Sustainable Intensification of Agriculture and Transition to a Bioeconomy

Madhu Khanna

ACES Distinguished Professor of Environmental Economics

Alvin H. Baum Family Chai and Director,

Institute for Sustainability Energy and Environment

University of Illinois, Urbana-Champaign

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Three-fold Mission

RESEARCH

Foster actionable, interdisciplinary **research** to address fundamental challenges in sustainability, energy, and environment

EDUCATION & OUTREACH

Provide national and international leadership in these areas through interdisciplinary **educati** **outreach** activiti

CAMPUS SUSTAINABILITY

Develop and implement strategies for a **sustainable environment on the University of Illinois campus** and beyond.

Five Interdisciplinary Themes

iSEE seed-funds, secures multimillion-dollar external grants, and shepherds projects, centers, and initiatives in five distinct themes

CLIMATE SOLUTIONS

Impacts on human health, our ecosystems, and society

ENERGY TRANSITIONS

Transitioning to renewable energy to sustain economic growth while reducing carbon emissions

SECURE AND SUSTAINABLE AGRICULTURE

The gap between production and demand can be closed with better landuse, substituting crops, and new technologies

SUSTAINABLE INFRASTRUCTURE

Harness technology and policy for low carbon transport-ation and infrastructure

WATER AND LAND STEWARDSHIP

Sustainable use of natural resources — air, water, forests, grasslands, and marine assets

