# Bioenergy Crops in Illinois : Competitiveness and Non-Market Benefits

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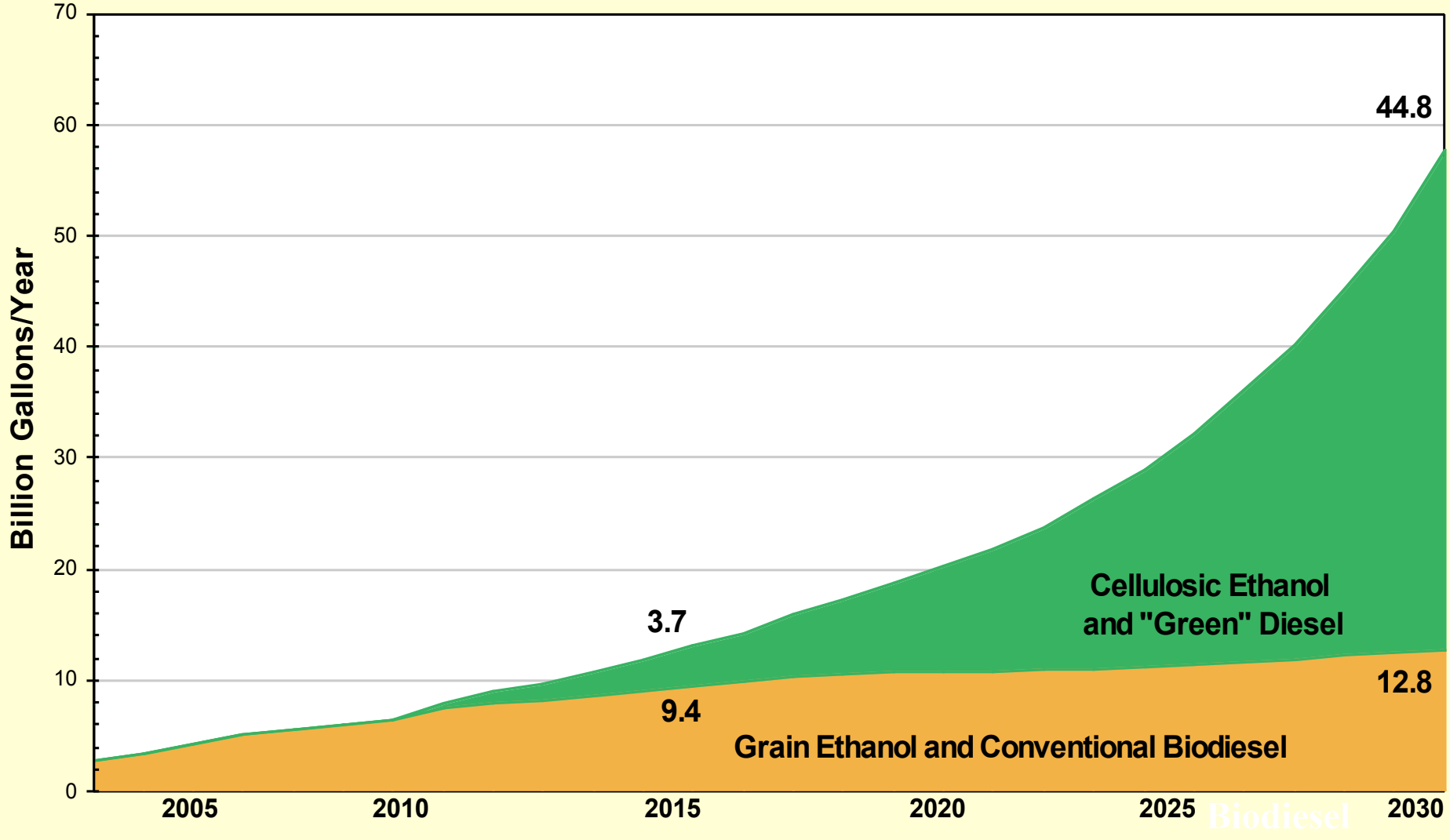
# Required Growth of Cellulosic Ethanol to Supply 30% of U.S. Gasoline Demand by 2030

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Source: Stanley R. Bull, NREL

# Two "Model" Crops for Biofuel Production: Switchgrass and Miscanthus

Adaptable to wide range of growing conditions

- High yielding perennials
- Low initial and annual input requirements; translocate inputs to roots
- Compatible with row crop production
  - — require conventional equipment; winter harvests

Source: Miscanthus and Switchgrass at experimental fields at the University of Illinois

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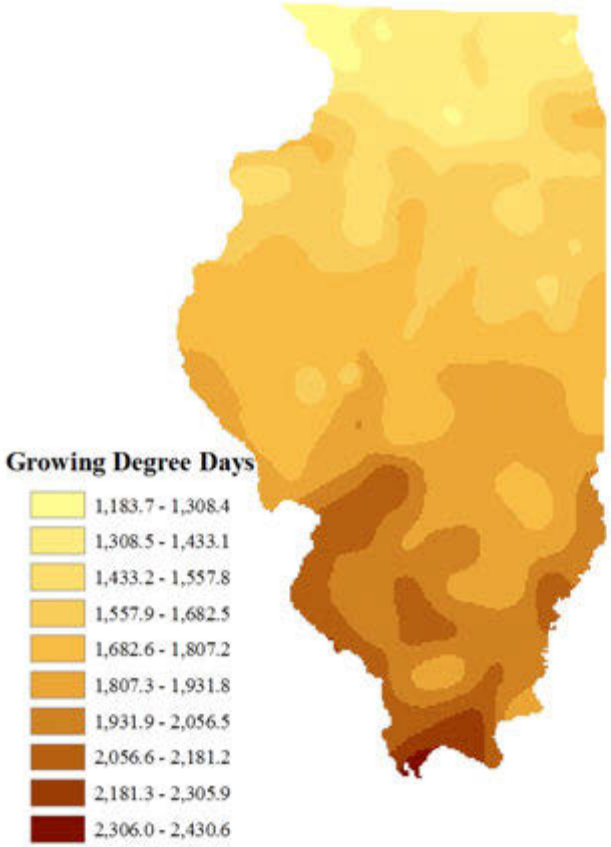
# Economic Potential of Bioenergy Crops

