U.S. Department of Energy (DOE)
Bioenergy Technologies Office (BETO)
2017 Project Peer Review

Pathways Toward Sustainable Bioenergy Feedstock Production in the Mississippi River Watershed

March 6, 2017
Analysis and Sustainability Review

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Goal Statement

- The overall goal of this project is to use an ecosystem service framework and an integrated modeling approach to evaluate potential environmental effects of various biomass sources and their placement on the landscape so as to guide the burgeoning bioenergy industry toward greater sustainability.
- The outcome of this project is a diverse portfolio of biomass feedstocks that provide environmental benefits in support of a vibrant bioeconomy.

Quad Chart Overview

Timeline

- Project start date: 9/30/2010
- Project end date: 12/31/2015
- Percent complete: 100%

Budget

	Total Costs (Start–End)
DOE Funded	$ 790,943
Cost Share (Univ. of MN)	$ 208,530

Barriers

- Barriers addressed
  - St-C. Sustainability Data Across the Supply Chain
  - St-D. Implementing Indicators and Methodology for Evaluating and Improving Sustainability
  - St-E. Best Practices for Systems for Sustainable Bioenergy Production

Partners

- All work was conducted at the University of Minnesota (sole grant recipient).
- Ongoing collaborative work with EPA, NREL, Argonne, and various academic institutions (*e.g.*, Iowa State, University of Washington, and University of Illinois).

1 - Project Overview

- Response to a call for proposals from DOE/EERE: “These projects will take important steps to help design, model, and implement sustainable biomass production systems across different regions of the country.”
- Smallest of three grants to academic institutions: NCSU $4,807,390; Purdue $1,991,117; UMN $999,473).
- 5 years of 12-month support (~$130k/yr in direct costs) for 2 FTE postdoctoral research associates and partial summer support for PI (Hill) and Co-PI (Twine)
- In addition to providing actionable information on life cycle environmental impacts of biomass production and use, we developed methods and models currently used by others in the assessment of bioenergy, transportation, and agriculture.
- We coordinated with synergistic efforts where possible, such as with USDA grants on switchgrass (CenUSA-UMN), woody biomass (UMN), and information dissemination and planning (UMN).

2 – Approach (Management)

- Management was streamlined as personnel included only a PI, a co-PI, and 2 FTE postdoctoral research associates.
- All work took place in nearby buildings on the St. Paul Campus of the University of Minnesota.
- Duties of adhering to research goals, conducting research, manuscript preparation, and grant reporting were shared among personnel.
- PI and Co-PI trained postdoctoral research associates in techniques, publication preparation, and career development.
- No major difficulties in management were encountered during the project, and all goals, milestones, and deliverables were met.

2 – Approach (Technical)

- Proposal stated use of Agro-IBIS (Integrated Biosphere Simulator) and InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)
- Modeling efforts were augmented by in-house development of:
  - WRF-CLM4crop-Biofuels model as a module of WRF-CLM4crop (Weather Research and Forecasting coupled to Community Land Model)
  - InMAP (Intervention Model for Air Pollution) http://spatialmodel.com/inmap/
  - GREET-cst to provide Chemical, Spatial, and Temporal profiles to each unit process in GREET
- Scenarios modeled were informed largely by biomass targets of DOE (Billion Ton Study Updates), EPA (RFS2 RIA), and USDA (Regional Roadmap)

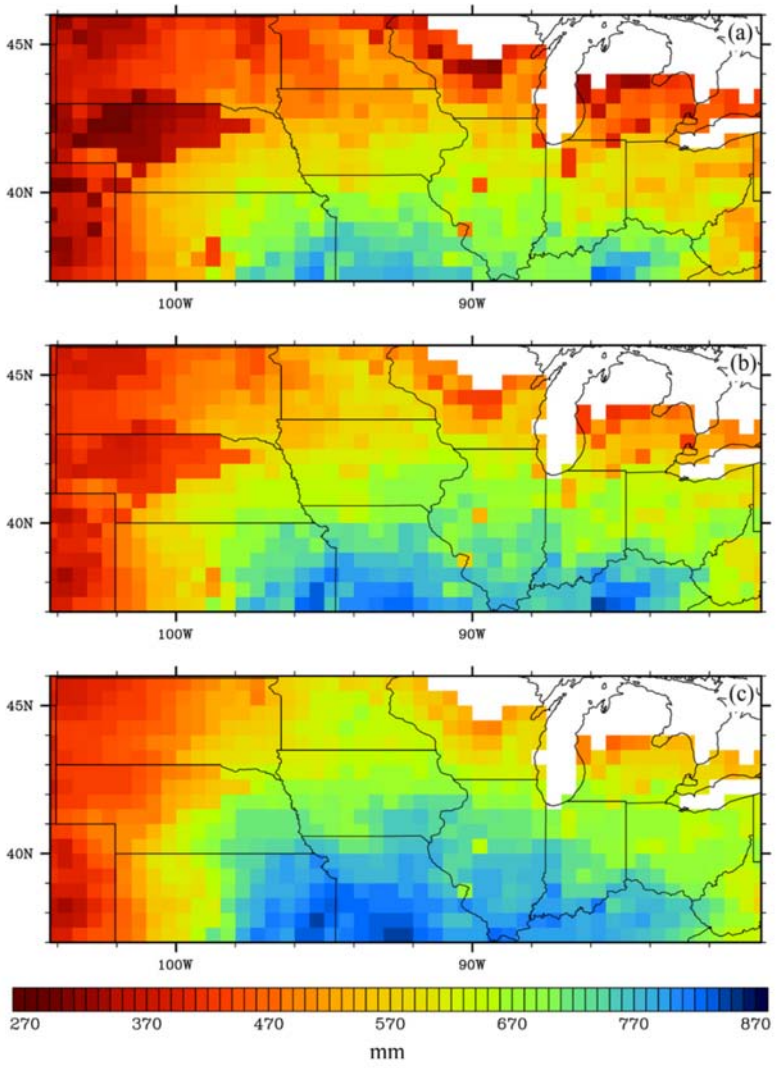
3 – Technical Accomplishments/ Progress/Results

A regional comparison of water use efficiency for miscanthus, switchgrass and maize

