Biomass Feedstock Research and Development for Multiple Products in the United States

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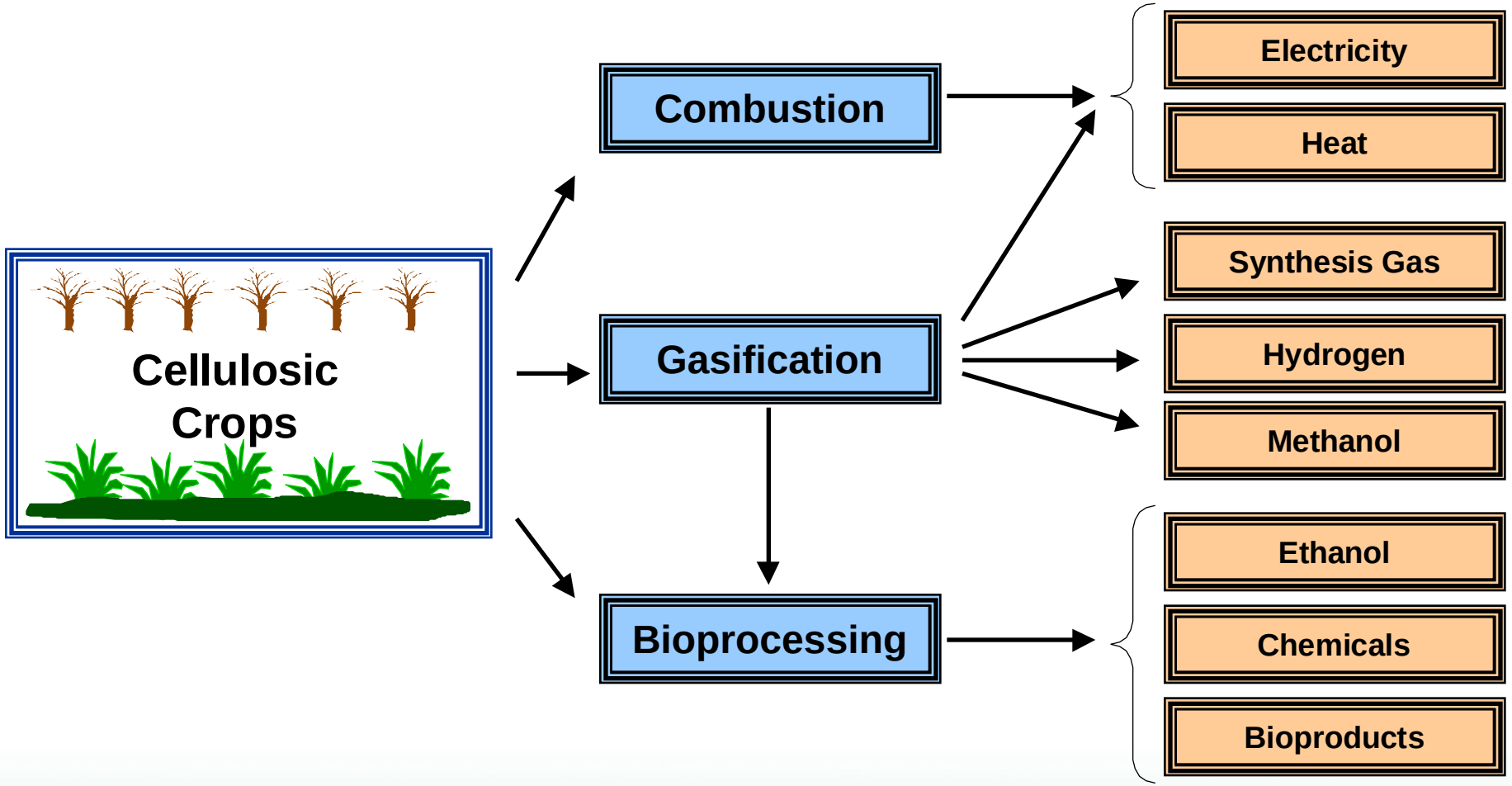
BIOENERGY FEEDSTOCK DEVELOPMENT PROGRAM
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

UT-BATTELLE

The Bioenergy Feedstock Development Program Has Been Developing New Feedstocks for Multiple Purposes Since 1978



Bioenergy Feedstock Development Program Elements

Resources & Sustainability

- Urban & Mill Residues
- Crop & Forest Residues
- Energy Crop Development
  - Poplars
  - Willows
  - Switchgrass
  - Other

Supply Logistics & Infrastructure

- Supply Chain Logistics
- Equipment Improvement
- Infrastructure modifications
- Operational Validations

