Potential Yield Mapping of Dedicated Energy Crops

Christopher Daly and Michael Halbleib
PRISM Climate Group
Sun Grant Western Region GIS Center
Oregon State University
Corvallis, Oregon, USA

OSU Oregon State UNIVERSITY

PRISM GROUP

RMA

SunGrant INITIATIVE
WESTERN REGIONAL CENTER
Oregon State University

SunGrant INITIATIVE
WESTERN REGIONAL CENTER
Oregon State University

Sun Grant Initiative

- Consortium of the nation's land-grant universities addressing national bioenergy and bioproduct challenges
- Five Regional University Centers
- Engaging agricultural and natural resource colleges in every state and territory

Regional Feedstock Partnership

SunGrant INITIATIVE
WESTERN REGIONAL CENTER
Oregon State University

U.S. Department of Energy
- Regional Biomass Feedstock Partnership
- Regional Competitive Grants

U.S. Department of Agriculture
- Sustainable Feedstock Production
- Regional Competitive Grants

Feedstock Partnership

- Field studies
- Production potentials
- Economic practicality
- Composition and utility

Feedstock Development
- Plant Breeding
- Agronomic Management
- Sustainable Production
- Equipment Technology

Logistics
- Feedstock Production
- Harvest, Delivery, and Storage
- Transportation
- Pre-Processing

Conversion Processes
- Conversion Technologies
- Cost of Production
- Biological Conversion
- Thermochemical Conversion

System Analysis
- Industrial Ecology
- Feedstock Transport
- Biofuels Transport
- Delivery Infrastructure

Economics, Marketing, and Policy
- Economics and Policy
- Impact on Food, Feed, and Fiber Markets
- Economic Return
- Production Economics

Environmental Impacts
- Life Cycle Analysis
- Greenhouse Gas Emissions
- Carbon and Energy Balance
- NOX Emissions

An Environmental Suitability Modeling Framework (PRISM-EM)

- Develop gridded, “first-guess” maps of feedstock relative yield across the entire conterminous US, based on known tolerances to climate and soil characteristics

- Provide a spatial framework for assimilating and interpreting field data, which in turn, refines the first guess maps and allows conversion to actual yield

PRISM Environmental Model

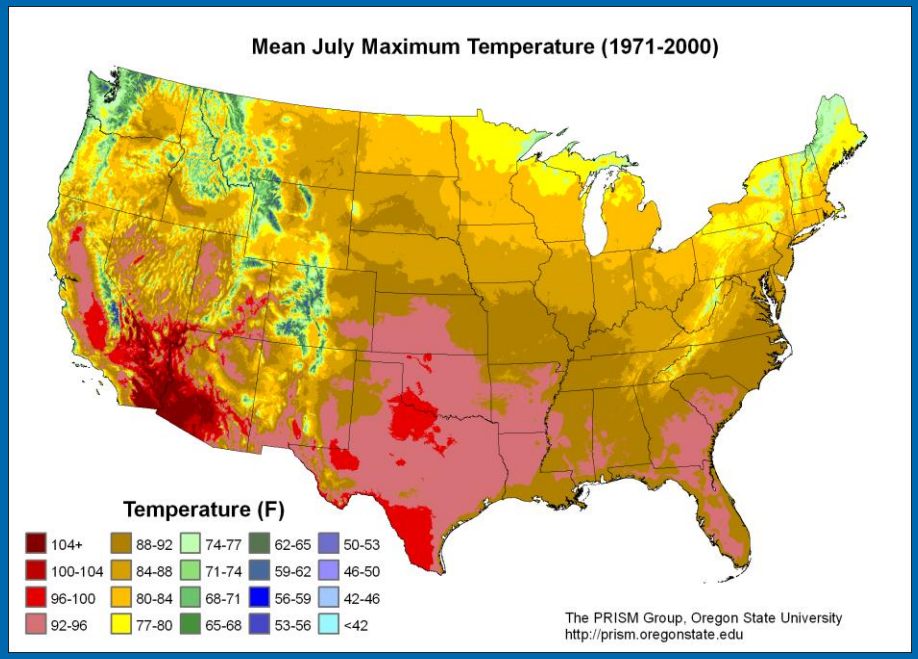
"Limiting Factor" Approach

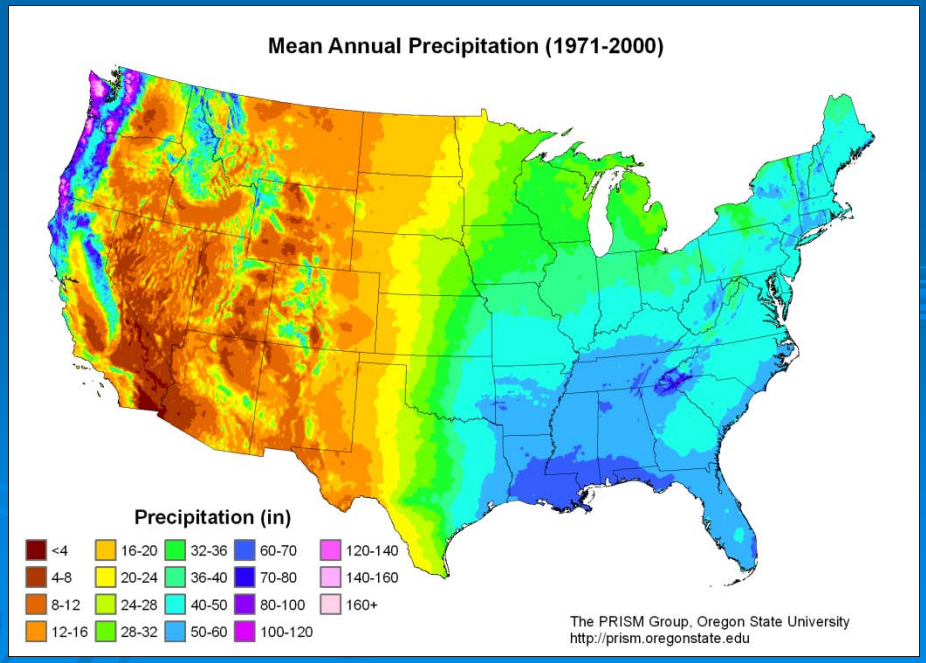
Final Relative Yield (0,100%) =
Lowest relative yield resulting from the following functions:

- Water Balance Simulation
- Winter Low Temperature Constraint
- Summer High Temperature Constraint
- Soil pH
- Soil Salinity
- Soil Drainage

PRISM
Climate Mapping

- The world's most advanced climate mapping science
- Developed and operated by the PRISM Climate Group, Oregon State University
- Accounts for variations in climate due to elevation rain shadows, coastal effects, temperature inversions, and more
- Mean temp and precipitation provided to PRISM-EM twice monthly