Maize

Switchgrass

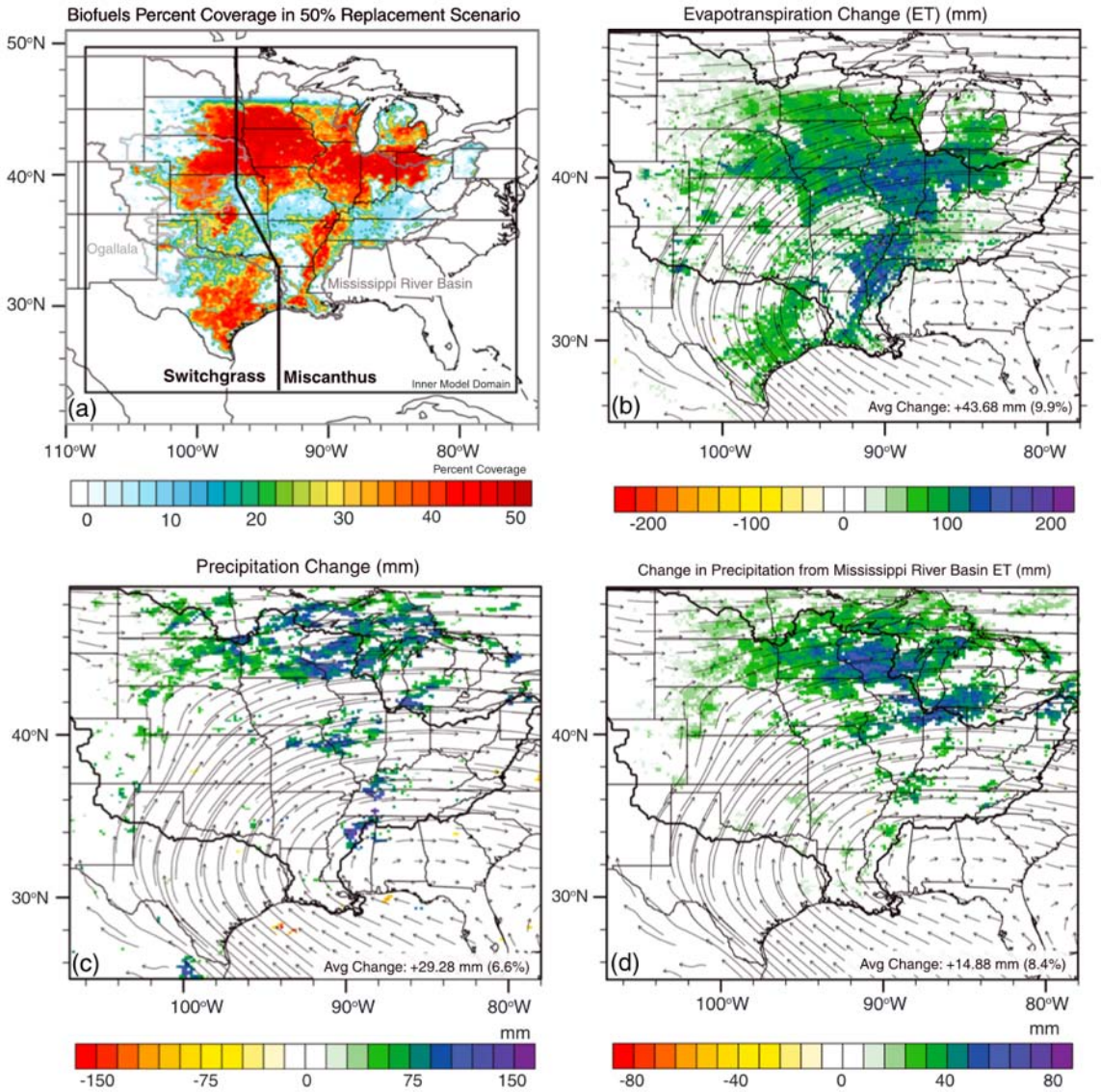
Miscanthus



VanLoocke *et al.* (2012) *Agr. Forest. Meteorol.*

3 – Technical Accomplishments/ Progress/Results

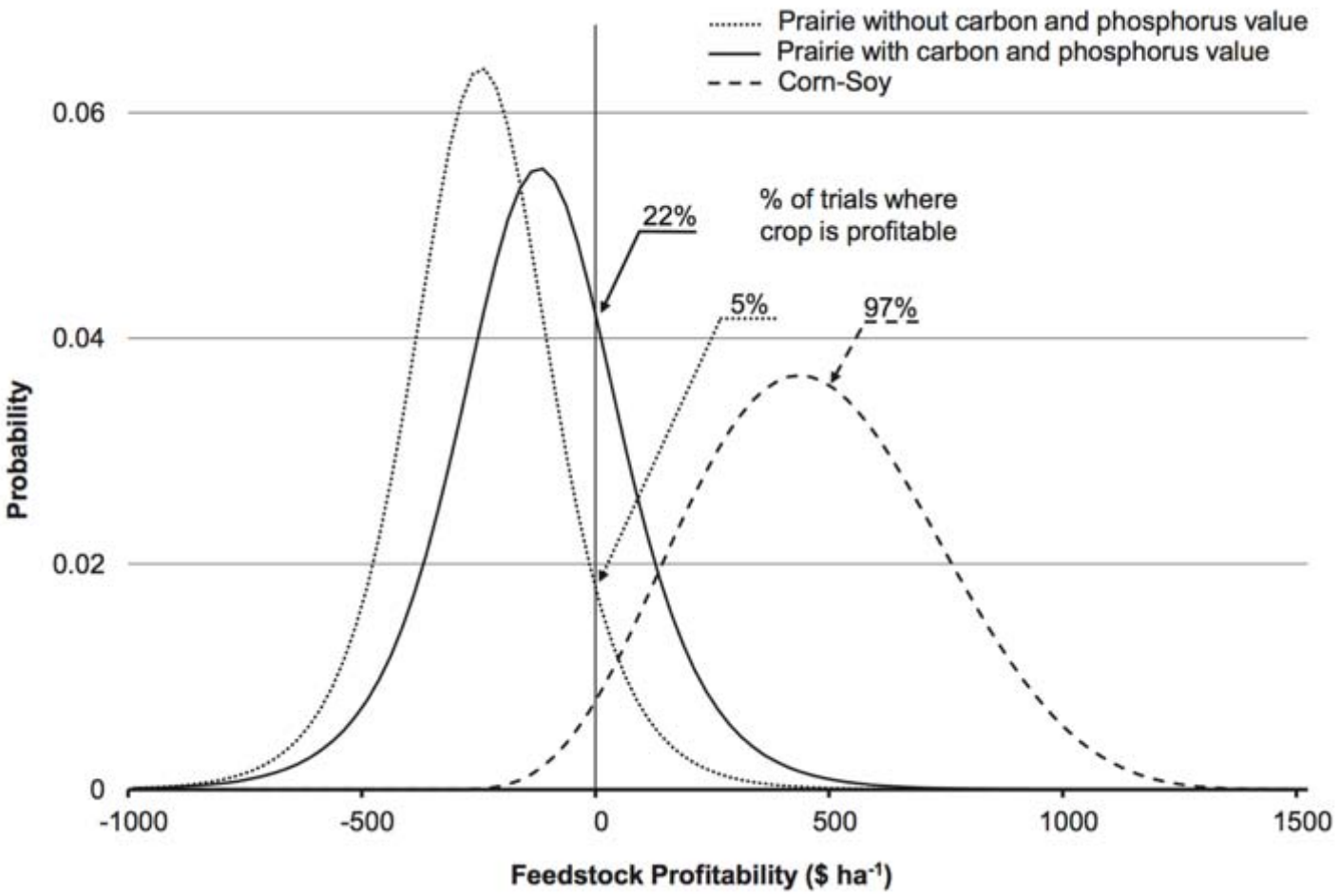
Impacts of second-generation biofuel feedstock production in the central U.S. on the hydrologic cycle and global warming mitigation potential



