Is the Price of Biomass Right for You? Calculating Your Cost of Producing Energy Crops and Crop Residues

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University of Illinois, Urbana-Champaign

Agenda

- Introduction and overview: Madhu Khanna
- Agronomics of energy crop production: Tom Voigt
- Key determinants of the profitability of biomass production: Madhu Khanna
- Introduction to the calculator and customization: Nick Paulson

Questions and Comments

- Please record any questions and comments you may have during the webinar and send them to khanna1@Illinois.edu
- Following the webinar, the presenters will provide responses to selected questions
- Slides from these presentations will be posted on farmdoc

Objective: To provide a decision tool

- Enabling farmers to calculate the break-even biomass price at which it would be profitable to
  - Convert land from an existing use to a dedicated energy crop
  - Select the most profitable dedicated energy crop to produce
  - Harvest crop residues
- Providing processors and aggregators of biomass information about likely costs of acquiring biomass or leasing land for vertically integrated production from different locations
- To analyze the profitability of biomass production with the Biomass Crop Assistance Program (BCAP)
- With inbuilt (default) values on crop yields and costs but customizable to individual needs
- Today's discussion will focus on
  - Two energy crops
    - Miscanthus and Switchgrass
  - Crop Residues: Corn stover

Background

- Over 10 years of experimental research at the 300 acre Energy Farm at the University of Illinois and several other locations in the rainfed US with Miscanthus and Switchgrass
- Calibration and validation of a biogeochemical model DayCent for rainfed US
  - Extrapolation of crop yield estimation to
    - Other locations, weather conditions, soil types, nitrogen fertilizer application rates

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USDA/NIFA
Energy Biosciences Institute, UC Berkeley
USDOE
Illinois Council for Food and Agr. Research

Calculator

- Available on-line and can be downloaded
- Excel-based
- Inbuilt data is at the county level
- Allows users to make choices agronomics, input application rates and costs, economic assumptions such as interest rates on loans, expected prices based on their site-specific information

Publications

- Dwivedi, P., W. Wang, T. Hudiburg, D. Jaiswal, W. Parton, S. Long, E. DeLucia, and M. Khanna, "Cost of Abating Greenhouse Gas Emissions with Cellulosic Ethanol. *Environmental Science and Technology*," 49(4): 2512-2522, 2015
- Song, Y., A. K. Jain, W. Landuyt, H.S. Kheshgi, and M. Khanna " Estimates of Biomass Yield for Perennial Bioenergy Grasses in the United States," *Bioenergy Research* doi 10.1007/s12155-014-9546-1, 2014
- Miao, R. and M. Khanna, "Are Bioenergy Crops Riskier than Corn? Implications for Biomass Price," *Choices*, 29(1), 6 pages, 2014
- Jain, A., M. Khanna, M. Erickson and H. Huang, "An Integrated Biogeochemical and Economic Analysis of Bioenergy Crops in the Midwestern United States," *Global Change Biology Bioenergy*, 2: 217–234, 2010
- Khanna, M., B. Dhungana and J. Clifton-Brown, "Costs of Producing Miscanthus and Switchgrass for Bioenergy in Illinois," *Biomass and Bioenergy*, 32: 482 – 493, 2008.
- Khanna, M., "Cellulosic Biofuels: Are They Economically Viable and Environmentally Sustainable?" *Choices*, 3rd Quarter 23(3): 16-21, 2008

Agronomics of Energy Crop Production

Tom Voigt

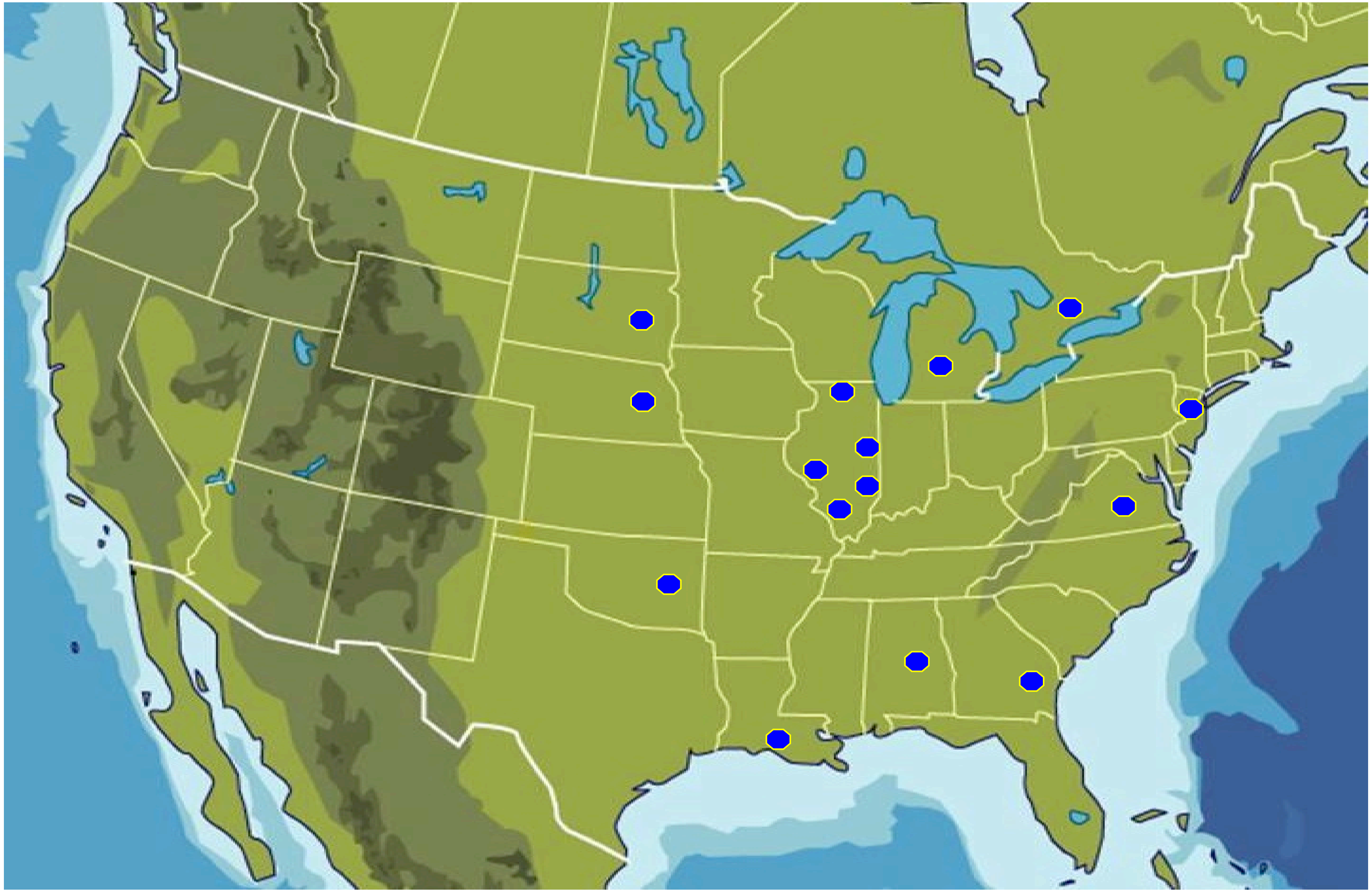
Professor, Department of Natural Resources and Environmental Sciences, University of Illinois

Switchgrass and Giant Miscanthus Agronomy

The goal of this presentation is to understand switchgrass and Miscanthus x *giganteus* (Mxg) *establishment and management.*

- **Switchgrass selection**
- **Establishment**
  - **Planting**
  - **Weed control**
- **Post establishment maintenance**
  - **Fertilizer application**
  - **Eradicating Mxg**
- **Harvest management**

Switchgrass and Giant Miscanthus Collaborative Research Sites



Switchgrass Characteristics

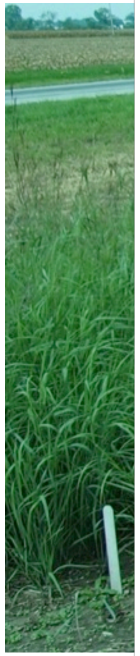
- Long-lived, native, warm-season, perennial sod-former.
- Eastern 2/3 of North America in tallgrass prairie.
- Extensive genetic variation related to latitude.
- Established by seed.
- Planted as energy crop, soil and water conservation, livestock feed, and wildlife habitat.
- Responds to N.
- Yields can average 6 dry tons or more per acre.

