Meeting the Demand for Biofuels: Implications for Land Use, Greenhouse Gas Emissions and Nitrogen Use

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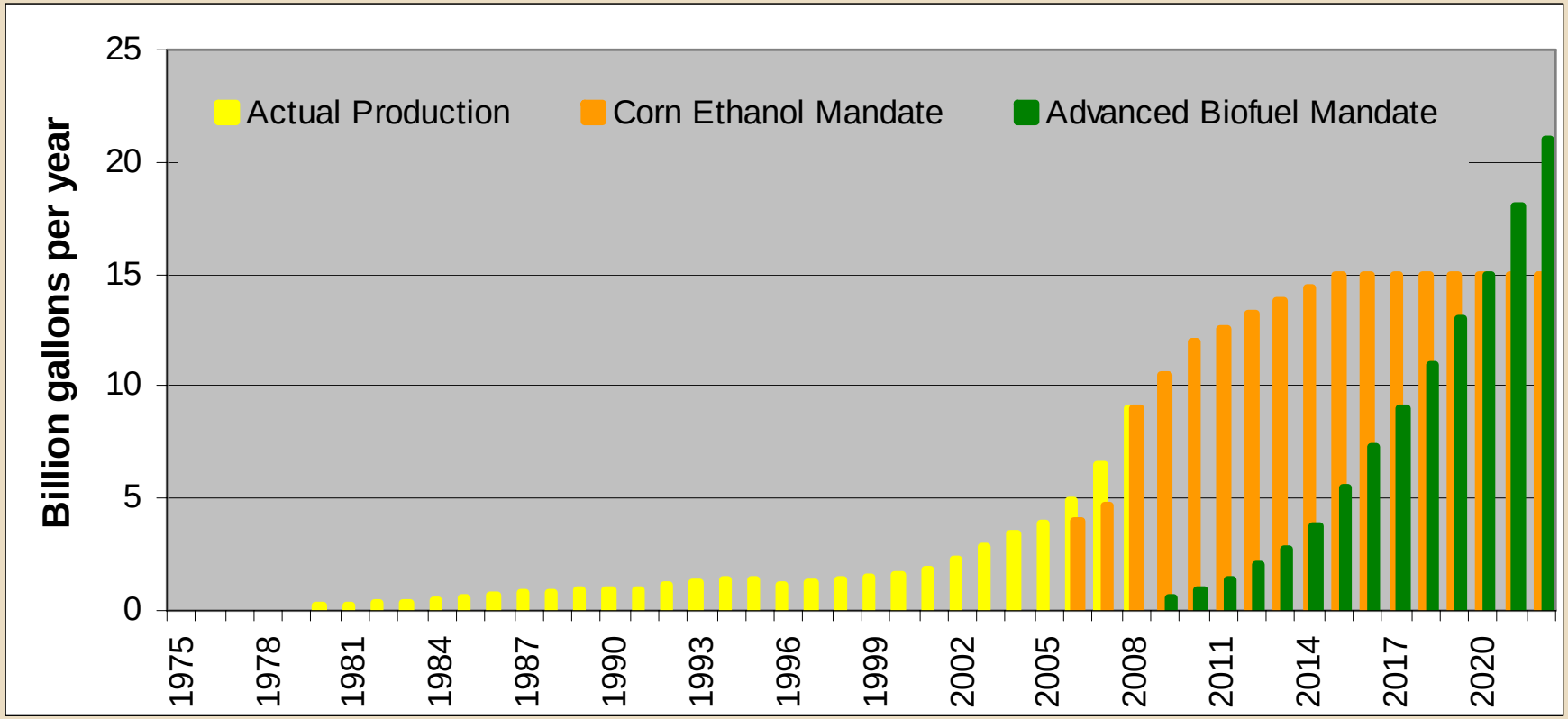
Motivations for Biofuels

- Energy Security: Reducing dependence
  - On foreign oil
  - On exhaustible supplies of oil and rising oil prices
- Rural economic development
- Technological solution for mitigating greenhouse gas emissions from transportation with existing infrastructure and vehicle technology

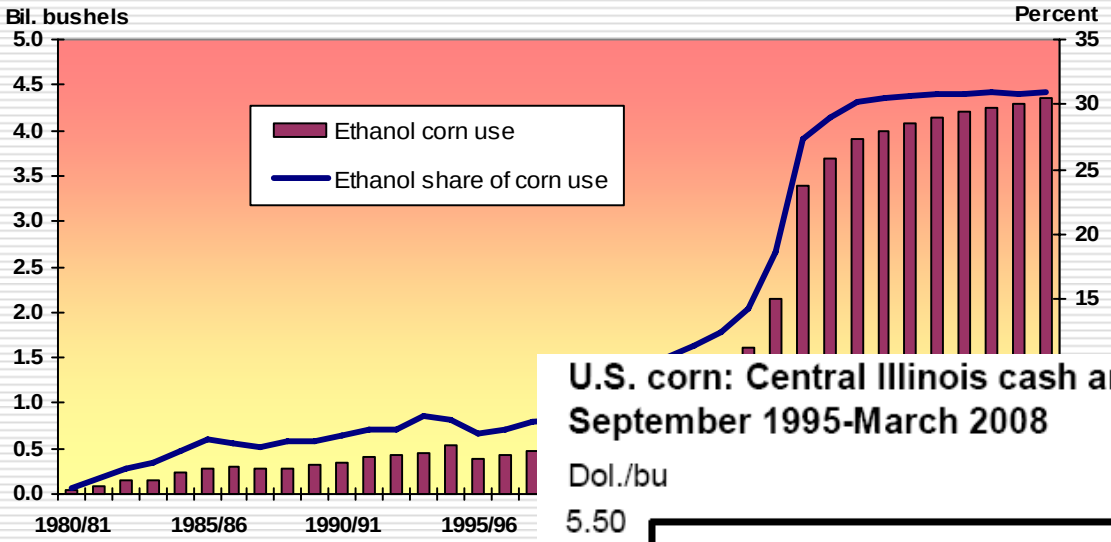
Energy Independence and Security Act of 2007: Biofuel Mandate



- 36 billion gallons to be produced annually by 2022
  - Of this 58% to come from advanced biofuels that reduce greenhouse gas emissions by at least 50%

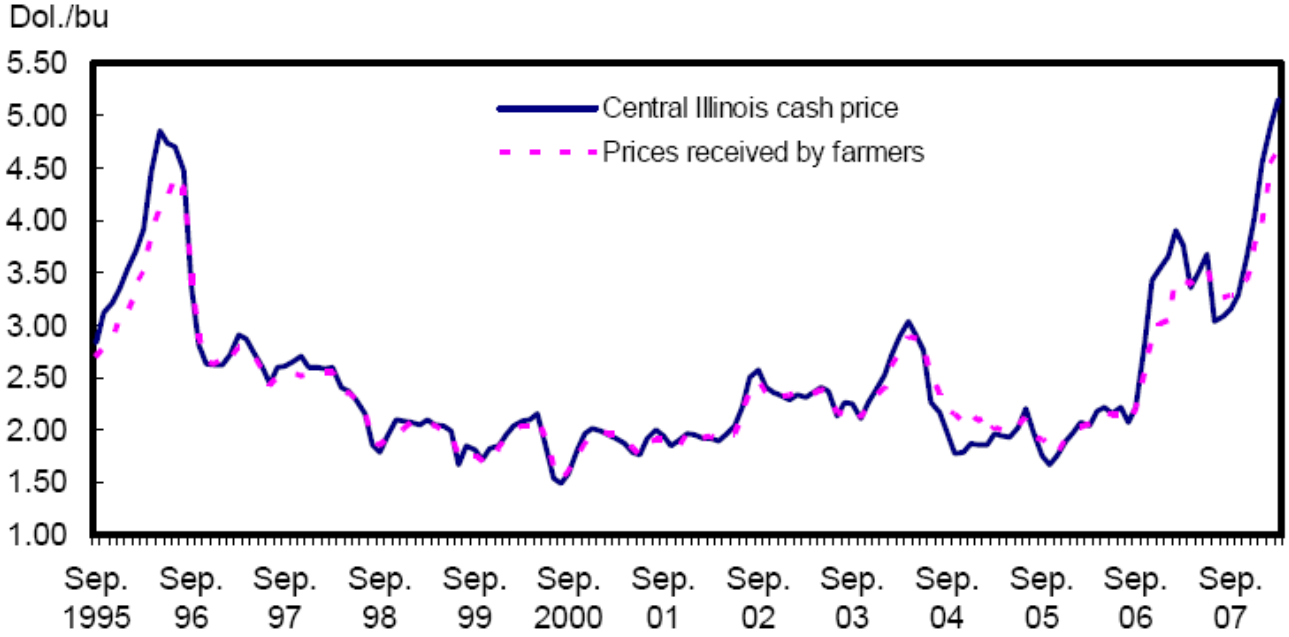
U.S. Corn Used in Ethanol Production

1995/96 through 2007/08F



Note: 2006/07 through 2015/16 are projected based on the *World Agricu*
Agricultural Projections to 2016, February 2007 .