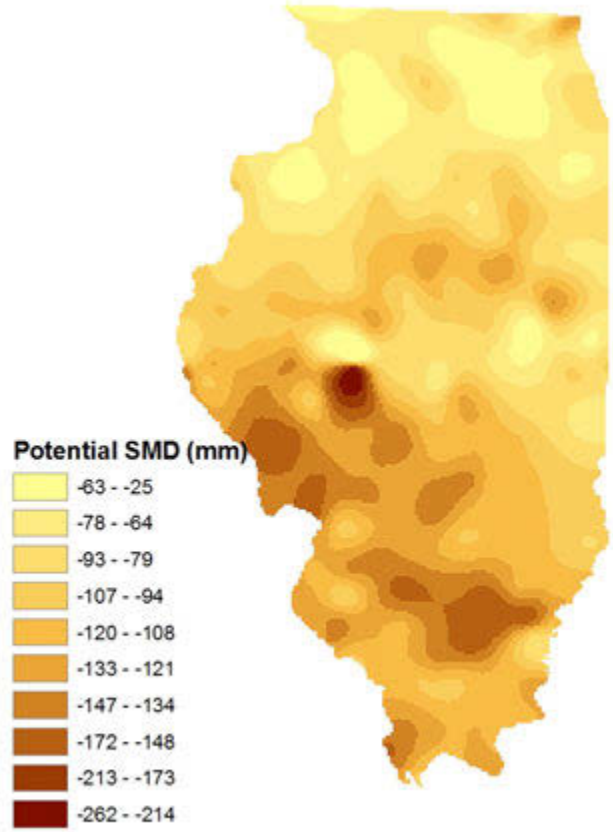
- Competition with row crops for land
  - Yield per hectare
  - Costs of production
  - Opportunity cost of land
    - Depends on row crop prices
- Competition with fossil fuels/corn ethanol
  - Energy content relative to gasoline
  - Cost of conversion to usable fuel
  - Price of gasoline and corn-ethanol
  - Non-market benefits of bioenergy crops/fuels
  - Policy induced value of non-market benefits

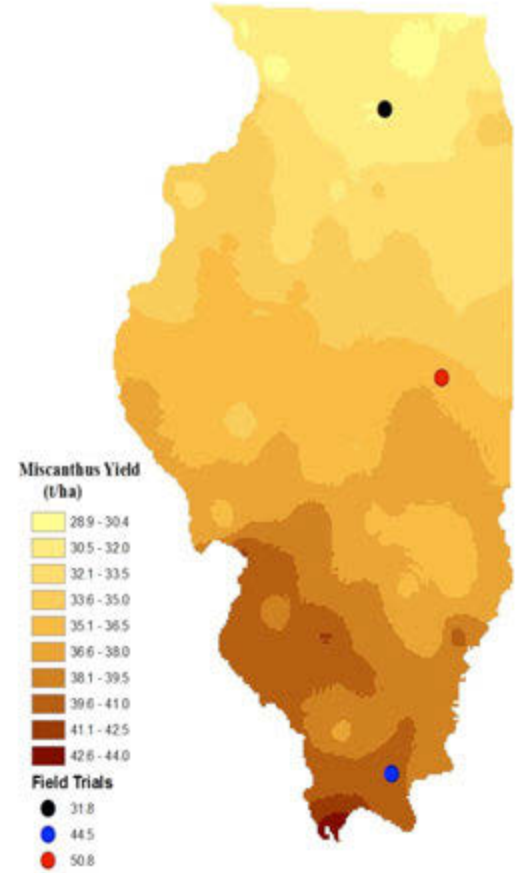
# Issues Addressed

- Profitability of growing bioenergy crops in Illinois
- Spatial variability in profitability
- Competitiveness of biofuels
- Life cycle carbon emissions of alternative fuels
  - Implications of carbon prices for net costs of production of biofuels with alternative feedstocks

# Growing Conditions for Miscanthus in Illinois




- Yield of Miscanthus simulated using 30 year climate data on solar radiation, temperature, frost dates, precipitation, soil evaporation and water holding capacity at 2 sq km level
- Temperature most important factor in leaf expansion with optimal water and nutrients

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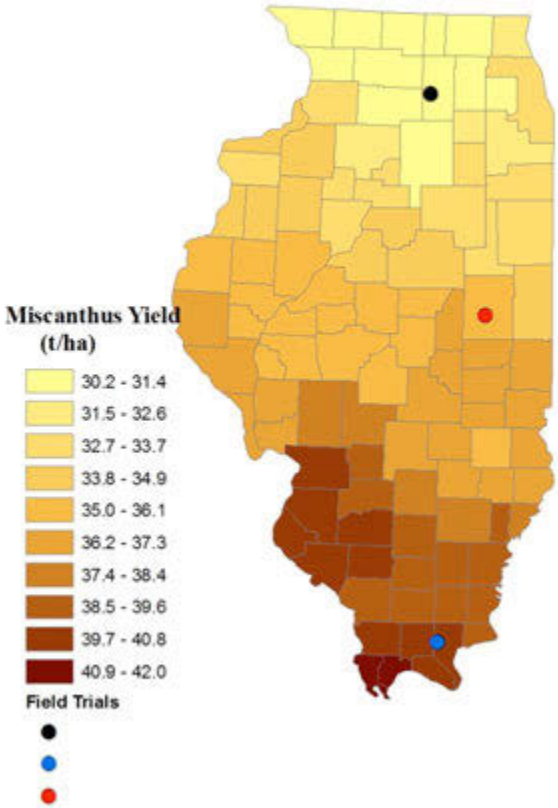
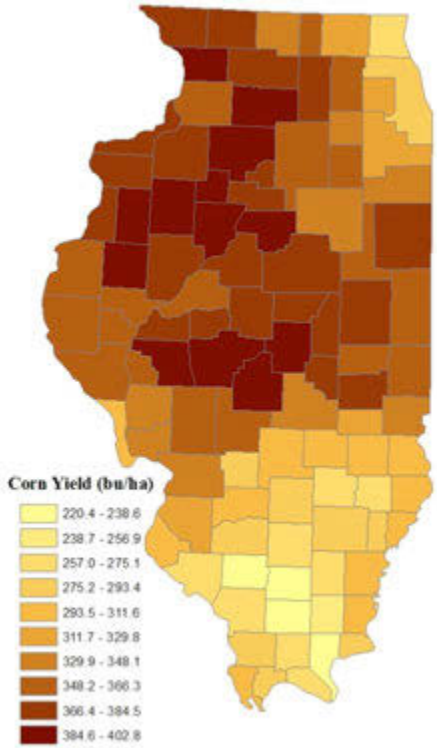
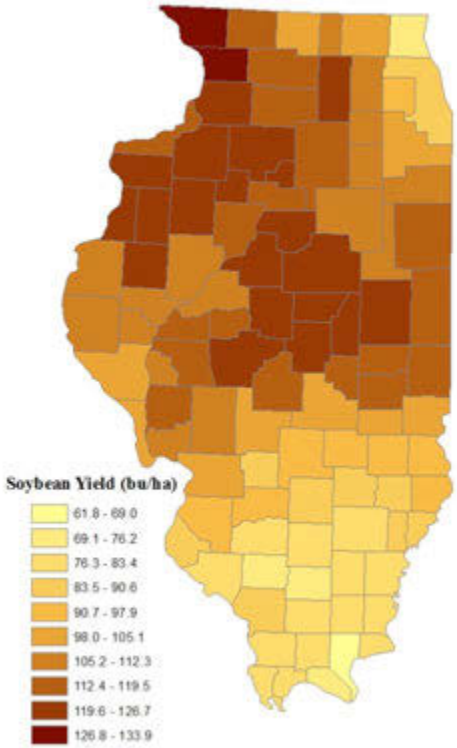
# Yield/Hectare: Miscanthus, Corn and Soybeans

