

Task 1. Estimating Biomass Feedstock Production Potential

S.B. McLaughlin

Bioenergy Feedstock Development Program

ORNL/UT, TN

J. Kiniry

USDA Grassland, Soil, and Water Research Lab.

Temple, TX

Daniel De La Torre Ugarte

Agricultural Policy Analysis Center, UT, Knoxville, TN

Objectives

- Estimate future biomass production potential based on an aggressive yield improvement program
 - Economic Issues
 - Feedstock cost/Mg for biorefinery economics
 - Producer profit and level of participation
 - Resource Issues
 - Land area for feedstock supply per plant
 - Carbon savings/sequestration
 - Fossil energy displacement/savings
 - Soil and ground water quality
 - Wildlife habitat

Research Strategy

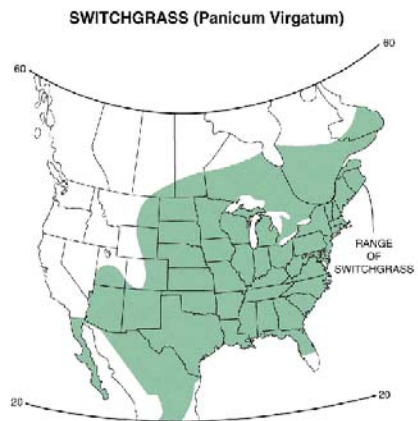
- Evaluate 7 decades of breeding gains in corn to establish yield gain potential
- Project switchgrass yield gain trajectory
 - 10 y of yield baseline evaluation in the field
 - Comparative genetics and physiology
 - 10 y of switchgrass breeding research

Some Advantages of Dedicated Energy Crops

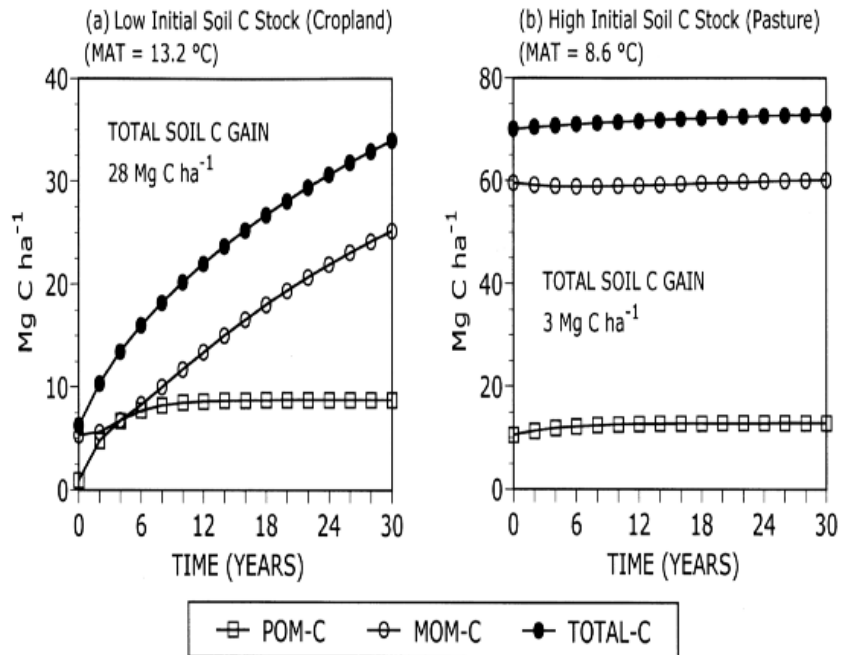
- Feedstock quality/consistency/dependability
- Regional diversity of sites and participants
- Significant benefits to the agricultural industry
- Strong societal benefits
 - Net fossil energy displacement
 - Greenhouse gas reduction rate
 - Farm economy/government subsidy gains

Attributes of Switchgrass

- Native perennial grass - Farm-compatible - High yield and energy efficiency- Ecological and economic gains for agriculture



Switchgrass can significantly improve soil quality, stability, while storing soil carbon

