BIOLOGICAL & AGRICULTURAL ENGINEERING
TEXAS A&M UNIVERSITY

GIS-Based Allocation of Lignocellulosic Biorefineries

A Case Study in Texas

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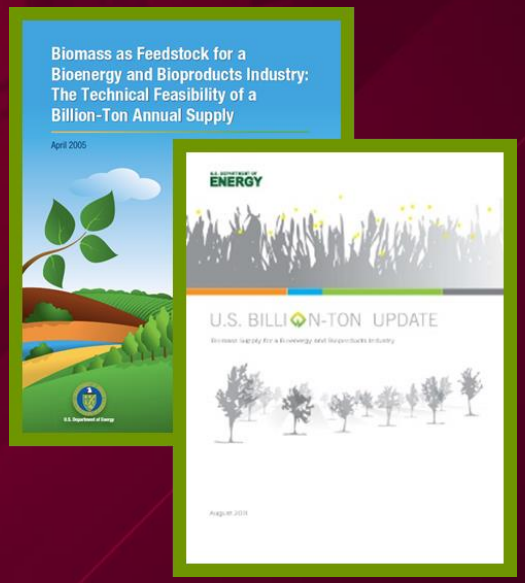
August 14th, 2014

1. Biorefinery Allocation
2. BT2 Analysis for Texas
3. Supply Curves
4. IBSAL Project

MOTIVATION

- Increase renewable energy production.
  - Biofuels for 2022
    - 15 BGY conventional biofuel (corn)
    - 21 BGY advanced biofuel
      - 16 BGY cellulosic biofuel
- National assessments identify sufficient biomass
- Resource is inaccessible using current biomass supply systems



PRESENTATION OUTLINE

1. Biorefinery Allocation
2. BT2 Analysis for Texas
3. POLYSYS Runs
4. BioMODS with IBSAL

1. BIOREFINERY ALLOCATION

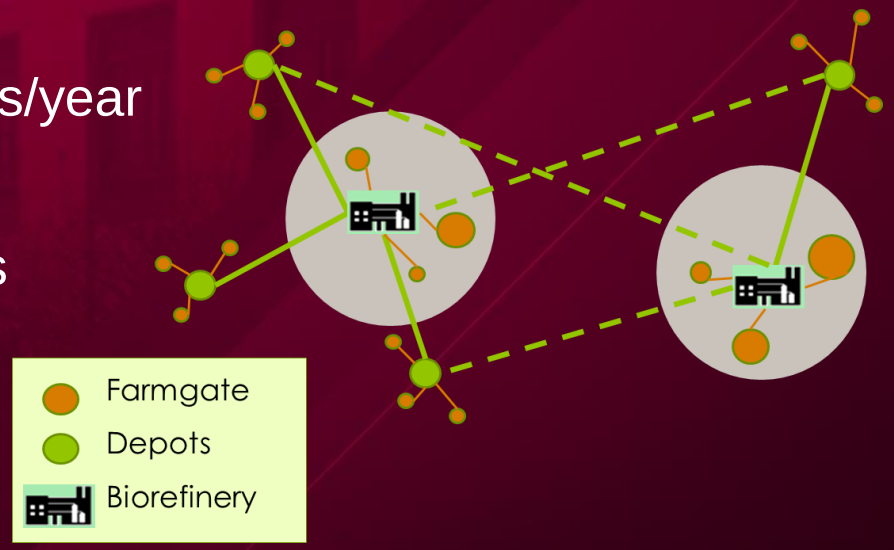
OBJECTIVE

Allocate biorefineries and depots in Texas based on:

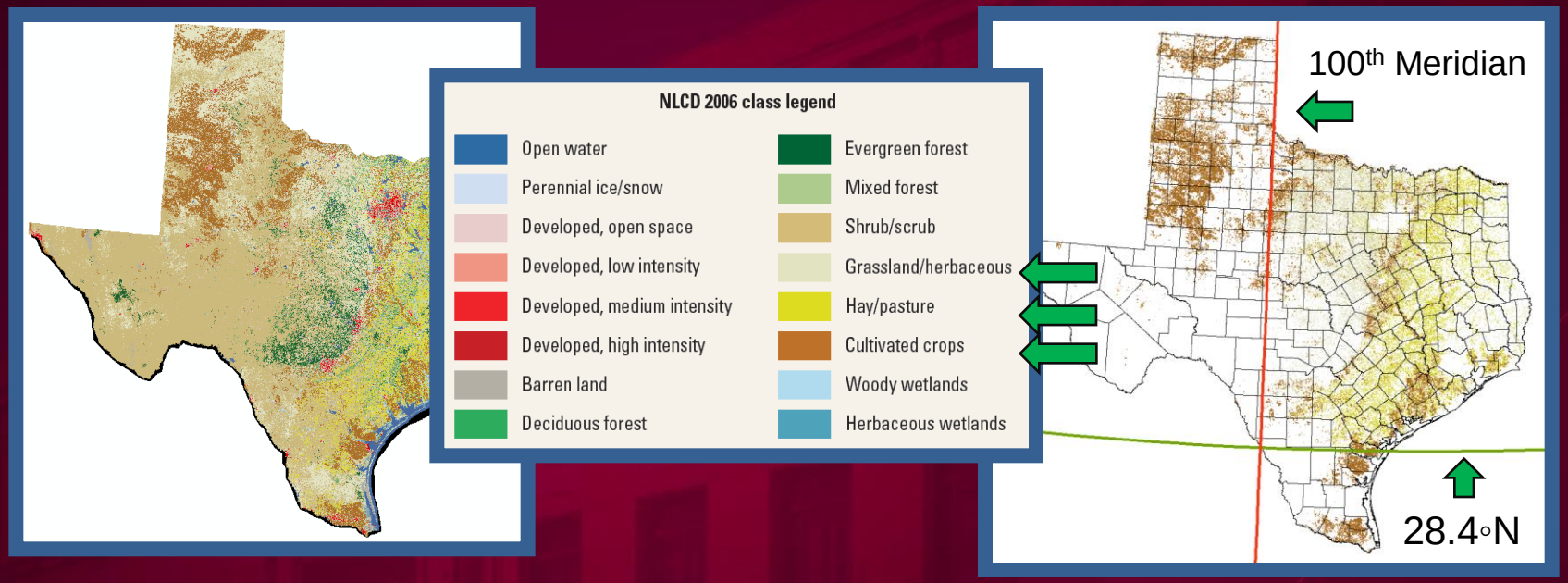
- BT2 results for herbaceous biomass in 2022 at the $50 per DMT price level at the farmgate
  - 1% annual increase in corn yield
  - 1% annual increase in energy crop yield
- Current transportation networks
  - Road and rail network
- Geographical data
  - Land Cover Data (NLCD)

ASSUMPTIONS & PARAMETERS

- Conversion rate = 85 gallons/ DMT
- Biorefinery
  - Supply radius = 50 miles
  - Located less than 1 mile away from road and rail network
  - Feedstock = **crop residues** (barley, corn stover, oats, sorghum, wheat) and **energy crops** (annual energy crops, perennial grasses).
  - At least 11 million gallons/year
- Depot
  - Supply radius = 20 miles
  - Located less than 1 mile away from road and rail network



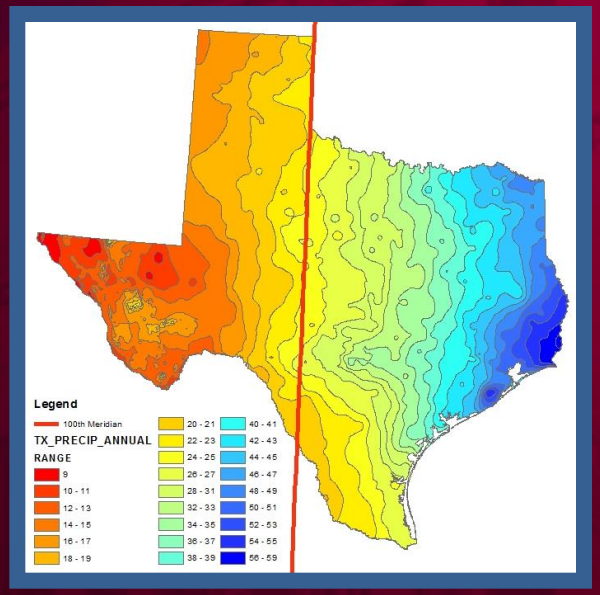
TEXAS: 2006 LAND COVER DATA



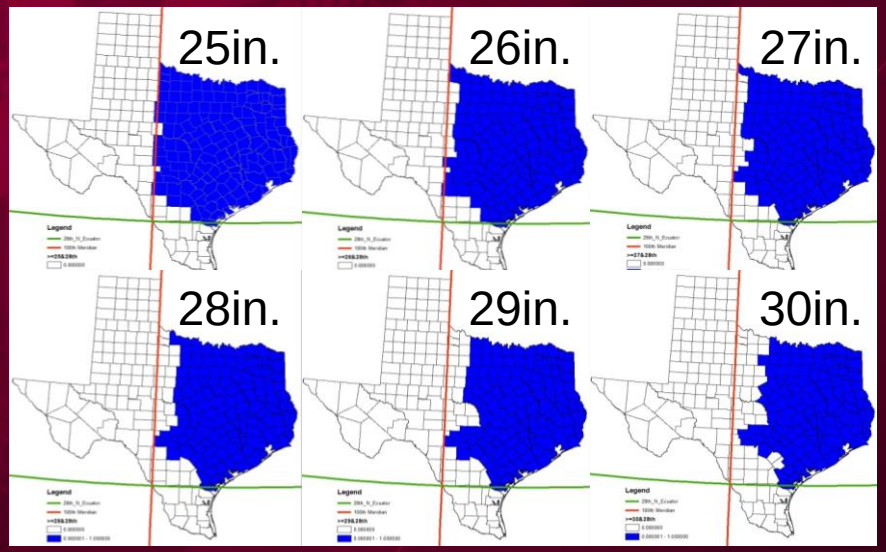
- Suitable land :
  - Grassland/herbaceous & hay/pasture → perennial grasses
  - Cultivated crops → crop residues & annual energy crops
- Total suitable land = 34,432 acres
- Cell size used = 1 mile square

ANNUAL PRECIPITATION

- Muir et al. suggested a southern limit of adaptation for Alamo switchgrass between Stephenville, TX (32.22◦N) and Beeville, TX (28.4◦N) that is unrelated to rainfall or soil type (Muir, Sanderson, Ocumpaugh, Jones, & Reed, 2001).