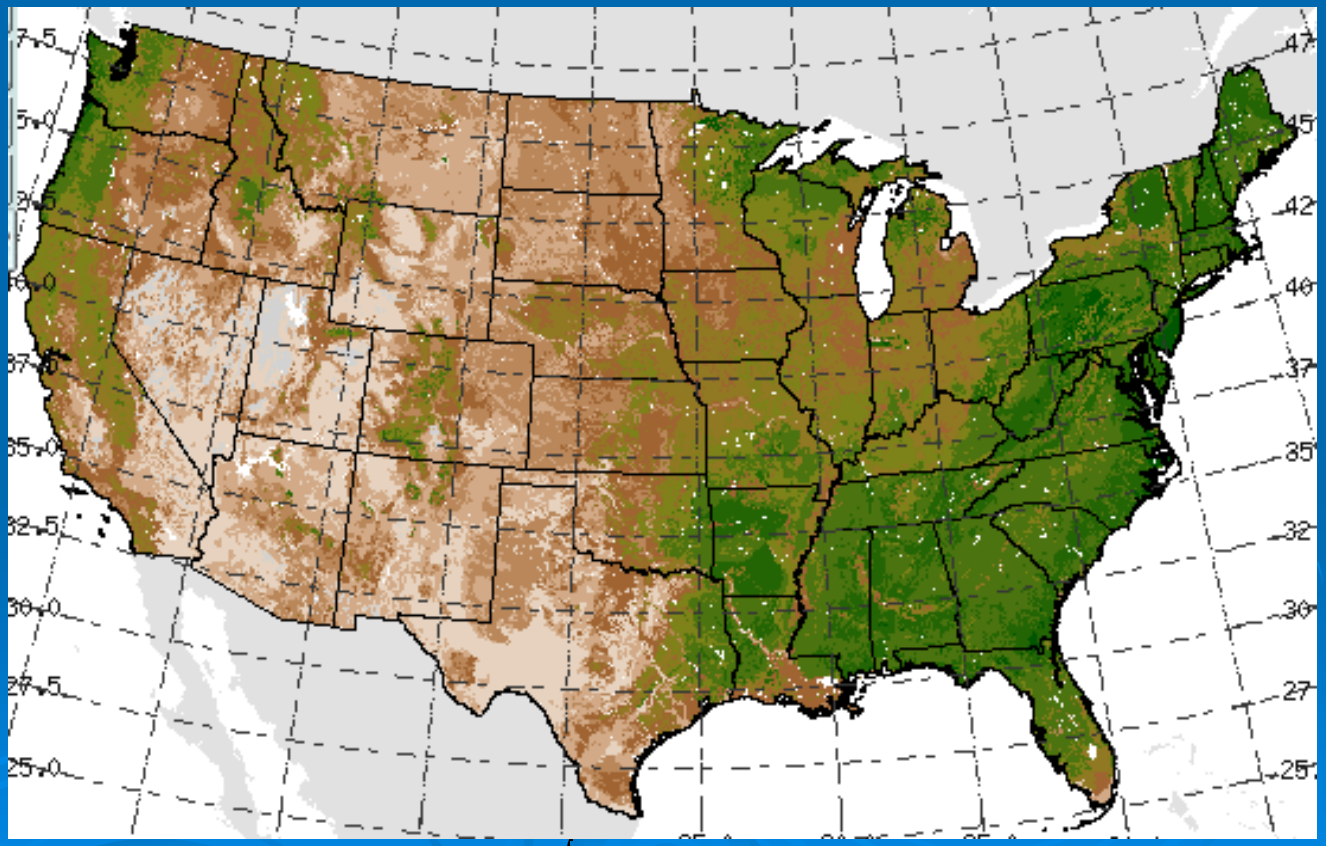


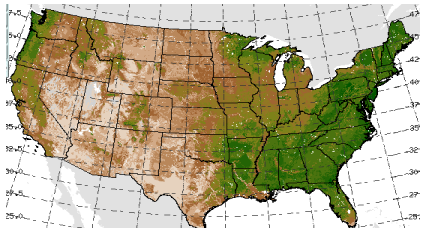
OSU Oregon State University

PRISM GROUP

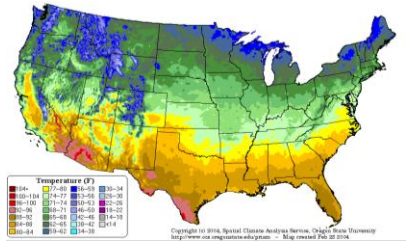
NRCS
SSURGO Soils Data

- National coverage
- Provides soils information to the model:
  - Available Water Content
  - pH
  - Salinity
  - Drainage

