Development of Switchgrass as a Bioenergy Crop

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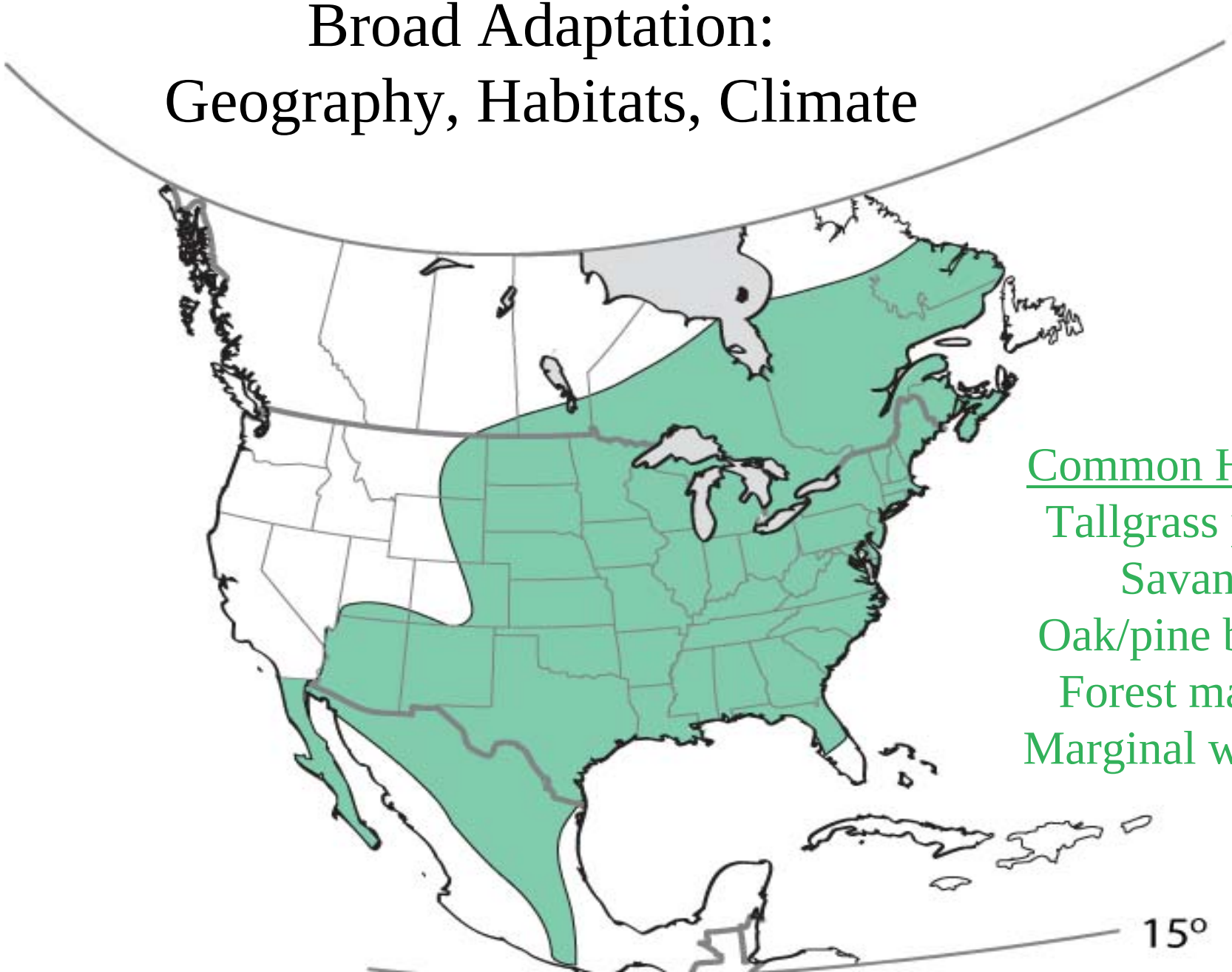
- "… to identify the best varieties and management practices to optimize productivity, while developing an understanding of the basis for long-term improvement through breeding and sustainable production in conventional ecosystems."
- Two model species
  - Switchgrass, *Panicum virgatum* (herbaceous)
  - Popular, *Populus* (woody)