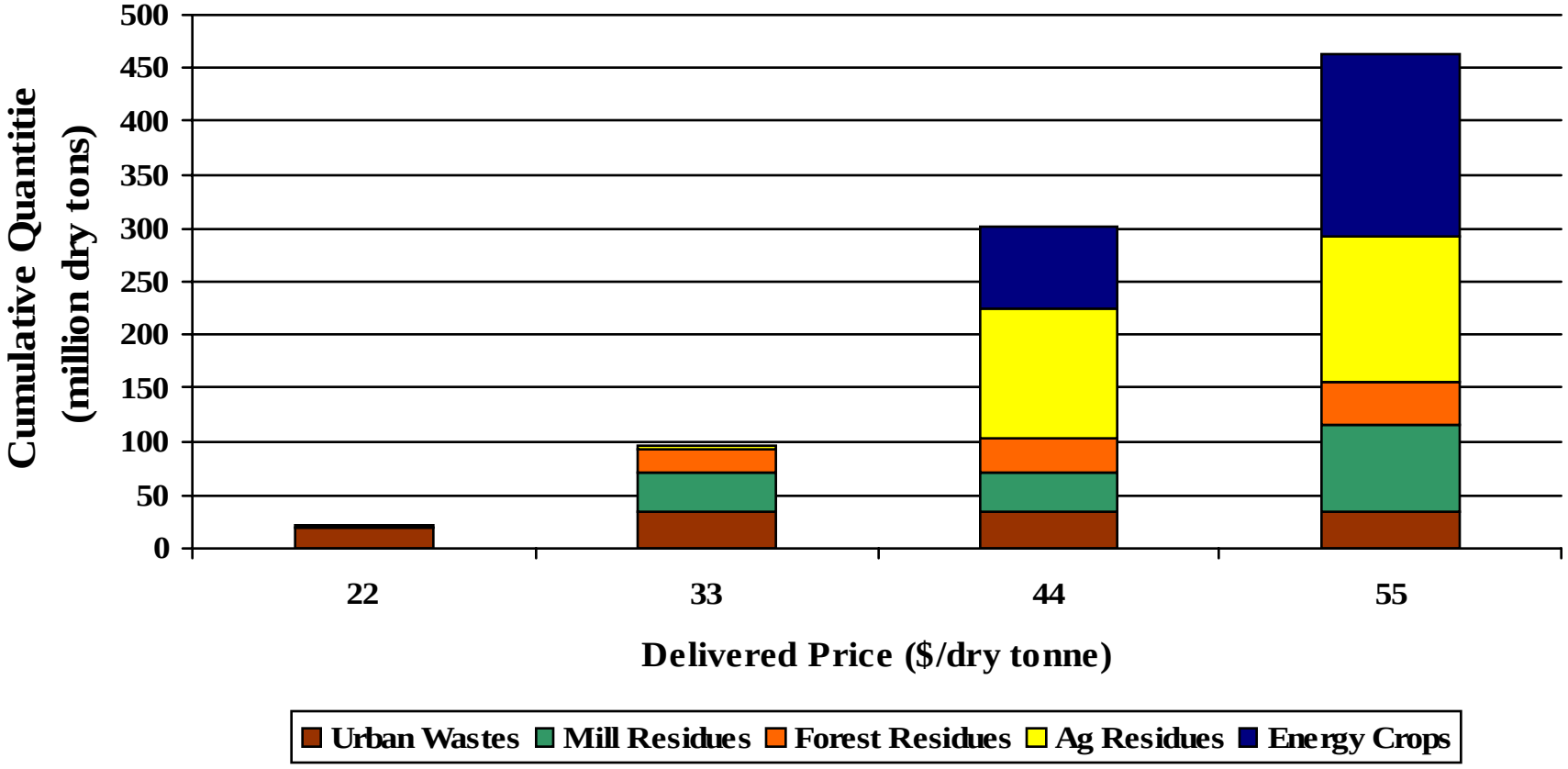
Integrated Analysis

- Resource Economics
- Institutions &Regulation
- Value-chain Models
- Equilibrium Models

