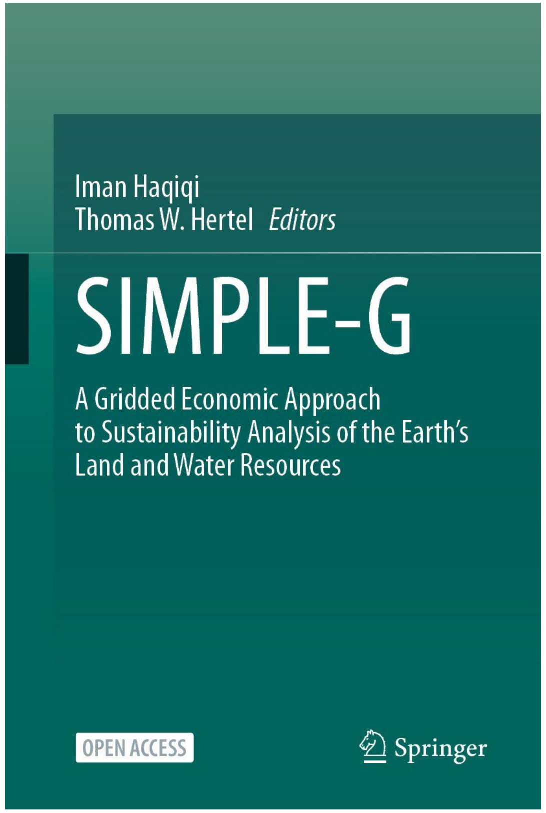
Global Trade Analysis Project

Global-Local-Global Analysis of Systems Sustainability
GLASSNET
An International Network of Networks



GTAP Virtual Seminar Series

SIMPLE-G: A Gridded Economic Approach to Sustainability Analysis of the Earth's Land and Water Resources

Dec 17, 2024 9-10 AM EST Zoom

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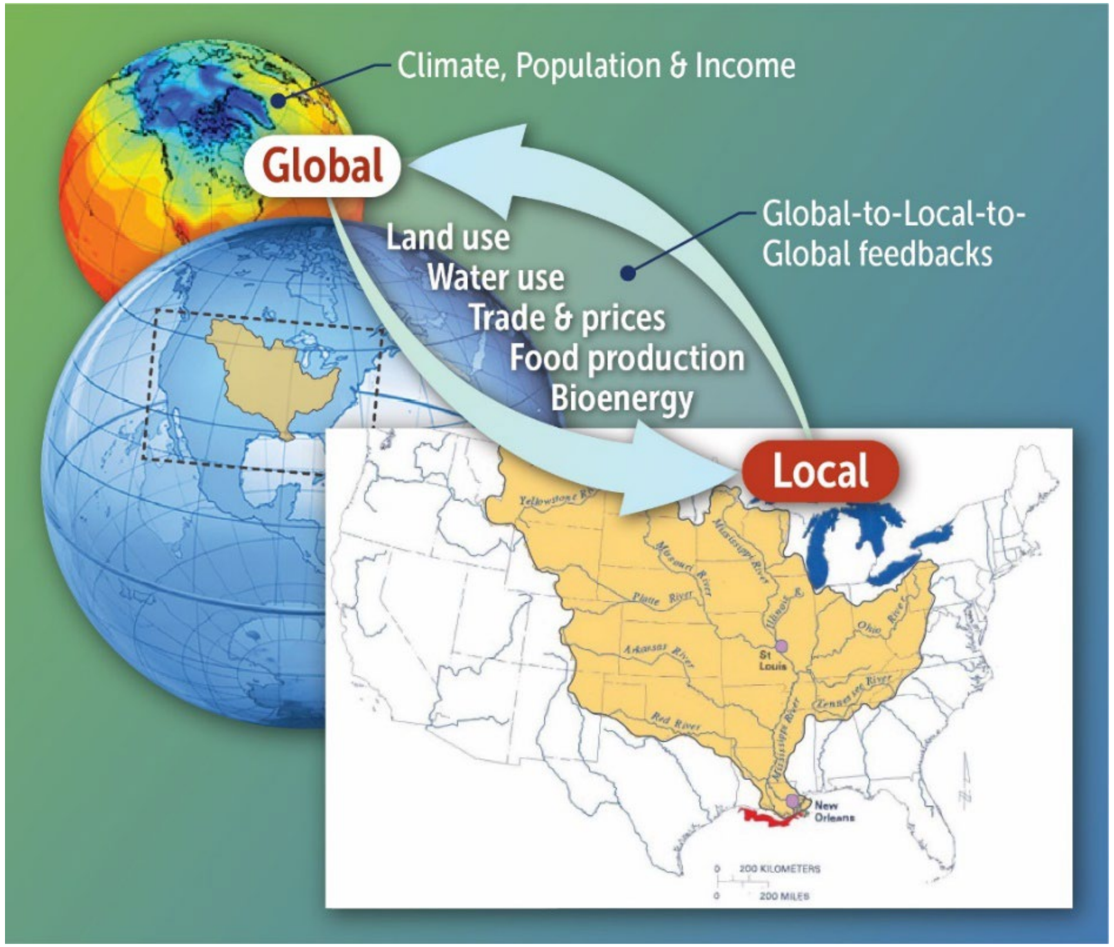
Introduction to the Seminar

- **Like GTAP:**
  - **SIMPLE-G is a framework, intended for modification by members of the community; not a single model**
  - **SIMPLE-G is global and covers international trade amongst regions**
  - **SIMPLE-G is implemented in GEMPACK, taking advantage of the many useful features of this software package (esp. condensation)**
- **Unlike GTAP**
  - **SIMPLE-G is a partial equilibrium model, focusing on primary, land-using activities in the economy**
  - **SIMPLE-G has gridded (e.g., 10km x 10km) resolution; specific regions may have grid-level detail**

SIMPLE-G allows for Global-to-Local-to-Global analysis of land and water sustainability



- Global forces are driving the food system and associated sustainability stresses
- Yet the character of these stresses & associated solutions are generally location-specific
- Furthermore, local responses can have spillover effects, giving rise to regional and global consequences
- GLG analysis is necessary

For more discussion of Global to Local to Global analysis visit GLASSNET: https://glassnet.net

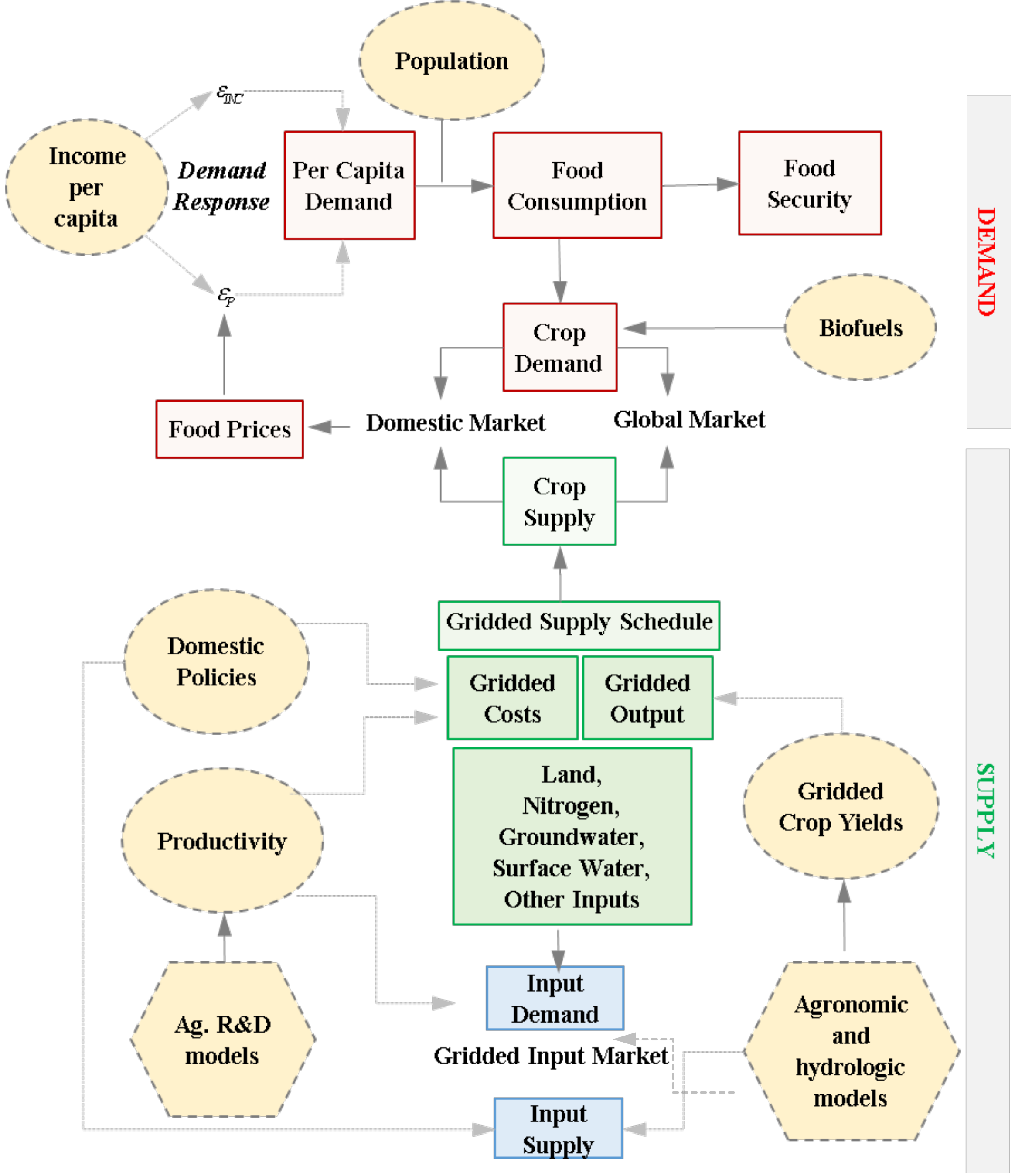
Chapters 4 and 5

How Does SIMPLE-G Work?

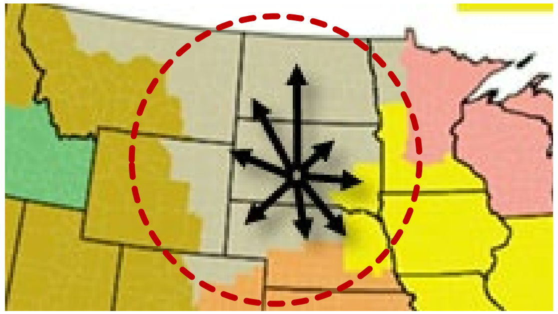
Iman Haqiqi

What is SIMPLE-G?

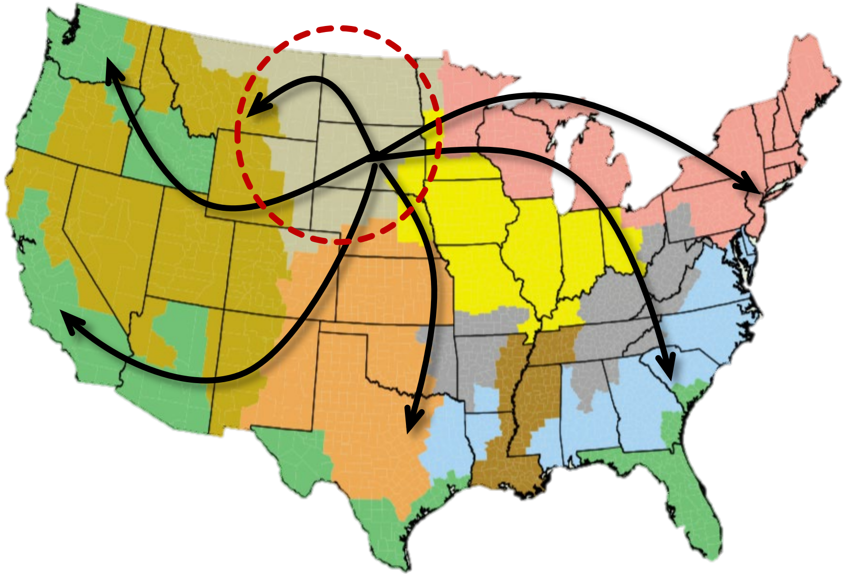
- **SIMPLE-G: a Simplified International Model of agricultural Prices, Land use and the Environment-Gridded**
  - multi-scale,
  - partial equilibrium,
  - gridded economic model.
- **by 17 global regions:**
  - Global crop trade
  - Global food choice and consumption
  - Global production of livestock and processed food
- **by grid cell (10 thousand to 2 million grid cells)**
  - Crop production
  - Fertilizer, labor, land, and water
  - Conservation policy
  - Environmental shocks



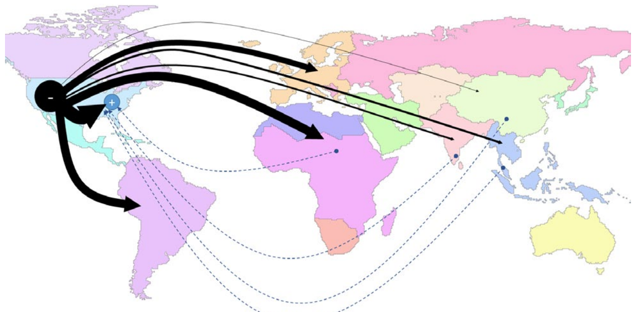
Market-Mediated Spillover Effects



- Local changes have implications for local production and land use

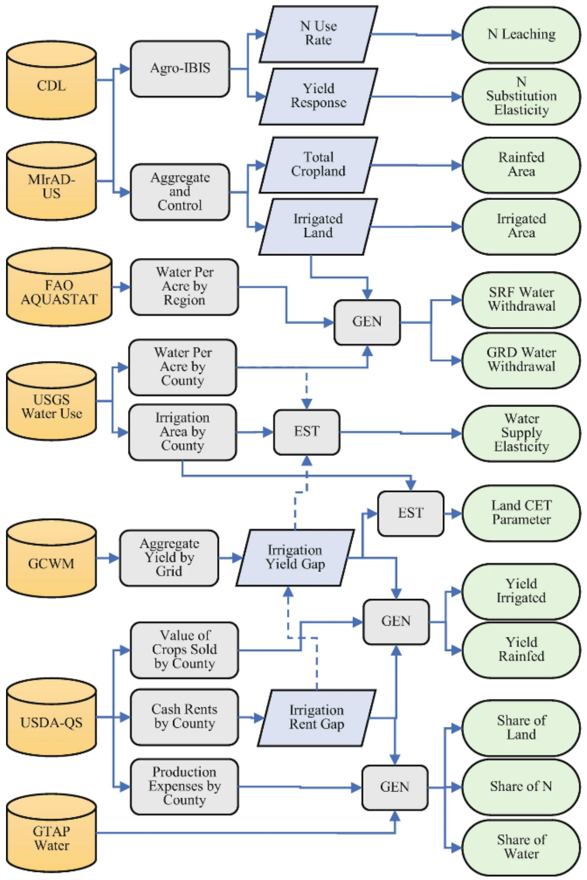


- This can cause changes in grid cells with similar crop outputs
- It can also affect remote grid cells within a region
- Finally, it may have an impact on other countries

