Feedstock Production I: Best Practices, Production Systems, and Breeding & Improvement

Rob Mitchell

USDA-ARS
Grain, Forage, and Bioenergy Research Unit
Lincoln, Nebraska

USDA ars

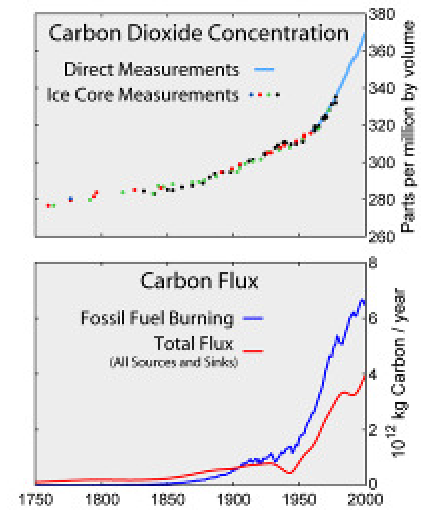
UNIVERSITY OF Nebraska Lincoln

Where are We Going?

- The Need for Biomass
- Crop Residues
- Dedicated Energy Crops
- Switchgrass as a Perennial Model
- Production, Energy & Economics
- Status Report

Reliance on fossil fuels.

Increasing levels of greenhouse gases.



Increasing human population requires an increase in food, feed, & fiber production.