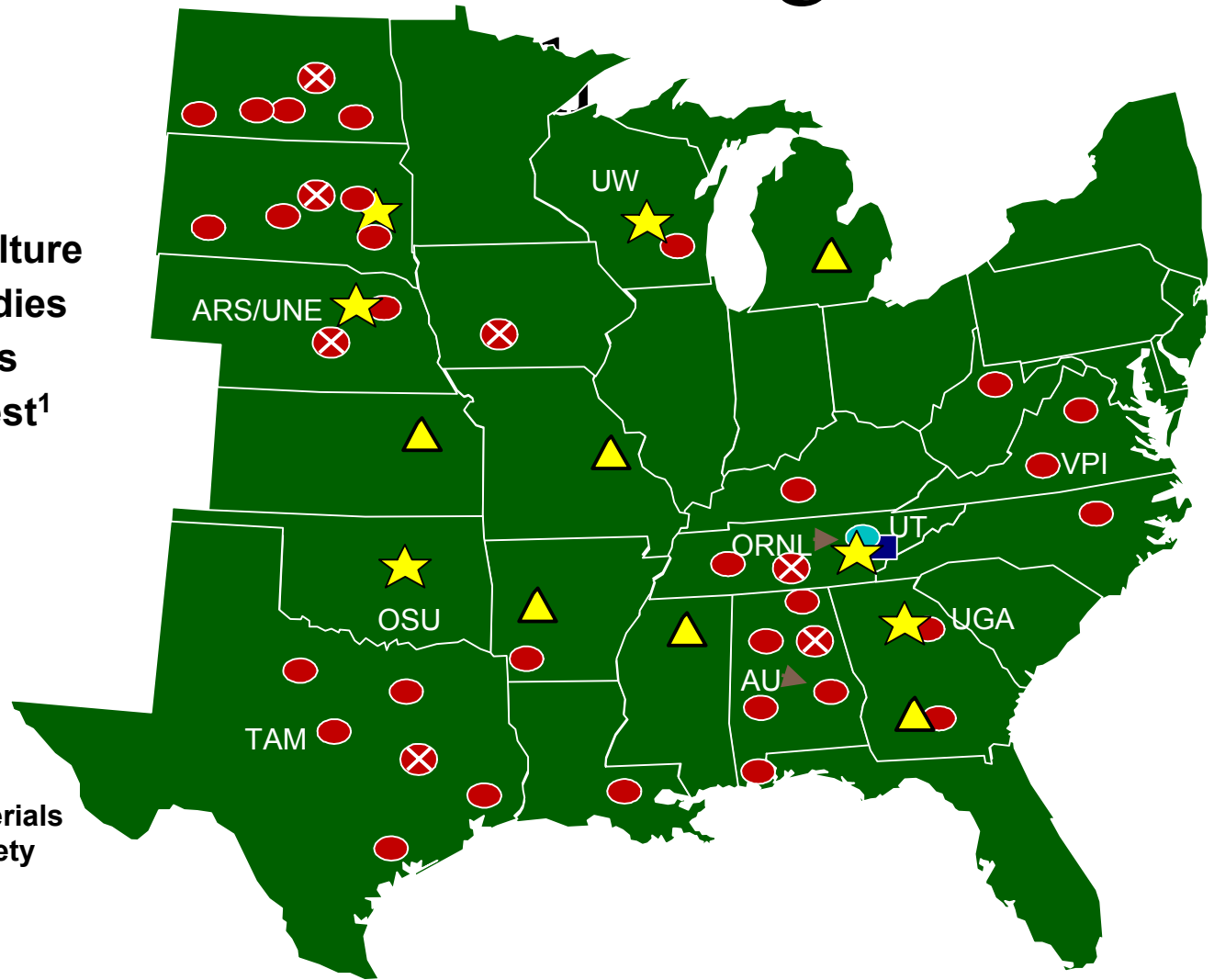


Analytical Resources

- **Field Research** - >10 Years of switchgrass productivity, breeding, and ecological research and development
- **ALMANAC** - A physiologically-based crop production model parameterized for switchgrass
- **POLYSYS** - A regional econometric model to project feedstock supply, economics, and impacts on conventional crop production