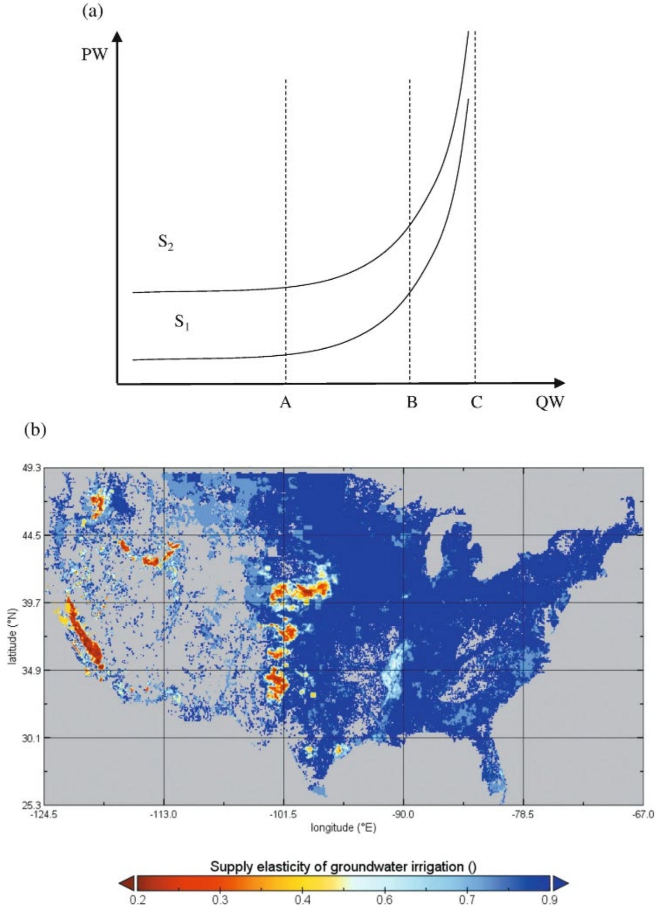


- Relative prices, market shares, and elasticities determine the magnitude of the spillover effect

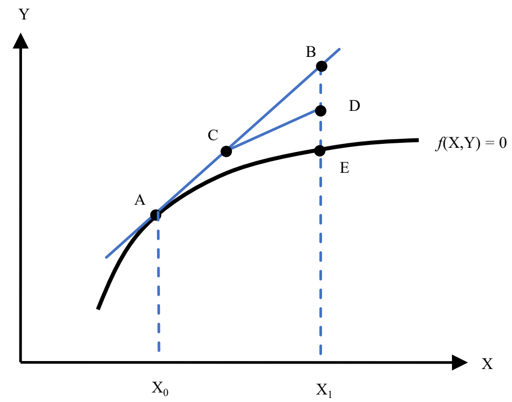
Chapter 6: Benchmark Data

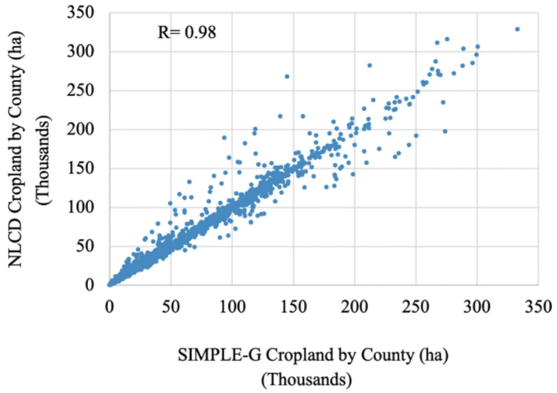


Chapter 7: Behavioral Parameters



Chapters 8-9: Computation and Validation





Chapter 12

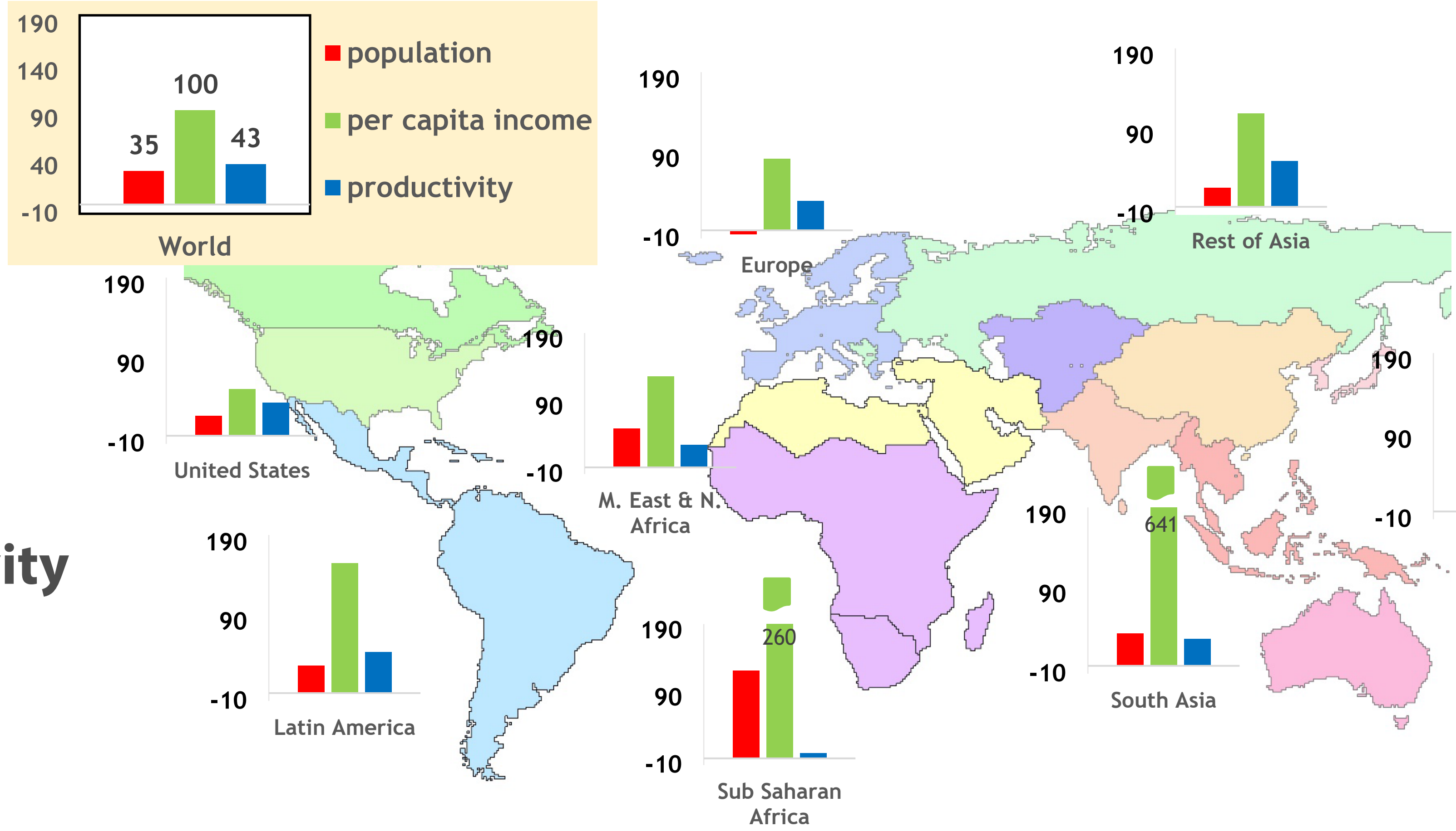
Global Drivers of Local Stresses and Global Responses to Local Conservation Policies

Iman Haqiqi

Haqiqi, et al. 2023. Global drivers of local water stresses and global responses to local water policies in the United States. Environmental Research Letters 18: 065007. https://doi.org/10.1088/1748-9326/acd269

Global Drivers

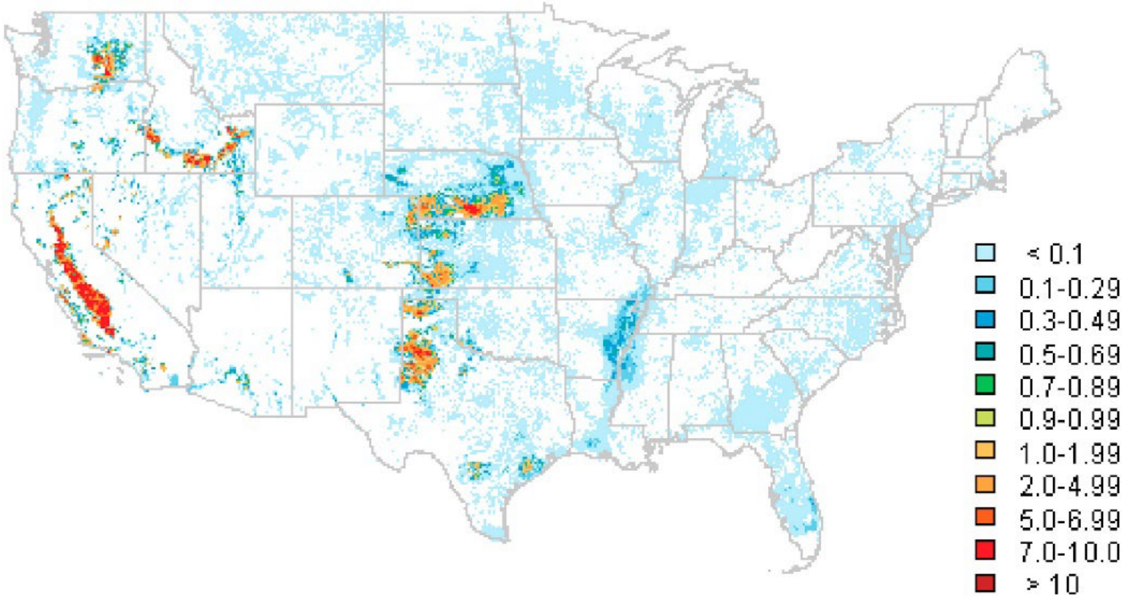
- **Demand:**
  - **Population**
  - **Income**
  - **Biofuel**



- **Supply:**
  - **Relative productivity growth**
  - **Relative resource availability**

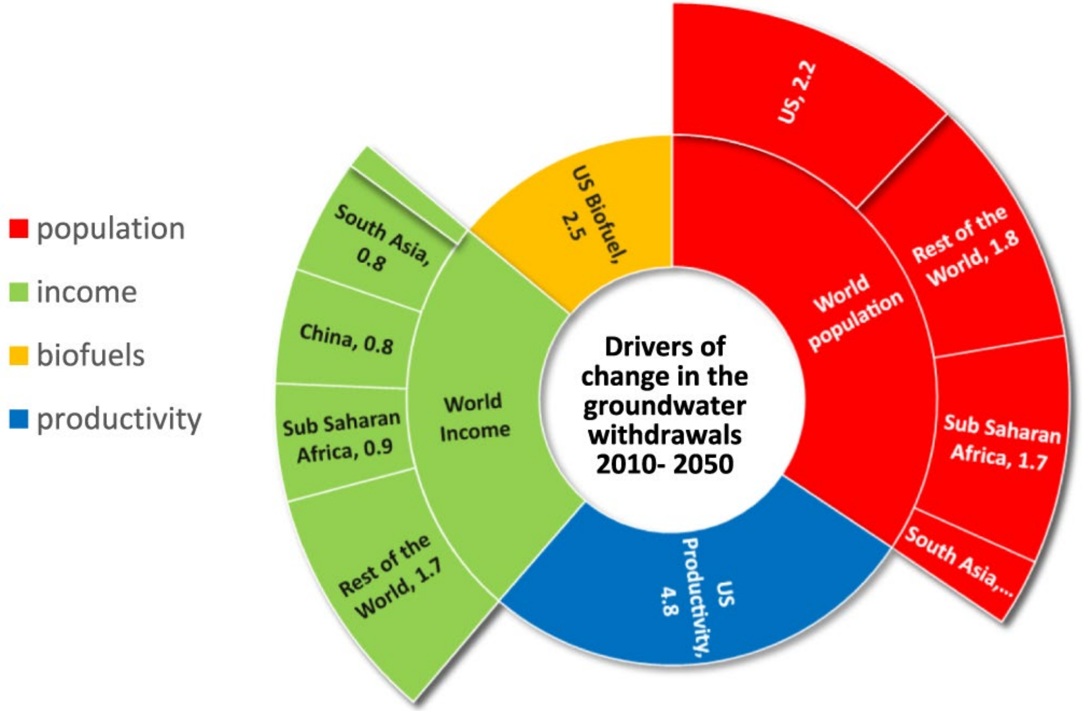
Current & Future Groundwater Stress

Current Stress Index (2010)



The extraction to recharge ratio illustrates the speed of groundwater depletion.

SIMPLE-G Projections 2010-2050



% change in US groundwater withdrawals

Chapter 16

Global Drivers of Local Stresses and Global Responses to Local Conservation Policies

Iman Haqiqi

Haqiqi et al. 2023. Global drivers of local water stresses and global responses to local water policies in the United States. Environmental Research Letters 18: 065007. https://doi.org/10.1088/1748-9326/acd269

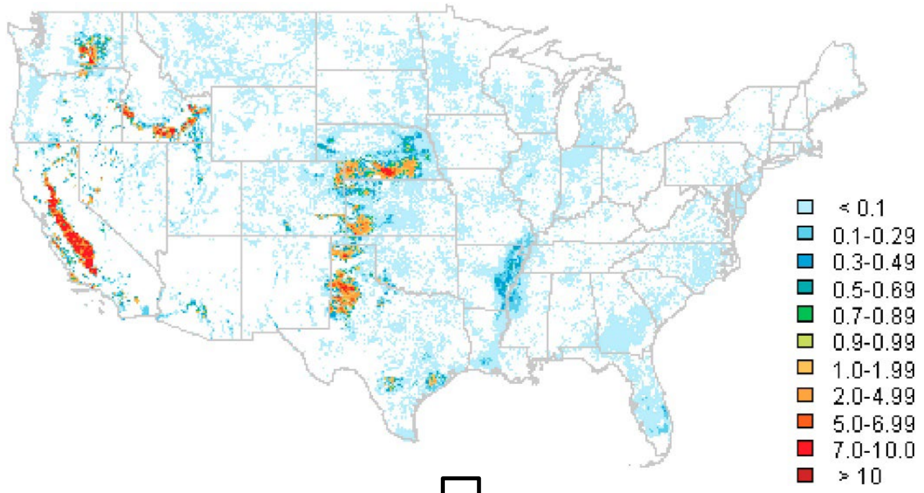
Haqiqi, Perry, and Hertel. 2022. When the virtual water runs out: Local and global responses to addressing unsustainable groundwater consumption. Water International 47: 1060–1084. https://doi.org/10.1080/02508060.2023.2131272

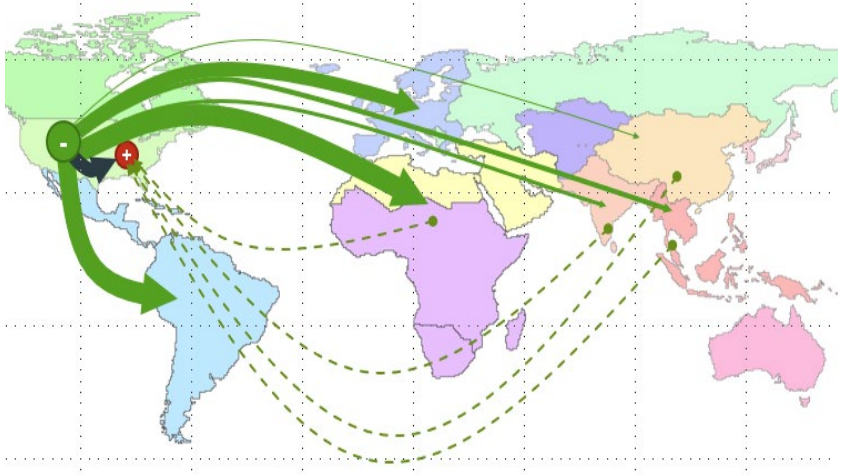
Global Impacts of Sustainability Restrictions

