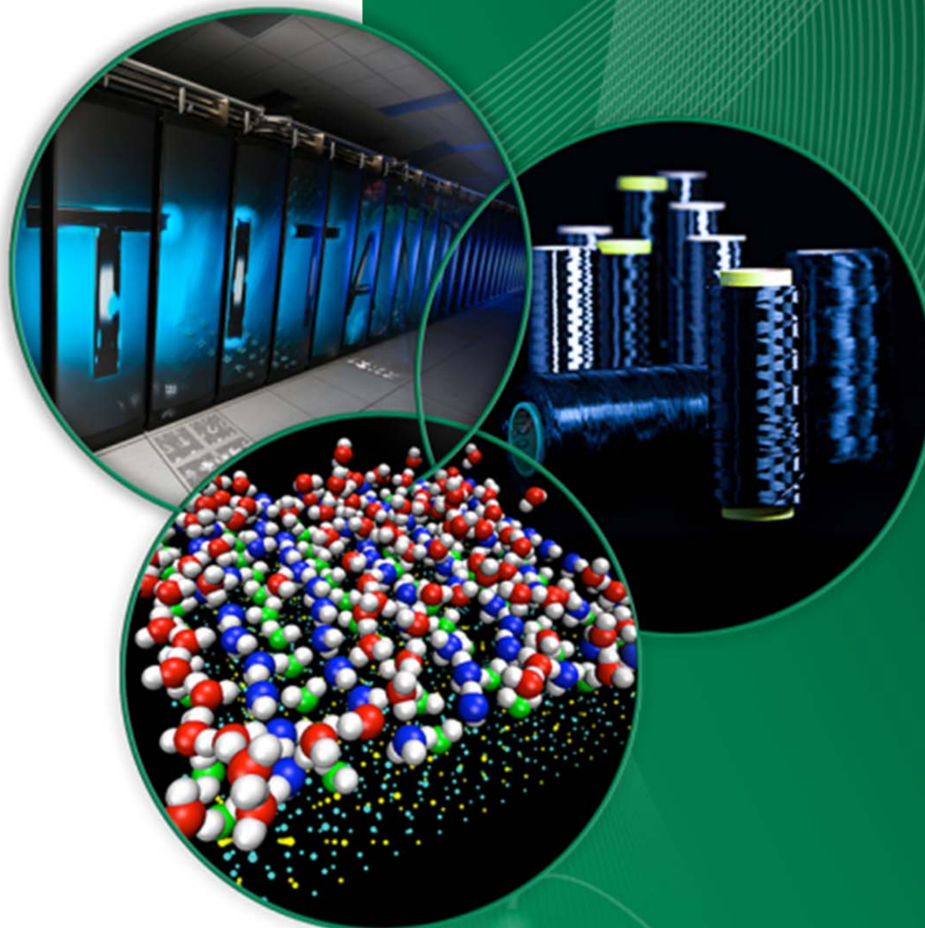
Enhanced National Feedstock Supply Modeling of Woody Crops for Bioenergy and Bioproducts



Laurence Eaton
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19 July 2014

10th Biennial SRWCOWG
Seattle, WA

Contributors

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- Tim Rials, Jessica McCord, University of Tennessee
- Tim Volk, SUNY-ESF
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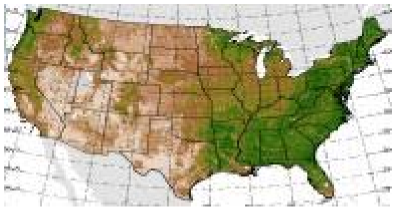
- Ray Miller, Michigan State University
- Jeff Wright, Arborgen
- Rich Shuren, Greenwood Resources
- Bryce Stokes, CNJV, LLC
- Marilyn Buford, USDA-FS
- Matt Langholtz, Craig Brandt, Oak Ridge National Laboratory
- Danny Inman, National Renewable Energy Laboratory

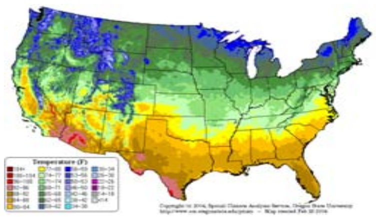
Outline

- PRISM-EM Overview, Results
- FY13 Results
- FY14 Enhancements/Results
- Testing the design of Biochemical and Thermochemical Conversion Pathways

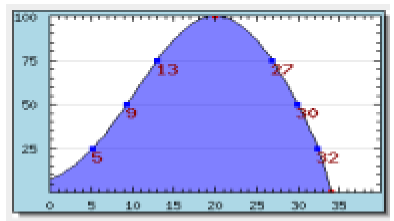
Sun Grant Energy Crop Mapping Process



SSURGO Soil Maps

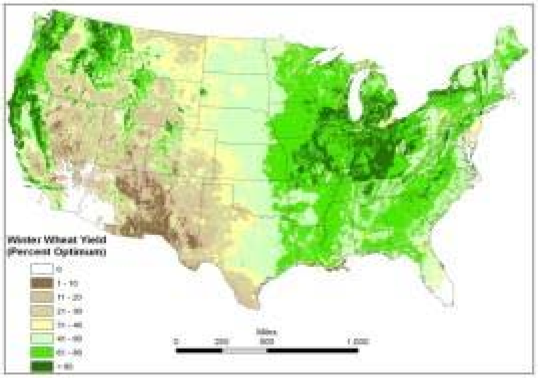


PRISM Climate Maps

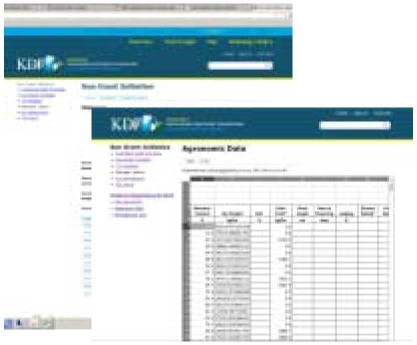


PRISM-EM Crop Suitability Model

Percent of Maximum Yield
(Relative Yield Map)