ORNL - BFDP Switchgrass

- ★ Breeding
- Tissue Culture
- Basic Studies
- Field Trials
- ▲ NRCS - Test¹
- ⊗ Scaleup



¹ARS-NRDC Plant Materials Testing Centers - Variety Evaluation

Modeling Crop Production Levels and Impacts

- ALMANAC

- Crop production and resource use
- Canopy light interception
- Soil depth, water, and nutrient supply
- Site specific radiation, rainfall, and temperature

- POLYSYS

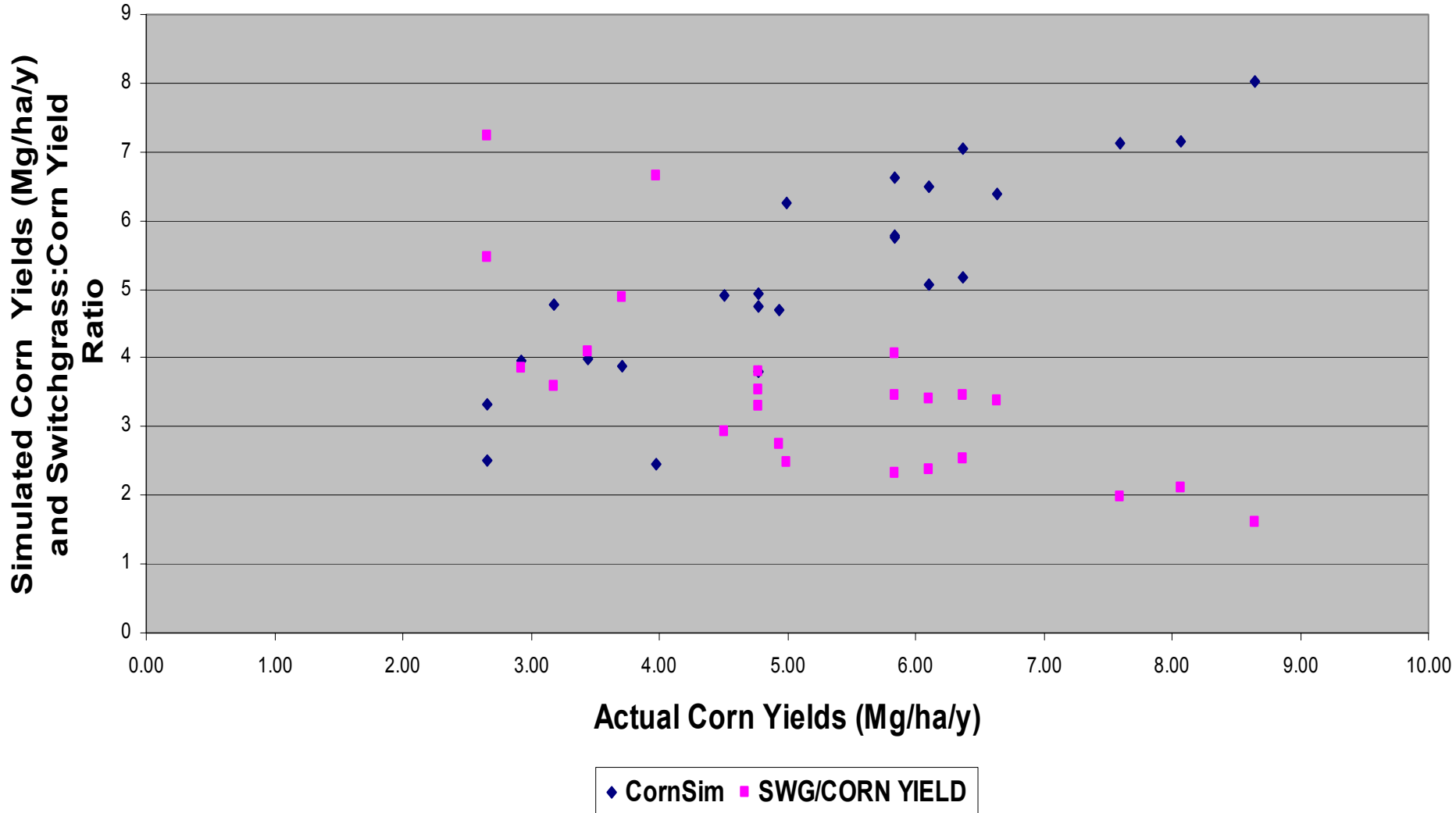
- Econometric model for agricultural policy
- Competitive profit/land among crops
- 305 regional supply districts
- Includes production levels costs and govt. subsidy impacts.

