GREAT LAKES BIOENERGY RESEARCH CENTER

# Integrating Biogeochemical and Price Forecasting Models to Predict Bioenergy Crop Supply and Environmental Impacts

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U.S. DEPARTMENT OF ENERGY

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# In a nutshell

- Research questions
  - What biomass crops will be grown in Great Lakes region?
  - What environmental consequences?
  - How do market feedbacks affect future trajectories?
- Model elements: Biochemical & Multi-market
- Model comparisons (biomass supply & environmt)
  - Fixed prices
  - Market price feedbacks

A. Egbendewe-Mondzozo et al. 2015, *App. Econ Persp & Policy*

# How would bioenergy crops change economic & environmental performance on Great Lakes cropland?

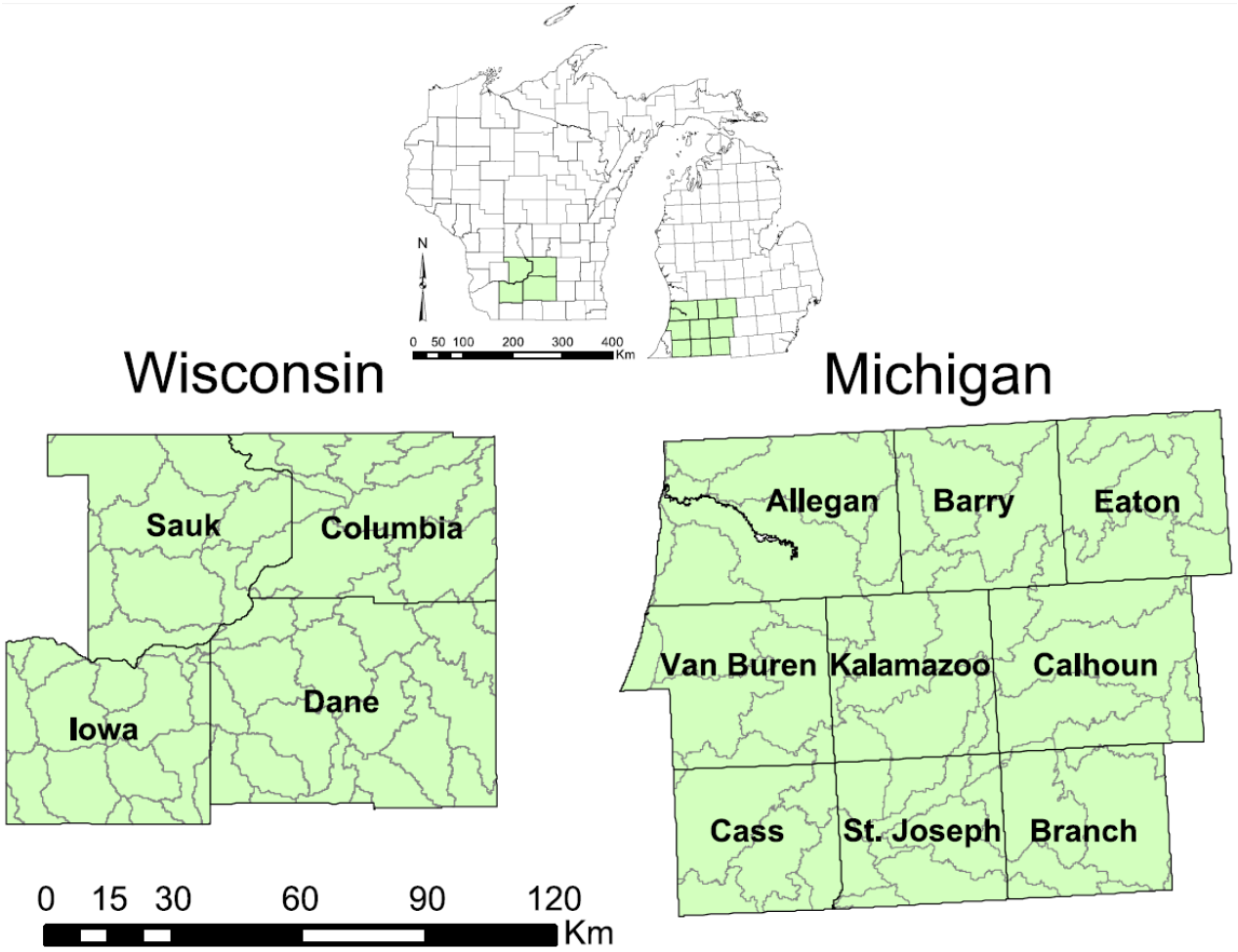
## Research Questions

- What conditions to supply energy crops?
- What crops grown and which ones displaced?
- Environmental consequences?
- Effect of market feedbacks on predicted trajectories?

