Biofuels in Polysys

Model design, simulation and expansion

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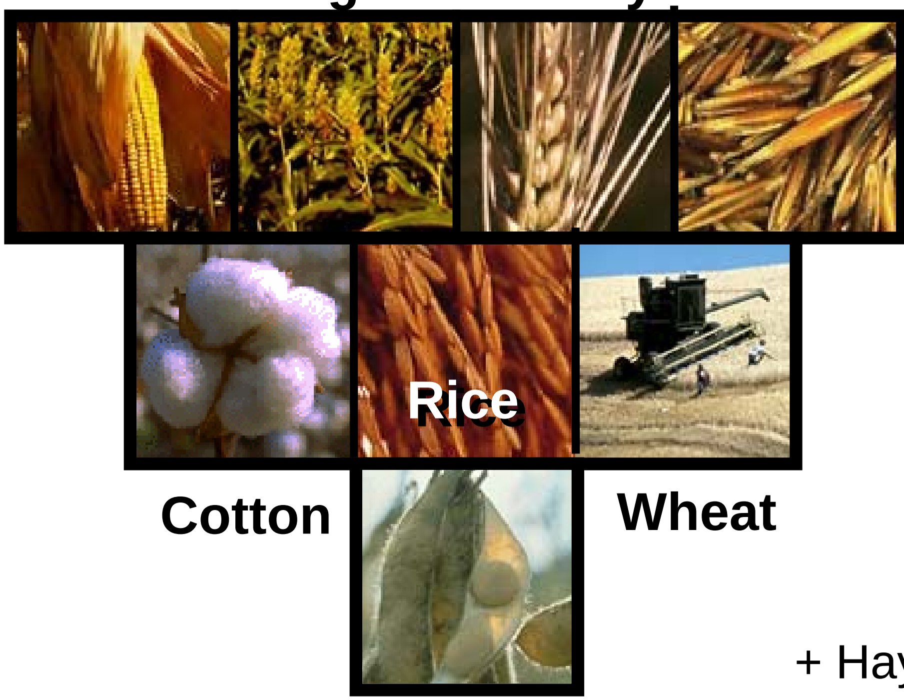
I will present…

- A Brief Introduction to POLYSYS
- Biofuel model design and modifications
- Our recent results of 25 x 25' simulation
- Undergoing expansion for energy and net carbon flux estimation

POLYSYS Introduction

Corn Sorghum Barley Oats



Cotton Wheat

Soybeans

+ Hay

ERS Livestock Model

Beef Pork

Turkeys Broilers

USDA Baseline (10 year)

USDA Basline Corn	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	2011/12	2012/13	2013/14	2014/15	2015/16
Planted acres (Mil)	80.90	81.60	80.50	81.00	82.00	84.00	84.50	85.00	85.00	85.00	84.50	84.50
Harvested acres	73.60	74.30	73.20	73.70	74.70	76.70	77.20	77.70	77.70	77.70	77.20	77.20
Yield/harvested acre	160.40	148.40	147.70	149.50	151.30	153.10	154.90	156.70	158.50	160.30	162.10	163.90
Exports	1,814	2,000	2,100	2,025	2,075	2,100	2,125	2,175	2,225	2,275	2,325	2,375
Farm price	2.06	1.80	2.00	2.20	2.45	2.55	2.60	2.60	2.60	2.55	2.60	2.60
Net returns (per ac)	197.05	135.40	124.44	125.37	164.79	182.16	192.15	194.51	197.01	191.54	202.15	204.73

Regional Acreage and Production

(305 Linear Programming Models)

National Demands, Prices, Exports and Government Payments

(Elasticities for price and export response)

Simulate Change

Demand, Exports, Land Availability, etc.

2004/05 2005/06 2006/07 2007/08 2008/09 2009/10 2010/11 2011/12 2012/13 2013/14 2014/15 2015/16

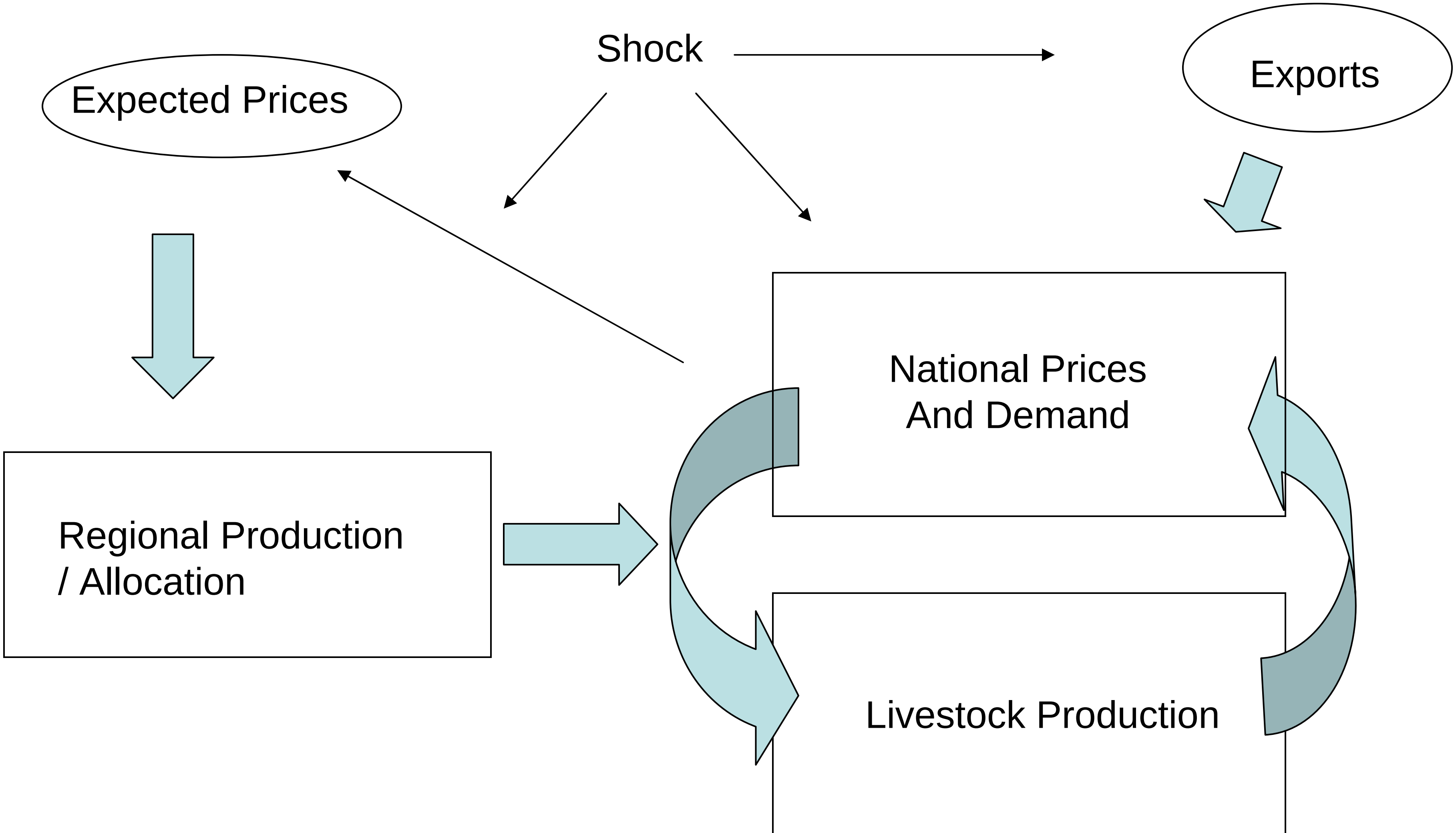
POLYSYS Regional Output

Annual acreage, production, government payments, income

POLYSYS National Output

Annual Prices, production, government payments, exports, income.

POLYSYS Simulation
Structure and Flow (Annual)



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Additions for Biofuels Model

- Add Feedstocks
  - Energy Dedicated Crop – switchgrass.
  - Crop Residues – corn and wheat.
  - Wood Residues – forest trimmings, and wood and mill wastes.
- Potential conversion of pasture.
- Make corn grain and biomass ethanol compete.

Pasture Conversion

1) Only pasture classified as historical cropland is available.
2) Pasture can only come in at the rate at which hay acreage can grow.
3) Hay lands must replace lost forage production at regional hay yield levels.
4) There must be a crop with positive net expected income to absorb the new land available.

Out of 60 million acres available, 33 million come in.

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Corresponding Price

- If we are producing corn grain ethanol, what feedstock price could we offer to biomass to produce ethanol at the same price?

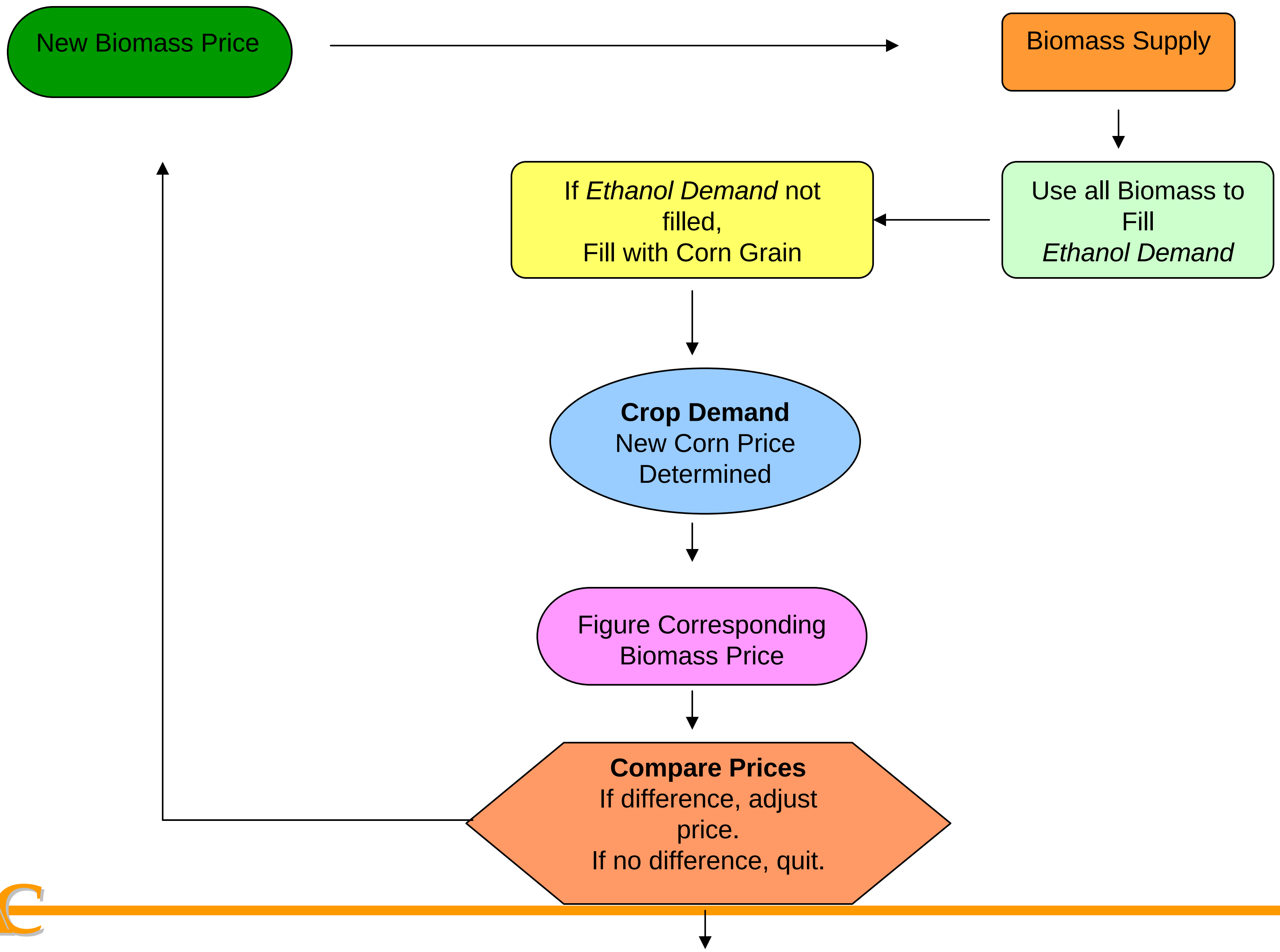
Corn Grain Ethanol Cost = Biomass Ethanol Cost