Alvin H. Baum Family Fund Chair & Director

MADHU KHANNA

ACES Distinguished Professor of Agricultural and Consumer Economics

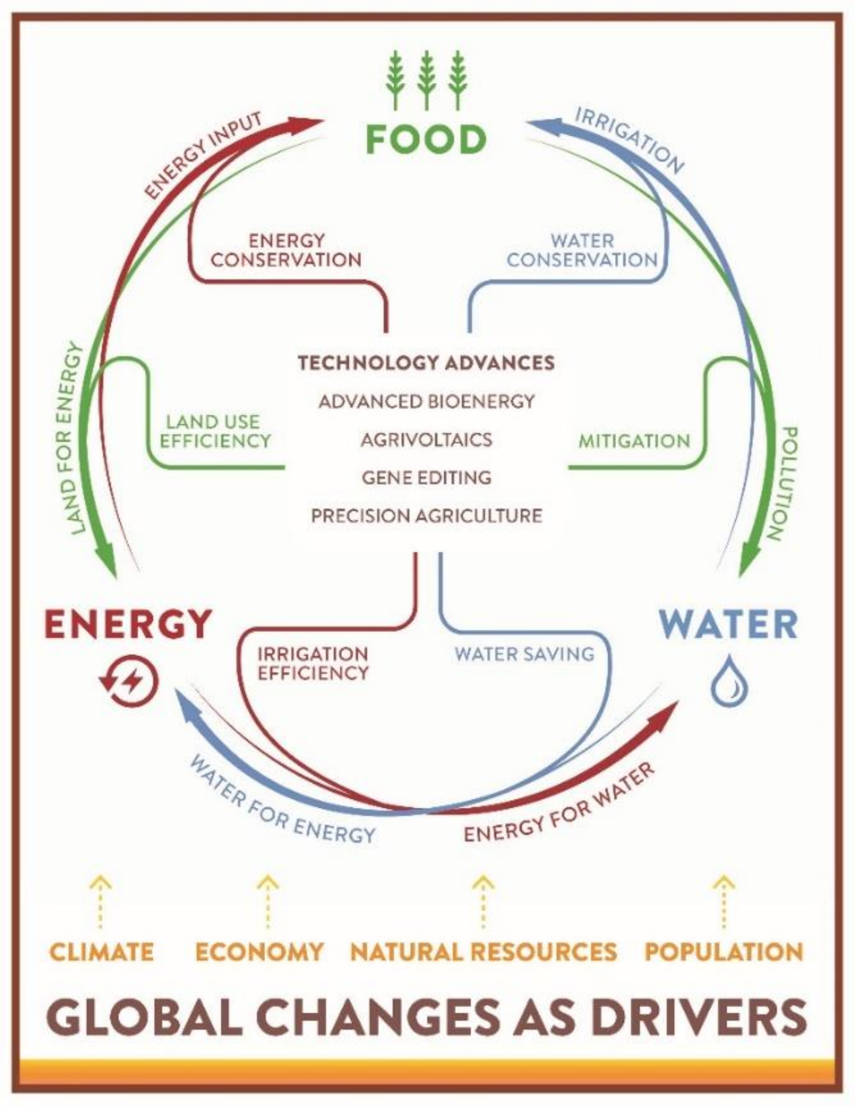
Associate Director

JEREMY GUEST

David C. Crawford Faculty Scholar & Associate Professor of Civil and Environmental Engineering

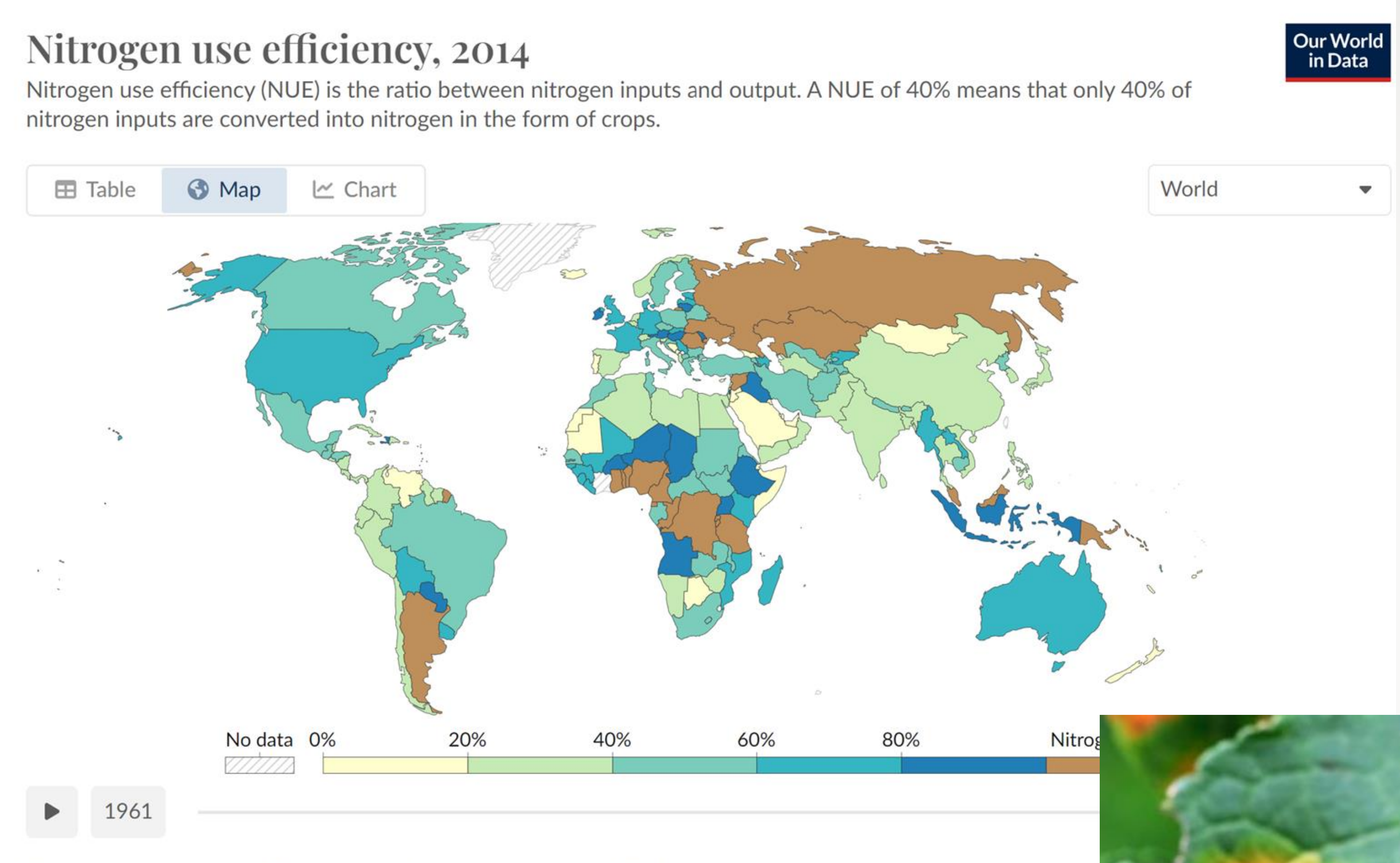
Complex Challenges that Motivate My Research