U.S. corn: Central Illinois cash and average farm price, monthly, September 1995-March 2008



Sources: USDA, Agricultural Marketing Service, *Weekly Grain Market News Summary,* and USDA, Economic Research Service, *Feed Grains Database.*

Key questions

- What are the implications of meeting future demands for biofuels for land use and food prices
  - spatial and temporal pattern of land use
- What mix of cellulosic feedstocks is likely to be produced and where?
- What are the likely costs of producing cellulosic biofuels?
- What are the environmental implications of biofuel production
  - Greenhouse gas emissions
  - Nitrogen applications

Some Options for Cellulosic Biofuels on Cropland

- Corn Stover
- Perennial Grasses: Miscanthus and Switchgrass

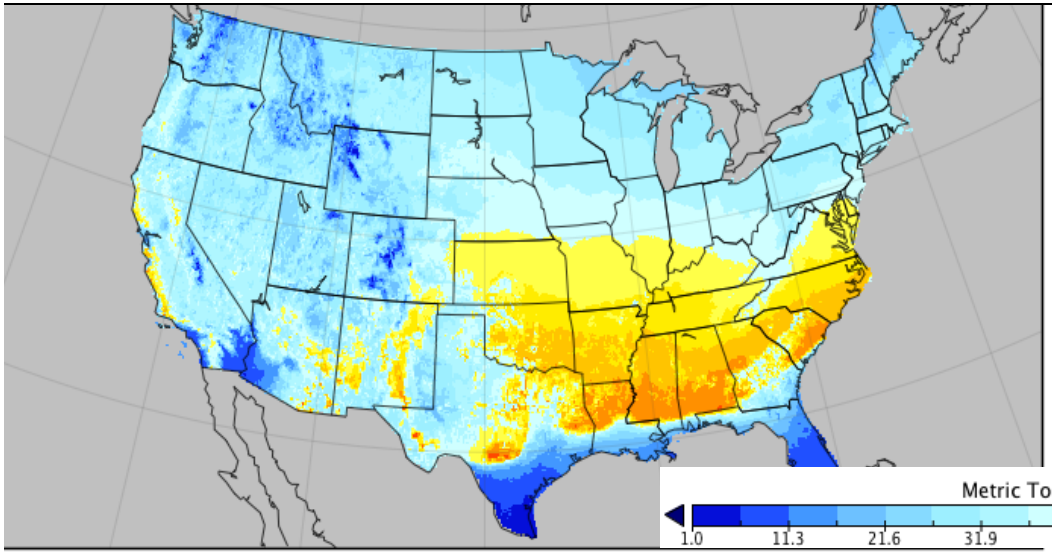
Cellulosic Feedstocks

- Corn Stover Potential: 7 Billion gallons a year

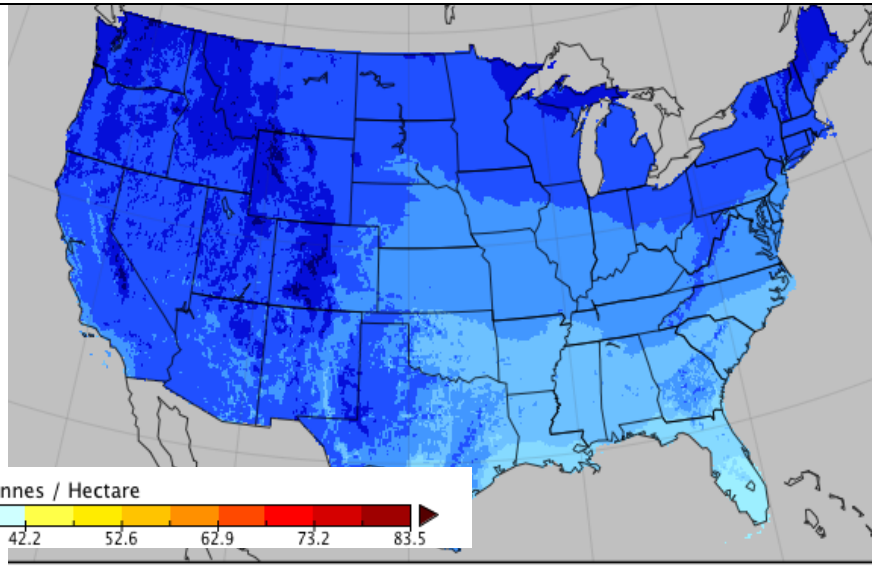
- Switchgrass and Miscanthus
  - Adaptable to wide range of growing conditions
  - High yielding perennials
  - Low initial and annual input requirements; translocate inputs to roots
  - Compatible with row crop production
  - require conventional equipment; winter harvests

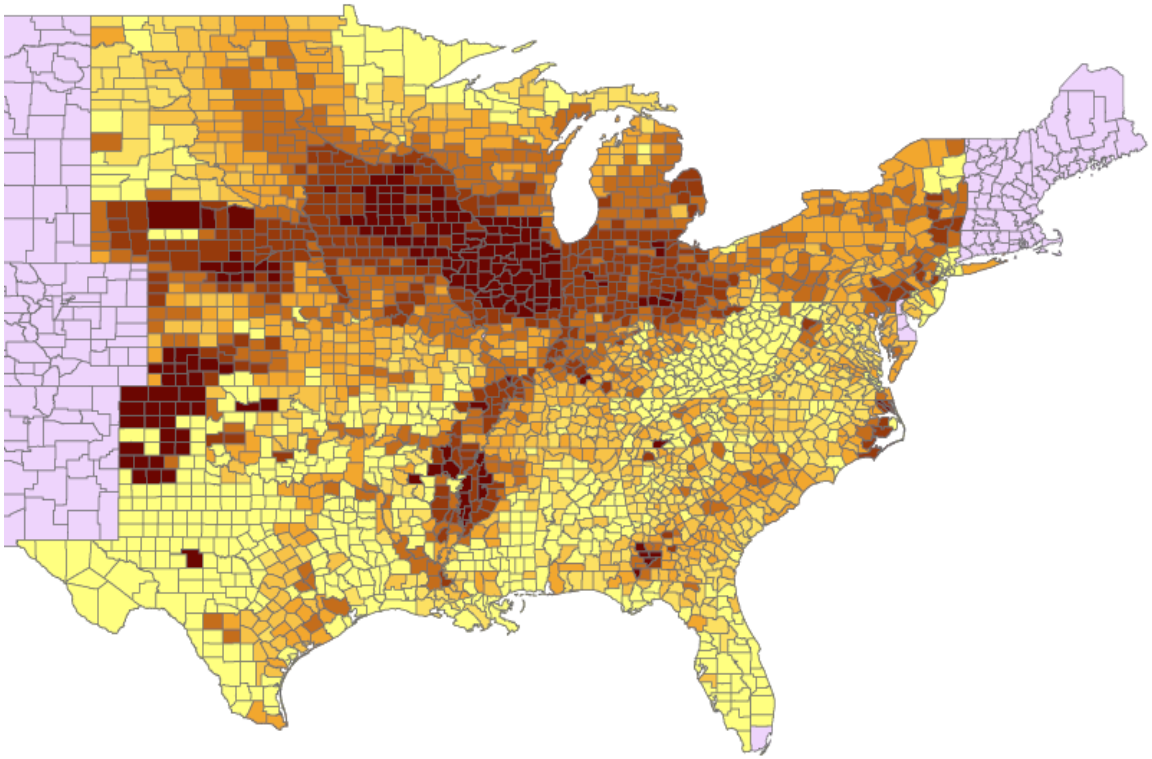
- Corn Stover: 2-4 tons/acre in Illinois
- Switchgrass: 3-6 tons/acre in Illinois
- Miscanthus: 12-18 tons/acre in Illinois

Miscanthus Yields



Switchgrass Yields





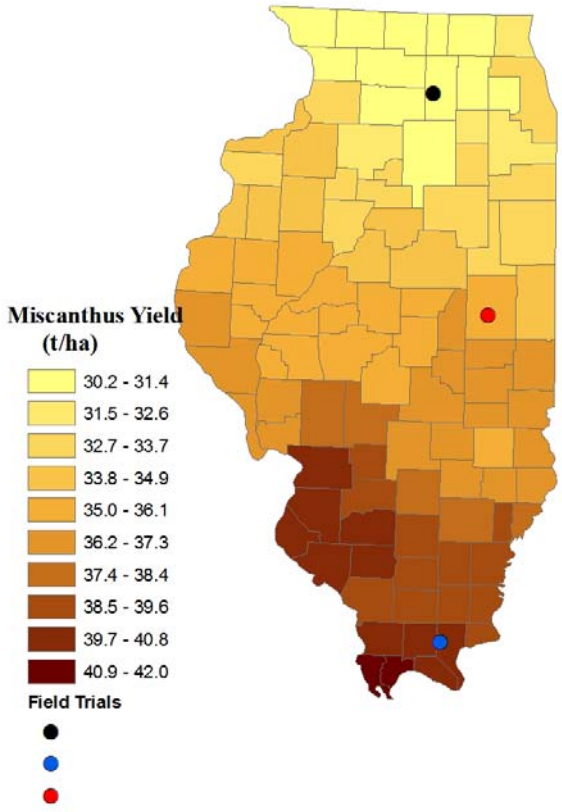
Preliminary estimates
Source: Jain and Erickson, 2008