- CONVcorn + Pcorn / TECHcorn = CONVbiomass + ***Pbiomass*** / TECHbiomass
- ***Pbiomass*** = (Pcorn / TECHcorn + CONVcorn – CONVbiomass) * TECHbiomass
- Where:
  - CONVcorn is the conversion cost of corn grain to ethanol per gallon*,
  - Pcorn is the price of corn grain,
  - TECHcorn is gallons of ethanol per bushel of corn grain,

  - CONVbiomass is the conversion cost of biomass to ethanol per gallon,
  - Pbiomass is the corresponding price of biomass,
  - TECHbiomass is the gallons of ethanol per dry ton of biomass.

*transportation costs of biomass are included (average of $8.85 per ton)

Finding Optimal Feedstock Mix



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To displace 25% of liquid fuel* use by 2025, we will need to produce…

- **86 billion gallons of ethanol**
- **1.1 billion gallons of biodiesel**

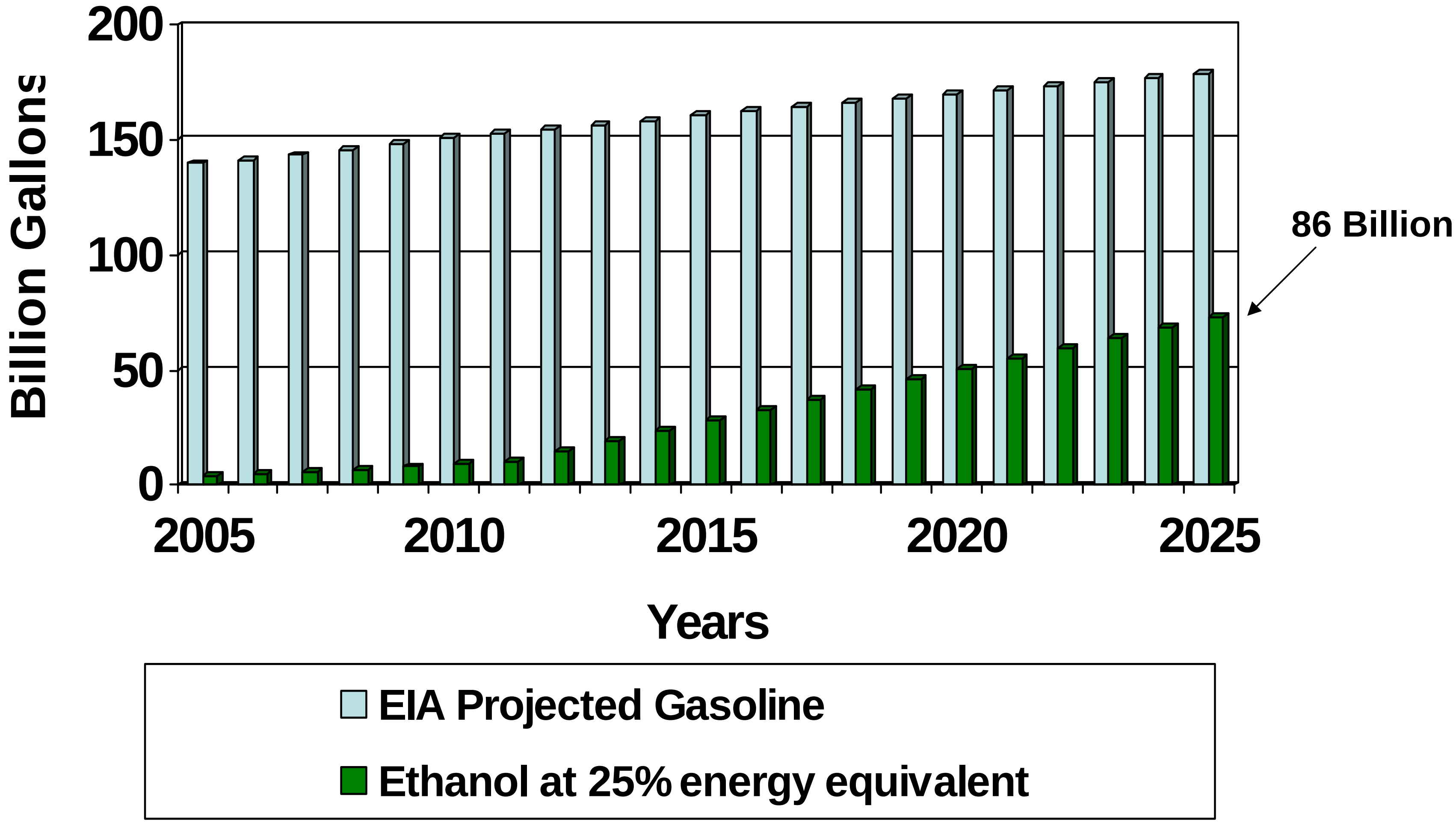
Can agriculture do it?

What feedstocks would fill it?

What would commodity prices look like?

*different from scenarios reported in 25x25' document

Expansion Assumption



Scenario Assumptions

- Yields by 2025:
  - Major crops continue w/ trend line: corn (195 bu/ac), soybeans (51 bu/ac), wheat (53 bu/ac)
  - Energy crops (6 to12 dt/acre)
- Management practices by 2025:
  - Corn: no-till (20% to 50%); reduced till (20% to 30%)
  - Wheat: no-till (12% to 50%; reduced till (20% to 30%)
- Land:
  - 60 million pasture acres available (33 come in)
  - +15 million CRP acres into biomass production

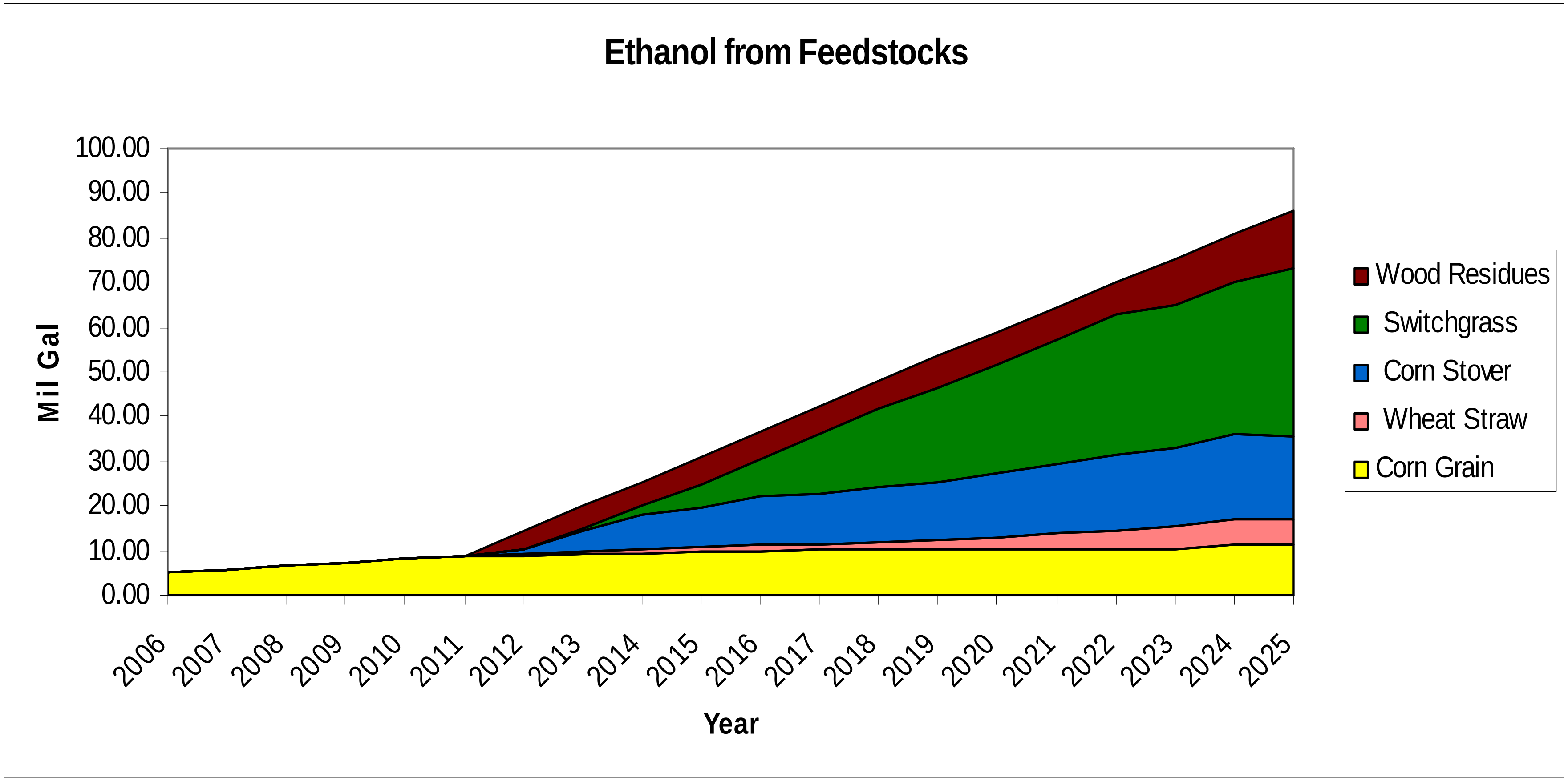
Scenario Assumptions

- **Commodity Programs:**
  - **Remain as specified in 2006**
- **Conversion Efficiency:**
  - **Improved cellulosic ethanol to 89 gallons/ton by 2025 and corn ethanol conversion to 3 gallons/bushel by 2015**

Average Commodity Prices

	Projected Change in Avg Price			
	2010	2015	2020	2025
Corn	6%	4%	-7%	13%
Wheat	-4%	-6%	1%	6%
Soybeans	2%	0%	11%	20%
Cotton	0%	7%	6%	4%
Ded. Energy Crop ($/ton)	0.00	34.61	36.75	46.75