Broad Adaptation:
Geography, Habitats, Climate



Common Habitats

Tallgrass prairie

Savanna

Oak/pine barrens

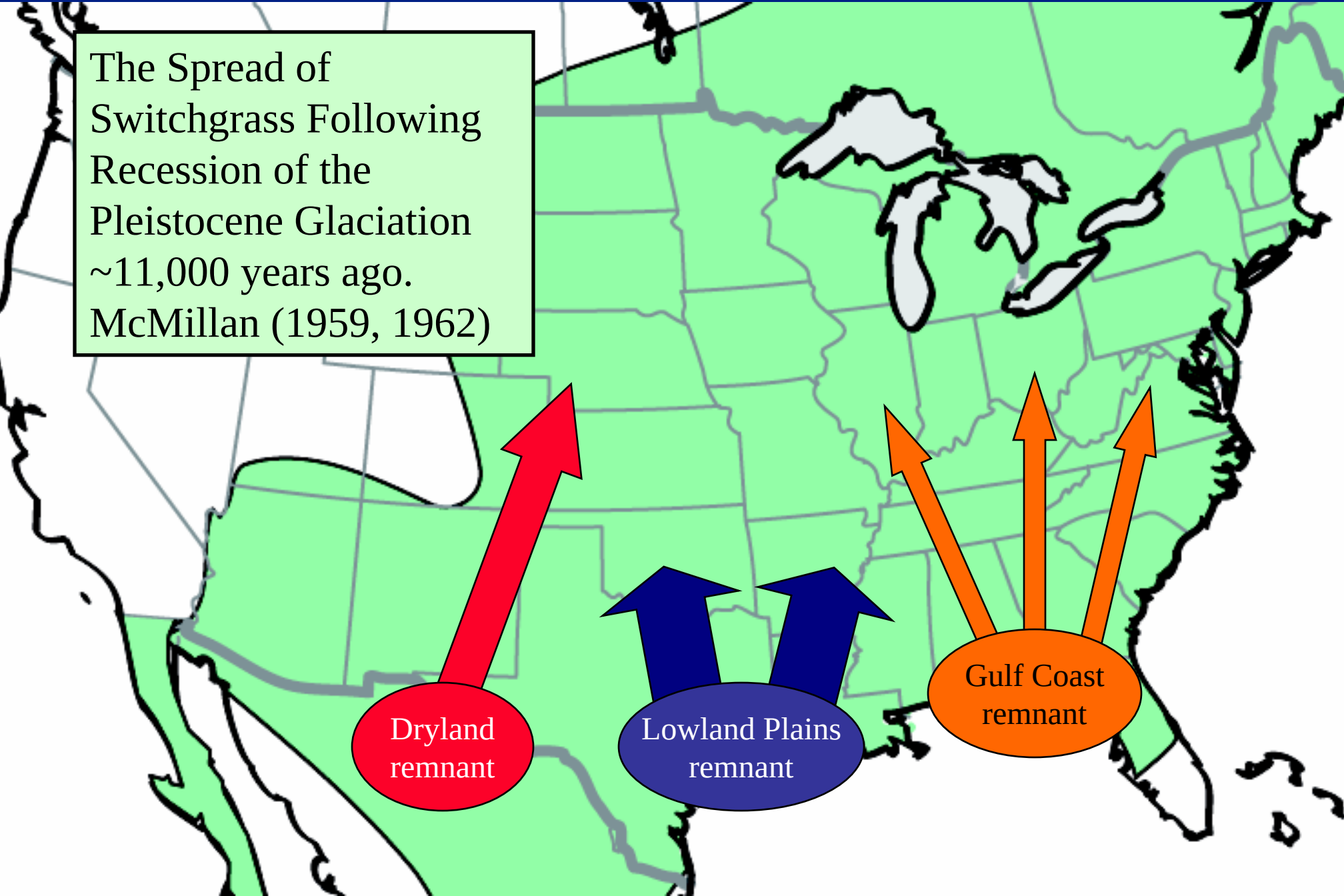
Forest margins

Marginal wetlands

Native plant with broad public and commercial appeal.

Multifunctional plant:

- High biomass yields
- Livestock grazing
- Soil conservation
- Prairie restoration


The Spread of Switchgrass Following Recession of the Pleistocene Glaciation ~11,000 years ago. McMillan (1959, 1962)
Dryland remnant
Lowland Plains remnant
Gulf Coast remnant

Switchgrass Genetics

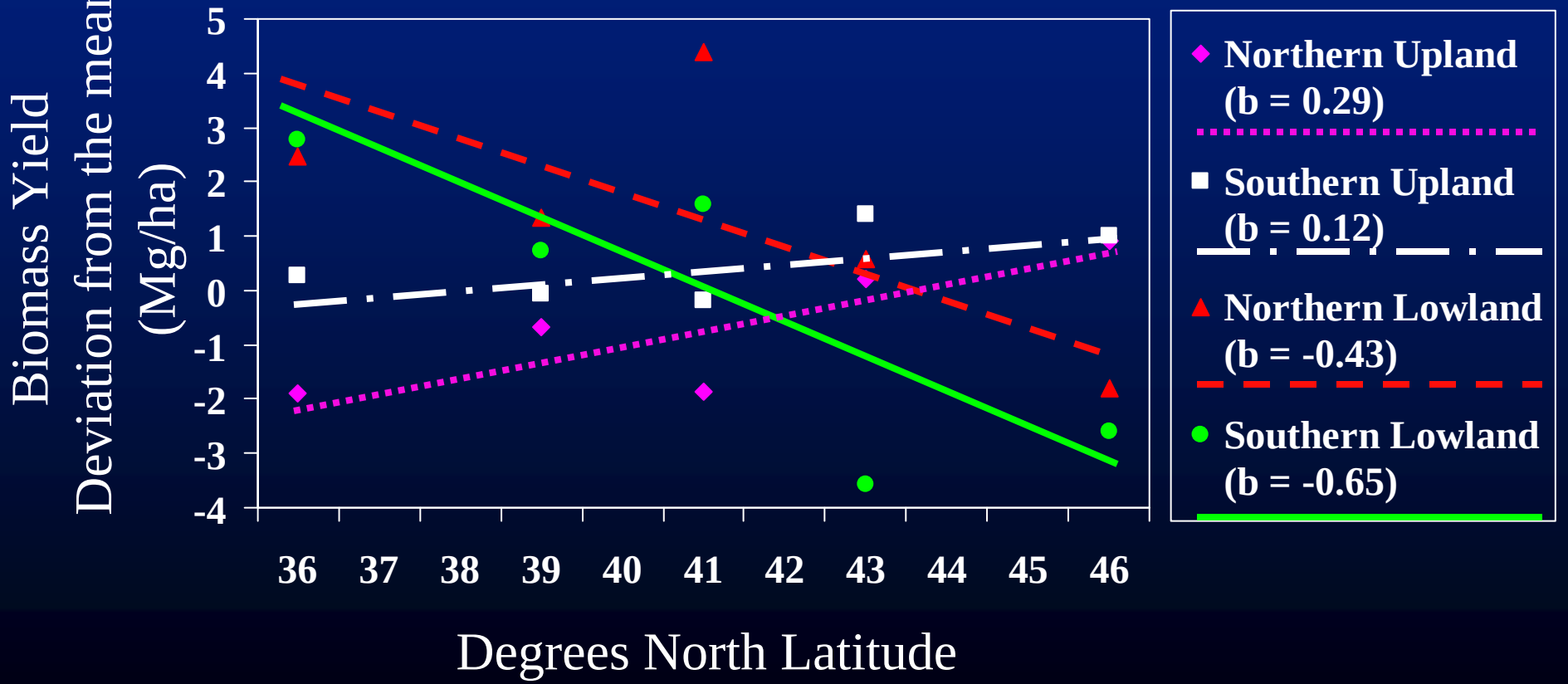
- Upland cytotype
  - Found from Texas to Canada
  - Reported chromosome numbers from 2n=2x=18 (diploid) to 2n=12x=108; 2n=4x=36 and 2n=8x=72 are most common. *Is this really true?*
- Lowland cytotype
  - Typically found from Mexico to Nebraska.
  - Chromosome number: 2n=4x=36 (no known variants)
- Disomic (diploid) inheritance *(most likely)*