30-year Normal Precipitation: Annual by PRISM (1981–2010)



Average Annual County Precipitation for Counties North of 28◦N

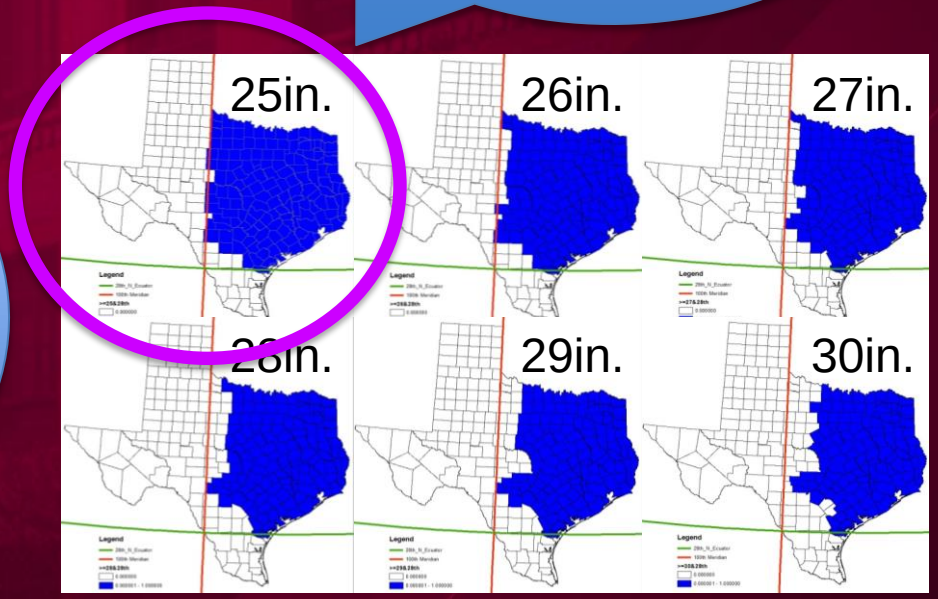
ANNUAL PRECI

- Muir et al. suggested a southern lim
switchgrass between Stephenville, T
TX (28.4◦N) that is unrelated to rainfa
Sanderson, Ocumpaugh, Jones, & Reed

The 100th Meridian assumption does align with an average county precipitation of 25 inches.

Based on the literature review, counties south of the 28◦N would not be suitable for switchgrass

30-year Normal Precipitation: Annual by PRISM (1981–2010)