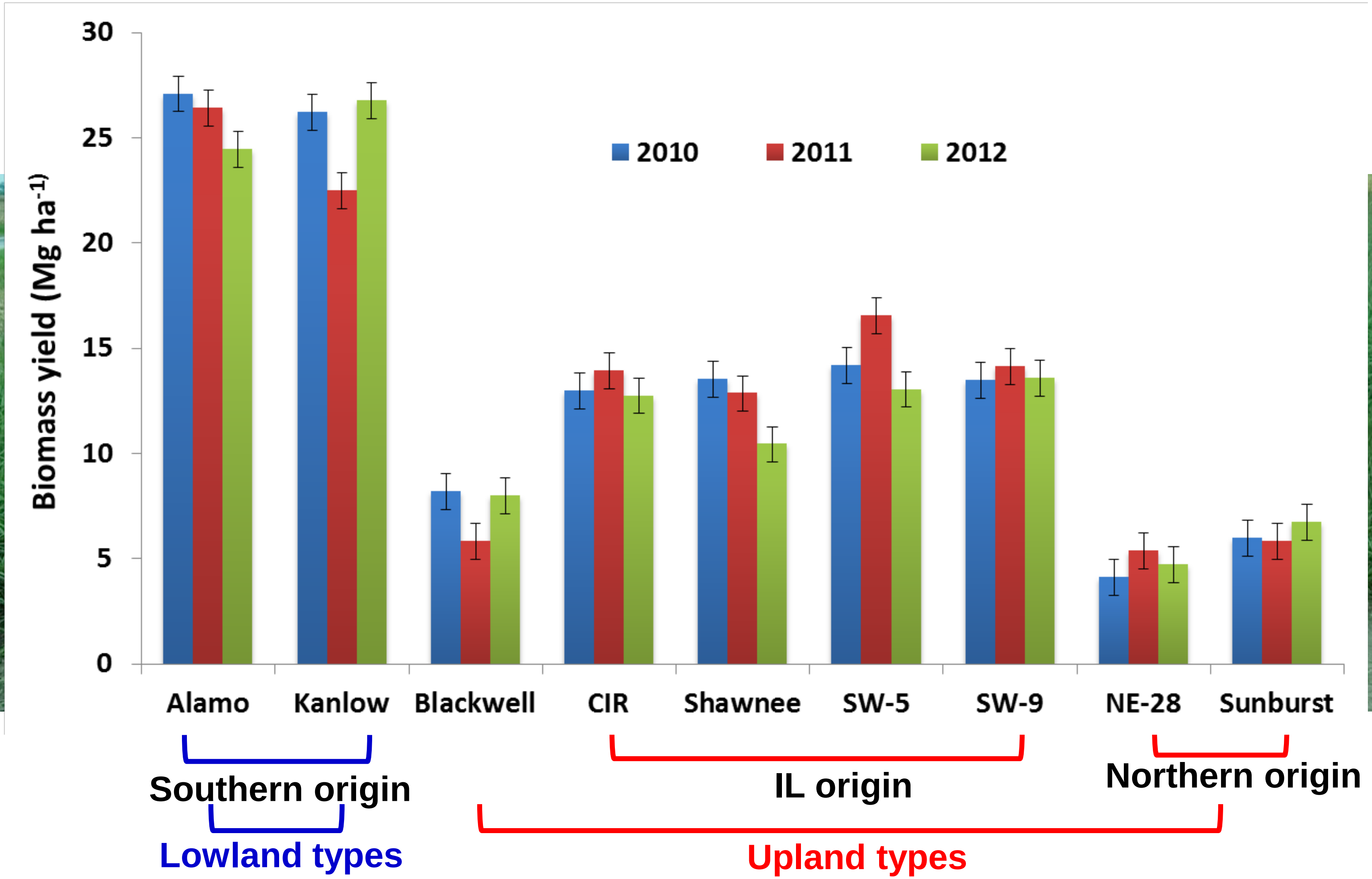
Switchgrass Selection

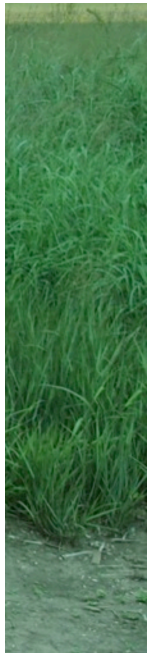
- **Factors to consider for choosing a cultivar**
  - **Yield potential**
  - **Adaptation**
  - **Feedstock quality**
- **Lowland and upland types**
- **Kanlow, Blade EG-1102 good selections for IL**

Biomass Potential of Switchgrass

Cultivar selection







Switchgrass Planting

Successful switchgrass establishment

- Plant high quality seed
- Develop a firm seedbed
- Use a well calibrated drill
- Seed usually planted 1/4-1/2 inch deep
- Plant 2-3 weeks before or after corn
- Control weeds early
- Plant before a rainy period
- Stands with densities less than 10 plants per square meter should be over-seeded or reseeded

Switchgrass Seeding Equipment

JOHN DEERE 750 with Small Seed Box

Brillion Drop Seeder with Packing wheel

Great Plains Grass drill

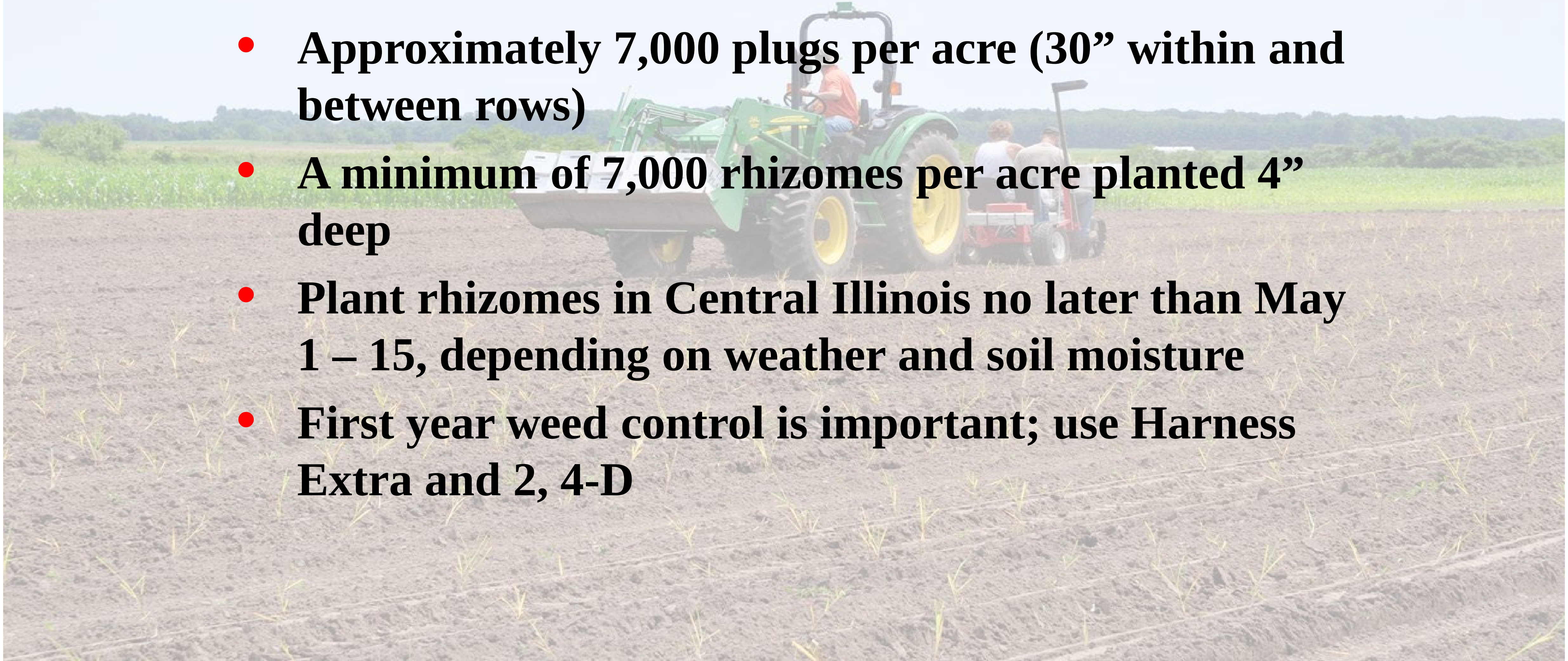
Giant Miscanthus
(*Miscanthus x giganteus* or Mxg)

- **Long-lived, sterile, warm-season, perennial sod-former, Asian native**
- **At present, a single genotype**
- **Established vegetatively.**
- **Planted for energy production and absorbency**
- **Occasional responds to N**
- **Yields typically average 7-10 dry tons per acre**

Giant Miscanthus

Miscanthus x *giganteus* is planted vegetatively

- Approximately 7,000 plugs per acre (30” within and between rows)
- A minimum of 7,000 rhizomes per acre planted 4” deep
- Plant rhizomes in Central Illinois no later than May 1 – 15, depending on weather and soil moisture
- First year weed control is important; use Harness Extra and 2, 4-D



Miscanthus x giganteus Planting

Miscanthus x *giganteus*
Next generation planter (30+ acres per day)