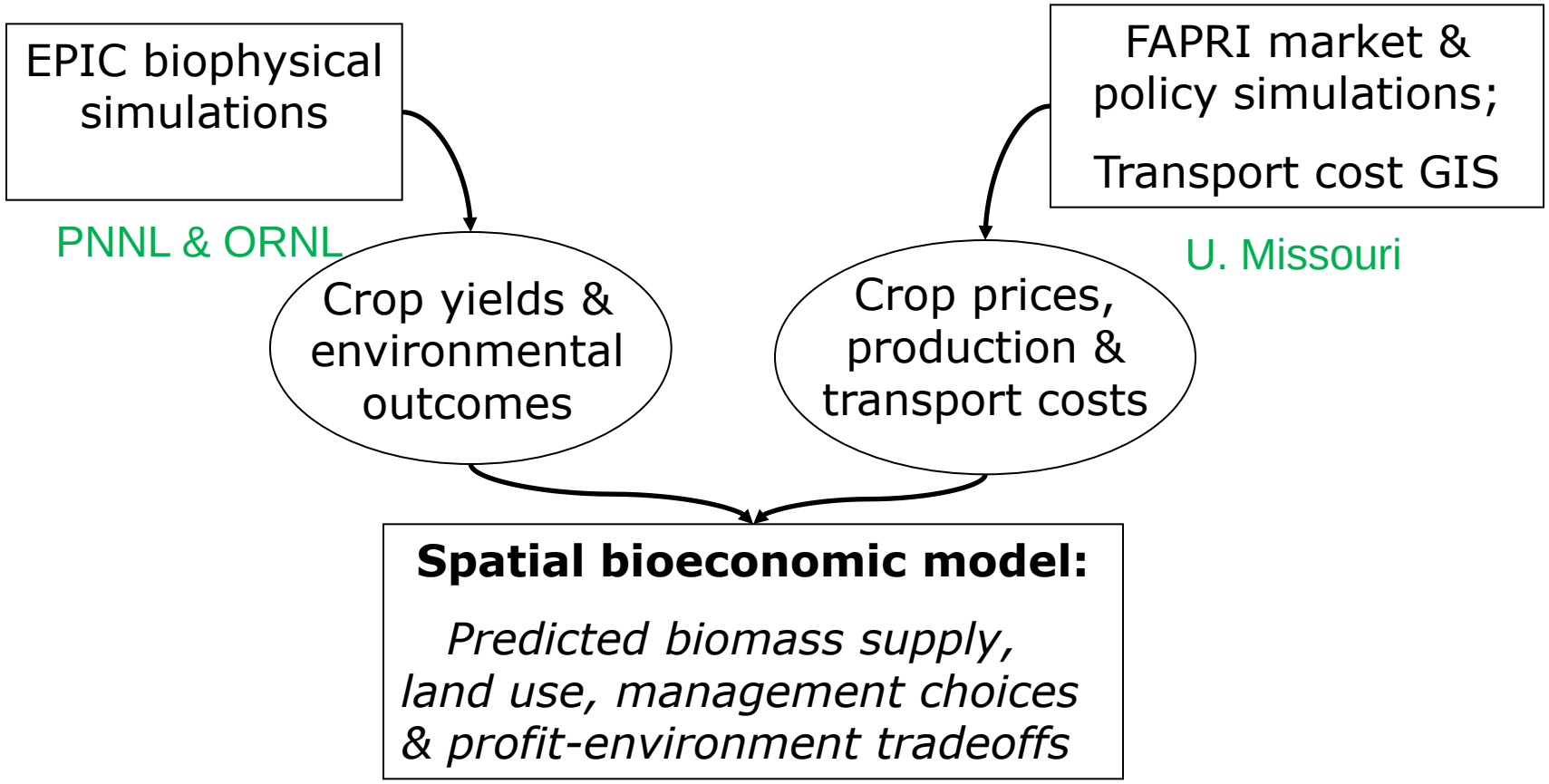
## Sub-teams by model

- Great Lakes Bioenergy Research Center (GLBRC)
  - Biophysical models (EPIC) at Oak Ridge & Pacific Northwest Labs (ORNL, PNNL)
  - Market price & quantity models at U. Missouri Food & Ag Policy Research Inst (FAPRI)
  - Land use bioeconomic decision model at Michigan State U.