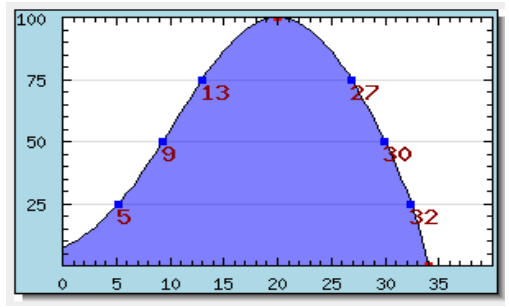




SSURGO Soil Maps



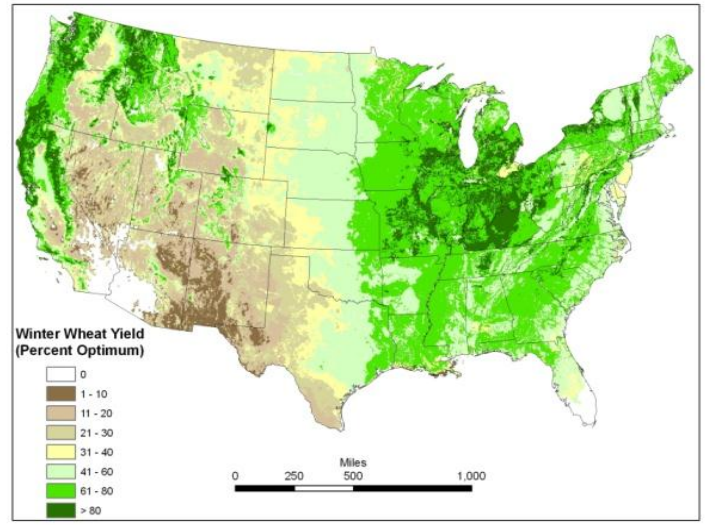
PRISM Climate Maps

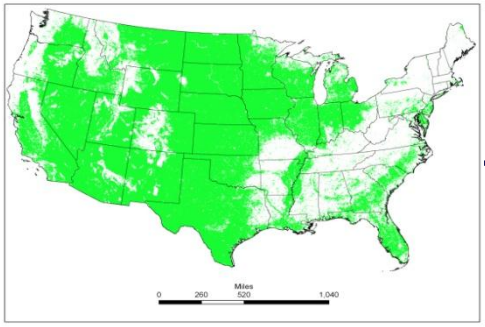


Environmental Model

PRISM-EM

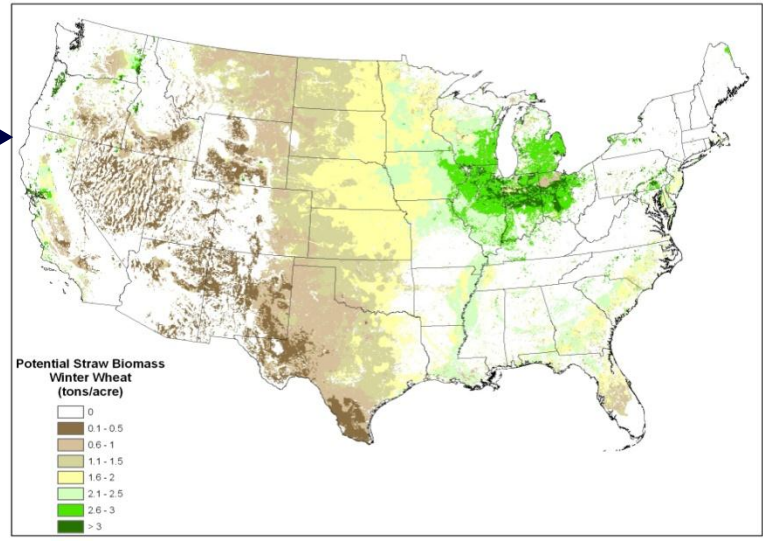
Percent of Maximum Yield



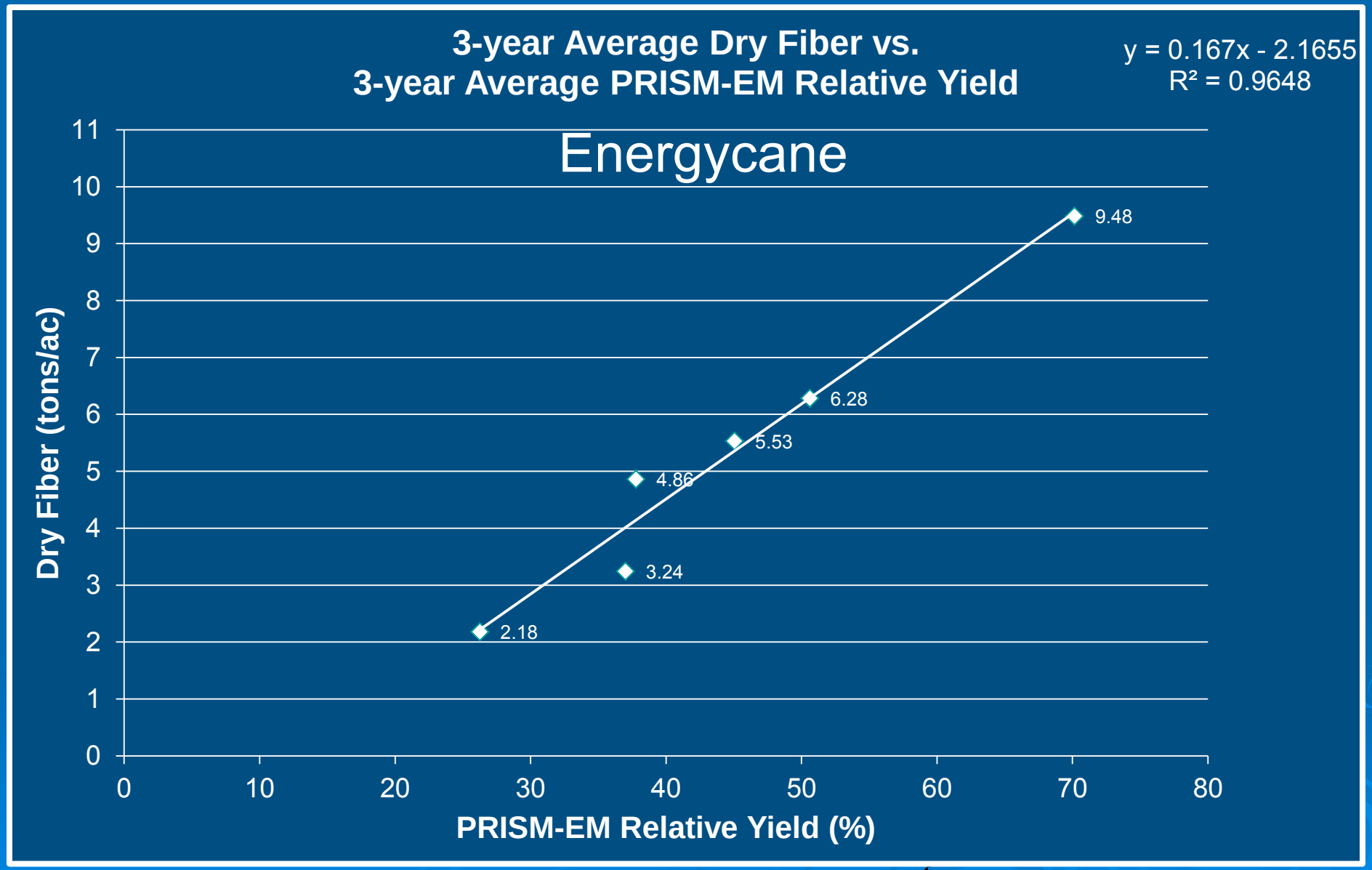


Terrain/Land Cover Constraints (Optional)

Biomass Yield



Observed Yield


3-year Average Dry Fiber vs.
3-year Average PRISM-EM Relative Yield
y = 0.167x - 2.1655
R² = 0.9648
Energycane
Dry Fiber (tons/ac)
PRISM-EM Relative Yield (%)
0
1
2
3
4
5
6
7
8
9
10
11
0
10
20
30
40
50
60
70
80
2.18
3.24
4.86
5.53
6.28
9.48

