Preparing, testing, and applying a modeling framework for high-resolution prediction of production and attributes of biofuel systems

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JGCRI
Joint Global Change Research Institute

September 19-22, 2011
DOE Climate and Earth System Modeling PI Meeting
Washington, DC

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Acknowledgements

Collaborators	
Texas A&M	JR Williams
U. Northern British Columbia	WB McGill
DOE Great Lakes Bioenergy Research Center	<u>Sustainability Area:</u> Gelfand, Robertson, Meehan, Gratton, Landis, Egbendewe-Mondzozo, Swinton, Reinemann, Dale, Sinistore

Sponsors

DOE Office of Science Great Lakes Bioenergy Research Center

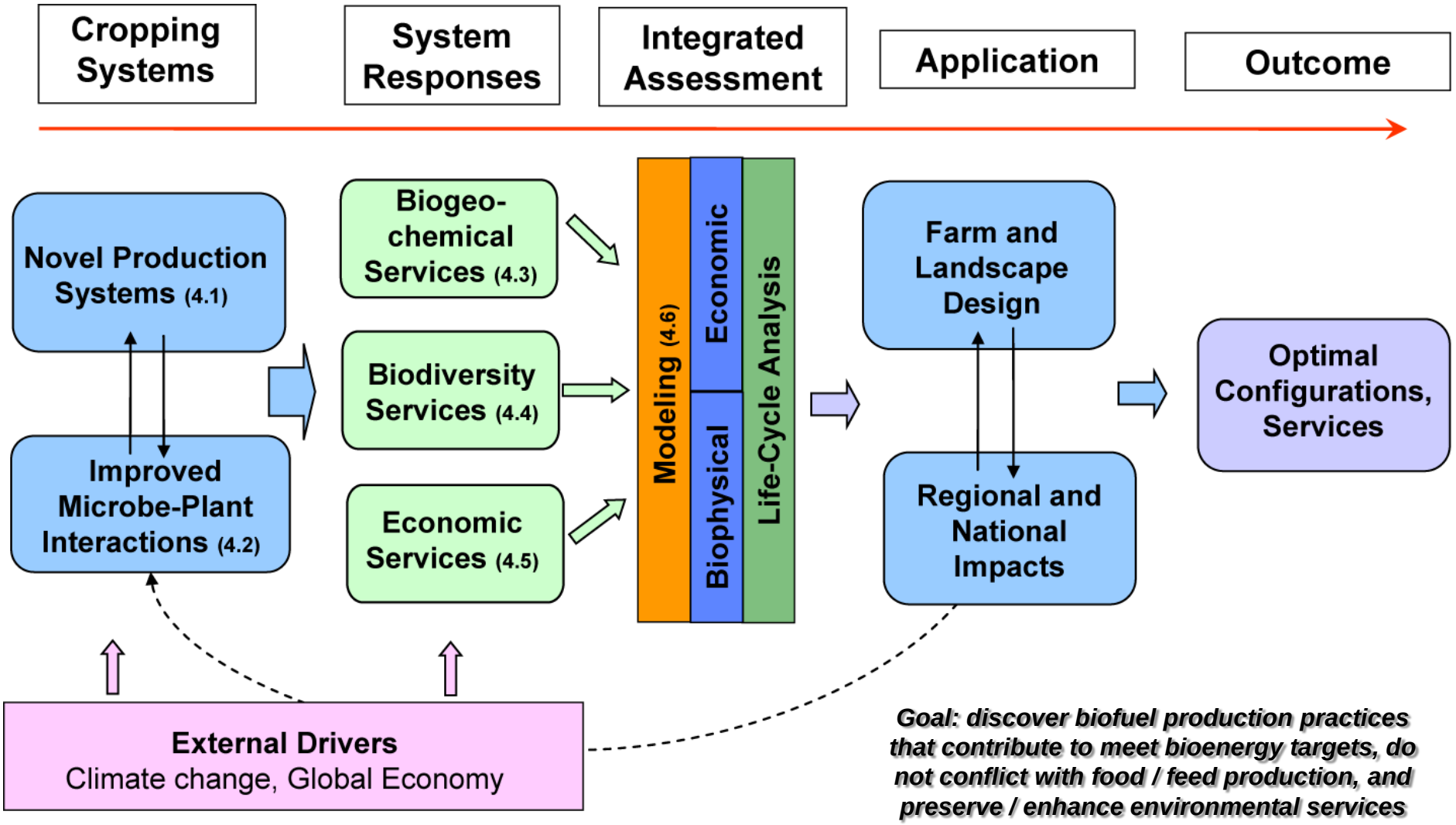
DOE EERE Office of Biomass Program Great Lakes Bioenergy Research Center