2007 Corn Yields (Bu/acre)

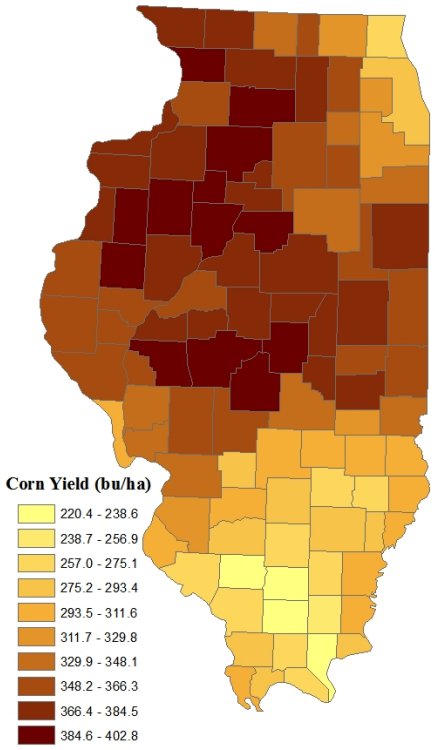
- 0.000000 - 30.800000
- 31.700000 - 75.500000
- 75.800000 - 102.000000
- 102.500000 - 126.000000
- 126.100000 - 148.300000
- 148.700000 - 172.200000
- 172.500000 - 223.000000