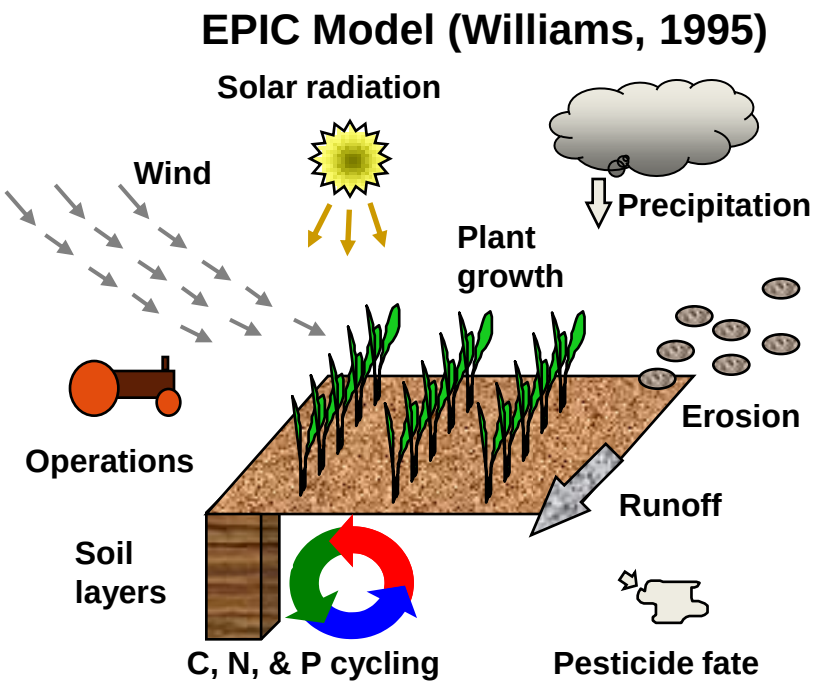
# Regional Intensive Modeling Areas in Michigan & Wisconsin represent agricultural land in southern Great Lakes

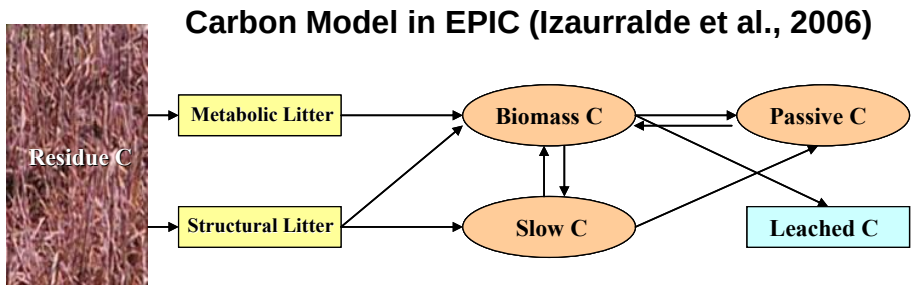


# Spatial bioeconomic model of crop production: Biomass supply & environmental trade-offs



# EPIC simulates biophysical and biogeochemical processes as affected by climate, soil, and management interactions




- Developed by USDA and maintained and Texas A&M University
- Key processes simulated
  - Weather: generated, historical, climate projections
  - Plant growth and yield
    - Crops, grasses, trees
    - Complex rotations, intercropping, land use change
    - Radiation use efficiency
    - Plant stresses
  - Water balance; irrigation, drainage
  - Heat balance; soil temperature
  - Carbon cycling, including eroded carbon
  - Nitrogen cycling
  - Erosion by wind and water
  - Plant environment control: tillage, fertilizers, irrigation, pesticides
  - Carbon emissions coefficients

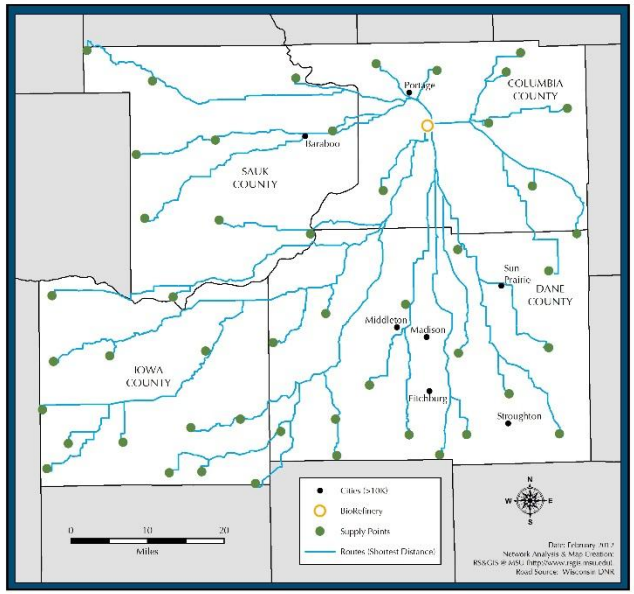
(Slide: Izaurralde, 2009)