DOE Office of Science Carbon Sequestration in Terrestrial Ecosystems

DOE Office of Science Integrated Assessment Program

NASA Earth Applications Division

GLBRC Sustainability Research Roadmap



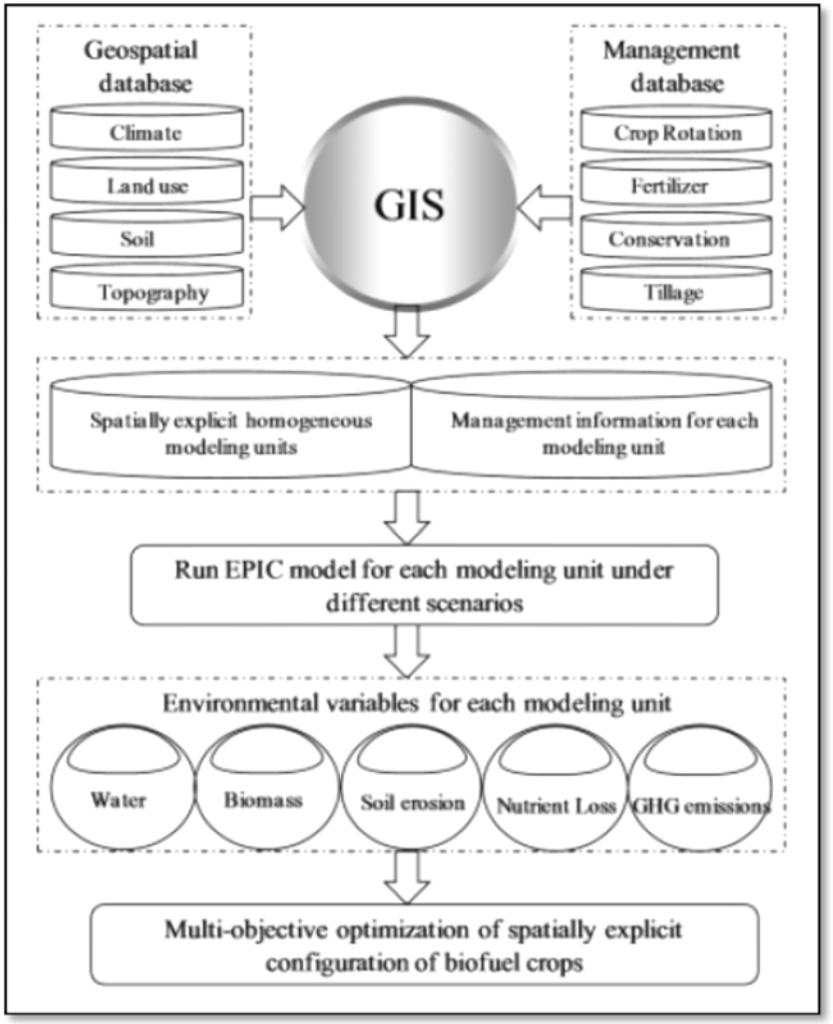
Goal: discover biofuel production practices that contribute to meet bioenergy targets, do not conflict with food / feed production, and preserve / enhance environmental services

http://www.greatlakesbioenergy.org

SEIMF: Spatially-Explicit Integrated Modeling Framework

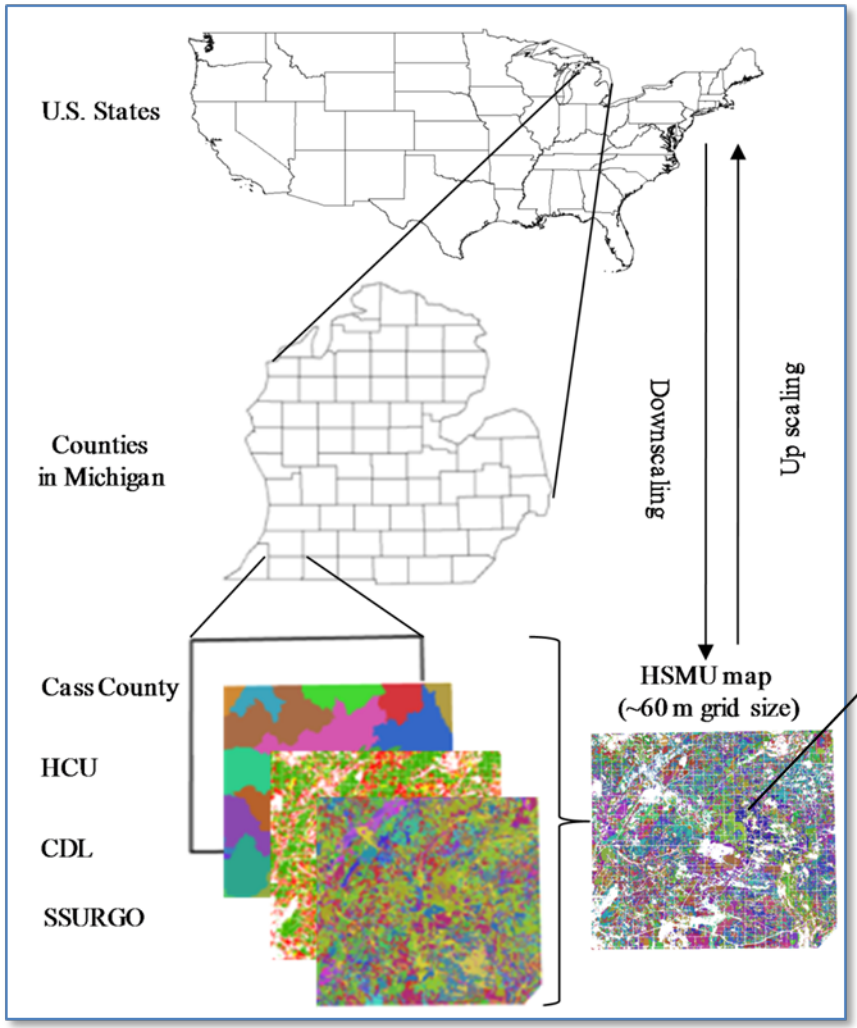
SEIMF has three components:

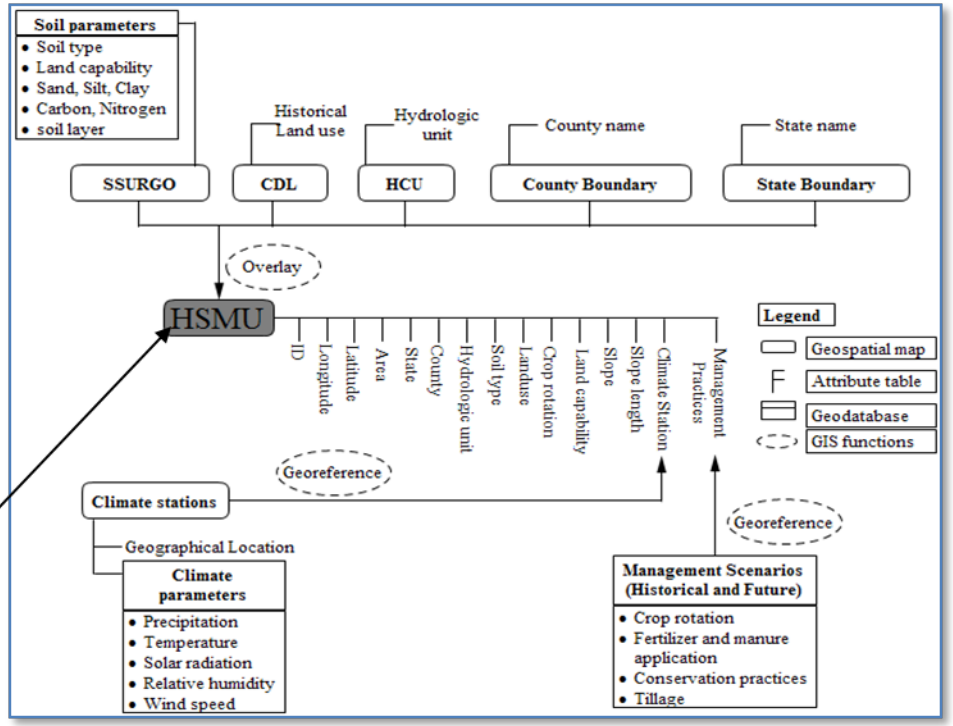
- GIS to define spatially-explicit modeling units
- EPIC (Environmental Policy Integrated Climate) model
- Evolutionary objective optimization algorithm