Crop Yields in Illinois

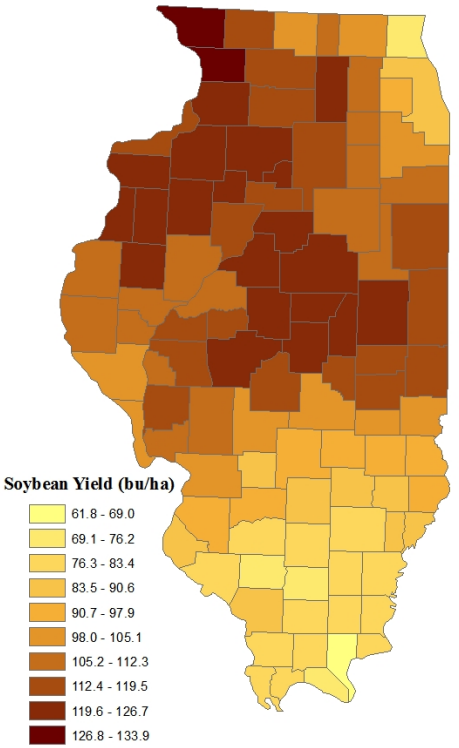
Miscanthus



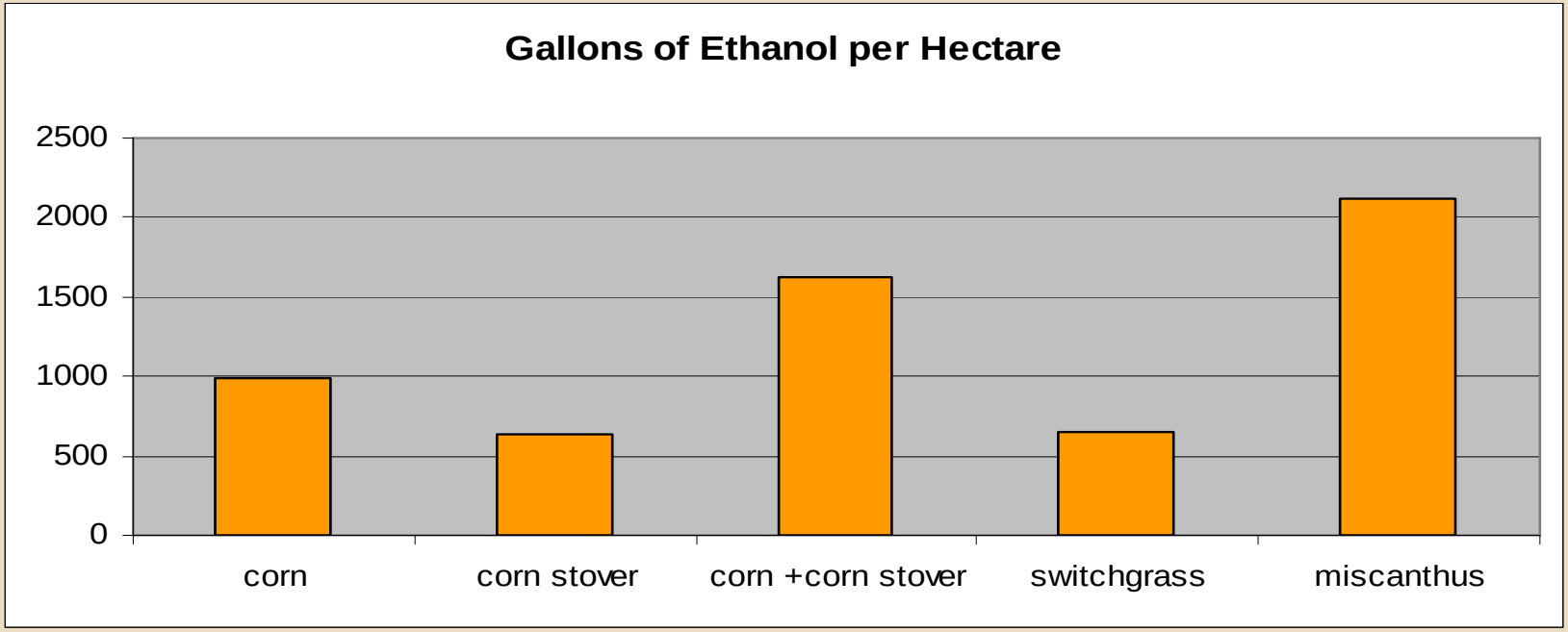
Corn

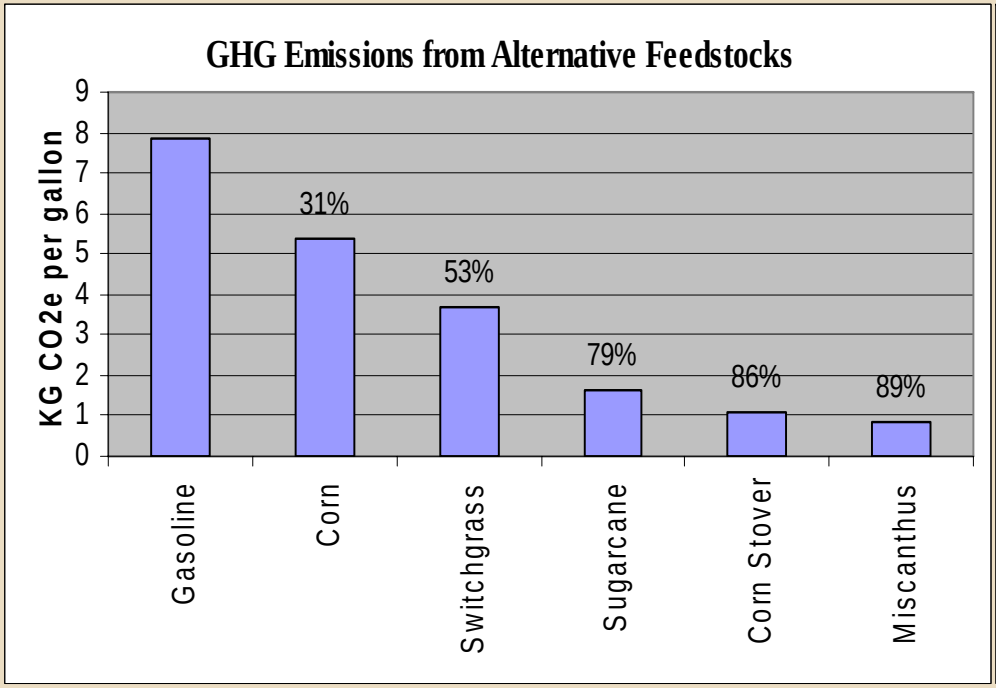


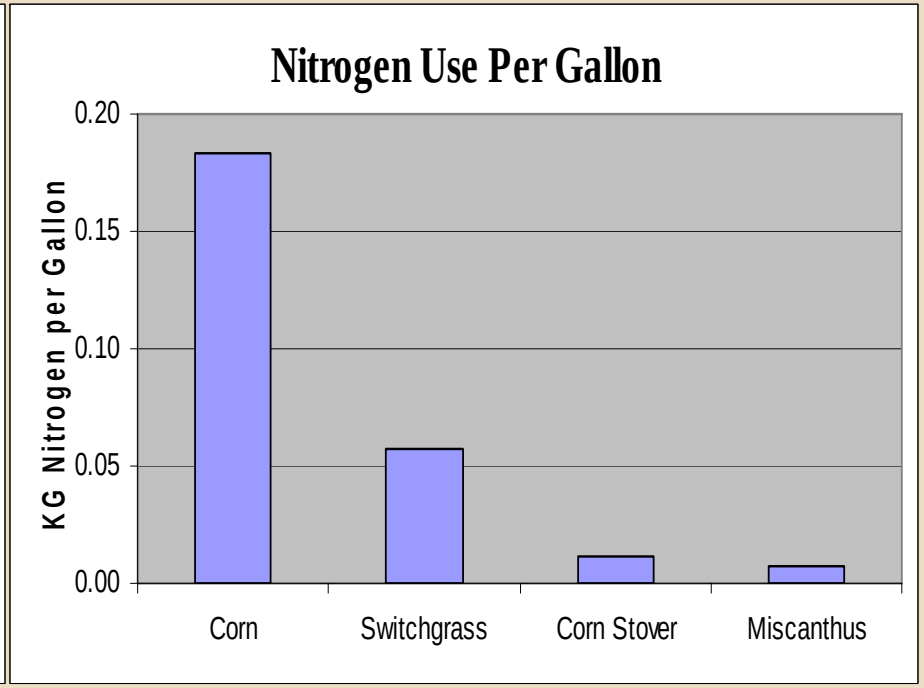
Soybeans



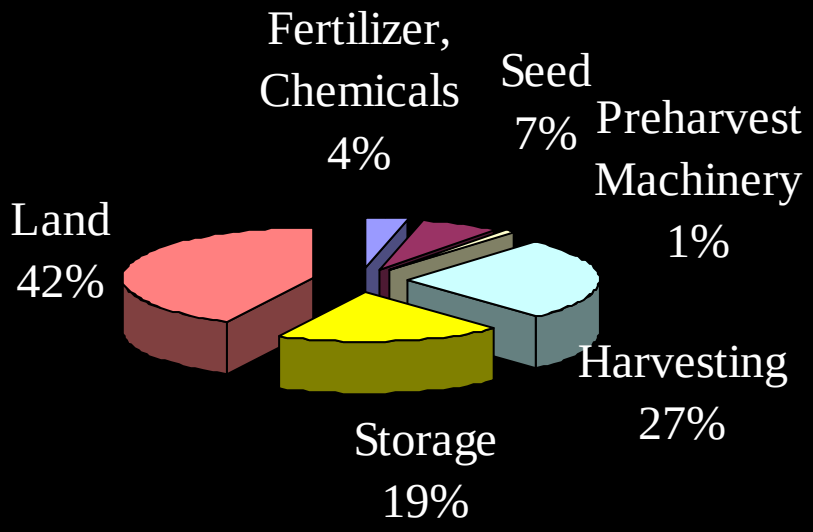
Field Trial Locations (2005-06)	Actual average yield of Miscanthus (t DM/ha)	Simulated yield of Miscanthus (t DM/ha)	Actual average yield of Switchgrass (t DM/ha)
North (DeKalb)	28.5	30.6	8.1
Central (Champaign)	42.4	35.4	16.8
South (Dixon Spring)	46.0	39.9	8.6
State Average	**39.0**	**35.3**	**11.2**


Gallons of Ethanol per Hectare
2500
2000
1500
1000
500
0
corn
corn stover
corn +corn stover
switchgrass
miscanthus


GHG Emissions from Alternative Feedstocks
KG CO2e per gallon
9
8
7
6
5
4
3
2
1
0
31%
53%
79%
86%
89%
Gasoline
Corn
Switchgrass
Sugarcane
Corn Stover
Miscanthus

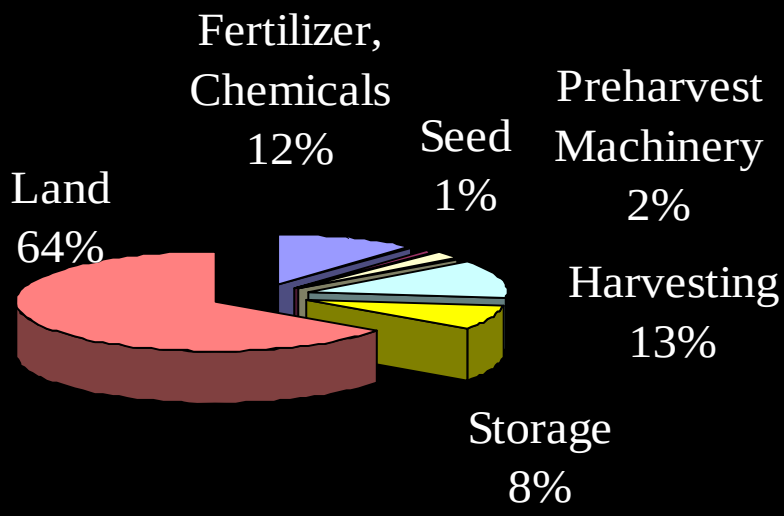

Nitrogen Use Per Gallon
KG Nitrogen per Gallon
0.20
0.15
0.10
0.05
0.00
Corn
Switchgrass
Corn Stover
Miscanthus

Cost of Producing Miscanthus ($/ton)



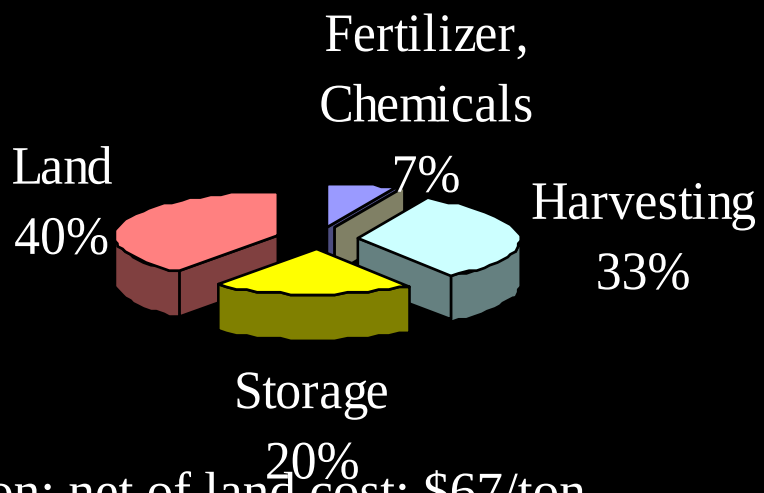
Total: $ 122/ton; net of land cost: $70/ton

Cost of Producing Switchgrass ($/ton)



Total: $ 276/ton; net of land cost: $96/ton

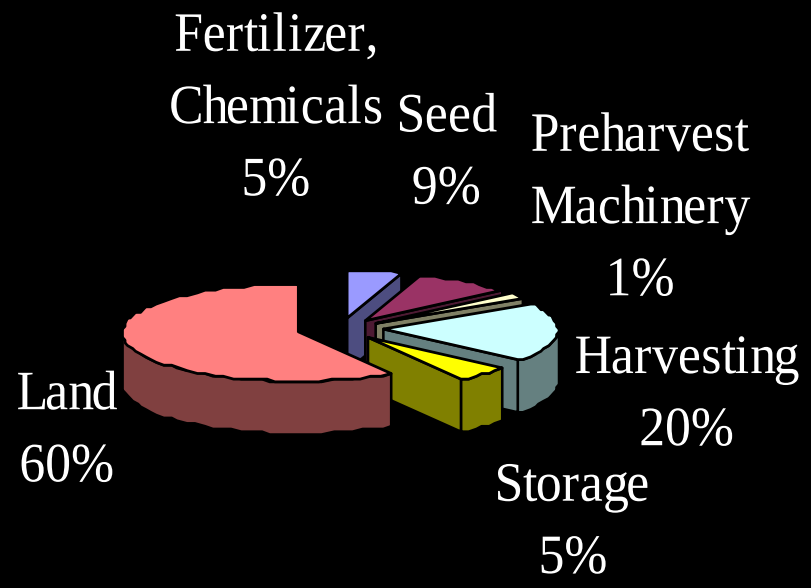
Cost of Producing Corn Stover ($/ton)



Total: $ 112/ton; net of land cost: $67/ton

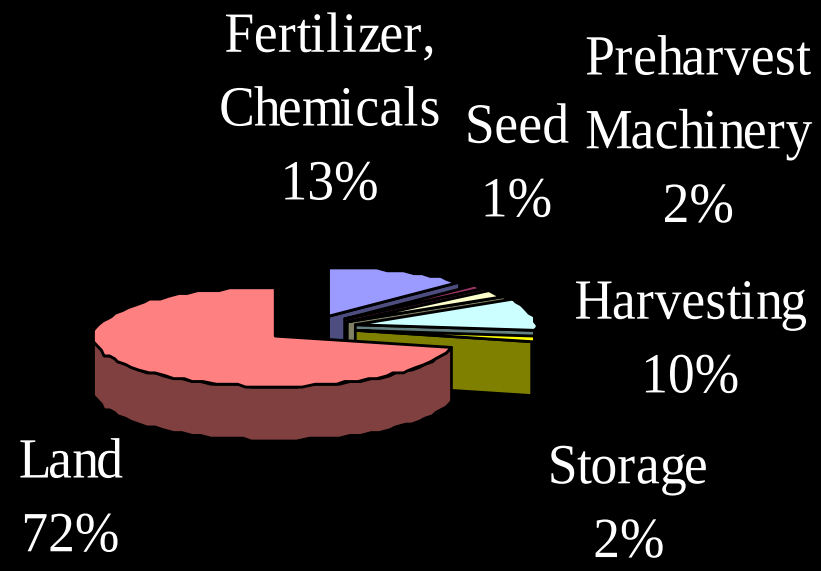
High Harvesting and Storage Cost Scenario

Cost of Miscanthus ($/ton)