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| Field Trial Locations (2005-06) | Actual average yield of Miscanthus (t DM/ha) | Simulated yield of Miscanthus (t DM/ha) | Actual average yield of Switchgrass (t DM/ha) |
|---|---|---|---|
| ● North (DeKalb) | 28.5 | 30.6 | 8.1 |
| ● Central (Champaign) | 42.4 | 35.4 | 16.8 |
| ● South (Dixon Spring) | 46.0 | 39.9 | 8.6 |
| **State Average** | **39.0** | **35.3** | **11.2** |

# Annualized Costs of Production for Switchgrass and Miscanthus

| Cost Items/hectare | Switchgrass $/ha (10 yrs) | Miscanthus ($/ha) (20 yrs) |
|---|---|---|
| Fertilizer costs | 57.39 | 40.42 |
| Herbicide cost | 4.16 | 1.27 |
| Seed cost | 15.69 | 23.69 |
| Interest on operating inputs | 5.41 | 4.58 |
| Pre-harvest Machinery cost | 21.46 | 25.68 |
| Harvesting/Storage expenses | 224.88 | 735.57 |
| Operating Costs at Farmgate ($ $ha^{-1}$) | 328.99 | 831.20 |
| Transportation cost | 45.68 | 157.68 |
| Operating Cost including Transportation ($ $ha^{-1}$) | 374.67 | 988.88 |
| Yield at Farmgate/Delivered (t $ha^{-1}$) | 5.78 | 19.95 |
| Break even farmgate price excluding land rent ($ $t^{-1}$) | **56.93** | **41.67** |
| Break even delivered price excluding land rent ($ $t^{-1}$) | **64.84** | **49.58** |

All cost estimates are in 2003 prices. Peak dry yield for Switchgrass in September and Miscanthus in October is assumed to be 9.42 and 35.8 t $ha^{-1}$, respectively. Costs are discounted at a rate of 4%.

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# Annualized Cost of Production for Perennials and Row Crops

| Cost Items ($/ha) | Switchgrass | Miscanthus | Corn Stover | Corn | Soybeans |
|---|---|---|---|---|---|
| **Fertilizer** | 57.4 | 40.4 | 22.91 | 132.5 | 59.5 |
| **Chemicals** | 4.2 | 1.3 | 0 | 76.6 | 89.0 |
| **Seed** | 15.7 | 23.7 | 0 | 89.0 | 47.4 |
| **Interest on operating inputs** | 5.4 | 4.6 | 1.60 | 13.9 | 9.1 |
| **Storage/Drying/Crop Insurance** | 23.9 | 87.7 | 16.95 | 59.3 | 27.2 |
| **Machinery cost** | 222.4 | 673.6 | 158.51 | 202.6 | 173.0 |
| **Transportation cost** | 45.7 | 157.7 | 32.39 | | |
| **Annualized Operating Cost** | 374.7 | 988.9 | 232.36 | 573.9 | 405.2 |
| **Annualized Yield** | 5.8 t/ha | 19.9 t/ha | 4.5 t/ha | 358.3 b/ha | 123.6 b/ha |
| Low Opportunity Cost of Land<br>High Opportunity Cost of Land | 192.8<br>533.9 | 192.8<br>533.9 | 143.1<br>154.99 | | |
| Cost of Production ($/ton) with<br>Low opportunity cost of land<br>High opportunity cost of land | <br>**98.2**<br>**157.2** | <br>**59.2**<br>**76.3** | <br>**83.1**<br>**85.70** | | |

Low opportunity cost with soybean price $5.1/b; corn price $2.05/b; High cost with 50% higher crop prices

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# Sensitivity Analysis of Breakeven Price of Bio-energy Crops

| | Switchgrass | | Miscanthus | |
|---|---|---|---|---|
| | ($/ton) | % change | ($/ton) | % change |
| 25% increase in corn-soybean price | 127.71 | 30.1 | 67.80 | 14.4 |
| 25% decrease in pre-harvest and harvesting machinery costs | 88.57 | -9.8 | 50.80 | -14.3 |
| 25% decrease in transportation costs | 96.22 | -2.0 | 57.27 | -3.3 |
| 25% increase in yield of Switchgrass and Miscanthus | 78.5 | -20.0 | 47.4 | -20.0 |
| 100% higher discount rate | 100.76 | 2.6 | 60.51 | 2.1 |
| 25% increase in fertilizer costs | 100.85 | 2.7 | 59.79 | 0.9 |
| 25% decrease in fertilizer cost | 95.54 | -2.7 | 58.70 | -0.9 |

Base price of Switchgrass: $98.19/t; Miscanthus: $59.24/t; Corn: $2.05/b; Soybeans: $5.1/b