Average Annual County Precipitation for Counties North of 28◦N

NLCD & BT2

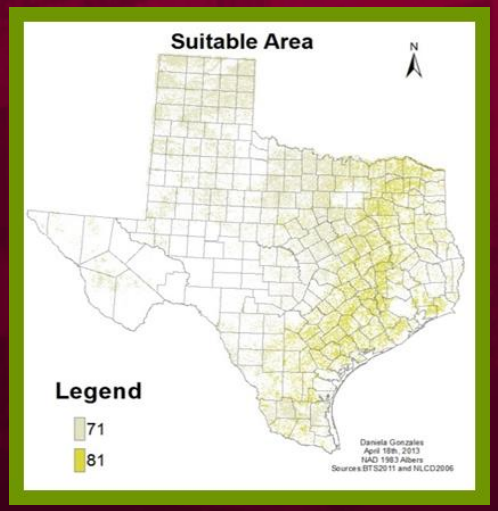
For each land type

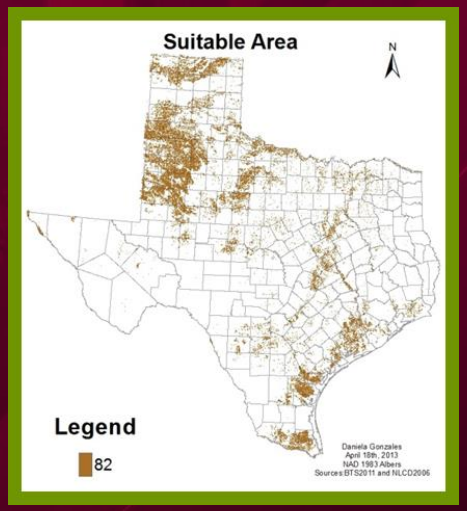
For each county

A = Total suitable area from NLCD

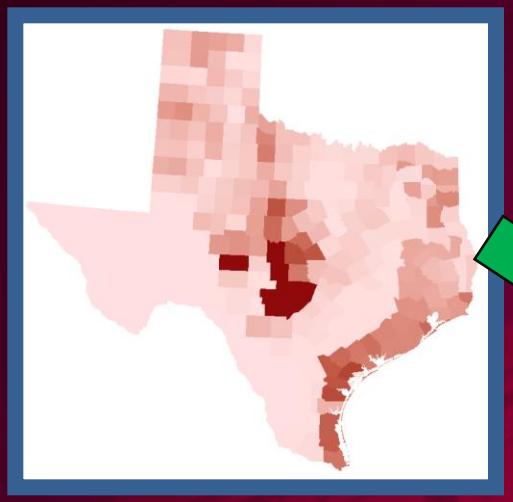
B = Total biomass from BT2

Value of each cell in county = A / B

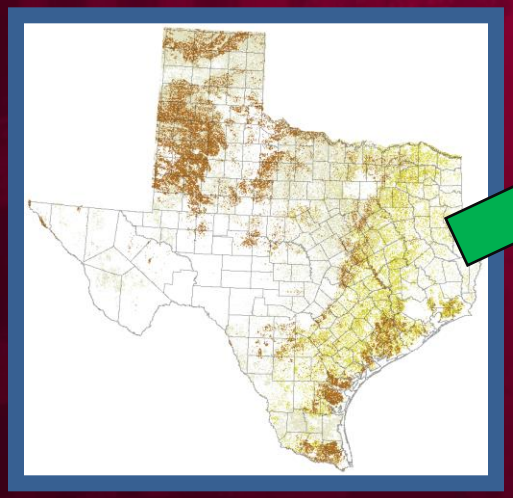




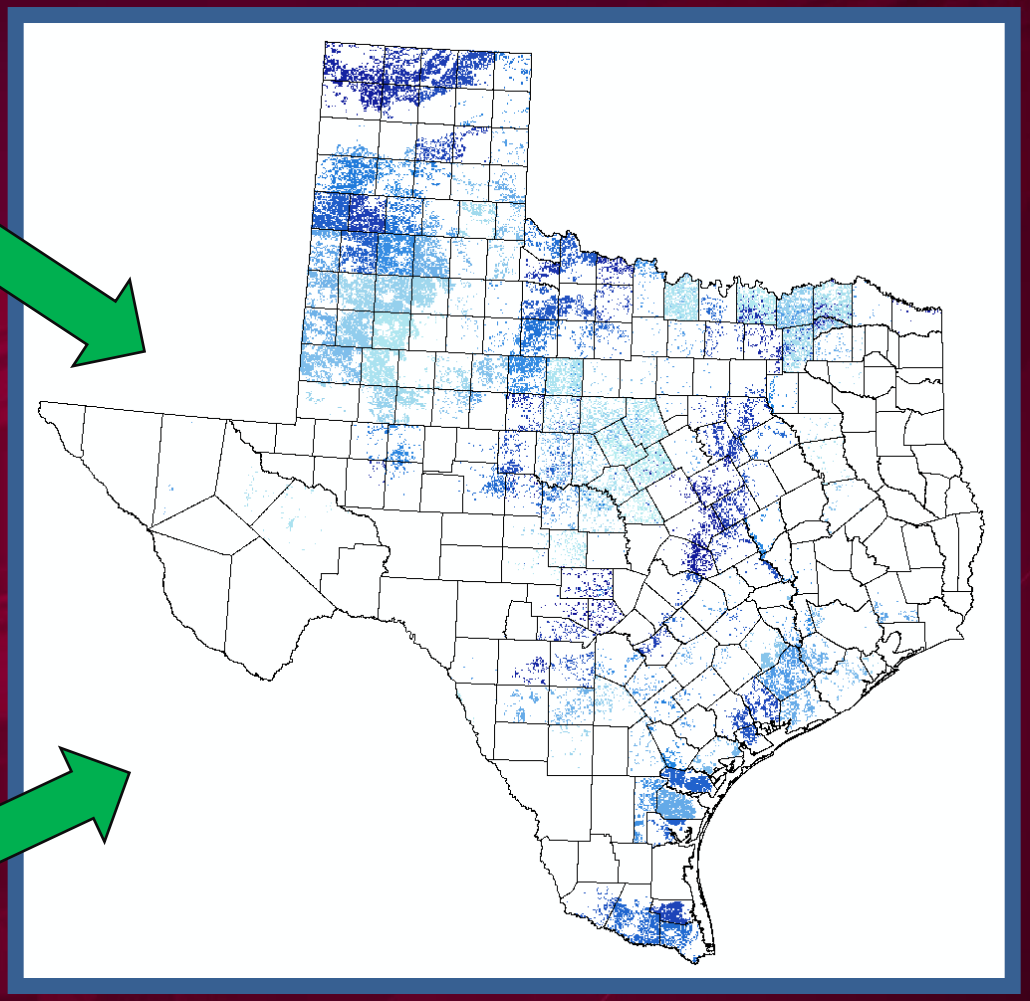
GIS Masking Tool



Input : Biomass Density per County



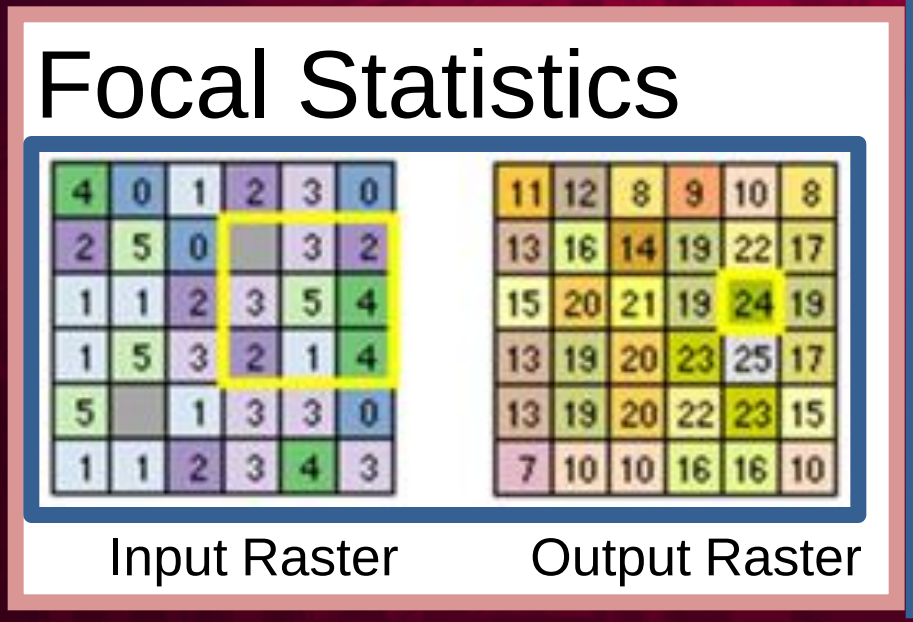
Mask: Suitable Area

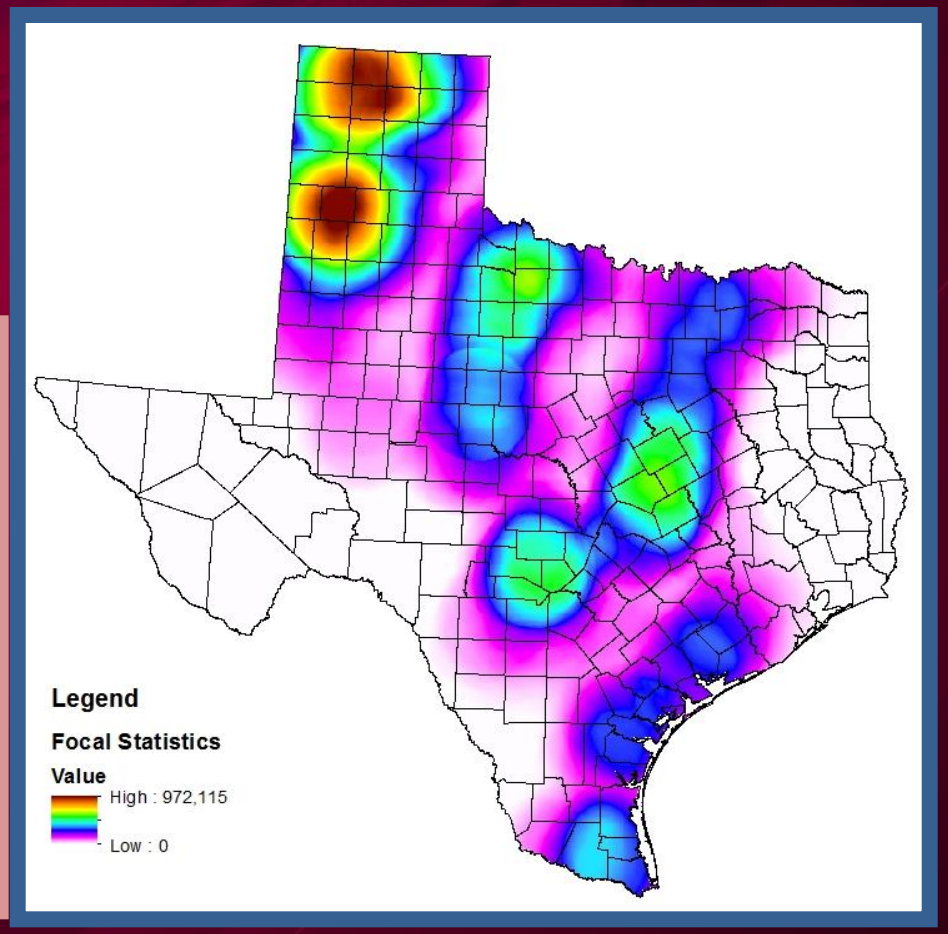


Potential Biorefineries

FOCAL STATISTICS

- Neighborhood of 50-mile radius
- Statistics Type: Sum

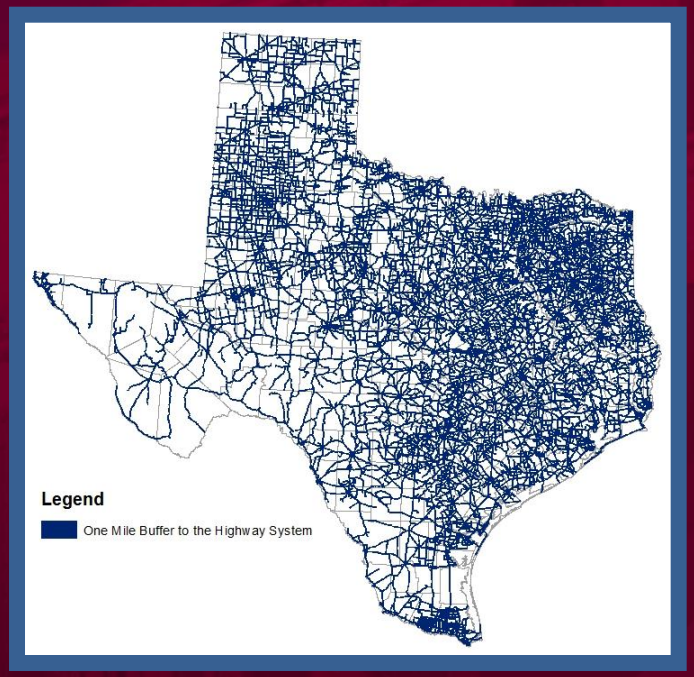


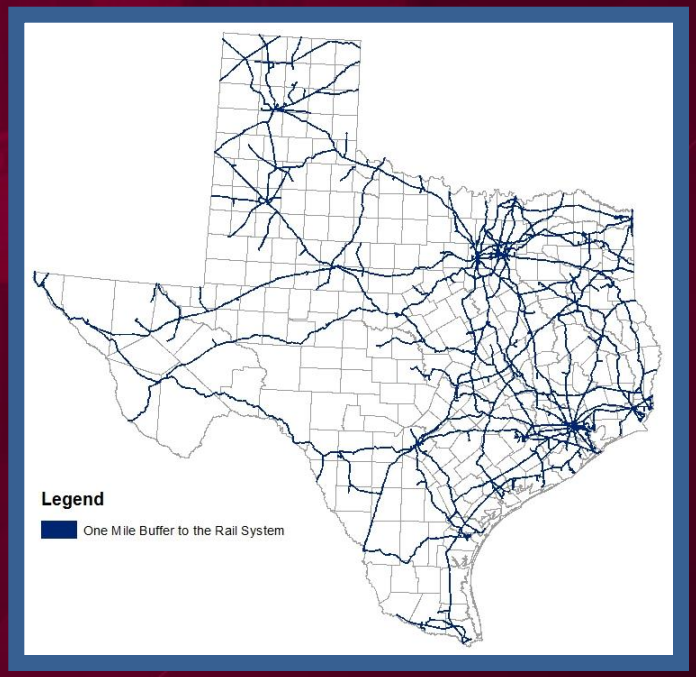


TRANSORTATION NETWORK

- Intersection of focal statistics and both the one mile buffer networks

Buffer of a line feature





ALLOCATING BIOREFINERIES

Do While cell values <> 0

Run focal statistics

Look only at cells that intersect with the transportation network

If highest cell value > 130K DMT/year **Then**

Allocate biorefinery

Eliminate cells within 50 miles of biorefinery

Else End loop

Loop

Castro County 967K DMT	Sherman County 876 DMT	Bell County 551 DMT	Bexar County 469 DMT	Knox County 457 DMT

. . .