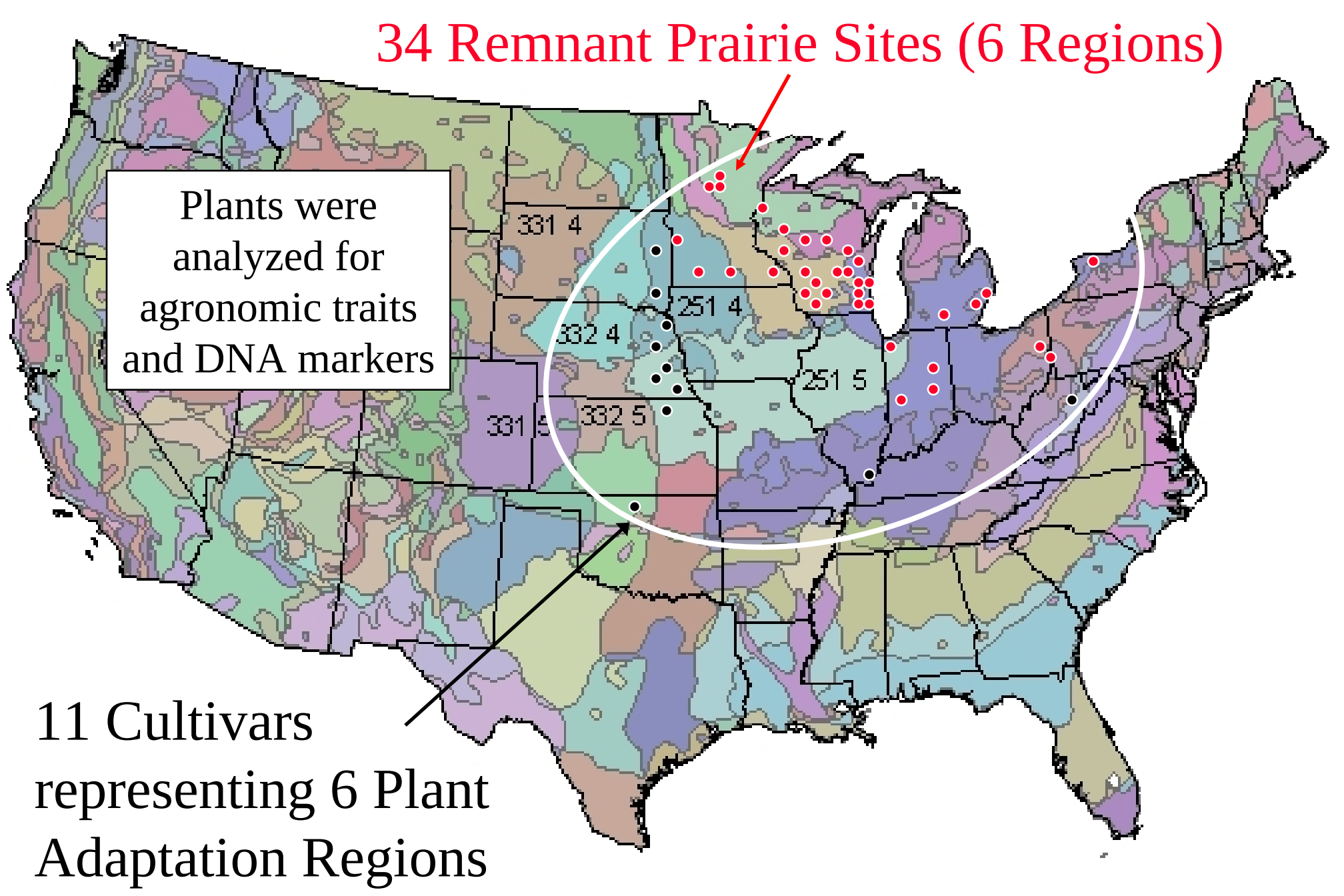
Lowland vs. Upland Cytotypes

- Lowland cytotypes…
  - Greater plant height and biomass yield.
  - Fewer tillers, greater tiller diameter, more phytomers.
  - Lower cold/freezing tolerance.
  - Greater heat tolerance.
  - Up to 2-3 weeks later in heading, anthesis, mature seed.
  - Adapted to longer growing season with reduced photoperiod.

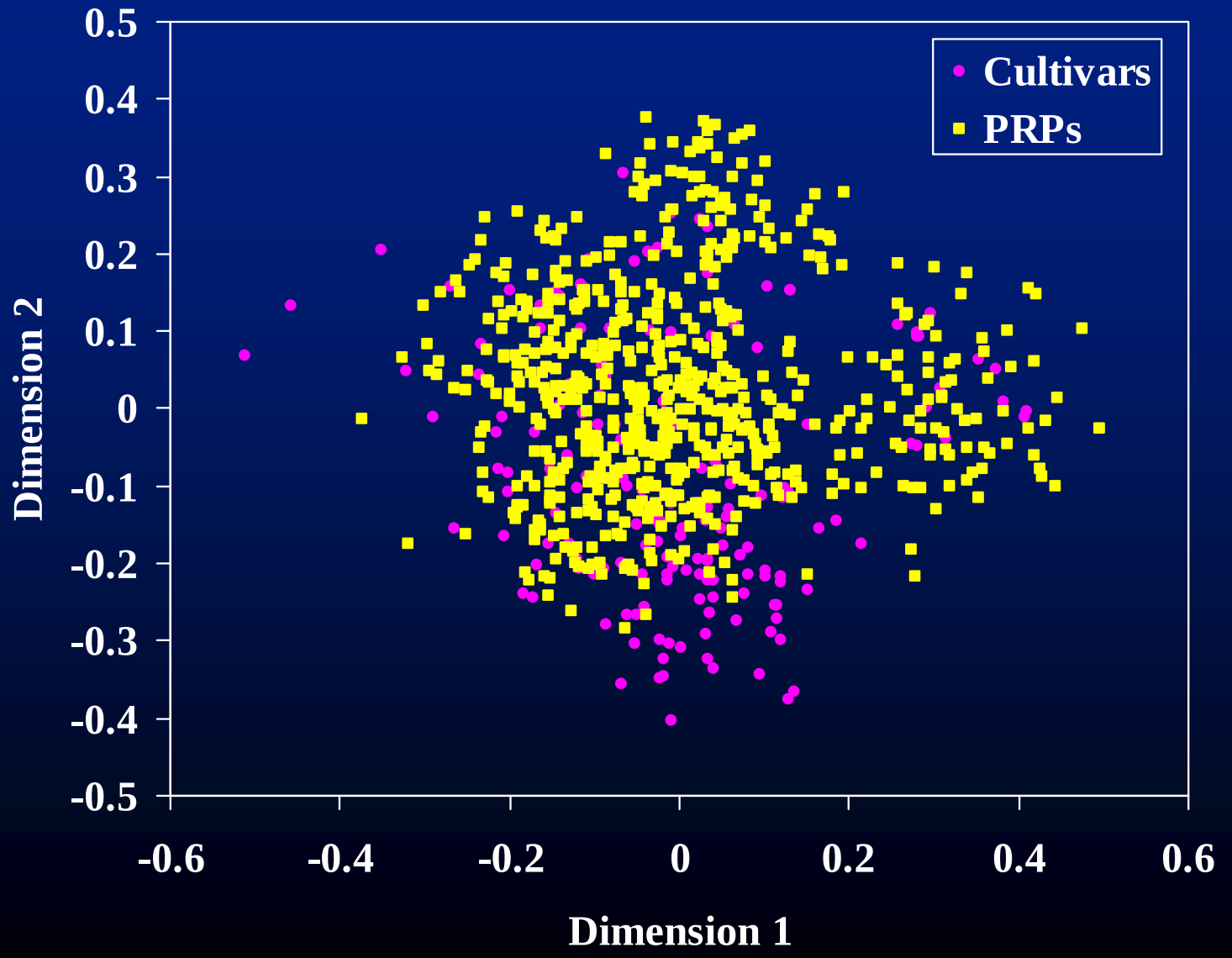
- Moving southern populations north provides a “quick fix” to boost biomass yields, *provided that they survive*.