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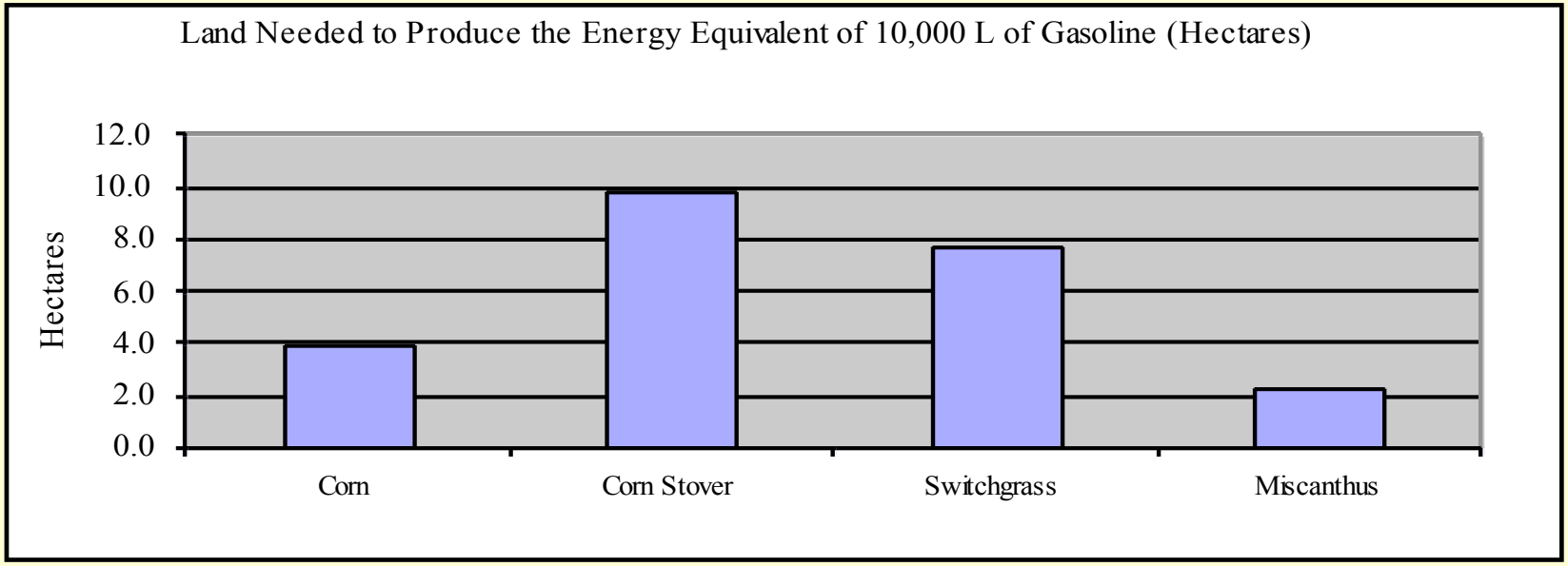