- Potential local responses
  - Surface water substitution
  - Change in crop mix (less water per acre)
  - Rainfed conversion

  => Reduction in production
- Regional market-mediated effects
  - Price increase
  - Increase in production in non-targeted locations
  - Land use and fertilizer application

  => New sustainability challenges
- Global effects:
  - Change in exports and imports
  - Increase in land and water use overseas





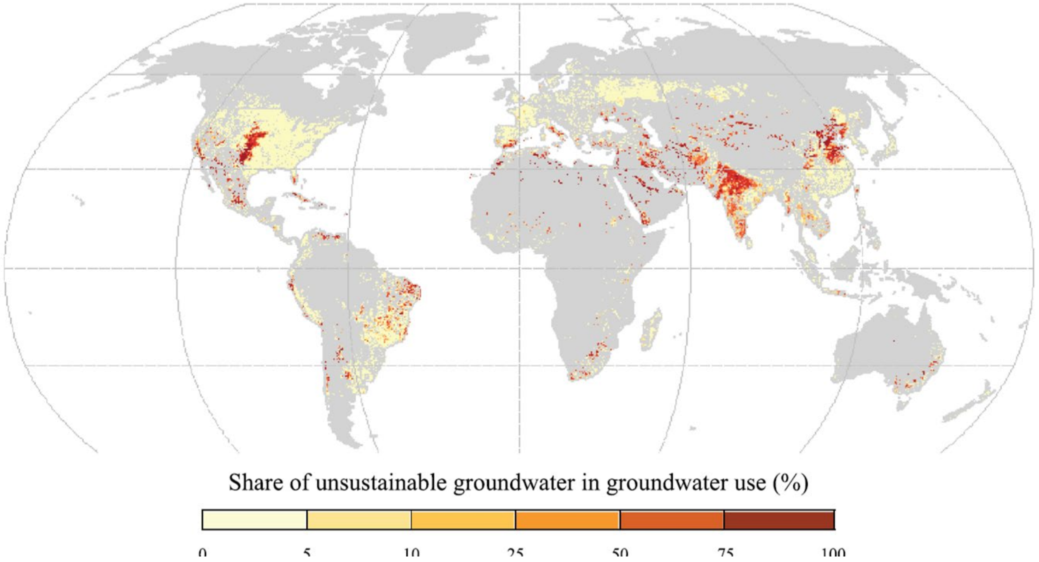
Global Groundwater Sustainability and Virtual Water

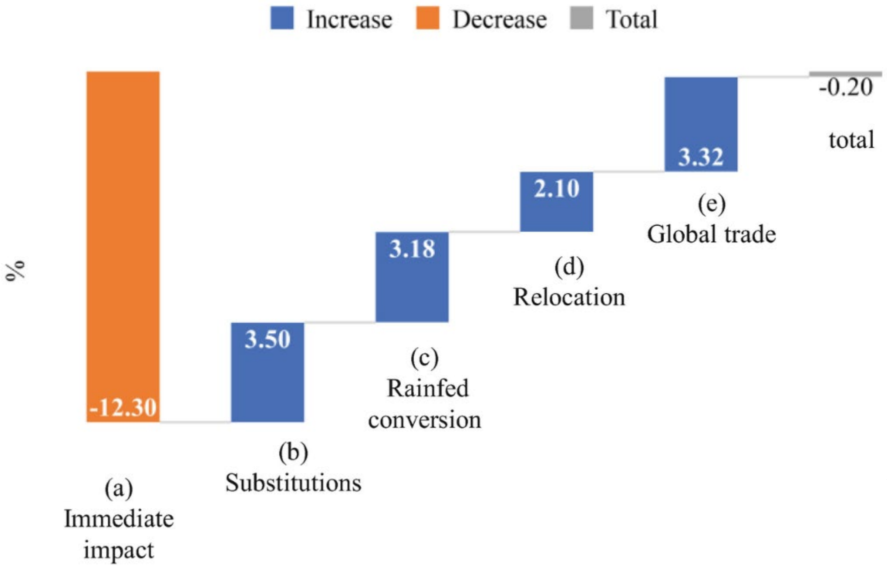
- Potential local responses
  - Surface water substitution
  - Change in crop mix (less water per acre)
  - Rainfed conversion

  => Reduction in production
- Regional market-mediated effects
  - Price increase
  - Increase in production in non-targeted locations
  - Land use and fertilizer application

  => New sustainability challenges
- Global effects:
  - Change in exports and imports
  - Increase in land and water use overseas

=> Final impact on food system is small



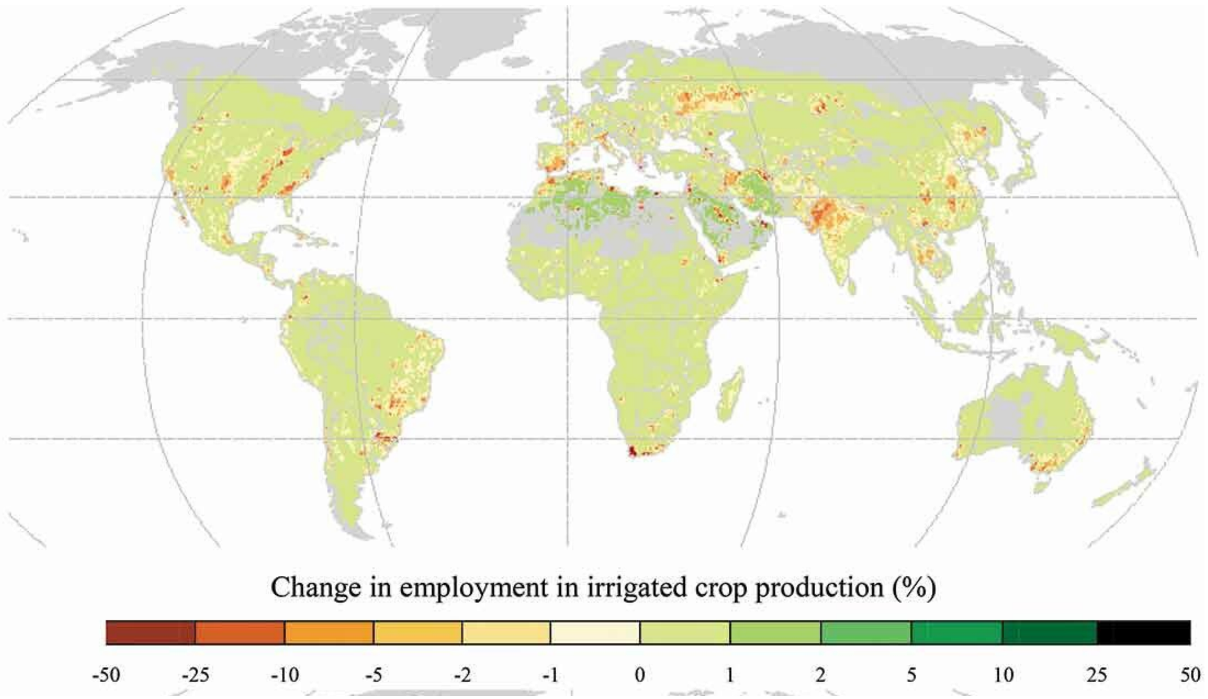


Employment Implications

Δ Change in employment in crop production

	irrigated	rainfed	total
East Europe	491	3,213	3,705
North Africa	6,060	4,300	10,360
Sub Saharan Africa	4,613	127,523	132,137
South America	1,533	2,994	4,527
Brazil	1,170	12,885	14,054
Australia & New Zealand	16	167	183
Europe	1,079	5,093	6,171
South Asia	124,365	138,087	262,452
Central America	1,650	5,696	7,346
South Africa	96	829	924
South East Asia	20,727	68,506	89,233
Canada	4	181	185
United States	318	1,518	1,836
China	103,236	105,044	208,279
Middle East	3,064	5,888	8,952
Japan & Korea	410	656	1,066
Central Asia	2,666	3,538	6,203
World	271,498	486,117	757,615

% Change in employment in irrigated production



Chapter 13

The Role of Labor Markets in Determining Efficacy and Distributional Impacts of Sustainability Policies

Srabashi Ray

Ray et al. 2023. Labor markets: A critical link between global-local shocks and their impact on agriculture. Environmental Research Letters 18: 035007. https://doi.org/10.1088/1748-9326/acb1c9

SIMPLE-G: Human-Natural Coupled System Modelling

- Conservation policies are likely to have human impacts
  - Job opportunities
  - Wages
- Integrated Assessment Models (IAMs) often overlook labor markets
- Labor markets mediate policy impacts
  - Effectiveness
  - Distributional

Source: Flickr, USDA

SIMPLE Model and Experiment

- **Sustainable groundwater policy in Western US:**
  - **Restricts groundwater extraction to the recharge rate in each grid cell**
- **Compare the impacts for contrasting labor market structure:**
  - **Restricted labor mobility**
  - **Perfect labor mobility**

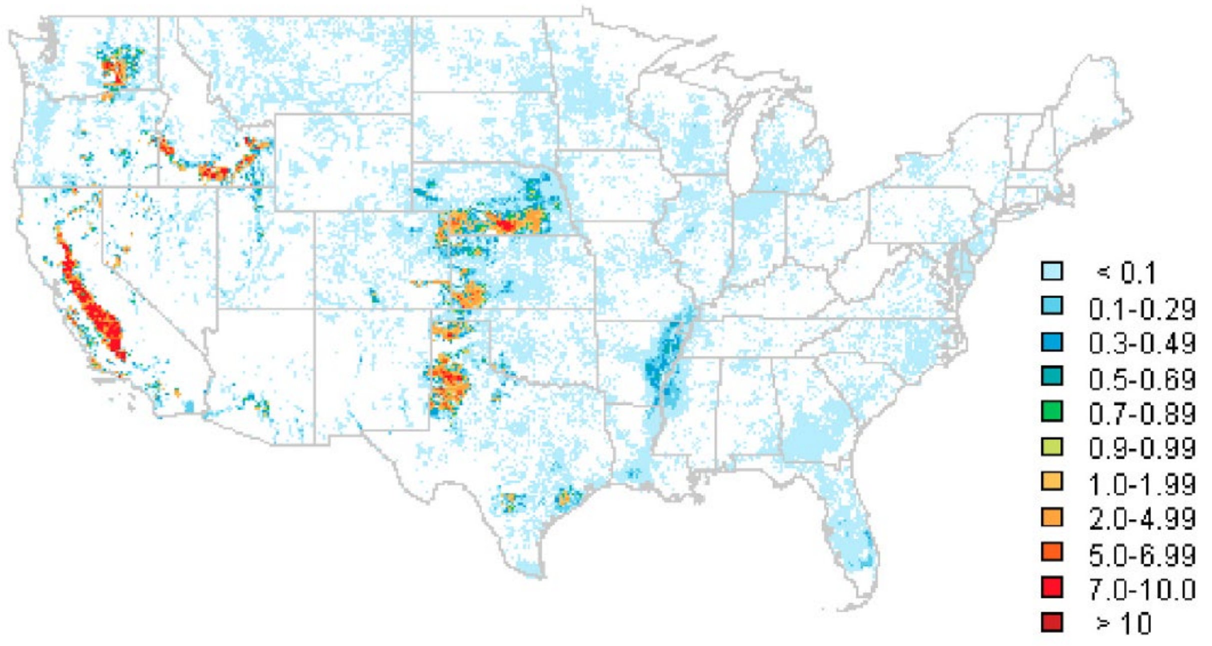


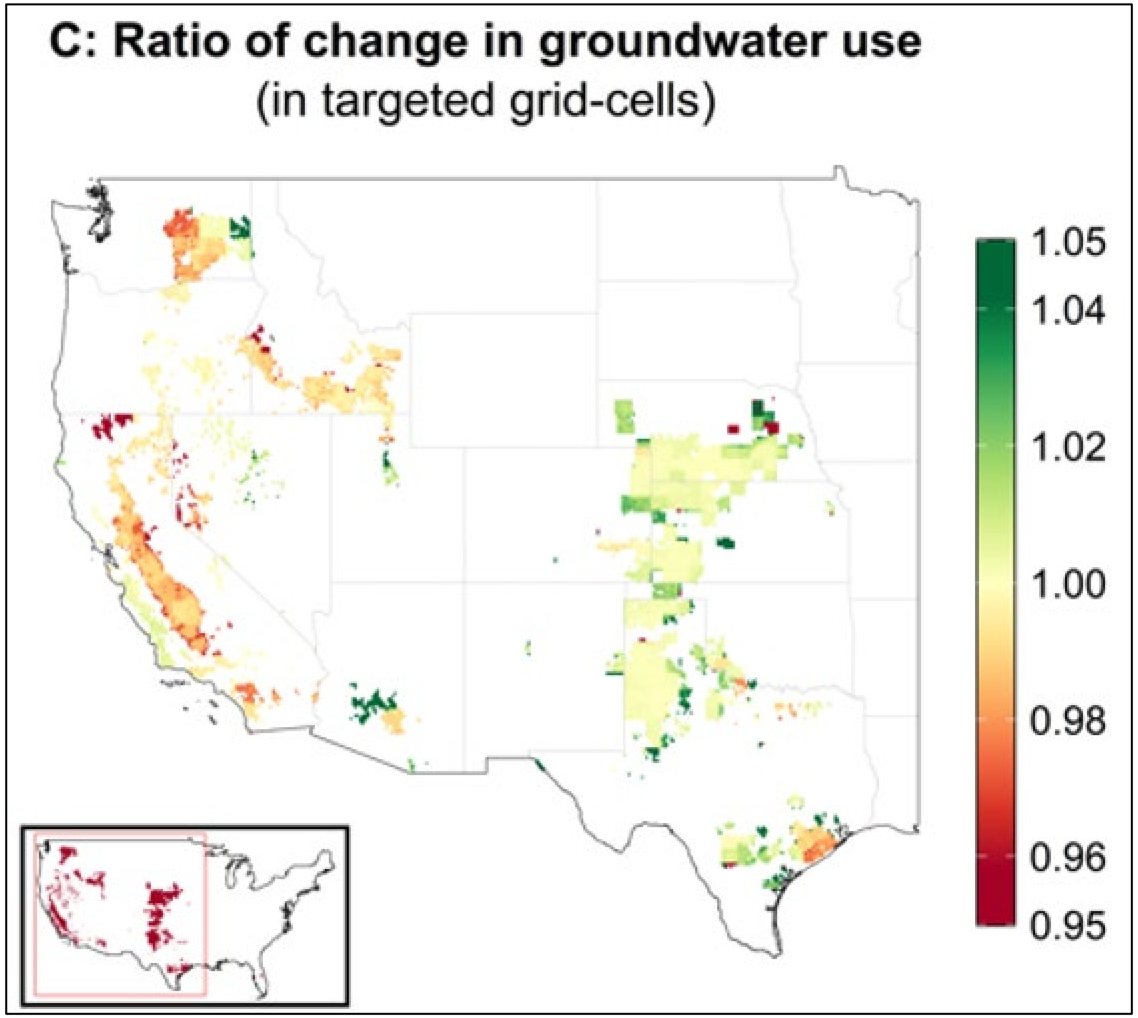
Fig. 4. Ratio of groundwater extraction over local groundwater recharge by 5 arc min grid cells for 2010.