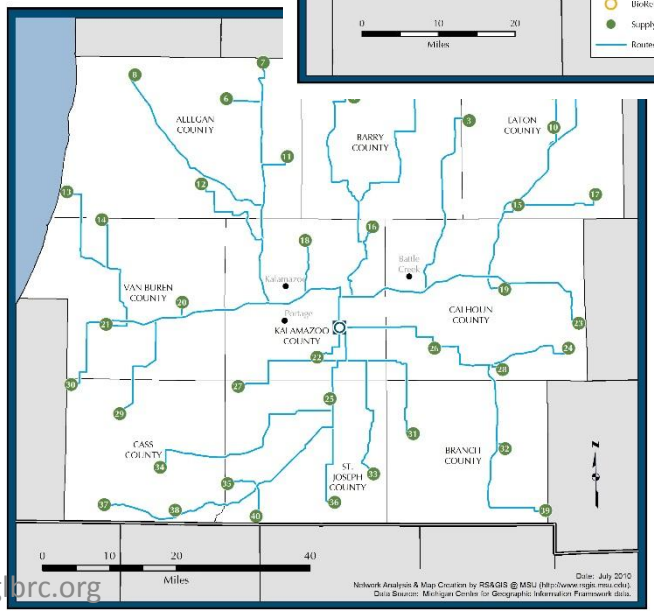
# EPIC simulation of crop yield and environmental outcomes in SW Mich & SC Wisc

- 82 cropping systems (70 land units in Mich.; 80 in Wisc.):
- Crops
  - 6 annuals: Corn, corn silage, soy, wheat, canola, & alfalfa
  - 7 perennial: Switchgrass, miscanthus, poplar, 4 grass & prairie mixes
- Tillage: no-till or chisel
- Fertilization: high or medium
- Residue removal: No or 50%

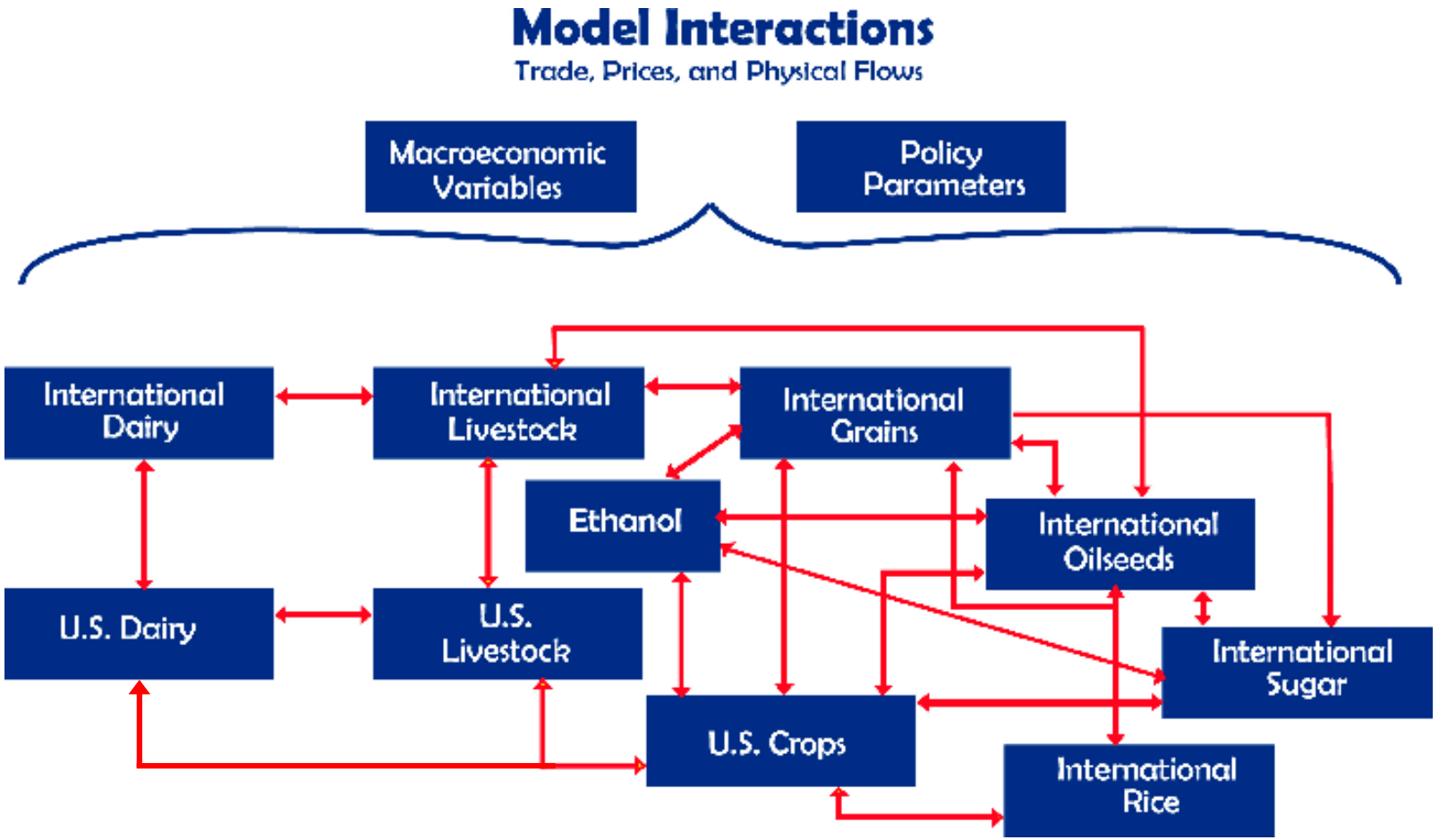
# Simulated land use near central, imagined biorefinery in each region