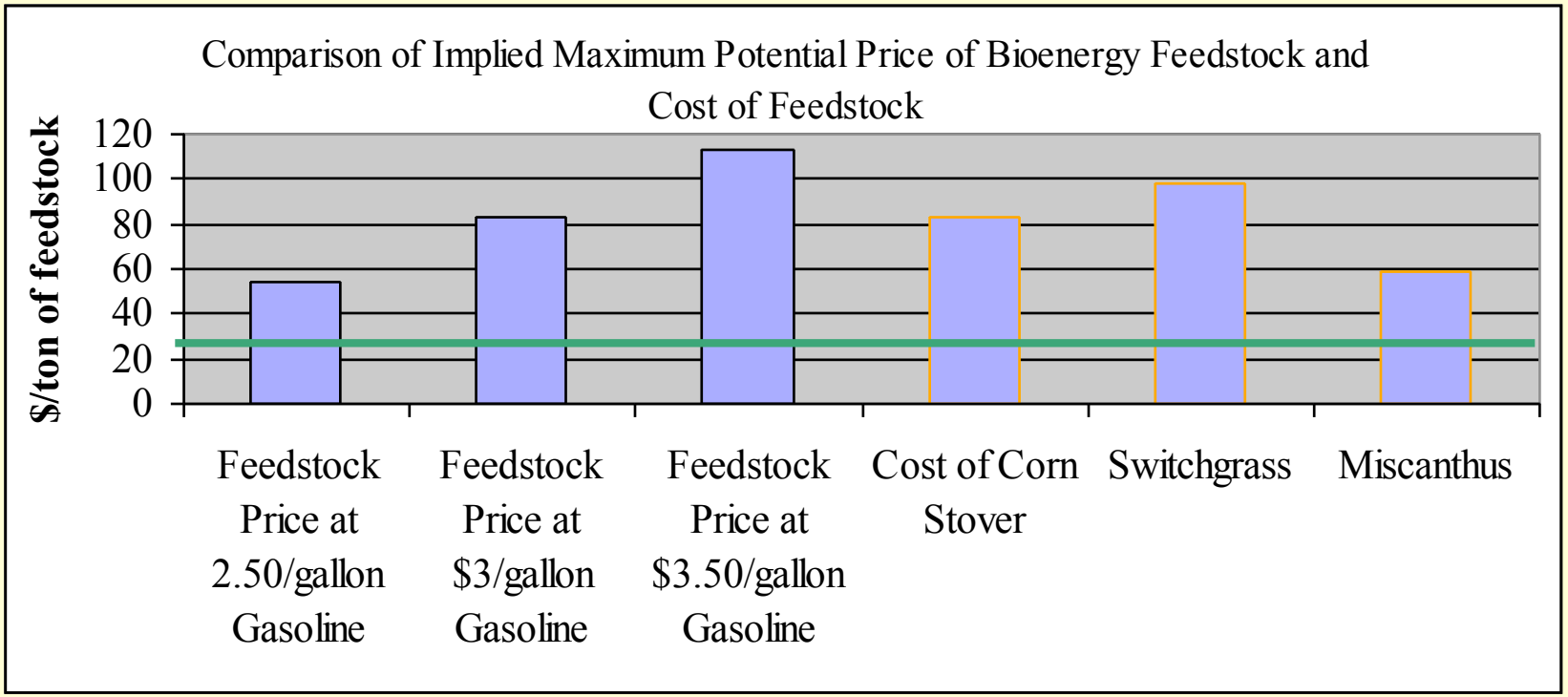


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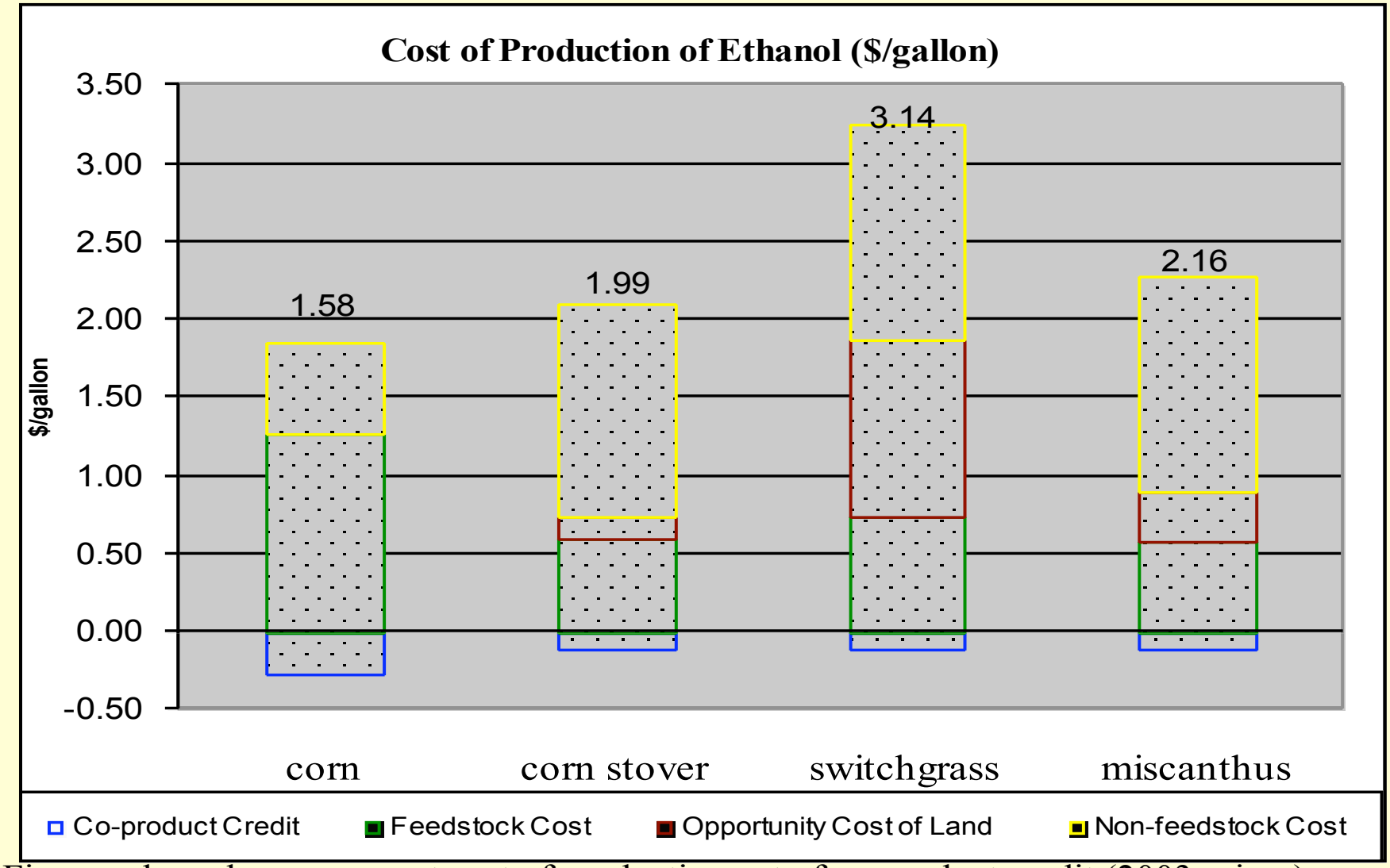


- Figures above bars represent cost of production net of co-product credit (2003 prices); 40 M gallon corn-ethanol plant and 25 M gallon cellulosic ethanol plant
- Corn price of $3.50/b and Soybean Price $7/b
- Process for cellulosic ethanol production with mature technology: dilute acid prehydrolysis with enzymatic saccharification of the remaining cellulose and co-fermentation of glucose to ethanol (USDA/USDOE, 2005)

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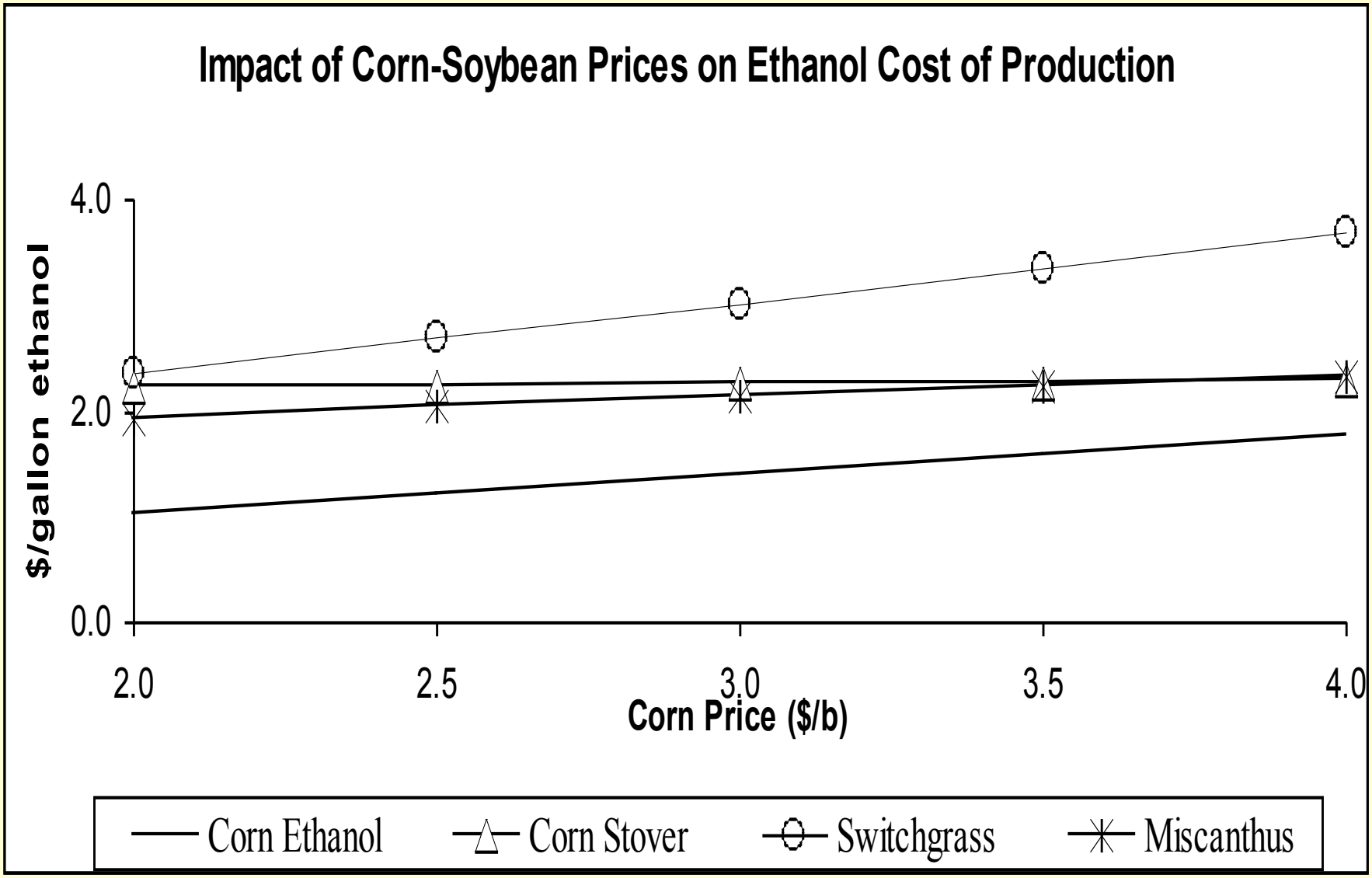