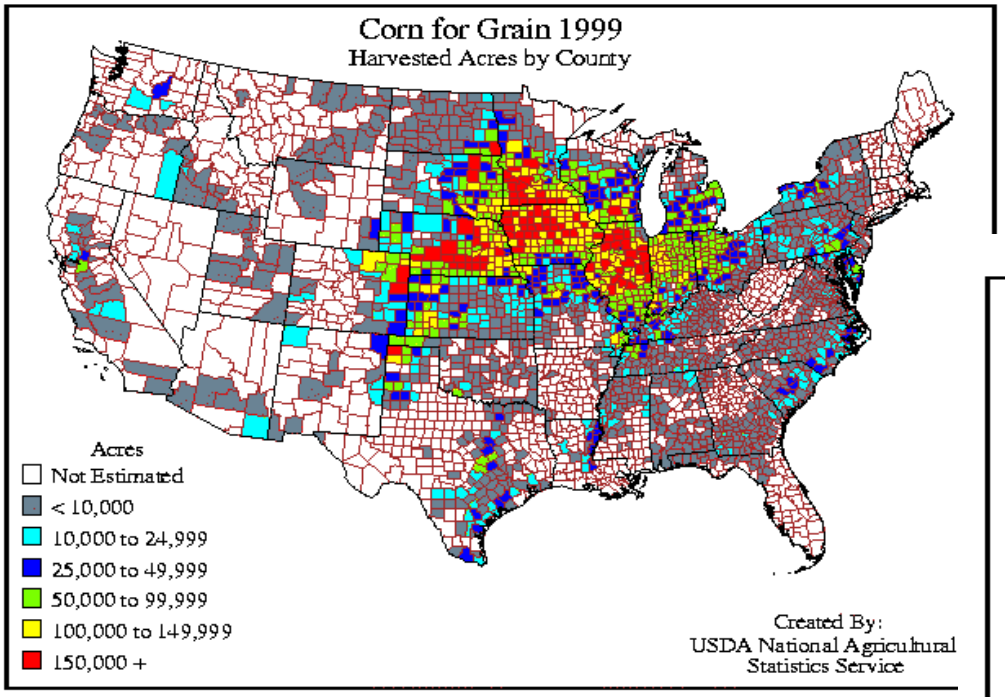
Communication & Education

- Environmental Risks & Benefits
- Stakeholder Concerns
- Web Sites & databases
- Educational Materials

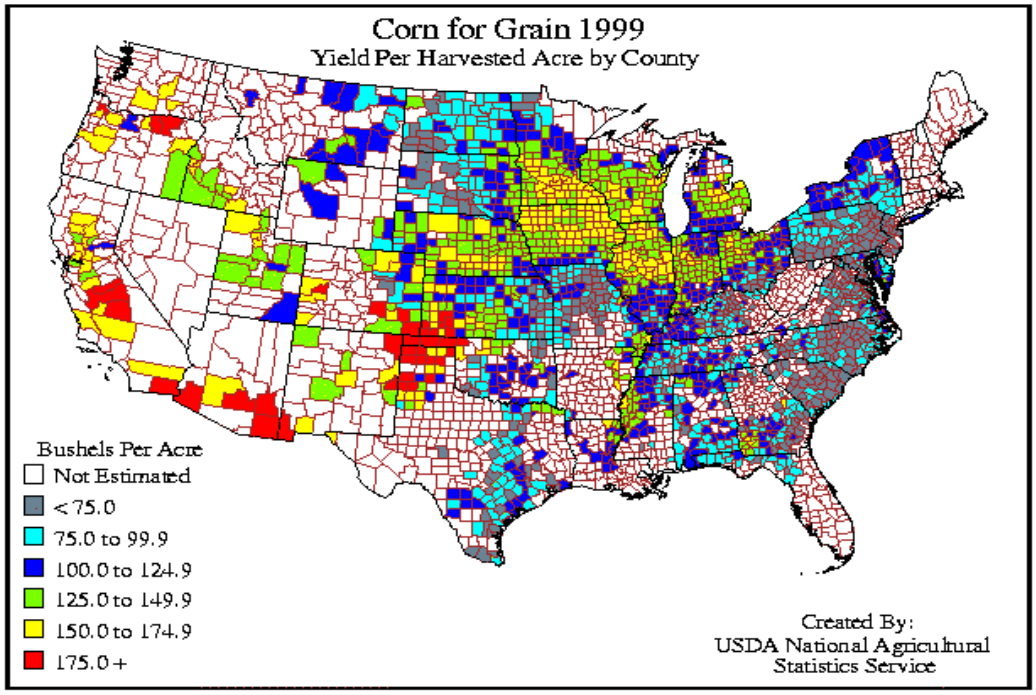
Potential Available Cellulosic Feedstock Quantities