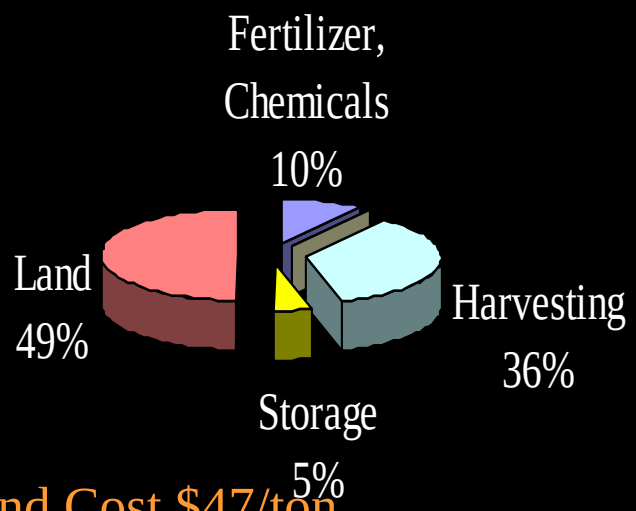
Non-land Cost $38/ton

Cost of Switchgrass ($/ton)



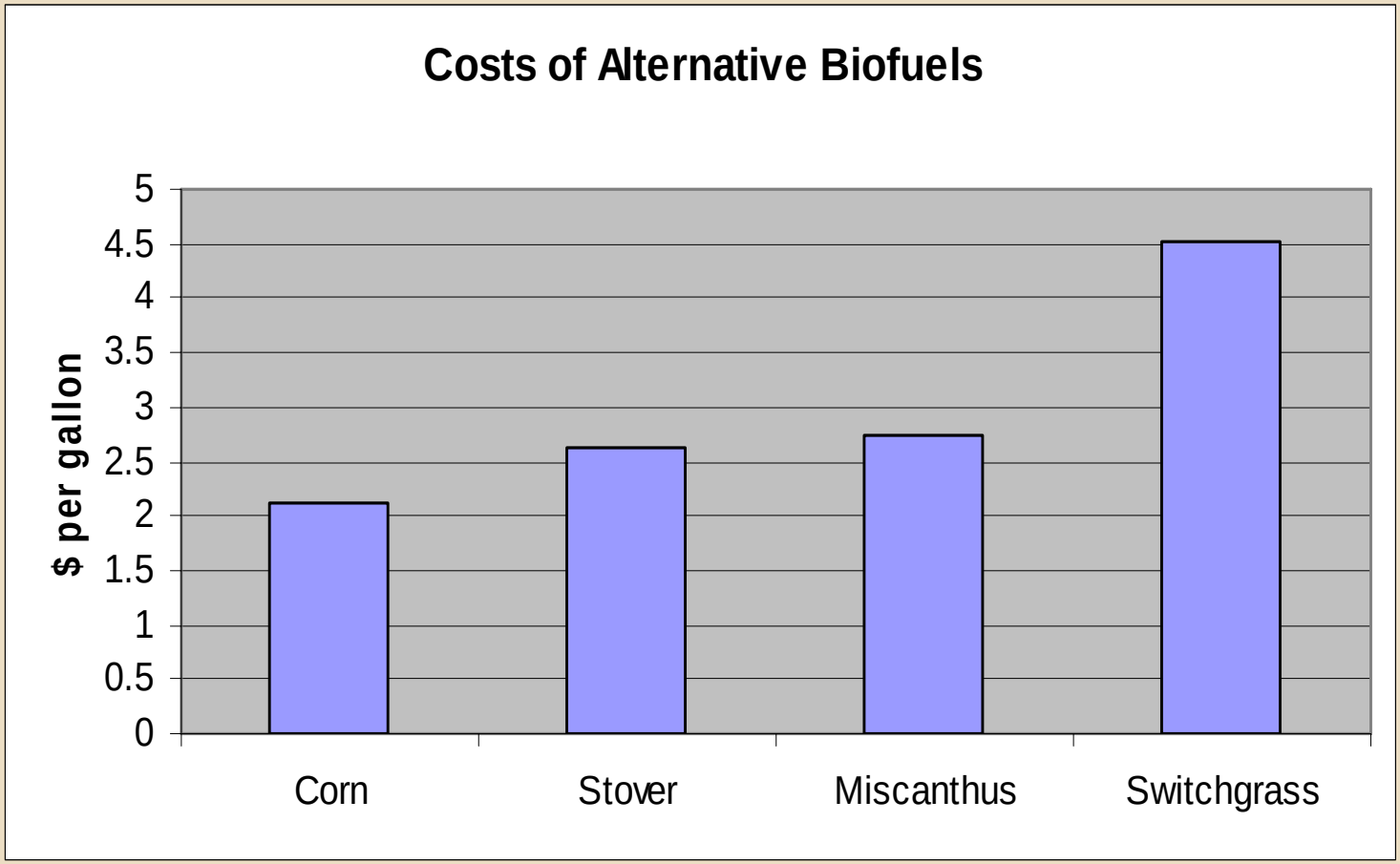
Non-land Cost $76/ton

Cost of Corn Stover ($/ton)



Non-land Cost $47/ton

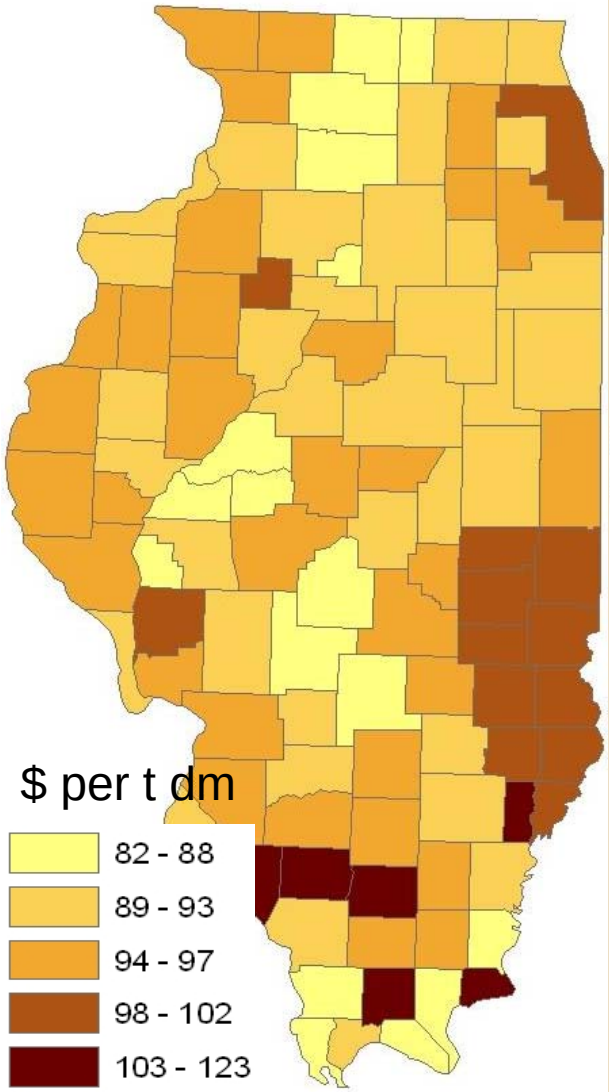
Low Harvesting and Storage Cost Scenario



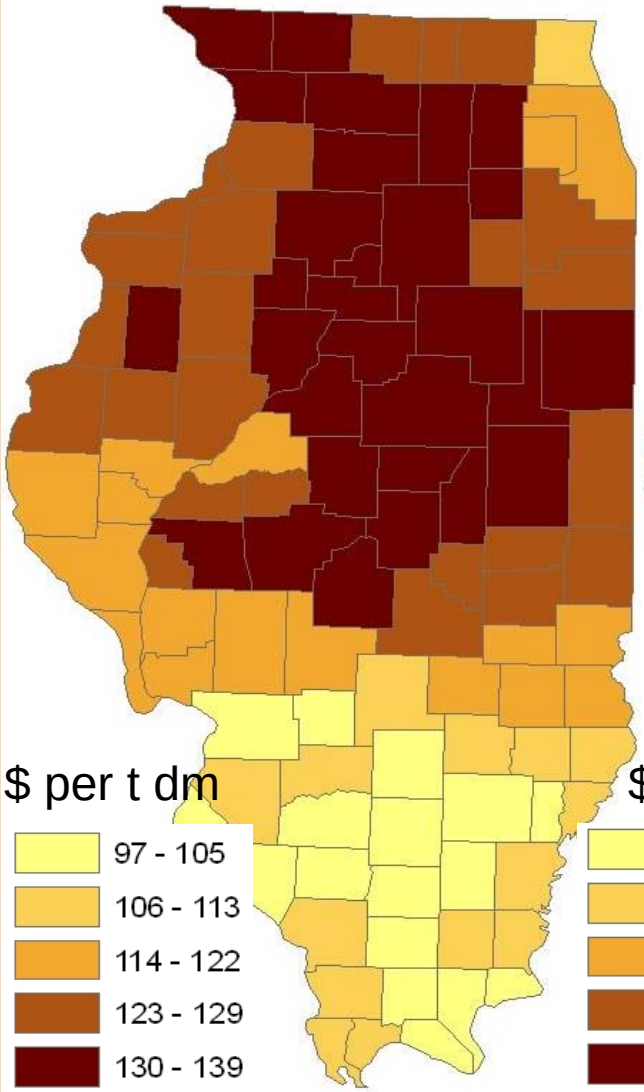
(with high cost scenario)