Zhang et al. 2010. Global Change Biol. – Bioenergy 2:258–277

Multi-scale modeling system





Zhang et al. 2010. Global Change Biol. – Bioenergy 2:258–277

EPIC

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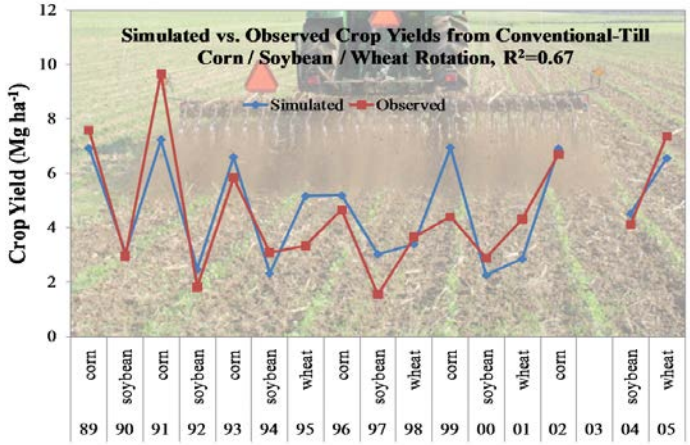
- Comprehensive, process-based terrestrial ecosystem model
- Modeled processes
  - Plant growth and yield: crops, herbaceous and woody vegetation; plant competition
  - Plant stresses: water, nutrients, aeration, acidity, salinity, pests
  - Wind and water erosion; sedimentation
  - Simplified heat flux, soil temperature
  - Water and nutrient cycling
  - Ecosystem C: NPP, NEP, NEE, [CO_2], lateral C flux, soil C with depth
  - Ecosystem N: storage and turnover, plant uptake, biological fixation, volatilization, leaching, denitrification
- Management
  - Tillage, fertilization, irrigation, drainage, liming, fire, grazing, conservation structures
- Scales:
  - Temporal: daily, hourly
  - Spatial: field, region, nation, global

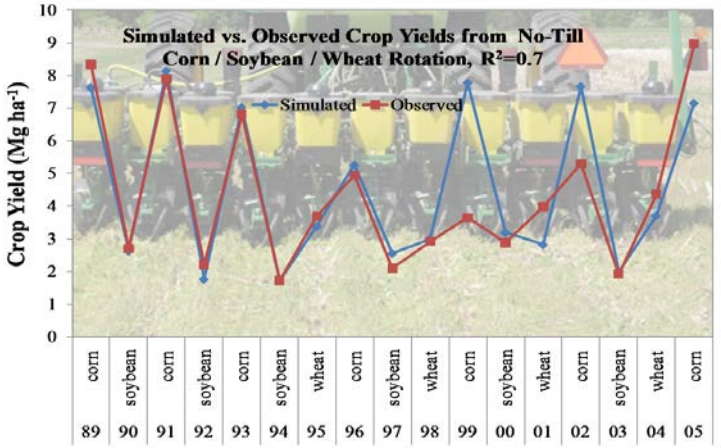
- Data
  - Land use, land cover
  - Daily weather, climate parameters
  - Topography
  - Soil layer properties
  - Management
- Applications
  - Climate change and variability impacts on agriculture
  - Soil carbon sequestration
  - Bioenergy production

Net Ecosystem Productivity in croplands of Iowa in 2007 - NACP

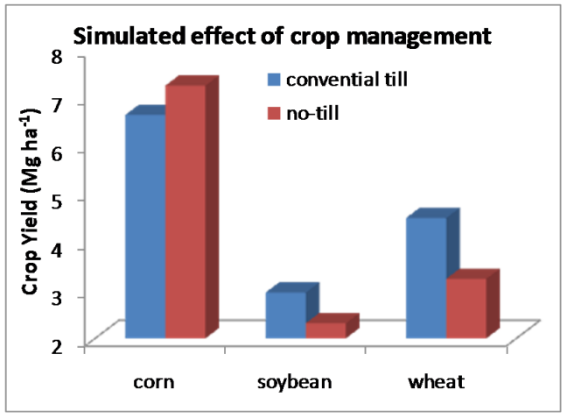
Testing EPIC with site data

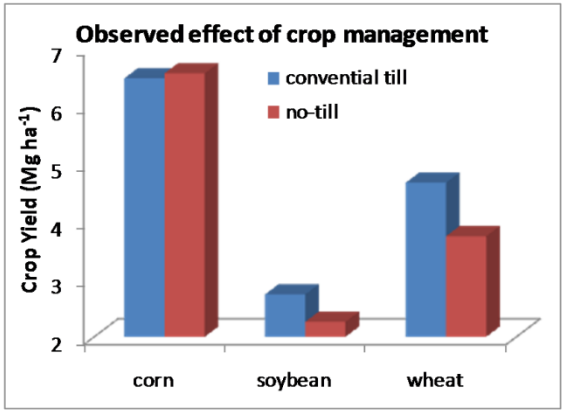
Simulated and observed crop yields in corn-soybean-wheat rotation at Kellogg Biological Station, Michigan





Simulated and observed effects of management practices on long-term crop yields at Kellogg Biological Station, Michigan