- EPIC simulates crop yield & 5 environ. outcomes
  - Soil erosion
  - Soil carbon loss
  - Nitrate leaching to water
  - Phosphorus runoff to water
  - Greenhouse gas (GHG) flux ($CO_2$ + $N_2O$ + methane)



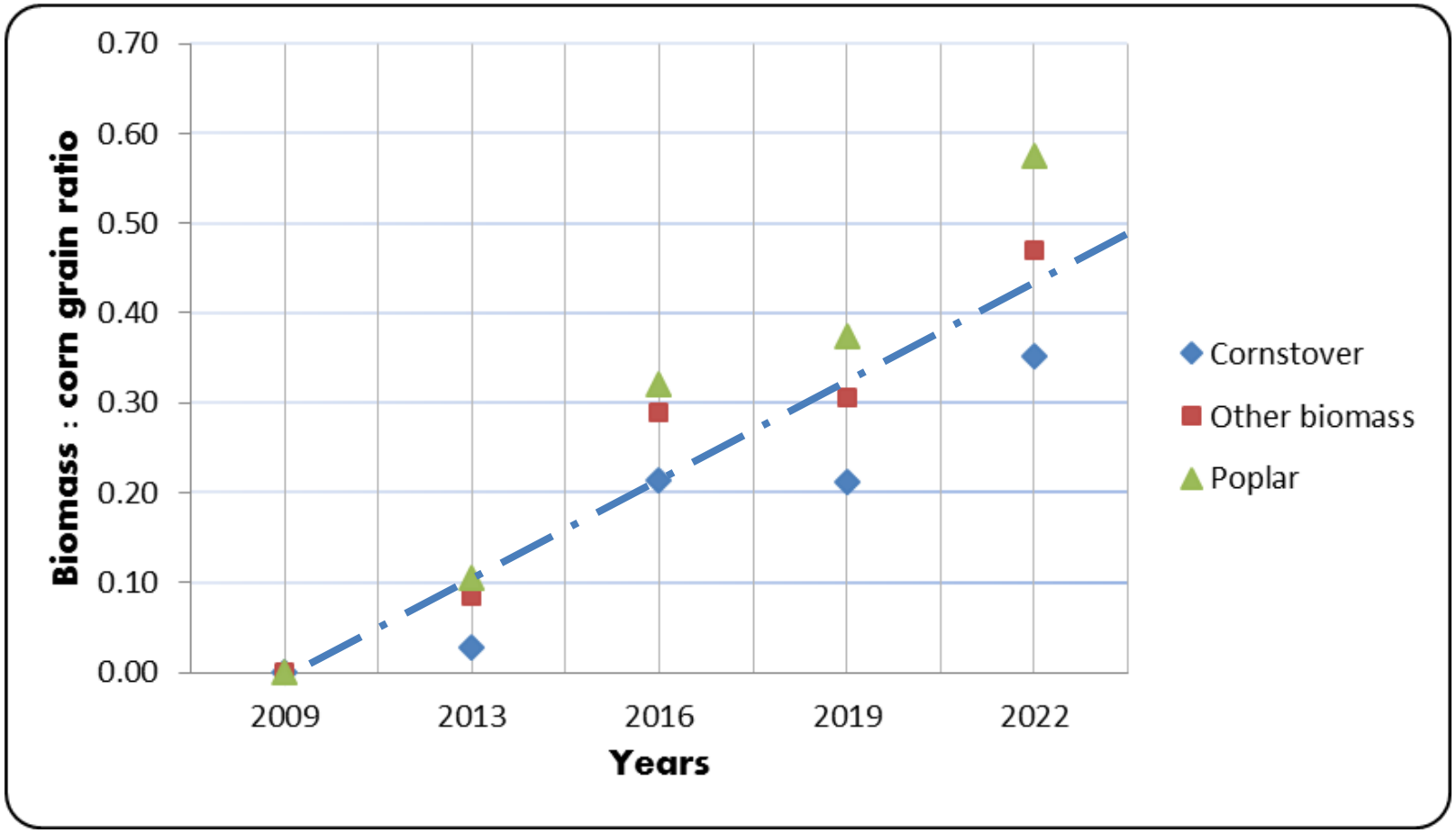



# FAPRI multi-market supply-demand model predicts U.S. ag prices & quantities



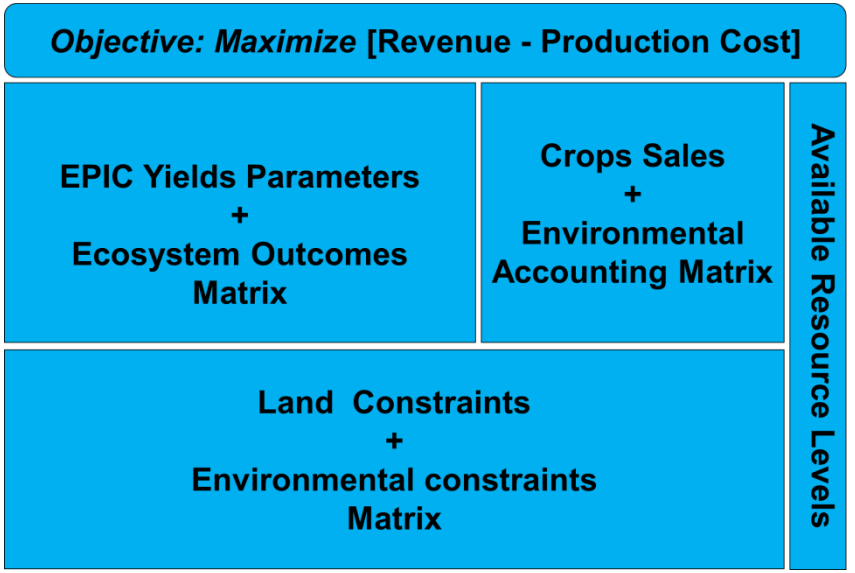