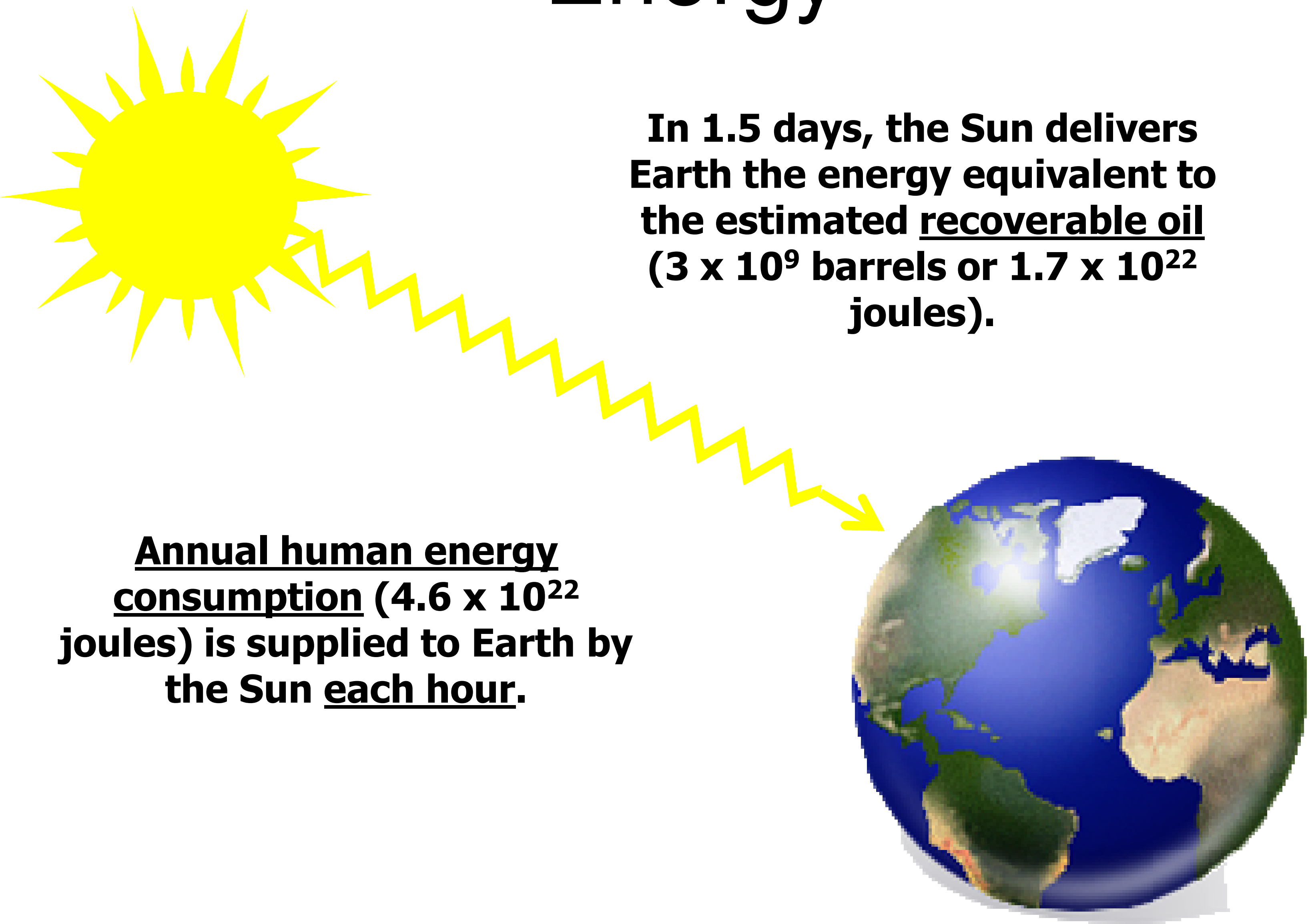
Increased Expectations for Agriculture

- Provide traditional outputs for an <u>increasing</u> world population
  - Food
  - Feed
  - Fiber
- Environmental services
  - Control erosion
  - Sequester C
  - Wildlife habitat
  - Water quality
- Renewable energy feedstock*
  - 1 billion tons (428 million ton from crop residues)

* Perlack et al., 2005; http://bioenergy.ornl.gov

Energy

In 1.5 days, the Sun delivers Earth the energy equivalent to the estimated <u>recoverable oil</u> (3 x 10^9 barrels or 1.7 x 10^{22} joules).

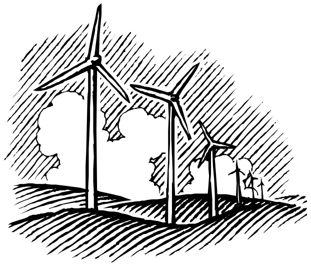


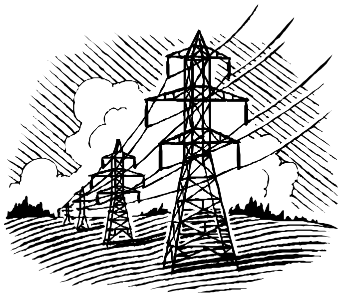
<u>Annual human energy consumption</u> (4.6 x 10^{22} joules) is supplied to Earth by the Sun <u>each hour</u>.

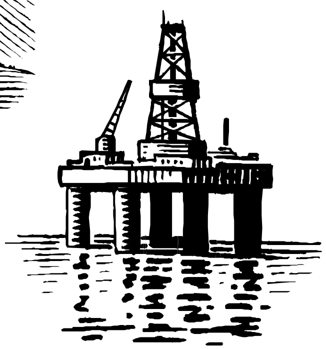
Crabtree and Lewis. 2007. Physics Today 60:37-42.

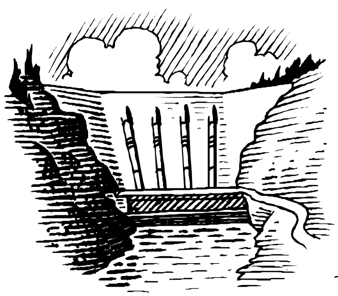
Our energy supply

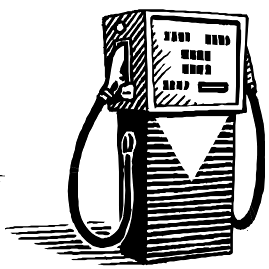
We have an <u>energy collection, format, and use problem</u>, not <u>an energy supply problem</u>.