Harding *et al.* (2016) *Geophys. Res. Lett.*

3 – Technical Accomplishments/ Progress/Results

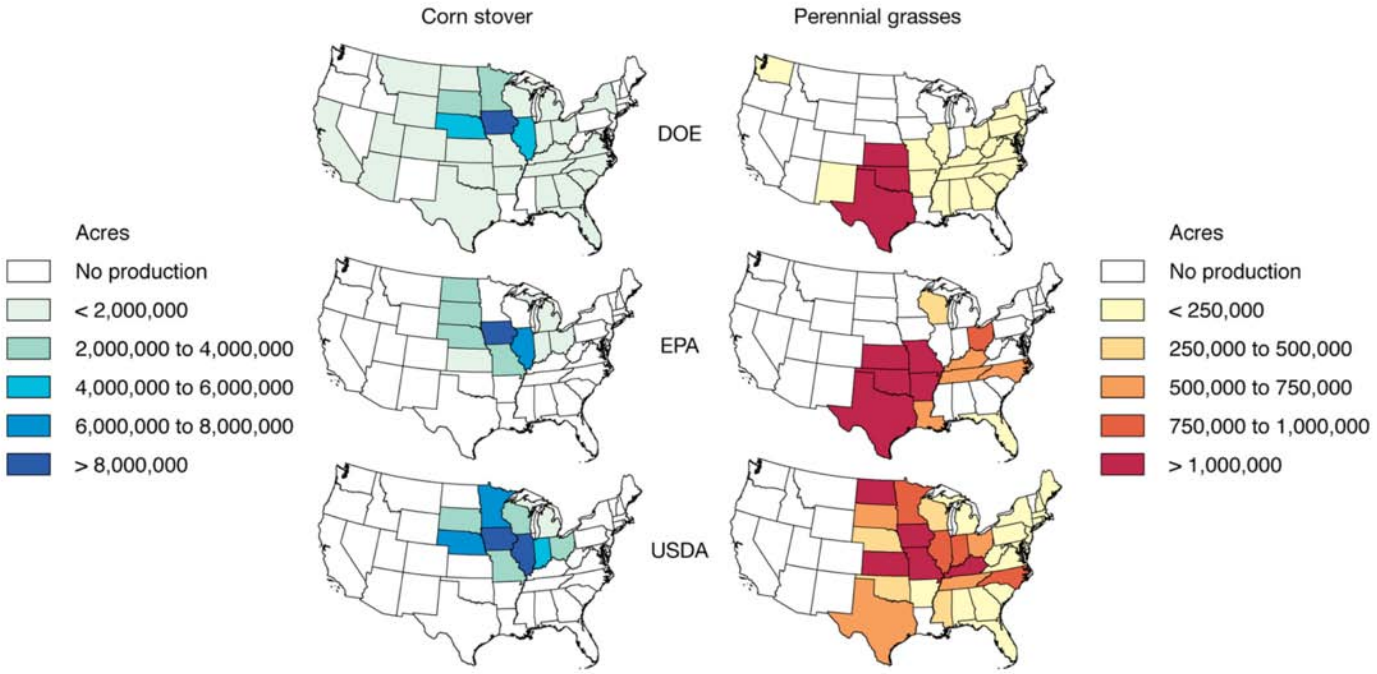
Assessing uncertainty in the profitability of prairie biomass production with ecosystem service compensation

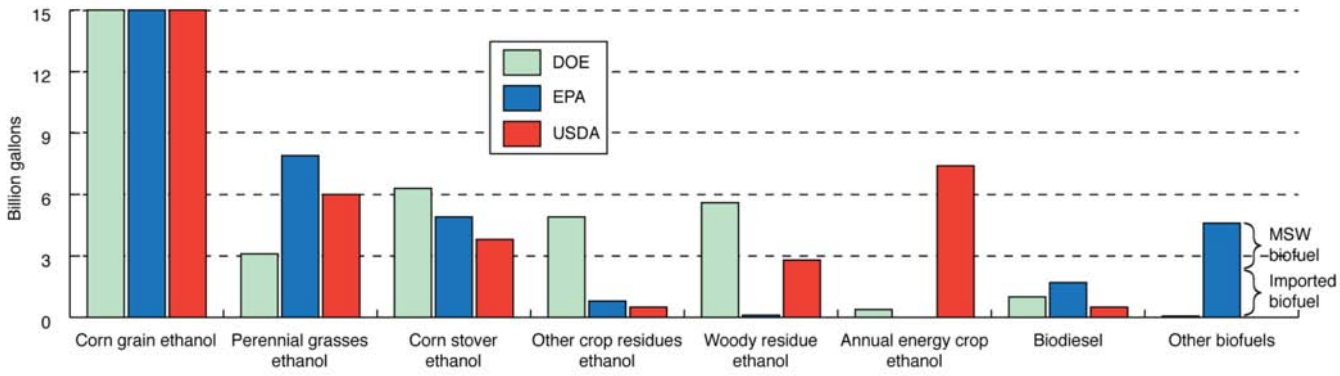


Noe *et al.* (2016) *Ecosyst. Serv.*

3 – Technical Accomplishments/ Progress/Results

U.S. Federal agency models offer different visions for achieving Renewable Fuel Standard (RFS2) biofuel volumes