Corn Residue is a large potential cellulosic bio-resource

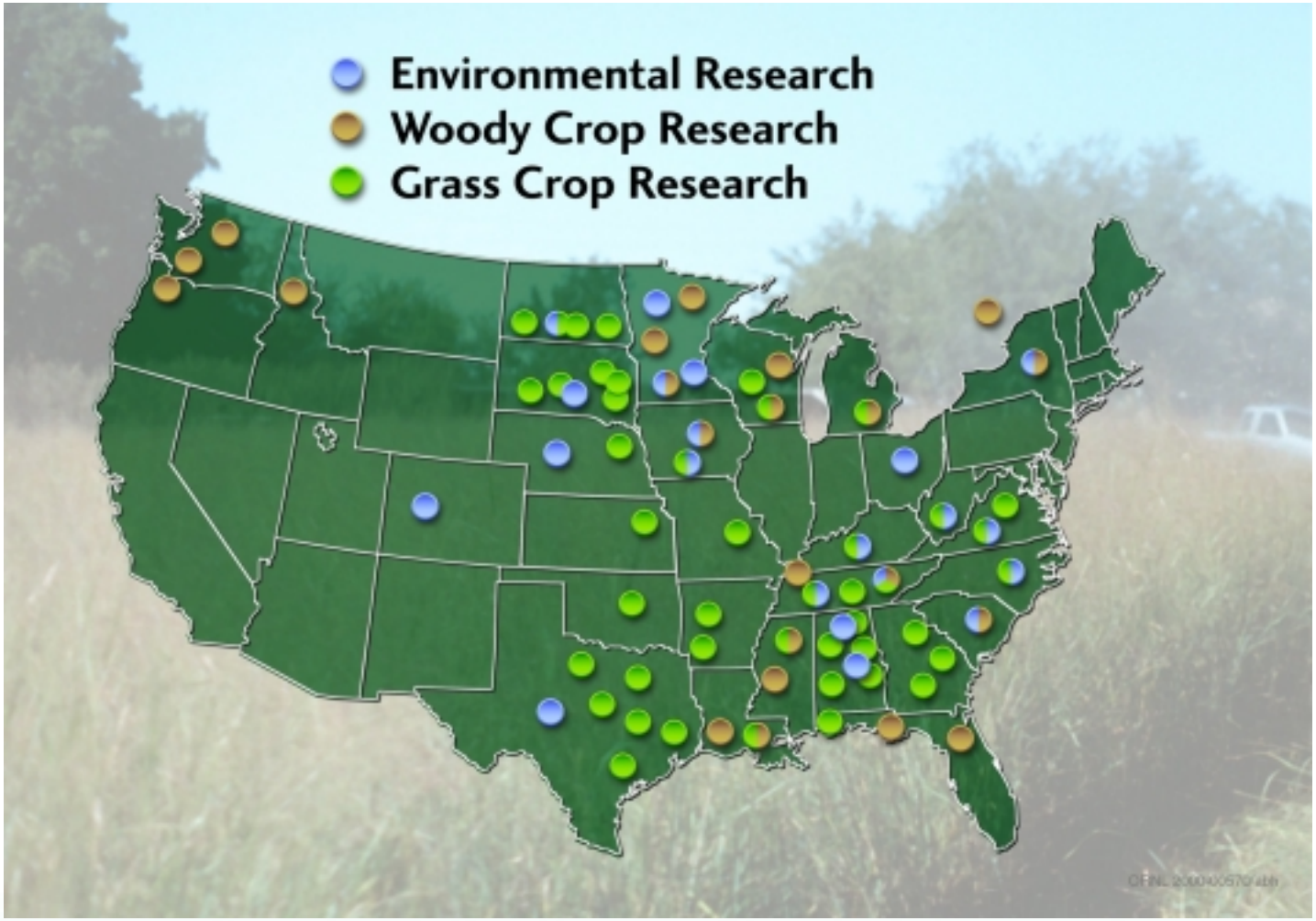


About 10 billion bushels of corn are produced annually



About 136 million dt of corn and wheat residue could be collected sustainably

Bioenergy Feedstock Experimental and Operational Research Sites in the U.S.



Bioenergy Crops--Hybrid Poplar

- **Hybrids of two or more *Populus spp.* which includes aspens and cottonwoods**
- **Produced in wide spacing with 6-10 year rotations depending on region; ~ 50,000 ha in U.S.**
- **Utilizes conventional agricultural and forestry equipment**
- **R&D - Breeding, Yield testing, Host-pathogen interactions, Soil carbon effects, Molecular genetics, Genetic transformation, Sustainable management, Harvesting, Operational trials**

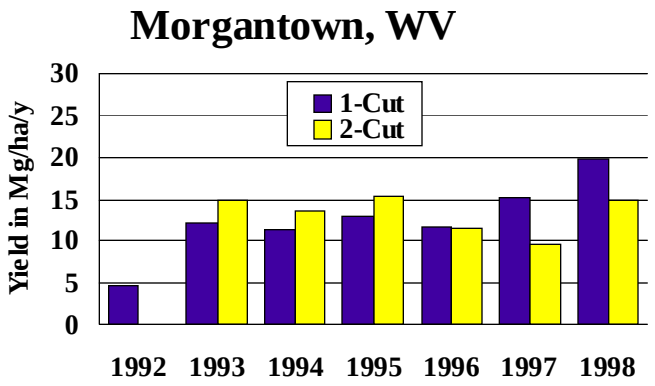
Bioenergy Crops--Switchgrass

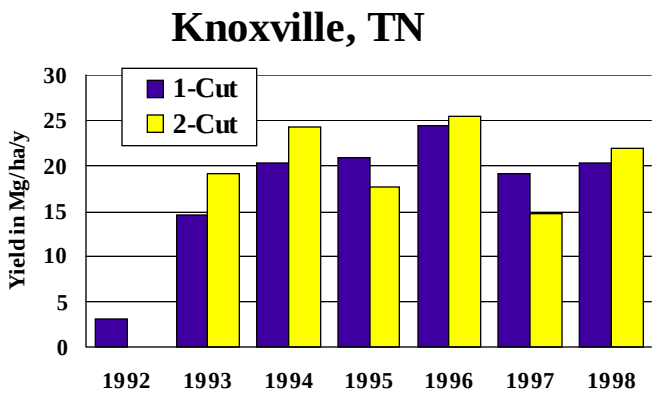
- Native perennial grass and dominant species of tall grass prairies in US
- Wide geographic distribution and high yield potential
- Produced in 10 year rotations with annual harvest, using conventional agricultural equipment
- R&D - Breeding, Yield testing, Physiology, Sustainable management, Molecular genetics, Soil carbon effects, Harvesting, Operational trials
- Farmers involved in projects