Establishment Summary

- Select the best grass for your area and needs
- Plant high quality seed/or vegetative material at the optimal timing
- Prepare a firm seedbed for seeding switchgrass, a tilled bed for Mxg rhizomes and plugs
- Control weeds

Fertilizer Management

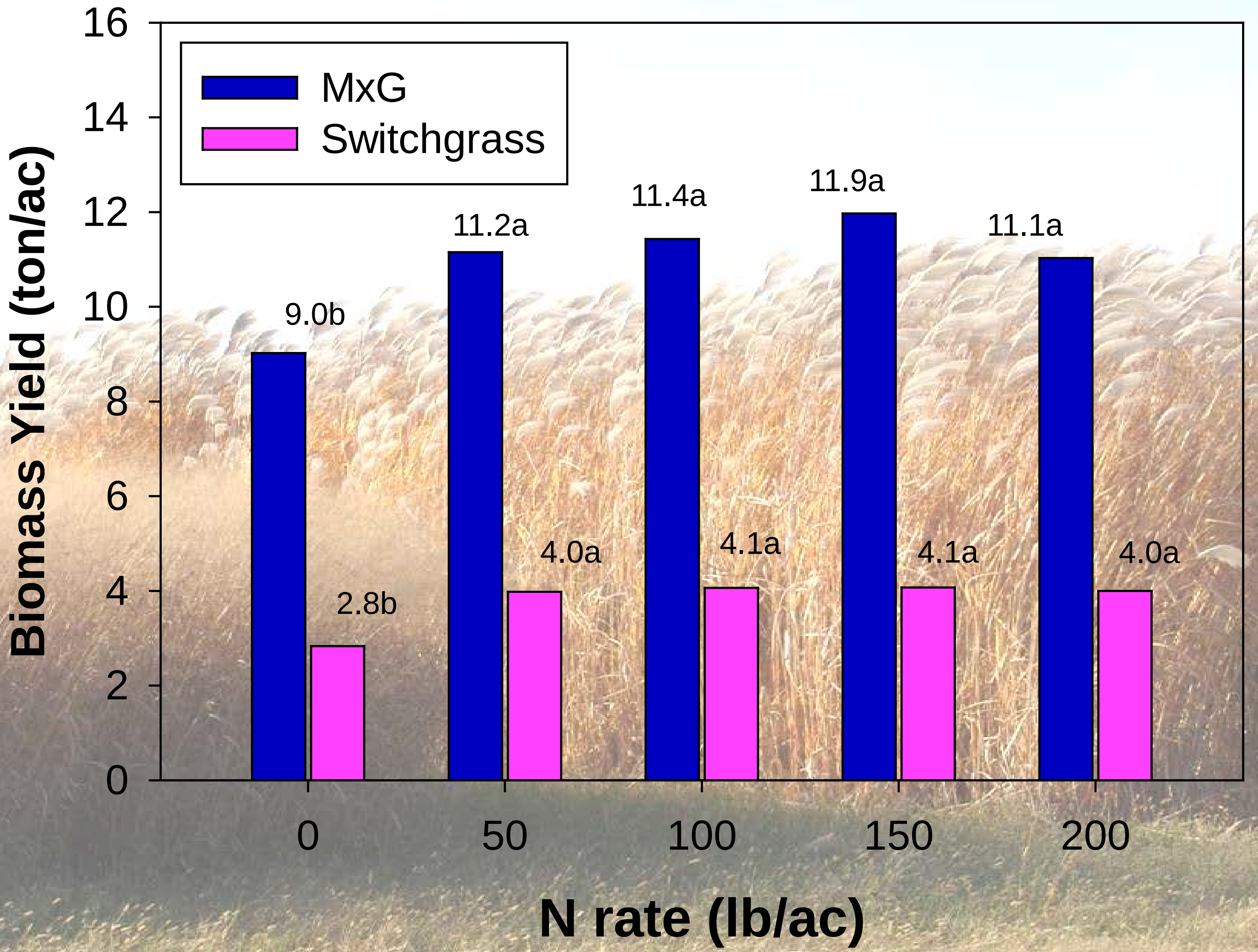
- Energy crop fertilizer recommendations are function of:
  - Site productivity
  - Species/cultivar yield potential
  - Time of harvest
- Most warm-season (C4) grasses tolerate low soil fertility, but may require fertilization to optimize biomass and maintain stand persistence
- The primary limiting nutrient for grass biomass is nitrogen
- Warm-season grass responses to phosphorus P and potassium have been variable and existing levels are generally adequate on most cropland soils
- Apply P and K before planting and incorporate into soil
- Continuous biomass production depletes soil P and K and application may be necessary for long-term biomass production

Nitrogen Management

- Time of N application
  - apply just prior to period of most rapid growth (May in IL)
  - do not apply during establishment year
  - early spring or late summer encourages cool-season species

- N Application rates
  - Usually, 40 - 75 lbs./acre depending on moisture and use

Miscanthus and switchgrass response to N rate



Harvest Management

Timing and Frequency

The primary objectives of harvest management are:

- **Maximize biomass recovery**
- **Match feedstock quality to the conversion platform**
- **Maintain productive stand**

Harvest Timing and Frequency

Recommendations

- Early harvests, before senescence, often lead to crop deterioration
- Switchgrass: A single annual harvest after a killing frost is the best for nutrient recycling and stand sustainability and feedstock quality
- Mxg: A single annual harvest during the winter and early spring following full senescence and prior to the onset of spring emergence, Mid December through March in Illinois
- Harvesting at peak standing crop could have negative impacts on stand health and longevity

Harvesting

Eradicating Giant Miscanthus

Roundup 1 application

Roundup 2 applications

No application

Management and Harvest Summary

- Control weeds as necessary – usually little need on well-established energy grasses
- Supply minerals, especially N, as necessary. Usually annually for switchgrass, while giant miscanthus is less predictable
- A combination of glyphosate and tillage is used to eradicate giant miscanthus
- A single annual harvest after a killing frost (switchgrass) or following full senescence (Mxg) is desirable
- Bales store more easily than chopped material

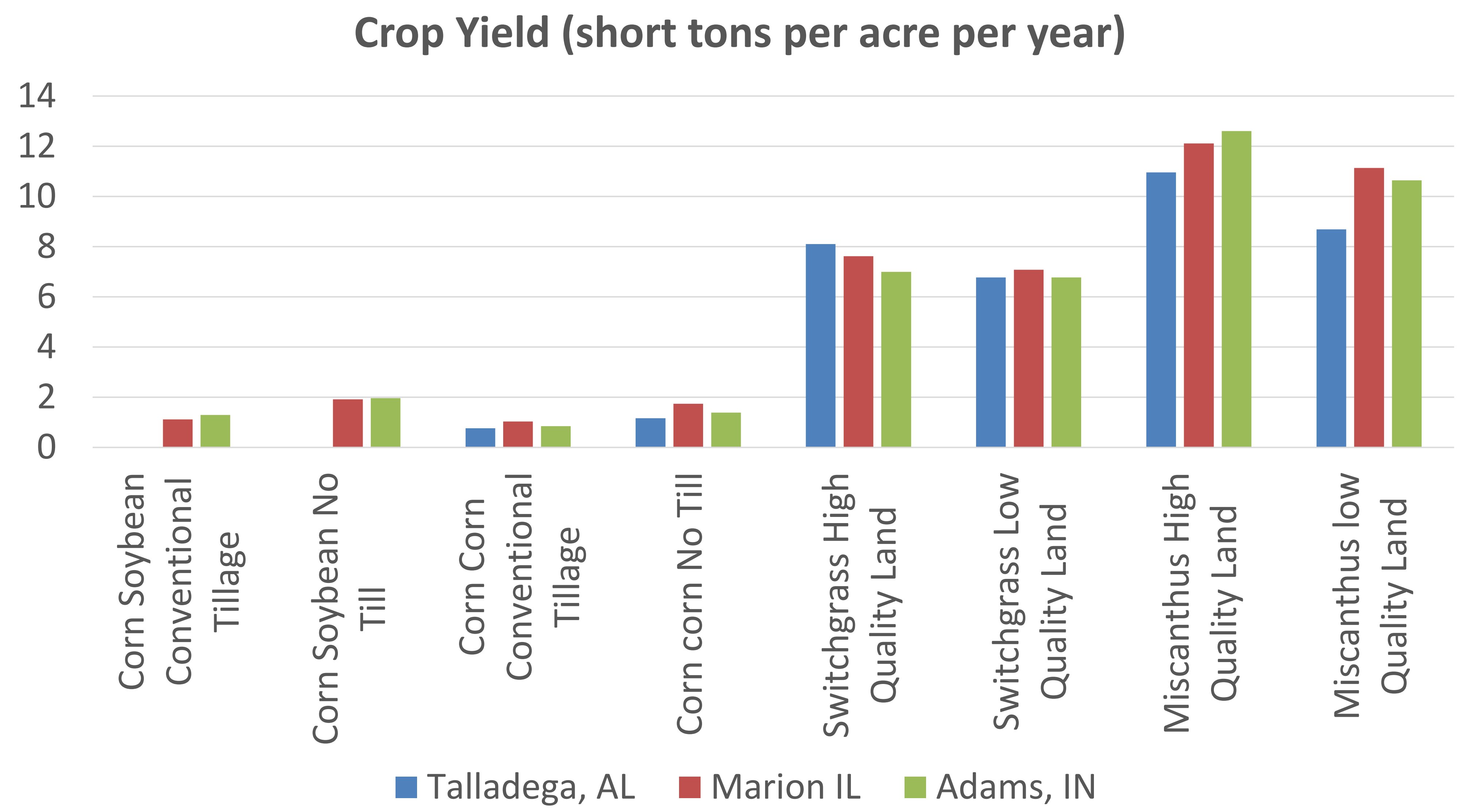
Factors Affecting the Cost of Biomass Production