Biomass yield: Cytotypes & Origins

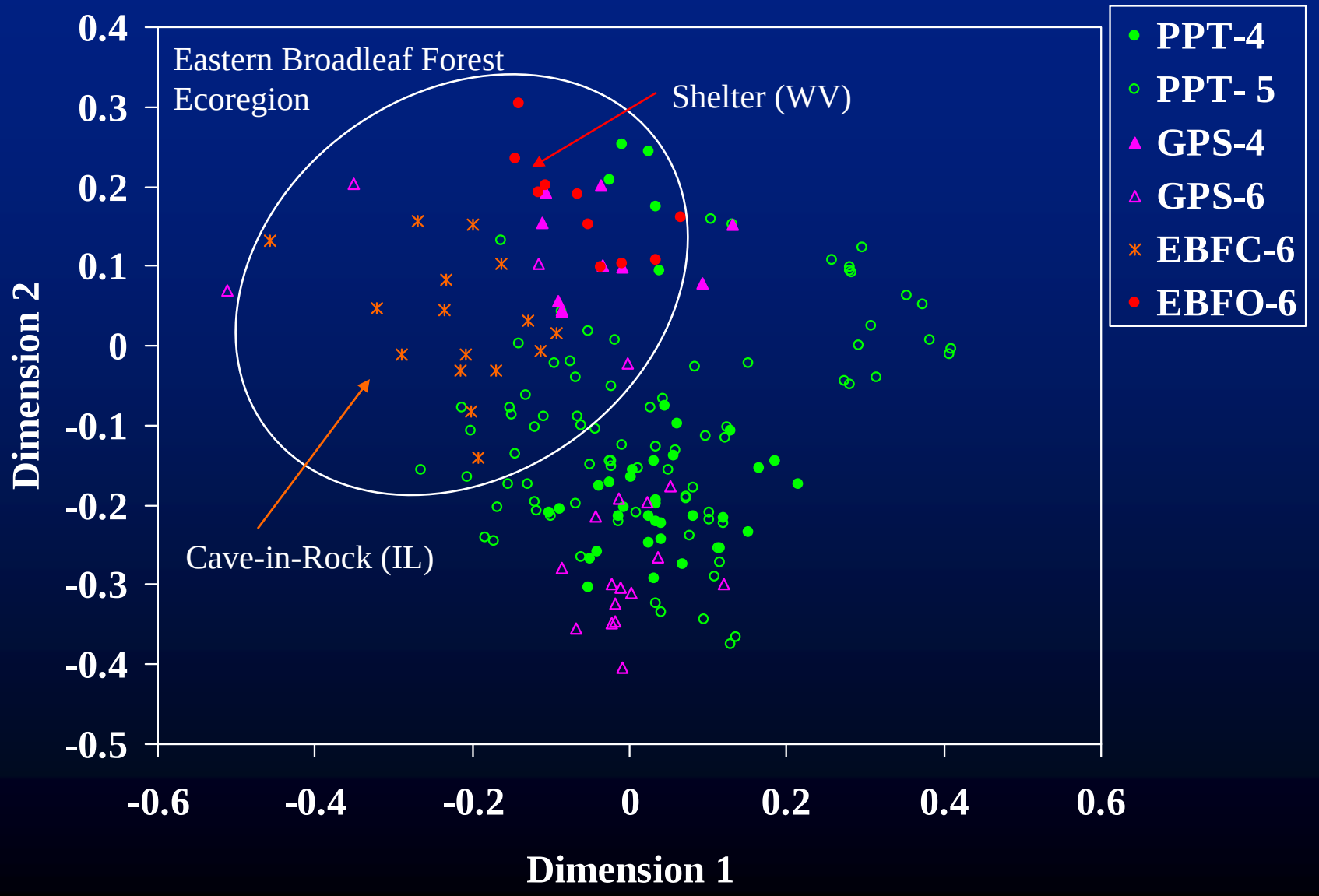



34 Remnant Prairie Sites (6 Regions)
Plants were analyzed for agronomic traits and DNA markers
331 4
251 4
332 4
251 5
331 5
332 5
11 Cultivars representing 6 Plant Adaptation Regions