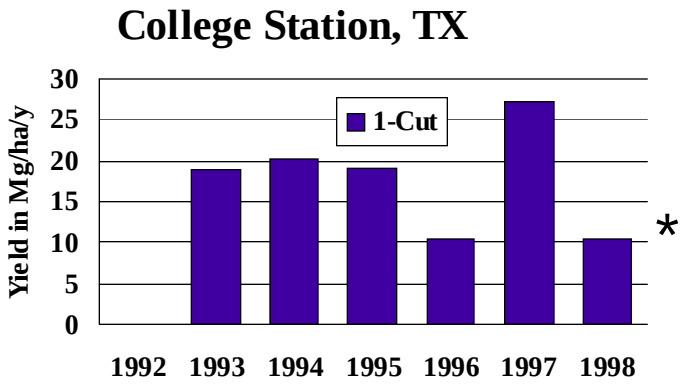
Bioenergy Crops--Willow

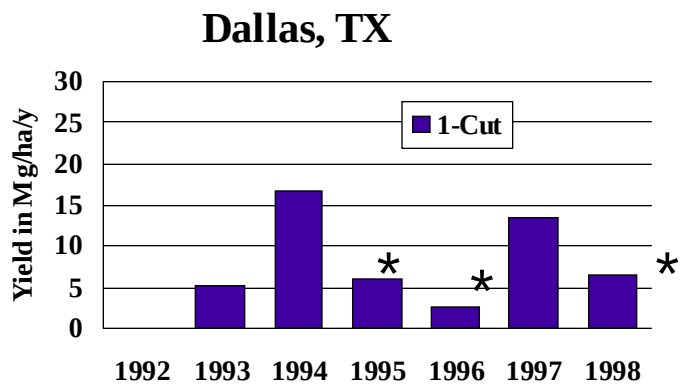
- **Hybrids of *Salix spp.***
- **Produced in tight, double-spaced rows with coppice regrowth**
- **Utilizes special harvest equipment**
- **Currently limited to Northeast and North Central Regions**
- **R&D- Breeding, Yield trials, Sustainable management, Harvesting, Operational trials, Molecular genetics**
- **Farmers involved in project**

