hertel, Irwin, Polasky and Ramankutty wrote a synthesis article, published in September, 2023**

GLASSNET: An International Network of Networks to tackle GLG challenges: https://glassnet.net

- *Special issue* of Environmental Research Letters
- *Early career scholar exchanges*
- *GLASSNET Use Cases and Workshops*
- *SIMPLE-G short course* in April/May 2024
- SIMPLE-G book: Forthcoming from Springer

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