Spatial Variability in Costs of Production of Feedstocks

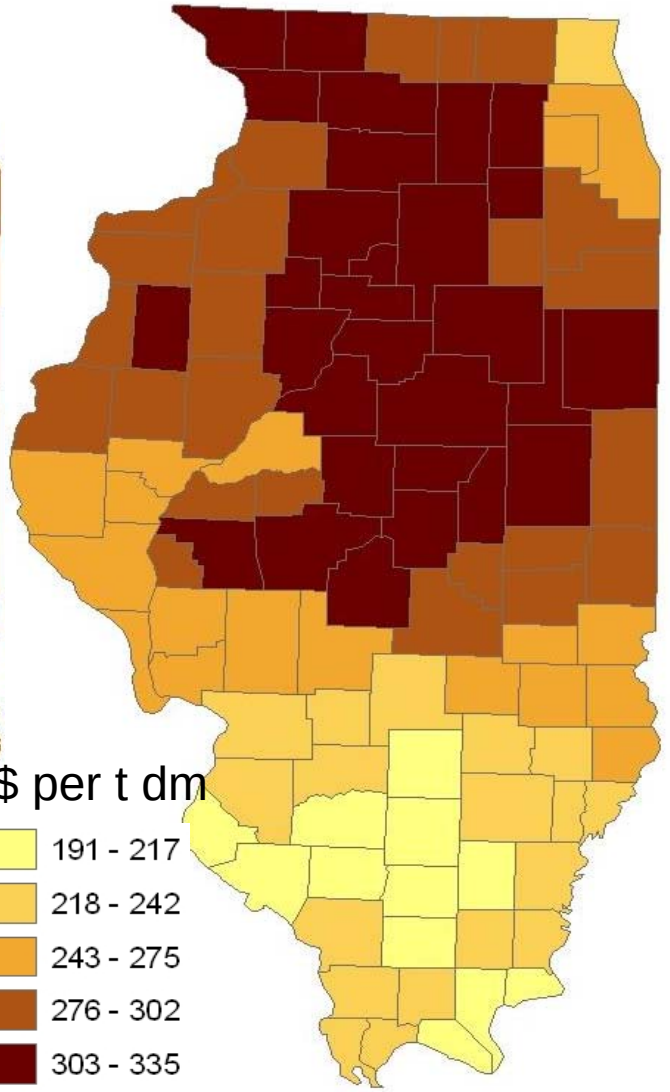
Corn Stover



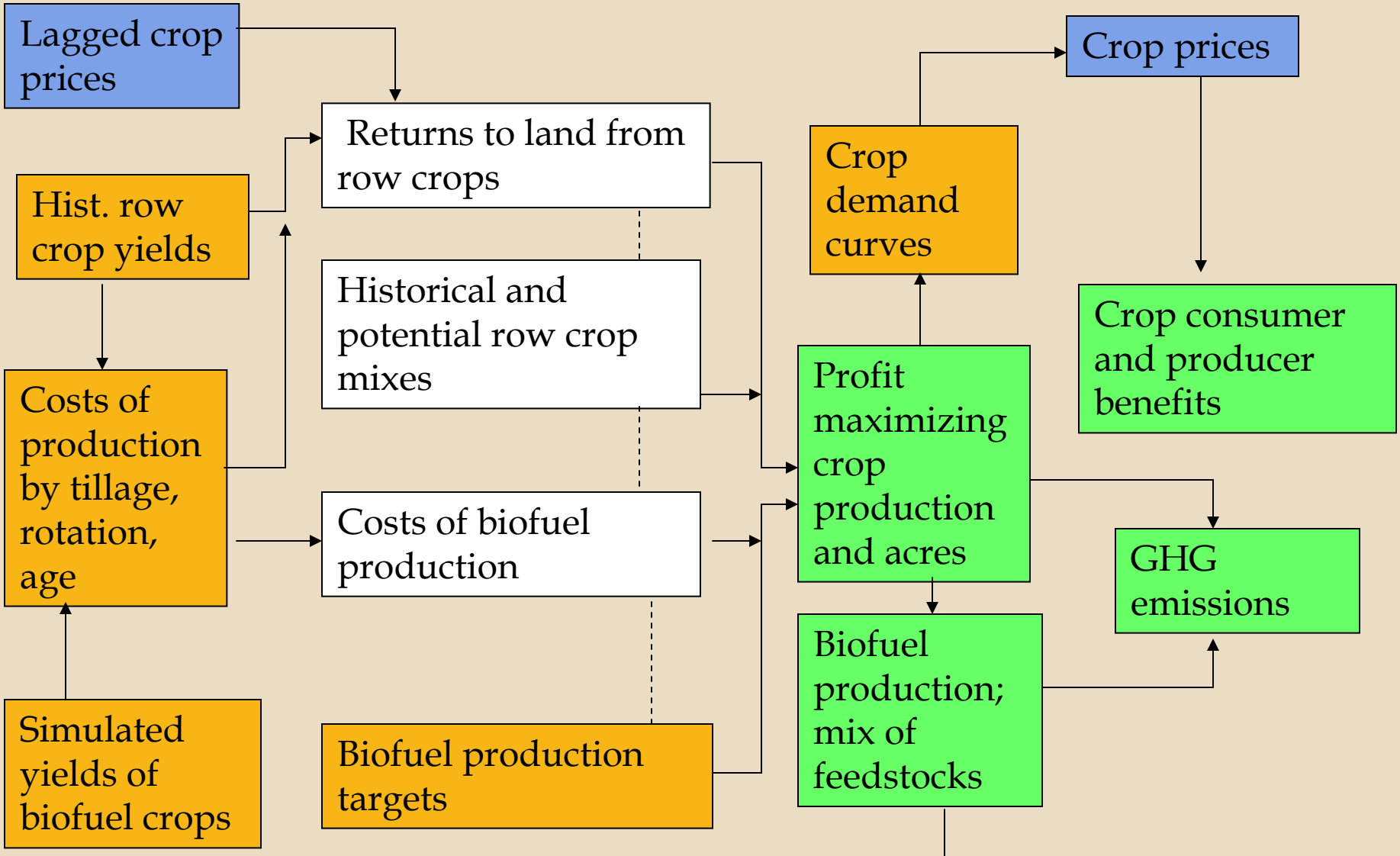
Miscanthus



Switchgrass

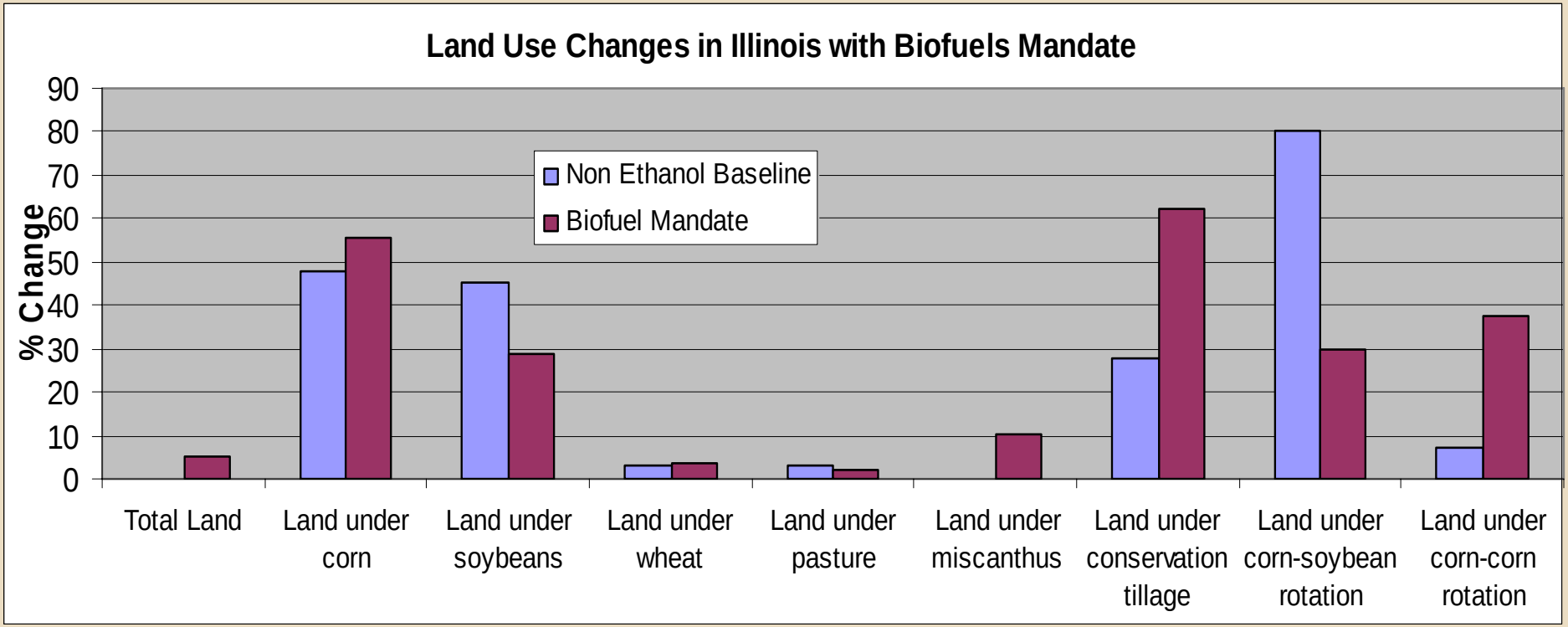


Dynamic Land Use Economic Model (2007-2022)