Meyers et al. 2010, *J Intl Ag Trade & Devt*

# FAPRI predicts rising relative price of biomass compared to corn grain to 2022



# Profit maximization model simulates choice of crop systems

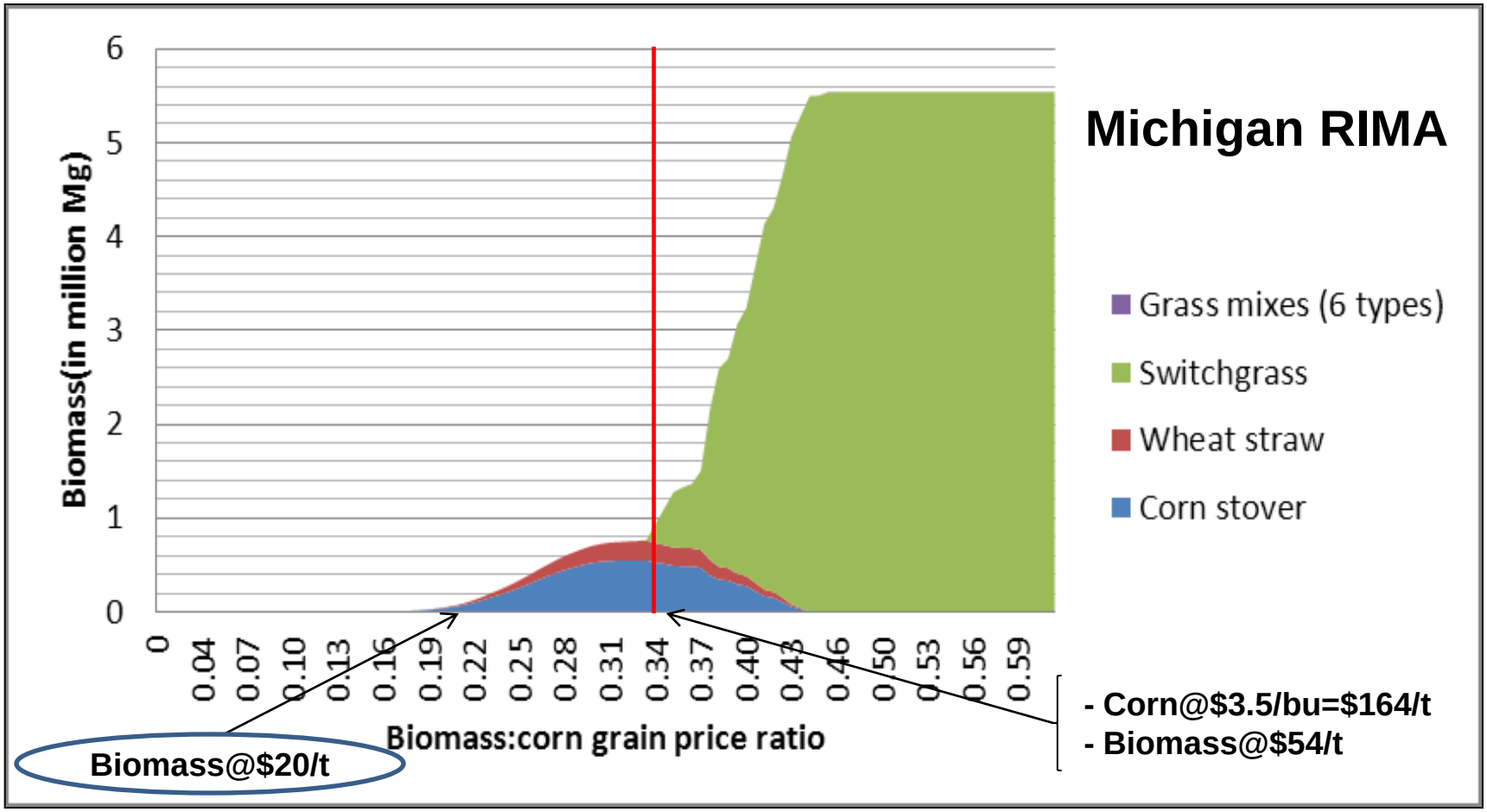
- Choose crops to maximize expected profit given parameters for:
  - Crop yield & selected ecosystem outcomes
  - Land quality by watershed
  - Prices & policy