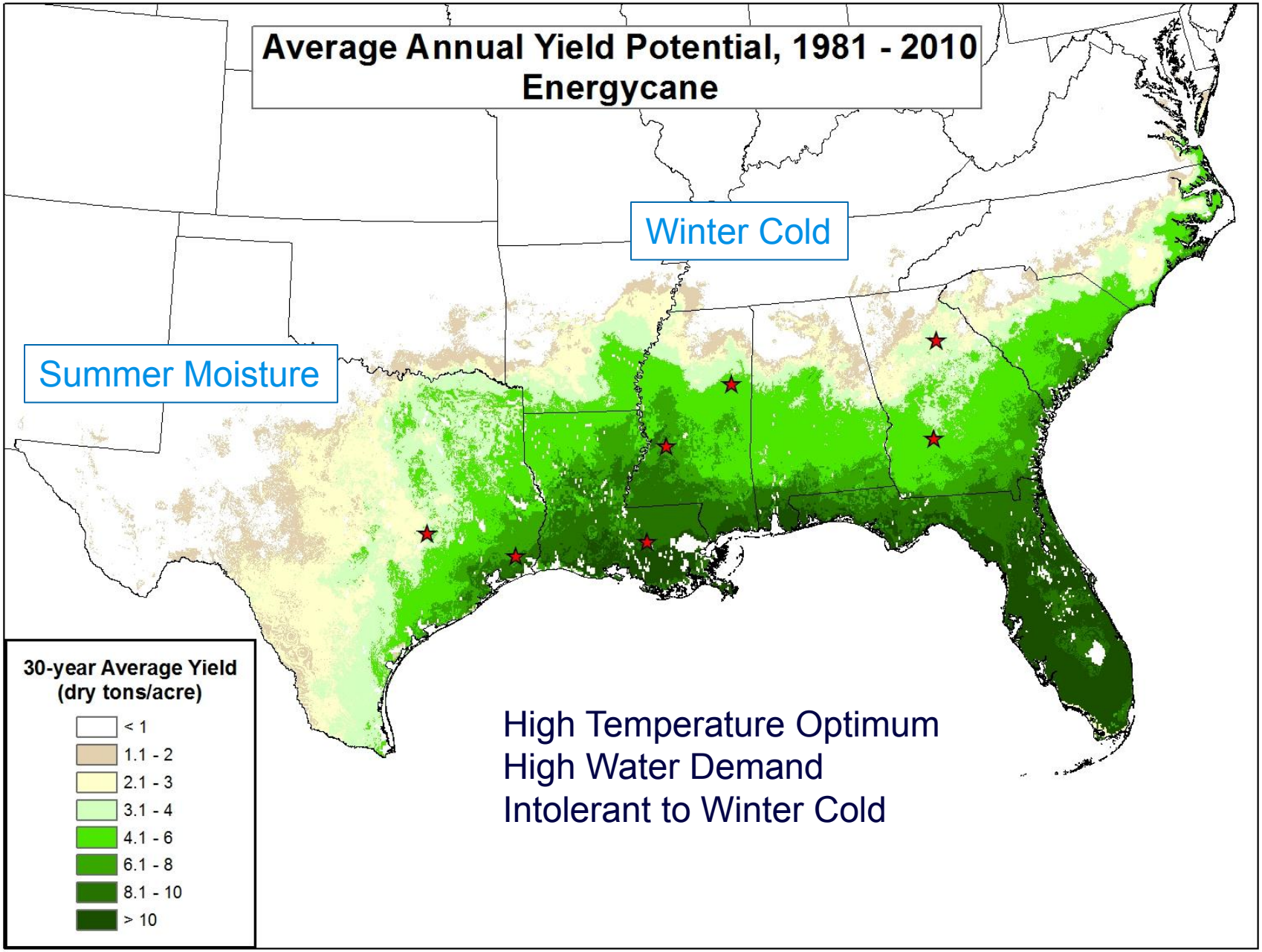
Relative Yield Modeling Assumptions

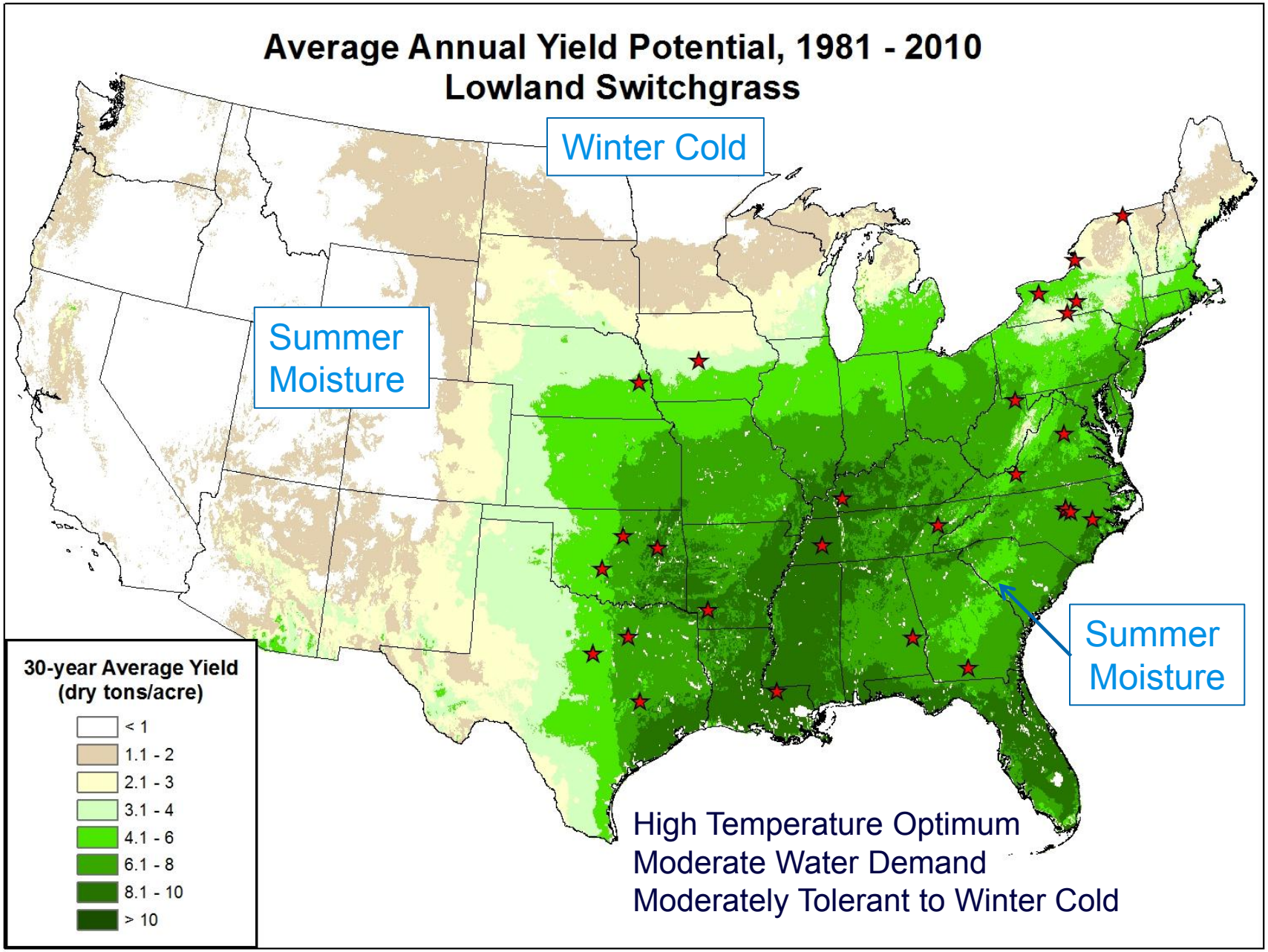
- Climate:
  - 30-year average conditions (1981-2010)
  - Does not account for damaging events, such as hail, flooding, and wind
- Irrigation: Non-irrigated conditions
- Soil pH and drainage improvements: "Reasonable" soil liming and tiling (economic considerations)
- Cultivar selection: "Best local cultivar"
- Harvest frequency: Once per year, but does not apply well to woody perennials