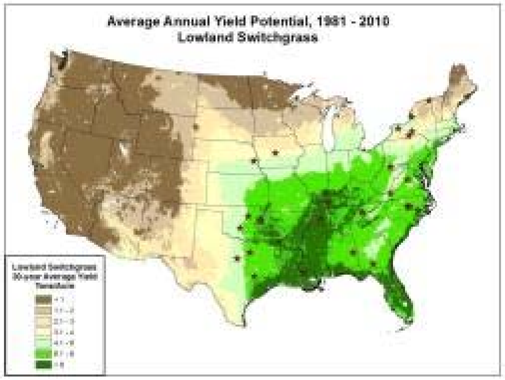


Interface with Crop Experts



Field Trial Data

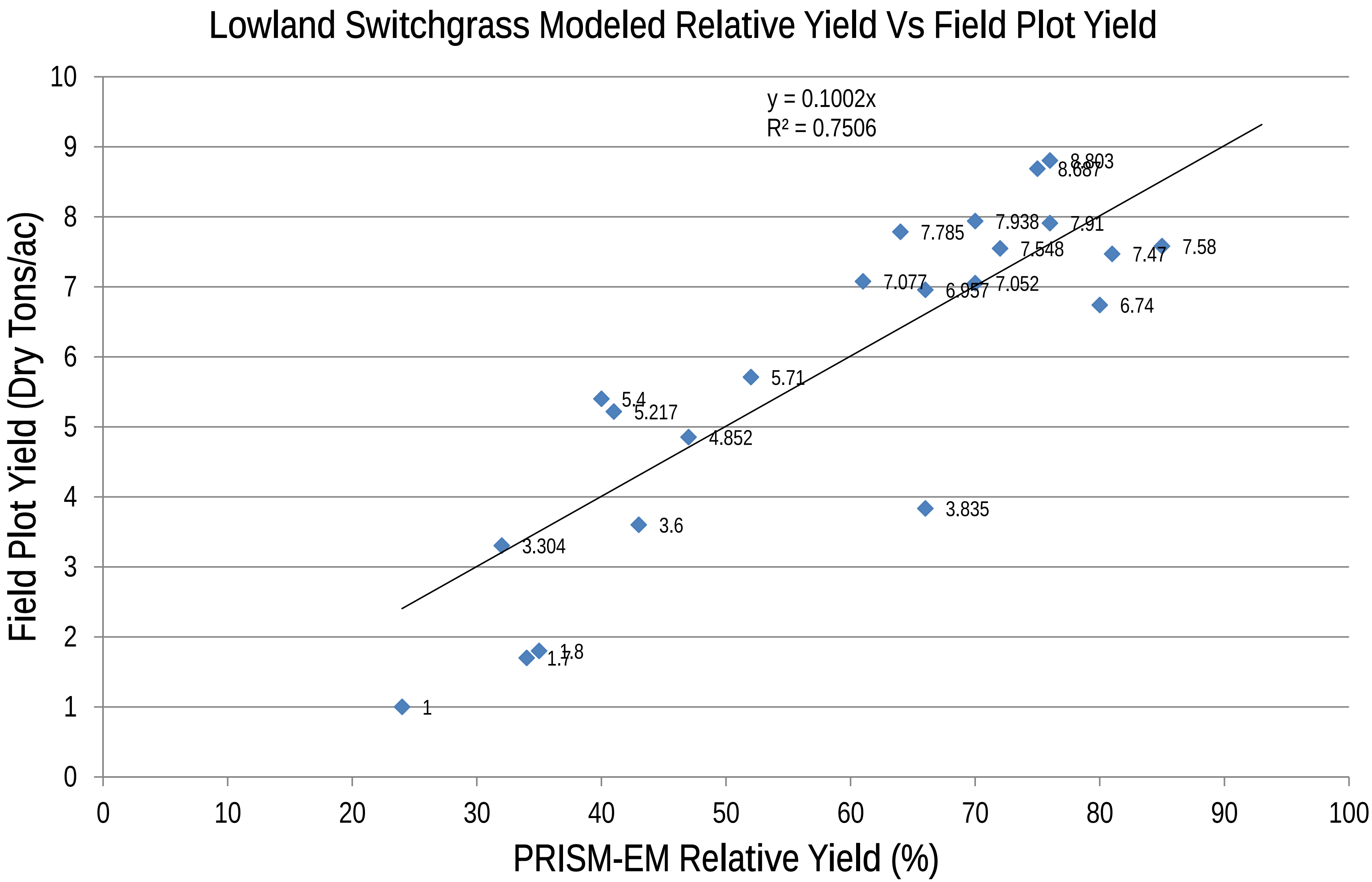
Biomass Yield
(Absolute Yield Map)



Absolute Yield Modeling Assumptions

- Yield Gap: Account for "yield gap" between test plot and farm for small trials
- Establishment: Assume perennial crop has been established
- Fertilizer Application: Generally "mass balance" approach or standard soil test recommendation
- Fungicide/Pesticide Application
- Other considerations
  - For example, scale up of older clone yields from willow trials

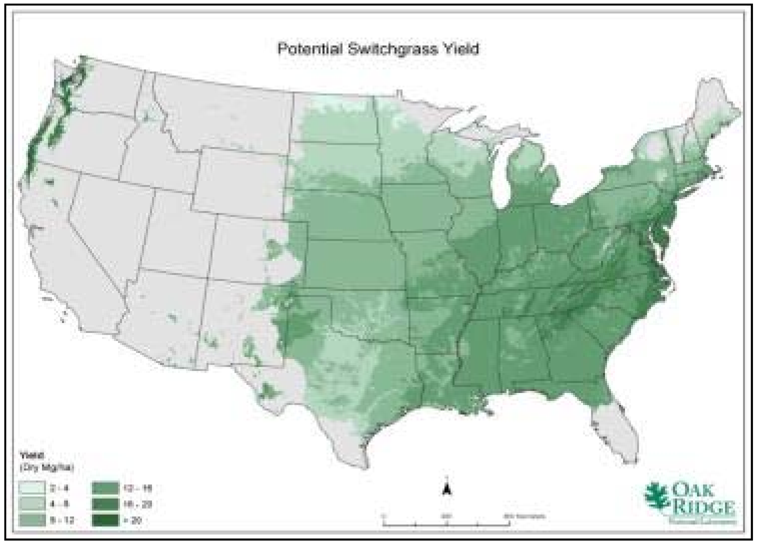
Transformation of Relative to Absolute Yield