ALMANAC Yield Comparisons with Field Data

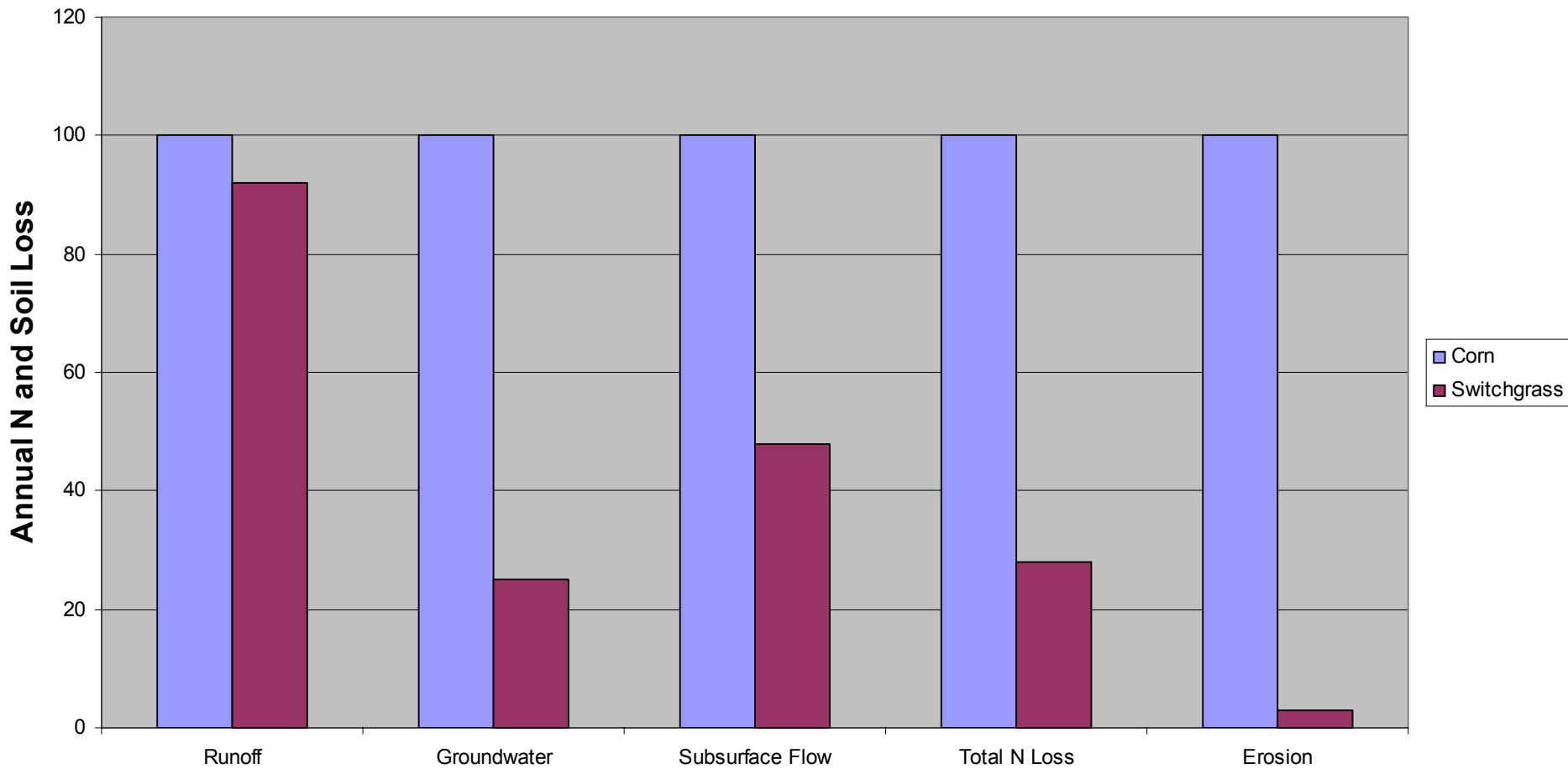
SITE	Conditions	Field Yield (Mg/ha)	ALMANAC Yield (Mg/ha)
Blacksburg, VA	6 yr avg.	12.3	12.0
Meade, NE	2 yr avg.	13.4	13.8
Beeville, TX	1993 2 cut	11.8	11.7
	1994 2 cut	16.7	15.7
	1993 1 cut	13.6	13.6
	1994 2 cut	18.0	10.2
Tallasee, AL	9 yr avg. 2 cut	10.5	10.6
	9 yr avg. 1 cut	10.1	10.2