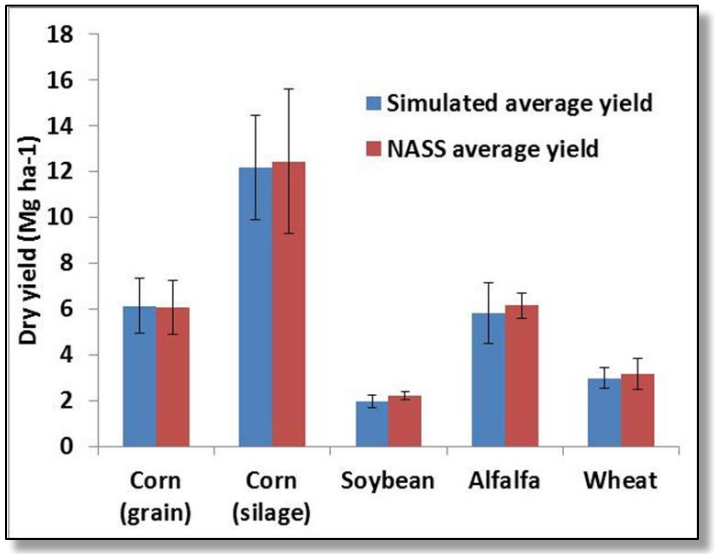




Simulations by D.H. Manowitz

Testing EPIC with regional and literature data

EPIC vs. NASS yields



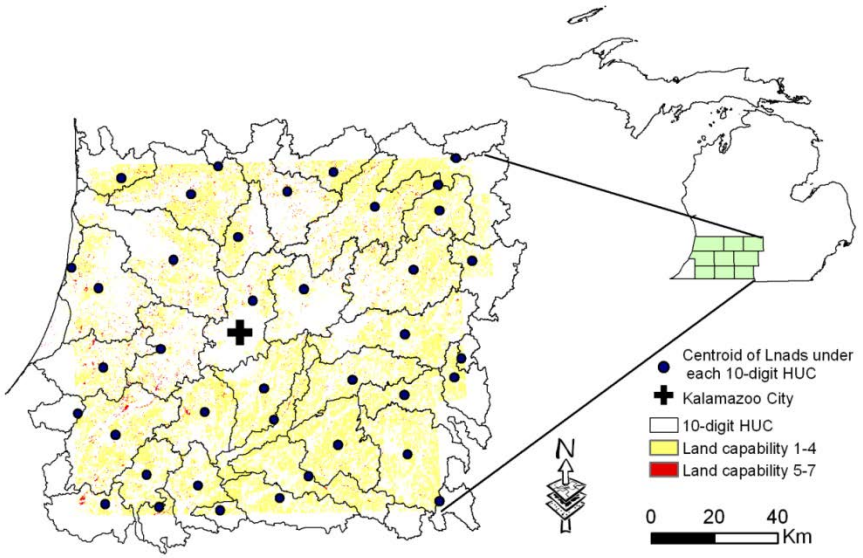
Simulations by D.H. Manowitz

	Simulated (Mg ha^{-1})	Literature reported (Mg ha^{-1})
Grass mix 05	10.2-12.2	7.8[G]
Grass mix 06	10.8-12.8	7.8[G]
Native prairie cool season	8.0-8.4	4.8[N] - 6.8[K]
Native prairie warm season	7.2-7.8	4.8[N] - 6.8[K]
Miscanthus	18.0-19.5	(6.9-24.1)[M1] (22.4 4.1) [M2]
Hybrid poplar	8.2	4.2 (1989-1998) 3.5 (1999-2007)
Switchgrass	12.7-14.3	(10-15)[S]

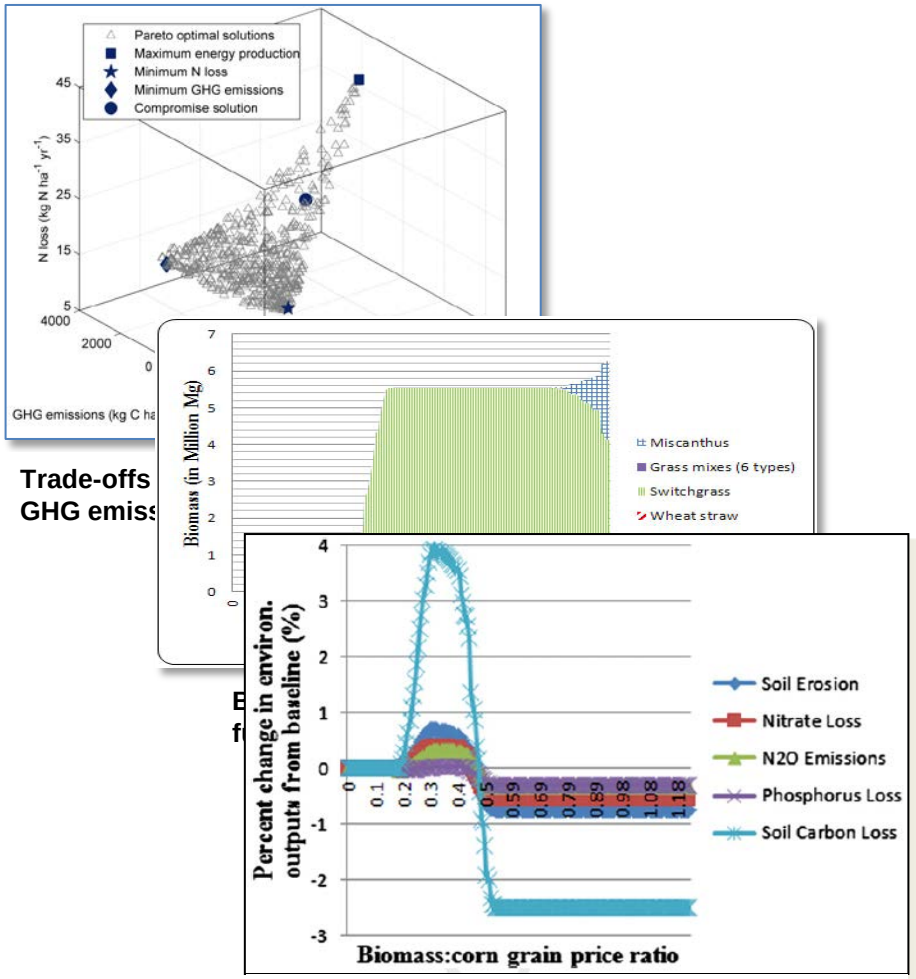
[S] From switchgrass yield map (Jager et al.; 2010) for southern Michigan
[M1] Price et al. (2004); [M2] Heaton et al. (2004)
[N] Tilman et al. (2006)
[G] Estimated by James et al. (2010)
[K] KBS LTER