Madhu Khanna

Professor, Department of Agricultural and Consumer Economics, University of Illinois

Miscanthus and Switchgrass: Yields

- Perennials: life-span of 10-20 years
- Establishment period 1-3 years with reduced yield
- Harvested yields vary across counties and with weather conditions over time
  - Yield varies across land quality
  - High quality cropland and low quality pastureland



Crop Yield (short tons per acre per year)
14
12
10
8
6
4
2
0
Corn Soybean Conventional Tillage
Corn Soybean No Till
Corn Corn Conventional Tillage
Corn corn No Till
Switchgrass High Quality Land
Switchgrass Low Quality Land
Miscanthus High Quality Land
Miscanthus low Quality Land
Talladega, AL
Marion IL
Adams, IN

Miscanthus

Corn

Marginal Land

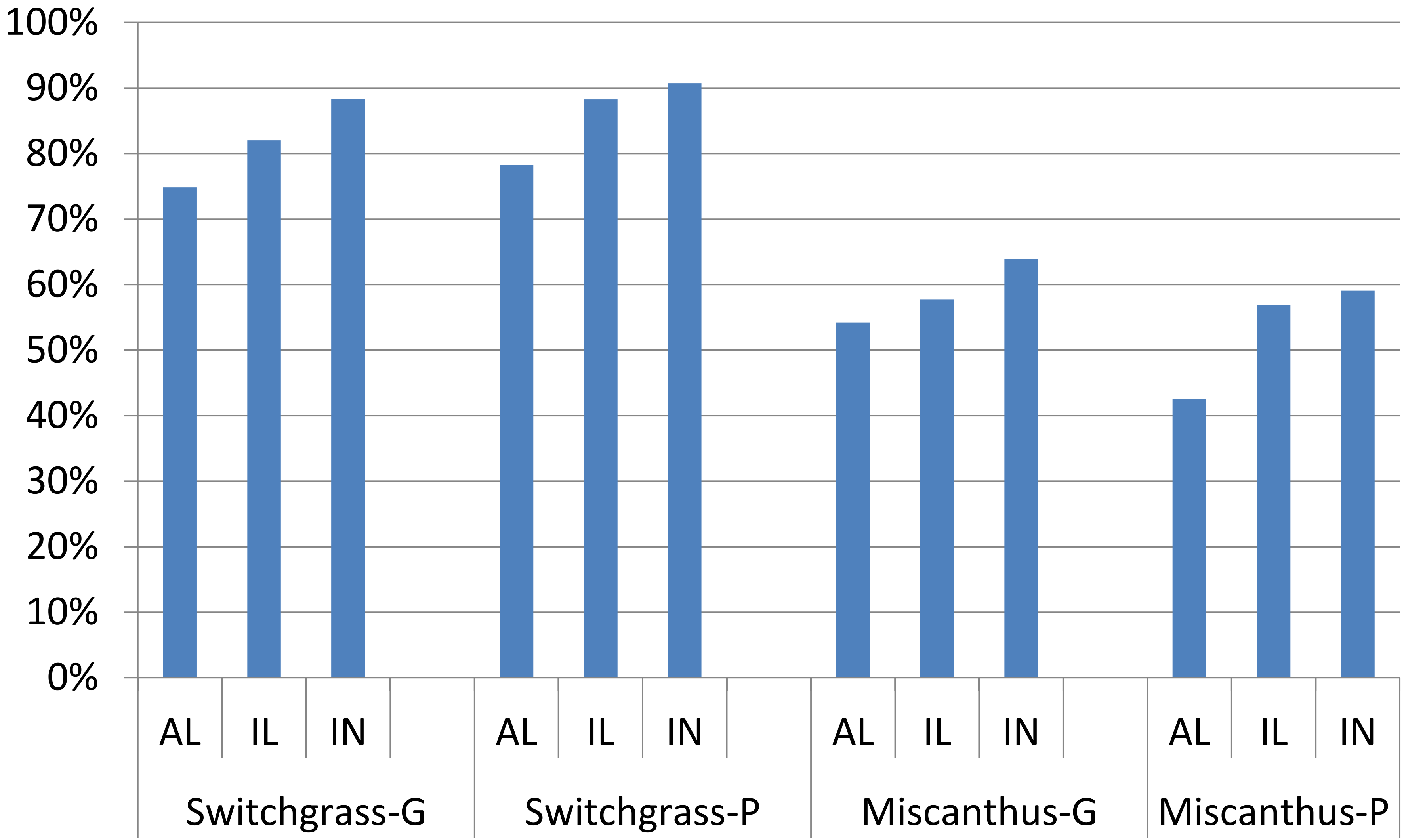
Cropland

Switchgrass

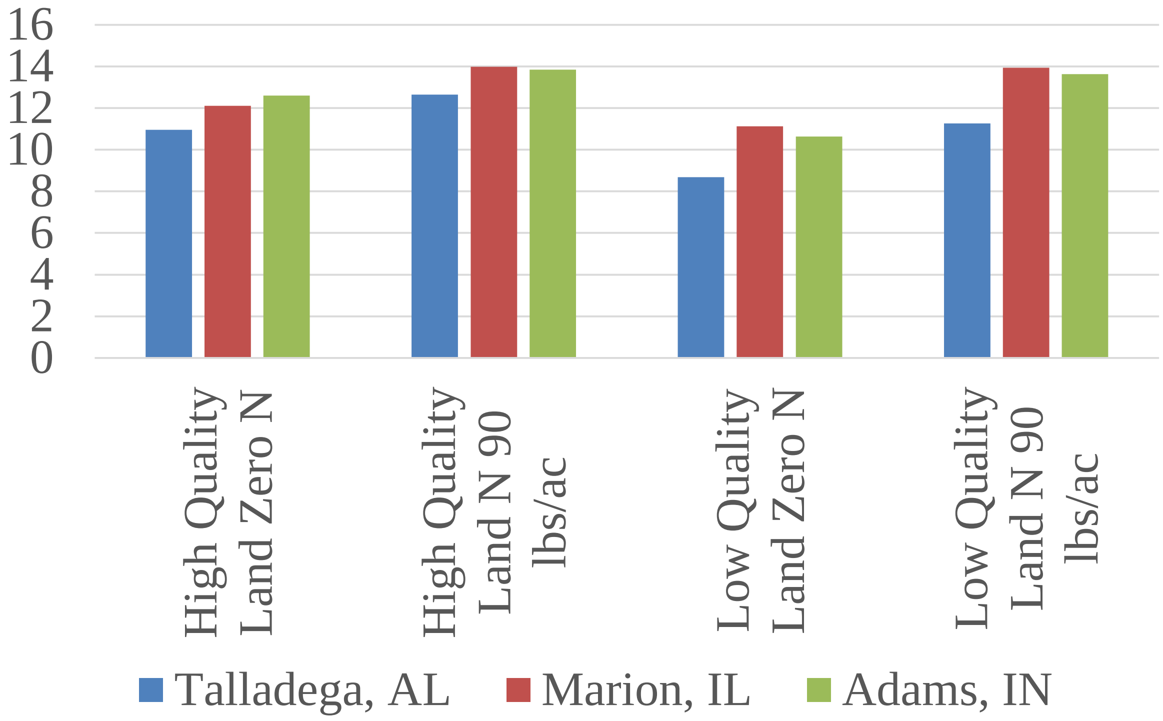
Soybean

County-level Average Yield with 30 years of Weather Data Using DAYCENT Model (short tons per acre)