Ethanol Sources



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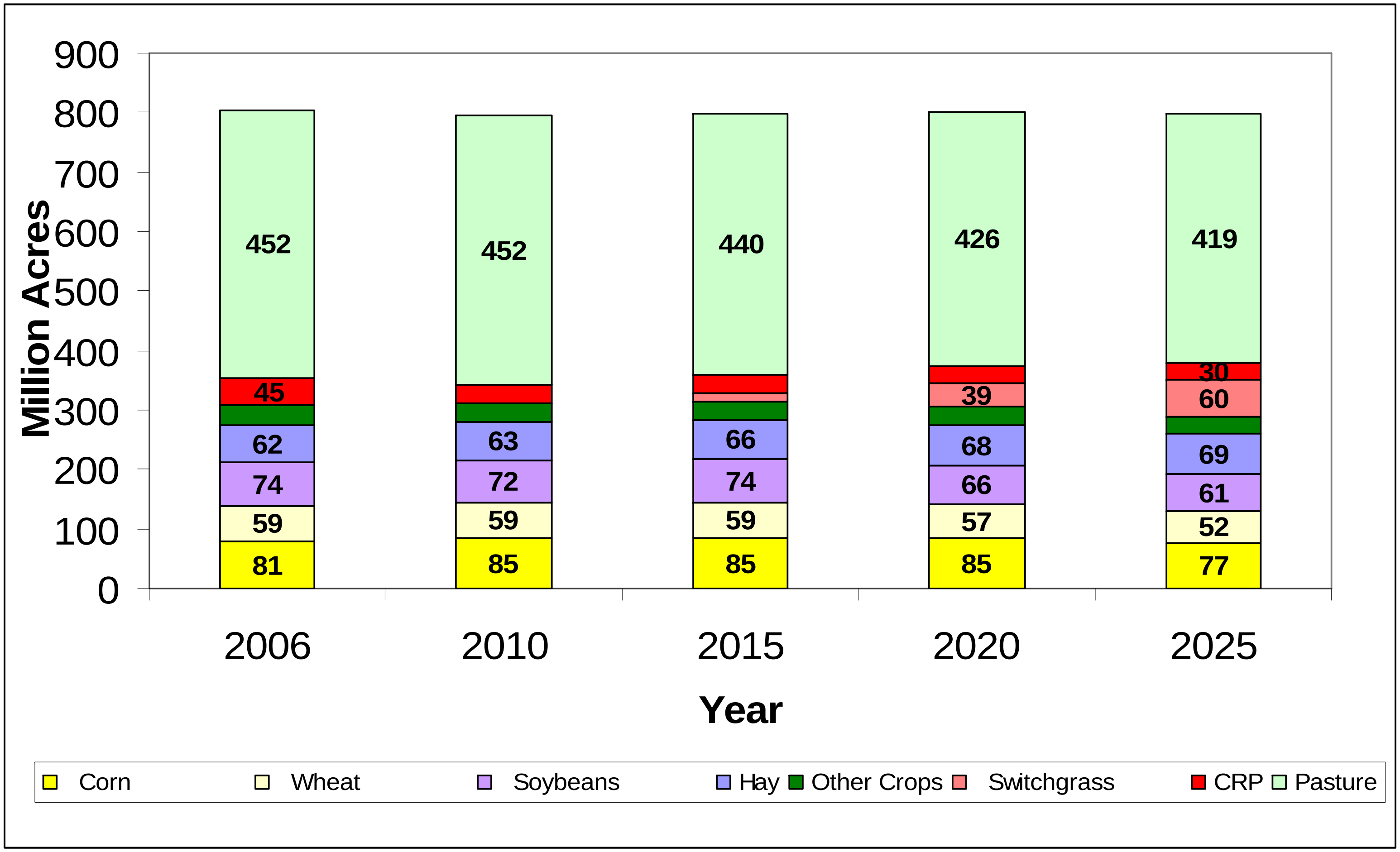
Acreage Changes



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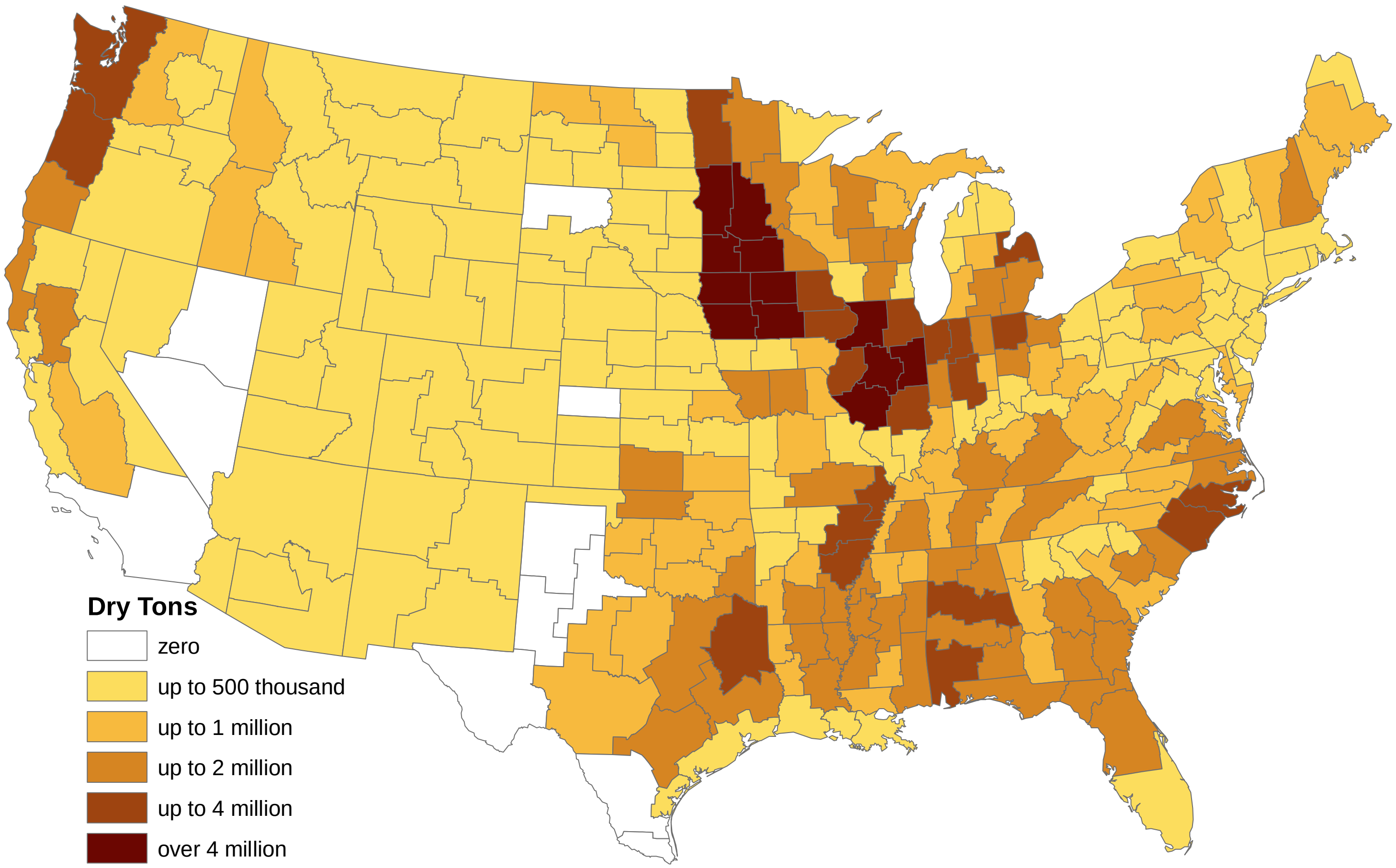
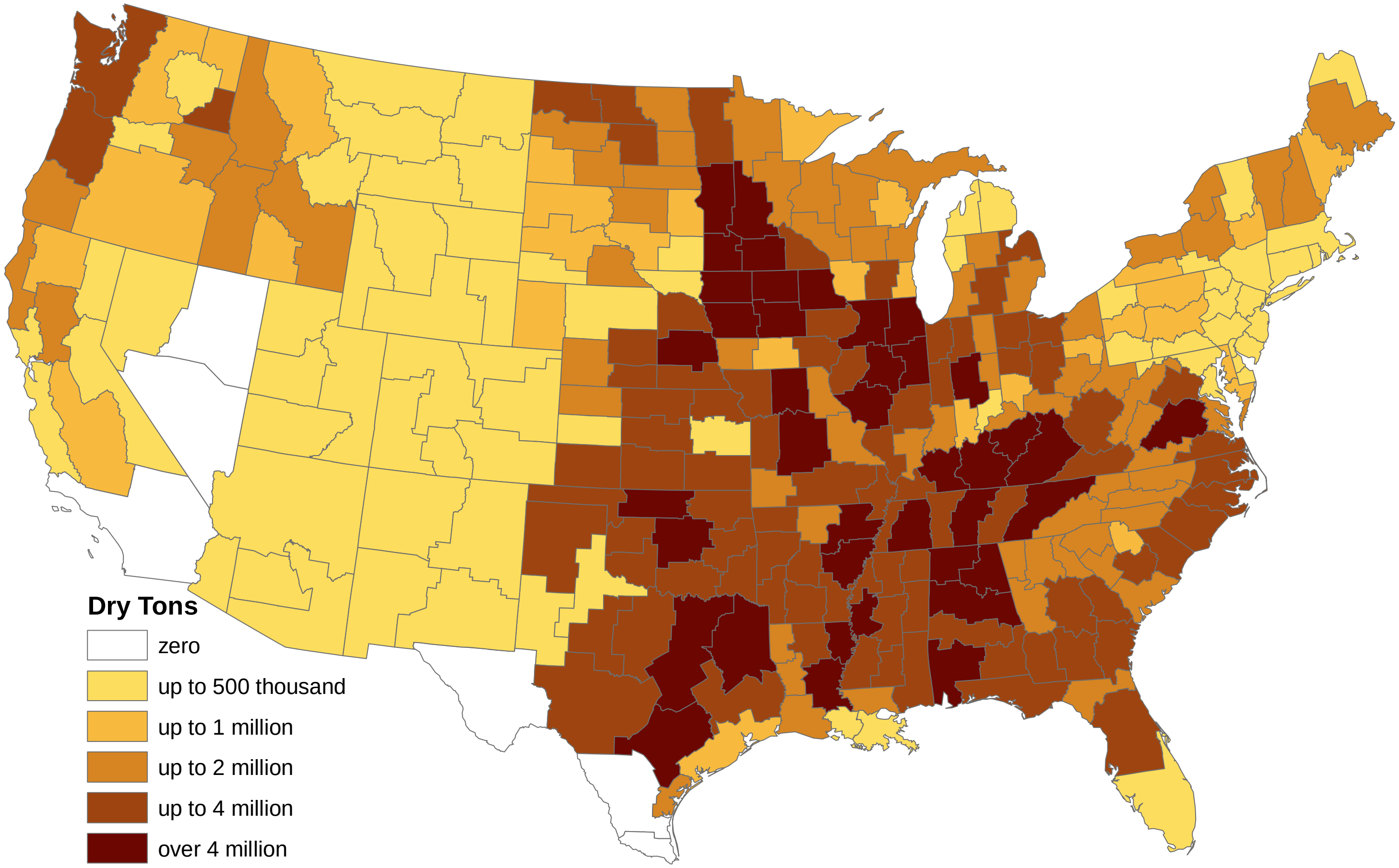
Biomass 2010