Biomass, bioenergy, and environmental modeling at biorefinery scale

Michigan Regional Intensive Modeling Area (RIMA)



Geospatial modeling allows for integrated analysis of productivity, environmental, economic, and LCA outcomes of diverse biofuel production systems practiced on land of different qualities

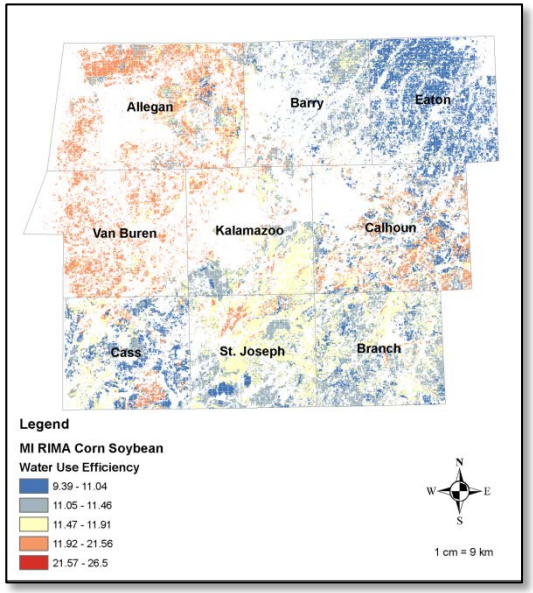


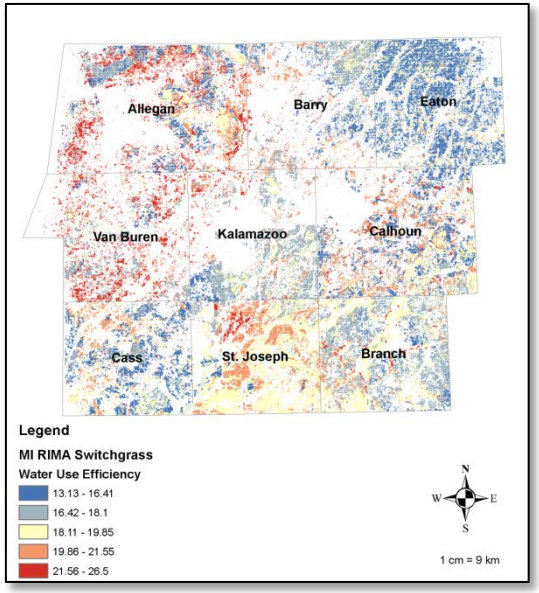
Trade-offs
GHG emiss

Change in environmental outcomes at different price ratios of biomass

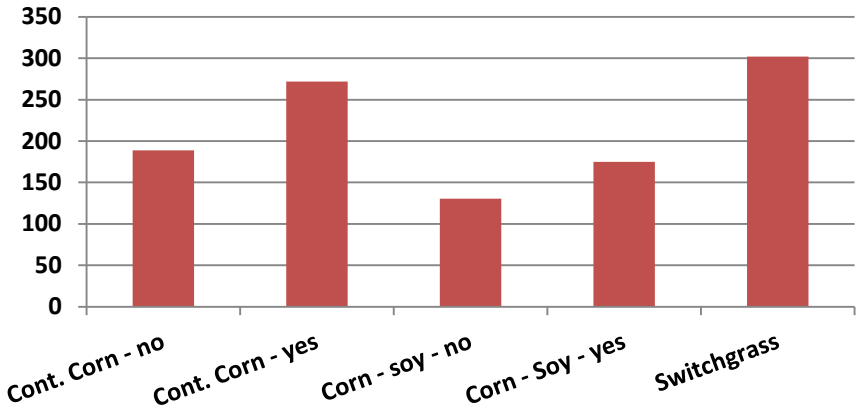
Egbendewe-Mondzozo et al. 2011. Biomass Bioenergy (in press)

Geospatial modeling of water-use efficiency (WUE, kg mm^{-1}) under two land uses

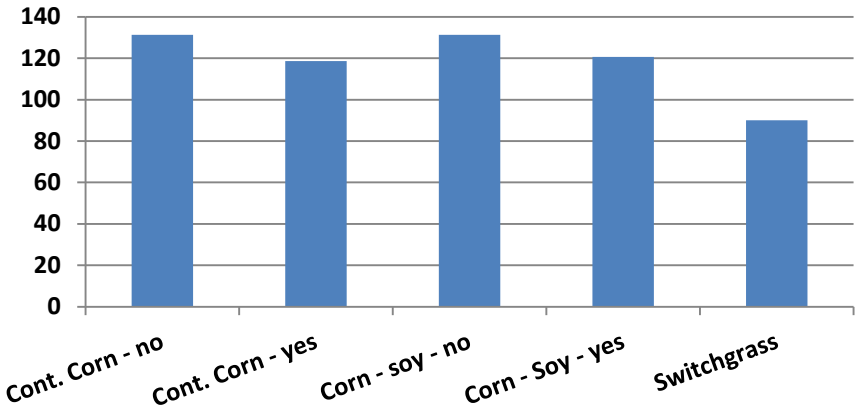




Bioenergy (GJ ha^{-1})



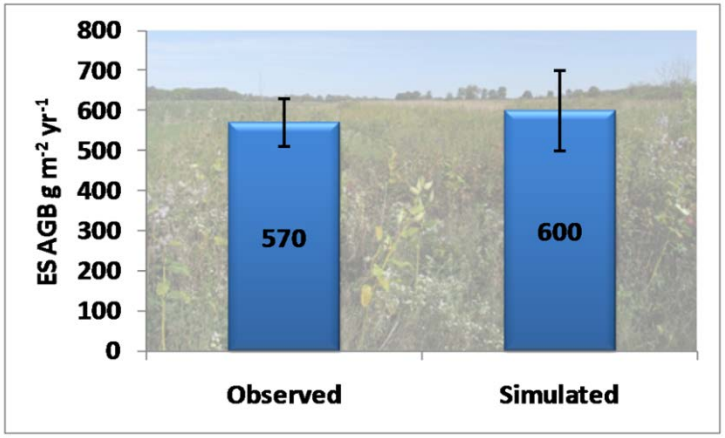
Water footprint (m^3 GJ^{-1})



Izaurralde, R.C., X. Zhang, R. Sahajpal, and D.H. Manowitz. (In preparation).