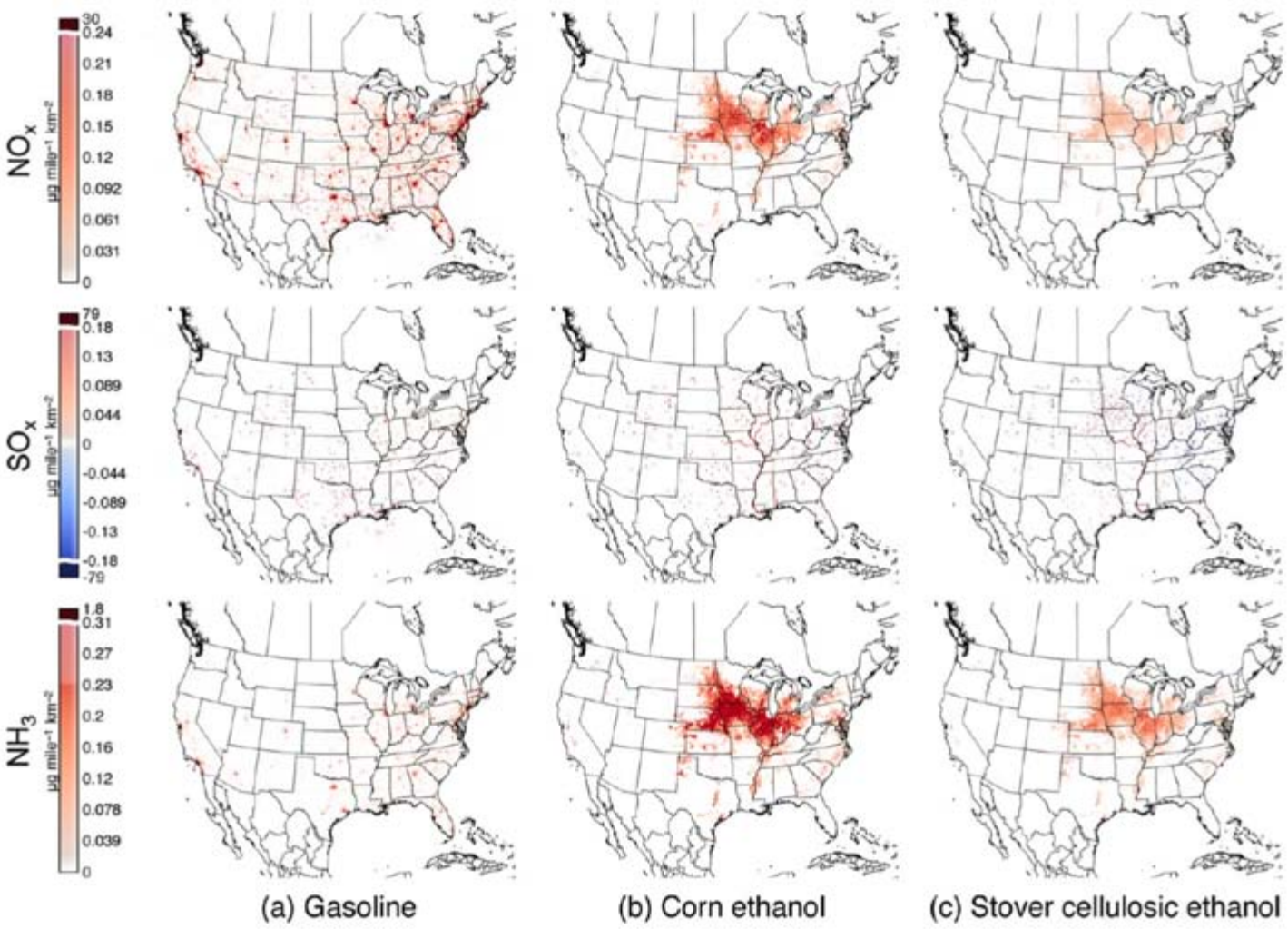




Keeler *et al.* (2013) *Environ. Sci. Technol.*

3 – Technical Accomplishments/ Progress/Results

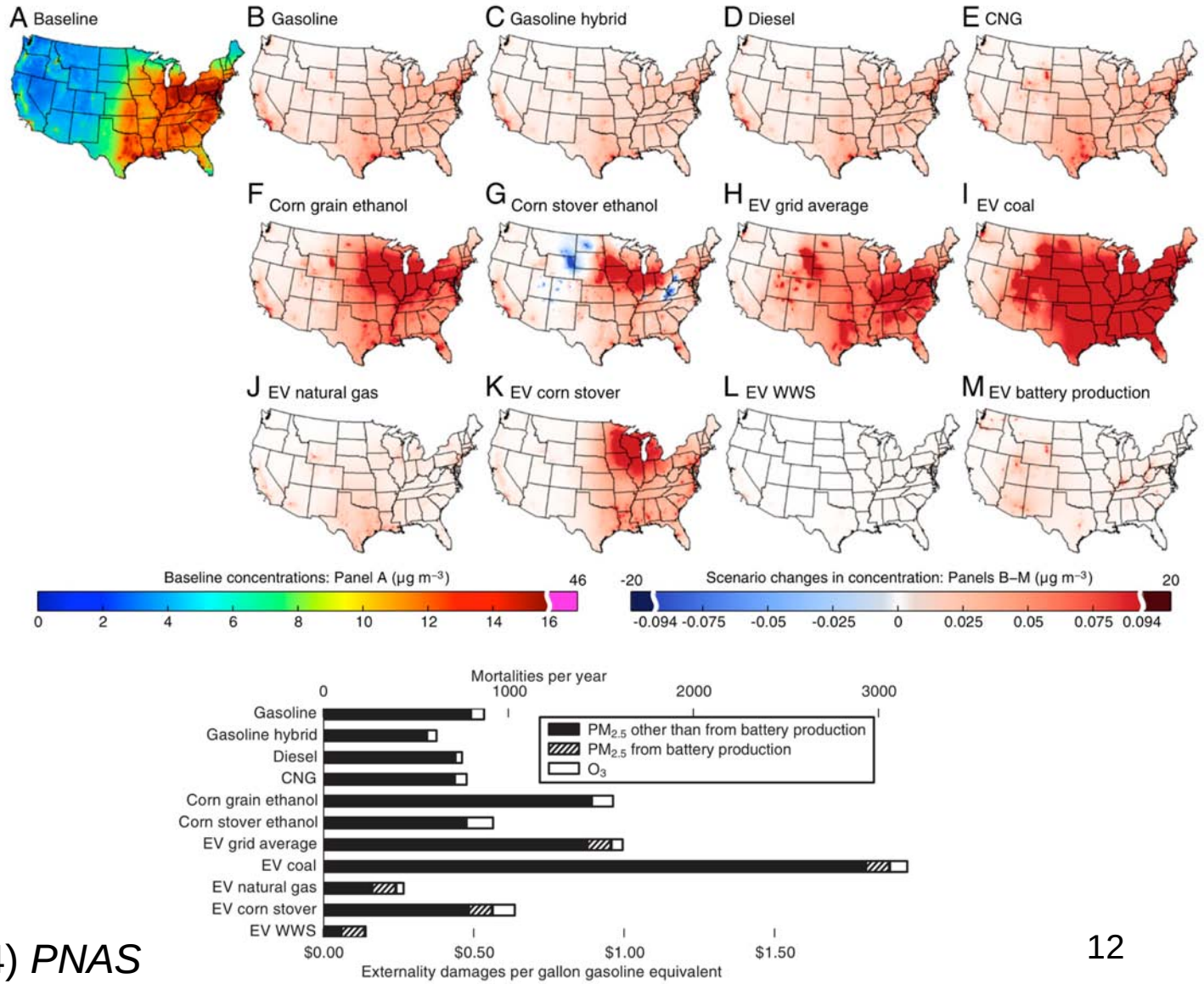
A spatially and temporally explicit life cycle inventory of air pollutants from gasoline and ethanol in the United States