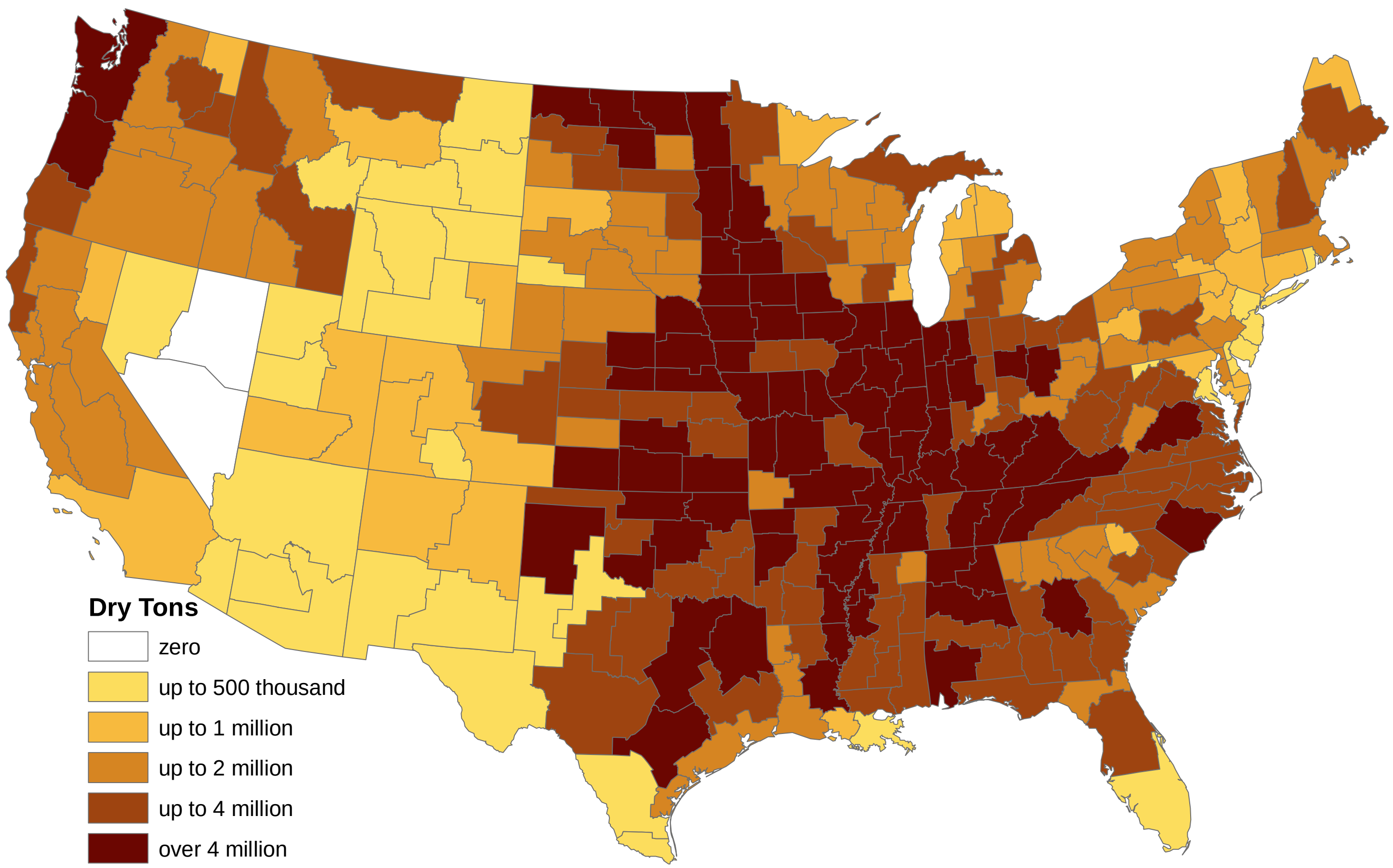
Biomass 2015



Biomass 2020



Biomass 2025



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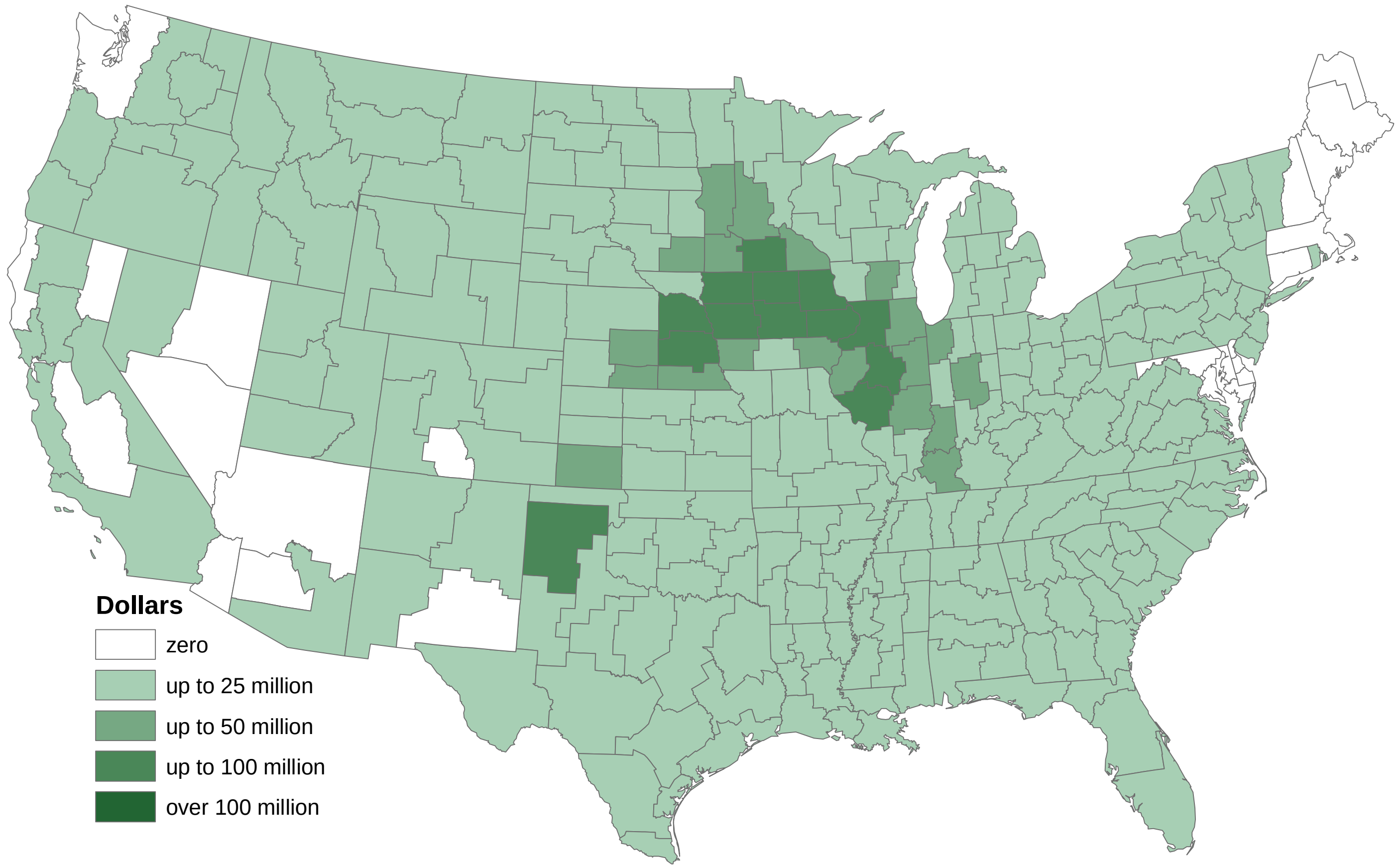
Change in Net Returns, 2010



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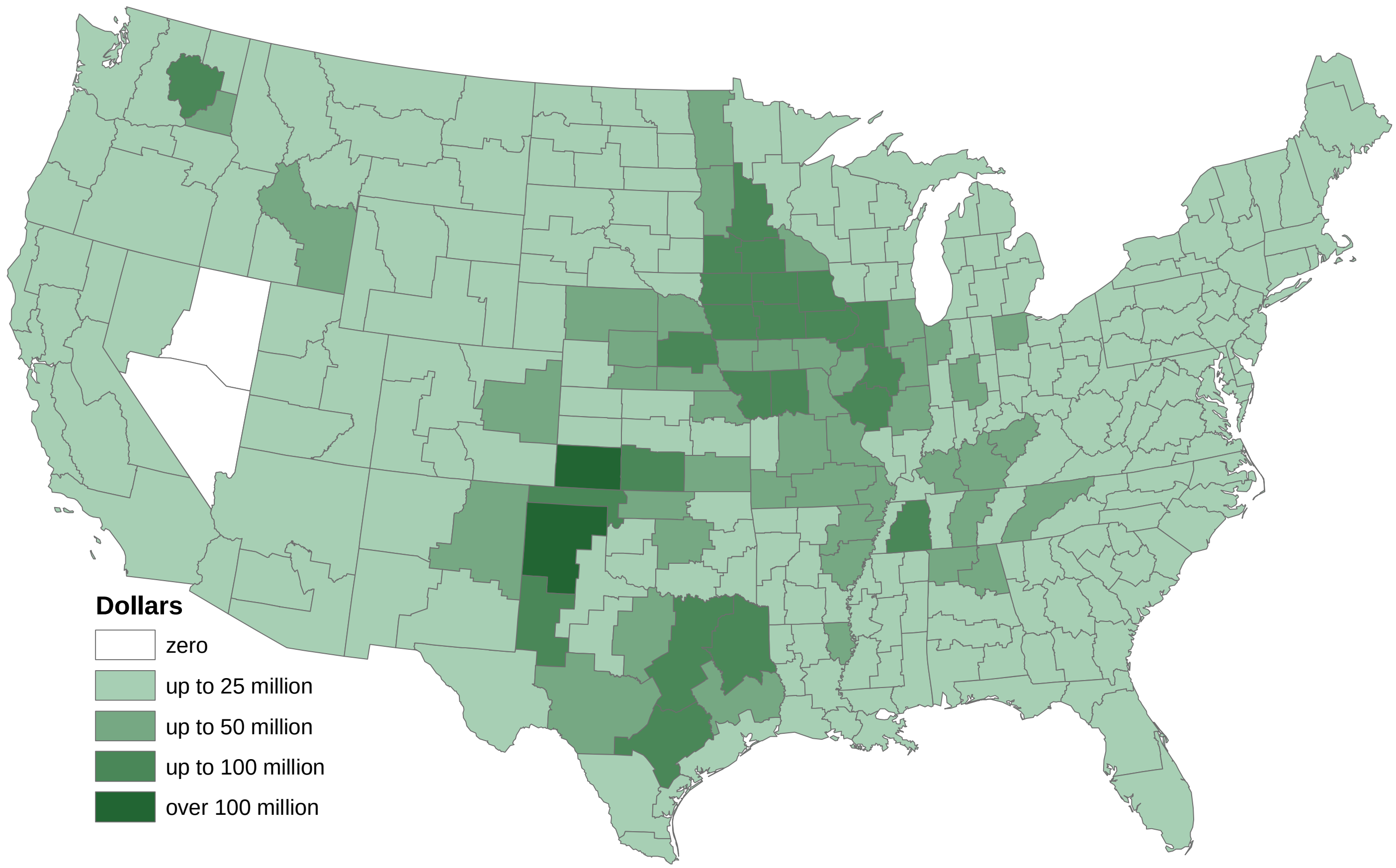
Change in Net Returns, 2015