Variability in Switchgrass Yields

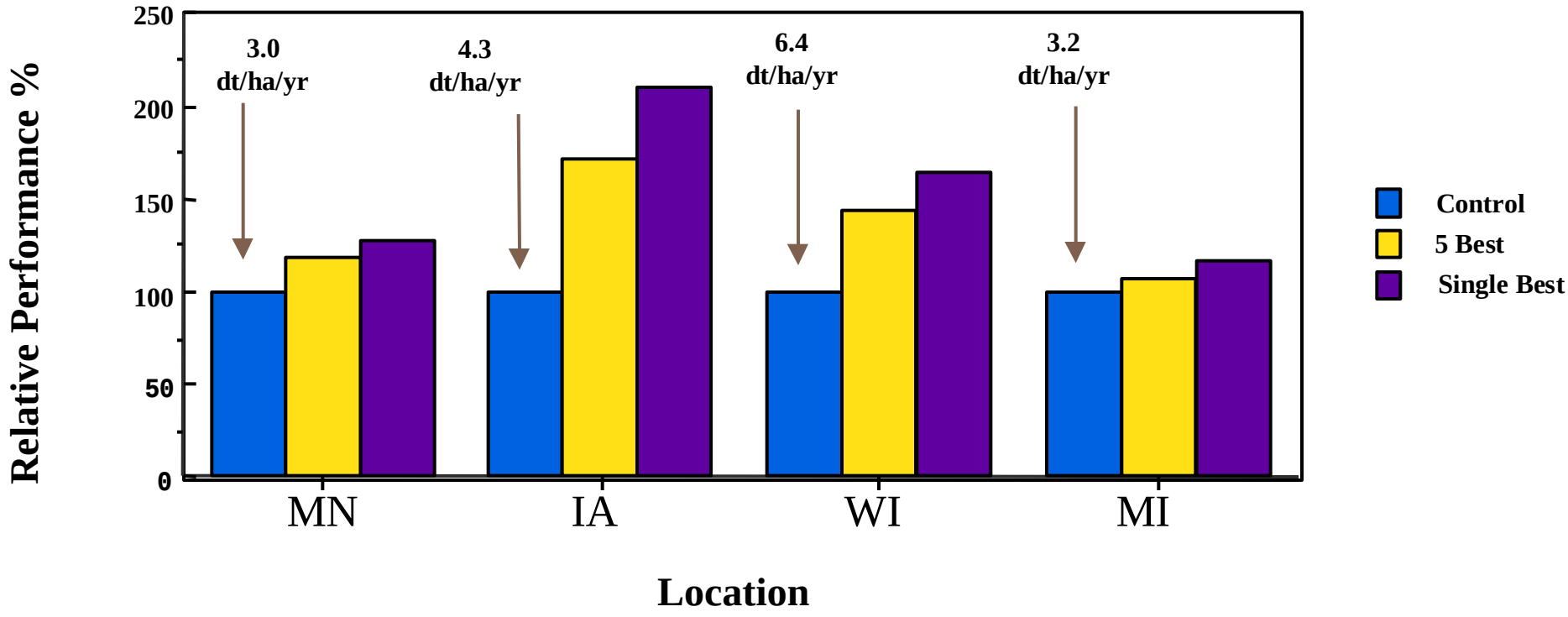
- 







Improvement and Variability of Woody Crop Yields in North Central Region of U.S.



4th year yields compared to controls for the 5 best poplar clones at test sites in 4 states. Expected final yield for MN control is 9.8 dt/ha/yr at about 10 years.

1999 Woody Crops Accomplishments

- 185 new mother-tree accessions were collected
- 38 successful control cross families were created
- 10 regionally tested hybrid poplar clones were ready for operational testing
- 73 Roundup Ready and 53 Bt transformed lines were made available to industry for field testing
- Molecular markers linked to a Melampsora resistance gene (*Mmd1*) were used successfully in a marker assisted selection experiment for rust resistance

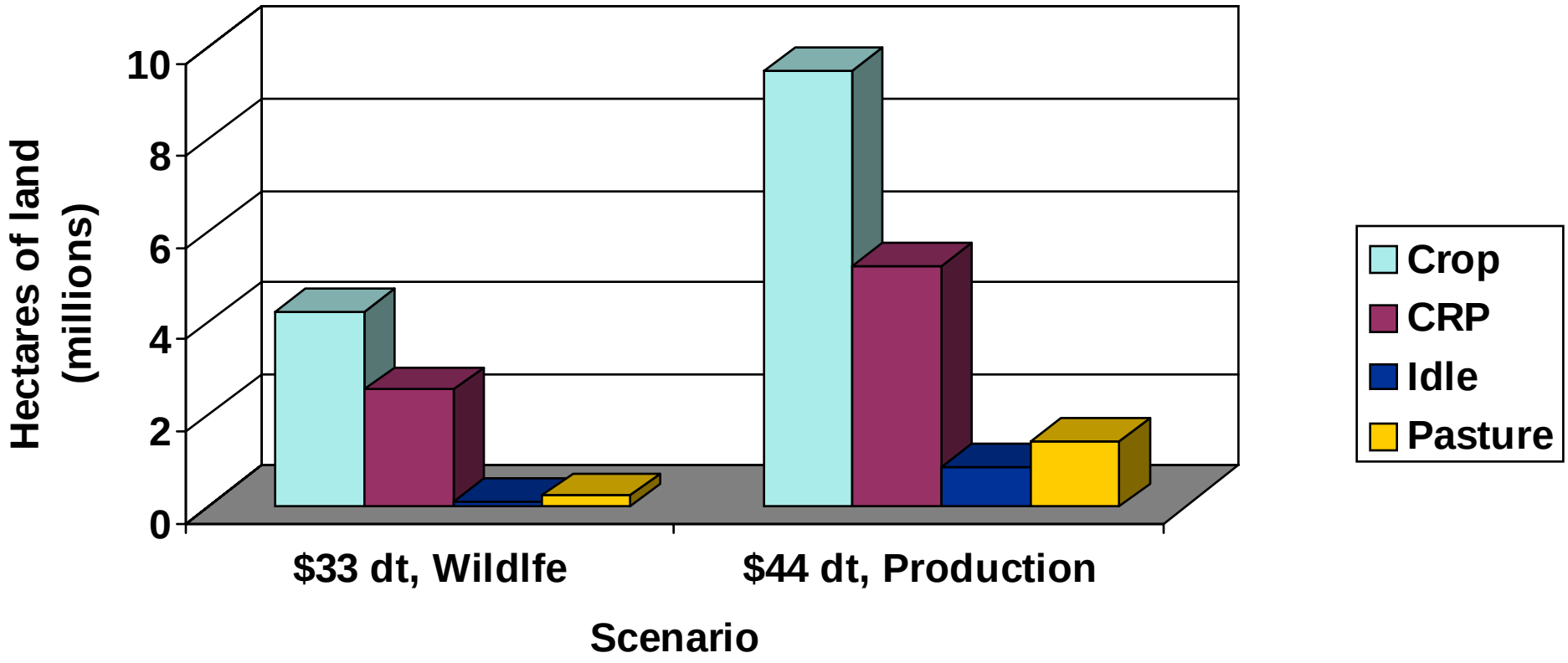
Environmental Research Results

- Energy crops and no-till annual crops can improve soil physical quality
- Soil cover is important for erosion control & carbon gain
- Soil carbon gains occur primarily in upper 15 cm
- Soil carbon increases under both woody and grass crops with time, but rate is faster under grass crops
- Soil carbon gained under perennial crops is lost if site is converted back to annual crops
- Energy crops can be located and managed to provide habitat for wildlife.