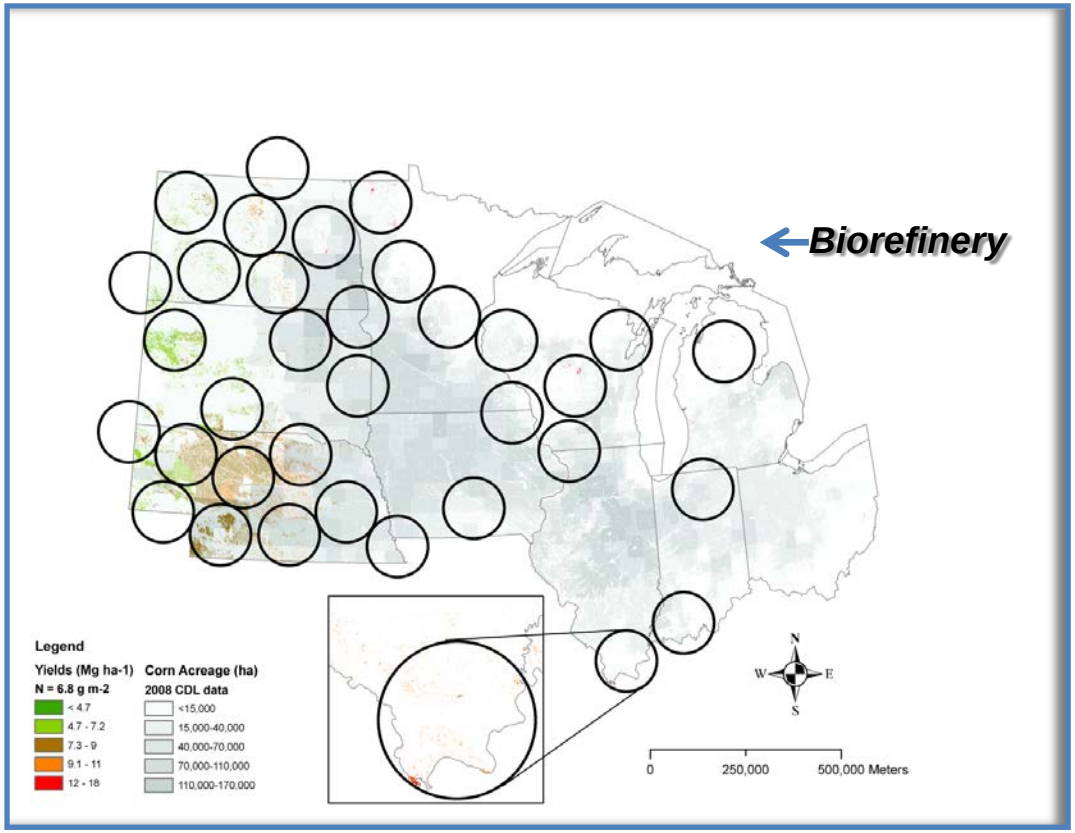
Biomass modeling and biorefinery siting on marginal lands in the US North Central Region

Observed and simulated yields of prairie mixes at KBS



- Area: 11.4 Mha
- Biomass yield: 6.0 ± 2.6 Mg ha^{-1}
- Yield increase by 36% with fertilizer N
- No. biorefineries: 34 with a minimum capacity of 105 ML ethanol yr^{-1}
- Ethanol production: ~21 GL yr^{-1} ≈ 27% of EISA target

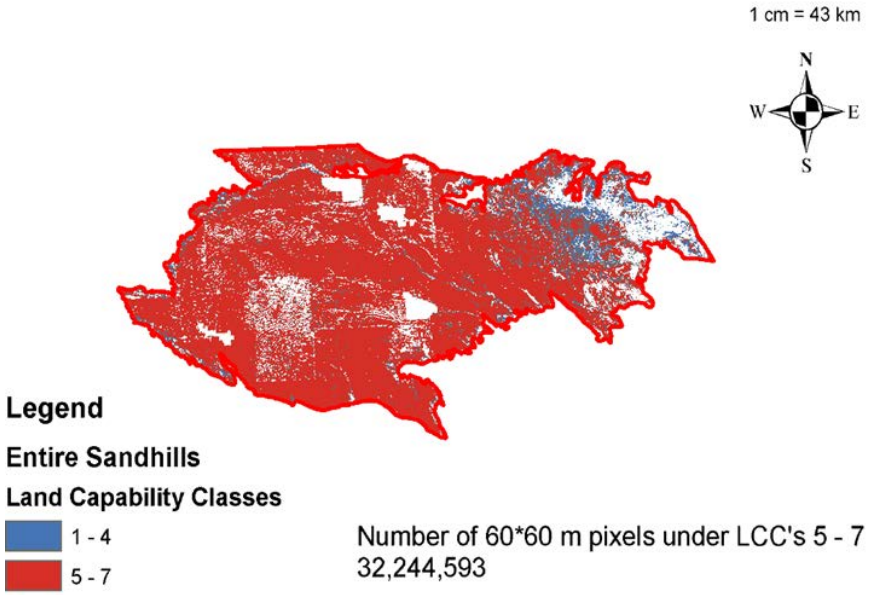
Cellulosic biomass yields on marginal lands and biorefinery locations