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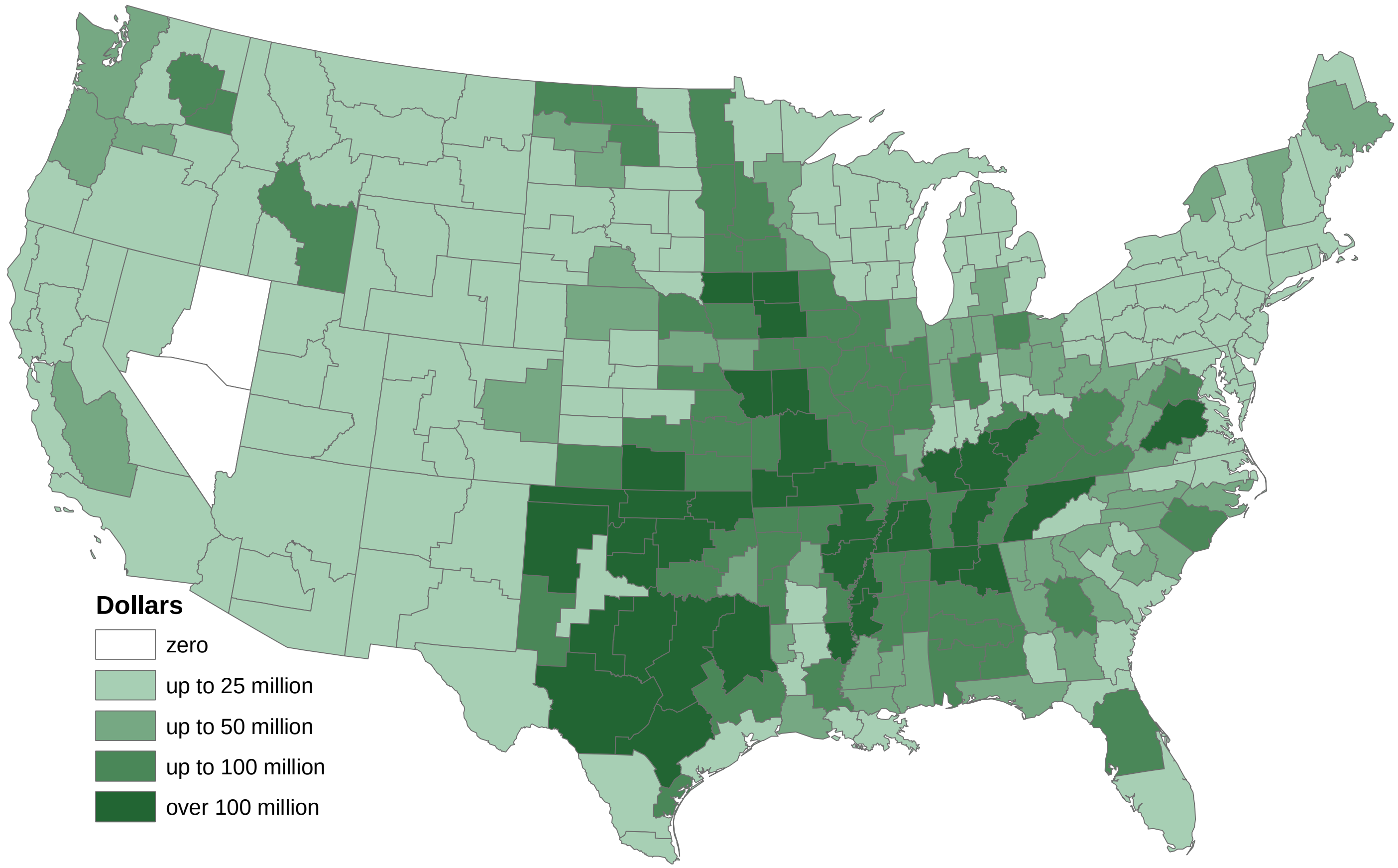
Change in Net Returns, 2020



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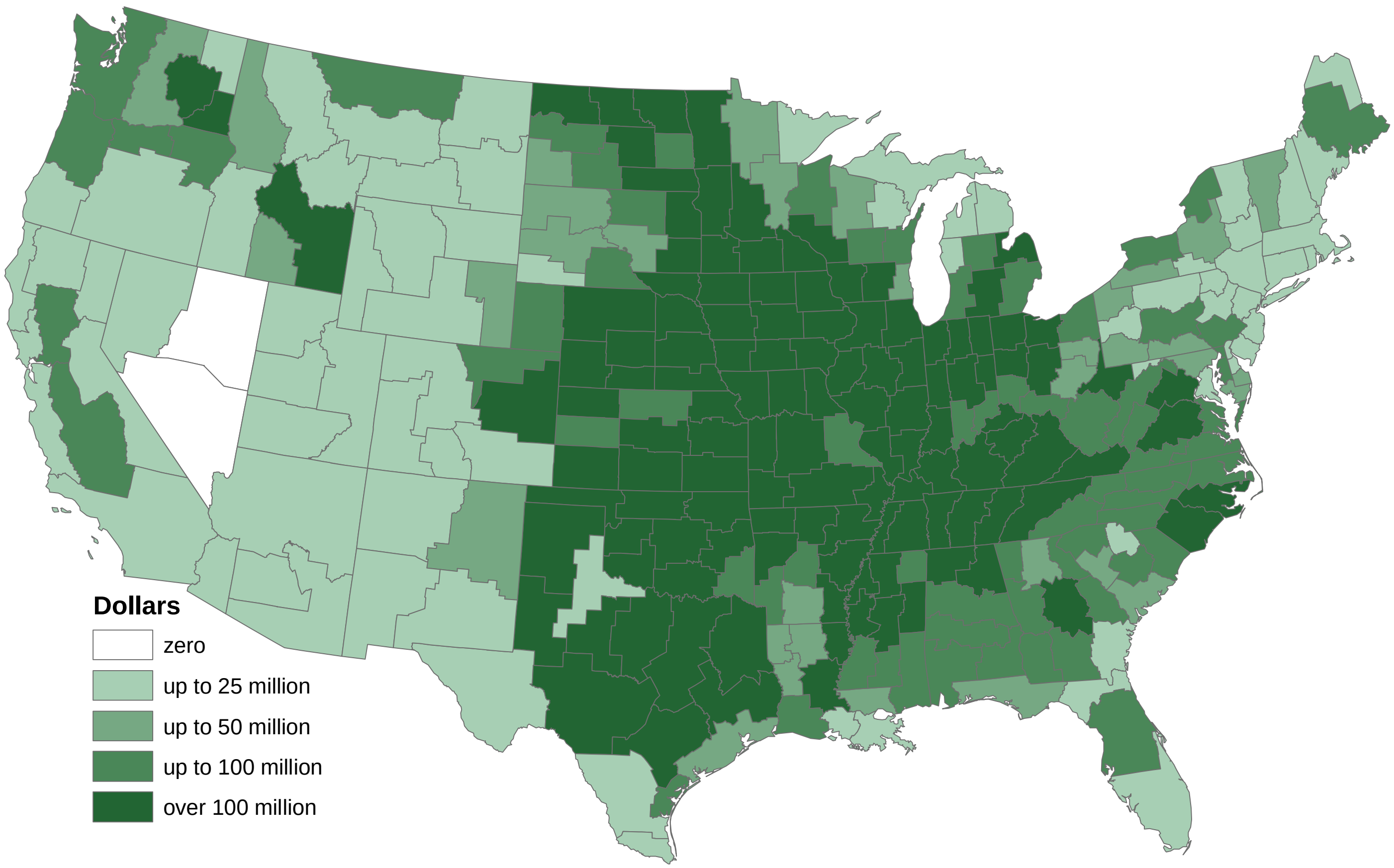
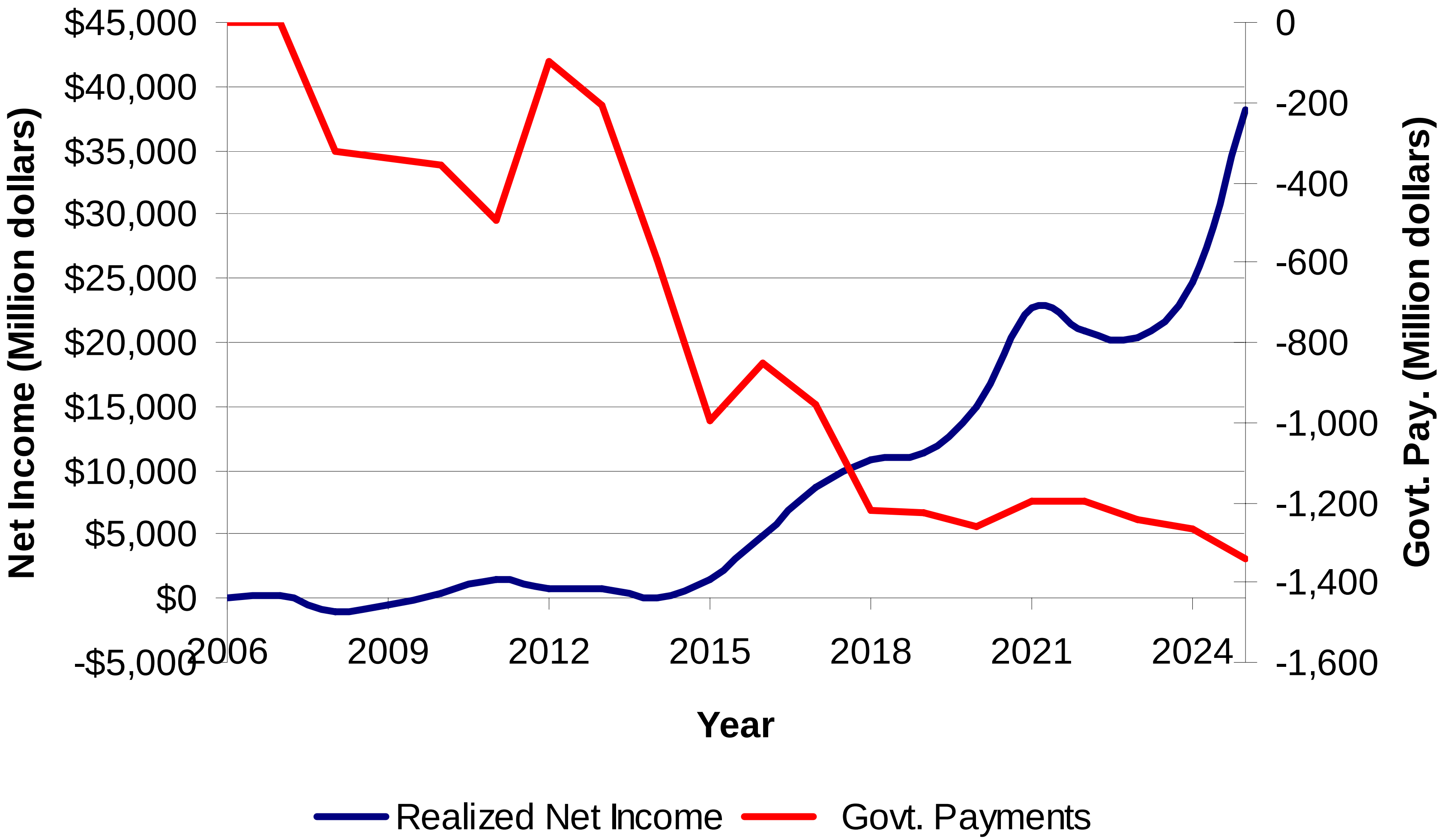
Change in Net Returns, 2025