BIOREFINERIES IN TEXAS

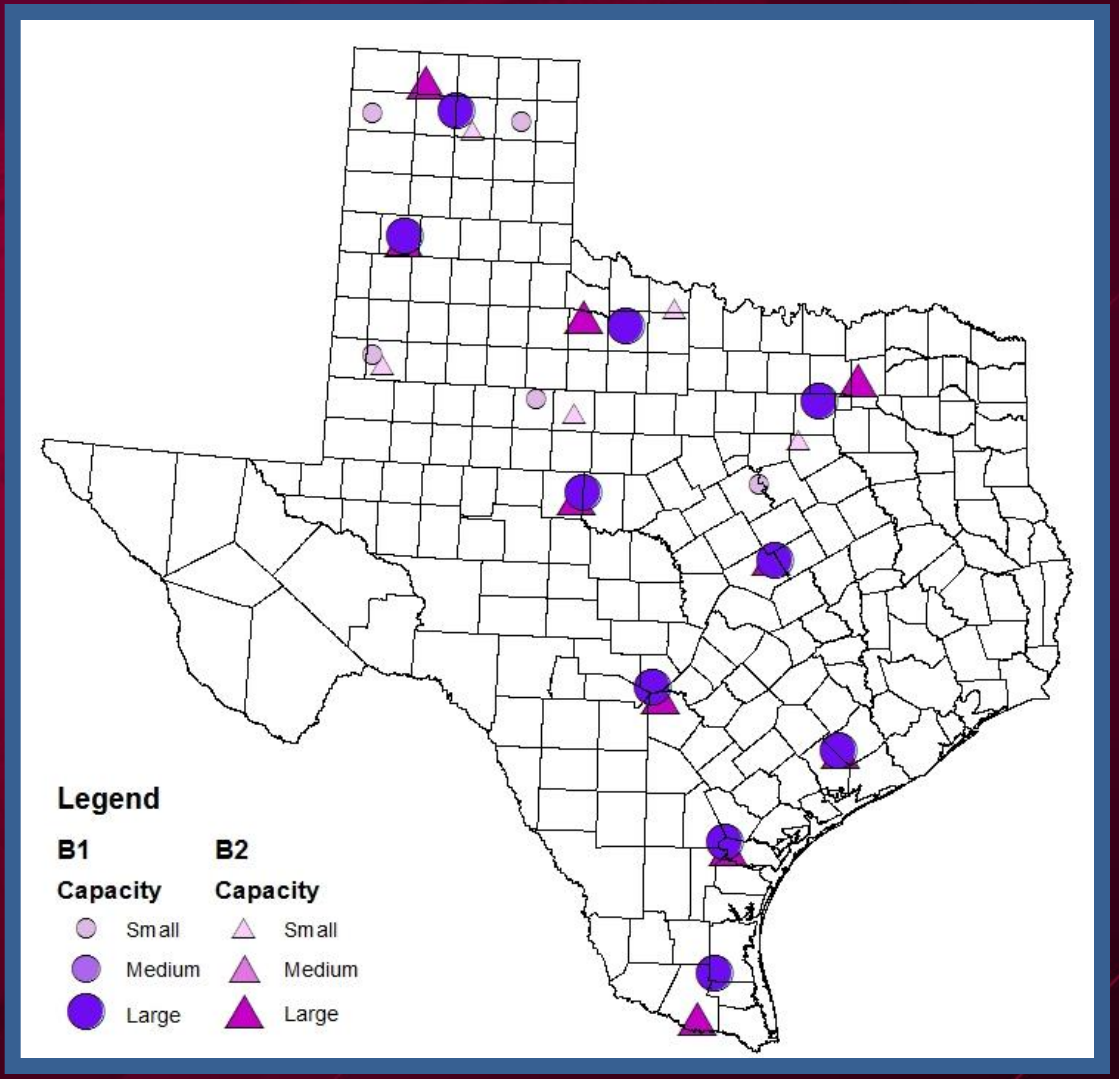
B1 : 514 MGY

- 4 Large
- 6 Medium
- 5 small

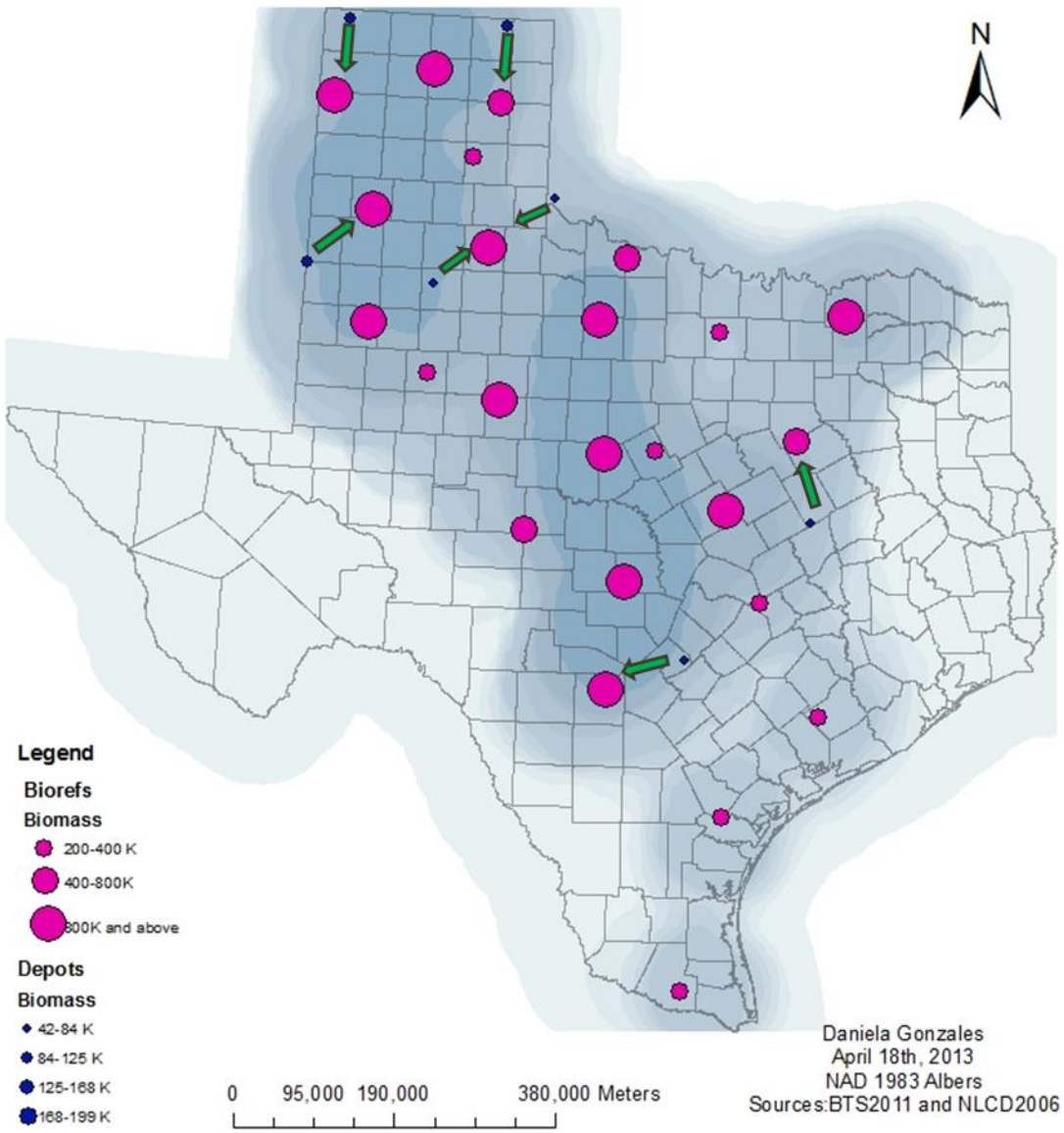
B2 : 508 MGY

- 3 Large
- 7 Medium
- 5 small

SIze	DMT/year (thousands)	Gallons/year (millions)
S	129.4	11
M	258.8	22
L	517.6	44
XL	1,035.3	88



Texas Biorefineries and Depots for Lignocellulosic Ethanol



BENEFITS OF THE MODEL

- Bases allocation on existing infrastructure
- Eliminates county boundaries for facility location
- Distributes biomass throughout county as opposed to using county centroid
- Sequence of biorefineries found might resemble sequence of biorefinery development in Texas.
- Nation wide analysis would eliminate state boundaries

2. BT2 ANALYSYS FOR TEXAS

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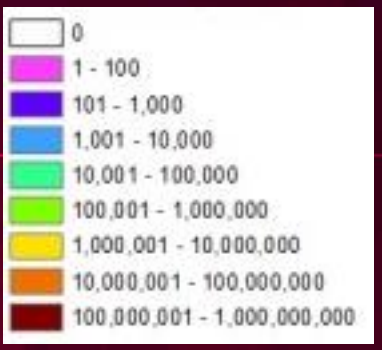
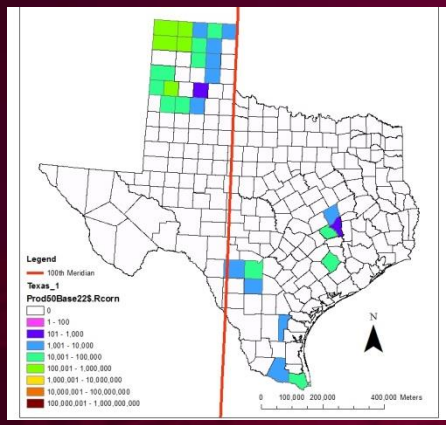


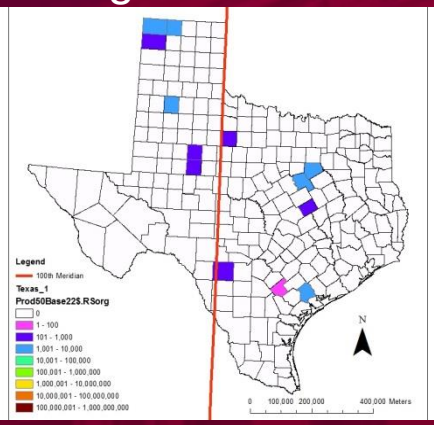
2011 BILLION TON STUDY RESULTS FOR TEXAS