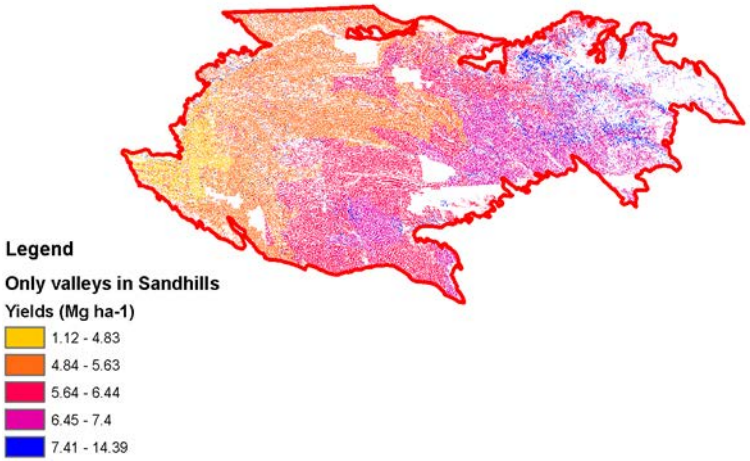
Gelfand, I., R. Sahajpal, X. Zhang, R.C. Izaurralde, K. Gross, and G.P. Robertson. (In preparation).

The Sandhills of Nebraska; how much land, really?