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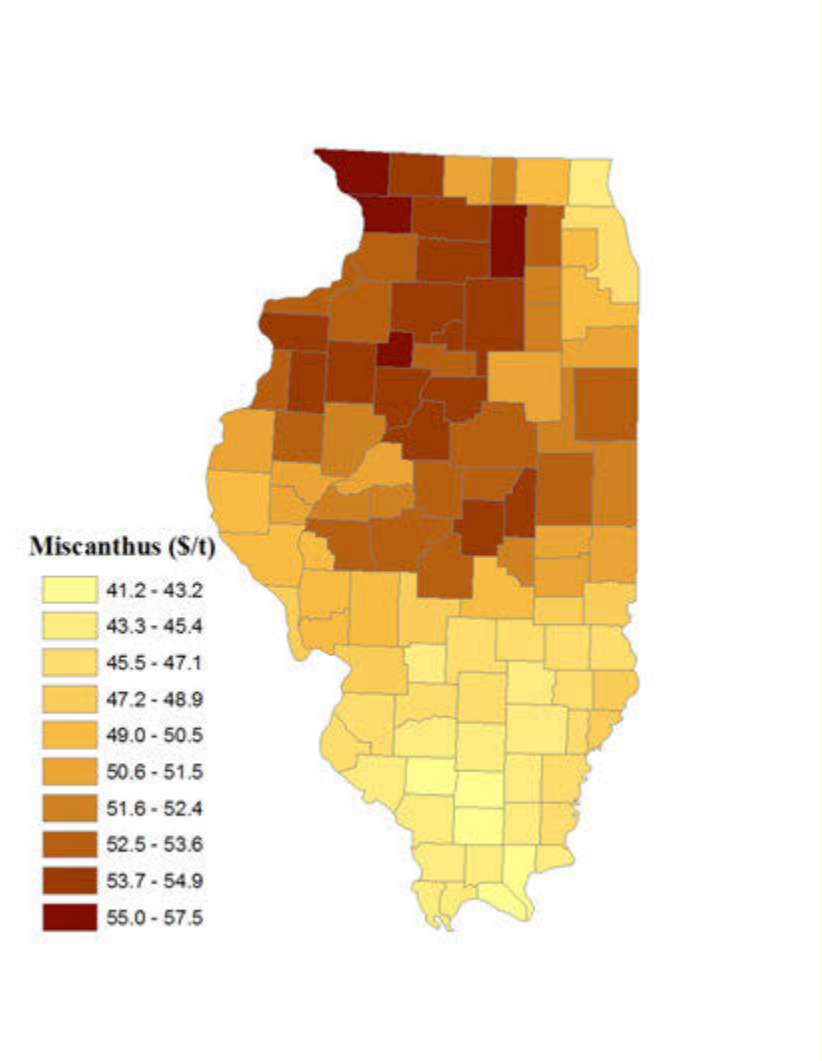
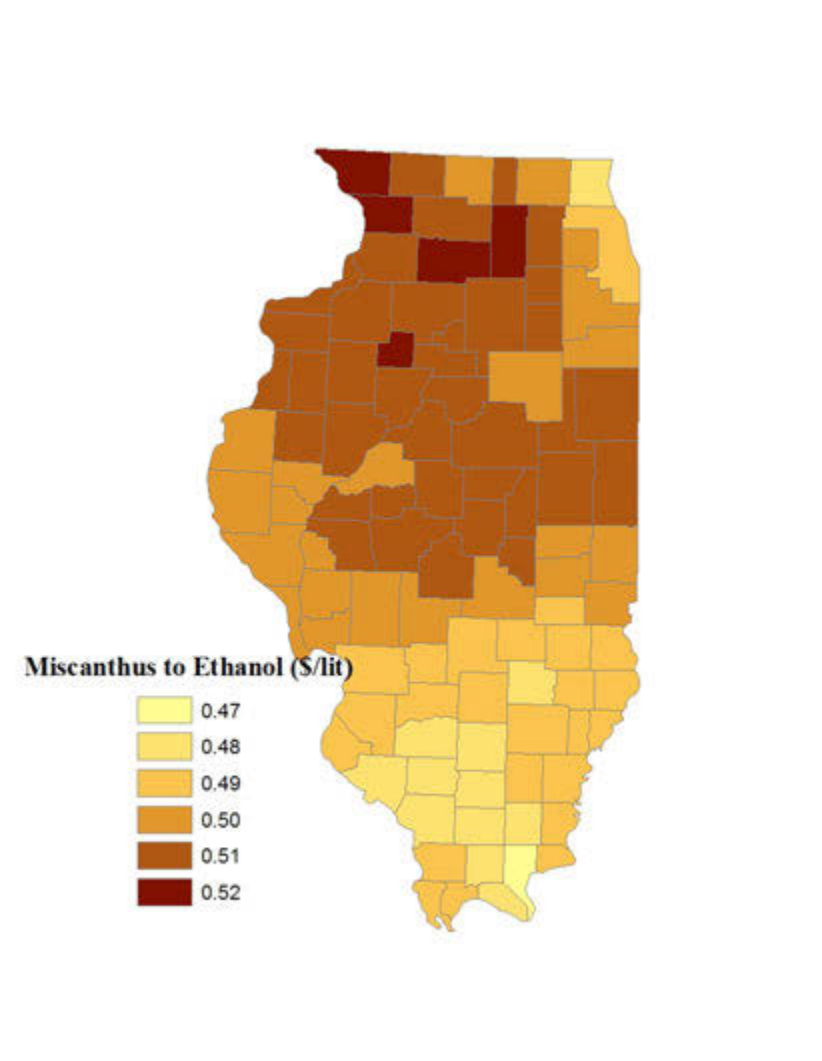
# Breakeven Farmgate Price $/t