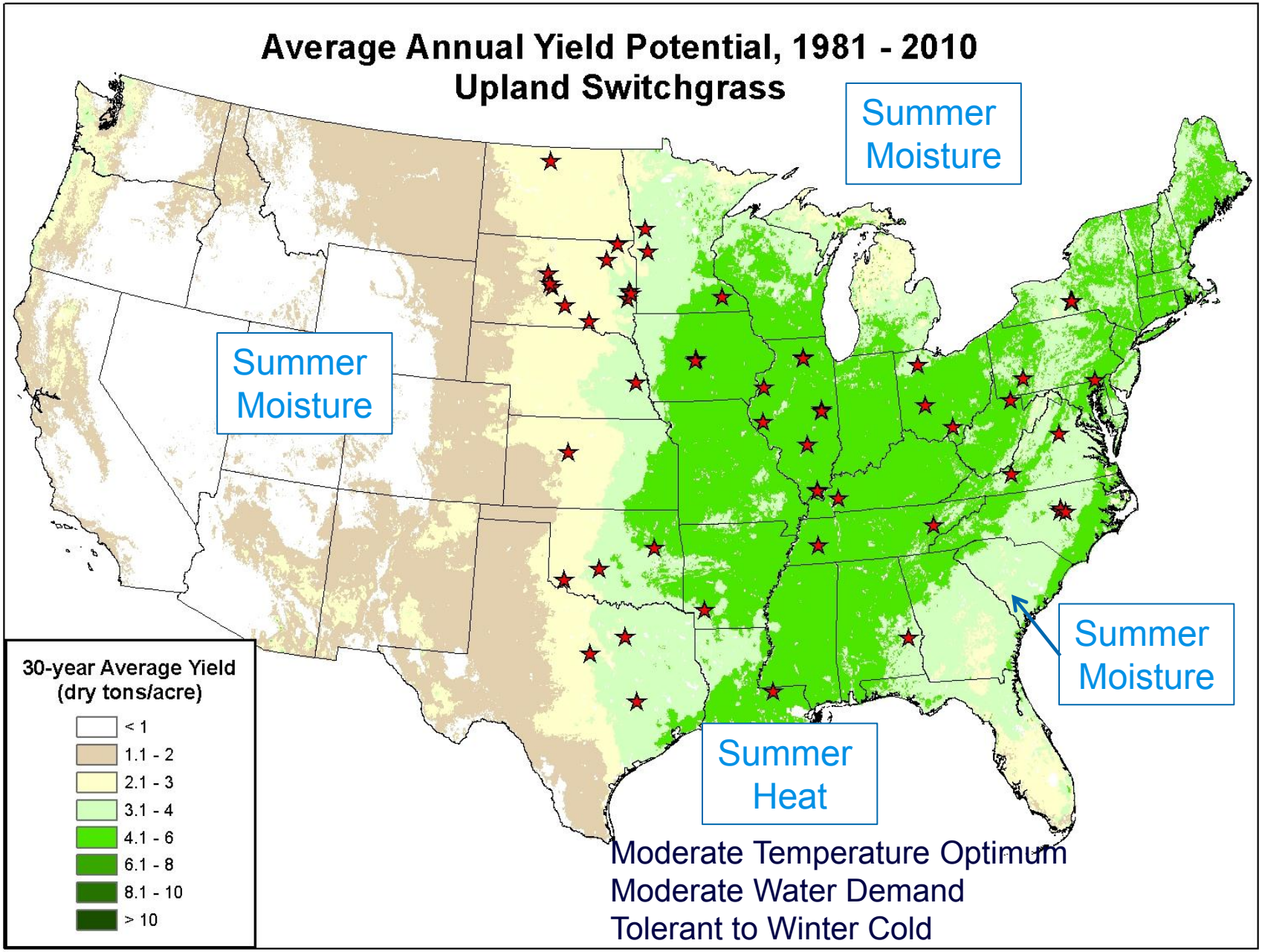
More Assumptions

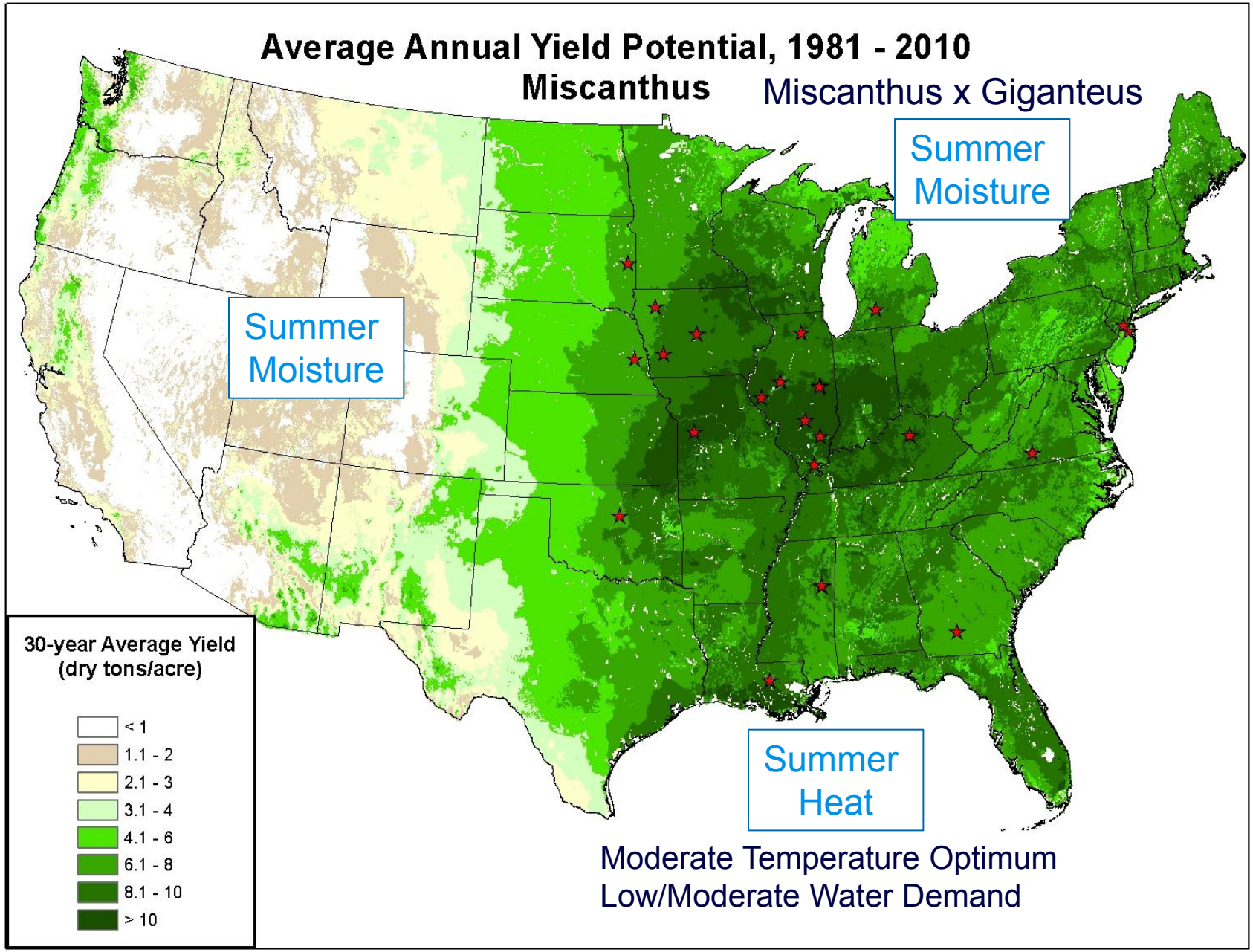
- Yield Gap: Account for “yield gap” between test plot and farm
- Establishment: Assume perennial crop has been established
- Fertilizer Application: “Sustainable” application rate
- Fungicide/Pesticide Application: Varies by crop, usually minimal

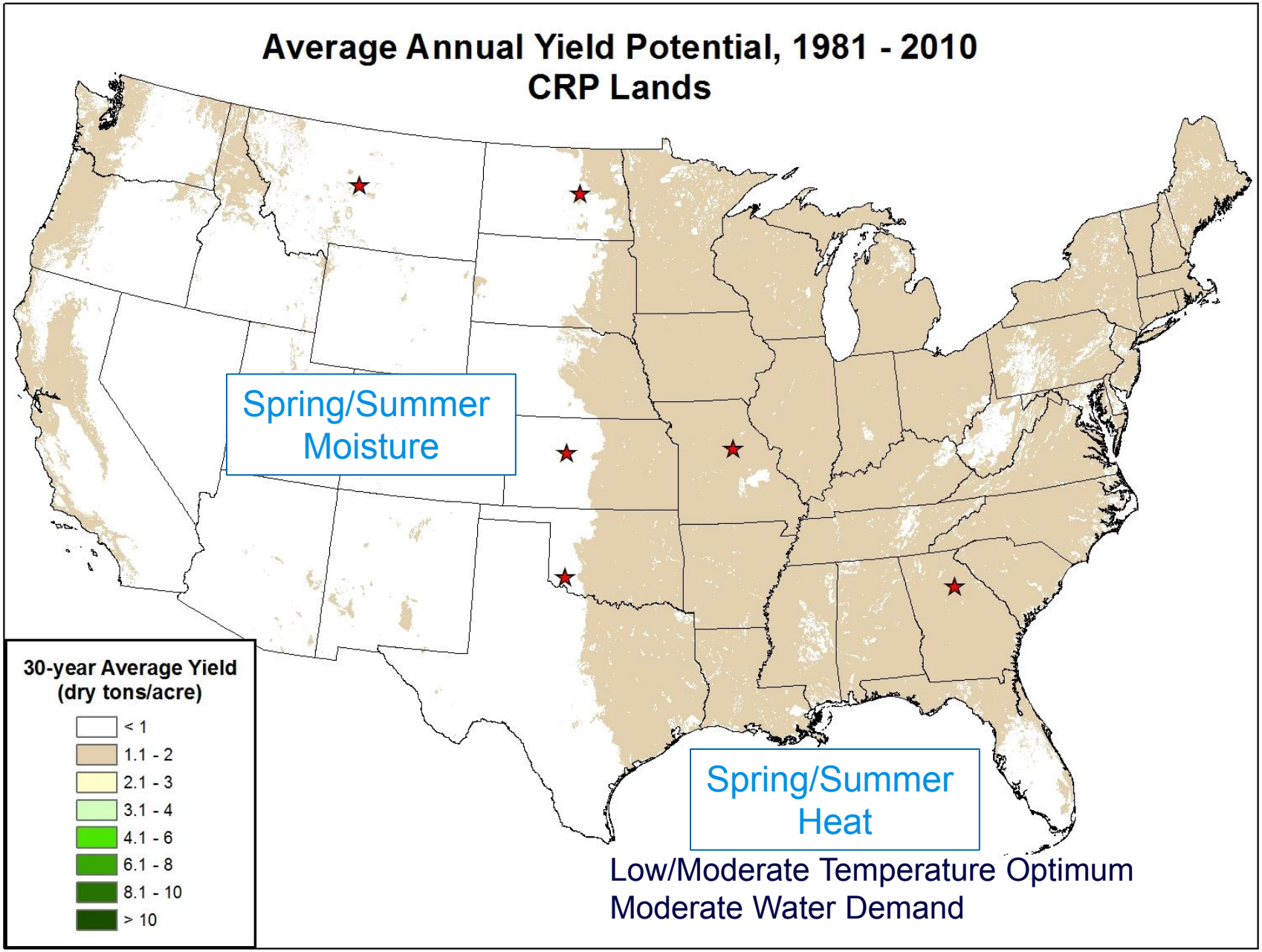
PRISM GROUP


Average Annual Yield Potential, 1981 - 2010
Energycane
Winter Cold
Summer Moisture
30-year Average Yield
(dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
High Temperature Optimum
High Water Demand
Intolerant to Winter Cold