Labor markets mediate policy effectiveness

- **Extent of groundwater conservation depends on labor markets and site specific parameters**

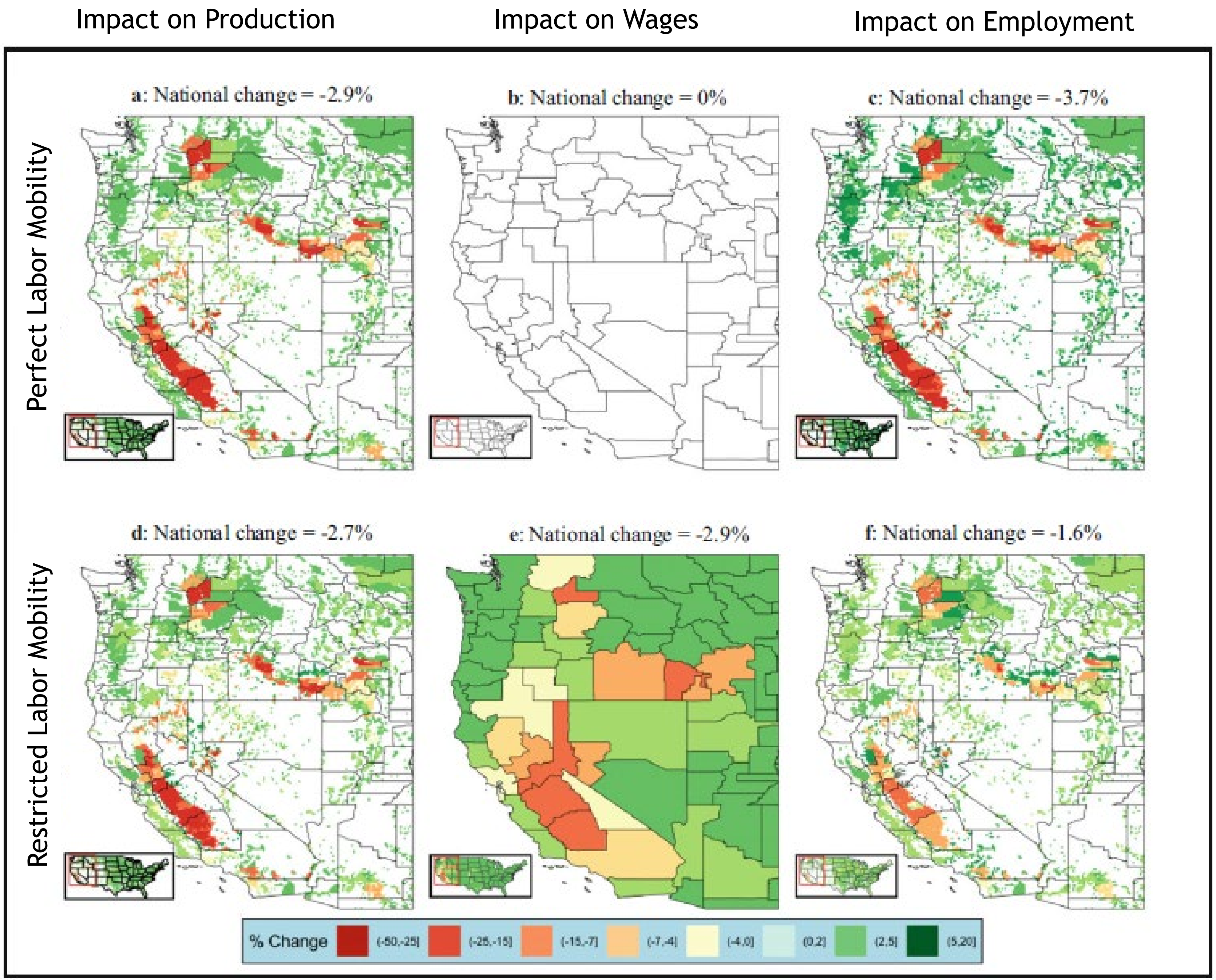
- $ratio = \frac{\Delta GW\ use\ under\ Restricted\ Mobility}{\Delta GW\ use\ under\ Perfect\ Mobility}$

- **Ignoring labor market (Ray and Hertel, forthcoming 2025):**
  - **Over-estimate conservation in Western US (reds)**
  - **Under-estimate conservation in the High Plains region (greens)**
  - **Site specific parameters explain variation**



Ignoring labor markets overlooks distributional impacts

- Wage impacts:
  - Targeted regions ~25-35% decrease
- Employment:
  - Perfect labor mobility over-estimates the changes in employment



Summarize

- We need to consider the human impacts of conservation policies
- Explicit modelling of labor markets
- Ignoring labor markets, over-estimates adjustments and under-estimated welfare impacts
- Next steps: labor types, labor sheds for agricultural workers

Chapter 14

Optimizing Conservation Strategies to Curb Nitrogen Loss in the U.S. Midwest

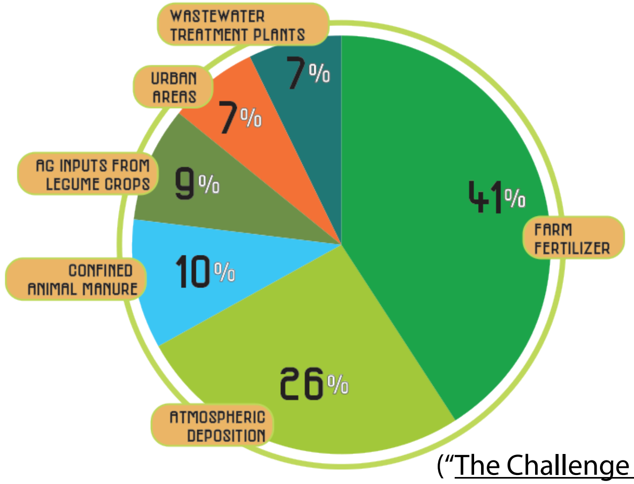
Jing Liu

Liu, Jing, Laura Bowling, Christopher Kucharik, Sadia Jame, Uris Lantz C. Baldos, Larissa Jarvis, Navin Ramankutty, and Thomas W. Hertel. 2023. Tackling policy leakage and targeting hotspots could be key to addressing the “wicked” challenge of nutrient pollution from corn production in the U.S. Environmental Research Letters 18: 105002. https://doi.org/10.1088/1748-9326/acf727.

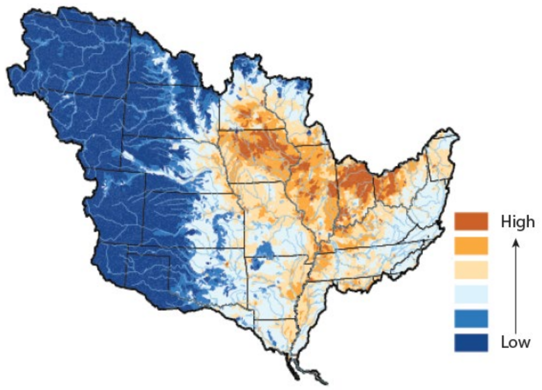
Introduction

- Persistent non-point source pollution from N fertilizer use
- No consensus on mitigation pathways or associated trade-off

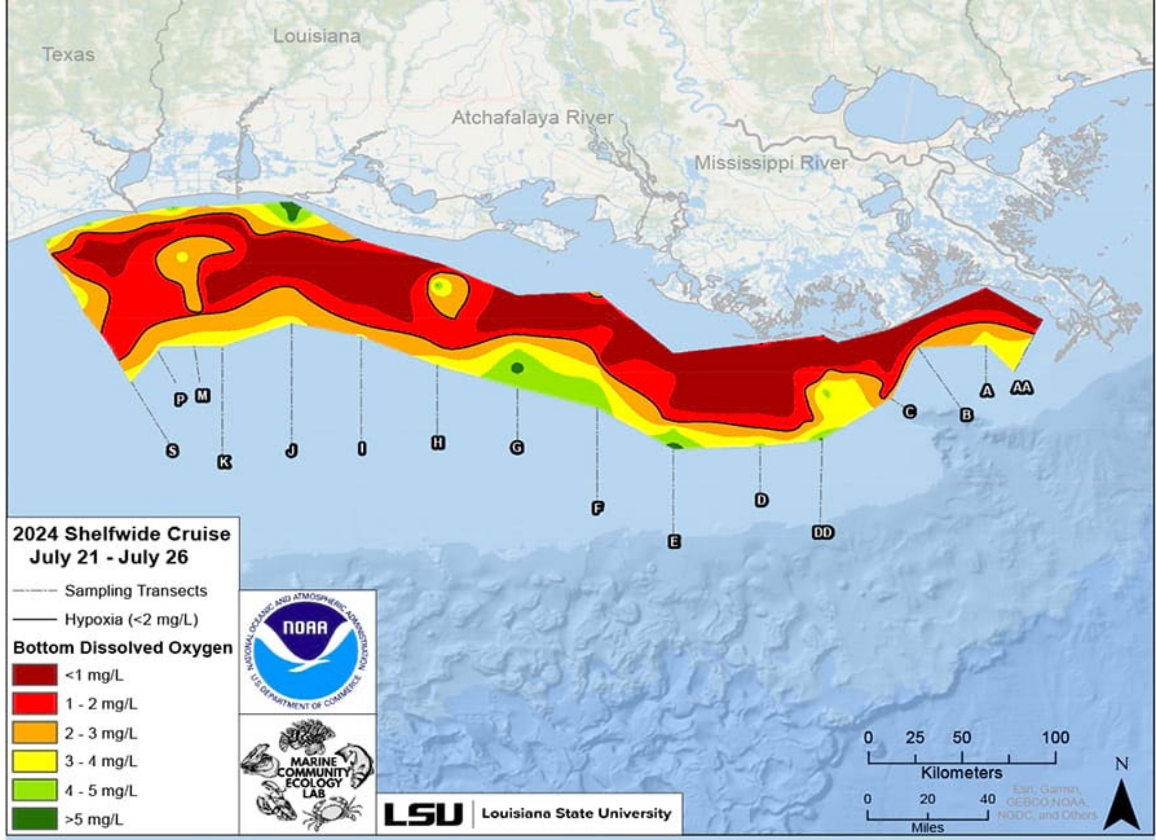
SOURCES OF NITROGEN DELIVERED TO THE GULF OF MEXICO

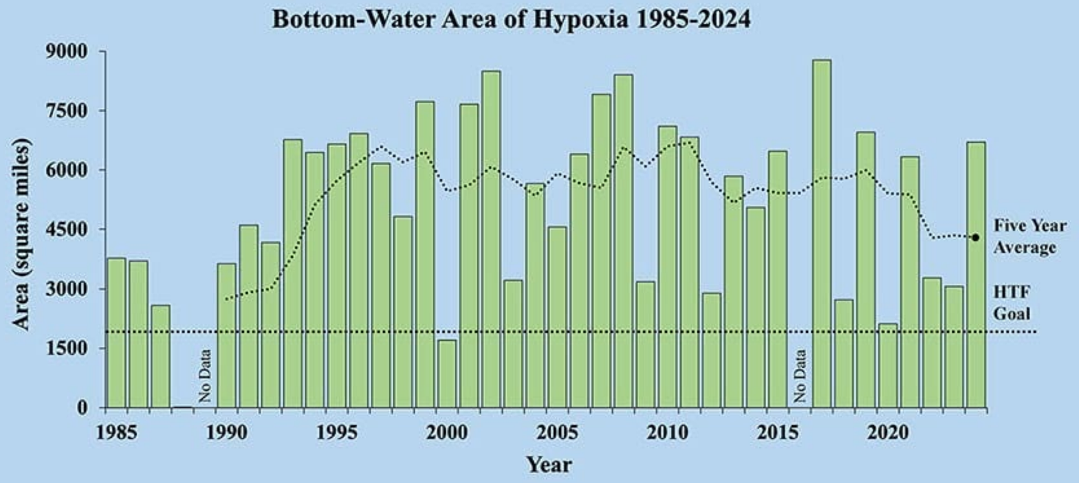


AREAS WITH THE HIGHEST NITROGEN YIELDS TRANSPORTED TO THE GULF OF MEXICO



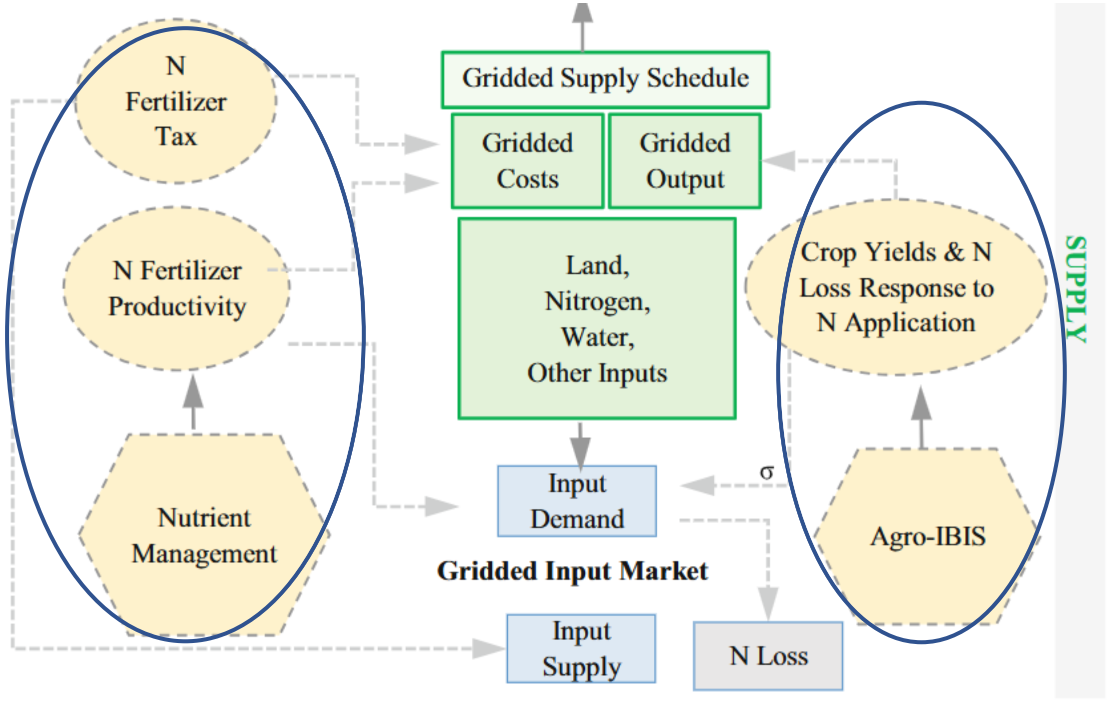
("The Challenge of Tracking Nutrient Pollution 2,300 Miles", USGS)