Simulated Annual Yield of Corn and Switchgrass Using ALMANAC

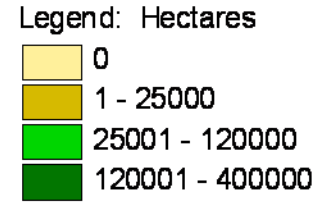
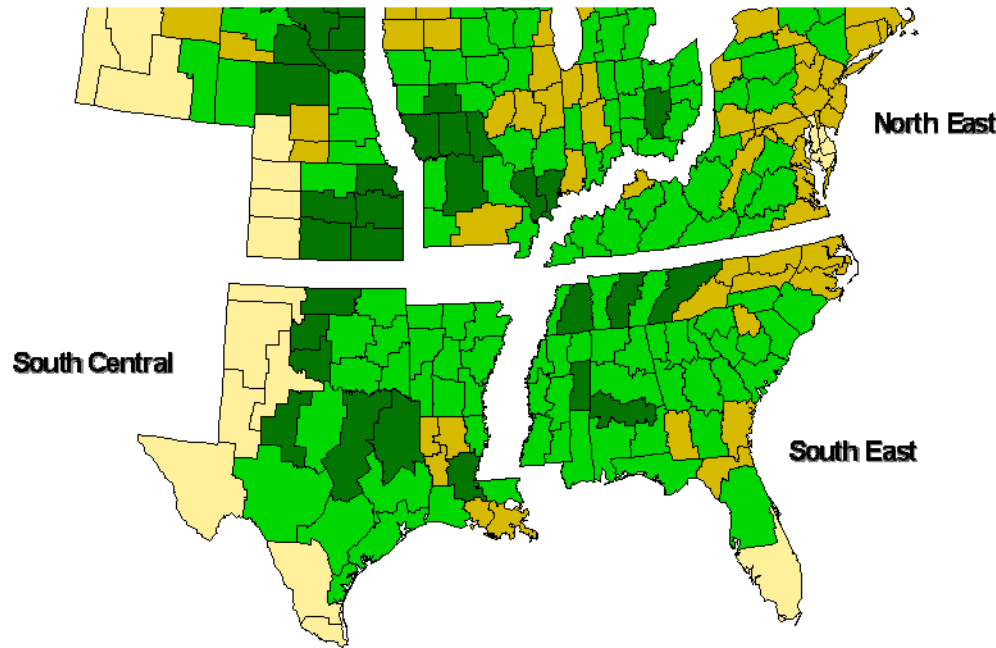
6 States, 27 Soil Types, 13 Years