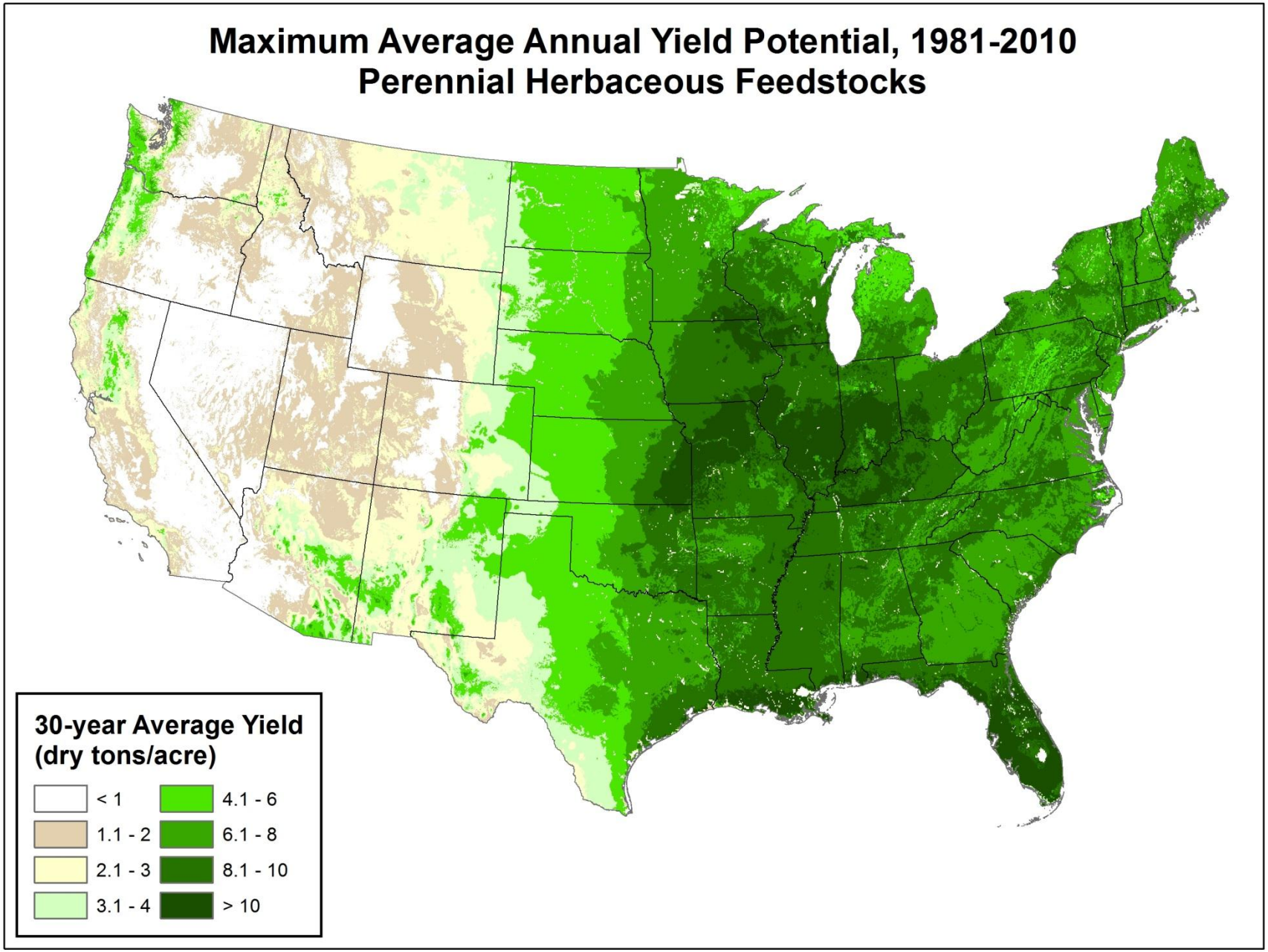

Average Annual Yield Potential, 1981 - 2010
Lowland Switchgrass
Winter Cold
Summer Moisture
Summer Moisture
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
High Temperature Optimum
Moderate Water Demand
Moderately Tolerant to Winter Cold

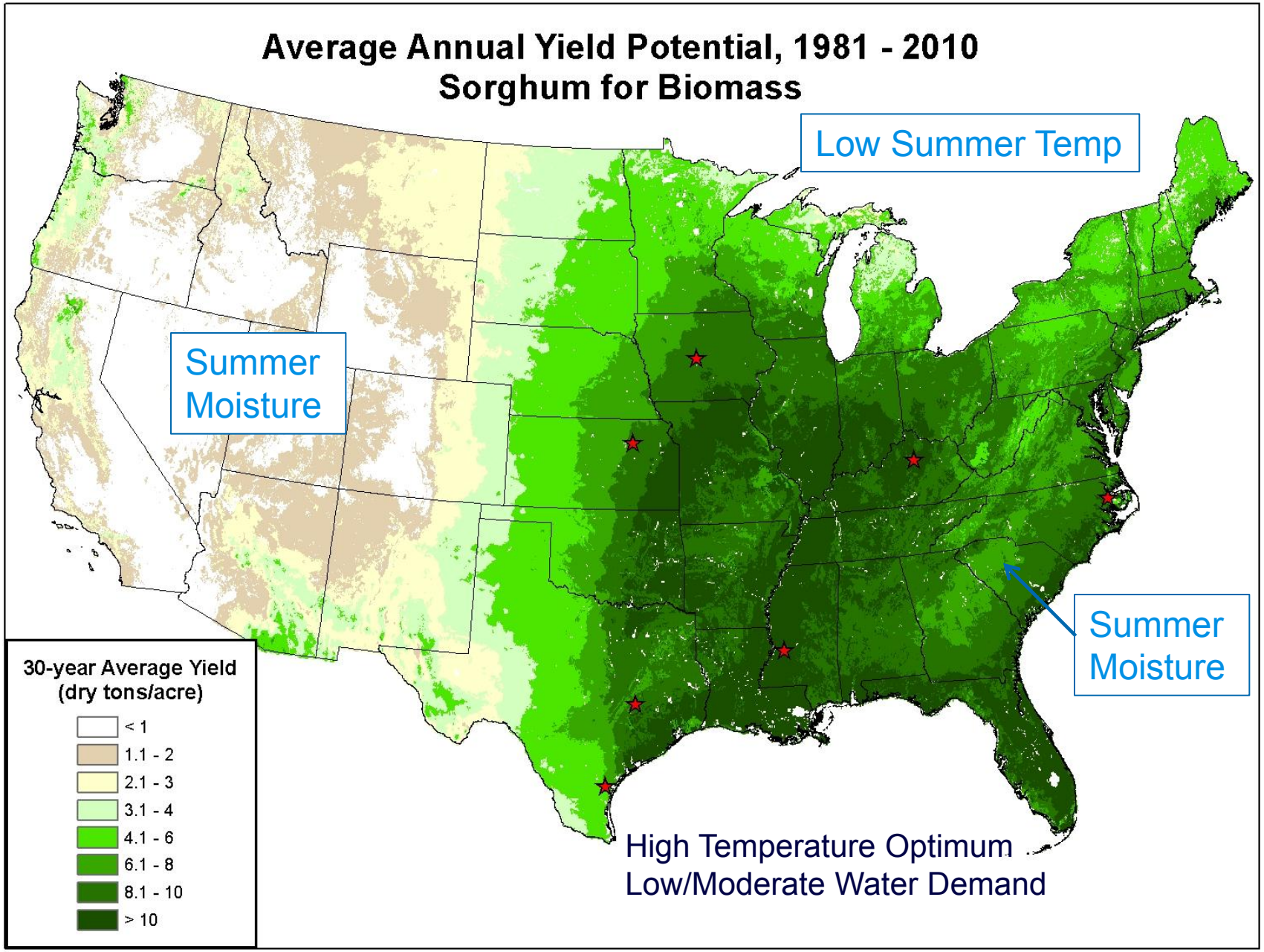

Average Annual Yield Potential, 1981 - 2010
Upland Switchgrass
Summer Moisture
Summer Moisture
Summer Moisture
Summer Heat
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
Moderate Temperature Optimum
Moderate Water Demand
Tolerant to Winter Cold