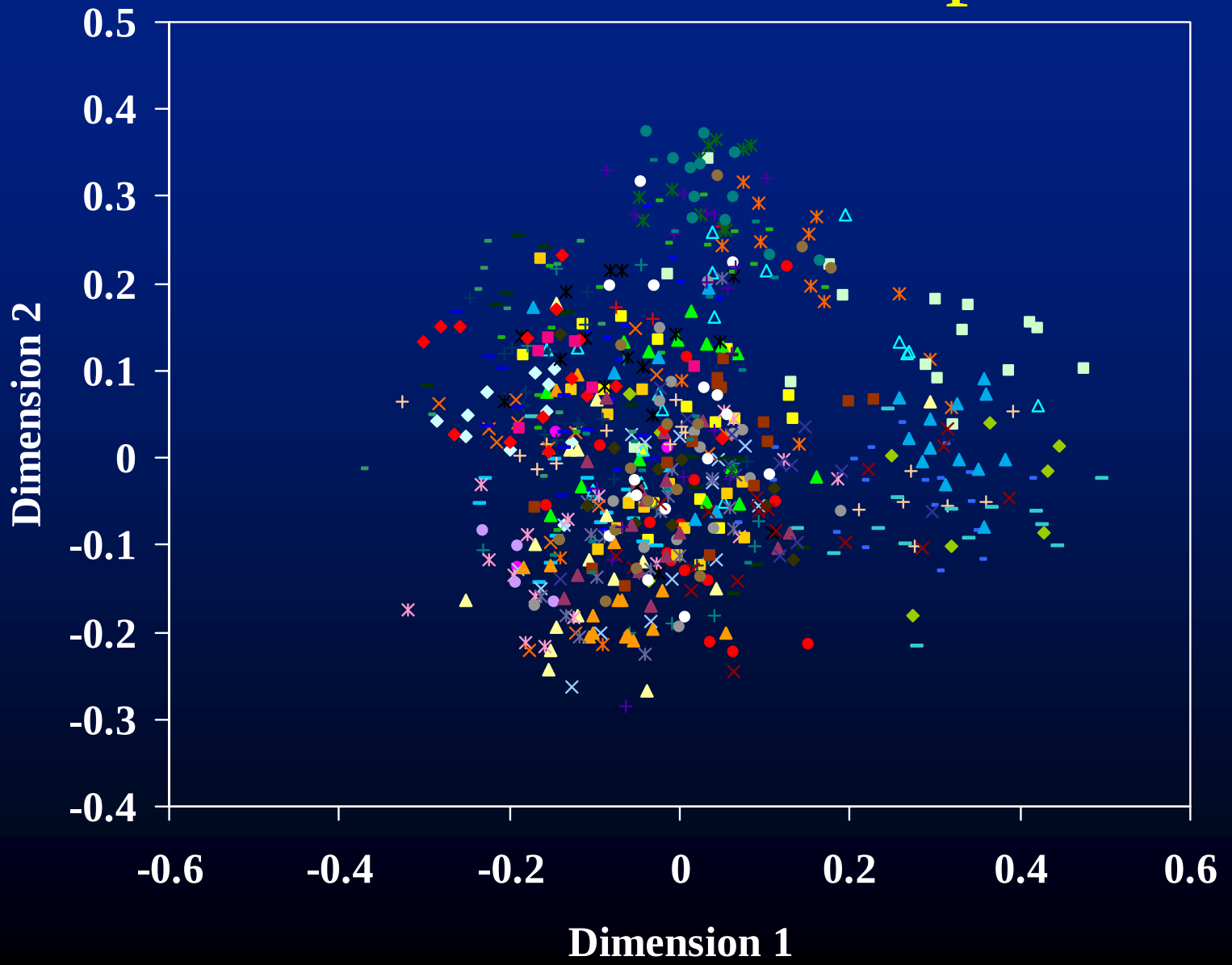
Cultivars vs. Prairie-Remnant Popns.