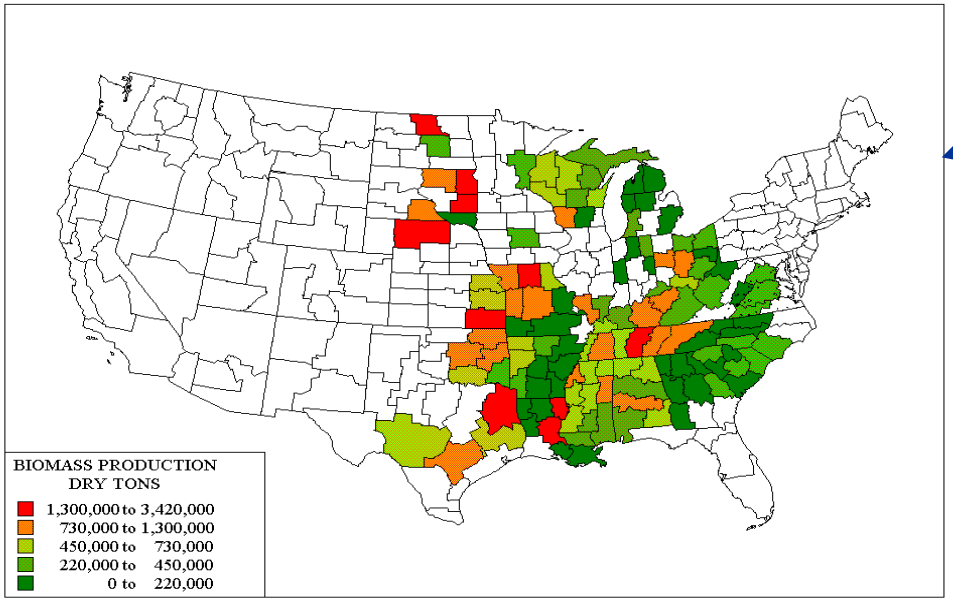
Resource Supply Analysis with Equilibrium Model (POLYSYS)

- Includes major crops (corn, sorghum, oats, barley, wheat, soybeans, cotton, rice, alfalfa, other hay)
- Includes food, feed, industrial, and export demand
- Includes livestock sector
- Based on 305 Agricultural Statistical Districts
- Anchored to 10 year baseline
- Includes land classified as cropland
  - currently planted to major crops
  - idled & in pasture
  - in Conservation Reserve Program (CRP)

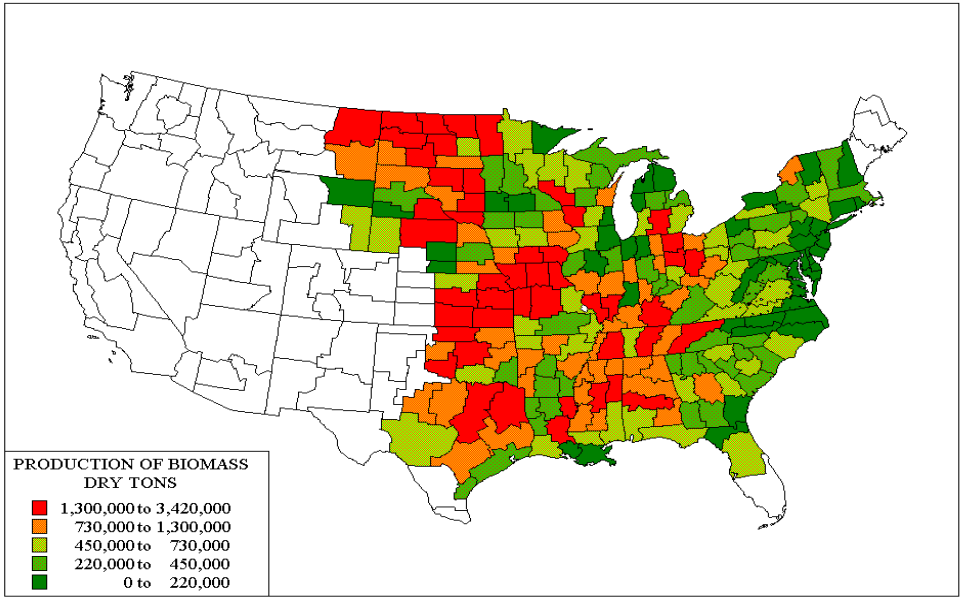
POLYSYS Predictions of Potential Energy Crop Production by 2008