Objective and Research Questions

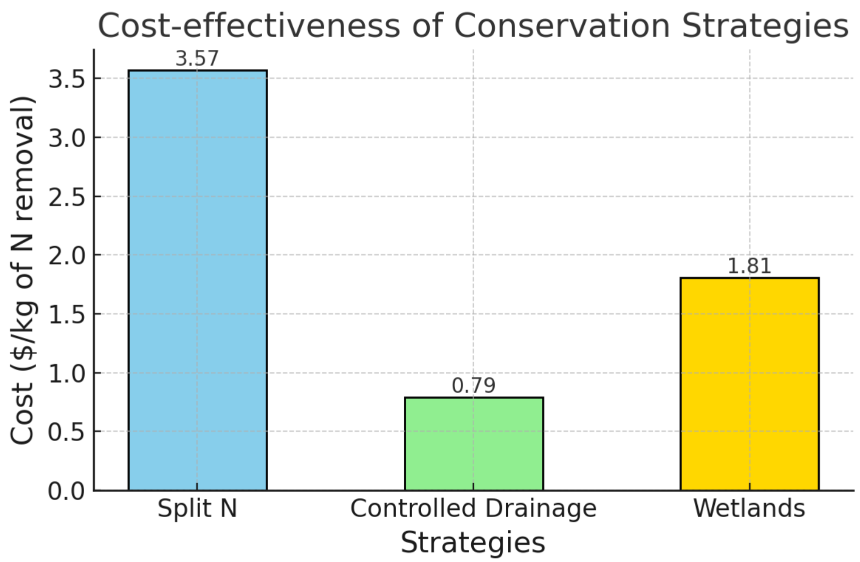
- Assess the effectiveness of 4 conservation strategies to reduce N loss
  - **N loss tax, split N, controlled drainage, wetlands**
- What are the cost-effectiveness ($/ton of N removal), and impacts on N use and crop production?
- **Why SIMPLE-G for this question?** Localized responses, systematic comparison of conservation policies

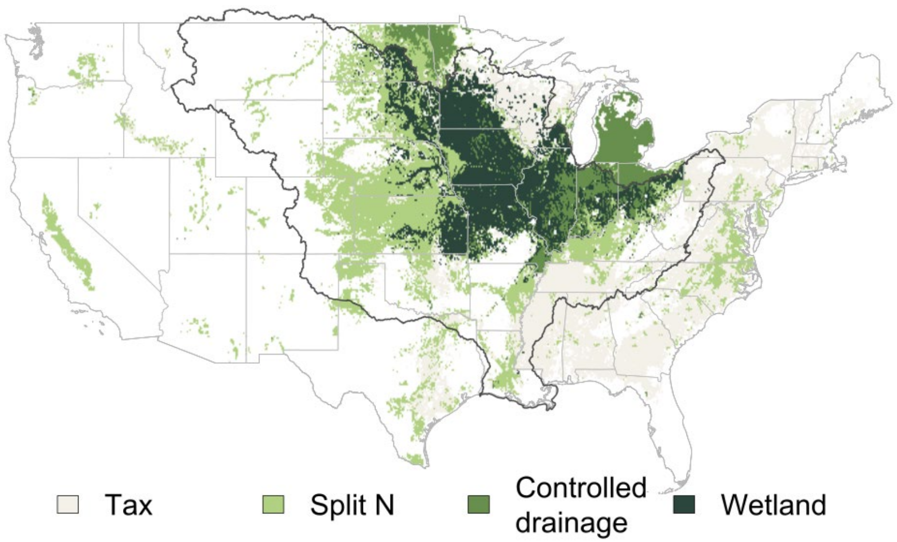


SIMPLE-G-CS model

Key Findings

- Combining **tax, split N and wetland** has the potential to reduce N loss by 30% with minor impact on production
- The **most effective strategy differs** depending on the location
- **10%** of locations account for half of the total N mitigation
- Site-specific strategies may result in **leakage effects**





Chapter 15

Infrastructure Investments

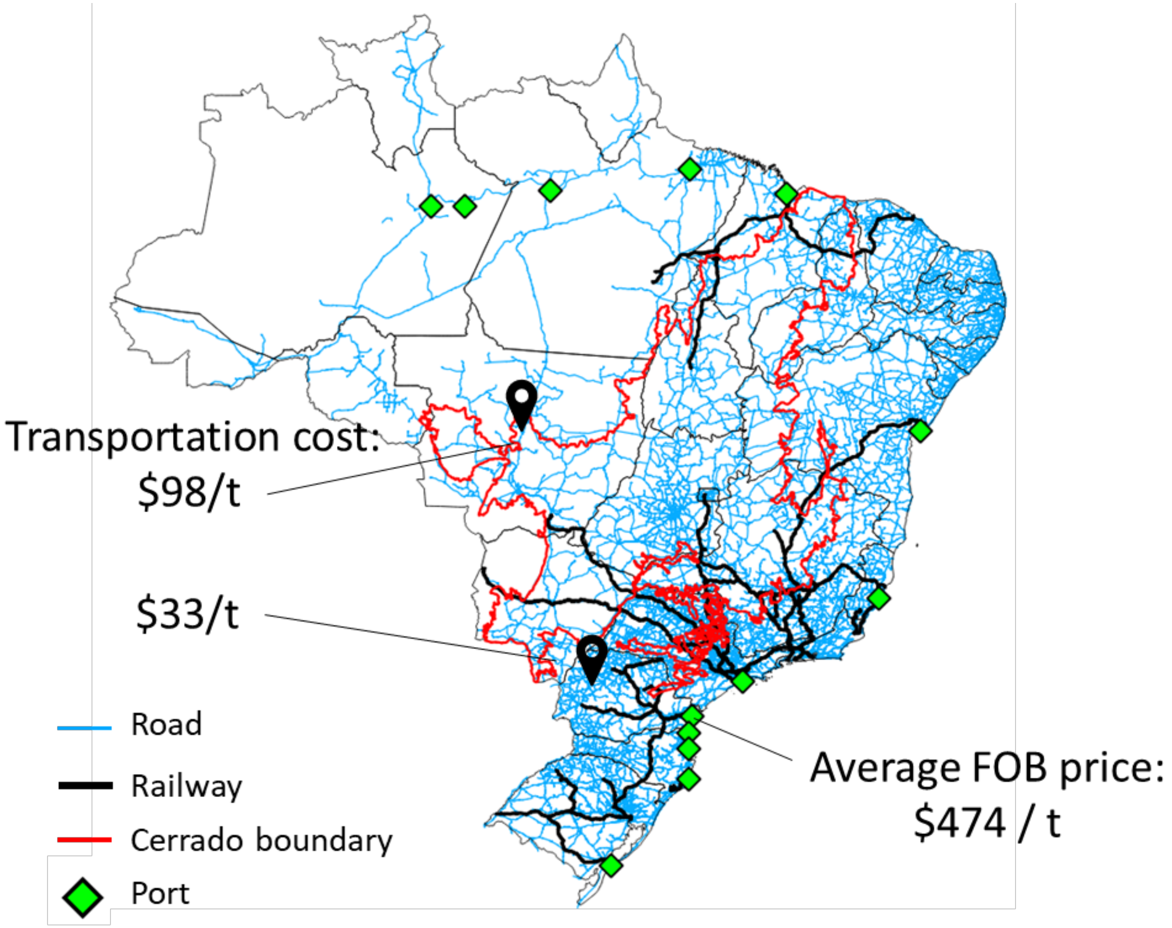
Zhan Wang

“Wang, Zhan, Geraldo B. Martha Jr, Jing Liu, Cicero Z. Lima, and Thomas W. Hertel. "Planned expansion of transportation infrastructure in Brazil has implications for the pattern of agricultural production and carbon emissions." *Science of The Total Environment* 928 (2024): 172434.”

Application: Infrastructure Investments

Motivation

- High transportation cost: the bottleneck of inland Brazilian agriculture

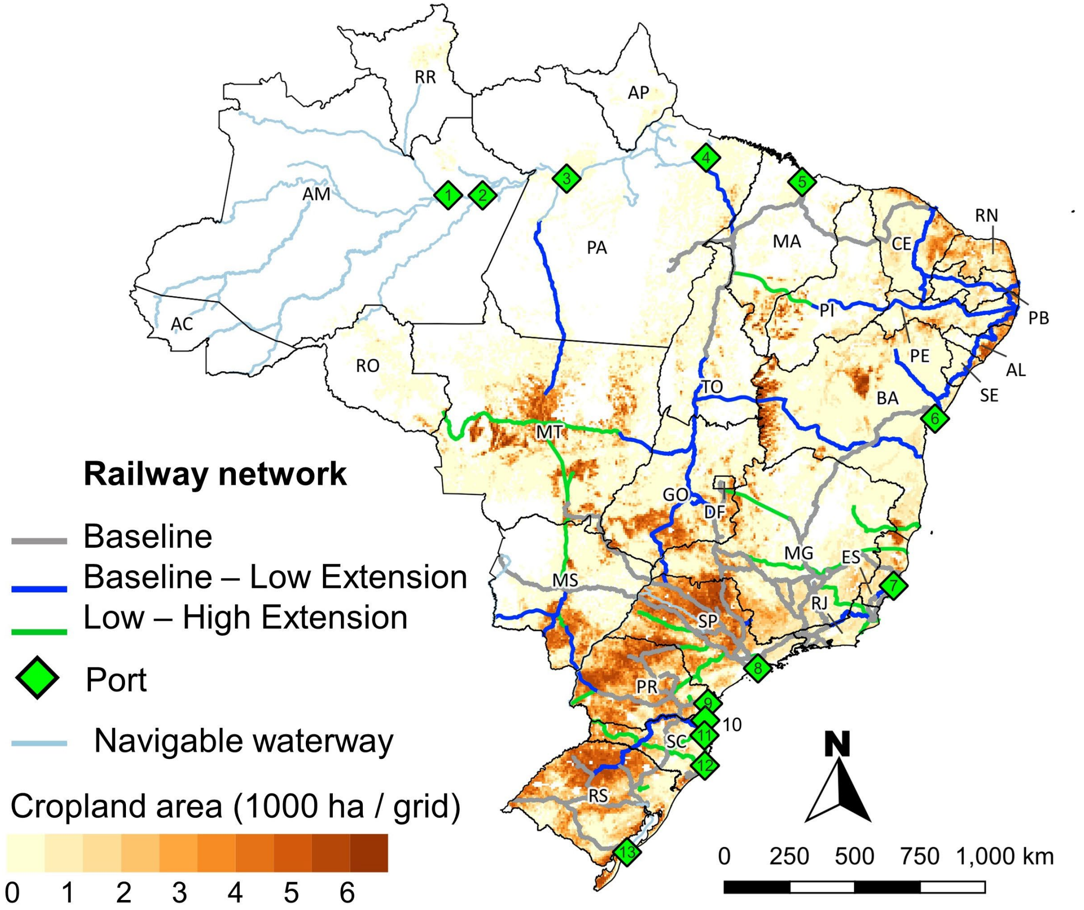


Road, railway and crop export ports in 2017

Application: Infrastructure Investments

Motivation

- High transportation cost: the bottleneck of inland Brazilian agriculture
- National logistic plan (PNL2035) aims to extend railway network by up to 91% (High extension)



Planned railway network expansion by 2035

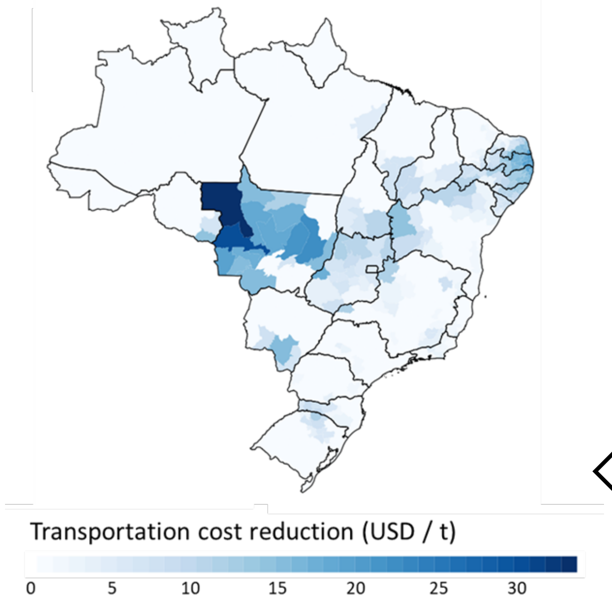
Research question

- How will PNL2035 interact with global crop price change and influence Brazilian crop production and land use?

Application: Infrastructure Investments

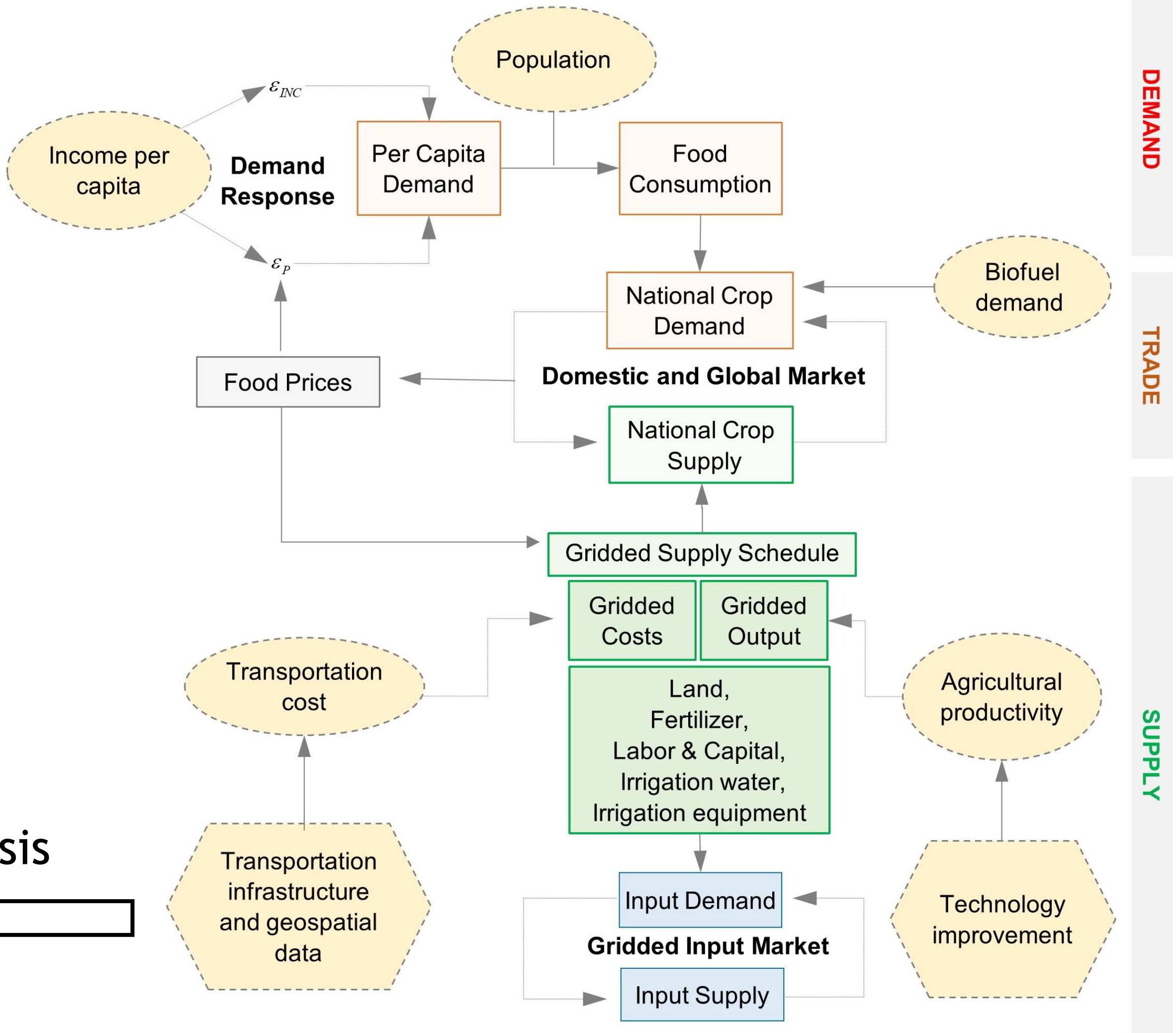
Why SIMPLE-G?