Tessum *et al.* (2012) *Environ. Sci. Technol.*

3 – Technical Accomplishments/ Progress/Results

Life cycle air quality impacts of conventional and alternative light duty transportation in the United States

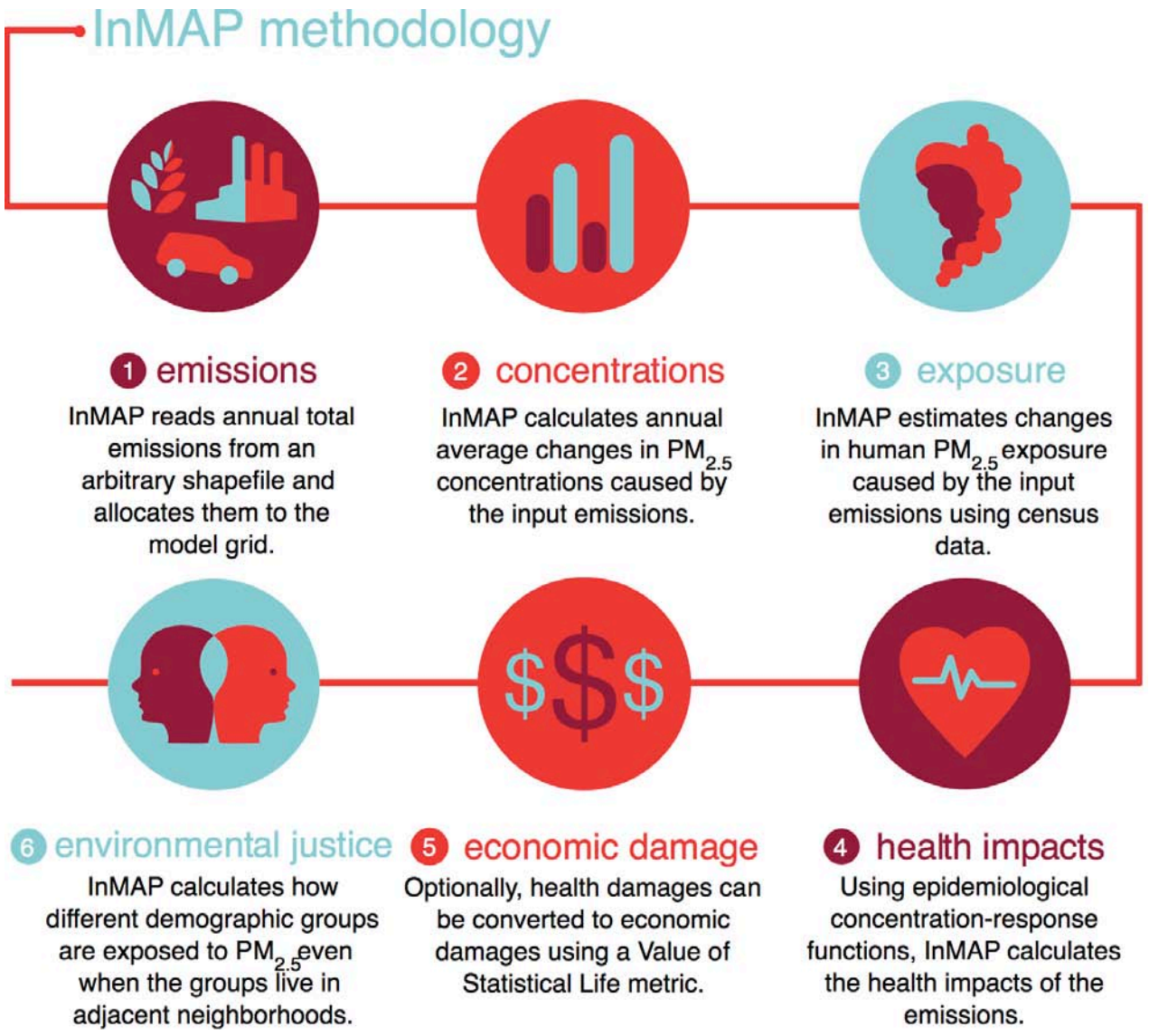


Tessum *et al.* (2014) *PNAS*

3 – Technical Accomplishments/ Progress/Results

InMAP: Intervention Model for Air Pollution

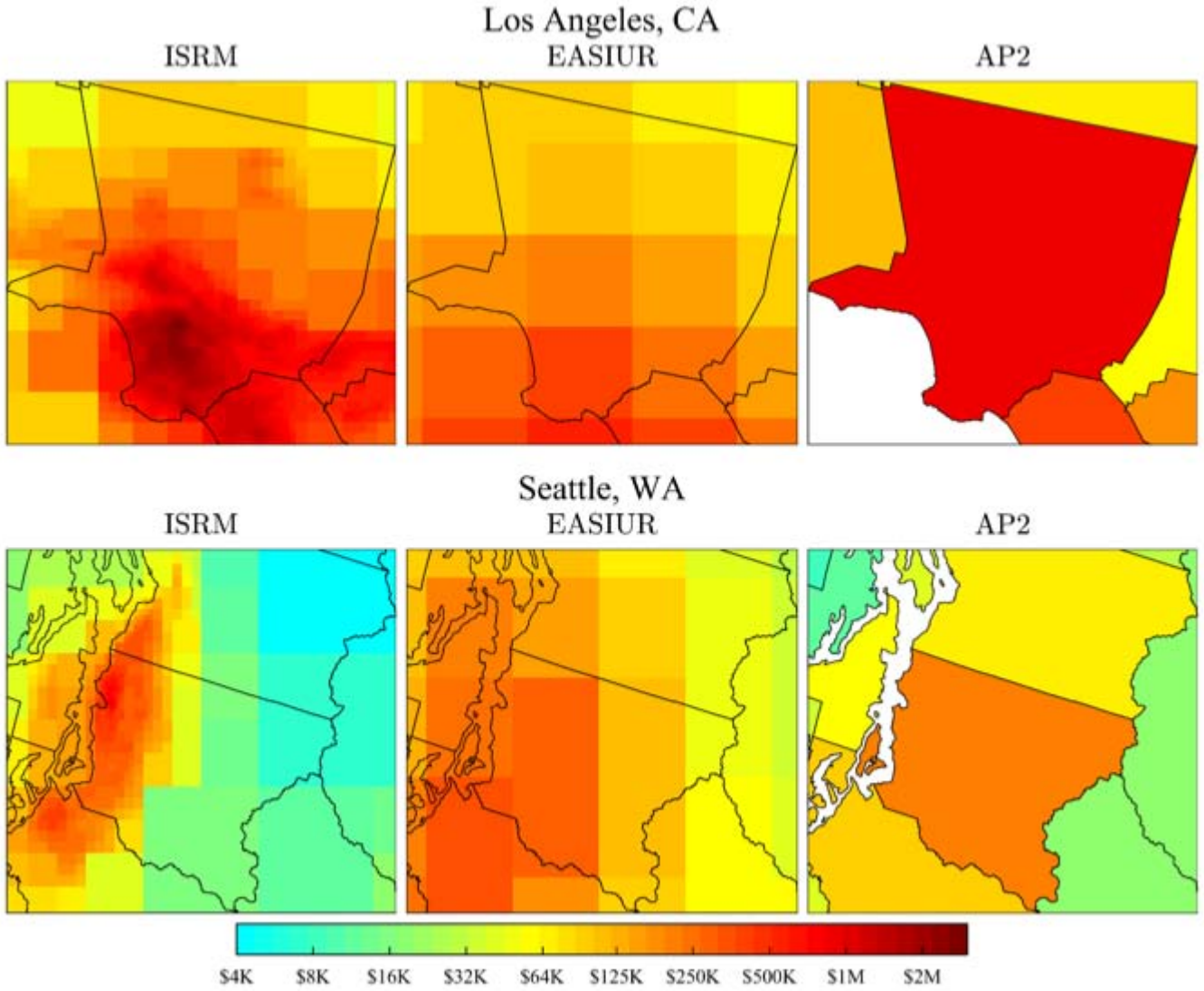
http://spatialmodel.com/inmap/



Tessum *et al.* (2015) *Geosci. Model Dev. Discuss.*