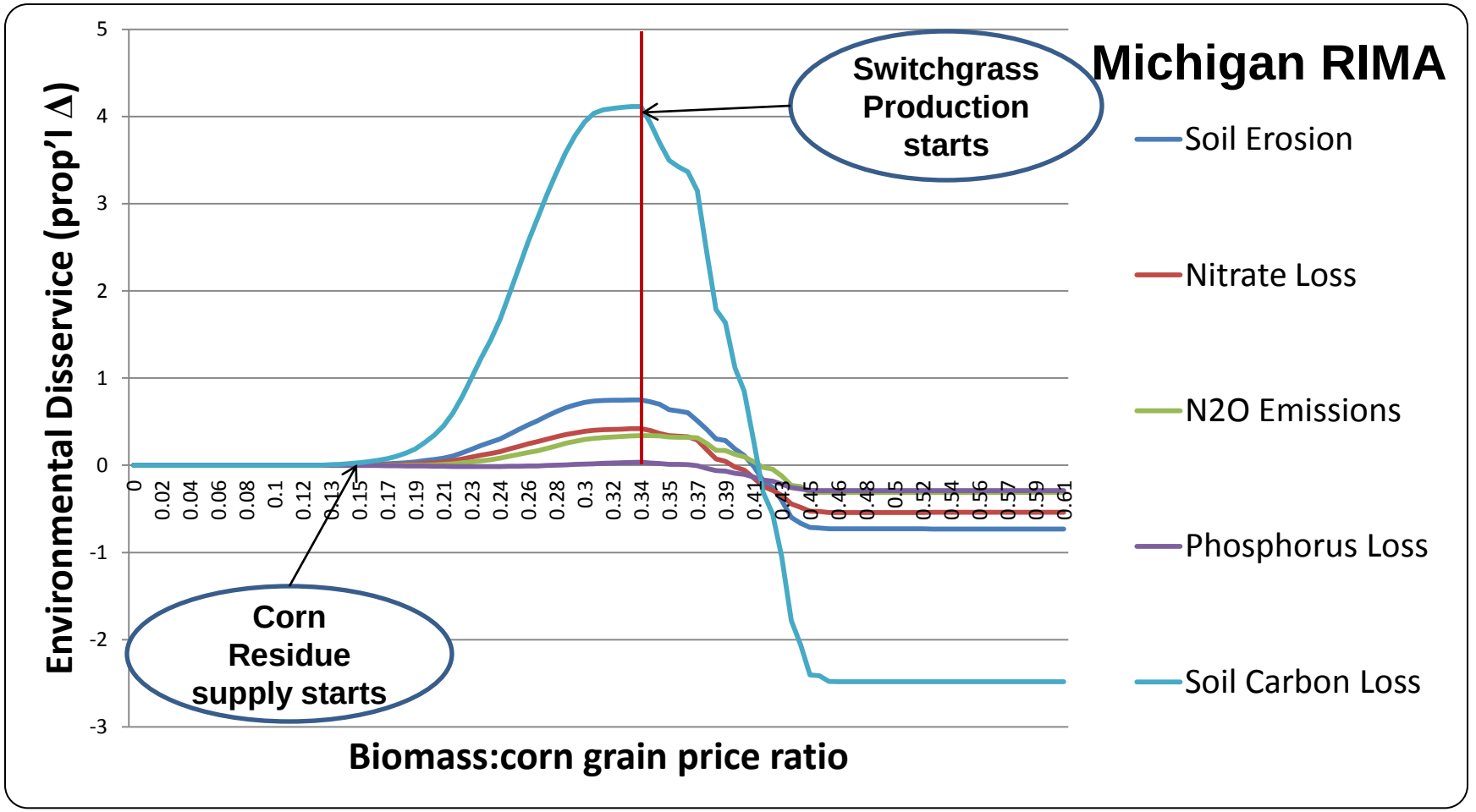

- Math programming
  - GAMS modeling language
  - Calibrated to validly represent baseline 2007-9

Egbendewe-Mondzozo et al, *Biomass & Bioenergy* (2011)