- Local heterogeneous drivers



Transportation cost reduction between baseline and high extension

Geospatial analysis

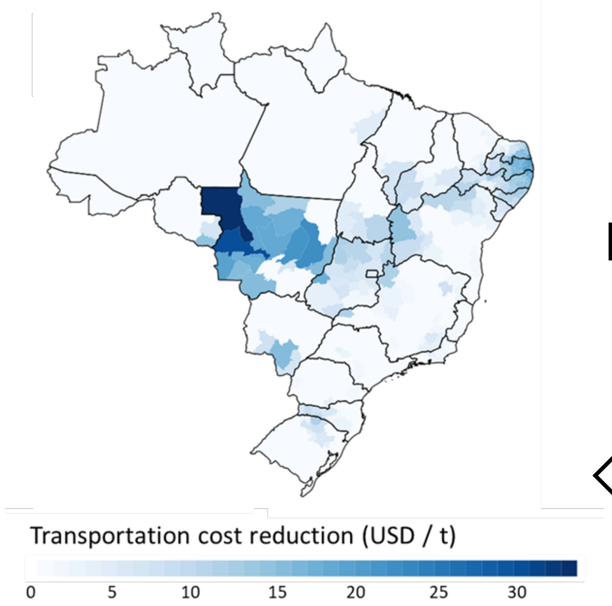


Structure of SIMPLE-G-Brazil

Application: Infrastructure Investments

Why SIMPLE-G?

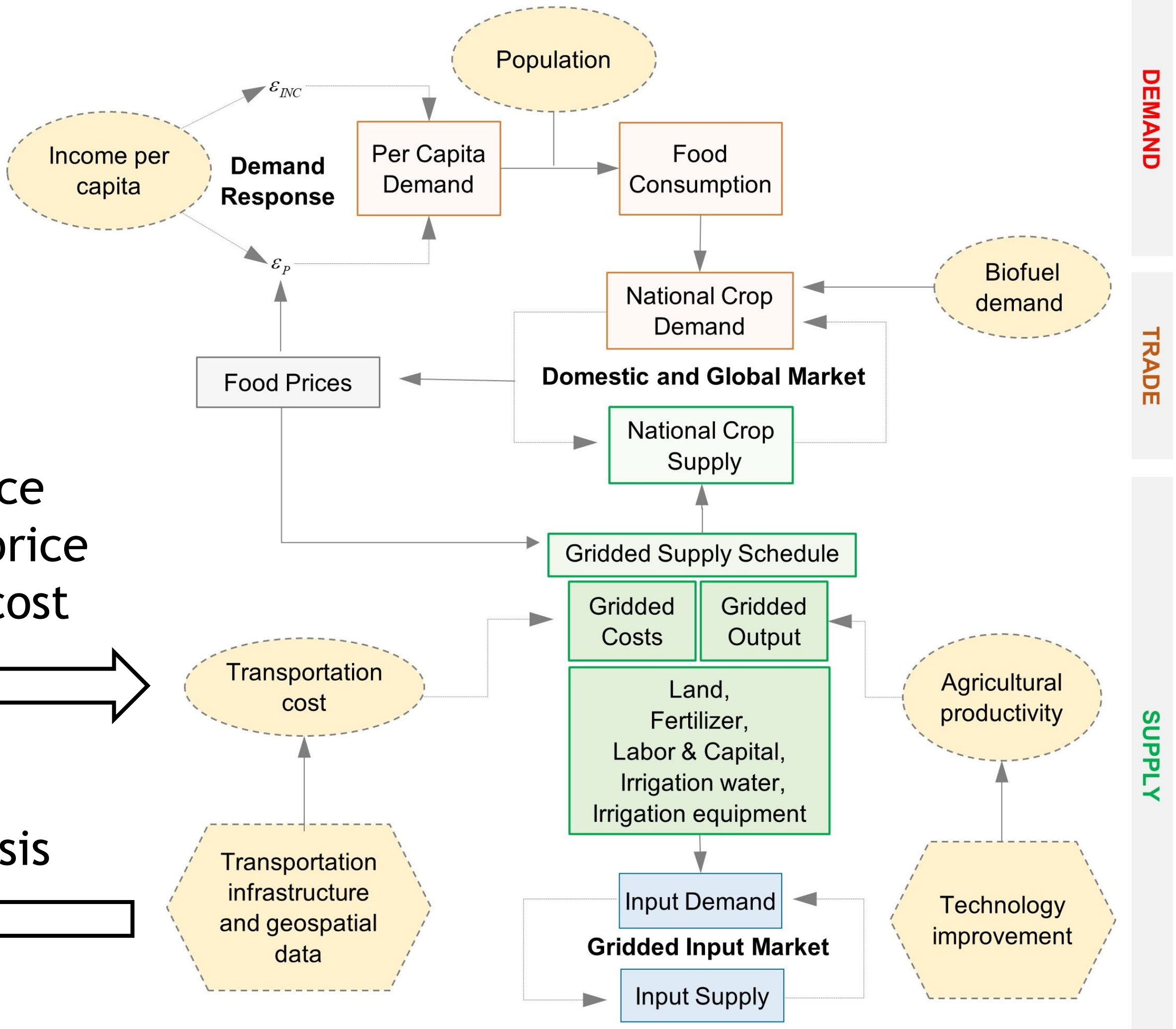
- Local heterogeneous drivers
- Spillover effects across grid cells



Gridded crop price
= national crop price
-transportation cost

Geospatial analysis

Estimated transportation cost reduction
between baseline and high extension

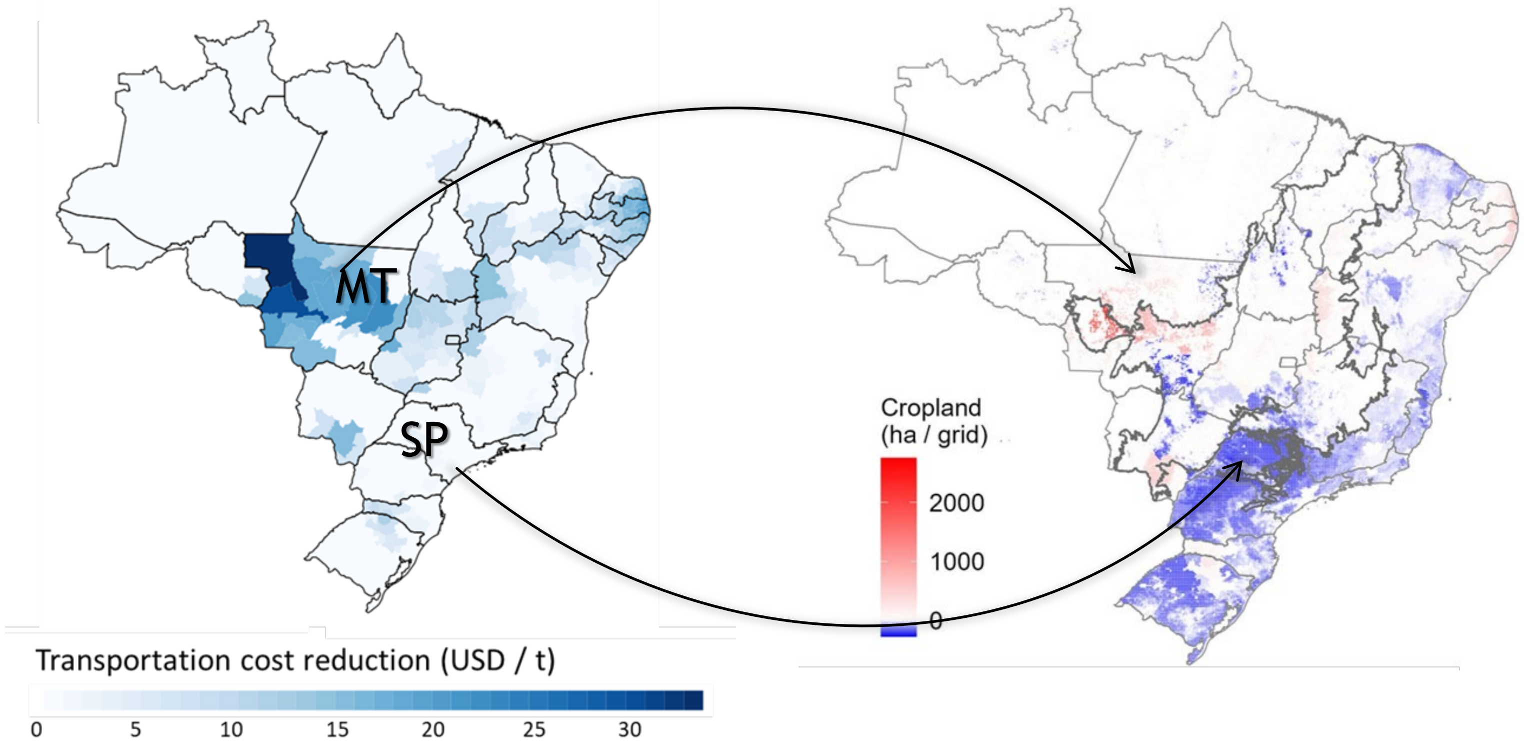


Structure of SIMPLE-G-Brazil

Application: Infrastructure Investments

Results

- Example: Mato Grosso (MT) from Center-West and São Paulo (SP) from South-Southeast
- MT gains relative advantage in agriculture than SP from PNL2035



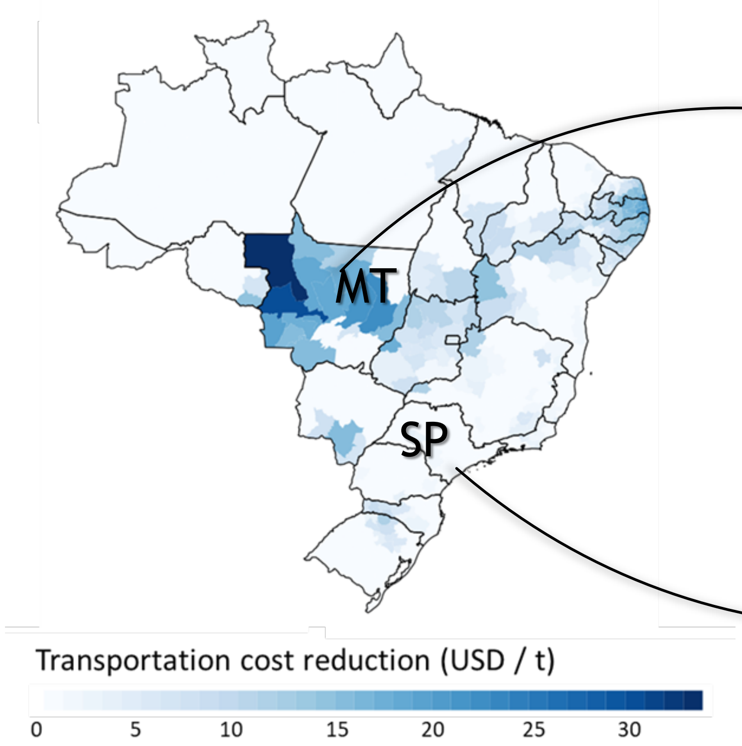
Transportation cost reduction

Change of gridded cropland use

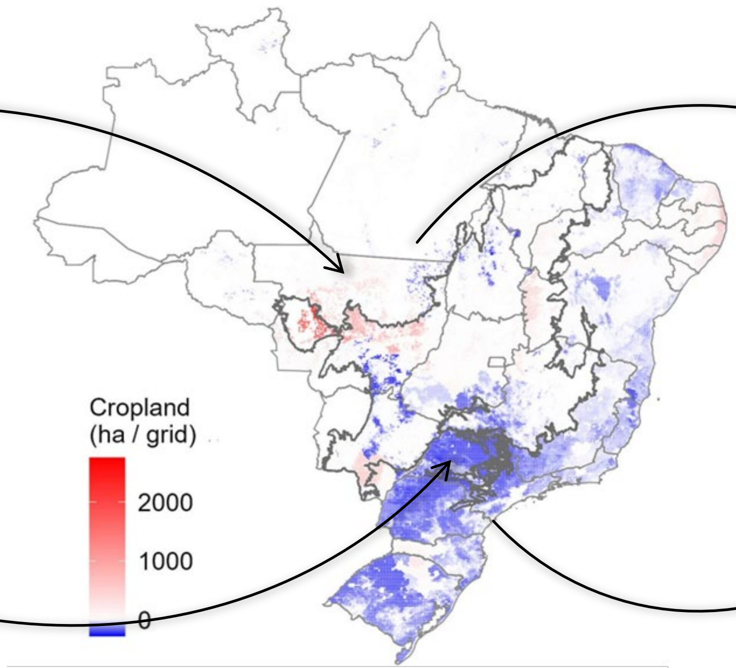
Application: Infrastructure Investments

Results

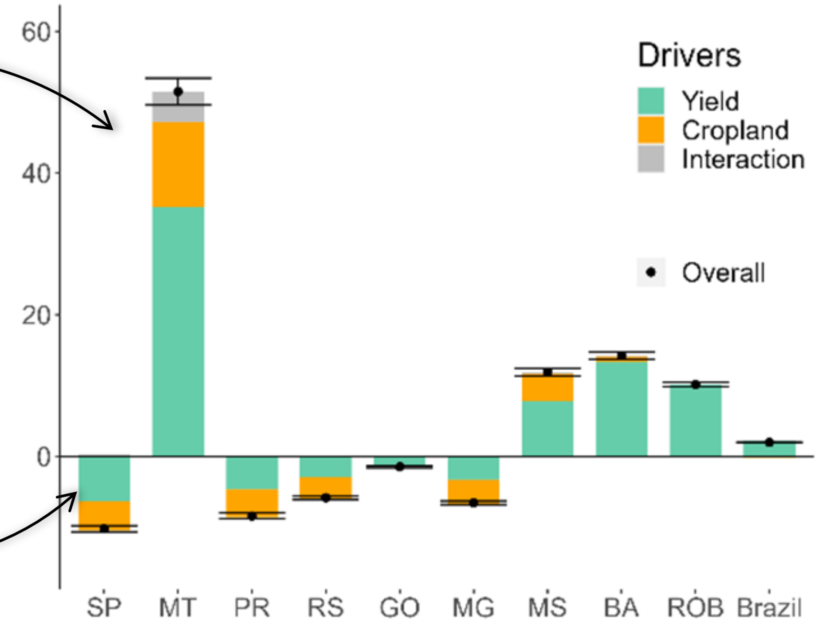
- Crop production patterns shifts from South-SE to Center-West
- Major driver: non-land inputs due to better mobility



Transportation cost reduction



Change of gridded cropland use



Percentage change (%) of crop output and its drivers (yield and cropland)