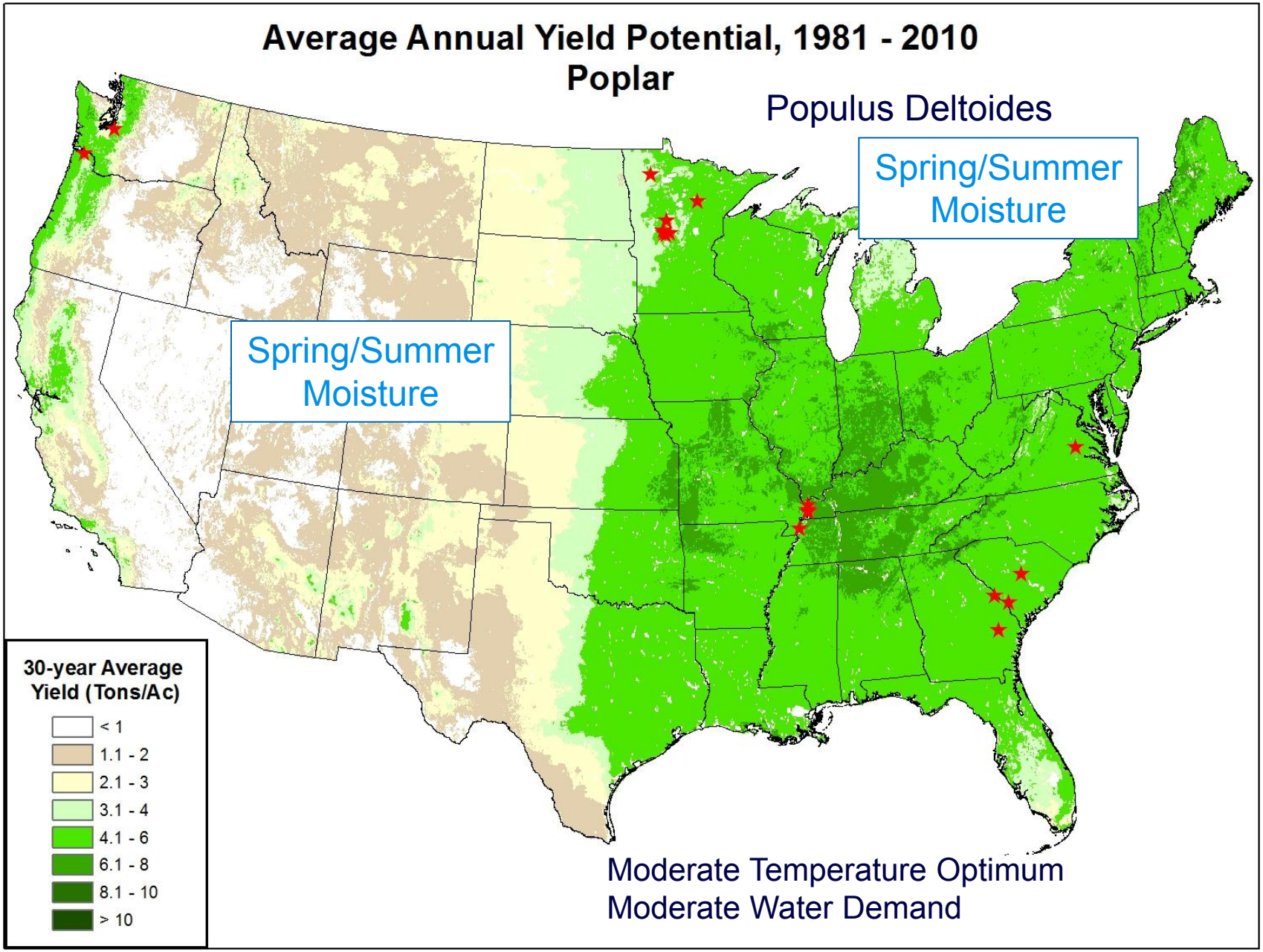

Average Annual Yield Potential, 1981 - 2010
Miscanthus
Miscanthus x Giganteus
Summer Moisture
Summer Moisture
Summer Heat
Moderate Temperature Optimum
Low/Moderate Water Demand
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10

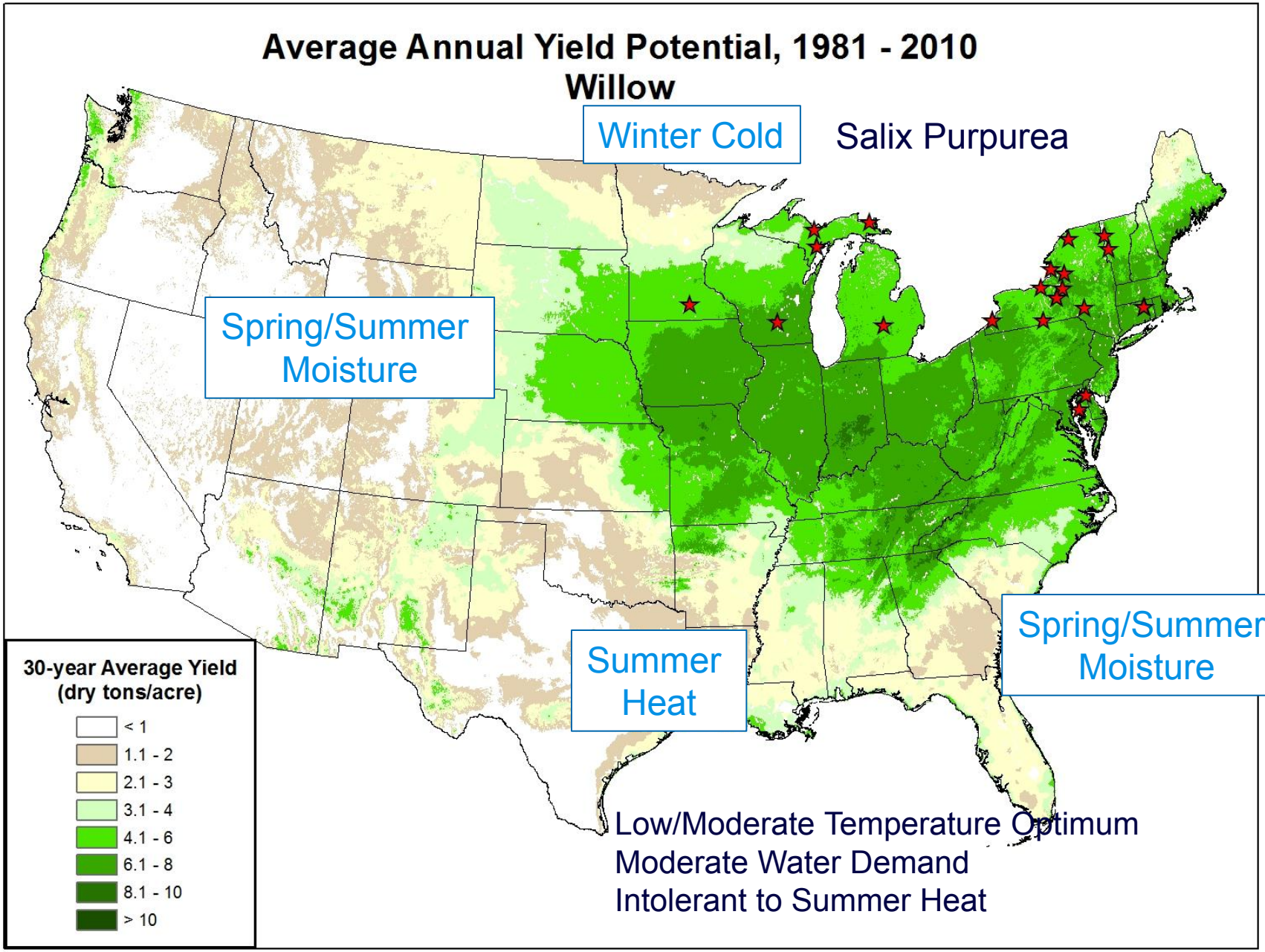

Average Annual Yield Potential, 1981 - 2010
CRP Lands
Spring/Summer Moisture
Spring/Summer Heat
Low/Moderate Temperature Optimum
Moderate Water Demand
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10