10 year rolling horizon with annual time steps

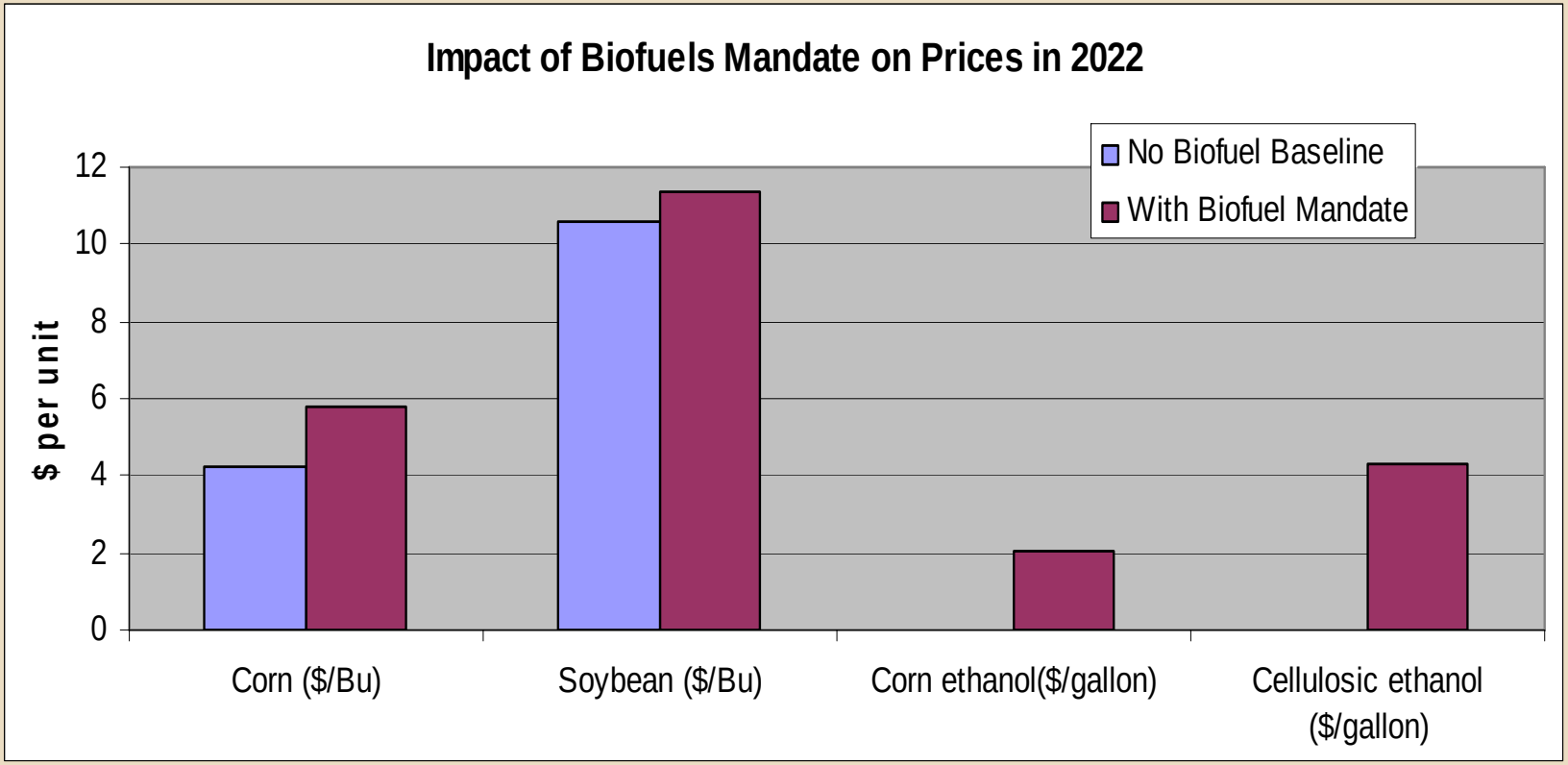
Key Results:

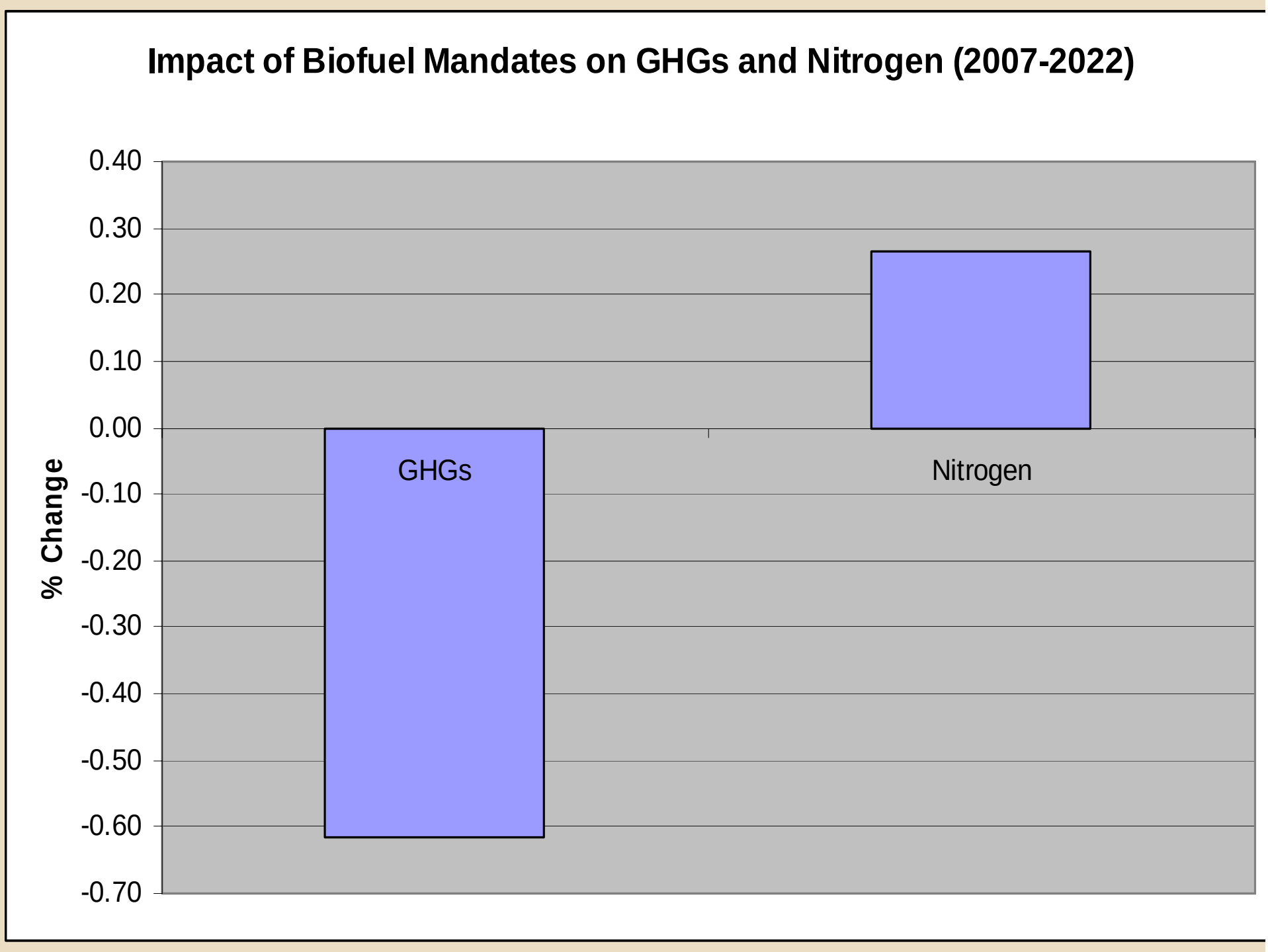


Biofuel production in Illinois (3 B gallons of corn ethanol; 4.2 B gallons of cellulosic in 2022)