- Production for year 2022 at $50 for the Baseline scenario

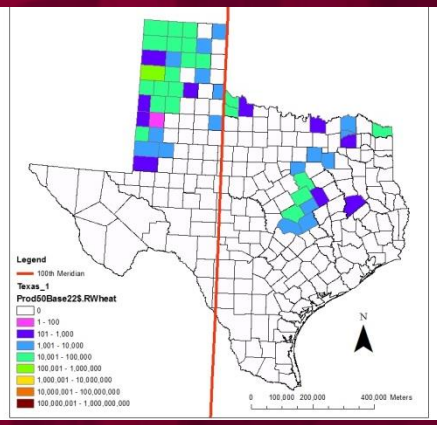
Corn Stover



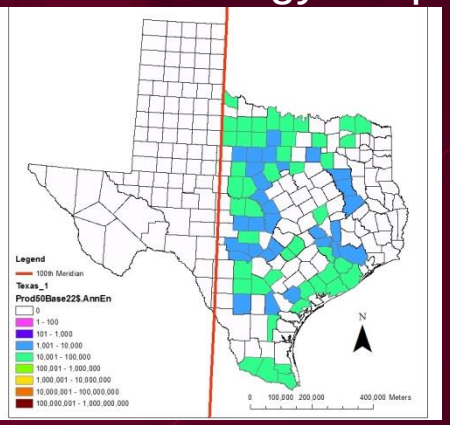
Sorghum Stubble



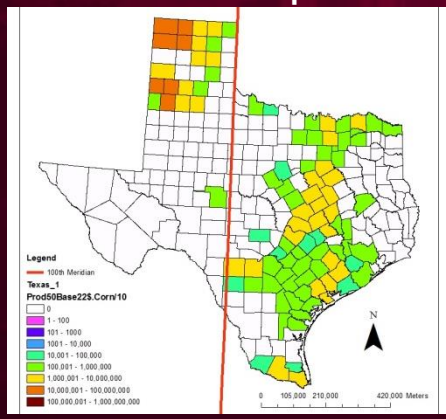
Wheat Straw



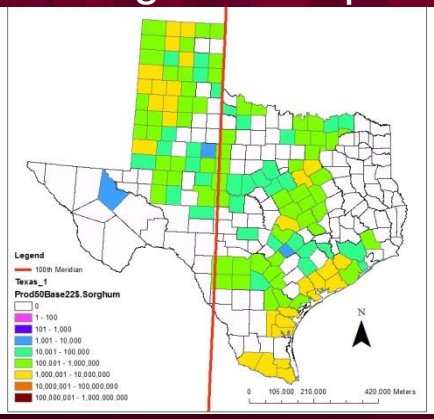
Annual Energy Crop



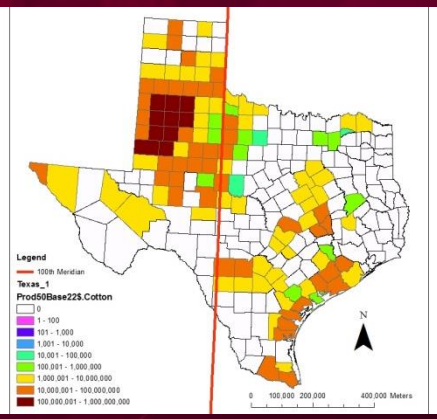
Corn Crop



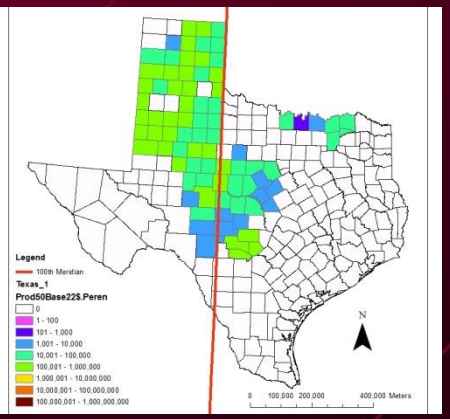
Sorghum Crop



Cotton



Perennial Grass



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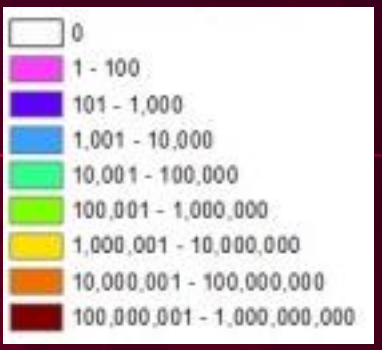
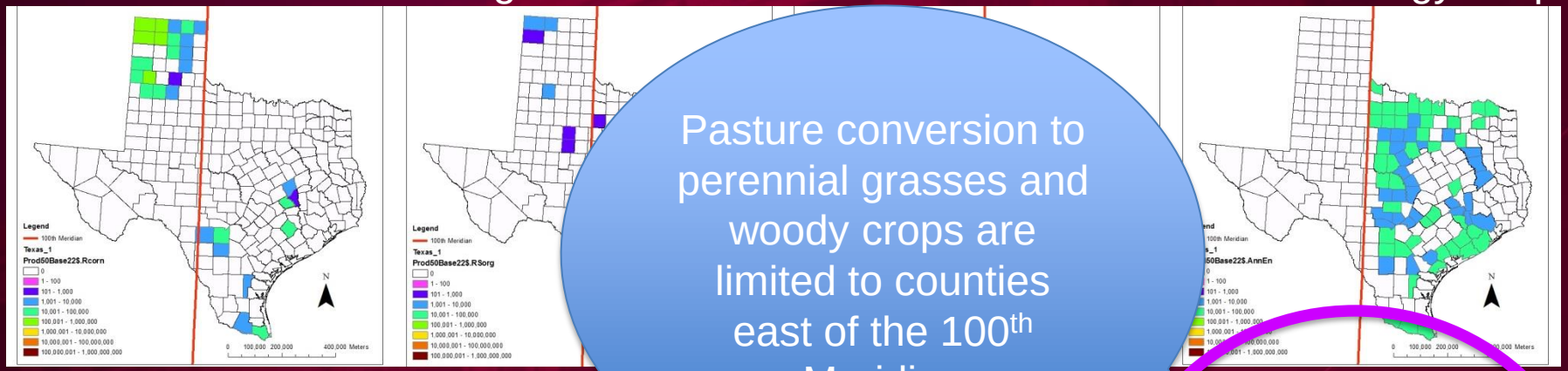


2011 BILLION TON STUDY RESULTS FOR TEXAS

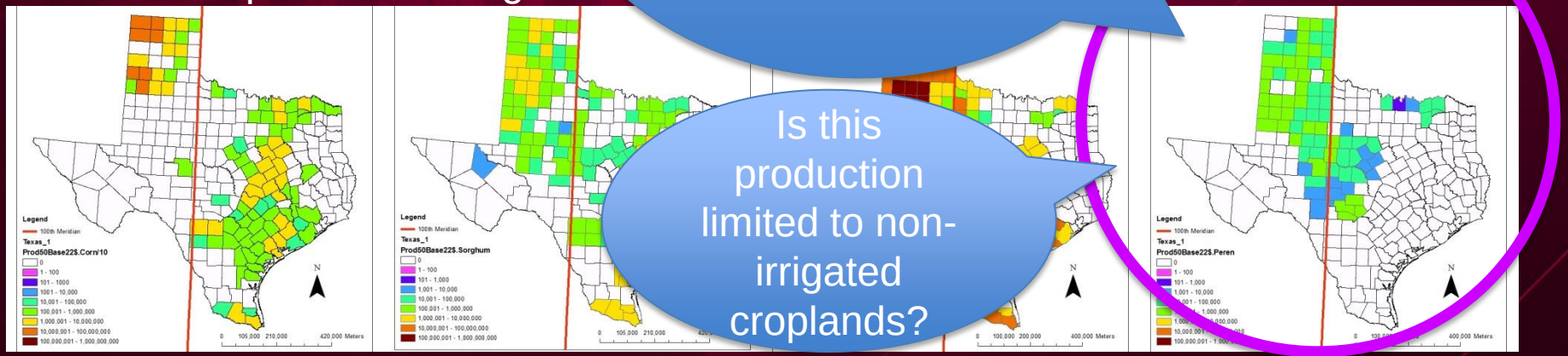
- Production for year 2022 at $50 for the Baseline scenario

Corn Stover | Sorghum Stubble | Wheat Straw | Annual Energy Crop



Pasture conversion to perennial grasses and woody crops are limited to counties east of the 100th Meridian

Corn Crop | Sorghum | Perennial Grass



Is this production limited to non-irrigated croplands?

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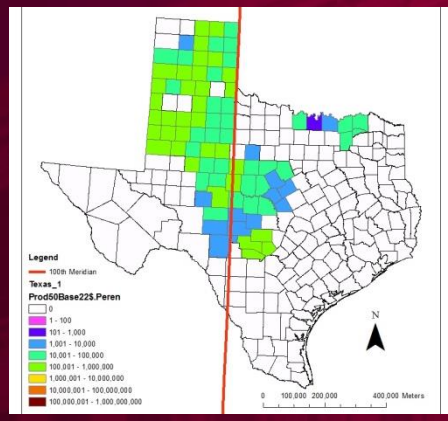
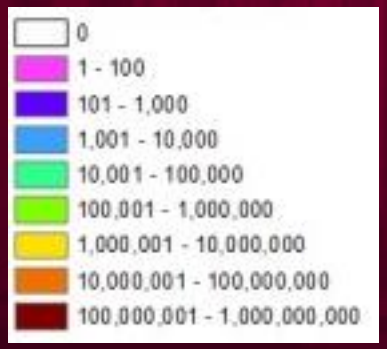
Legend
100th Meridian

2011 BILLION TON STUDY RESULTS FOR TEXAS

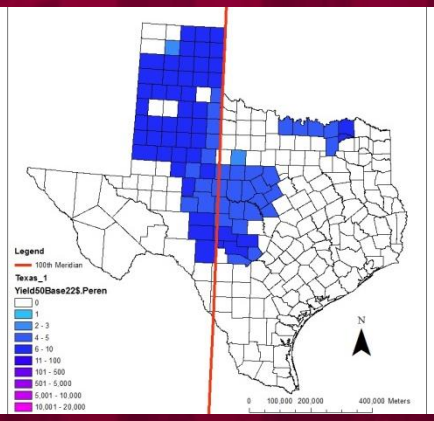
- Perennial Grass for year 2022 at $50 for the Baseline scenario