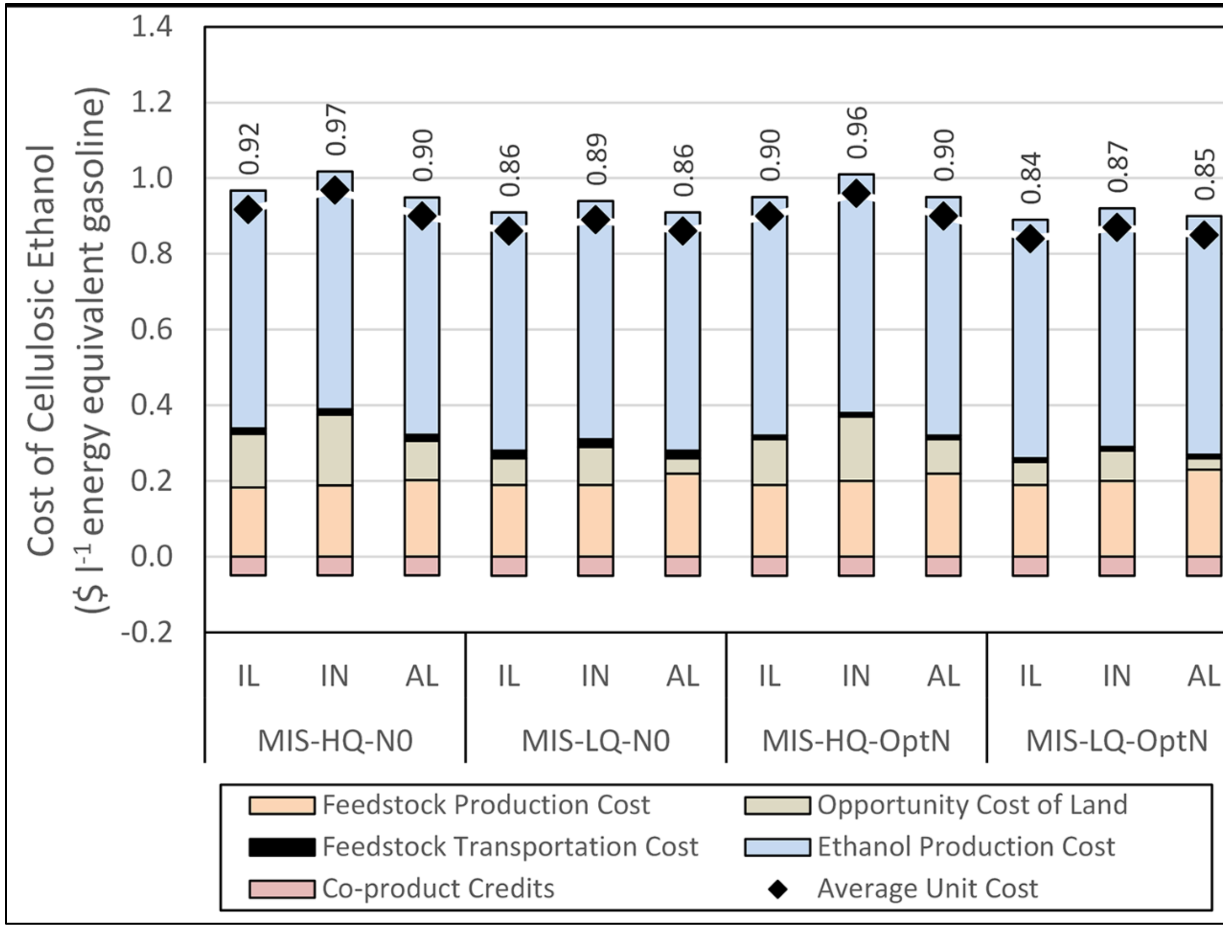
Ease of Establishment: Second Year Yield as a % of Average Yield



Effect of N Application on Miscanthus Yield (short tons/acre)



Effect of N Application on Cost of Miscanthus Production



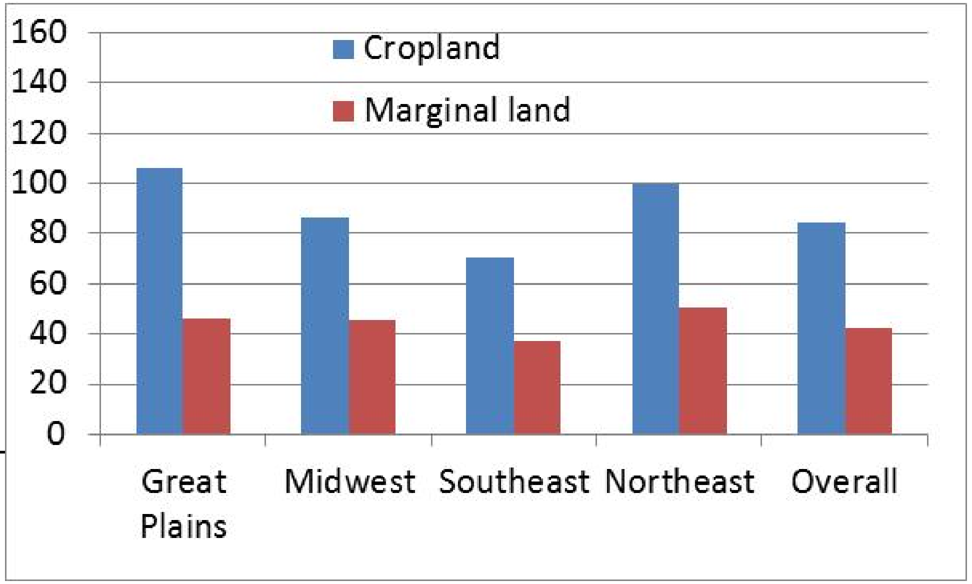
Costs of Production

- Establishment cost
  - Particularly high in the case of miscanthus, planted using rhizomes
  - Upfront cost
  - Involves a trade-off between upfront costs and returns to be earned in later years
  - Discount rate converts future returns to present value

- Opportunity cost of land
  - Could be different from the cash rent of the land
  - Highest foregone returns that could be earned with an alternative use of the land
  - Higher for cropland than for grazing/pastureland
  - Profits from corn/soybean for cropland
  - CRP soil rental payment for grazing/pastureland

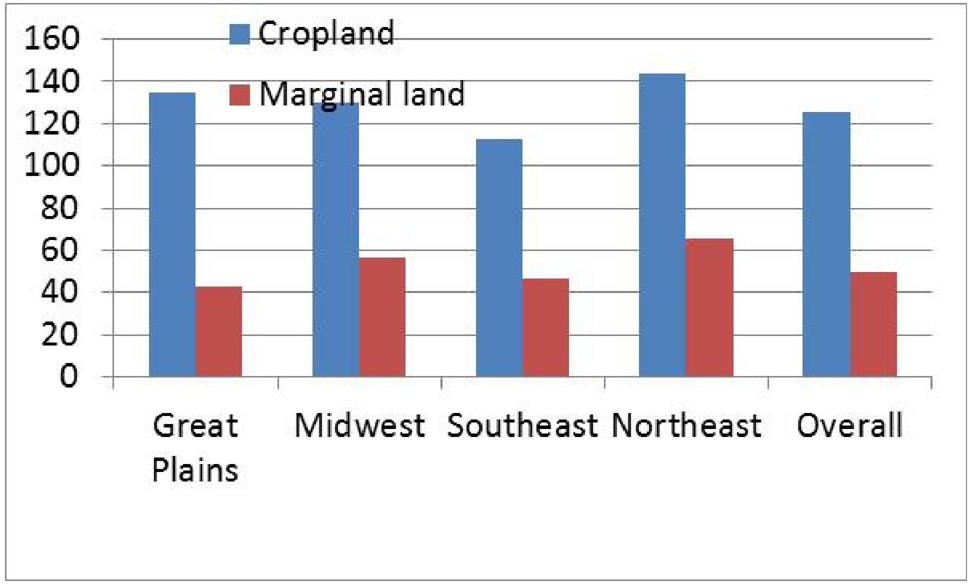
Breakeven Prices of Miscanthus and Switchgrass $ per ton