Chapter 10

The R&D Cost of Climate Mitigation in Agriculture

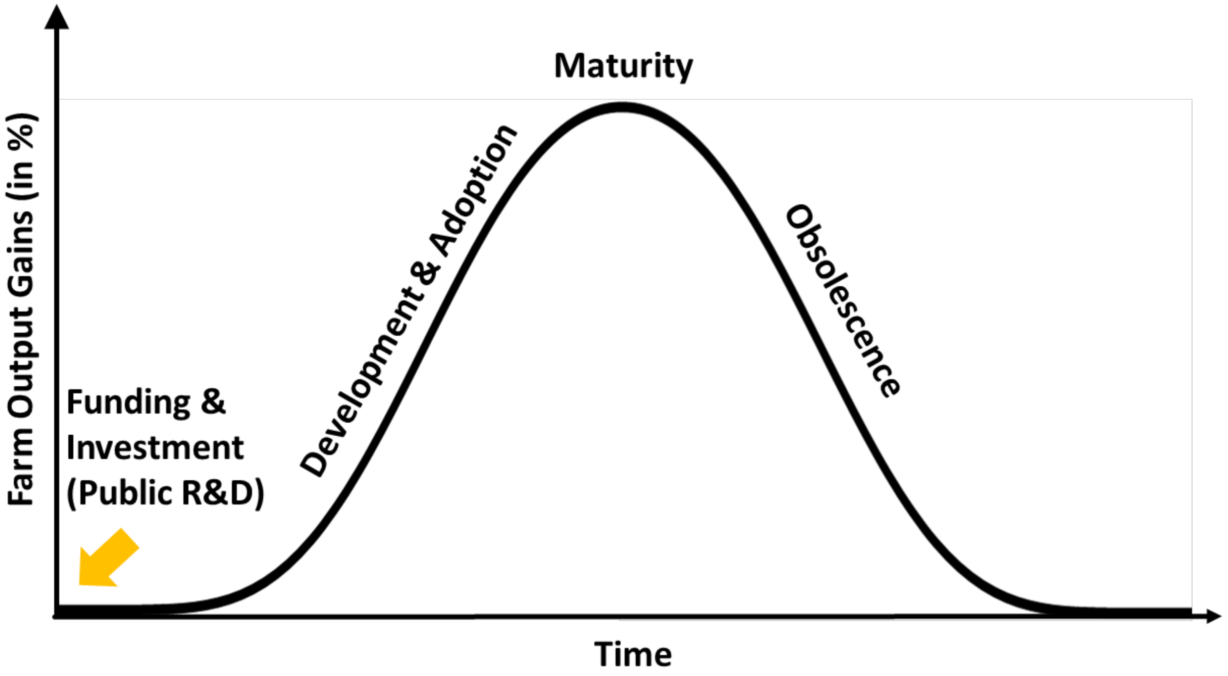
Uris Baldos

Fuglie, K., Ray, S., Baldos, U.L.C., Hertel, T.W. (2025). The R&D Cost of Climate Mitigation in Agriculture. In: Haqiqi, I., Hertel, T.W. (eds) SIMPLE-G. Springer, Cham.
https://doi.org/10.1007/978-3-031-68054-0_10

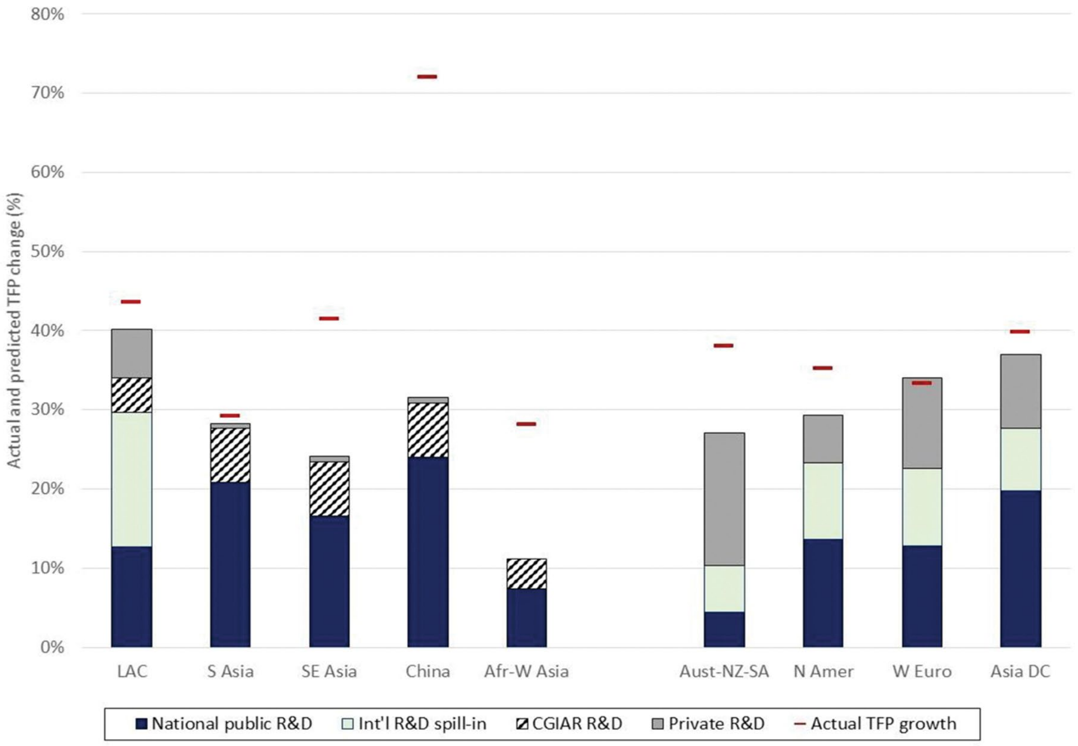
Motivation

- **Investments in agricultural research and development (R&D), is a key driver of agricultural productivity growth**

Stylized model of technology life cycle



R&D-led and Actual Productivity in Agriculture, 1990–2011

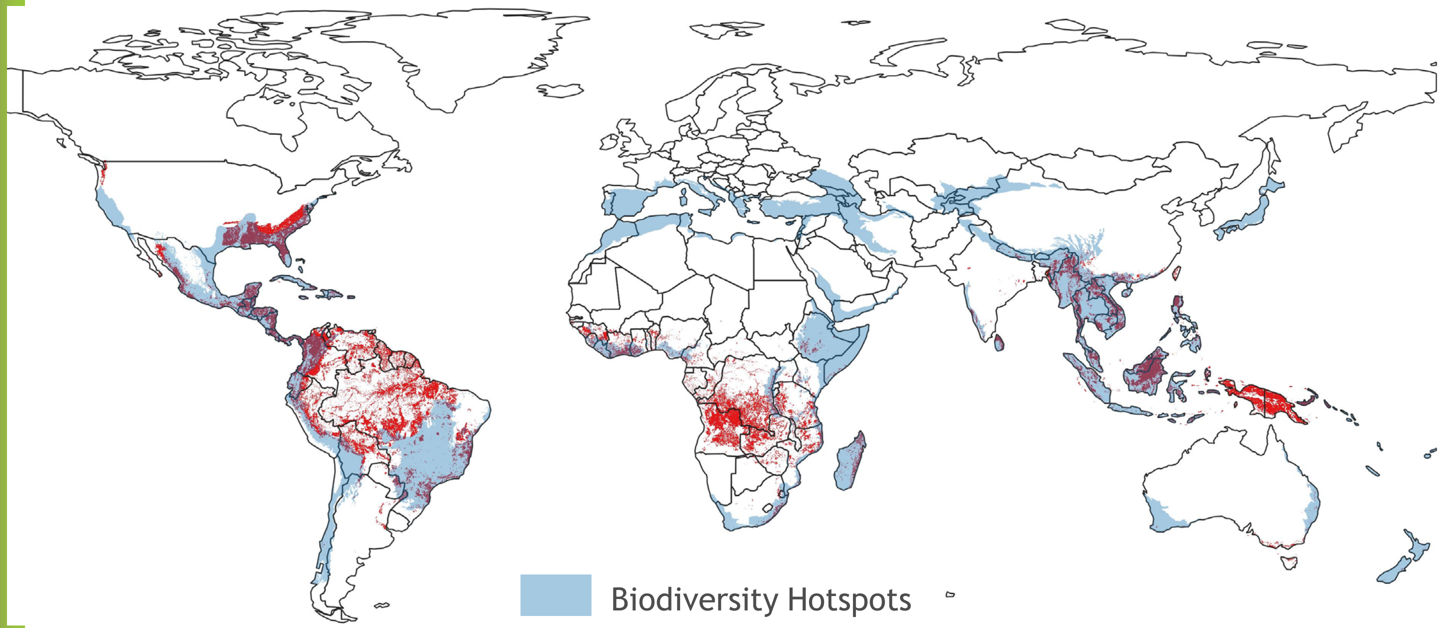


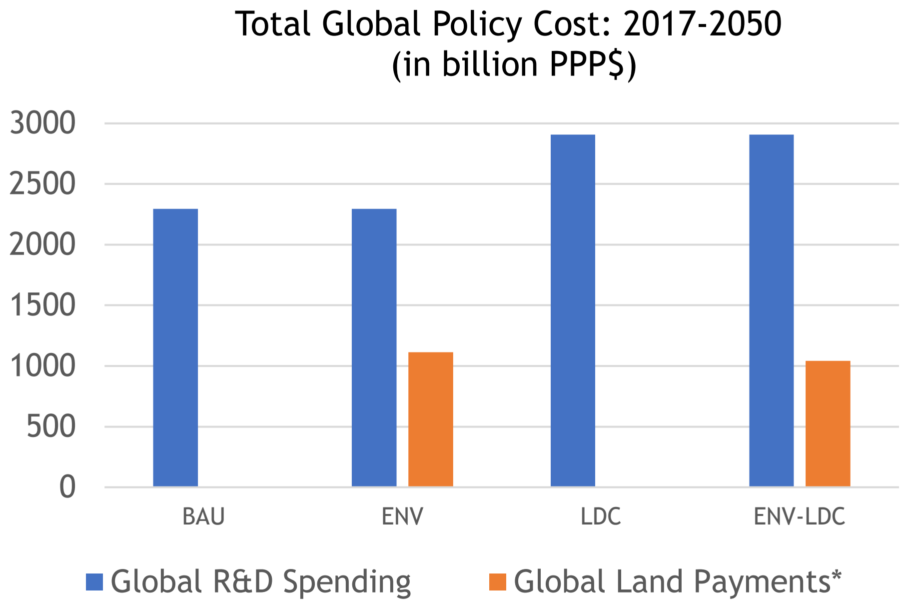
Source Fuglie, K. 2018. “R&D Capital, R&D Spillovers, and Productivity Growth in World Agriculture.” Applied Economic Perspectives and Policy 40(3):421–444.

Experimental Design

Scenario	Description of Future Scenarios (2017-2050)
S1 BAU	Business-as-Usual (BAU) case: continue current spending growth in global agricultural R&D
S2 ENV	Enact environmental policies that protect carbon-rich land from conversion with BAU R&D growth
S3 LDC	Accelerate public agricultural R&D spending in LDC
S4 ENV-LDC	Combines S2 & S3: Accelerate R&D spending in LDC and protect carbon-rich land from conversion

Areas targeted for cropland restrictions based on carbon intensity

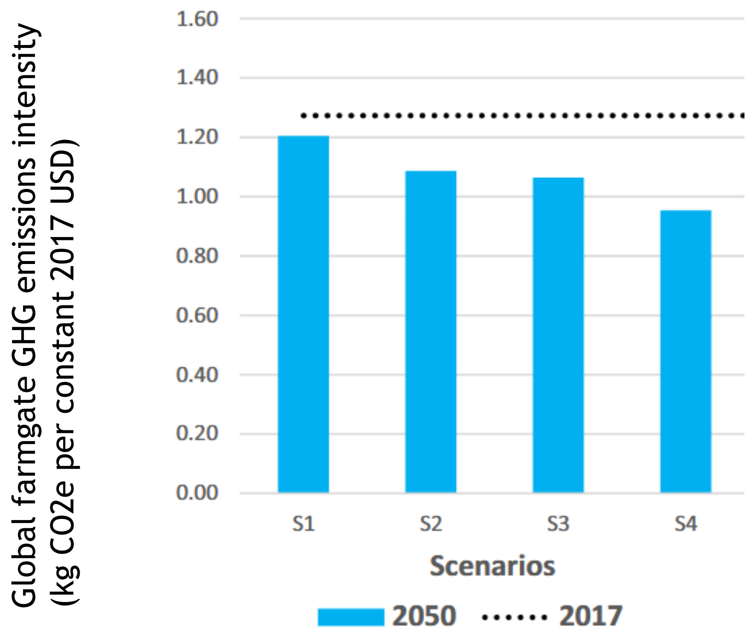




Calculated from Land Rents in SIMPLE

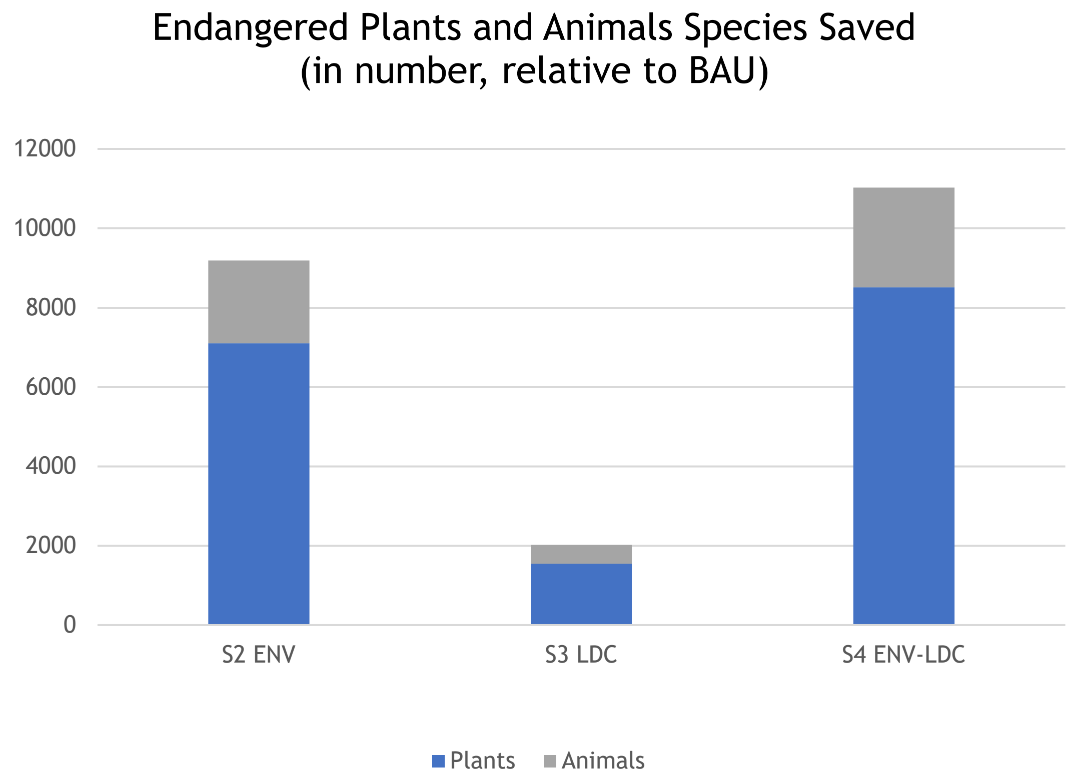
Key Findings

- **R&D investments and conservation policies help mitigate GHG emissions at relatively low cost…**



Scenario	Approximate marginal cost of GHG abatement (PPP$ $/ton CO2e)
S2 ENV	19.0
S3 LDC	21.7
S4 ENV-LDC	19.4

- **… and also save threatened plants and animals species from extinction**



Chapter 18

Future directions: Integrating GTAP with SIMPLE-G

Zhan Wang

Wang, Zhan. “GTAP-SIMPLE-G: Integrating Gridded Land Use, Crop Production and Environmental Impacts into Global General Equilibrium Model of Trade“, Journal of Global Economic Analysis, forthcoming in the December issue.