Changes in Farm Income and Government Payments

(million $)



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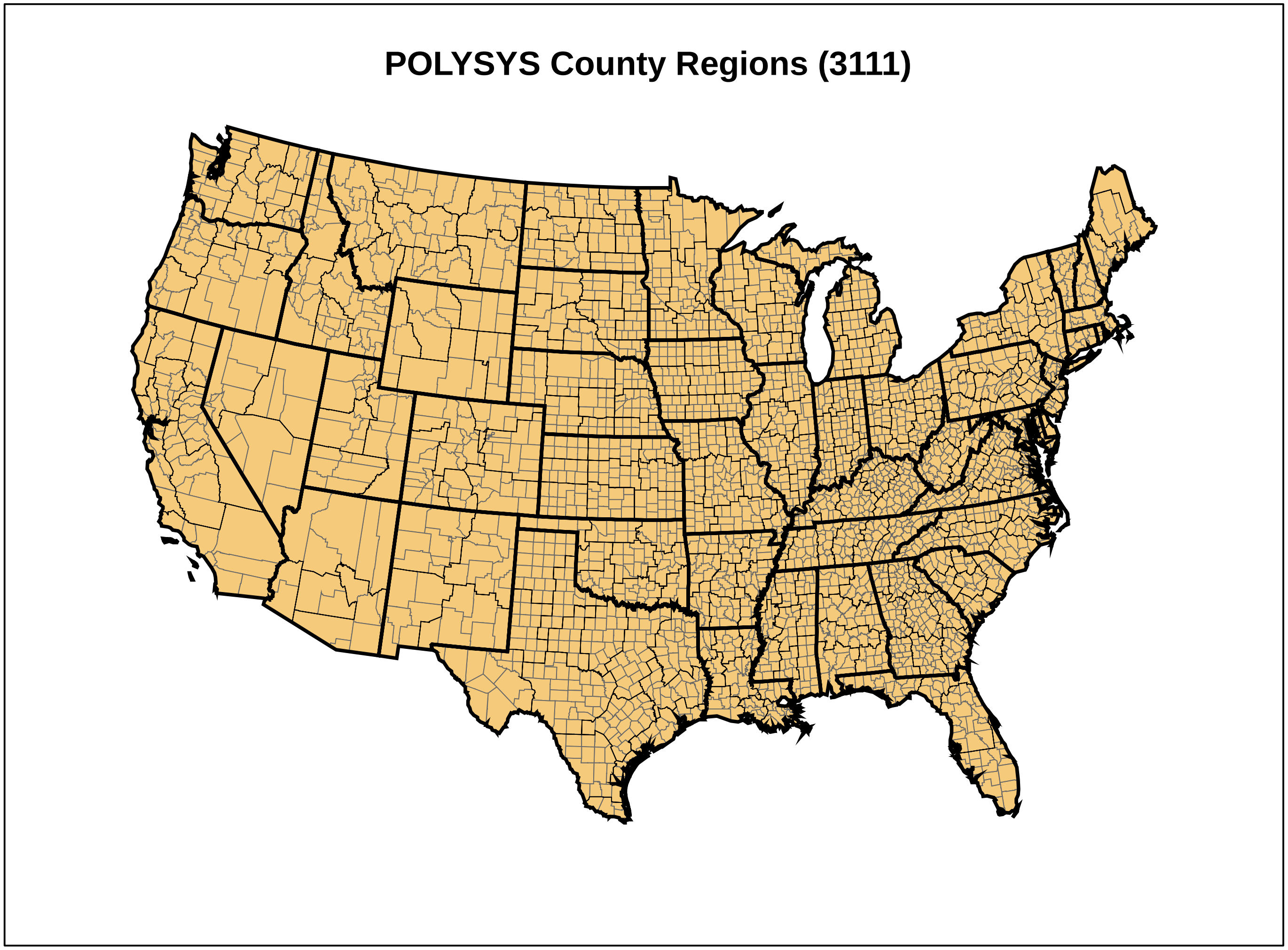
Simulation Conclusions

- 25% liquid fuels displacement can occur within ‘acceptable’ crop price increases.
- Corn grain ethanol will play a decreasing role in ethanol growth.
- Feedstock production and income benefits will be spread throughout nation.

Model Expansion:
Carbon Sequestration



Overall Objective

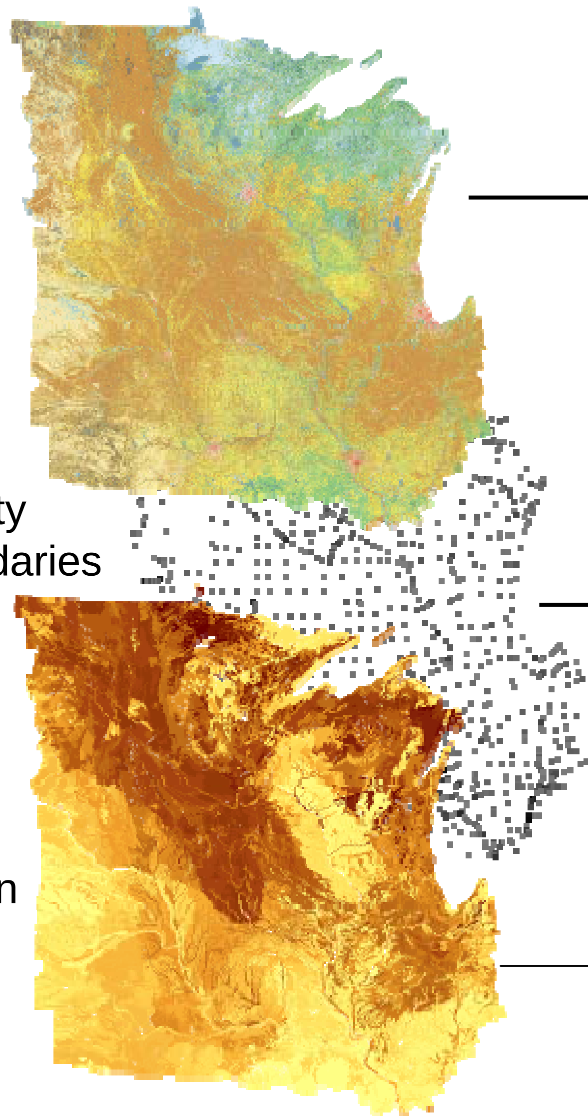
- To simulate changes in management practices and their implications upon,
    - National and regional soil carbon levels
    - National and regional emitted carbon
- Use satellite data to make estimation as geographically specific as possible – by knowing what soils underlie crops.

Data Layer Integration

Land cover

County boundaries

Soil carbon



30x30 meter Resolution Of land use

County Crop acres, tillage use, yield, and emissions

MUID level Soil organic matter

Carbon dynamics based on analyses of field data

Final product:
Simulate changes in net carbon flux with high degree of spatial resolution

Energy Use and Emissions Tied to each Budget

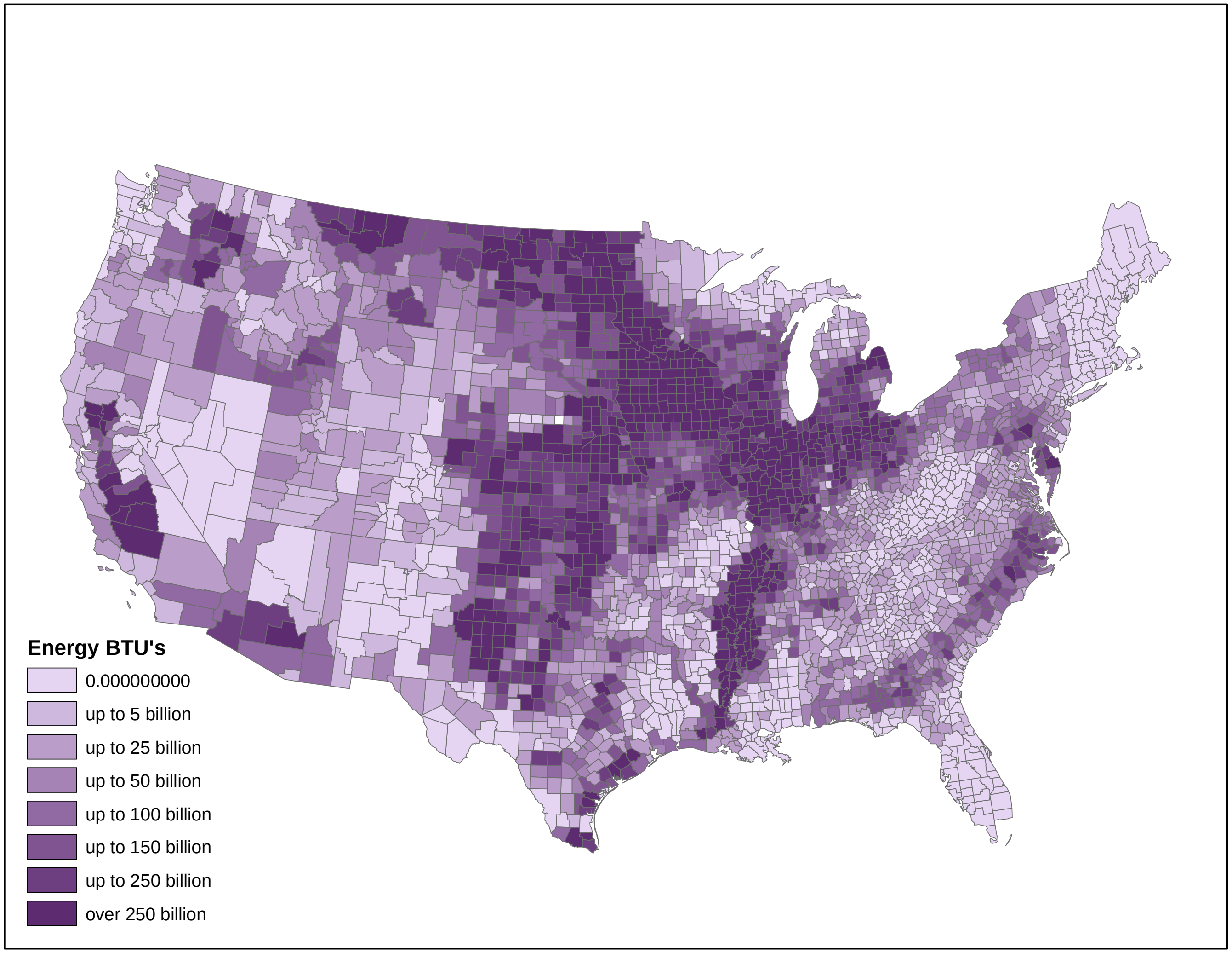
POLYSYS Crop	Direct Energy Use (Btu/ac)	CO2 Emissions from Direct Energy Use, tons per acre	Embodied Energy Use - Fertilizers (Btu/ac)	CO2 Emissions from Embodied Energy Use - Fertilizers (tons per acre)	Embodied Energy Use - Herbicides, Pesticides, Fungicides (Btu/ac)	CO2 Emissions from Embodied Energy Use - Herbicides, Pesticides, Fungicides (tons per acre)	Embodied Energy Use - Seeds (Btu/ac)	CO2 Emissions from Embodied Energy Use - Seeds (tons per acre)	CO2 from N2O emissions (tons per acre)	CO2 from Agricultural Lime emissions (tons per acre)
CornCT121	1,580,873	0.128	4,160,713	0.275	307,876	0.006	382,365	0.009	0.586	0.000
CornNT121	618,881	0.050	2,116,663	0.139	866,534	0.017	353,688	0.008	0.329	0.000
CornRT121	836,949	0.068	1,795,426	0.116	1,028,433	0.020	344,129	0.008	0.287	0.000
OatCT121	1,181,030	0.095	1,502,888	0.096	35,107	0.001	149,518	0.003	0.243	0.000
SoybeanCT121	1,379,197	0.111	669,502	0.047	53,751	0.001	331,746	0.008	0.000	0.000
SoybeanCT121	1,678,204	0.135	669,502	0.047	153,868	0.003	331,746	0.008	0.000	0.054
SoybeanNT121	1,467,789	0.118	669,502	0.047	307,737	0.006	331,746	0.008	0.000	0.054
SoybeanRT121	1,602,822	0.129	795,653	0.070	153,868	0.003	331,746	0.008	0.000	0.110