- Meeting growing demands for food, energy and water while reducing environmental harm and mitigating climate change
- Using land to contribute to carbon dioxide removal
  - Through soil carbon sequestration
  - Renewable energy: bioenergy, solar energy
- Intensifying agriculture sustainably
  - Improving the way we manage our cropland
    - Significant spatial heterogeneity in soils, climate
  - Inducing adoption of digital technologies/precision farming
- Economic incentives and environmental implications of these technologies and implications for public policy



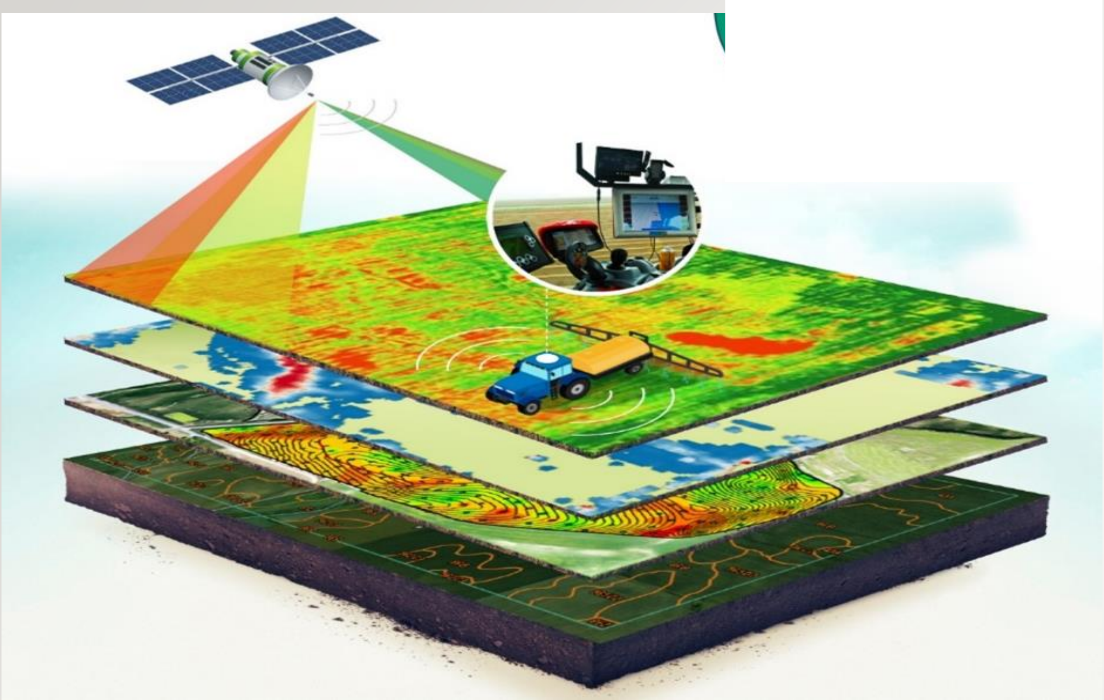
Miao, R and M. Khanna, "Harnessing Advances in Agricultural Technologies to Optimize Resource Utilization in the Food-Energy-Water Nexus," *Annual Review of Resource Economics*, 12: 65-85, 2020.

Challenges for Environmentally Sustainable Crop Management



- Low input-use efficiency of nitrogen, irrigation water, energy
- Herbicide resistant weeds:
- Intensive tillage practices- erosion of soil and reduced organic matter and soil health

Role for Digital Agriculture



- To manage spatial heterogeneity
  - With targeted and timely applications of nutrients
- Better monitor crop health and weed problems
  - Transition from chemicals to robotic weeding
- Improve soil health
  - No till and cover cropping

My research

- Examines the economic and behavioral drivers for farmers to adopt digital technologies
- Optimal extent and spatial location for technology adoption at a landscape level
- Policy incentives needed to induce adoption and the economic and environmental benefits of adoption

Khanna, M., B. M. Gramig, E. H. DeLucia, X. Cai and P. Kumar, "Harnessing Emerging Technologies to Reduce Gulf Hypoxia" *Nature Sustainability*, September 2019.