Miscanthus

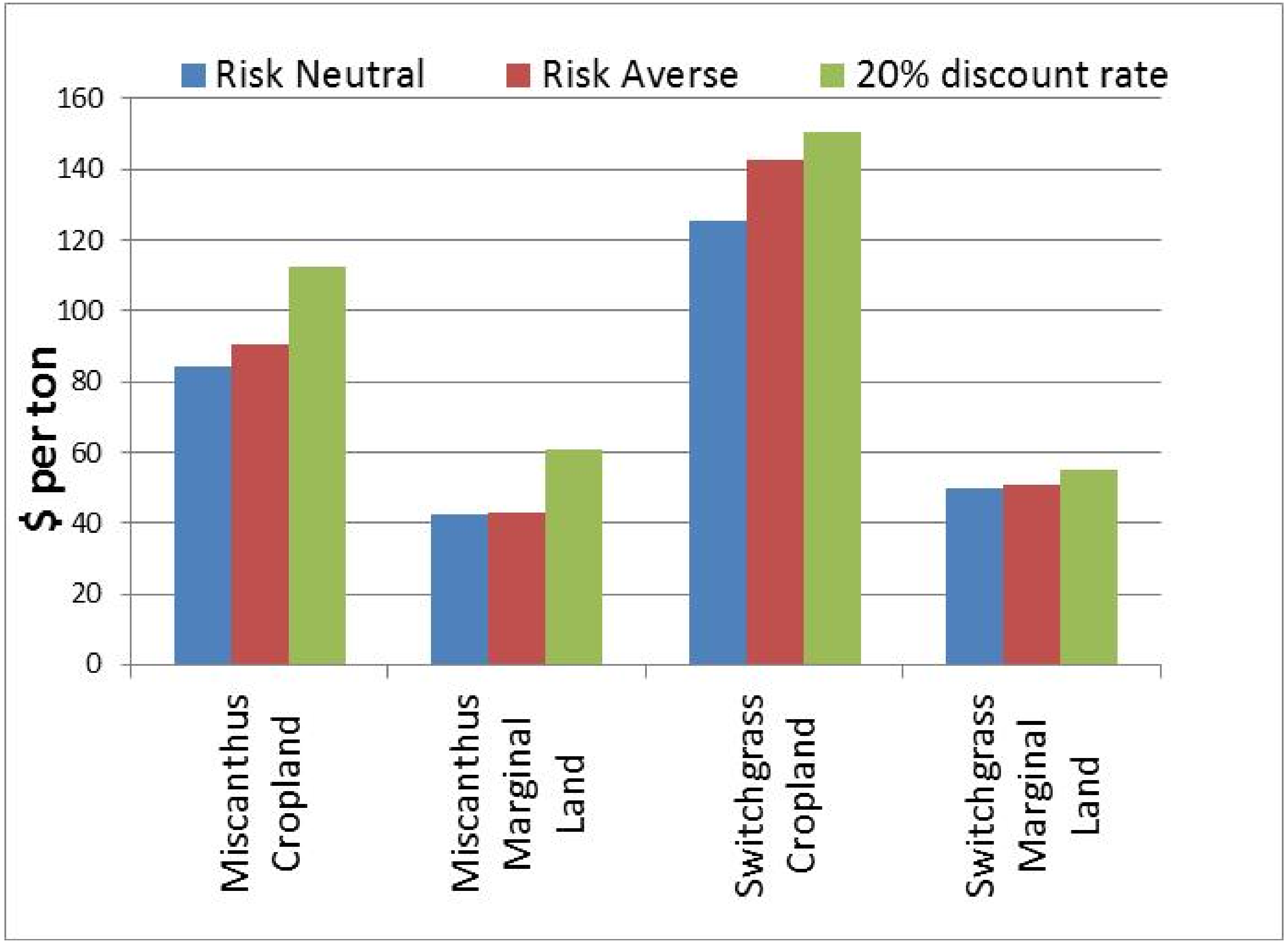


Marginal Land Cropland

Switchgrass



Risk and Time Preference Effects on Costs of Biomass Production



Corn Stover Production Practices

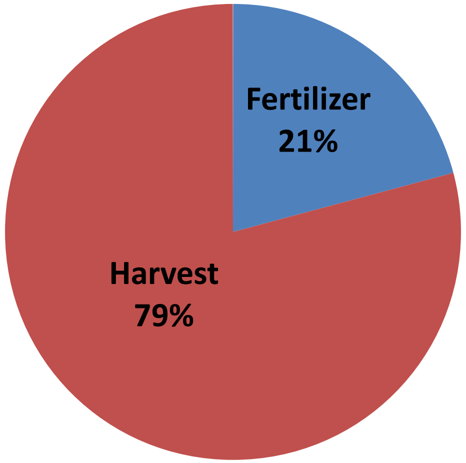
- Corn stover yield to grain ratio can vary from 0.7 to 2
  - Studies suggest it may decrease with yields
- Sustainable harvest to yield ratios vary across studies from 30% to 60%
  - While maintaining soil organic matter and preventing soil erosion
  - Higher with no-till than with conventional tillage
  - Assume here to be 30% with conventional tillage and 50% with no till
- Replacement nitrogen needs to be applied to compensate for nitrogen taken away with the stover
- Assuming there is no change in rotation or tillage practice due to corn stover production
  - if there is a loss of profitability due to change in crop rotation or tillage then that loss is an added cost of stover production

Breakeven Price Calculation

- Breakeven price is the price that would be needed each year of the life of the energy crop to ensure that the present value of the revenues is equated to the present value of the costs of production.
- It will decrease
  - If the lifespan of the crop is longer
  - Yield is higher
  - Establishment cost is lower
  - Opportunity cost of land is lower
  - Discount rate is lower
- For corn stover: Breakeven price is the price needed to just cover the incremental costs of collecting, harvesting and storing corn stover and adding replacement fertilizer. It decreases
  - With yield
  - With collection rates: No-till practice
  - If rotation remains the most profitable choice

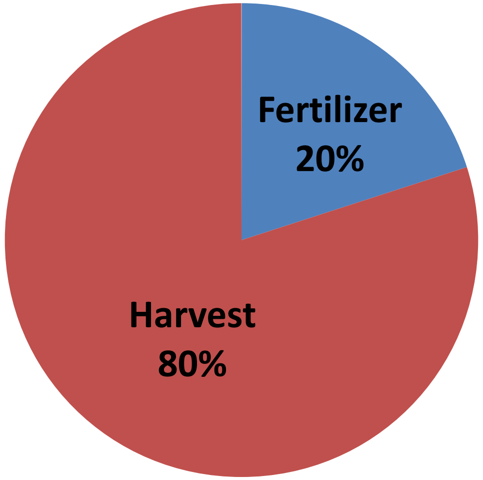
Cost of Production of Corn Stover in Marion, IL

Corn Stover, Conventional Tillage (Corn_soybean rotation)



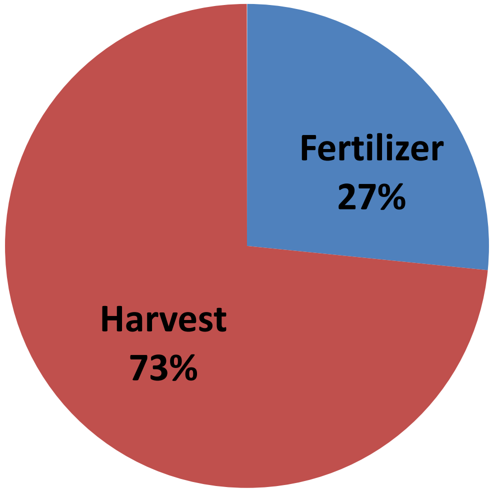
$70/Mg

Corn Stover, Conventional Tillage (Corn_corn rotation)



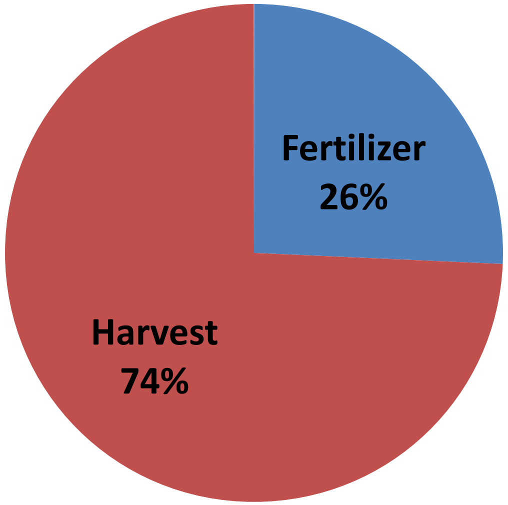
$74/Mg

Corn Stover, No Tillage (Corn_soybean rotation)



$55/Mg

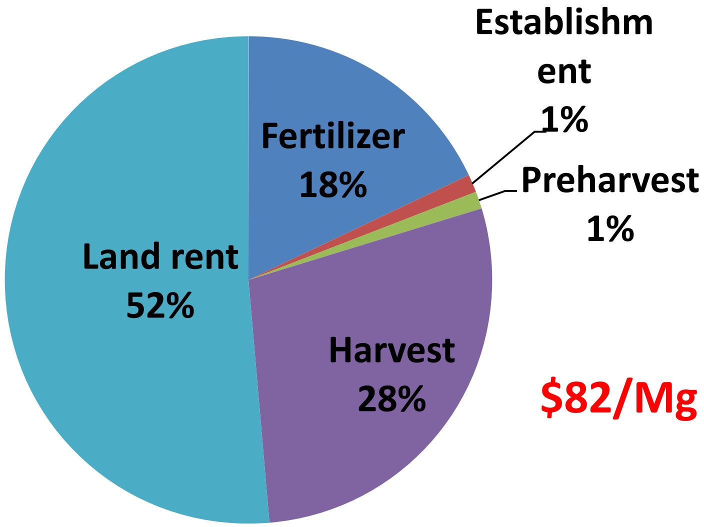
Corn Stover, No Tillage (Corn_corn rotation)