Future directions: Integrating GTAP with SIMPLE-G

GTAP

GE model focusing on national economy and trade

SIMPLE-G

PE model focusing on gridded crop production and factor use

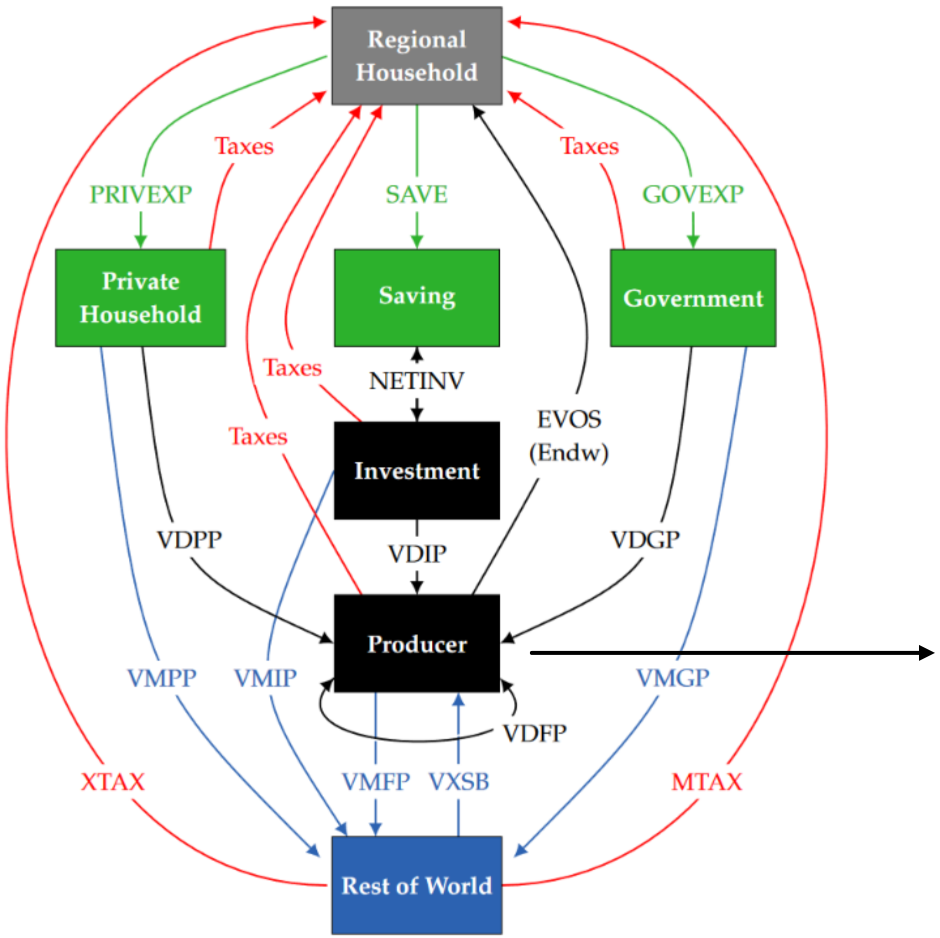
- National level
- Biliteral trade flows
- Multiple crops
- Ag / Non-ag sectors

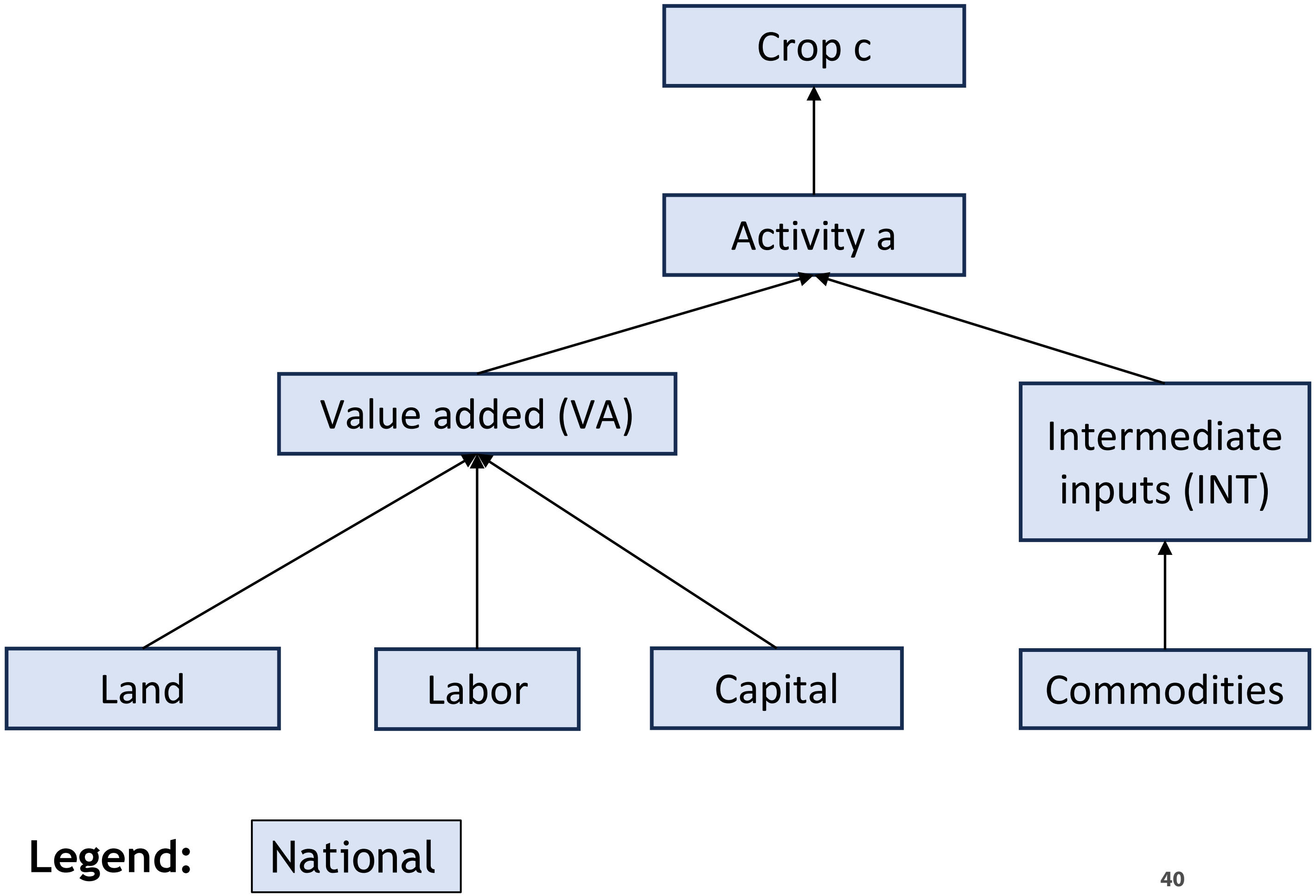
GTAP–SIMPLE-G Model

- Gridded crop supply and land use
- Spatial heterogeneity and spillover effects
- Fine-scale environmental impacts

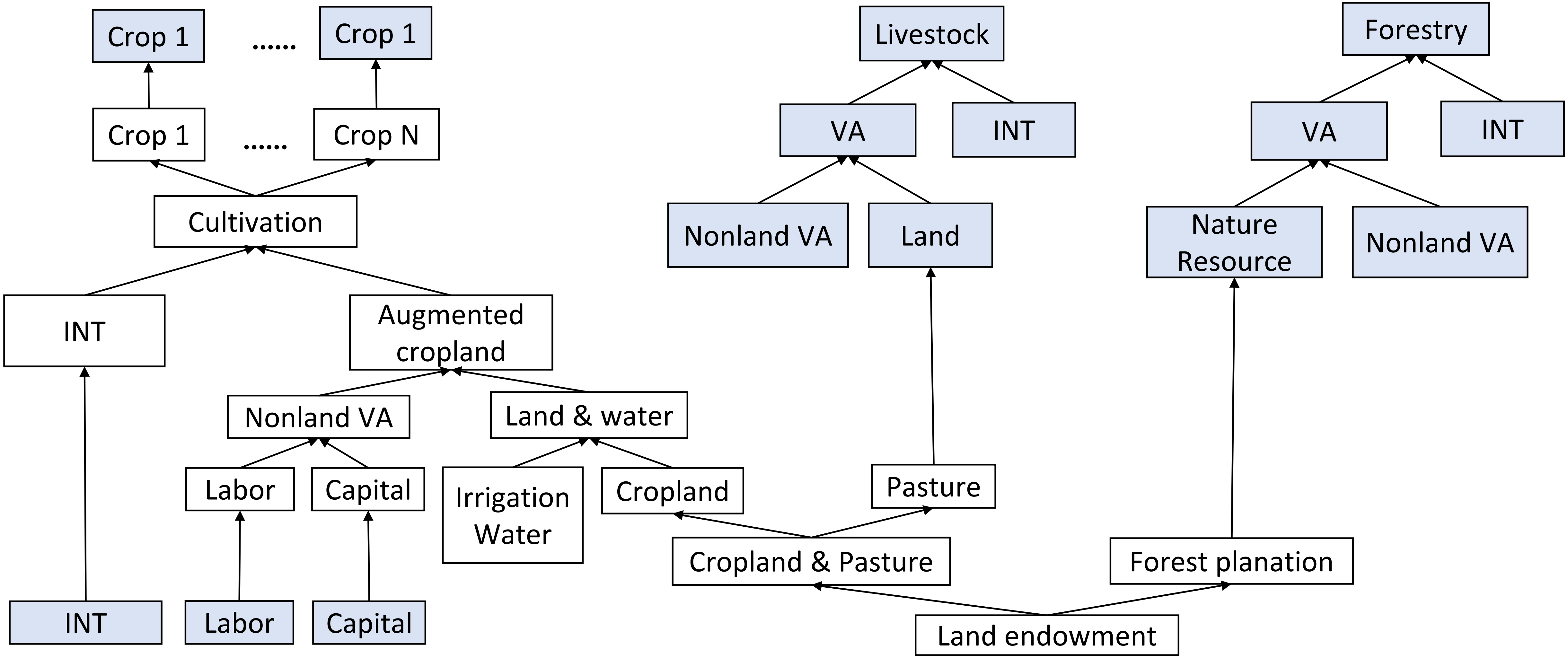
Structure of GTAP

GTAP multi-region (Corong et al. 2017)





Structure of GTAP-SIMPLE-G



Legend: National Gridded

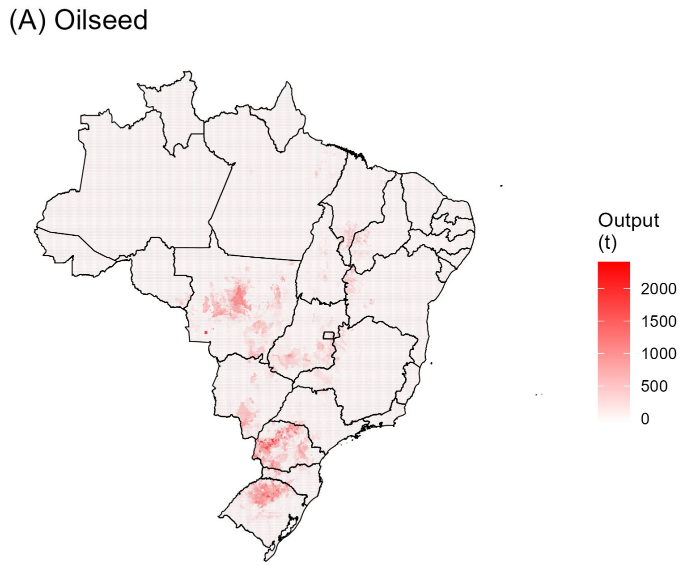
Application

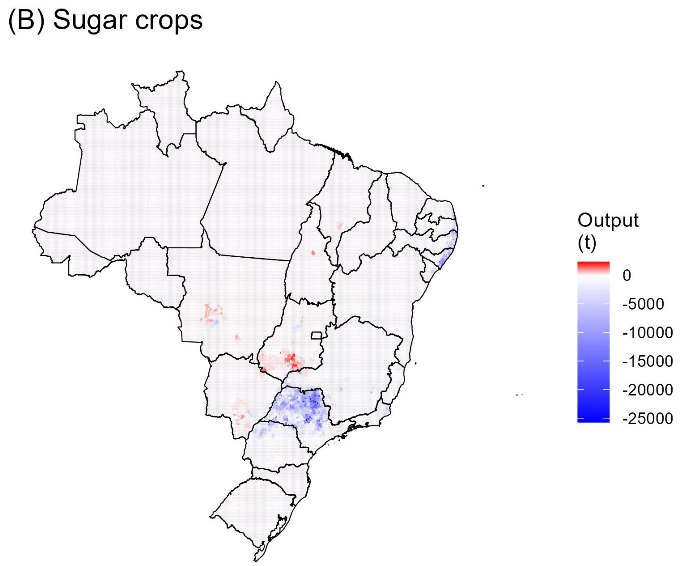
Experiments

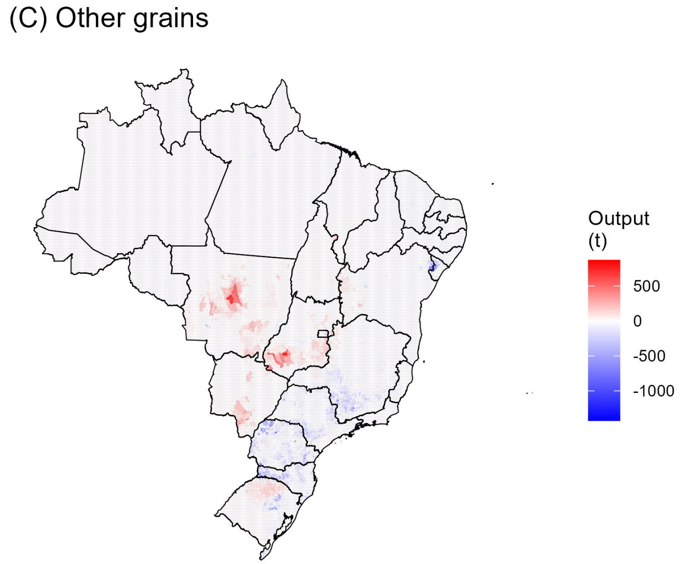
- 25% increase in the power of import tariff on oilseeds from the US to China

Results in Brazil

- Expansion in oilseed (soybean)
- Reduction in sugar crops (sugarcane)
- Other grains (maize) depends on multi-cropping
- Local heterogeneity in response







Change of crop output quantity (compared with baseline 2017)

Tools and Resources

- **SIMPLE-G Webpage:**
  - https://www.gtap.agecon.purdue.edu/simple-g/
- **SIMPLE-G Short Course:**
  - https://tinyurl.com/simpleg-course
- **SIMPLE-G YouTube Videos:**
  - https://tinyurl.com/SIMPLE-G-Book
- **SIMPLE-G Handout:**
  - https://tinyurl.com/simpleg-handout

Discussion Questions

- **Application to other regions?**
- **Application to other topics?**
- **Integration with other models?**
- **Questions and suggestions?**

Thank you!