ALMANAC - Changes in N Loss and Erosion In Conversion of Corn to Switchgrass



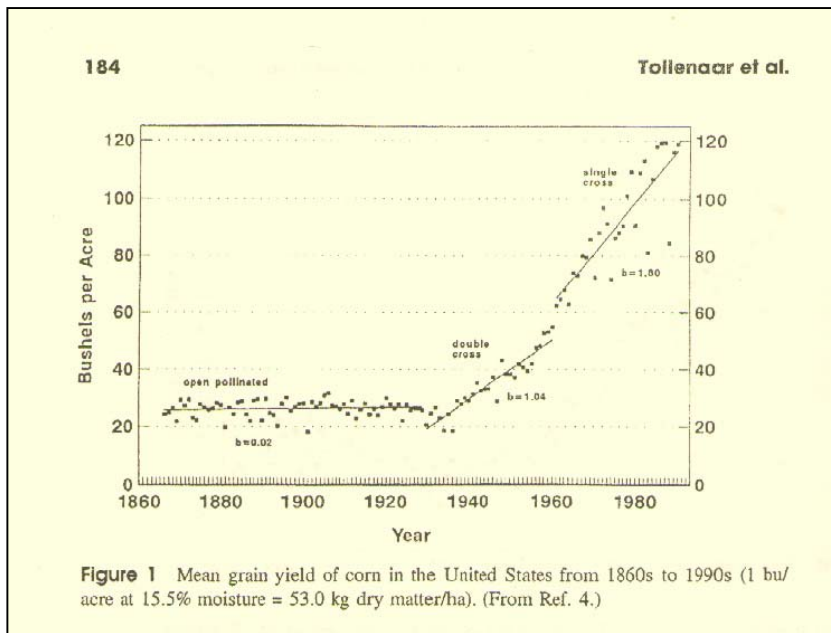
POLYSYS Projections - Potential switchgrass production density within the U.S. by agricultural supply cells. Distribution and density based on conversion to switchgrass production at a farmgate price of \$44 Mg⁻¹ (\$55 Mg⁻¹ delivered).



Projected gains to agriculture from POLYSYS simulations of switchgrass farmgate prices

Farmgate Price (\$/Mg)	30.3	44.0	52.4
M of hectares Planted to switchgrass	3.1	16.8	21.3
Increased farm revenue (\$ M)	1311	5925	7745
Reduced govt. Subsidies (\$ M)	1253	4035	5770
Sum of Benefits (\$ B)	2.5	9.9	13.4