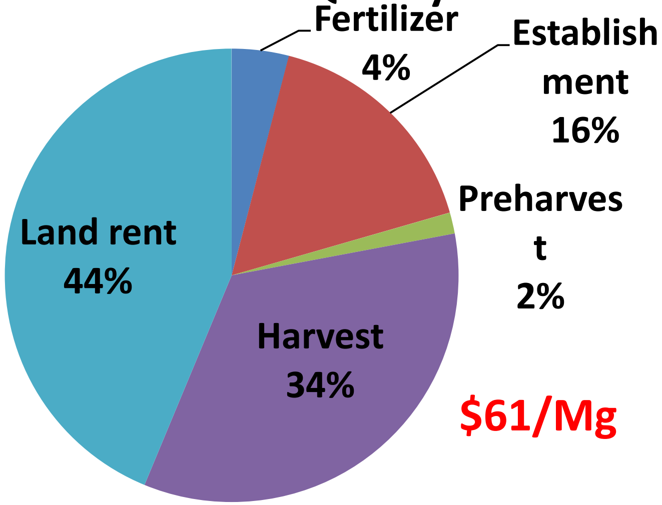
$58/Mg

Cost of Producing Energy Grasses in Marion, IL

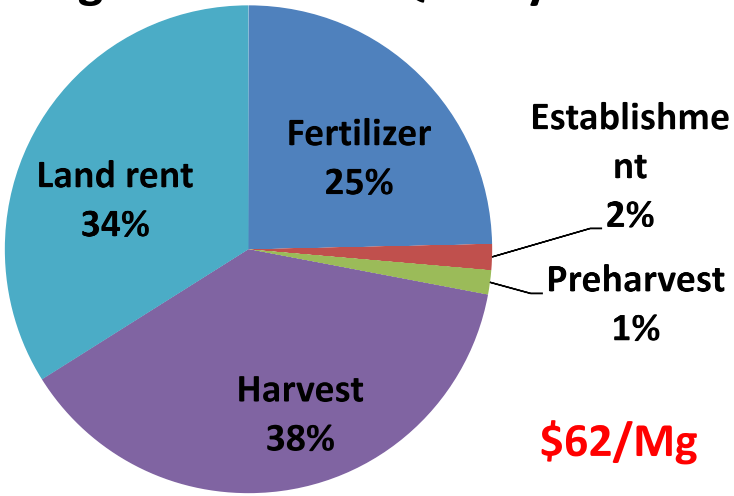
Switchgrass on Good Quality Land



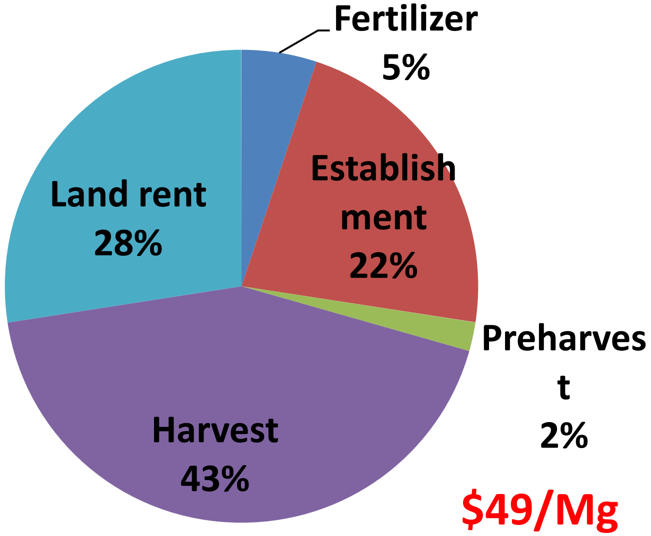
Miscanthus on Good Quality Land



Switchgrass on Poor Quality Land



Miscanthus on Poor Quality Land



Using the Feedstock Cost and Profitability Calculator

Nick Paulson
Associate Professor, Department of Agricultural and Consumer Economics
University of Illinois

Calculator Overview

- Excel-based, similar to *FAST* tools available through the *farmdoc* extension project website
  - Users will be able to download and use on their own computers or devices that can run Excel
- Inputs
  - Required: State and county, energy crop choice, current crop rotation or land use
  - Various optional inputs to tailor to current prices and individual farm's productivity and cost structure
- Outputs
  - Current crop budget
  - Energy crop budget and breakeven biomass price
  - BCAP program incentives and adjusted breakeven biomass price

Calculator Inputs

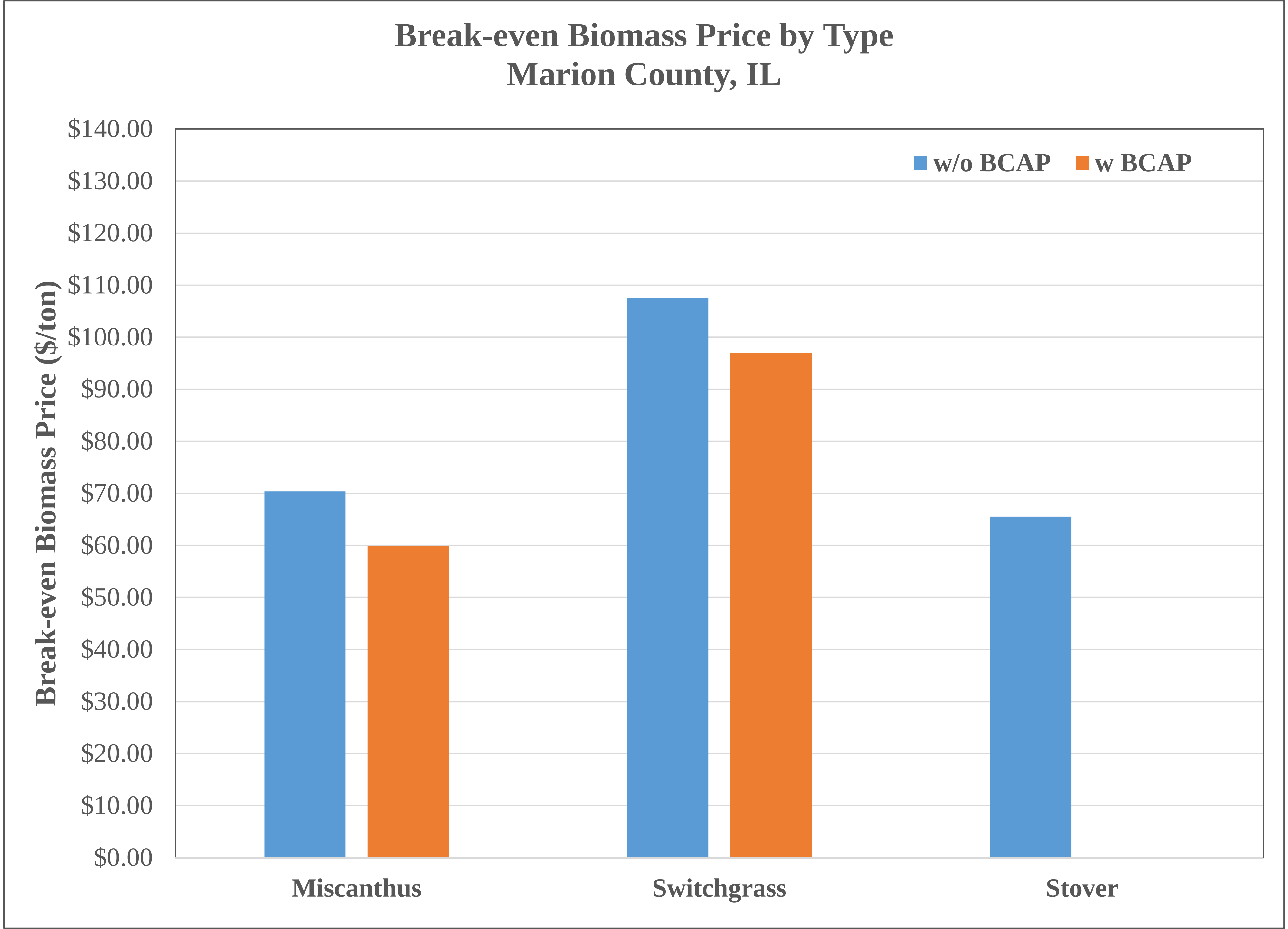
- Drop-down selection menus for:
  - State and county
  - Energy crop
  - Current crop rotation or land use
- Built-in default values are automatically loaded based on the location and crop selections
  - Users can change these values to tailor to their farm operation

