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Biomass Supply from Alternative Cellulosic Crops and Crop Residues: A Spatial Bioeconomic Modeling Approach

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RESEARCH OBJECTIVE

Develop, a spatially explicit bioeconomic model of bioenergy crops production to study:

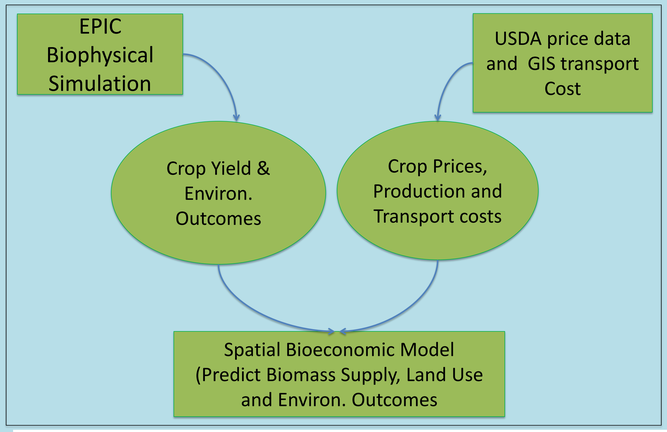
1) Conditions under which profit-maximizing farmers will produce cellulosic bioenergy crops,

2) Potential biomass supply and associated changes in ecosystem services linked to crop production.

RESEARCH QUESTIONS

- Under what price conditions would biomass production become attractive to profit-oriented farmers?
- What is the sequence of crop production systems and associated land uses as biomass supply increases?
- What are the environmental consequences of the changing crop production systems as biomass production increases?

MODEL STRUCTURE

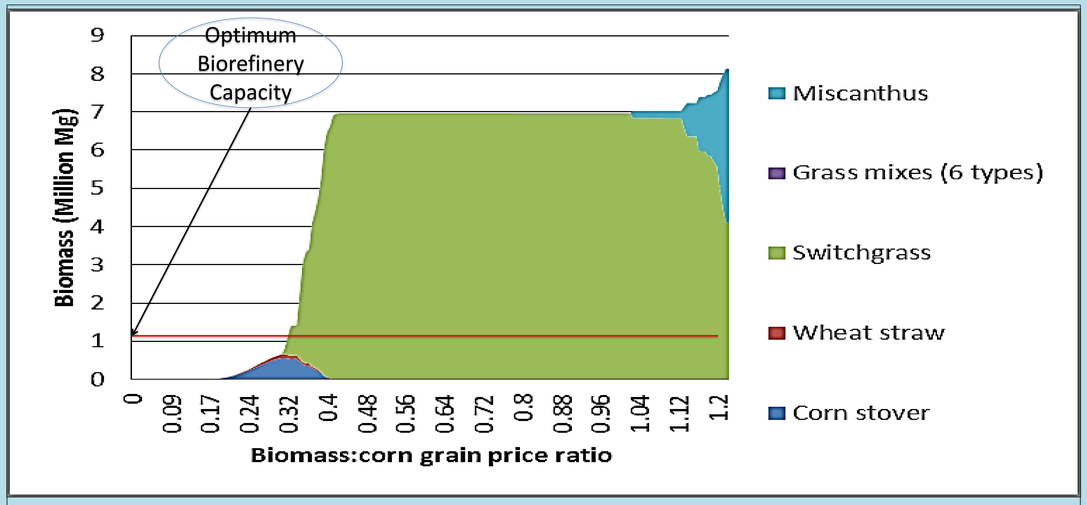


METHODS

The bioeconomic model uses mathematical programming to maximize expected profit from a set of crop production activities. Crop yields and associated environmental outcomes are simulated and linked to transportation costs and crop market prices.