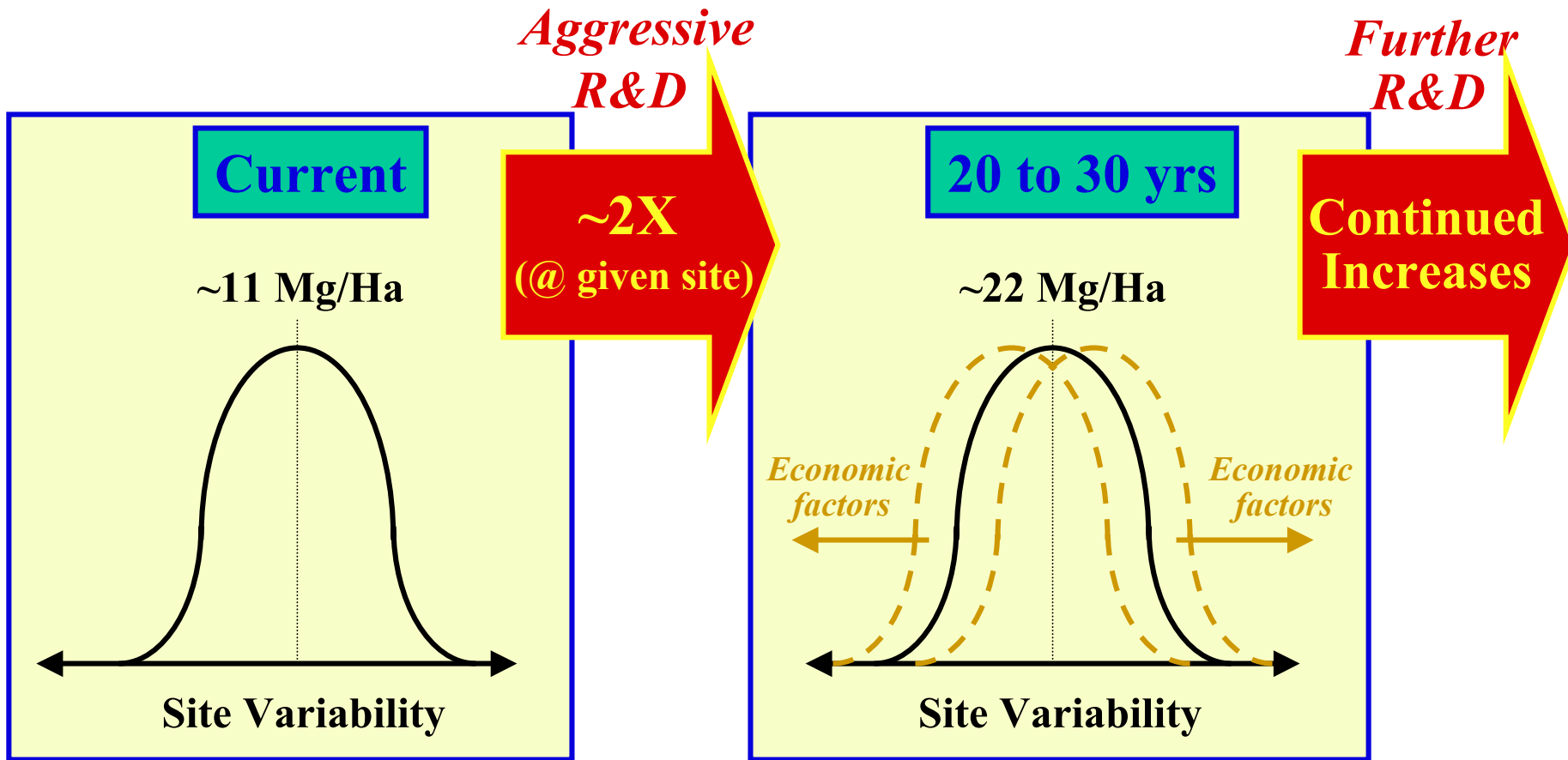
What have we learned from 70 years of corn breeding?



- Breeding gains have been approximately linear over time. 5-6X gain in 60 y
- Relative gains have decreased over time
- Improved management contributed ca. 45%
- Physiological efficiency has improved with yield

Comparative Traits of Corn and Switchgrass

- **Corn**
 - C4 annual grass
 - Yield potential (grain)
 - 25 Mg/ha - theoretical
 - 15-20 Mg/ha - actual field
 - 5-6 Mg/ha – US commercial
 - Yield Gains
 - 3-6%/y 1930's
 - 1.3-1.8%/y 1990's
- **Switchgrass**
 - C4 perennial grass
 - Yield Potential (plant)
 - 47 Mg/ha(max plant), 51.6 Mg/ha (Model)
 - 16-22 Mg/ha actual field
 - Commercial ?
 - Yield Gains (recent)
 - 5-7 %/y Southeast
 - 1-2%/y Midwest



Implications for a 5000Mg/d Biorefinery of 22 Mg/ha vs 11 Mg/ha yield

- Feedstock supply area per facility decreases by 50%
- Maximum feedstock transport distance for 10% land area use decreases from 44mi to 31.2 mi
- With subsidy recycle, feedstock cost could decrease by more than \$25 /Mg