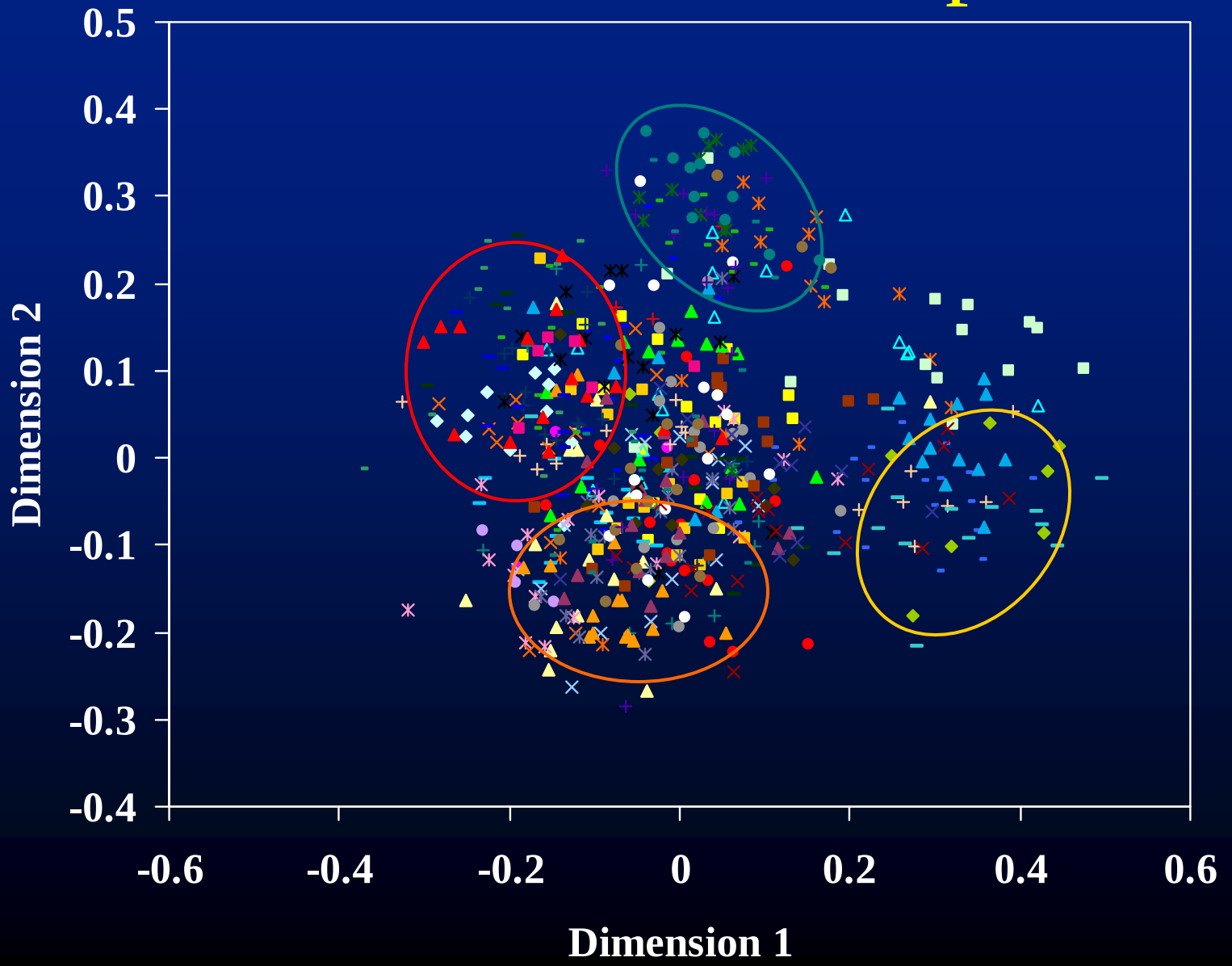
Switchgrass Cultivars

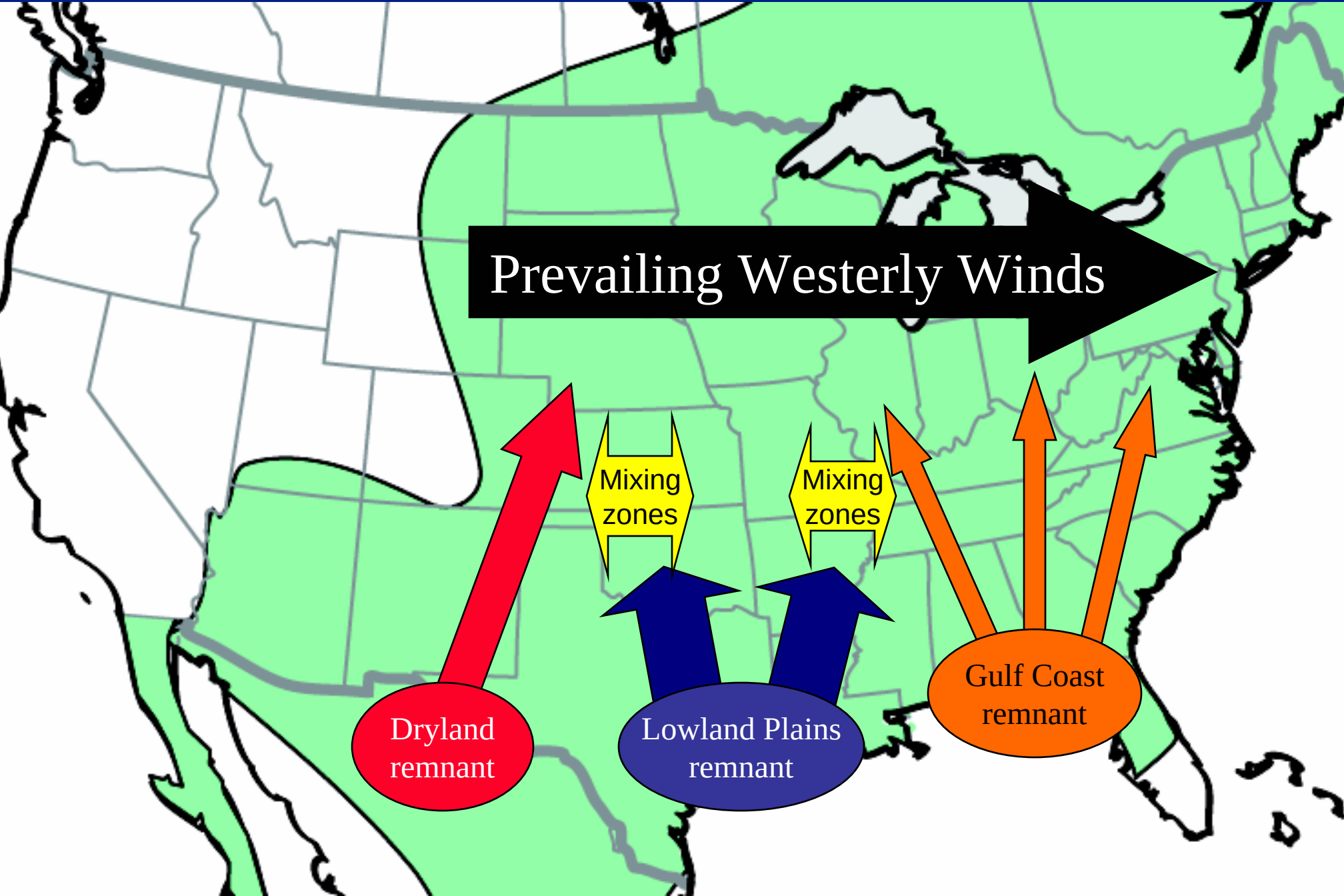


34 Prairie-Remnant Populations



34 Prairie-Remnant Populations




Prevailing Westerly Winds
Mixing zones
Mixing zones
Dryland remnant
Lowland Plains remnant
Gulf Coast remnant

Switchgrass Gene Pools

- Individual populations of switchgrass, originating in remnant prairies, contain vast amounts of genetic diversity (~65-70% of the total variability).

- Individual populations do not contain unique genotypes or gene sequences, but share most of their gene sequences with other populations across a broad landscape.

Switchgrass Gene Pools

- Most population differentiation is based on phenotype, likely due to a very small number of genes that control adaptation traits.

- Northern populations tend to be earlier heading, higher in DM concentration, shorter, lower in biomass yield, higher in cold tolerance, and lower in heat tolerance.