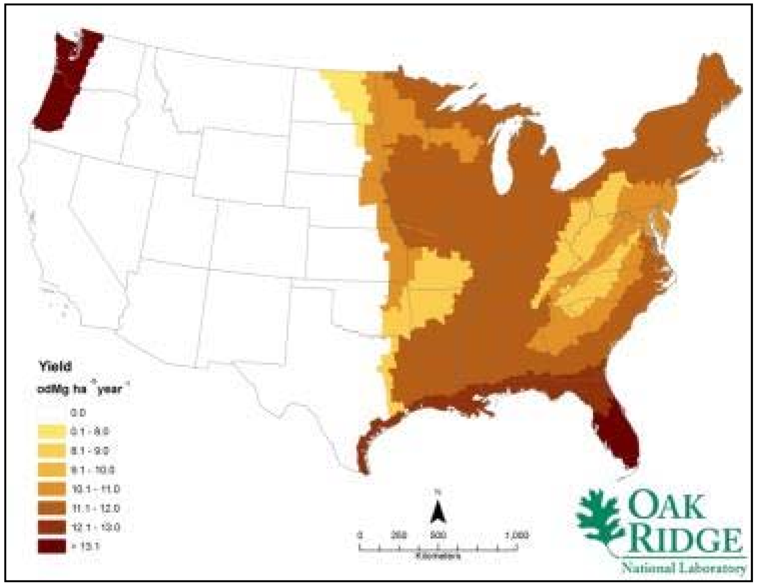


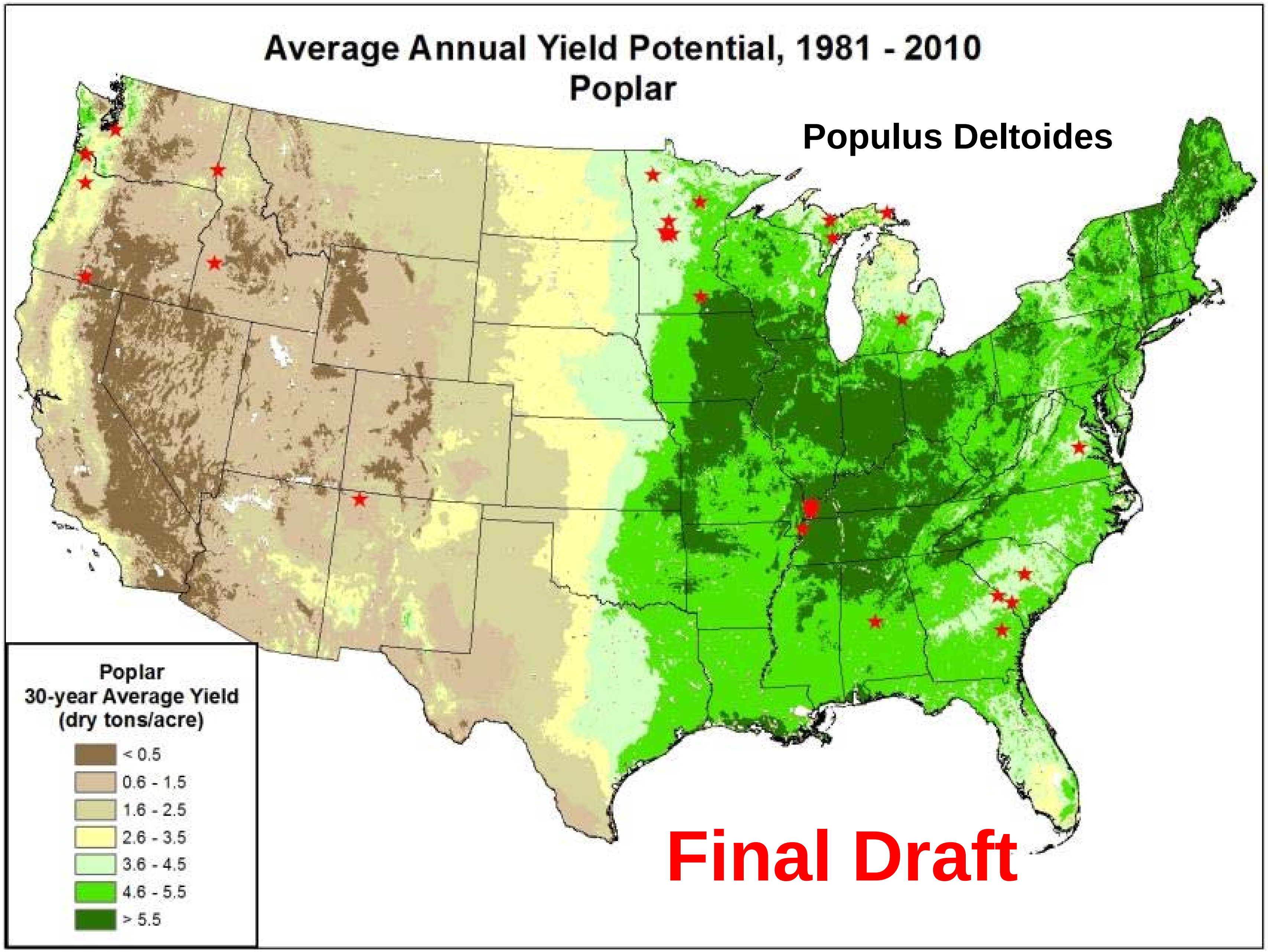
BT2- Energy Crop Productivity

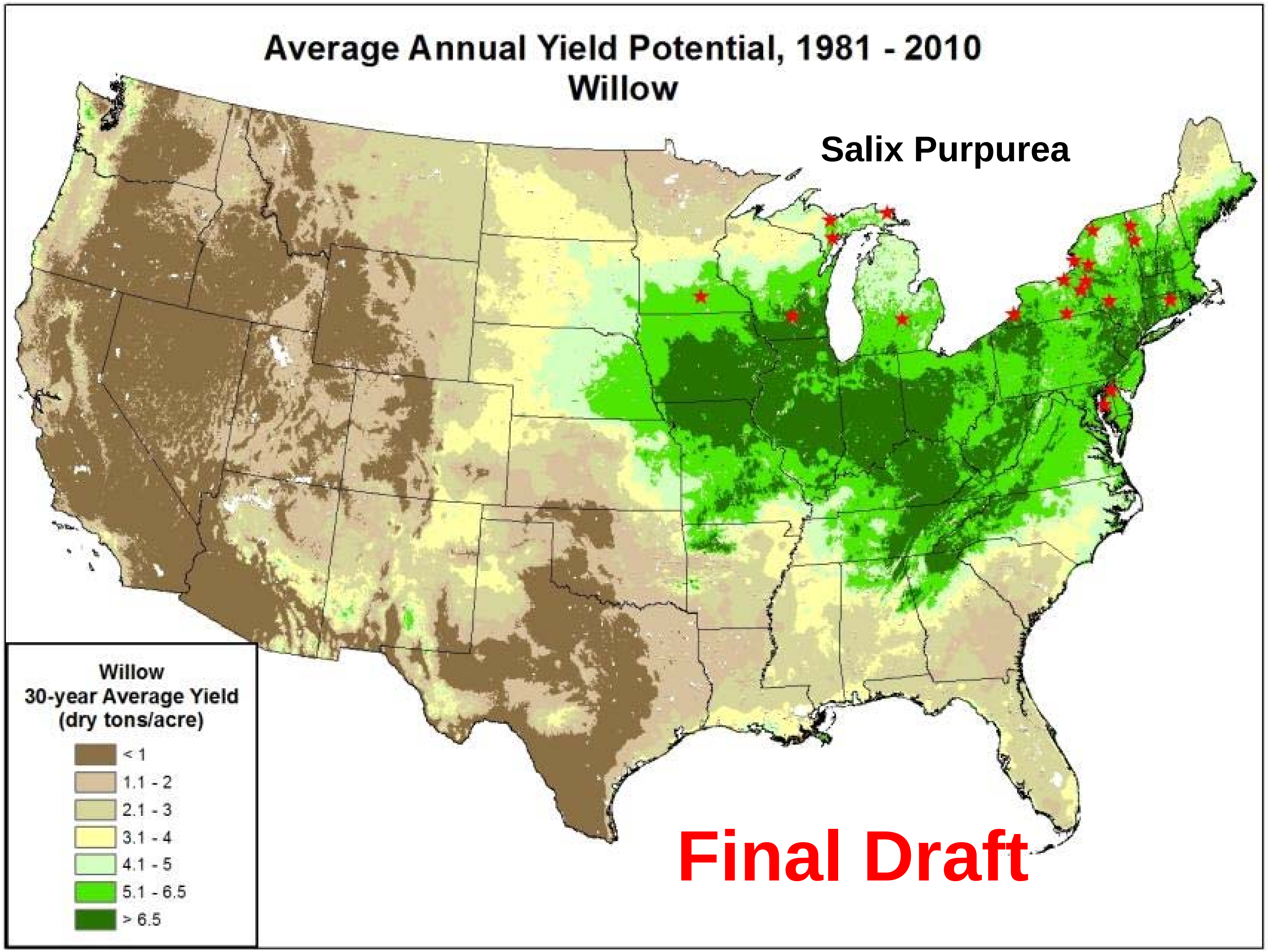
- Herbaceous crop productivity
  - Baseline yields (dry tons/acre)
    - 2014 – 3.0 - 9.9
    - 2030 – 3.6 - 12.0
- Woody crop productivity
  - Baseline yields (dry tons/acre)
    - 2014 – 3.5 - 6.0
    - Poplar: 6.7 dt/ac (Max)
    - Willow: 8.6 dt/ac (Max)