Additional Analytical Tasks

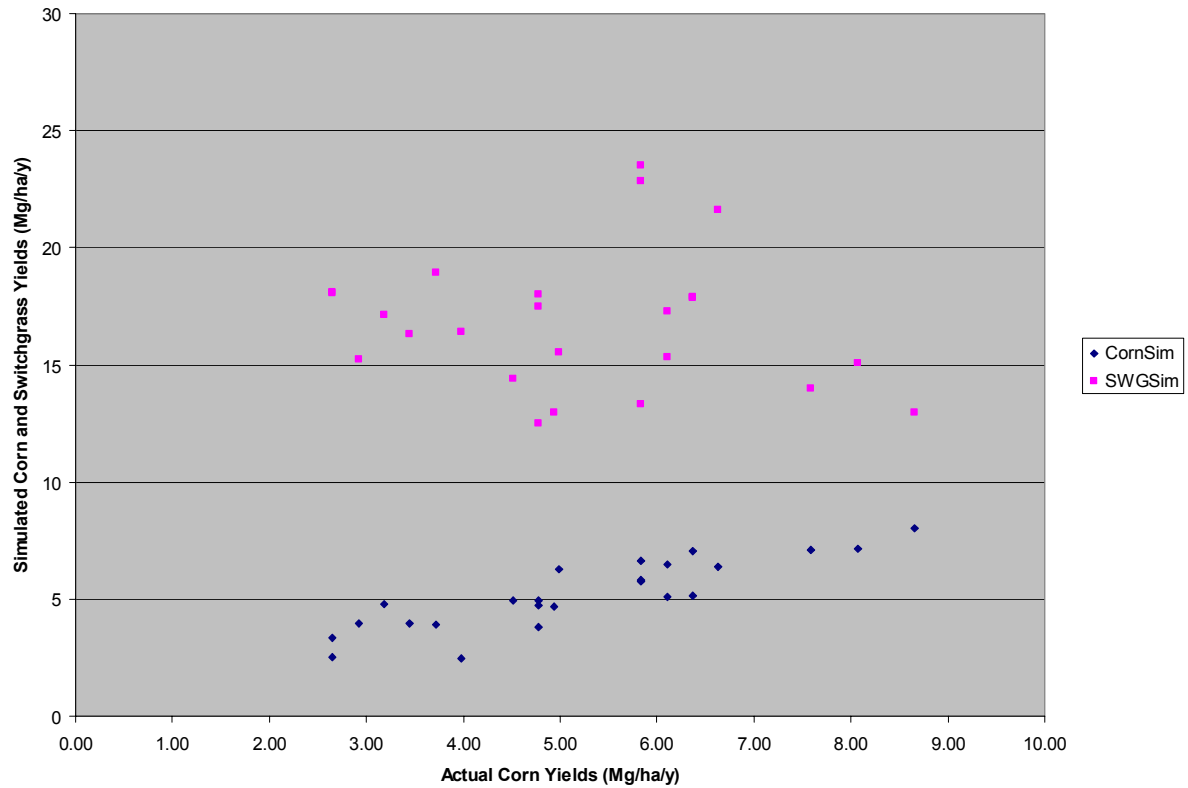
- Distribution of potential switchgrass production acreage at increased yields
- Sensitivity of price and profit to yield
- Sensitivity of yield/supply area to climate
- Changes in farm income and government price supports at higher yields/profitability
- Ecological issues - N and water use, C storage, wildlife edge increases

Estimating Future Switchgrass Yields (Mg/ha)

51.6	ALMANAC theoretical
47	Maximum single plant –unwatered nursery
34	Best small plot –single year
15-22	***Projected field-scale yield in 20 y ***
22	Typical best small plot each year for each of 3 regions in SE/SC
15	Current regional small plot average
9.4	POLYSYS average US at \$44/Mg (\$53.8 delivered)
11.1	“ “ at \$30.3/Mg (\$37.3 delivered)
9-22	Current range - - - field-scale

Simulating Corn and Switchgrass Yields with ALMANAC

Simulated Annual Yield of Corn and Switchgrass Using ALMANAC
6 States, 27 Soil Types, 13 Years



Economic Implications of Yield Improvement

-10 Y POLYSYS run - Feedstock price \$40/Mg-

- Yield Gain - 11.1 > 14.8 Mg/ha + 34%
- Hectares planted - 9.3 > 12.3Mha + 21%
- Net gain in farm income - \$1.2B
- Reduced Govt support needs - \$2.23B
- Potential price credit - \$24.7/Mg
- Total gain (income + govt support savings)

Vs. conventional crops

\$8.22B/Y