- Direct BTU and CO2 Emissions
- Embodied BTU and C02
  - Fertilizers
  - Chemicals
  - Seeds
  - CO2 from N20
  - CO2 from Lime

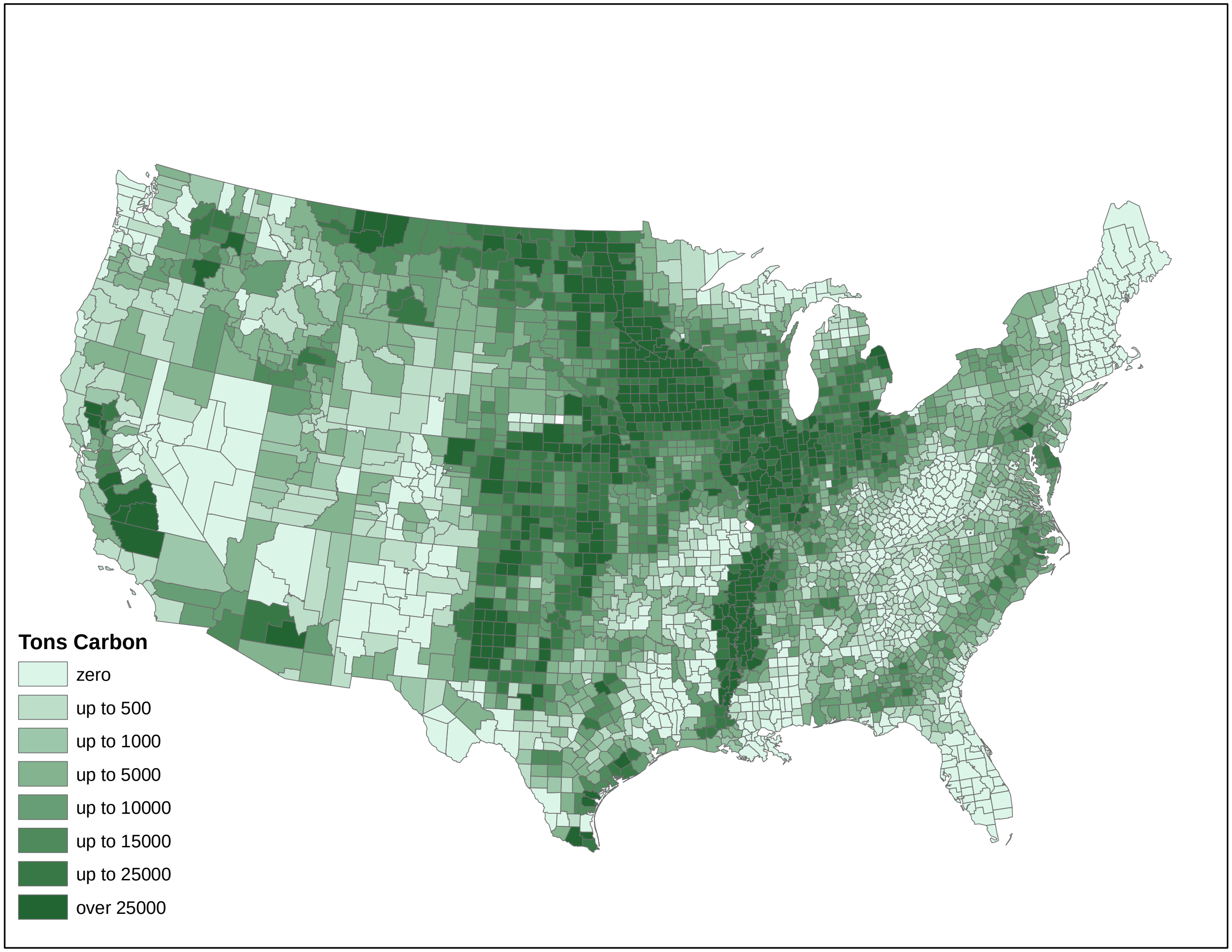
Thanks to Richard Nelson, Kansas State

for developing this database that links to APAC budgets

Direct Energy Consumption Crop Agriculture, 2015



Direct Carbon Emissions Crop Agriculture, 2015



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New version can help answer -

- What will be the effect of biofuel production on *net energy use* in agriculture?
- What will be the effect of energy cost changes upon *operation expenses* and therefore planting decisions?
- What conflicts or synergies may exist between biofuel production and carbon sequestration?

Questions Please!

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Byproducts

- Distiller’s dry grains from ethanol production and soybean meal from biodiesel production are integrated within the model to evaluate how their quantities and prices affect the final market equilibrium. For every bushel of corn grain used in ethanol production, 18.3 lbs of distiller dry grains are produced. It is assumed that distillers dry grains substitutes for livestock corn grain demand. One ton of distillers dry grain displaces 35.65 bushels of corn feed demand.
- DDGPRC = 22.7 + 30.8 * CornPrice

! BURT ENGLISH REGRESSION

Impacts on Livestock Industry

- Various components of the livestock industry react differently.
- The cattle sector is forecast to experience an increase in net returns.
- The hog and poultry industries are forecast to experience decreases in net returns, however the model is not fully capable of capturing the high degree of vertical integration in these industries making market adjustment predictions difficult.

Cropland in Pasture

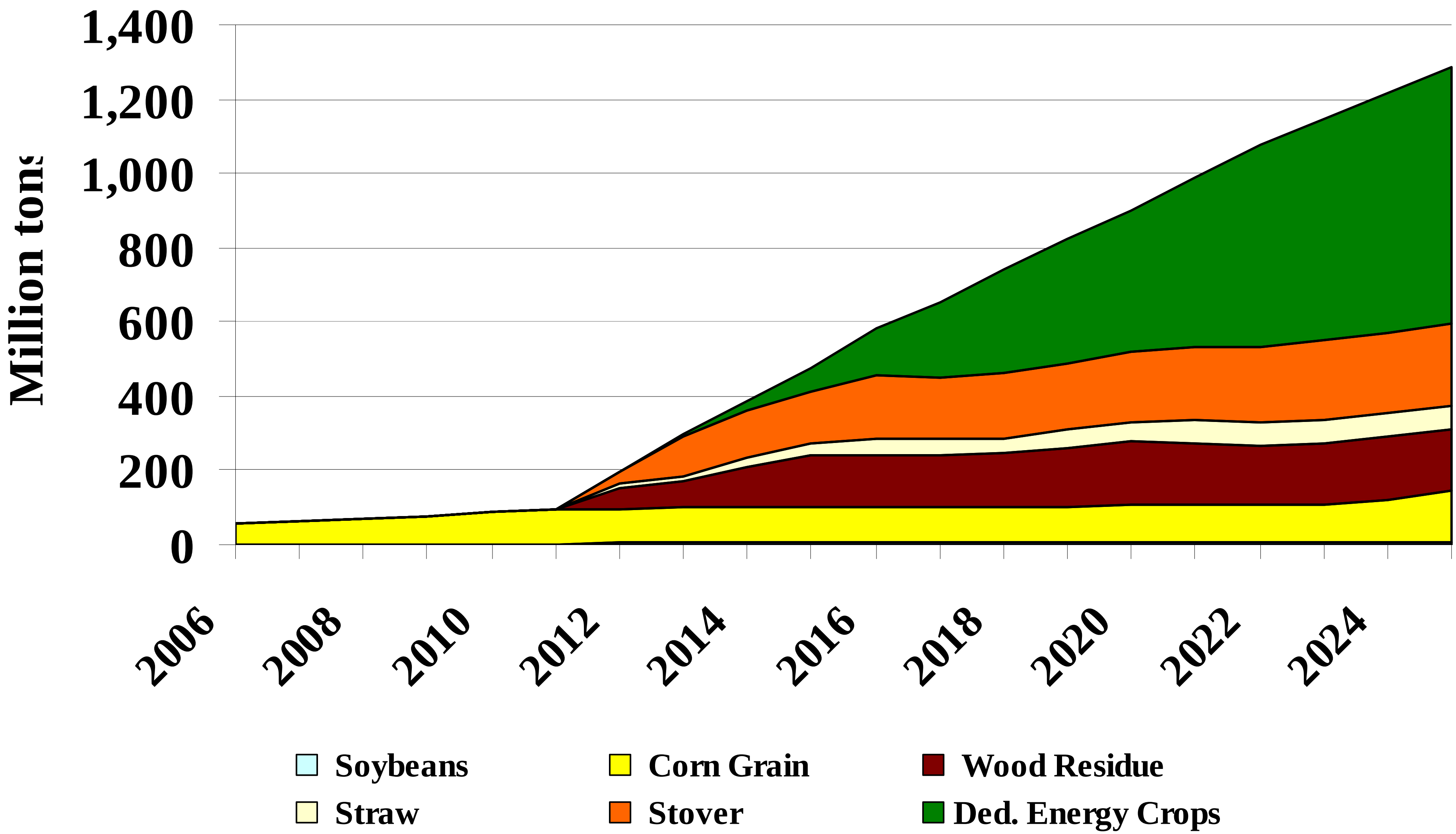
Pout = %Havail * Hacres * Hyield / Pyield

Hin =Pout * Pyield / Hyield

NGpot = Pout - Hin

- Where,
  - Pout is the amount of pasture that can come out of pasture if available.
  - %Havail is the percentage of current hay total acreage that can expand.
  - Hacres is the current hay total acreage.
  - Hyield is the yield per acre of hay.
  - Pyield is the yield per acre of pasture.
  - Hin is the acres of hay that will come in to replace Pout.
  - NGpot is the potential net gain in acreage.