- The Environmental Process Integrated Climate (EPIC) model simulates yield and environmental outcomes from 74 cropping systems in 37 watersheds (defined by 10-digit Hydrologic Unit Codes) covering 9 counties in southwest Michigan. To account for land quality, watersheds are divided into two groups of land capability classes. Biophysical simulation results are averaged across the 24 years, 1986-2009.
- Transport costs from the center of each watershed to a hypothetical biorefinery located in Kalamazoo are calculated using road network GIS data.
- Crop price parameters for all traditional crops are obtained from the USDA National Agricultural Statistics Service. Fertilizer input prices and production costs for each cropping system are calculated using data from Michigan State University Extension.
- EPIC-simulated yield data are validated against county-level observed yields reported by USDA-NASS. The whole bioeconomic model is calibrated to replicate observed mean land use values during the years 2007-2009 given the observed prices.

BIOMASS SUPPLY RESPONSE TO PRICE FOR S.W. MICHIGAN

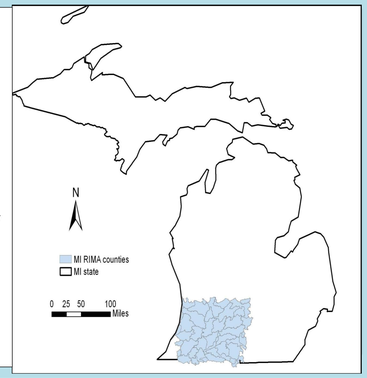


- Sequence of biomass sources depends on biomass:corn price ratio :
  - Crop residues (corn stover & wheat straw) (over 0.18 to 0.41).
  - Switchgrass (over price ratios of 0.31 to 1.03)
  - Miscanthus giganteus, the highest biomass yields (> 1.03)
- Price ratio benchmarks when biomass price is $60/Mg:
  - 0.44 price ratio if Corn price = $3.50/bushel
  - 0.22 price ratio if Corn price = $7.00/bushel

For details, see: Egbendewe-Mondzozo, A. et al.. 2010. "Biomass Supply from Alternative Cellulosic Crops and Crop Residues: A Preliminary Spatial Bioeconomic Modeling Approach." MSU Staff Paper 2010-07. (http://purl.umn.edu/98277).

MAP OF THE REGION

- 9 counties (Allegan, Eaton, Barry, Van Buren, Kalamazoo, Calhoun, Cass, St. Joseph, Branch)
- 37 watersheds, each divided into land capability classes I-IV (good) and V-VII (impeded productivity).



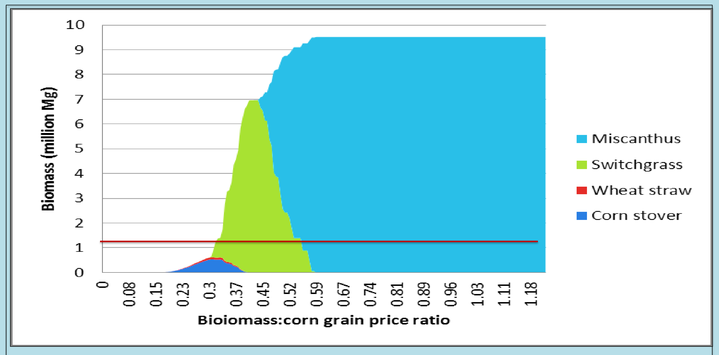
LAND USE IMPLICATION

- At lower prices, biomass demand via crop residues increases corn and wheat production land uses.
- At price ratios above 0.33, land use rapidly converts to switchgrass and other perennial grasses, with decreased grain crop production.

ENVIRONMENTAL IMPACTS

- Crop residues as biomass sources significantly increase greenhouse gas emissions (CO2 and N2O) and water-borne nutrient losses (NO3 and P).
- Perennial grass crops as bioenergy sources reduced both GHG emissions and water-borne nutrient losses.

IMPACT OF BCAP ON BIOMASS SUPPLY



Miscanthus becomes profitable at a price ratio of 0.42 under the USDA Biomass Crop Assistance Program (BCAP), which shares 75% of establishment costs, which alleviates the cost of expensive Miscanthus g. rhizomes.