3 – Technical Accomplishments/ Progress/Results

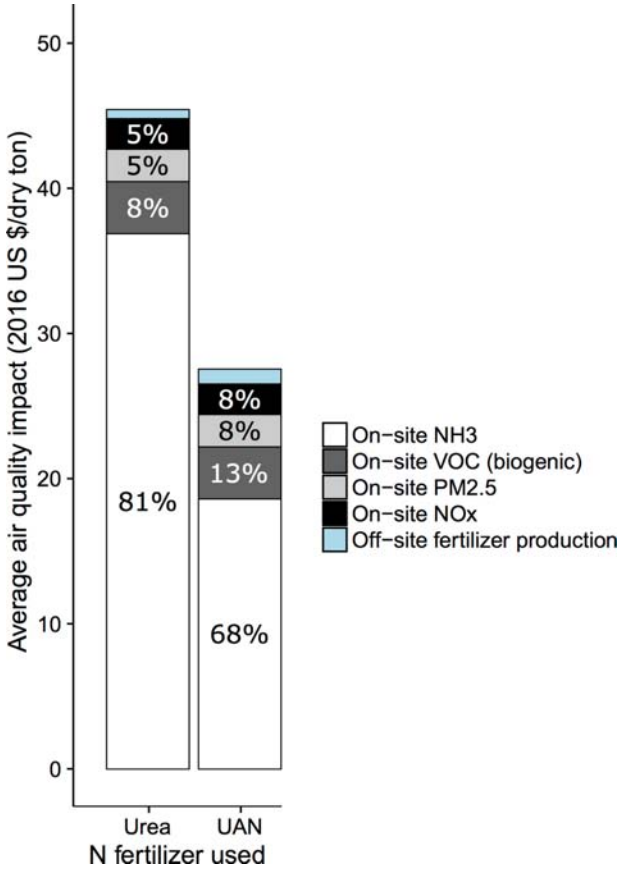
Fine-scale, spatially-explicit economic damage estimates of fine particulate matter and its precursors in the United States

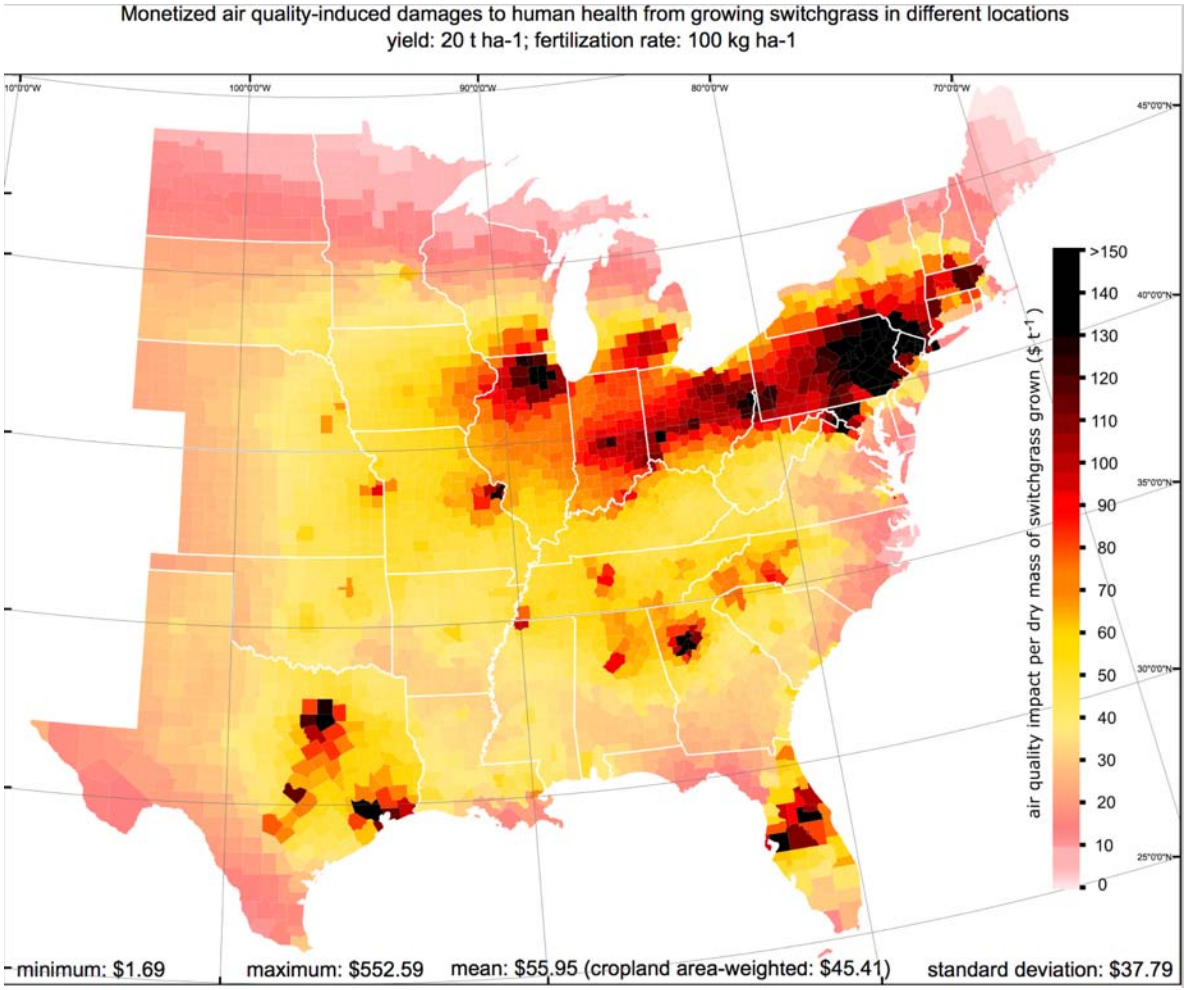


Goodkind *et al.* (In review) *Environ. Sci. Technol.*

3 – Technical Accomplishments/ Progress/Results

Life cycle air quality impacts on human health from potential switchgrass production in the United States