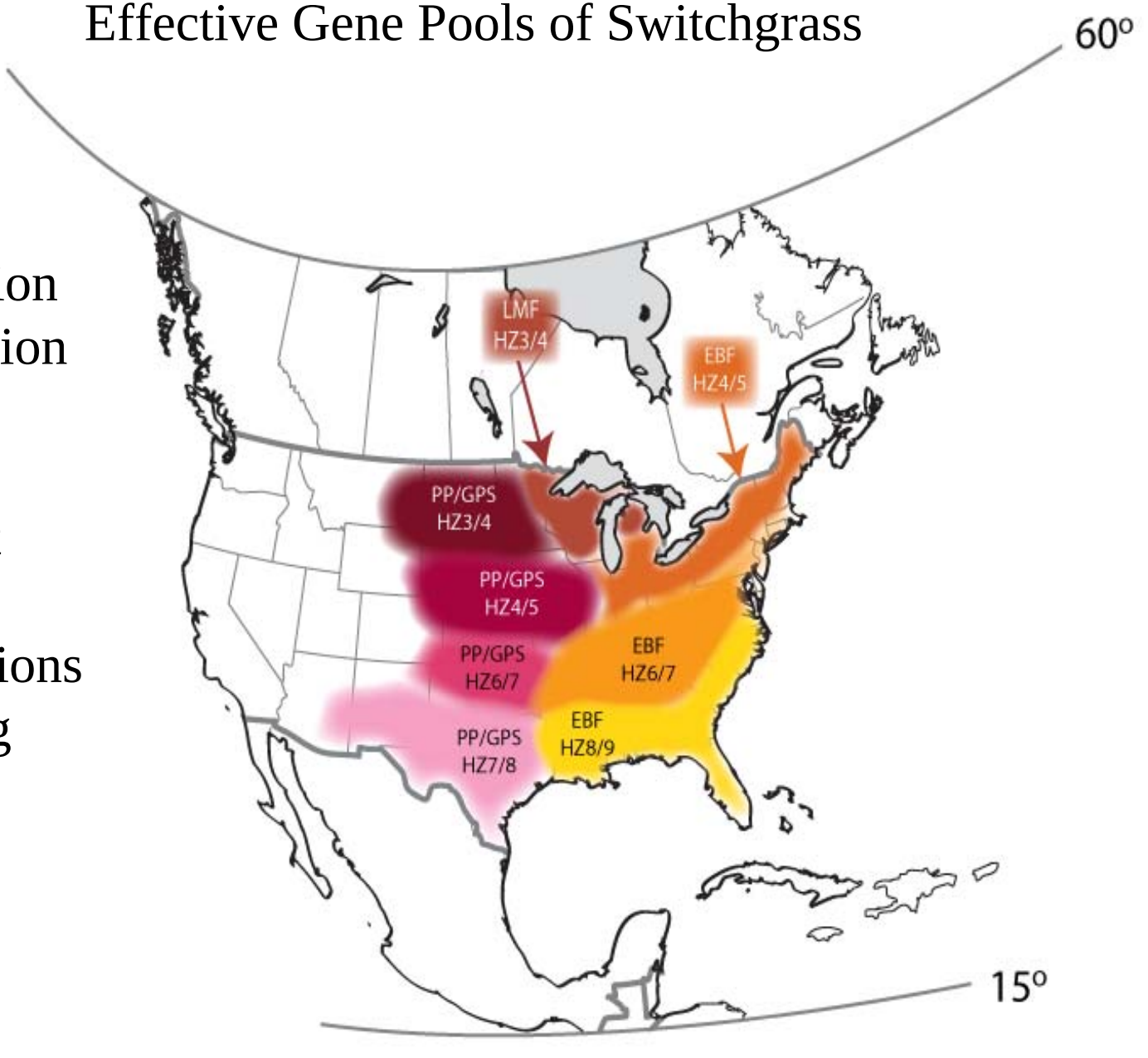
Switchgrass Gene Pools

- Switchgrass gene pools can be functionally described based primarily on USDA Plant Hardiness Zones and secondarily on Bailey's Ecoregions.

- Germplasm originating within functional gene pools can be considered "free-ranging" within fairly large geographic regions defined by its phenotypic adaptation.