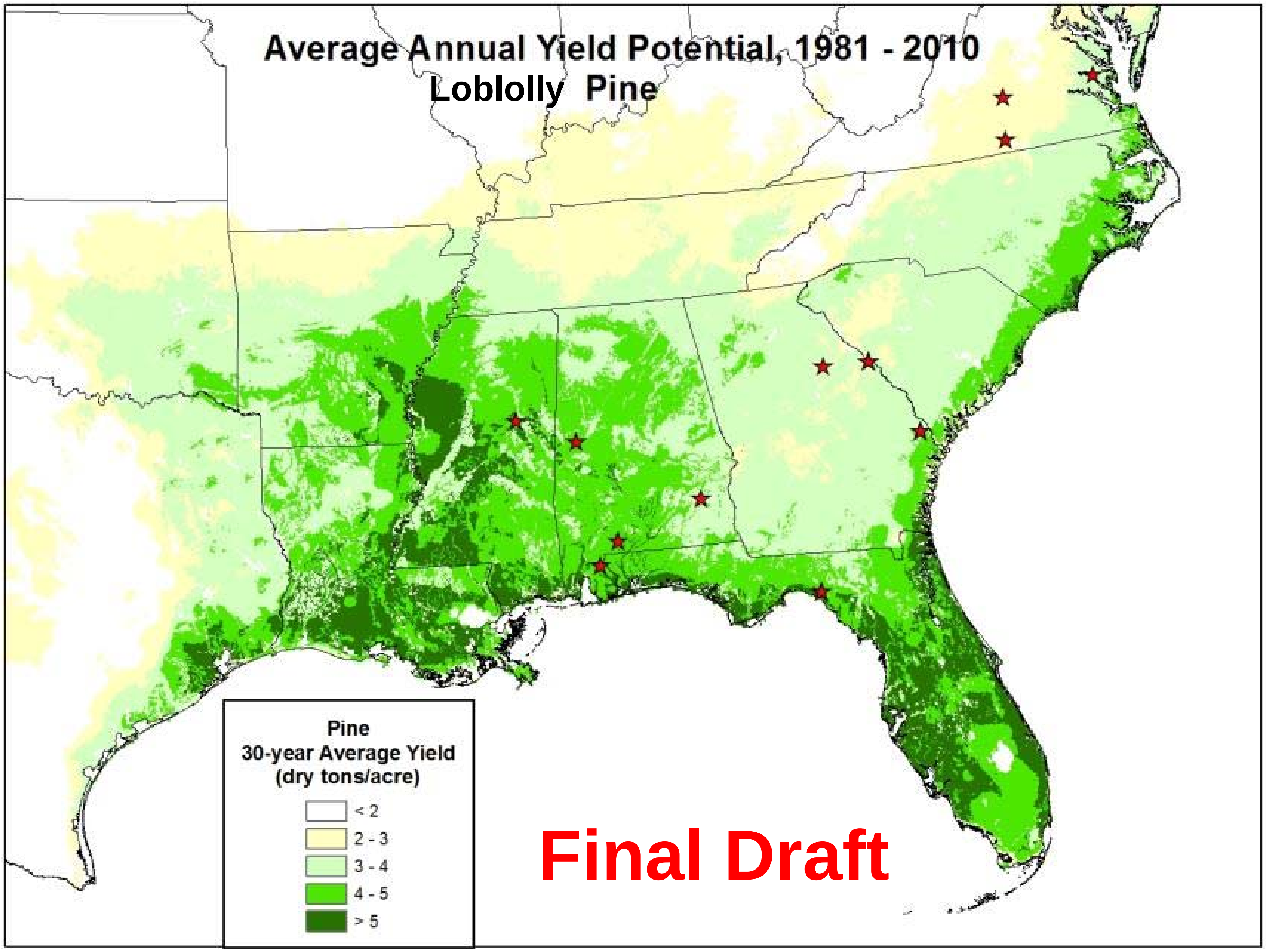
2012 Yield	2017 Baseline 1% annual growth	2022	2030	2017 High-yield 2%–4% annual growth	2022	2030
	Dry tons/acre/year			Dry tons/acre/year		
2	2.1	2.2	2.4	2.2 – 2.4	2.4 – 3.0	2.9 – 4.1
3	3.2	3.3	3.6	3.3 – 3.6	3.7 – 4.4	4.3 – 6.1
4	4.2	4.4	4.8	4.4 – 4.9	4.9 – 5.9	5.7 – 8.1
5	5.3	5.5	6.0	5.5 – 6.1	6.1 – 7.4	7.1 – 10.1
6	6.3	6.6	7.2	6.6 – 7.3	7.3 – 8.9	8.6 – 12.2
7	7.4	7.7	8.4	7.7 – 8.5	8.5 – 10.4	10.0 – 14.2
8	8.4	8.8	9.6	8.8 – 9.7	9.8 – 11.8	11.4 – 16.2
9	9.5	9.9	10.8	9.9 – 10.9	11.0 – 13.3	12.9 – 18.2
10	10.5	11.0	12.0	11.0 – 12.2	12.2 – 14.8	14.3 – 20.3
11	11.6	12.2	13.2	12.1 – 13.4	13.4 – 16.3	15.7 – 22.3
12	12.6	13.3	14.4	13.2 – 14.6	14.6 – 17.8	17.1 – 24.3






Average Annual Yield Potential, 1981 - 2010
Poplar
Populus Deltoides
Poplar
30-year Average Yield
(dry tons/acre)
< 0.5
0.6 - 1.5
1.6 - 2.5
2.6 - 3.5
3.6 - 4.5
4.6 - 5.5
> 5.5
Final Draft


Average Annual Yield Potential, 1981 - 2010
Willow
Salix Purpurea
Willow
30-year Average Yield
(dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6.5
> 6.5
Final Draft



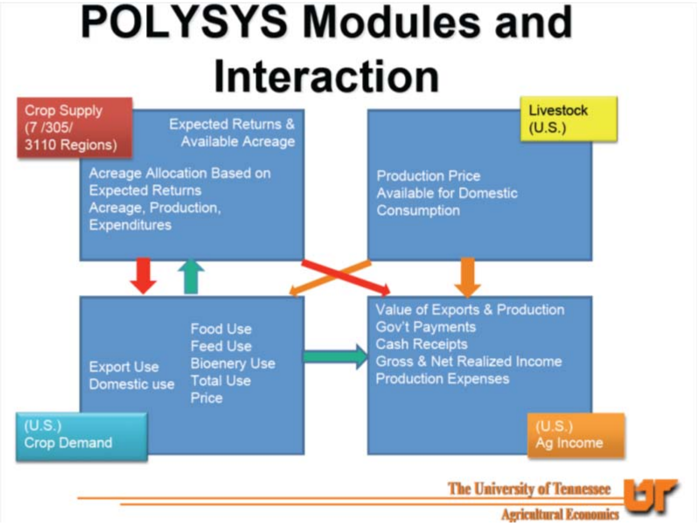
Average Annual Yield Potential, 1981 - 2010
Loblolly Pine
Pine
30-year Average Yield
(dry tons/acre)
< 2
2 - 3
3 - 4
4 - 5
> 5
Final Draft