Robotic Weed Management

- Conventional herbicides applied before plant canopy closes in early stage of growing season
- Small robots can drive under plant canopy, detect and mechanically remove weeds
- We examine effects on adoption of
  - Technology attributes
  - Biophysical conditions in the field
  - Economic conditions
  - Behavioral factors
- Implications for reducing resistance of weeds, increasing yields and profitability

Khanna, M., S. Atallah, S. Kar, B. Sharma, L. Wu, C. Yu, G. Chowdhary, C. Soman and K.Guan, "Digital Transformation for a Sustainable Agriculture in the US: Opportunities and Challenges," *Agricultural Economics*, 53 (6), 924-937, 2022.

Cover Crop Planting Robots

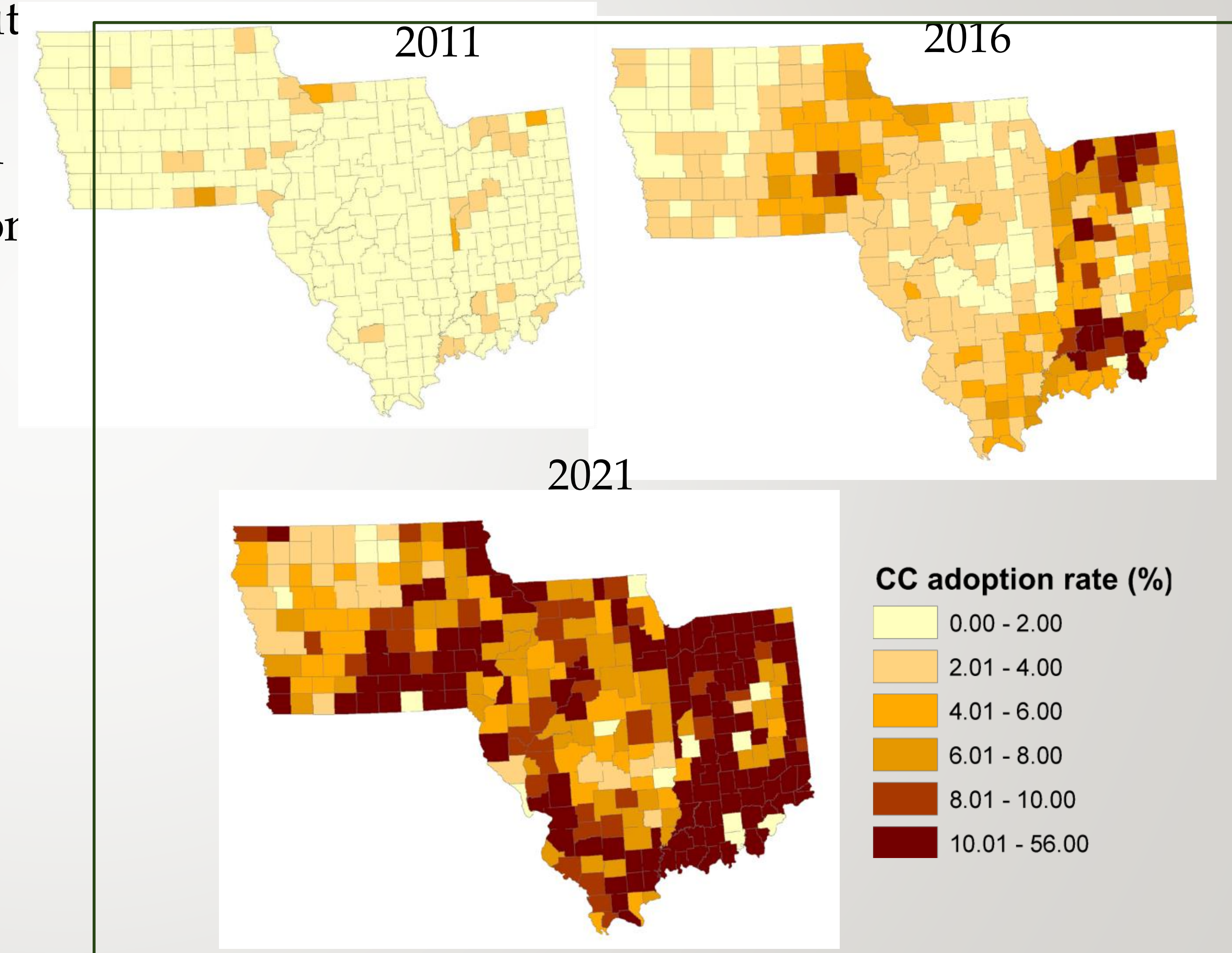
- Under the canopy robots can plant cover crop early in the season to improve establishment with low labor needs; Increase soil health, reduce need for fertilizer, weeds
- Economics of adoption and soil carbon benefits
- Design of carbon payment programs for farmers to adopt cover cropping