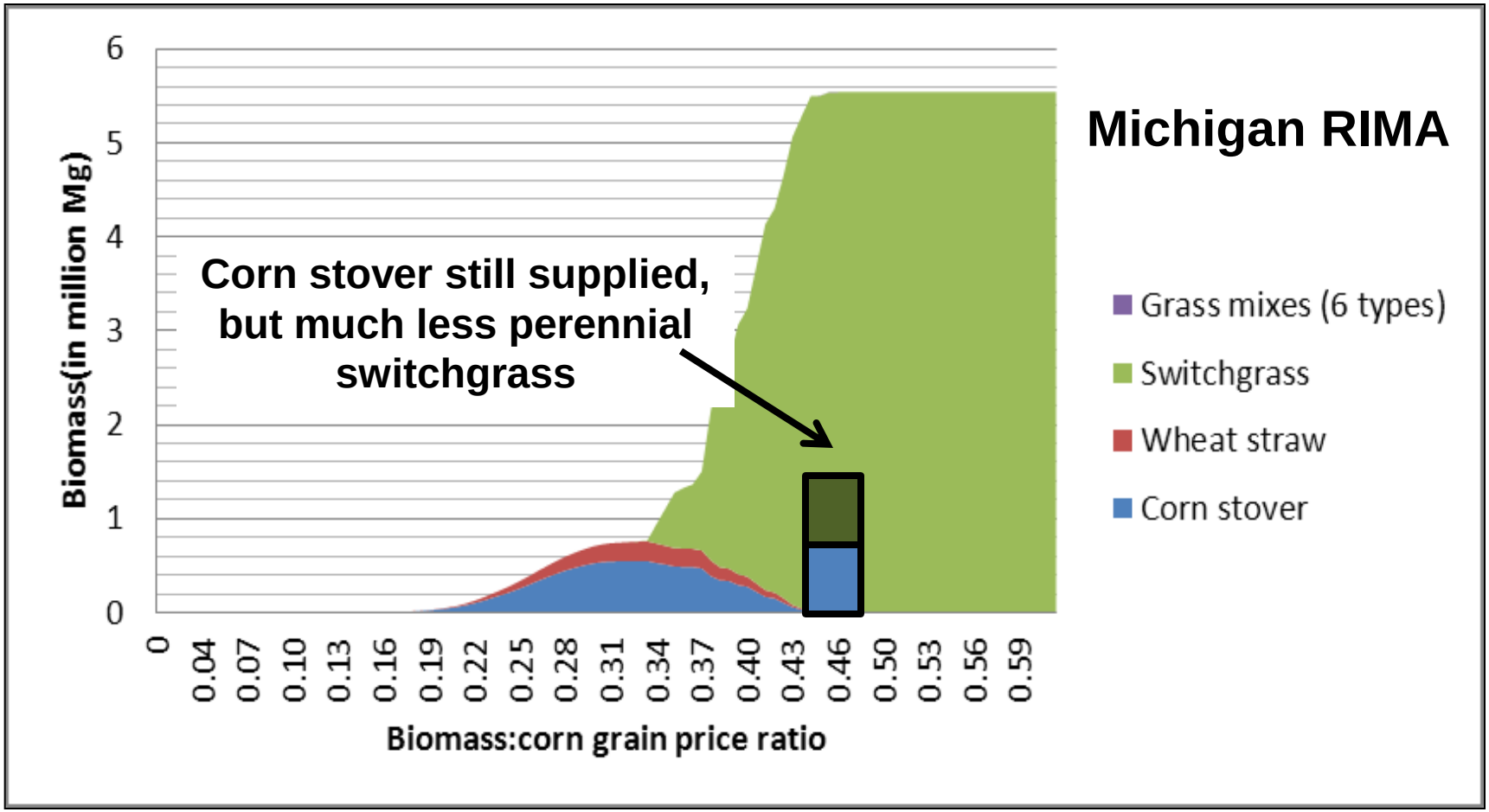
# Exogenous rise in biomass price: Annual biomass crops supplied first, then perennials



# Environmental disservices rise with annual crop biomass, fall with perennials



# Market-mediated biomass price rise compared to exogenous rise: Now food prices go up too, so much less biomass supply



# Markets dampen price effects, so predict worse environmental impacts from bioenergy production

**Exogenous biomass price rise**

- Faster bioenergy crop supply (food prices stay constant)
- Intensified corn prod. gives way to perennial grasses
- Environmental benefits rise with perennial grasses
- Both states grow bioenergy perennial crops

**Market-mediated price rise**

- Slower bioenergy crop supply (food prices adjust up)
- Intensified corn remains, even if some perennials too
- Environmental harm rises with intensive corn prod.
- Michigan RIMA grows some perennial grasses (due to low corn yields) Wisconsin stays with corn & food crops

# "Hub & spokes" approach to collaborative modeling

- Land use decision model at MSU integrated parameters from:
  - EPIC multi-year runs provided both commercial & environmental outputs
  - FAPRI provided price forecasts
- Evaluation
  - Good results: More realistic forecasts
  - But specialized roles, so …
    - Full modeling team never assembled
    - Lessons diffused from "hub" modelers

# Looking for future modeling collaborators. . .