Ethanol Sources in Tons



* Does not include standing forest harvest

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Conventional Corn Operations Central Iowa

Month	Day	Machinery	Power	Labor	Machine	Fert	lbs	Chem	Amount	Unit
4	10	Tandem Disk (reg) GE19ft	Tractor 2wd 135 hp (diesel)	0.1074	0.1181		0		0	
4	10	Dry Fert Spreader (trailer mtd)		0.0873	0.096	Limestone	490		0	
5	1	Field Cultivator GE15ft	Tractor 2wd 135 hp (diesel)	0.063	0.0693		0		0	
5	9	Chem Applicator GE30ft (trailer mtd)	Tractor 2wd 135 hp (diesel)	0.0391	0.043		0	Atrazine 90DI	2.5	LB
5	9	Chem Applicator GE30ft (trailer mtd)	--	0	0		0	Lasso 4E (Ala	0.2	GAL
5	14	8 Row Planter (regular)	Tractor 2wd 135 hp (diesel)	0.2619	0.3274		0		0	
5	14	Fert Applicator (attached to impl)	Multiple Operation	0.2619	0	N	44		0	
5	14	Fert Applicator (attached to impl)	--	0	0	P2O5	45		0	
5	14	Fert Applicator (attached to impl)	--	0	0	K20	36		0	
5	18	Row Cultivator GE15ft	Tractor 2wd 135 hp (diesel)	0.1281	0.1409		0		0	
6	15	Row Cultivator GE15ft	Tractor 2wd 135 hp (diesel)	0.1281	0.1409		0		0	
6	15	Anhyd Fert Applicator (trailer mtd)	Tractor 2wd 135 hp (diesel)	0.1058	0.1164	Anhydrous	122		0	
10	29	Combine w/ Row Header-2wd (self-prop)		0.1637	0.1801		0		0	
10	29	Single-axle Truck 2 ton (gas) (self-prop)		0.33	0.363		0		0	

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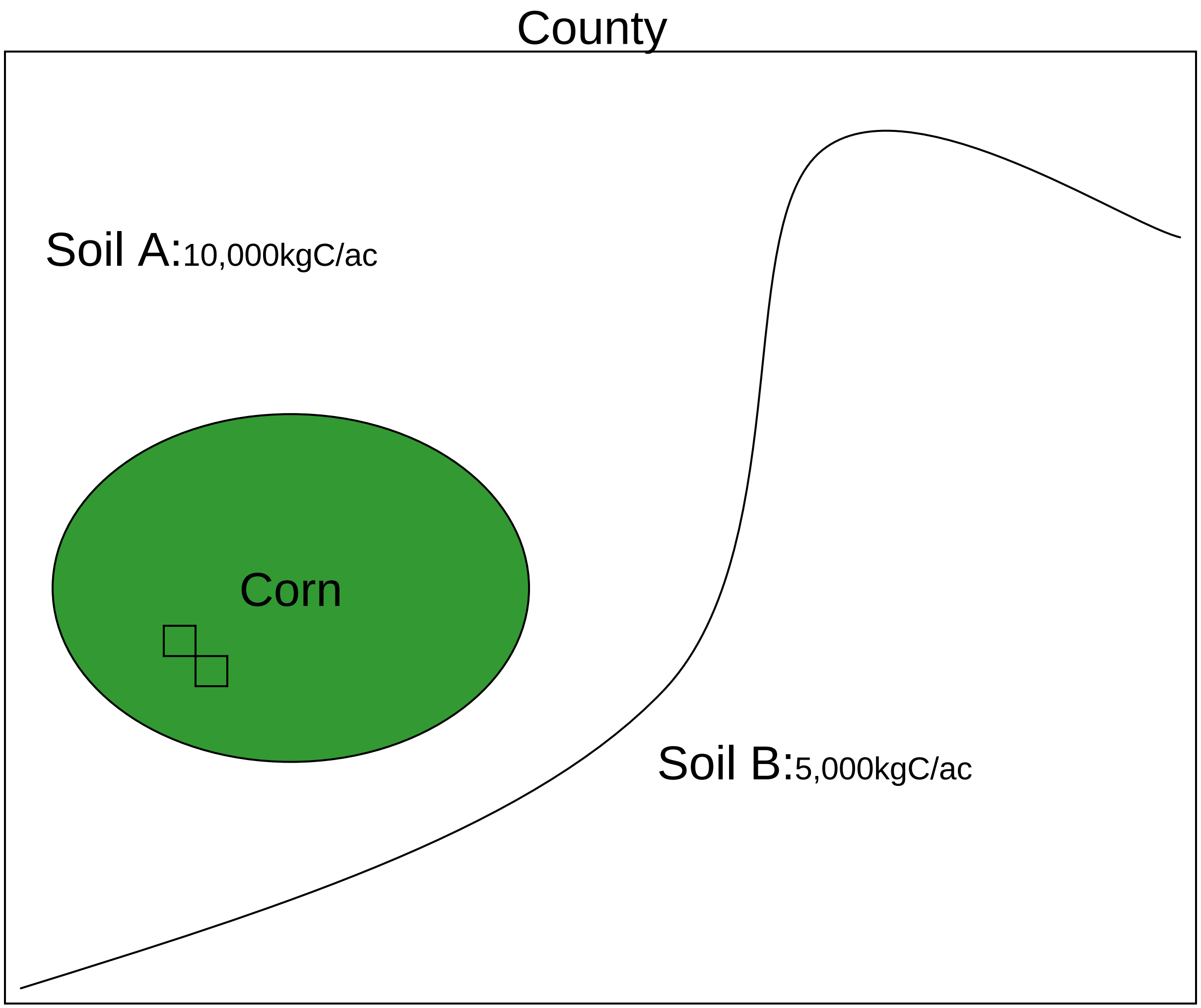
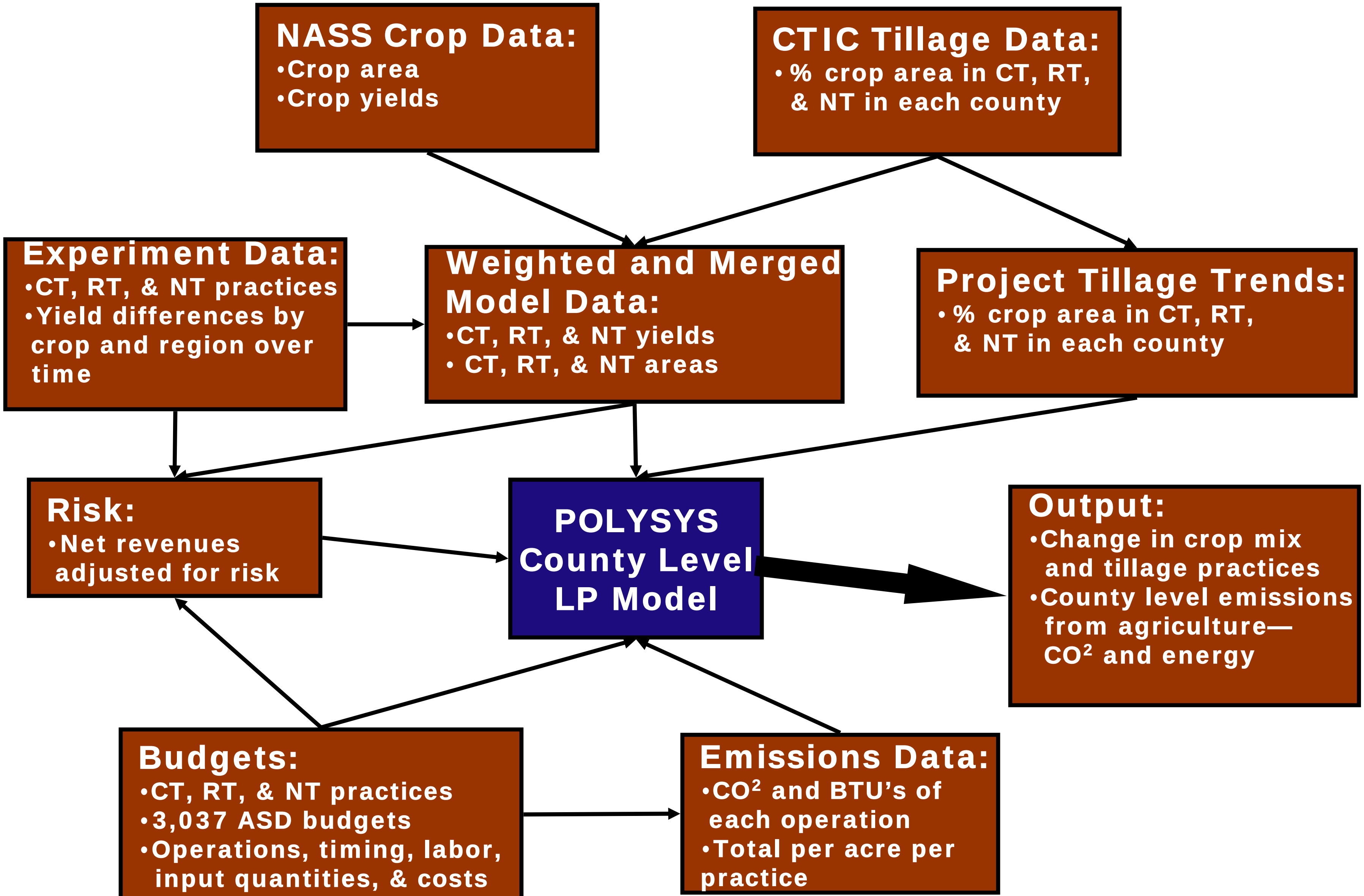
How specific can we get?



100 Corn Acres in County

With Satellite Data we can place corn acres in right soil.

POLSYS Supply Model



Output

- County Level
  - Annual change in acres of each major crop (and hay)
  - Annual changes in tillage practice used
  - Annual change in emissions and energy associated with each crop and management practice
  - (Satellite data will place crop acres into specific soil)
- National Level
  - Annual Emissions from agriculture
  - Price, production, income, government payments
  - Incentive program costs

Flexibility in Model Design

- May Want to Simulate:
  - $ per acre incentive to a management practice
  - $ per ton carbon sequestered
    - Permanence?
    - Leakage?
    - Incentive to All Users or just New Adopters?
    - Tax on land use change that emits?
  - $ per ton net carbon flux