Calculator Outputs

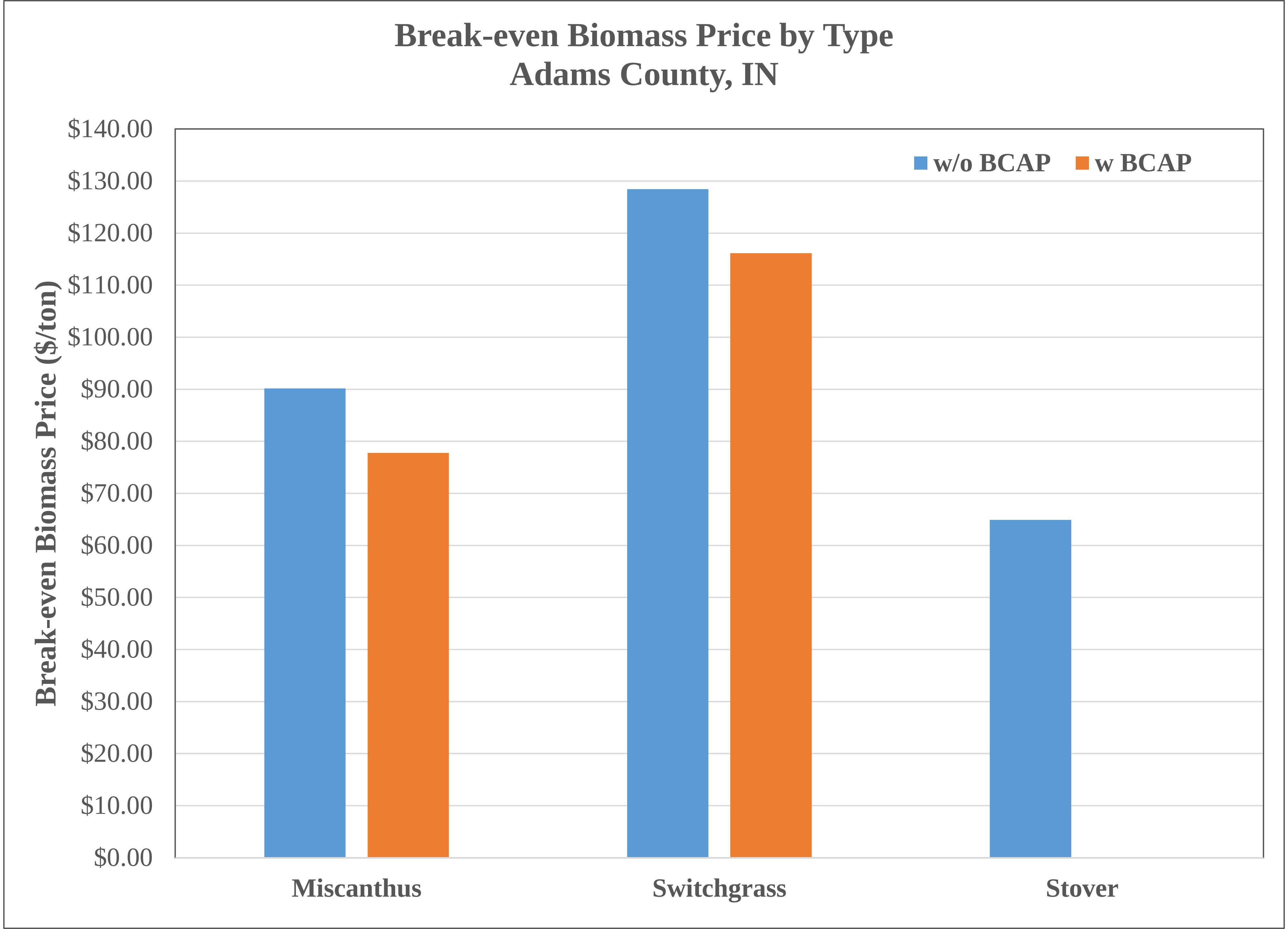
- Detailed, per-acre production budgets for current crops
  - Revenues
  - Expenses
  - Total Return
- Detailed, per-acre production budget for the energy crop
  - Yield
  - Inputs
  - Pre-harvest and Harvest Expenses
  - Land costs (opportunity cost from current crop, or CRP payment)
  - If applicable, estimated BCAP support
  - All used to generate a break-even biomass price (with BCAP if applicable)

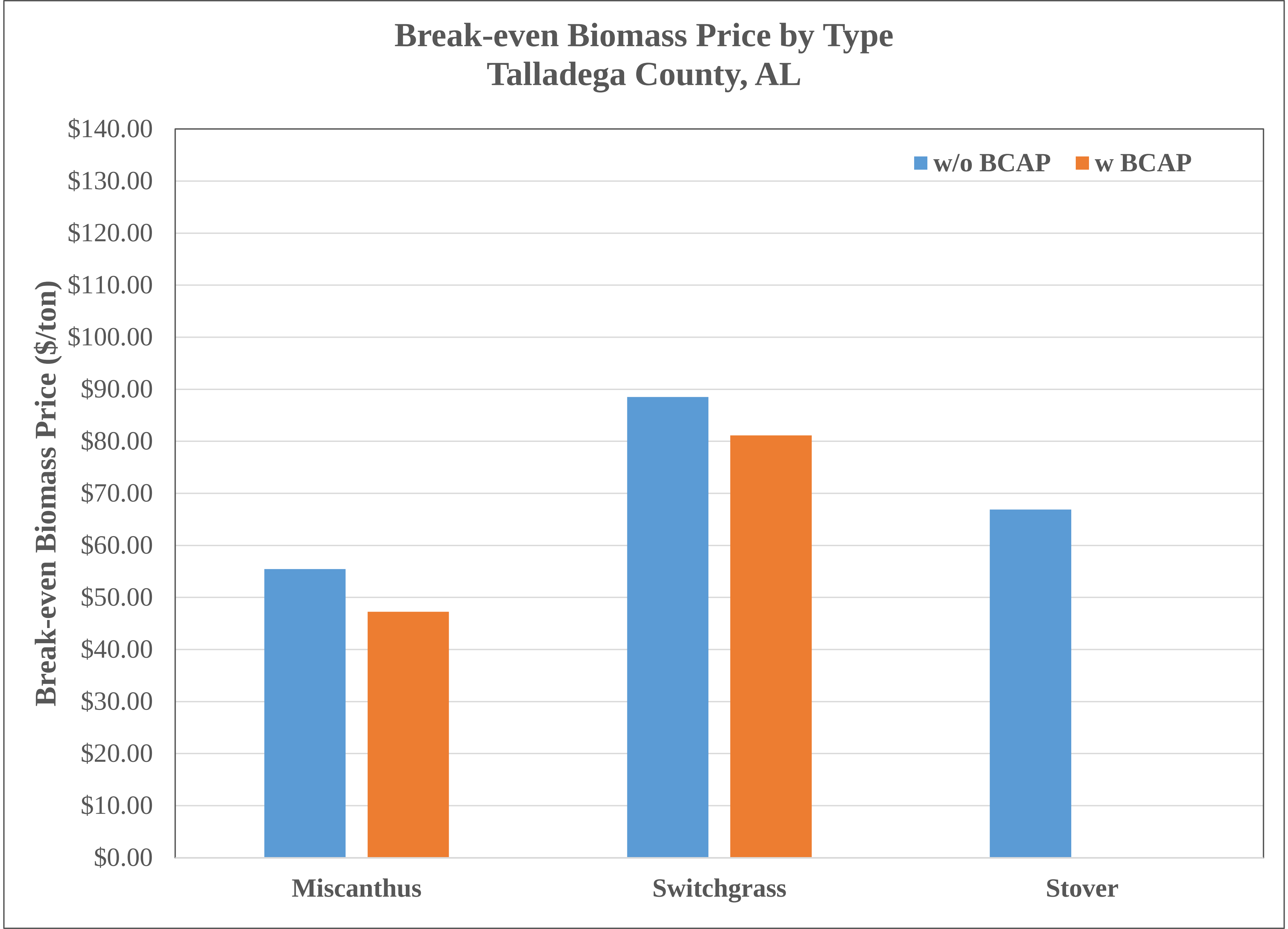
Biomass Crop Assistance Program

- The availability of BCAP payments will lower the breakeven price needed to cover the costs of production.
- Features of BCAP built into the calculation
- Matching payments: $20 per ton for up to 2 years
- Establishment cost share: 50% with a cap of $500 per acre
- Annual payments for up to 5 years
  - Based on CRP rental rates for cropland
  - Based on pastureland rental rates for cropland-pasture
  - Reduced once harvesting starts depending on the type of facility the biomass is being sold to



Break-even Biomass Price by Type
Marion County, IL
Break-even Biomass Price ($/ton)
$140.00
$130.00
$120.00
$110.00
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
w/o BCAP
w BCAP
Miscanthus
Switchgrass
Stover


Break-even Biomass Price by Type
Adams County, IN
Break-even Biomass Price ($/ton)
$140.00
$130.00
$120.00
$110.00
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
w/o BCAP
w BCAP
Miscanthus
Switchgrass
Stover


Break-even Biomass Price by Type
Talladega County, AL
Break-even Biomass Price ($/ton)
$140.00
$130.00
$120.00
$110.00
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
w/o BCAP
w BCAP
Miscanthus
Switchgrass
Stover

Planned Additions to the Calculator

Energy crop production and crop residues relative to conventional use of land:

- Riskiness of annual returns
- Value of soil carbon credits
- Life-cycle greenhouse gas intensity of ethanol