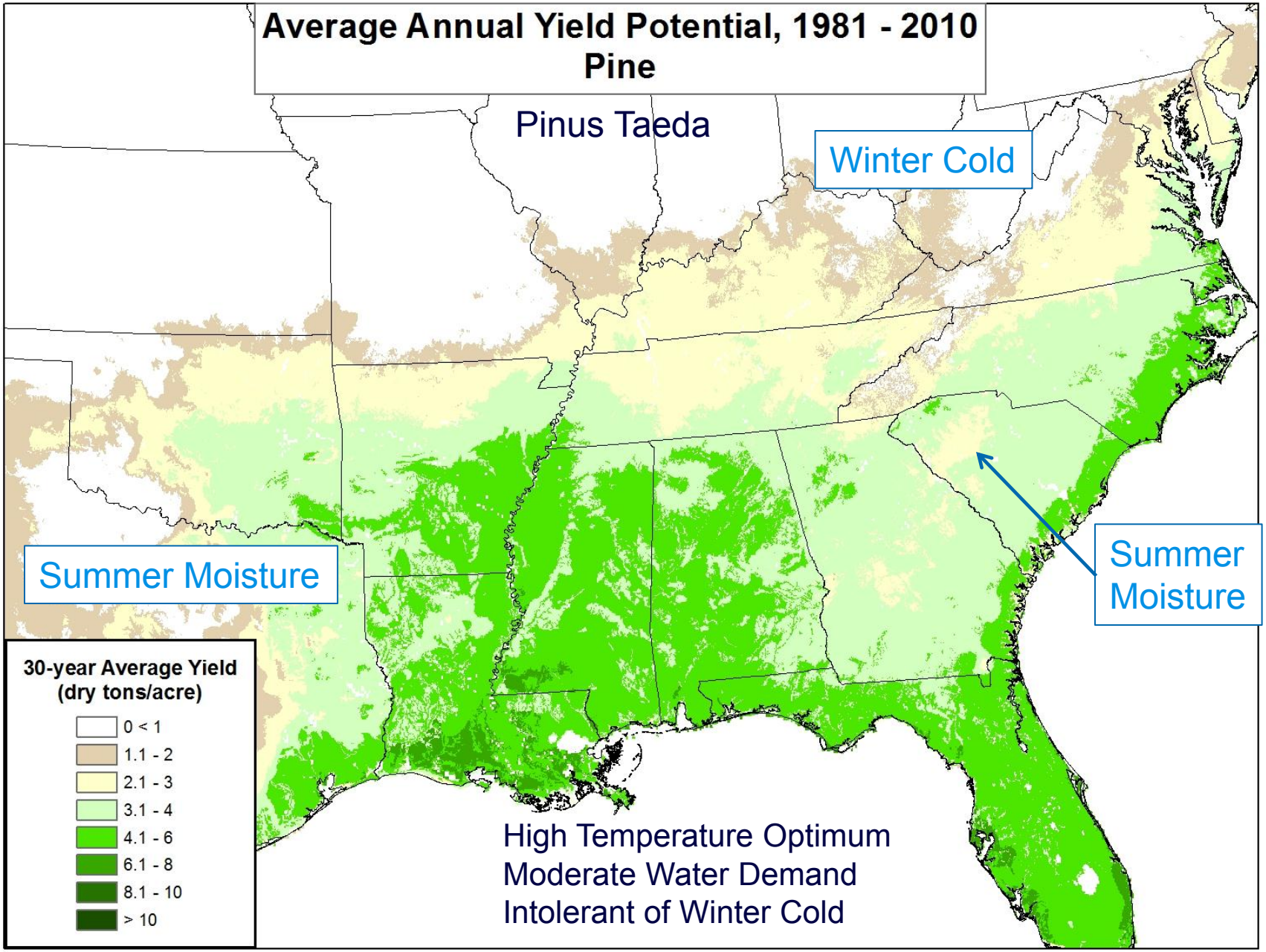
Maximum Average Annual Yield Potential, 1981-2010
Perennial Herbaceous Feedstocks



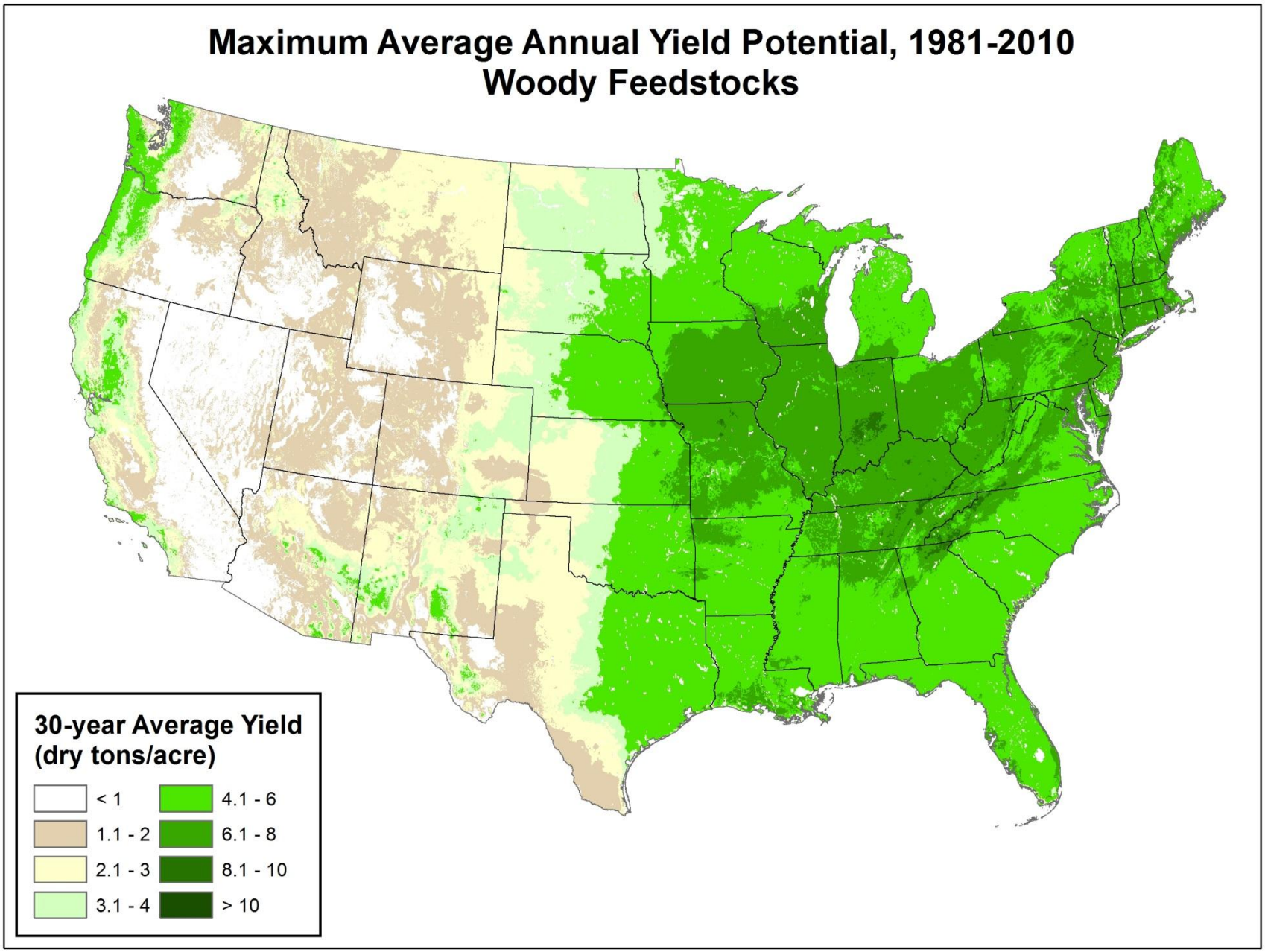

Average Annual Yield Potential, 1981 - 2010
Sorghum for Biomass
Low Summer Temp
Summer Moisture
Summer Moisture
High Temperature Optimum
Low/Moderate Water Demand
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10


Average Annual Yield Potential, 1981 - 2010
Poplar
Populus Deltoides
Spring/Summer Moisture
Spring/Summer Moisture
30-year Average Yield (Tons/Ac)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
Moderate Temperature Optimum
Moderate Water Demand


Average Annual Yield Potential, 1981 - 2010
Willow
Winter Cold
Salix Purpurea
Spring/Summer Moisture
Summer Heat
Spring/Summer Moisture
Low/Moderate Temperature Optimum
Moderate Water Demand
Intolerant to Summer Heat
30-year Average Yield (dry tons/acre)
< 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10


Average Annual Yield Potential, 1981 - 2010
Pine
Pinus Taeda
Winter Cold
Summer Moisture
Summer Moisture
30-year Average Yield
(dry tons/acre)
0 < 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
> 10
High Temperature Optimum
Moderate Water Demand
Intolerant of Winter Cold

Maximum Average Annual Yield Potential, 1981-2010
Woody Feedstocks



Closing Notes

- PRISM-EM provides potential yield distribution maps of biomass feedstocks; these serve as inputs to economic analyses
- Sun Grant field trials provided essential yield data under consistent, coordinated management conditions – more years needed!
- Face-to-face meetings with species experts were a key element to the process
- Maps will be updated with additional yield data and new varieties (maps based on varieties planted in 2008)
- Next Step: Temporal variability/risk maps