County-level Yield Estimates (MAI)

Region	Max of Willow	Max of Poplar	Max of Pine
Appalachia	7.9	5.4	5.4
Corn Belt	8.2	5.3	N/A
Delta States	6.2	4.7	6.1
Lake States	7.1	4.9	N/A
Mountain	3.5	2.2	N/A
Northeast	7.2	4.7	N/A
Northern Plains	6.2	4.7	N/A
Pacific	3.9	2.9	N/A
Southeast	7.9	5.4	5.8
Southern Plains	4.0	4.5	5.2
Grand Total	8.16754	5.41323	6.11066

POLYSYS Modeling Framework

- County model anchored to USDA 10-year projections extended to 2030
  - 8 major crops (corn, soybeans, wheat, sorghum, oats, barley, rice, cotton) and hay, livestock, food/feed
  - Projected demands for food, feed, industry, exports
  - Biomass resources include stover, straws, energy crops (perennial grass, coppice and non-coppice woody, annual energy crop)
  - Land base includes cropland (250 million acres), cropland pasture (22 million acres), hay (61 million acres), permanent pasture (118 million acres)
    - Forage made up through intensification
  - Sustainability constraints for residues and limits on land use change
- Analysis of scenarios
  - Set exogenous prices for feedstocks and estimate the potential supply
  - Set biofuel targets (e.g., RFS2) and estimate feedstock prices required to achieve targets



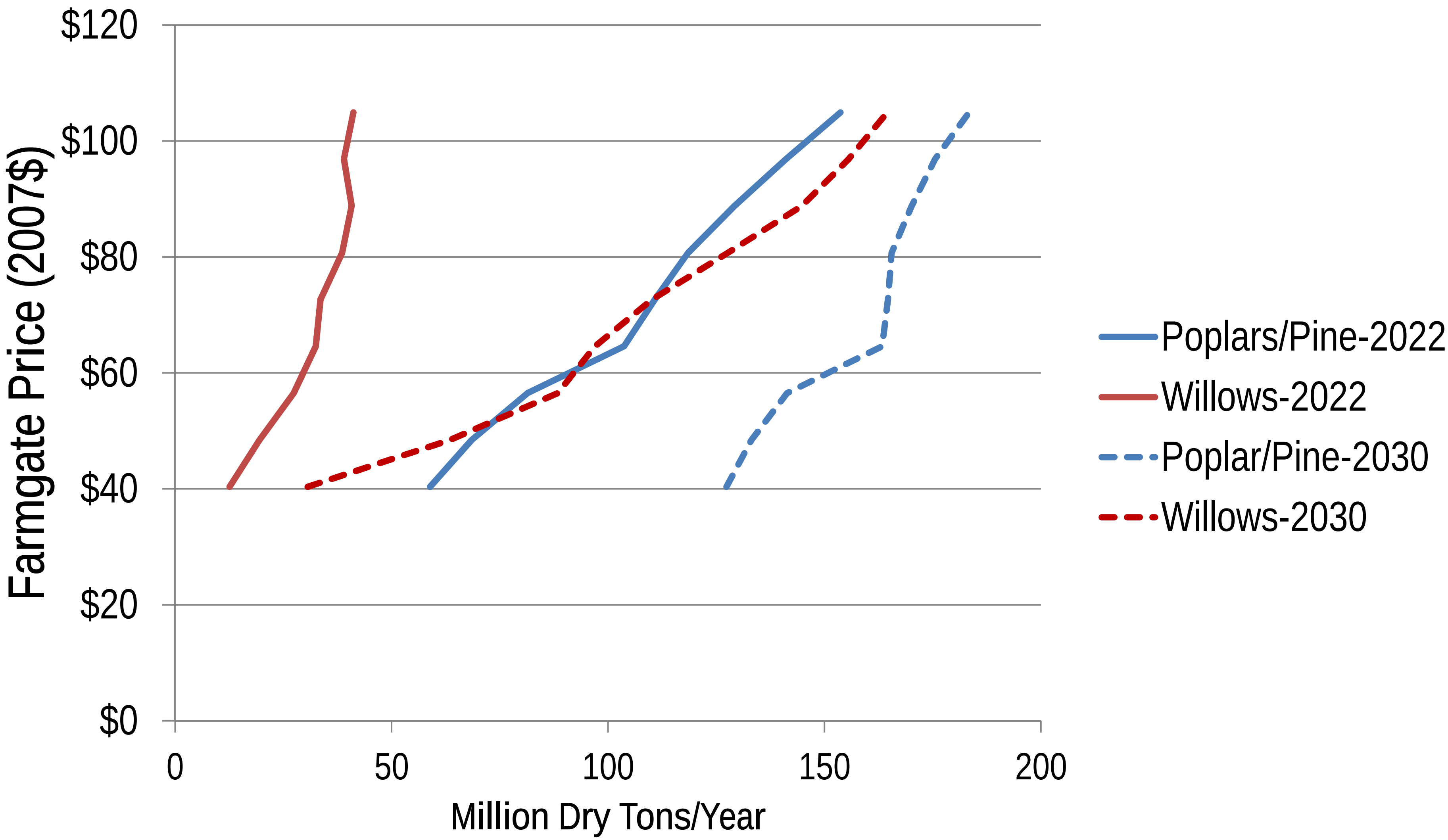
Chad Hellwinckel – University of Tennessee - Agricultural Policy Analysis Center (APAC) (http://www.agpolicy.org/)

POLYSYS with Forest Module under development: Burt English & Daniel De La Torre Ugarte – University of Tennessee

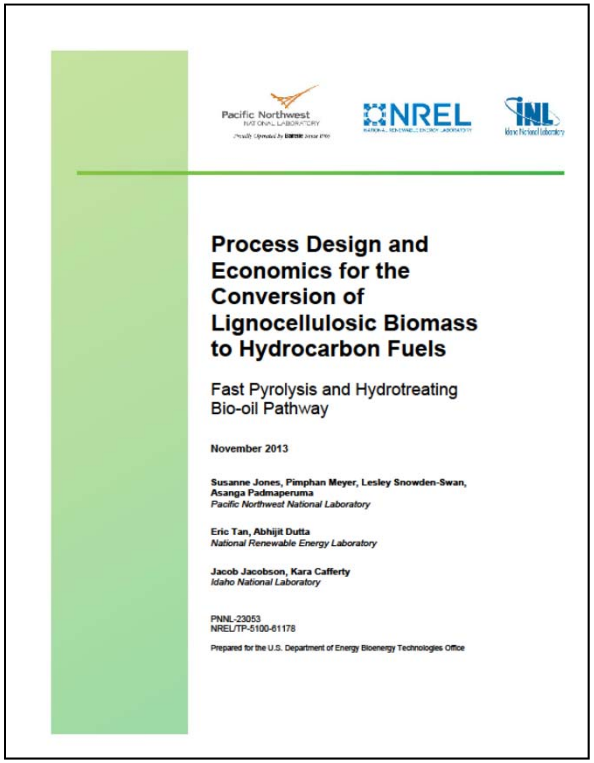
Modeling Assumptions

- *Poplar and Willow budgets*
  - Planting costs (engineering-economic costs or survey/contract cost)
- Willow: 21 year rotation, 3-year cutting cycle (range overlaps with Poplar)
- Poplar: 6-8 year rotation (range does not overlaps with Pine)
- Multi-year contracts begin in 2016