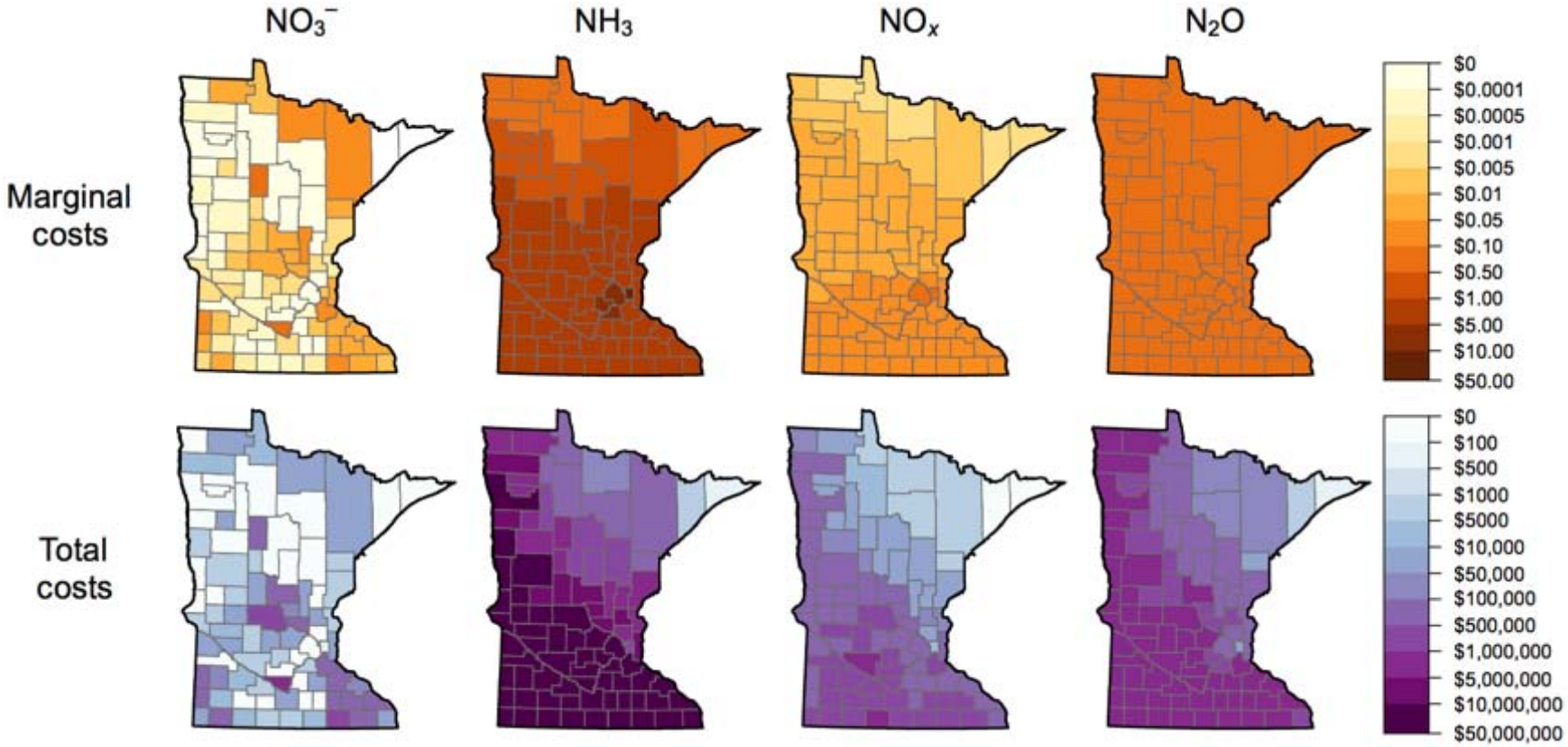




Thakrar *et al.* (In review) *Biomass and Bioenergy*

3 – Technical Accomplishments/ Progress/Results

The social costs of nitrogen



Keeler *et al.* (2016) *Sci. Adv.*

3 – Technical Accomplishments/ Progress/Results

2013 Conference with Hypoxia Task Force/USDA

https://vimeo.com/84352256

3 – Technical Accomplishments/ Progress/Results

Conference with Hypoxia Task Force/USDA

Participants

Agricultural Watershed Institute
Argonne National Laboratory
Bill McGuire Conservation, LLC
Coastal Protection and Restoration Authority
DAK Renewable Energy
Environmental and Energy Study Institute
Environmental Working Group
Great Plains Institute
Green Lands Blue Waters
IDALS
Illinois EPA
Illinois Farm Bureau
Indiana Department of Agriculture
Institute for Agriculture and Trade Policy
Iowa Department of Agriculture and Land Stewardship
Iowa Department of Natural Resources
Iowa Farm Bureau Federation
Iowa State University
Iowa State University Bio Economy Institute
Iowa State University CenUSA Bioenergy
Kentucky Department for Environmental Protection
Leopold Center for Sustainable Agriculture
Louisiana Coastal Protection and Restoration Authority
Louisiana Department of Environmental Quality
Louisiana State University
Lower Mississippi River Sub-basin Committee
Minnesota Board of Water and Soil Resources
Minnesota Department of Natural Resources
Minnesota Pollution Control Agency
Mississippi State University
Missouri Department of Natural Resources
National Park Service
National Wildlife Federation
Natural Resources Defense Council
NOAA
Office of US Sen. Klobuchar
Prairie Lands Biomass LLC
Praxik, LLC
Purdue University
Rural Advantage
State of Kentucky
Tennessee Department of Agriculture
The McKnight Foundation
The Ohio State University
Union of Concerned Scientists
University of Illinois
University of Iowa
University of Kentucky
University of Minnesota
University of Minnesota-Extension
University of Missouri
University of Wisconsin
University of Wisconsin Extension
US Department of the Interior
US Environmental Protection Agency
US Fish & Wildlife Service
US Geological Survey
USDA
USDA/ARS
USDA/NIFA
USDA/NRCS
USEPA
USEPA R6
Wisconsin Rural Energy Management Council

4 – Relevance

- The overall goal of this project is to use an ecosystem service framework and an integrated modeling approach to evaluate potential environmental effects of various biomass sources and their placement on the landscape so as to guide the burgeoning bioenergy industry toward greater sustainability.