https://www.earthsense.co/home

Drivers of Adoption of Cover Crops

- Cover crop adoption rates growing over time but still less than 10% of acres in the Midwest
- Significant spatial clustering in adoption pattern
- Using farmer survey and satellite-based detection of cover crop adoption, we find that adoption is more likely if
  - Greater share of ownership of land
  - Adoption by neighboring farms
  - Farmers are willing to take risks
  - Land quality is poor
  - Cost of cover-cropping is lower

Satellite Based Mapping of Cover Crop Adoption Rate (%): Illinois, Iowa and Indiana (41 M acres of cropland)



Transitioning to a Bioeconomy

- Choice of many feedstocks for transportation fuels, sustainable aviation fuels
  - Food crops – corn and soybeans
  - Sugarcane in Brazil
  - Non-food, dedicated energy crops
- Which feedstocks would be optimal to produce, at which location and how much?
- What are the implications for food prices?
- What is the effect on cropland expansion?
- What are the multiple environmental implications: carbon emission reduction, water quality impacts?

Miscanthus

Energy Sorghum

Energy Cane

Hudiburg, T.W., W. Wang, M. Khanna, S. P. Long, P. Dwivedi, W. J. Parton, M. Hartmann, and E. H. DeLucia, "Impacts of a 32 Billion Gallon Bioenergy Landscape on Land and Fossil Fuel use in the US," *Nature Energy*, 1:15005, 2016.

Collaborative Research on Brazil

Energy Policy
Volume 38, Issue 11, November 2010, Pages 7404-7415

Competitiveness of Brazilian sugarcane ethanol compared to US corn ethanol ☆

Christine L. Crago [a], Madhu Khc
Weber Amaral [e]

AGRICULTURAL ECONOMICS
The Journal of the International Association of Agricultural Economists

Original Article

Land use and economic effects of alternative biofuel policies in Brazil and the United States

Hector M. Nuñez, Hayri Önal, Madhu Khanna

First published: 08 June 2013 | https://doi.org/10.1111/agec.12032 | Citations: 18

Energy Economics
Volume 54, February 2016, Pages 133-143

Who pays and who gains from fuel policies in Brazil? ☆, ☆☆

Madhu Khanna [a], Hector M. Nuñez [b 1], David Zilberman [c 2]