Potential Bioenergy Crop Production Areas in 2008 based on POLYSYS Predictions



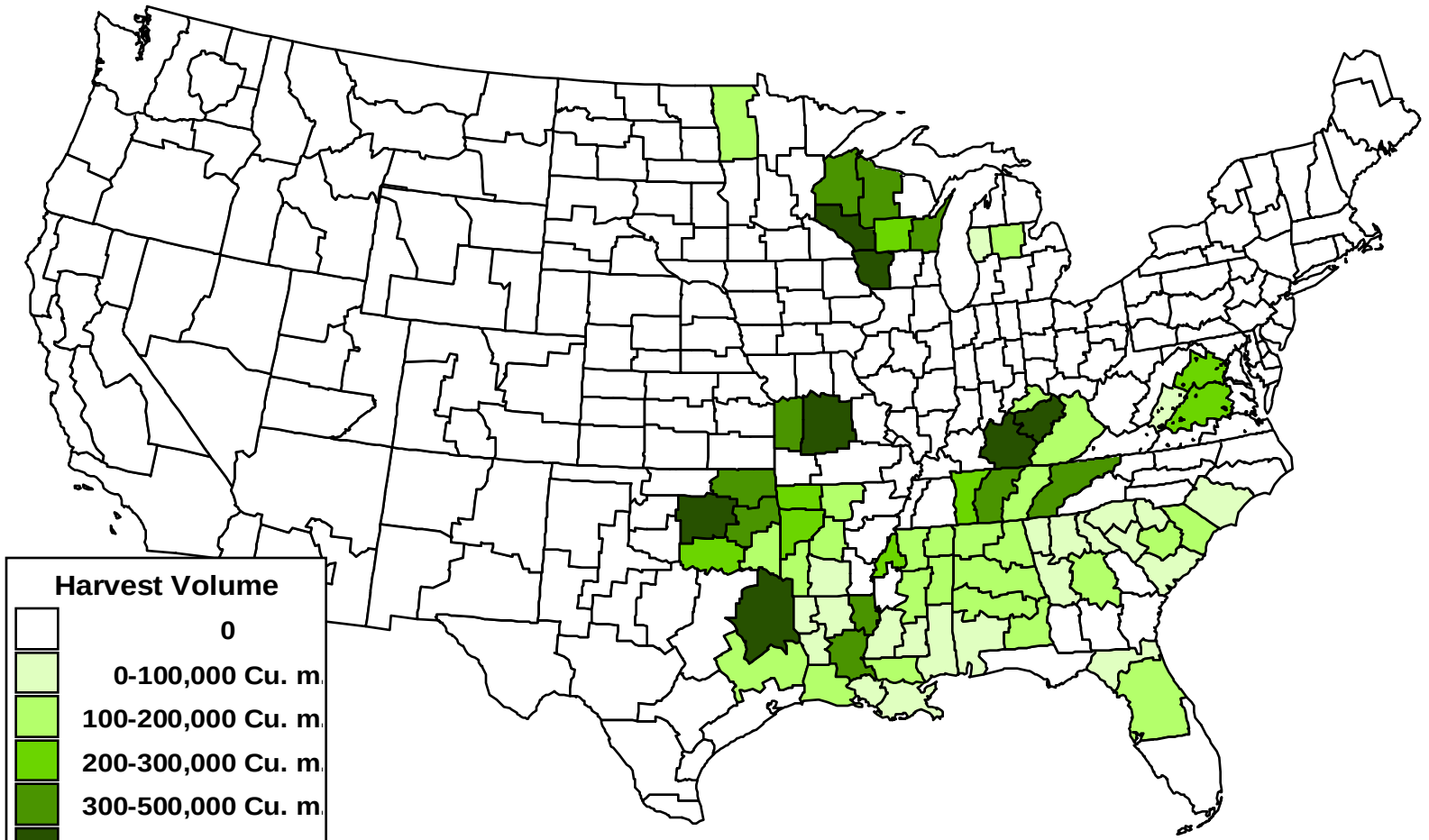
Scenario 1: $33-37/dt (farmgate)with wildlife restrictions and 75% of CRP land subsidy - 77 million dry tonnes of switchgrass and poplars



Scenario 2: $44-48 dt (farmgate) with no restrictions and 75% of CRP land subsidy - 170 million dry tonnes of mostly switchgrass

Projected SRWC harvest by Agriculture Statistical District, 2020--NAPAP/POLYSYS

Base RPA Data (May 2000), @ 2% Adoption Factor, 6% Discount Rate



Energy Equivalents of 170 million tonnes of Energy Crop Feedstock

	Scenario 1	Scenario 2
EJ Energy	1.3	3.07
10^9 Liters ETOH	26.5	63.2
10^6 Bbls. Oil	106	253
MW Elec Capacity	18,700	43,871
Percent U.S. Capacity	2.0	4.7
10^9 kWh	103.5	307
Percent Electricity	3.1	7.3

Potential for Meeting U.S. Goal of Increasing Bioenergy & Bioproducts by 3X by 2010

- **Sufficient cellulosic feedstocks are potentially available from residues and energy crop to meet the goal**
- **Cost of the cellulosic feedstocks will limit ability of industry to meet 3X goal by 2010**
- **NEEDS**
  - **Technology improvements/cost reductions**
  - **Technology transfer and education**
  - **Public acceptance and interest**
  - **Policy changes**