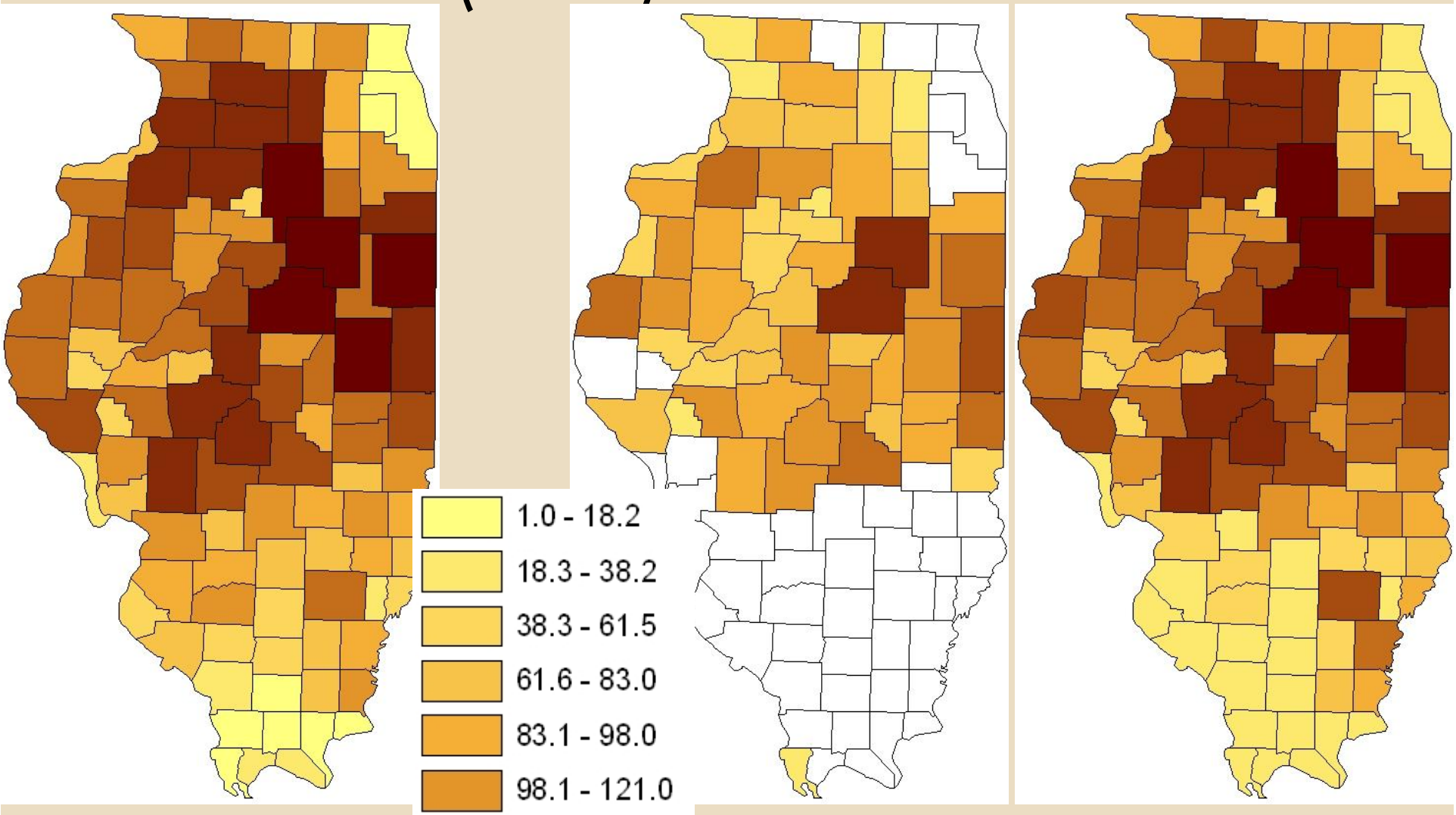
Increases total cropland acreage

- Shifts acres towards corn and miscanthus
- Reduces acreage under soybeans and pasture
- Shifts crop production practices towards conservation tillage and continuous corn
- Switchgrass is not found to be competitive due to low yields and high cost of land in Illinois


Impact of Biofuels Mandate on Prices in 2022
No Biofuel Baseline
With Biofuel Mandate
$ per unit
12
10
8
6
4
2
0
Corn ($/Bu)
Soybean ($/Bu)
Corn ethanol($/gallon)
Cellulosic ethanol ($/gallon)


Impact of Biofuel Mandates on GHGs and Nitrogen (2007-2022)
% Change
0.40
0.30
0.20
0.10
0.00
-0.10
-0.20
-0.30
-0.40
-0.50
-0.60
-0.70
GHGs
Nitrogen

Corn Acres ('000s) in 2015 and 2022

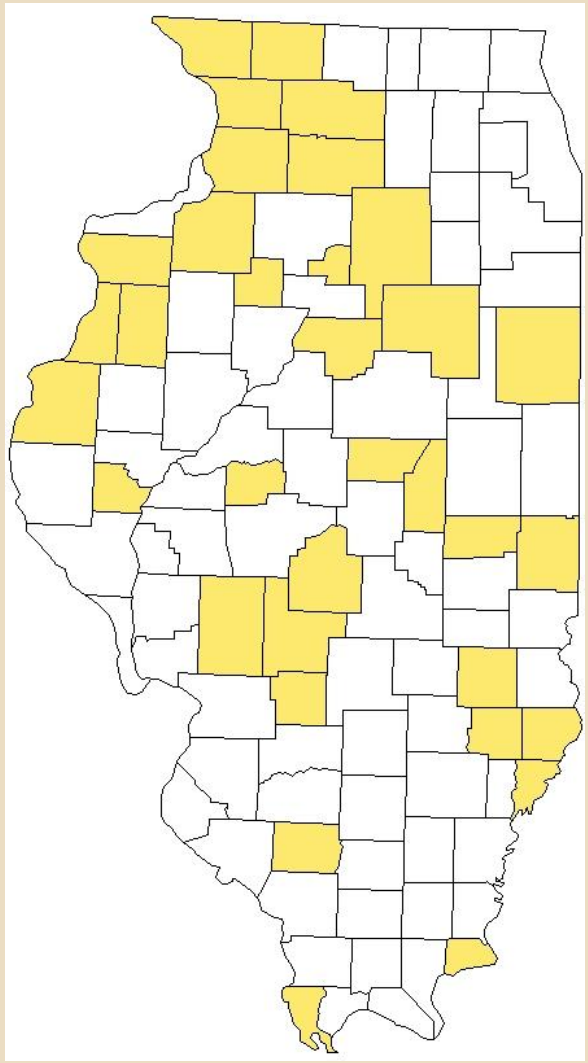


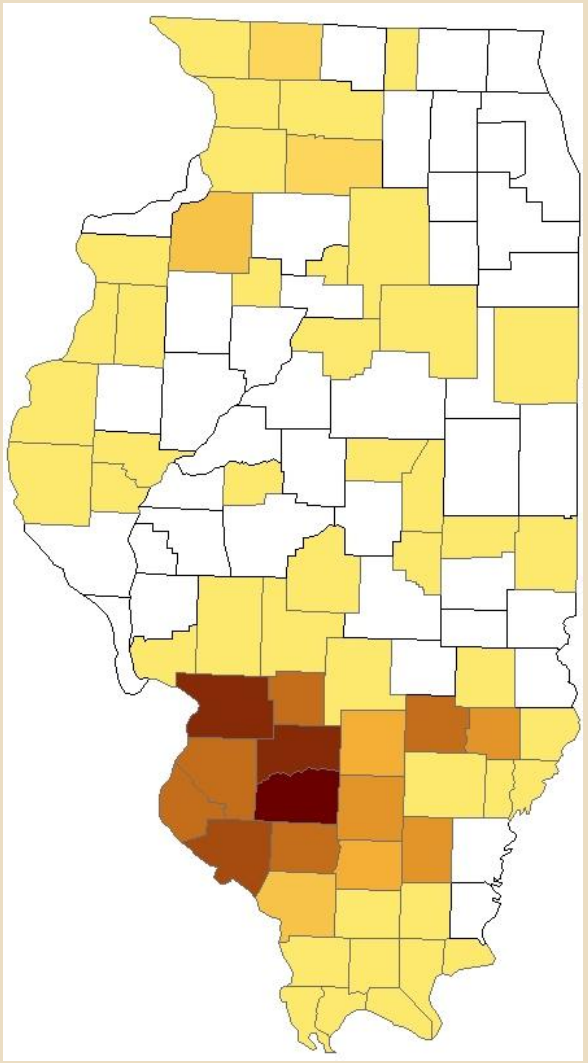
Corn in 2015

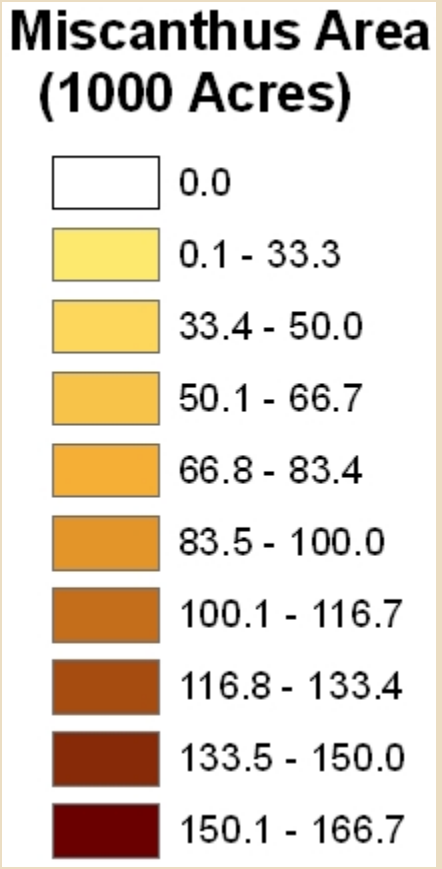
Stover in 2015

Corn and Stover in 2022

Miscanthus Acres in 2015 and 2022







Conclusions

- Spatial allocation of land for biofuel crops depends on
  - Yields, opportunity casts of land, biofuel mandates
  - Corn stover production occurring in central and northern Illinois
  - Most of miscanthus acreage be concentrated in the southern counties
  - Switchgrass not competitive at least based on current yields in Illinois
- Biofuel mandates could lead to
  - A significant shift in acreage from soybean and pasture to corn through a change in crop rotation practices
  - A change in tillage practices and a shift towards conservation tillage
  - A shift from corn-soybean rotation to continuous corn rotation
- Current biofuel mandate
  - Creates a trade-off between lower carbon emissions but higher nitrogen use with potential implications for water quality