Effects of US Biofuel Policies on Land Use Change in Brazil

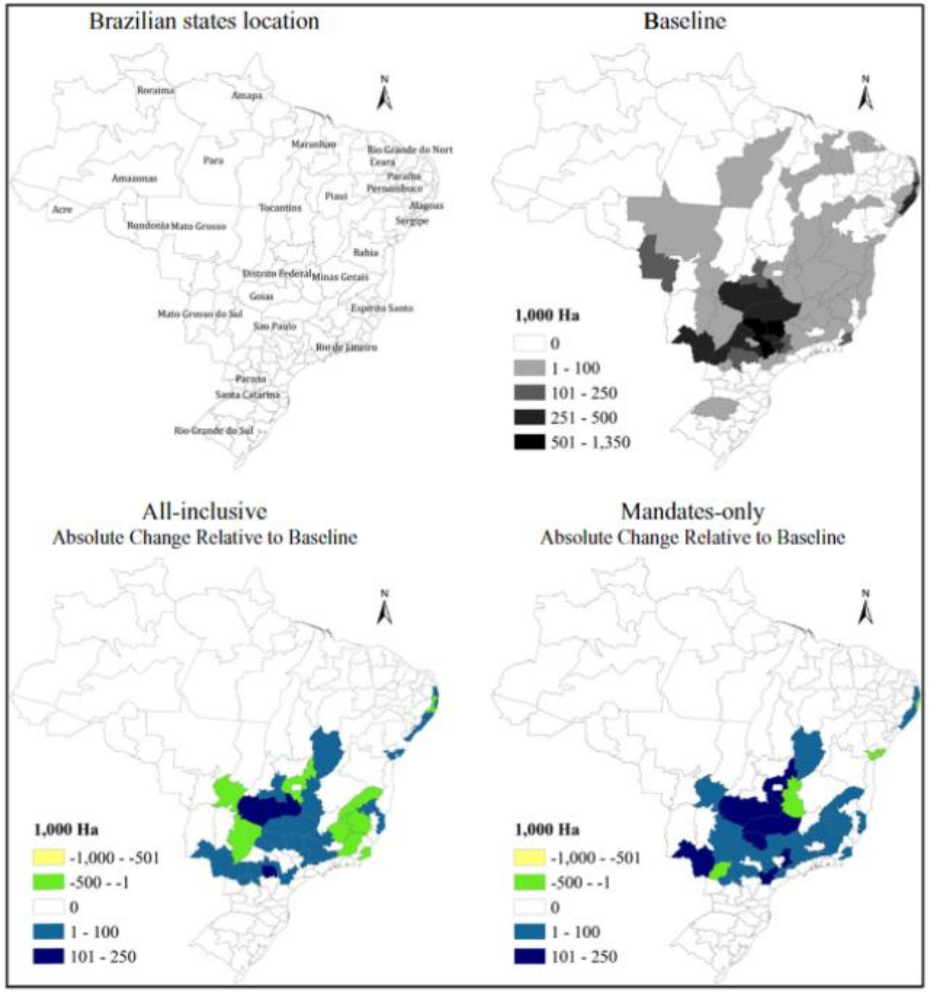


Fig. 1. Simulated sugarcane acreage in Brazil, 2022.

Costs and Benefits of Restoring the Araguaia Biodiversity Corridor

- Strategies for recovering almost one million hectares of legally protected areas in the Araguaia Biodiversity Corridor by following the Brazilian Forest code regulation.
- Two paths for recovery: ecological and economic (including timber and agroforestry systems).
- Consider the direct and indirect local costs, as well as monetized environmental benefits using the social cost of carbon and avoided soil erosion.
- In 50 years, the recovery of the Araguaia Corridor will lead to net societal benefits with either the ecological (US$ 19.8 billion) or economic (US$ 18.9 billion)

Fig. 1. Araguaia Biodiversity Corridor: states, Legal Amazon and biomes.

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Araguaia biodiversity corridor cost benefit analysis: Large scale restoration and sustainable agribusiness in Amazon and Cerrado

Andrea Lucchesi[a,*], Madhu Khanna[b], Paula C. Pereda[c], Keyi A. Ussami[c], Patricia G.C. Ruggiero[c], Victor S. Dornelas[d], Tess Lallement[b]

[a] *School of Arts, Sciences and Humanities, University of São Paulo – USP, Brazil*
[b] *University of Illinois Urbana Champaign, USA*
[c] *School of Economics, Management and Accounting, University of São Paulo – USP, Brazi*
[d] *Cornell University, USA*

Emerging Areas of Interest: US-Brazil Biofuel Markets and Policies

- Implications of recent biofuel policies in Brazil
  - Expanding sugarcane ethanol and corn ethanol as well as soy-based biodiesel production for global food and fuel markets
  - Tariff on corn ethanol imports from US
  - Land use change in Brazil: implications of expansion in cropland on the Cerrado and the Amazon forest
  - Land use effects of sustainable aviation fuel targets in Brazil
  - Greenhouse gas benefits of biofuel production in Brazil