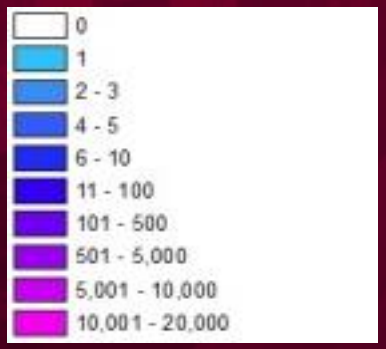
Production



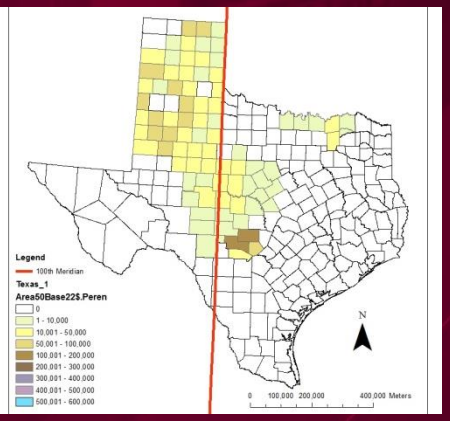


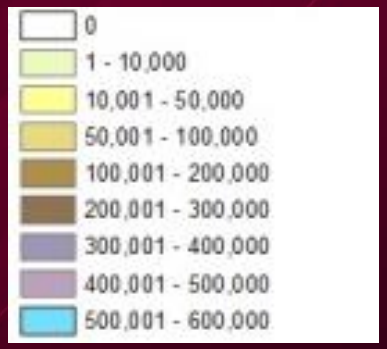
Yield

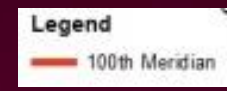




Harvested Area



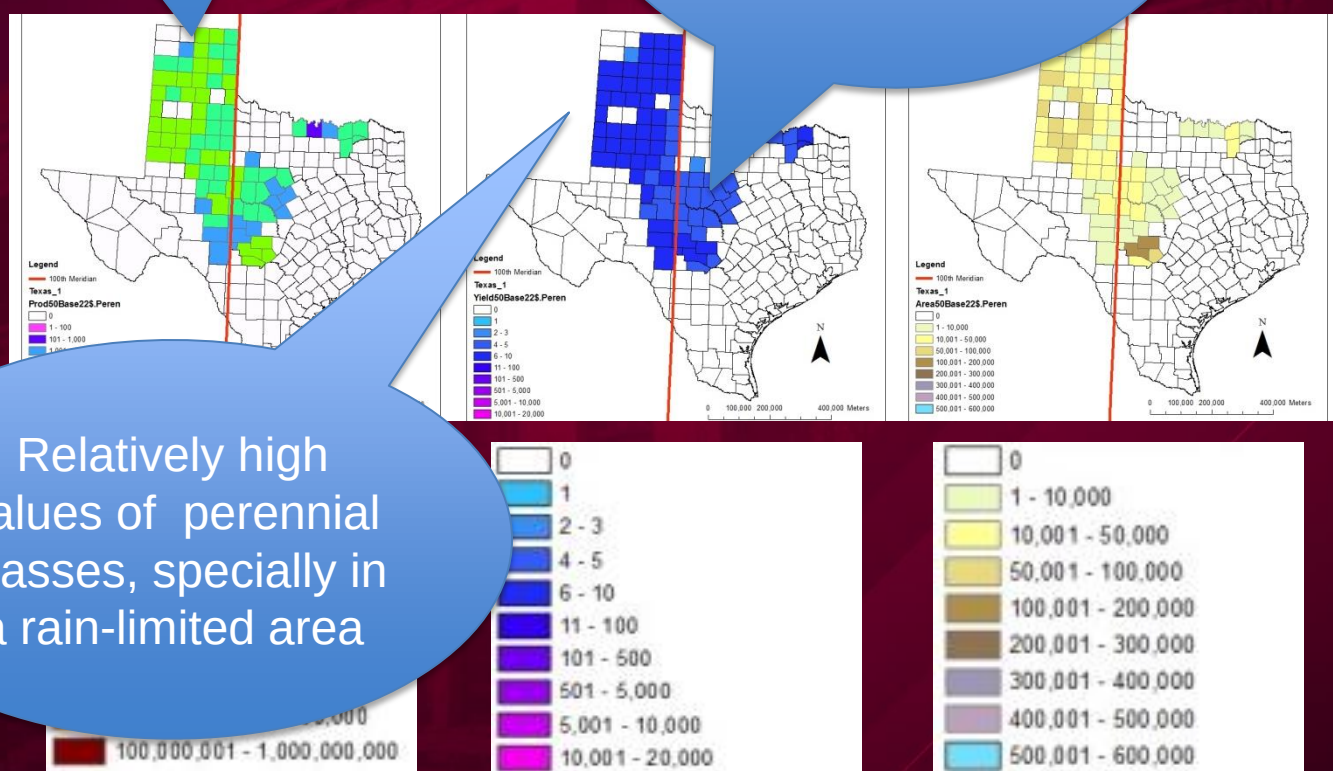




All perennial grass estimated in counties west of 100th would be on land currently classified as cropland

Most of this area will be rangeland, not suitable for perennial?

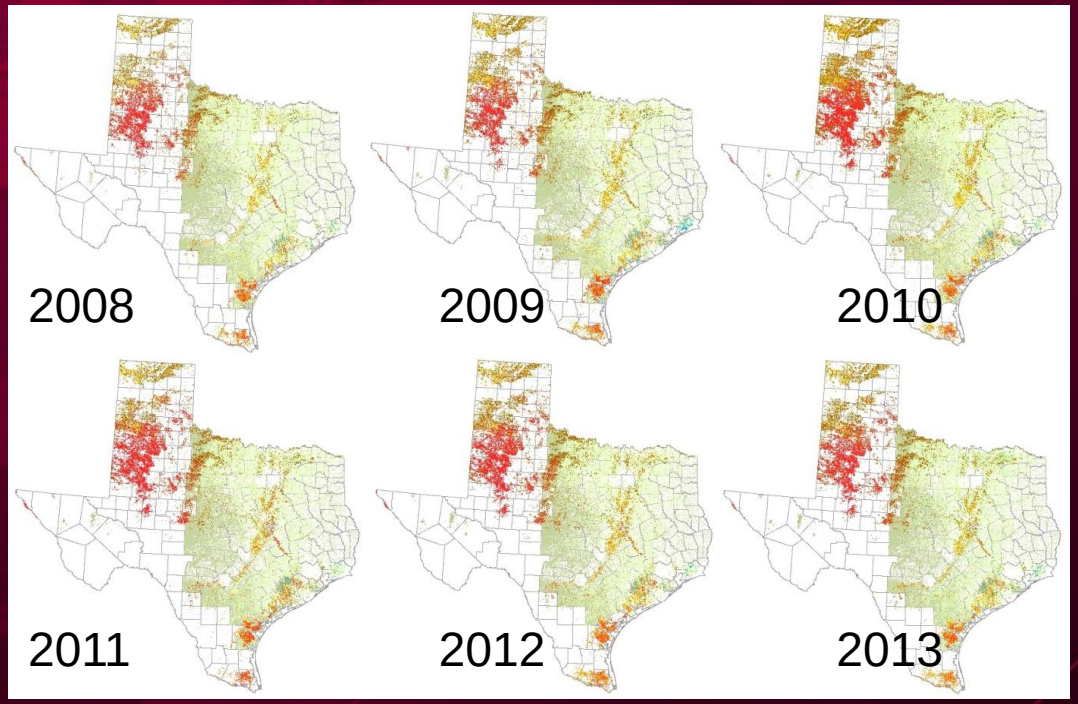
Relatively high values of perennial grasses, specially in a rain-limited area



CROPLAND DATA LAYER BY USDA-NASS IN CROPSCAPE

- Removed lands classified as:
  - Developed areas, wetlands, forest.
  - If average county precipitation is less than 25 inches, then also removed shrubland, pasture/grass, pasture/hay

2008 Cropland Data Layer



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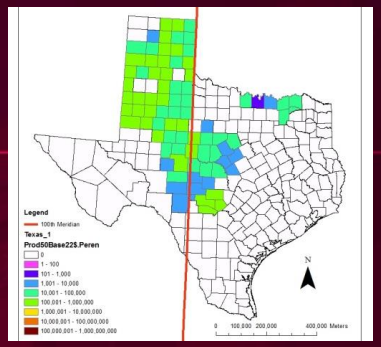
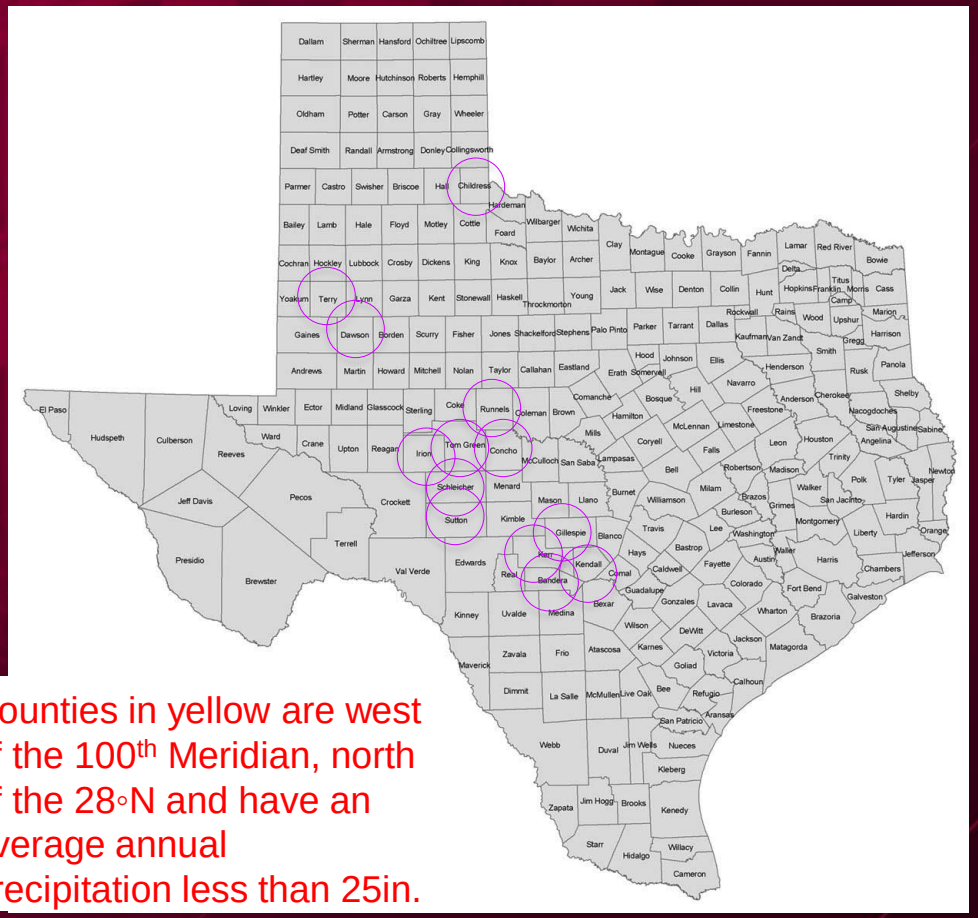


2011 BILLION TON STUDY RESULTS FOR TEXAS

- Perennial grass production for year 2022 at $50 for the Baseline scenario vs. Baseline Cropland Data Layer for 2008

#	County	BT2 Harvested Acres	2008 CDL Pastureland
1	Kerr	139,200	18,704
2	Gillespie	149,300	51,077
3	Kendall	79,700	31,542
4	Tom Green	42,800	3,880
5	Runnels	48,400	23,932
6	Childress	22,300	3,414
7	Concho	24,100	6,602
8	Terry	87,500	75,849
9	Bandera	46,200	37,355
10	Schleicher	5,500	130
11	Dawson	86,000	82,523
12	Irion	500	9
13	Sutton	300	0



Counties in yellow are west of the 100th Meridian, north of the 28◦N and have an average annual precipitation less than 25in.