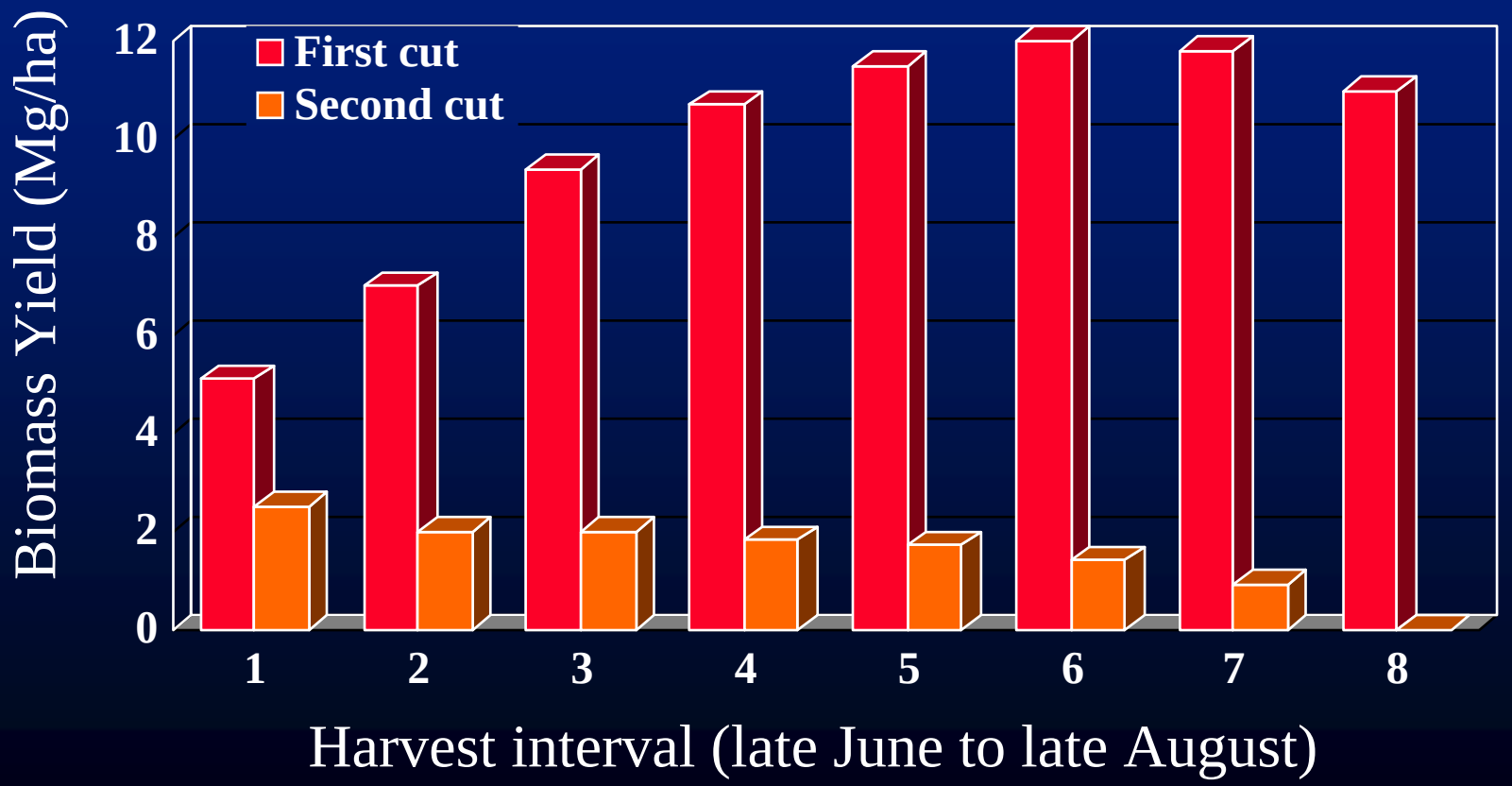
Effective Gene Pools of Switchgrass

- Conservation and restoration
- Cultivar deployment
- Target regions for breeding



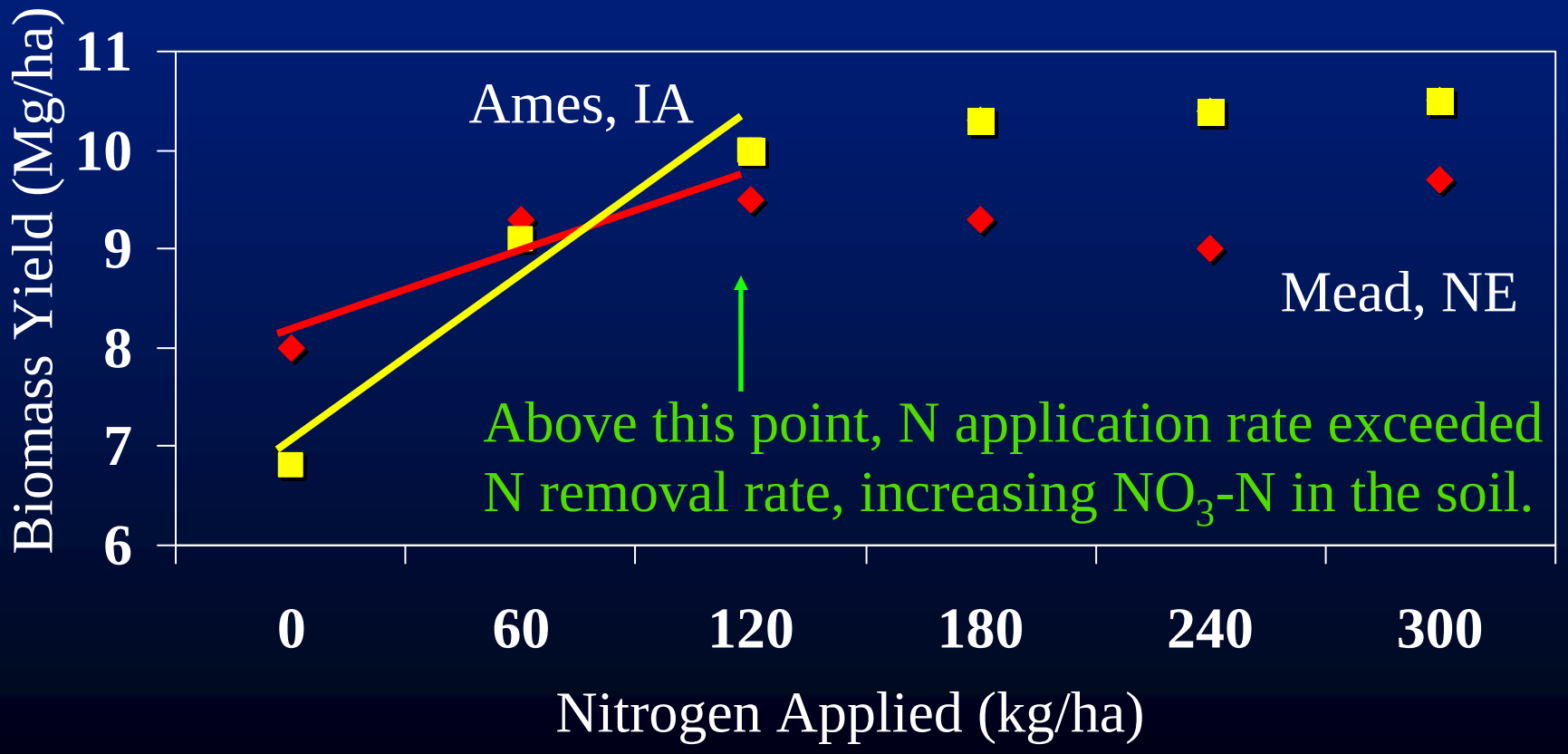
Harvest Management

Vogel et al. (2002)



Nitrogen Fertilization

Vogel et al. (2002)



Energy Production in the Great Plains On-farm Economic Analysis

- Field shown at right had a 5-yr average cost of $30/U.S. ton switchgrass biomass including land costs.
- Average costs for 10 farms was $49/ton; two experienced farmer's costs were $36/ton.
- Each big bale (right) represents a 50 gallon barrel of ethanol at 80 gal/ton & farm gate cost of $0.45/gallon.
- Bottom line – switchgrass economically feasible bioenergy crop.

Switchgrass field in NE South Dakota in 2005. Yields averaged 4 tons/acre (9 Mg/ha).

New “Biofeedstock” Cultivars

Cultivar	South	North	North
Blackwell	9.28	8.93	8.39
Cave-in-Rock	9.26	9.13	9.22
Pathfinder	8.12	8.51	8.39
Sunburst	8.31	9.20	10.44
St. Croix	9.30	9.40 (2%)	
Hiawatha	-	-	11.18 (7%)

Hybrid Vigor & Heterotic Groups

Group	Biomass yield (Mg/ha)
Lowland parent	7.1
Upland parent	6.1
Lowland x Lowland	7.3
Upland x Upland	6.2
Lowland x Upland	9.4 (32% heterosis)

Research Accomplishments

- Harvest management and timing
- Nitrogen fertilization rates
- Cultivar evaluations, classification, and geographic adaptation
- Genetic improvements and new cultivar development
- Genetic diversity and gene pools
- Production economics