Potential Woody Crop Supply



2017 DOE Design Cases



Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels

Fast Pyrolysis and Hydrotreating Bio-oil Pathway

November 2013

Susanne Jones, Pimphan Meyer, Lesley Snowden-Swan, Asanga Padmaperuma
Pacific Northwest National Laboratory

Eric Tan, Abhijit Dutta
National Renewable Energy Laboratory

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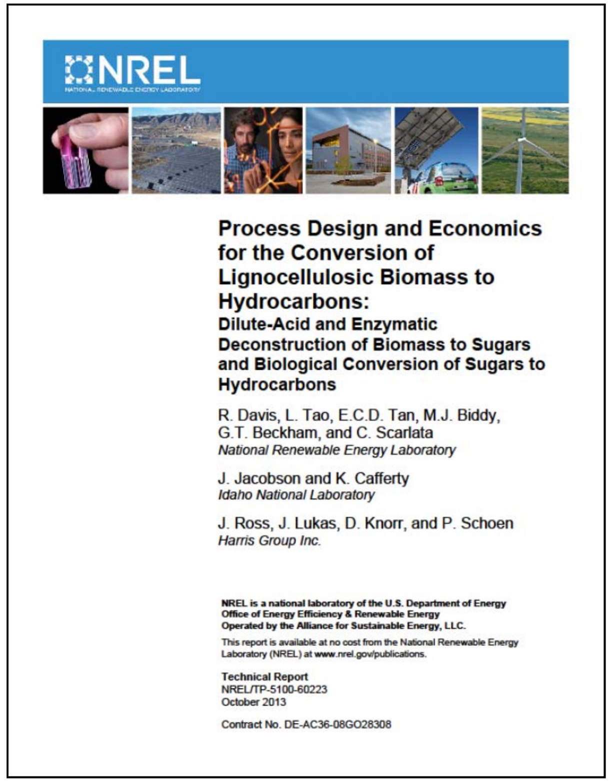
Idaho National Laboratory

PNNL-23053
NREL/TP-5100-61178

Prepared for the U.S. Department of Energy Bioenergy Technologies Office



Process Design and Economics for the Conversion of Lignocellulosic Biomass to Hydrocarbons:
Dilute-Acid and Enzymatic Deconstruction of Biomass to Sugars and Biological Conversion of Sugars to Hydrocarbons

R. Davis, L. Tao, E.C.D. Tan, M.J. Biddy, G.T. Beckham, and C. Scarlata
National Renewable Energy Laboratory

J. Jacobson and K. Cafferty
Idaho National Laboratory

J. Ross, J. Lukas, D. Knorr, and P. Schoen
Harris Group Inc.

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This report is available at no cost from the National Renewable Energy Laboratory (NREL) at www.nrel.gov/publications.

Technical Report
NREL/TP-5100-60223
October 2013

Contract No. DE-AC36-08GO28308

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Feedstock Supply System Design and Economics for Conversion of Lignocellulosic Biomass to Hydrocarbon Fuels

Conversion Pathway: Biological Conversion of Sugars to Hydrocarbons

"The 2017 Design Case"

September 2013

- Thermochem design: “pathway” for utilizing woody resources to the future, based on 2017 projection year
- Include resources: pulpwood, wood residues, woody C&D

2017 DOE Design Cases

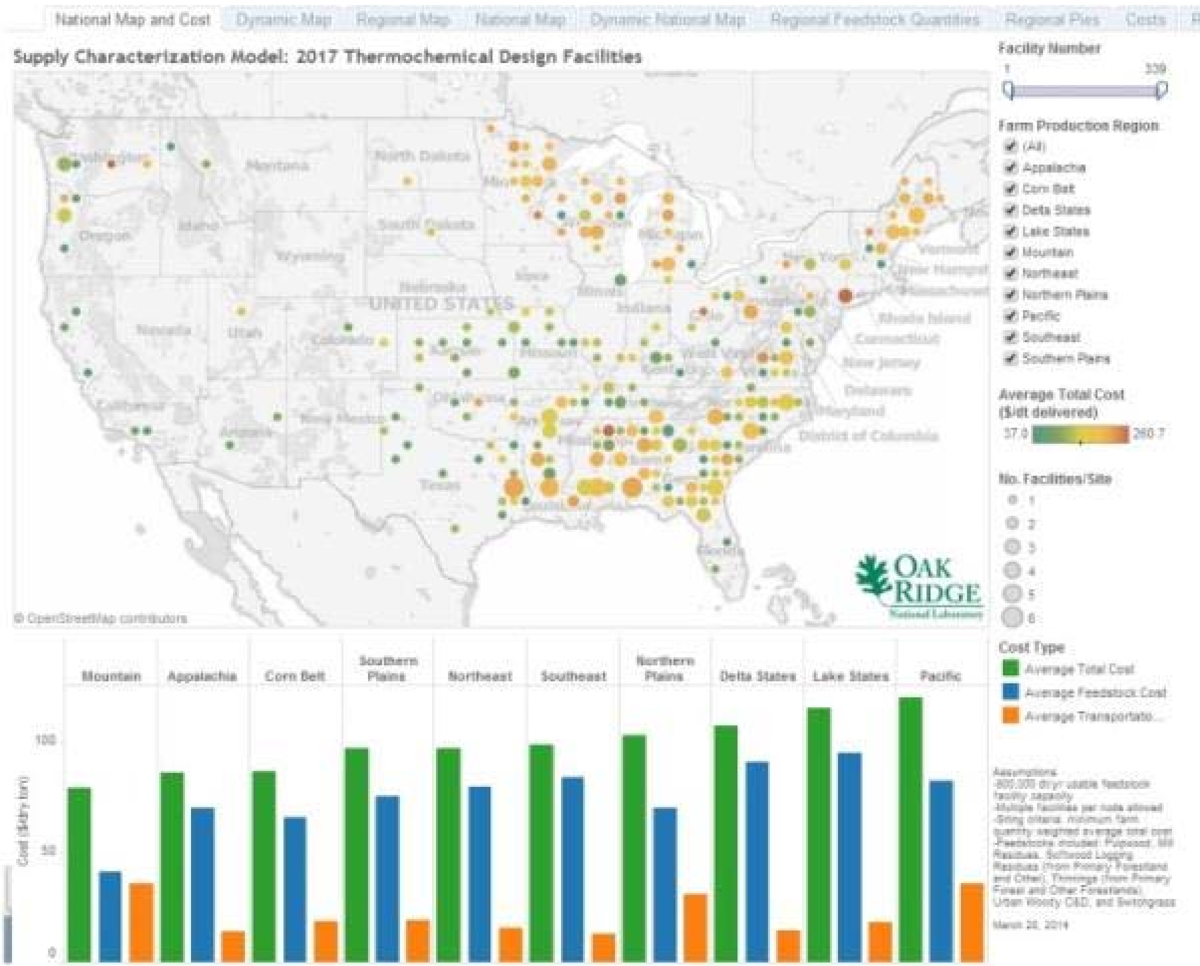
ES-1. Thermochemical feedstock design cost analysis for 2017.