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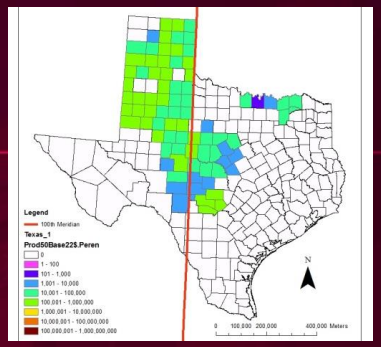
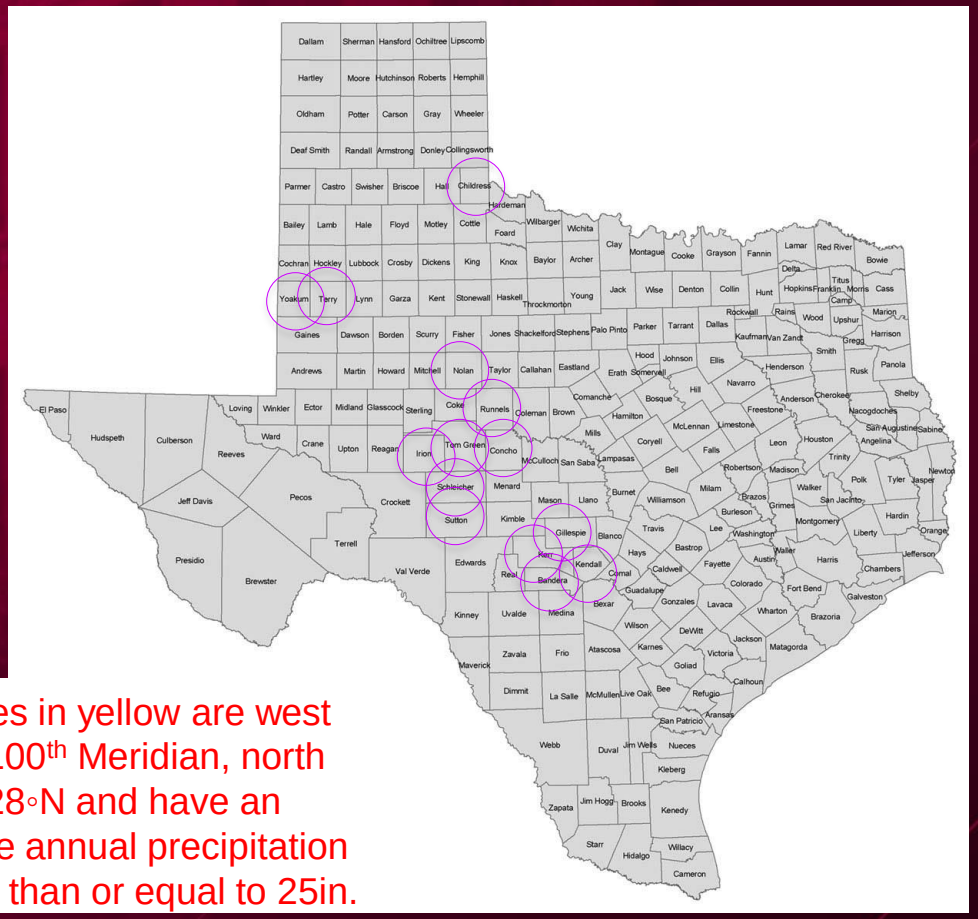


2011 BILLION TON STUDY RESULTS FOR TEXAS

- Perennial grass production for year 2022 at $50 for the Baseline scenario vs. Baseline Cropland Data Layer for 2009

#	County	BT2 Harvested Acres	2009 CDL Pastureland
1	Kerr	139,200	17,800
2	Gillespie	149,300	50,412
3	Kendall	79,700	35,592
4	Tom Green	42,800	3,034
5	Runnels	48,400	19,203
6	Terry	87,500	58,722
8	Concho	24,100	4,618
9	Childress	22,300	3,414
10	Nolan	19,400	10,960
11	Schleicher	5,500	150
12	Taylor	28,600	24,558
13	Bandera	46,200	43,523
14	Yoakum	35,200	33,203
15	Irion	500	285
16	Sutton	300	126

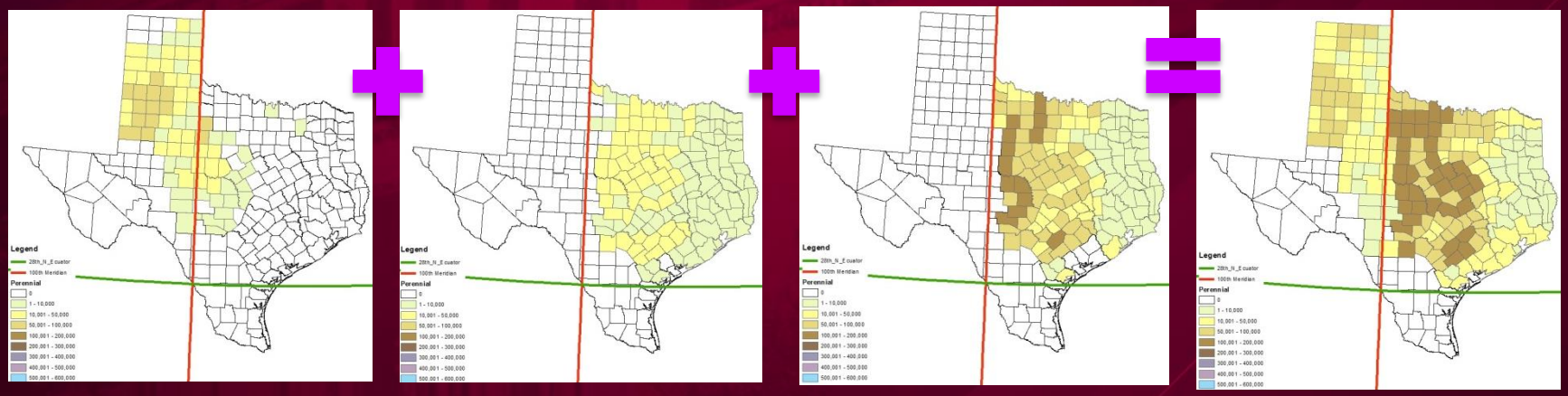


Counties in yellow are west of the 100th Meridian, north of the 28◦N and have an average annual precipitation greater than or equal to 25in.

DETAILED DATA PROVIDED BY LAURENCE EATON FROM BT2

- Perennial grass production for year 2021 at $80 for the high yield scenario with 3% increase in energy crops

Conventional Tillage Reduced Tillage No Tillage Total



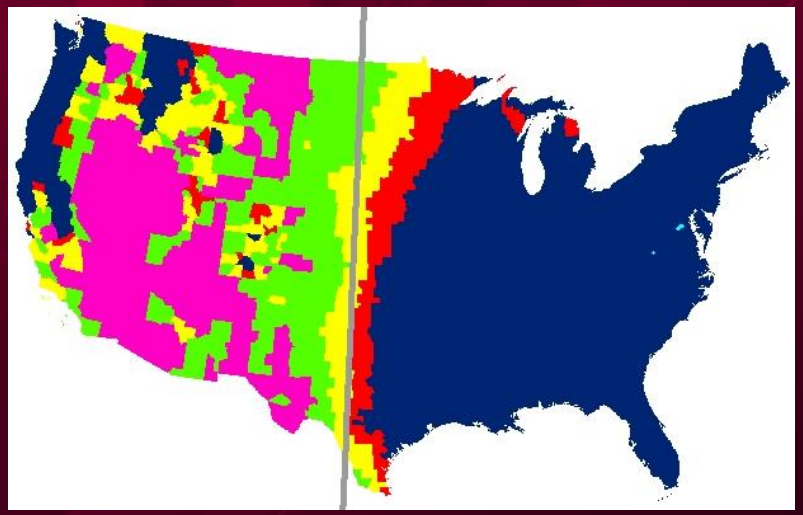
Cropland Cropland used as Pasture Permanent Pasture

3. POLYSYS RUNS

SENSITIVITY ANALYSIS TO BT2 ASSUMPTIONS FOR PERENNIAL GRASSES
Set of counties that allow conversion

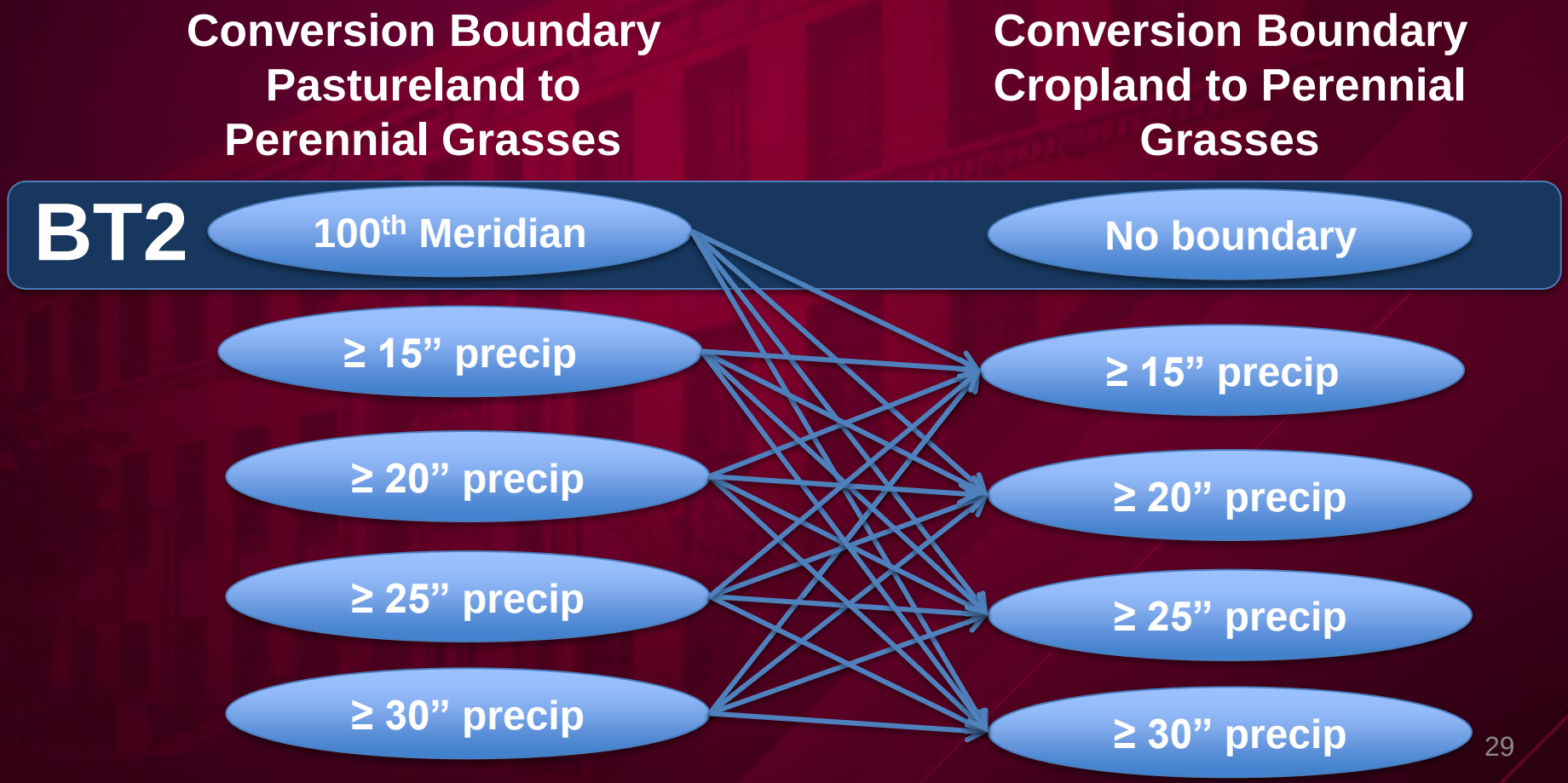
- Counties east of the 100th Meridian may allow for conversion of PASTURELAND to PERENNIAL GRASSES
  - Average annual precipitation is ≥ 15 inches, 20”, 25”, 30”
- All counties may allow for conversion of CROPLAND to PERENNIAL GRASSES
  - Average annual precipitation is ≥ 15 inches, 20”, 25”, 30”