- This project is important in expanding our understanding of how the potential environmental effects of biomass production can inform decision making about industrial and governmental investment. The ecosystem service approach we employed, and its end point of monetized benefits or damages, allows for effective deployment of programs such as payments for ecosystem services (PES) plans, which can benefit both farmers and industrial partners.

- The goals of this project are also those of the 2016 MYPP in R&D on sustainable, high-quality feedstock supply systems and in crosscutting, sustainability, analysis, and strategic communications activities.

- The results of this project support the 2016 MYPP Sustainability goals of, by 2022, validating landscape approaches for bioenergy systems with multiple sustainability benefits and evaluating environmental indicators of multiple sustainability criteria.

5 – Future Work

- Work on the deliverables of this project is complete, but we are continuing to publish and disseminate results
- Models we developed are currently in use by other academic (e.g., Univ. of Illinois and Univ. of Michigan) and governmental (e.g., EPA-OTAQ and US DOT) groups
- Continued model development of InMAP and GREET-cst is being funded by EPA ACE grant to the Center for Air, Climate, and Energy Solutions (CACES)

Summary

- The bioeconomy holds great promise for improving the sustainability of transportation, yet environmental effects of industrial-scale biomass production are largely unknown.
- This project uses an ecosystem service framework to evaluate various biomass sources and their placement on the landscape in the Mississippi River Watershed.
- In this five-year research program, we explored the effects of biomass production on climate change, air and water quality, biodiversity, and water and energy use.
- Among our key findings, we demonstrated the importance of air quality in bioenergy decision making, identified fertilizer use as a primary target for intervention, showed near-source evapotranspirational recycling for perennial herbaceous crops, and established that the environmental impacts of biomass are highly location specific at a regional level.
- Our project has led to novel advances in environmental assessment including the modeling of two-way interactions between biosphere and climate, reduced-form air quality modeling, and advanced methods of spatial life cycle assessment and of ecosystem service valuation and incorporation of uncertainty.
- Our work, which has been published in over a dozen peer-reviewed papers, has led to numerous academic collaborations and has received widespread interest from agricultural, industrial, and governmental stakeholders.

Additional Slides

Responses to Previous Reviewers' Comments

- "Opportunities for collaboration with other BETO projects analyzing air and water quality should be explored to capture synergies between similar efforts."
- We have reached out to researchers affiliated with other BETO projects, and for years have had fruitful collaborations with personnel at NREL and Argonne.
- "Overall, the project was strong on the science and technical aspects but weak on project management."
- Our project is small, (PI, co-PI, and 2 FTE postdocs), and project management was simple. All personnel were located close to one another on the St. Paul Campus of the University of Minnesota. No problems in performance or achievement of milestones were experienced.
- "If this project ends in 2015, how much more time/ capacity can be devoted to the important question of nitrogen/water quality?"
- Much of our work in the area of nitrogen and water quality had not completed journal peer review at the time of the 2015 Peer Review. Our work in this area has since been published in the journals *Science Advances* (The Social Costs of Nitrogen) and *Ecosystem Services (*Assessing uncertainty in the profitability of prairie biomass production with ecosystem service compensation).

Publications, Patents, Presentations, Awards, and Commercialization

1. Sun, J., T. Twine, J. Hill, R. Noe, J. Shi, and M. Li (2017) Effects of land use change for crops on water and carbon budgets in the Midwest USA. *Sustainability* **9**: 1–14. DOI: 10.3390/su9020225.
2. Noe, R., E. Nachman, H. Heavenrich, B. Keeler, D. Hernandez, and J. Hill (2016) Assessing uncertainty in the profitability of prairie biomass production with ecosystem service compensation. *Ecosystem Services* **21**: 103–108. DOI: 10.1016/j.ecoser.2016.05.004.
3. Harding, K., T. Twine, A. VanLoocke, and J. Hill (2016) Impacts of second-generation biofuel feedstock production in the central U.S. on the hydrologic cycle and global warming mitigation potential. *Geophys. Res. Lett.* **43**: 10773–10781. DOI: 10.1002/2016GL069981.
4. Keeler, B., J. Gourevitch, S. Polasky, F. Isbell, C. Tessum, J. Hill, and J. Marshall (2016) The social costs of nitrogen. *Sci Adv.* **2**: 1–9. DOI: 10.1126/sciadv.1600219.
5. Hill, J., L. Tajibaeva, and S. Polasky (2016) Climate consequences of low-carbon fuels: The United States Renewable Fuel Standard. *Energy Policy* **97**: 351–353. DOI: 10.1016/j.enpol.2016.07.035.
6. Tessum, C., J. Hill, and J. Marshall (2015) Twelve-month, 12 km resolution WRF-Chem v3.4 air quality simulation: Performance evaluation. *Geosci. Model Dev.* **8**: 957–973. DOI: 10.5194/gmd-8-957-2015.
7. Harding, K., T. Twine, and Y. Lu (2015) Effects of dynamic crop growth on the simulated precipitation response to irrigation. *Earth Interact.* **19**: 1–31. DOI: 10.1175/EI-D-15-0030.1.

Publications, Patents, Presentations, Awards, and Commercialization

8. Tessum, C., J. Hill, and J. Marshall (2014) Life cycle air quality impacts of conventional and alternative light duty transportation in the United States. *Proc. Natl. Acad. Sci. USA* **111**: 18490–18495. DOI: 10.1073/pnas.1406853111.
9. Keeler B., B. Krohn, T. Nickerson, J. Hill (2013) U.S. Federal agency models offer different visions for achieving Renewable Fuel Standard (RFS2) biofuel volumes. *Environ. Sci. Technol.* **47**: 10095–10101.
10. Tessum, C., J. Marshall, and J. Hill (2012) A spatially and temporally explicit life cycle inventory of air pollutants from gasoline and ethanol in the United States. *Environ. Sci. Technol.* **46**: 11408–11417. DOI: 10.1021/es3010514.
11. Millet, D., E. Apel., D. Henze, J. Hill, J. Marshall, H. Singh, and C. Tessum (2012) Natural and anthropogenic ethanol sources in North America and potential atmospheric impacts of ethanol fuel use. *Environ. Sci Technol.* **46**: 8484–8492. DOI: 10.1021/es300162u.
12. Anderson-Teixeira, K. J., P. K. Snyder, T. E. Twine, S. V. Cuadra, M. H. Costa, E. H. DeLucia. 2012. Climate regulation services of natural and agricultural ecoregions of the Americas, *Nature Climate Change*. DOI:10.1038/nclimate1346.
13. VanLoocke, A., T. E. Twine, M. Zeri, C. J. Bernacchi. 2012. A regional comparison of water use efficiency for miscanthus, switchgrass and maize, *Agricultural and Forest Meteorology* **164**: 82–95. DOI: 10.1016/j.agformet.2012.05.016.