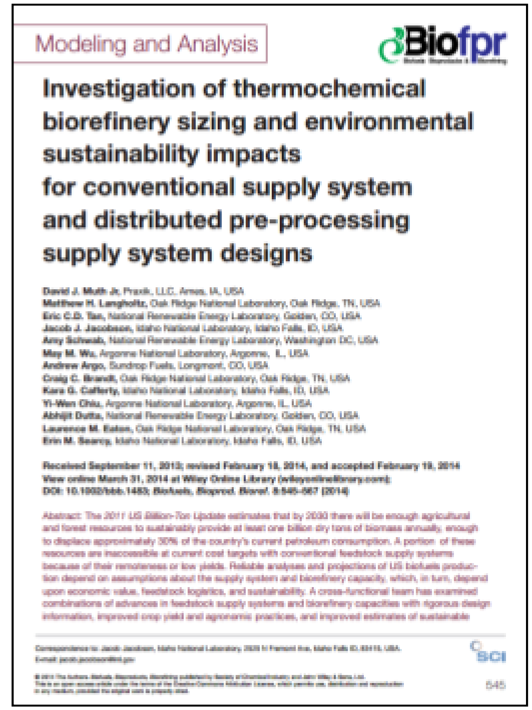
Cost Element	Pulpwood	Wood Residues	Switchgrass	Construction and Demolition Waste (C&D)	Blend
Formulation Contribution	45%	32%	3%	20%	–
Grower payment/access cost	25	26.35	19.67	8.15	21.9
Harvest and collection ($/dry T)	22.24	0	15.41	–	10.47
Landing Preprocessing/Sorting ($/dry T)	12.17	8.73	0	9.85	10.24
Transportation ($/dry T)	10.89	3.33	4.5	6.87	7.52
Preprocessing ($/dry T)	23.97	23.97	19.7	28.12	22.79
Storage ($/dry T)	3.23	3.23	5.5	3.23	3.3
Handling ($/dry T)	1.9	1.9	1.9	1.9	1.9
Total Delivered Feedstock Cost ($/dry T)	99.49	67.51	66.68	58.12	80

to the future, based on 2017 projection year

- Include resources: pulpwood, wood residues, woody C&D

Thermochemical Results





Modeling and Analysis

Biofpr

Investigation of thermochemical biorefinery sizing and environmental sustainability impacts for conventional supply system and distributed pre-processing supply system designs

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Eric C.D. Tan, National Renewable Energy Laboratory, Golden, CO, USA
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Erin M. Searcy, Idaho National Laboratory, Idaho Falls, ID, USA

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View online March 31, 2014 at Wiley Online Library (wileyonlinelibrary.com);
DOI: 10.1002/bbb.1483; ***Biofuels, Bioprod. Bioref.*** **8:545–567 (2014)**

Abstract: The *2011 US Billion-Ton Update* estimates that by 2030 there will be enough agricultural and forest resources to sustainably provide at least one billion dry tons of biomass annually, enough to displace approximately 30% of the country's current petroleum consumption. A portion of these resources are inaccessible at current cost targets with conventional feedstock supply systems because of their remoteness or low yields. Reliable analyses and projections of US biofuels production depend on assumptions about the supply system and biorefinery capacity, which, in turn, depend upon economic value, feedstock logistics, and sustainability. A cross-functional team has examined combinations of advances in feedstock supply systems and biorefinery capacities with rigorous design information, improved crop yield and agronomic practices, and improved estimates of sustainable

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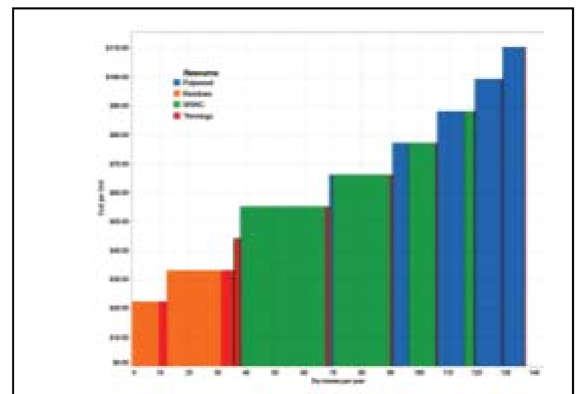

Figure 2. Supply curve of woody feedstock resources for the eleven SE US states[7].

https://public.tableausoftware.com/views/SCM_27Mar_18June/NationalMapandCost?:showVizHome=no#1

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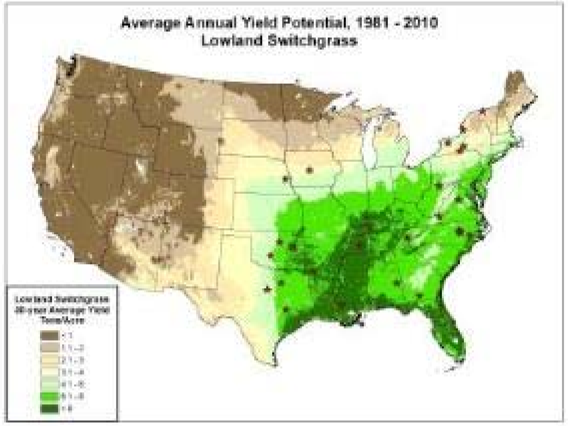
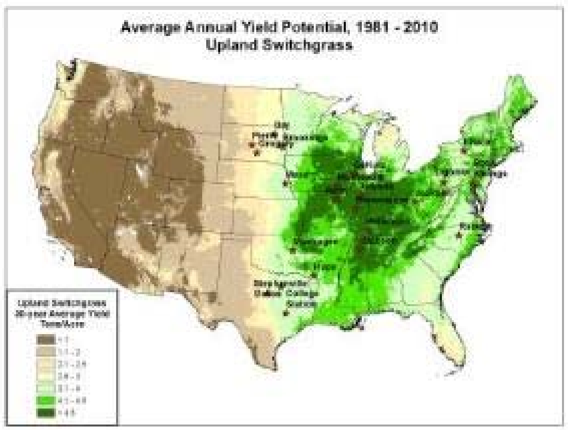
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