Average Annual Precipitation (in)

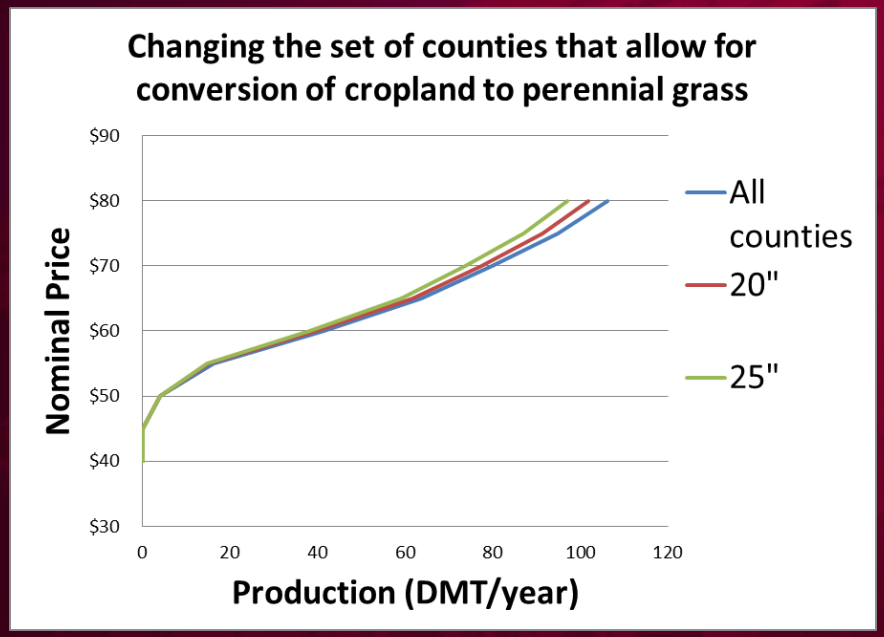


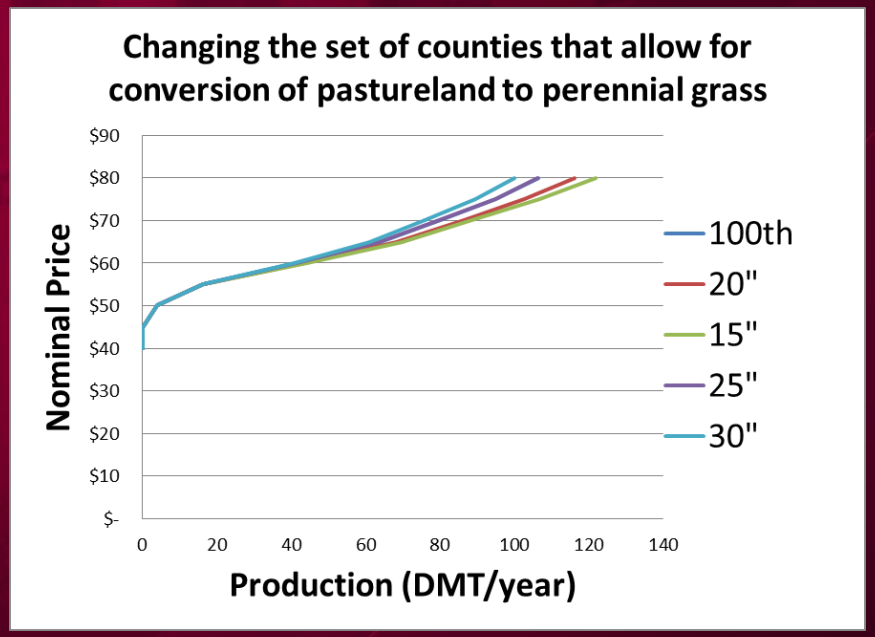
SENSITIVITY ANALYSIS TO BT2 ASSUMPTIONS FOR PERENNIAL GRASSES

Set of counties that allow conversion



SENSITIVITY ANALYSIS TO BT2 ASSUMPTIONS FOR PERENNIAL GRASSES
Acres available per county





SENSITIVITY ANALYSIS TO BT2 ASSUMPTIONS FOR PERENNIAL GRASSES
Acres available per county

- Price elasticity of supply

$$\varepsilon_S = \frac{\Delta Q}{\Delta P}$$

Elasticity		Pasture		
		20	BT2	30
Cropland	BT2	3.19	3.07	2.96
	20	3.19	3.07	2.95
	30	3.10	3.04	2.83

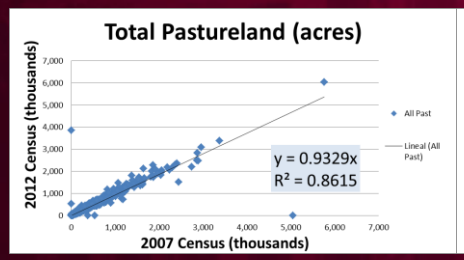
Change in Elasticity		Pasture		
		20	BT2	30
Cropland	BT2	0.04	0.00	-0.04
	20	0.04	0.00	-0.04
	30	0.01	-0.01	-0.08

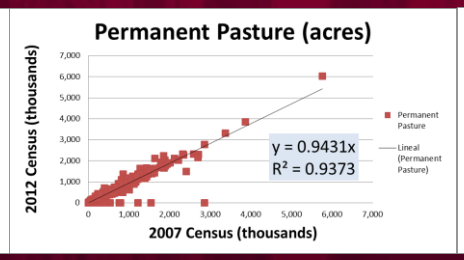
For every 1% increase in price, there is an average of 3.04% increase in supply

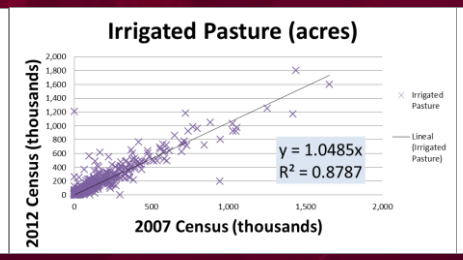
SENSITIVITY ANALYSIS TO BT2 ASSUMPTIONS FOR PERENNIAL GRASSES
Acres available per county

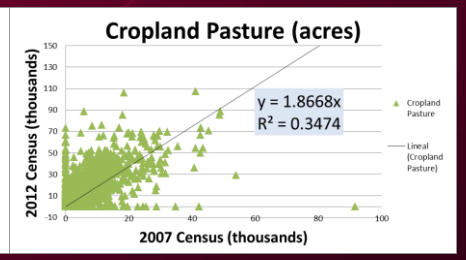
- Pastureland is based on the USDA NASS 2007 Census
  - USDA NASS 2012 Census
  - NLCD 2007, 2011
- Cropland is based on a 4-year average USDA NASS Surveys
  - NLCD 2007, 2011

USDA NASS CENSUS - 2007 vs 2012









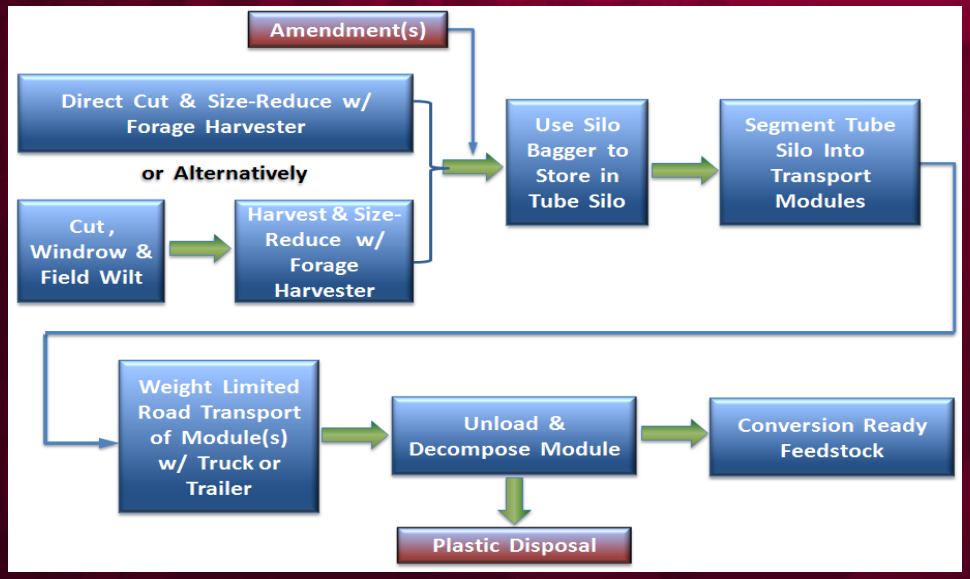
ONGOING RESEARCH

- Sensitivity analysis on land input to POLYSYS
- Effects of POLYSYS to the biorefinery allocation algorithm

4. BioMODS WITH IBSAL

ONGOING RESEARCH - AFRI

- PI's: Dr. Kevin Shinners from the University of Winsconsin
  Dr. Stephen Searcy from Texas A&M University
- Biomass Optimized Delivery System
  - Integrate mechanisms and processes proven successful in forage, cotton, and container industries to achieve a logistics system that will produce a lowest-cost biomass feedstock.



ONGOING RESEARCH - AFRI

EXPECTED OUTCOMES AND POTENTIAL IMPACTS:

- New mechanical system for creating tube silos capable of consistently achieving **15 lbs. DM/ ft^3** and with optimum cross-section for creating transport modules.
- Quantification of bagger performance so that **storage costs** can be determined.
- New mechanisms for segmenting the tube silo into transport modules.
- **Modifications to cotton module truck** to quickly and efficiently load the created modules.
- Techno-economic comparison of chopped, high density transport module system with competing technologies, specifically baled biomass.
- At the conclusion of the project, a system design for a complete, truly innovative biomass logistics system will be provided at a stage of development and validation sufficient for commercial adoption.

THANK YOU
Questions?

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Se habla español