Marginal lands across the Sandhills include many sandy ridges

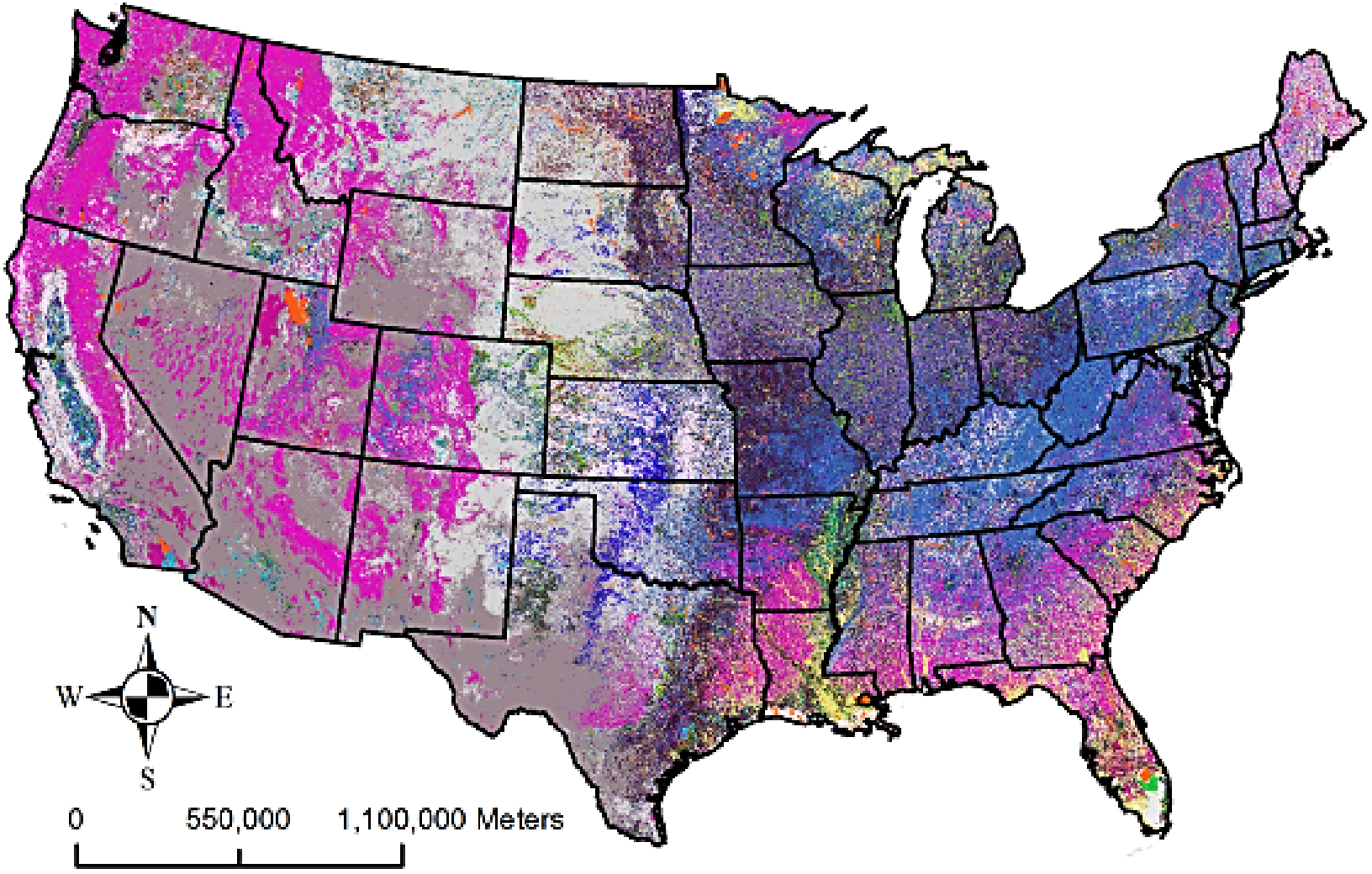


Cellulosic biomass yields (Mg ha-1) in valley portions of the Sandhills



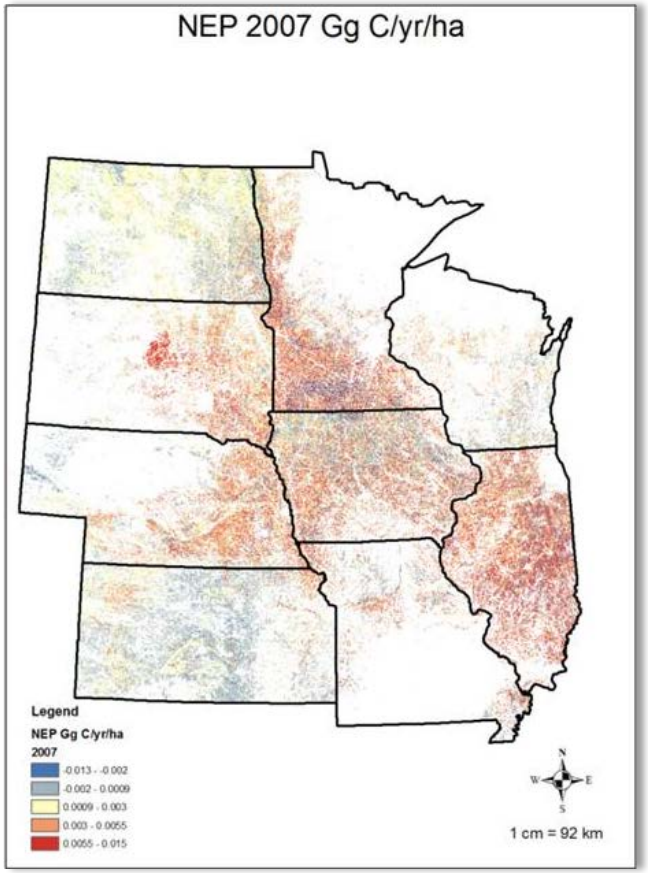
Analysis by R. Sahajpal

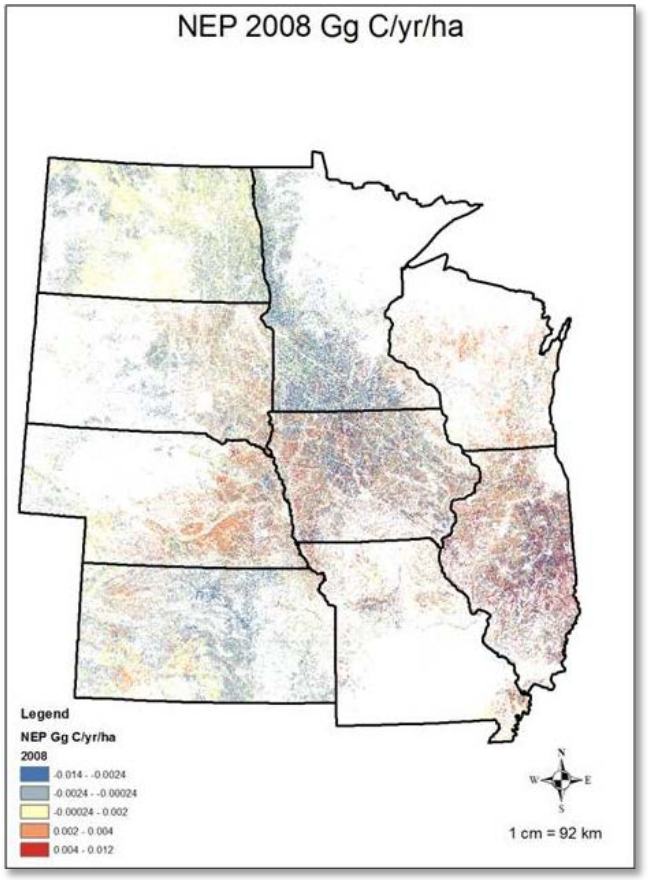
Land cover, land use, crop rotations map of the conterminous USA



Product developed by R. Sahajpal

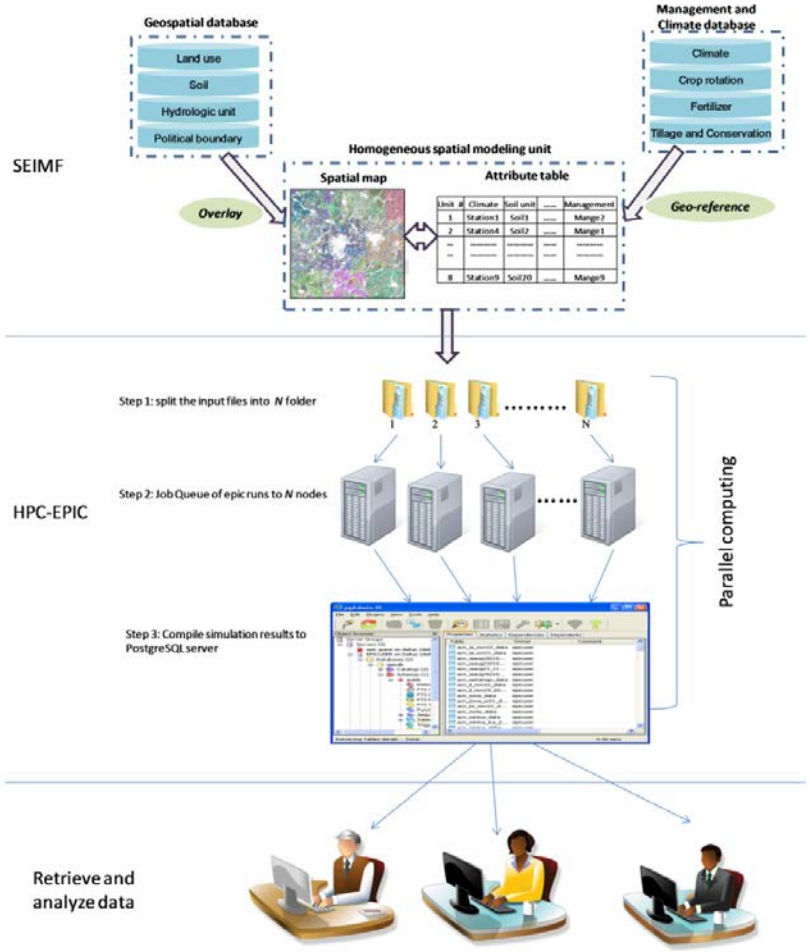
Simulated Net Ecosystem Productivity (NEP) in 2007 and 2008 in the NACP Mid Continent Intensive region





R.C. Izaurralde, X. Zhang, D.H. Manowitz, and R. Sahajpal. (In preparation).

Running EPIC on high-performance computing systems



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Nichols J., S. Kang, W. Post, D. Wang, P. Bandaru, D. Manowitz, X. Zhang, and R.C. Izaurralde. 2011. HPC-EPIC for high resolution simulations of environmental and sustainability assessment. Computers and Electronics in Agriculture (in press)