Herbaceous Energy Crops

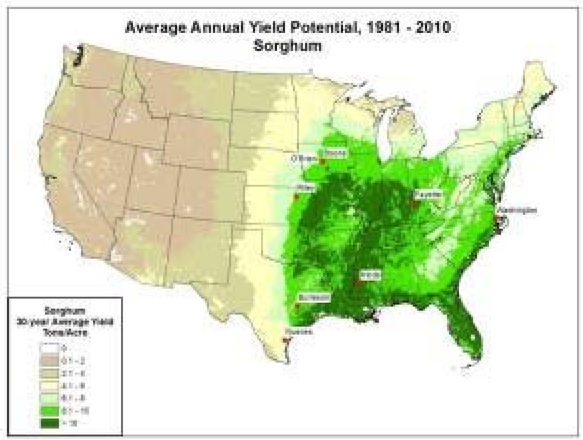
Lowland Switchgrass



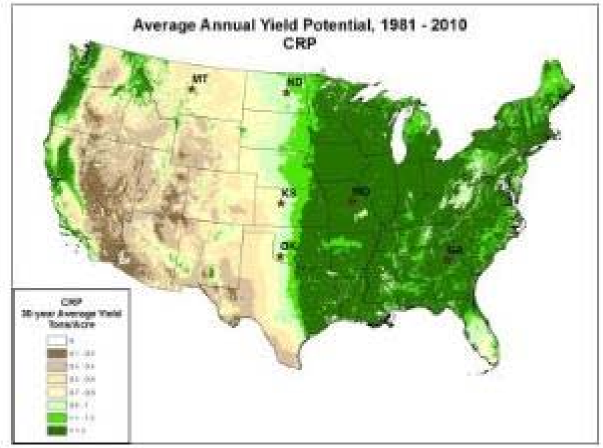


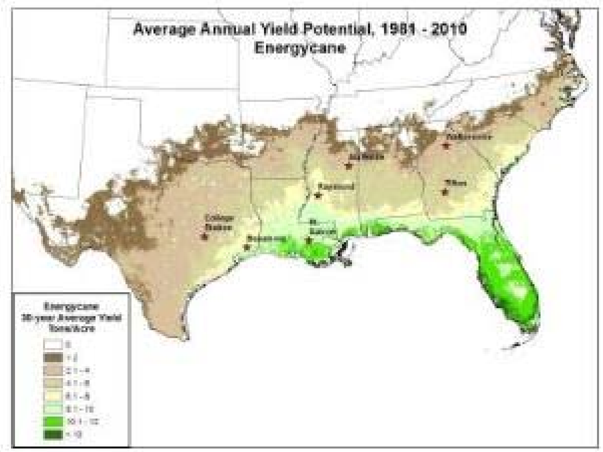
Upland Switchgrass

Sorghum



CRP Grasses

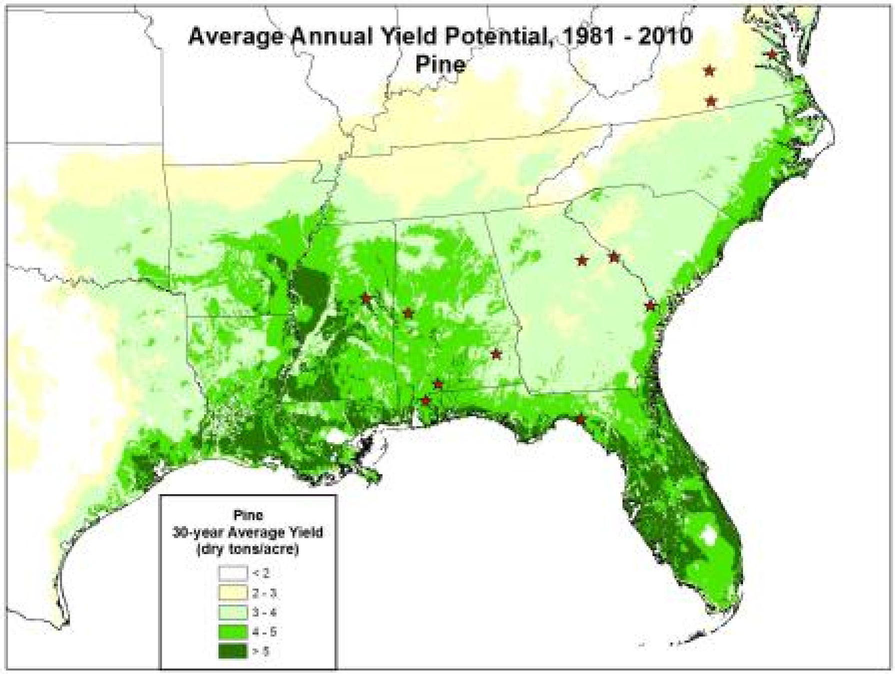




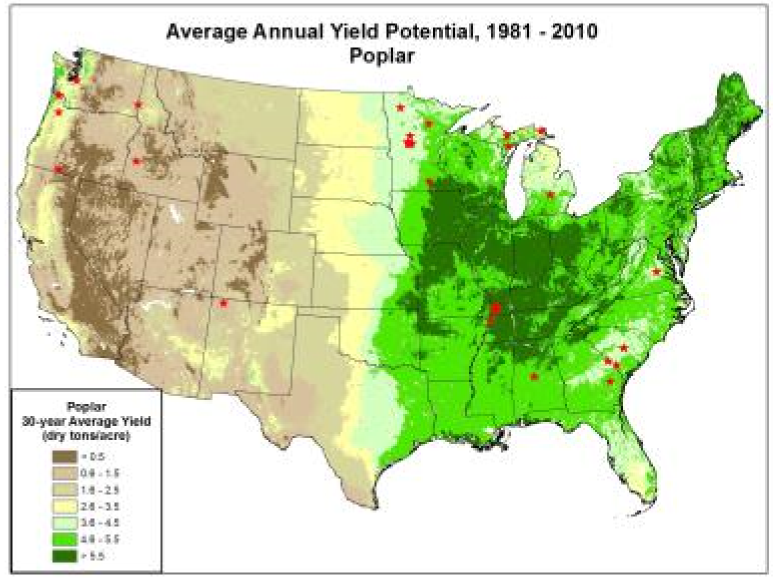
Energycane

Woody Energy Crops

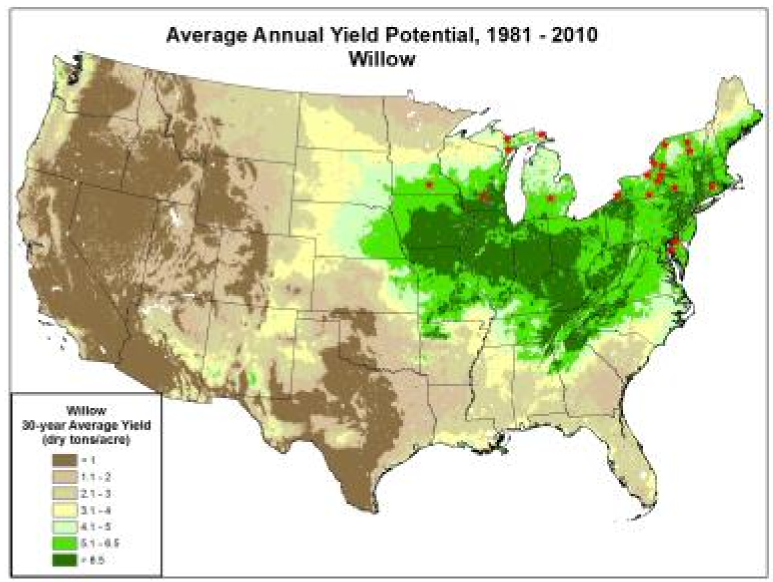
Pine



Poplar



Willow



Thank you for your attention!

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County-level Comparison