# Breakeven Price of Ethanol $/L

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# Life Cycle Carbon Emissions from Alternative Feedstocks

- Emissions during crop production
- Displacement of emissions
  - from corn and soybeans by bioenergy crops
  - from corn-soybean rotation to no-till continuous corn rotation by corn stover production
- Soil carbon sequestration

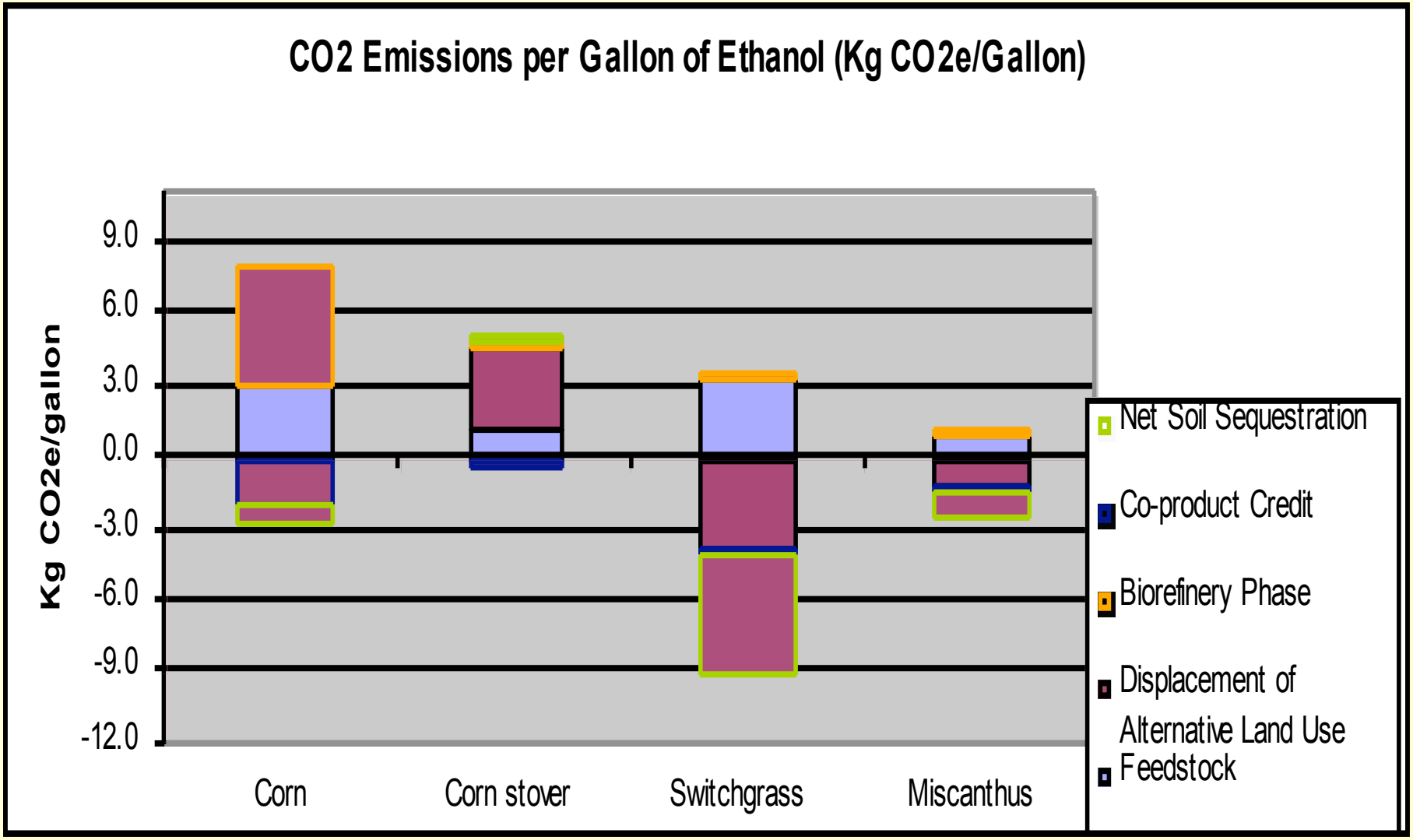
  Conservation tillage -- small potential:

  0.3-0.5 MT/ha/yr

  Miscanthus/Switchgrass -- 3 times higher potential:

  0.94-1.4 MT/ha/yr
- Emissions during the biorefinery phase
- Co-product credit

# Life Cycle Emissions of Biofuels

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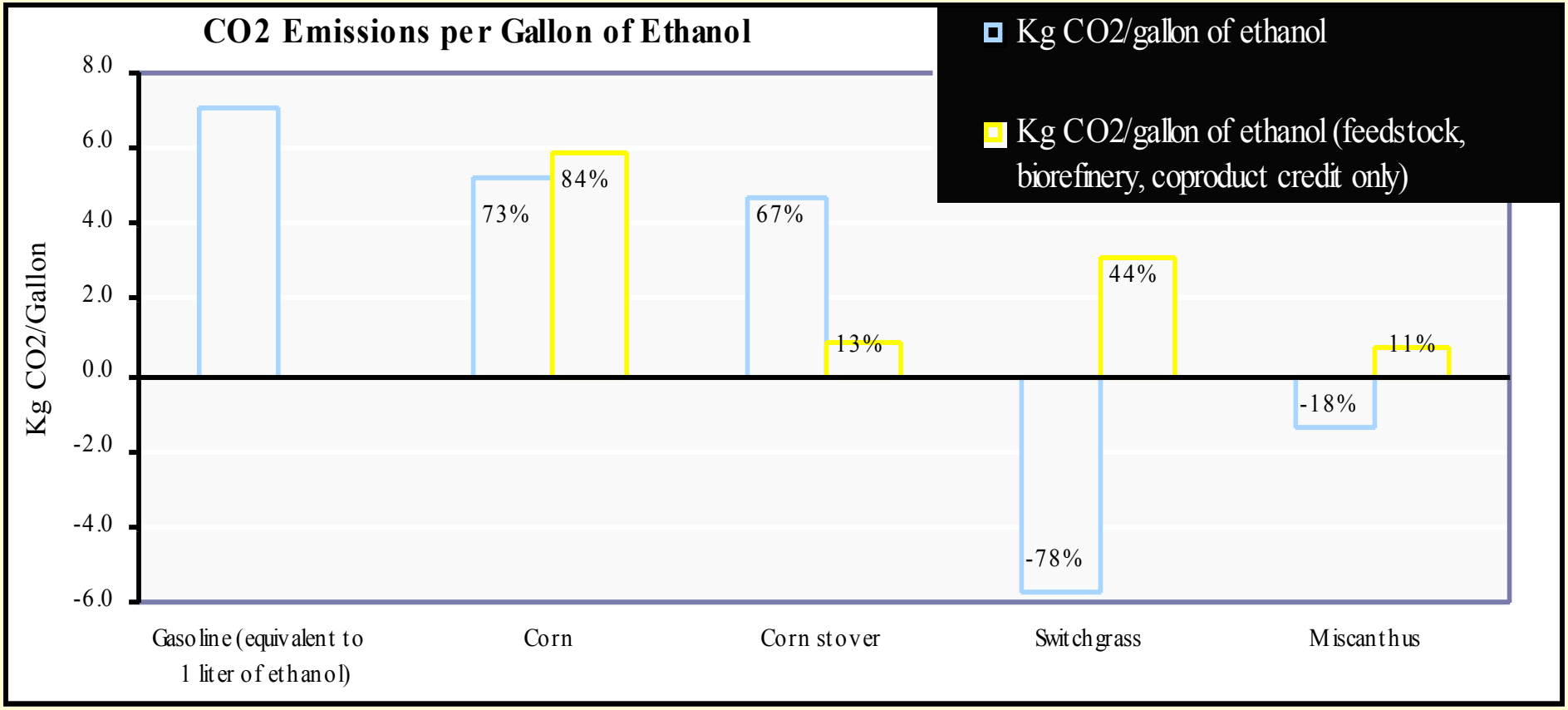
# Comparison of Net $CO_2$ Emissions of Biofuels and Gasoline

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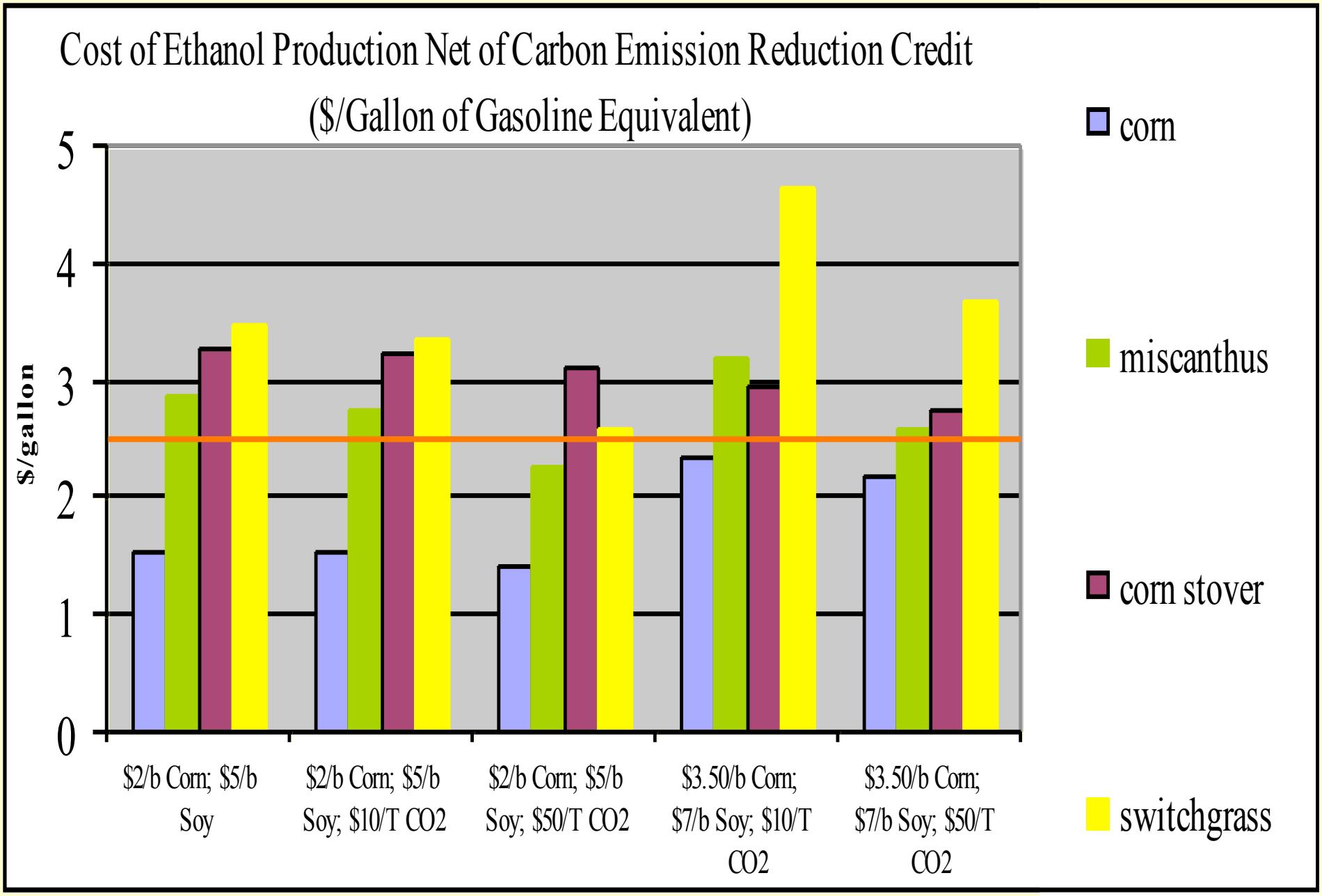


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# Summary

- Profitability of bioenergy feedstocks varies spatially
  - Depends on yields, transportation cost and opportunity cost of land
- Switchgrass not likely to be competitive with Miscanthus for fuel production in Illinois
- Ethanol from Miscanthus competitive with that from corn stover at current prices
- Incentives for production of cellulosic ethanol need to come from
  - Environmental policies restricting/pricing $CO_2$
- Alternatively, incentives for growing bioenergy crops need to come from
  - Agro-environmental policy rewarding carbon sequestration and other soil benefits from bioenergy crop production