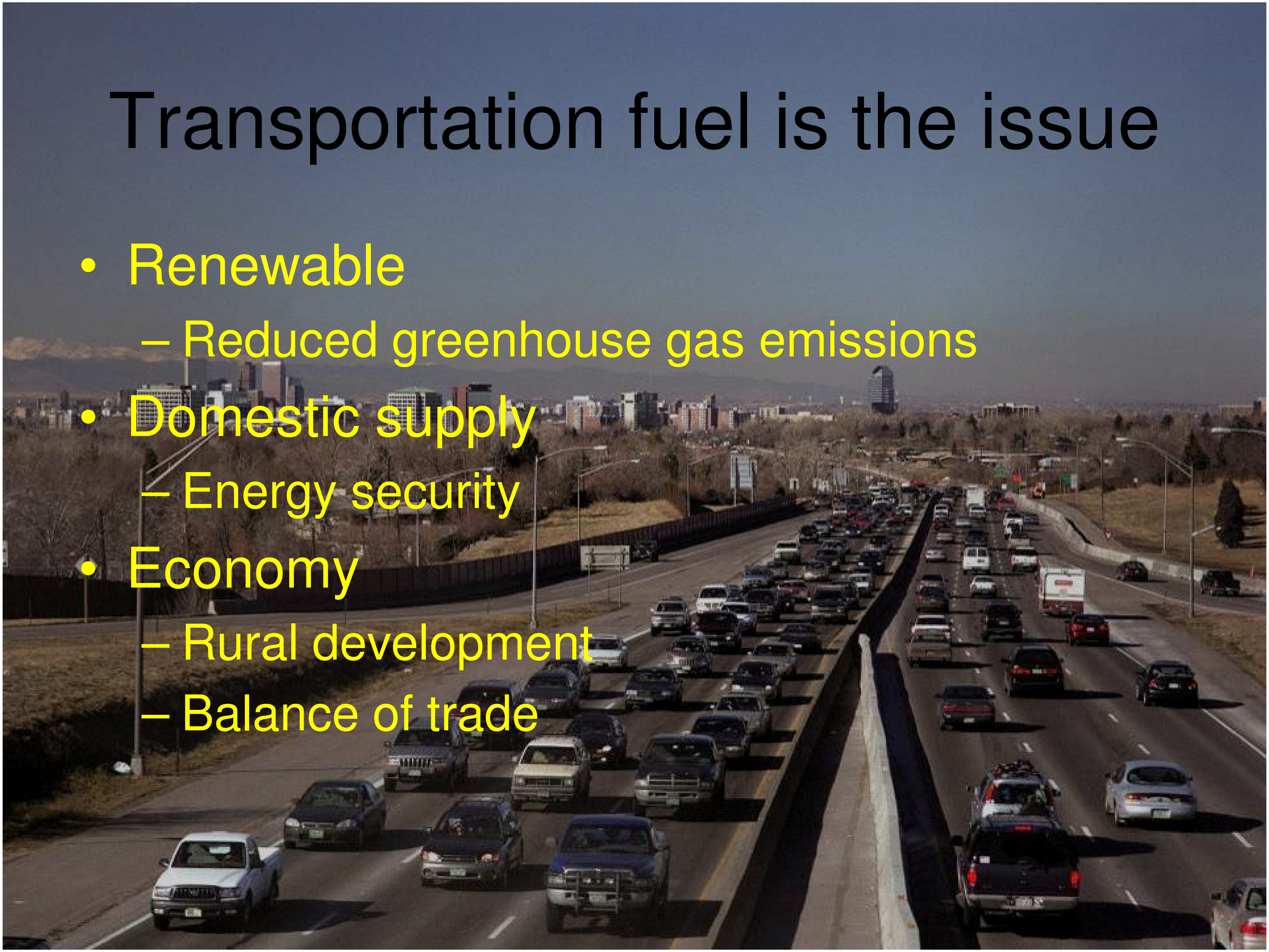




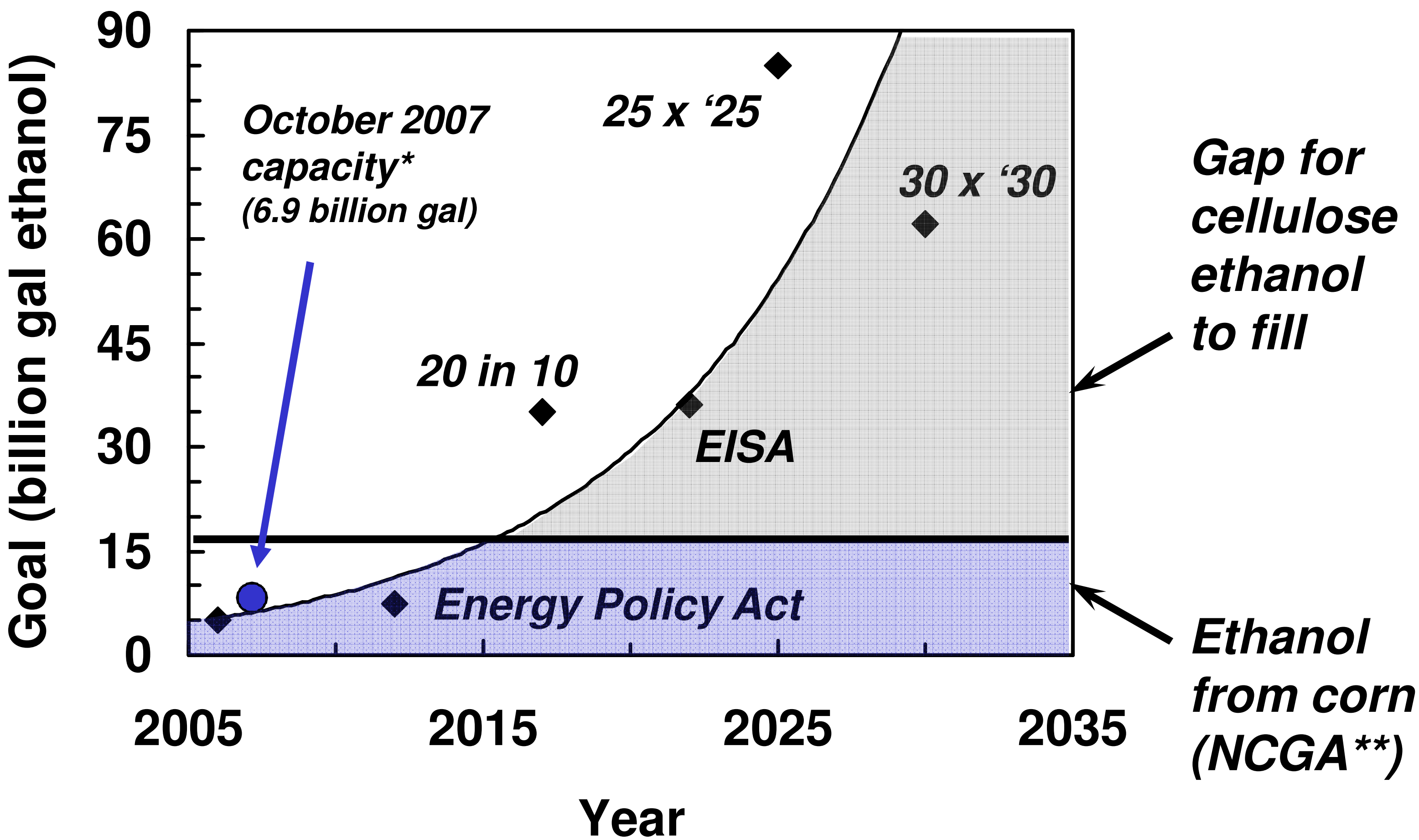


Transportation fuel is the issue

- Renewable
  - Reduced greenhouse gas emissions
- Domestic supply
  - Energy security
- Economy
  - Rural development
  - Balance of trade



Cellulose to Fill the Gap

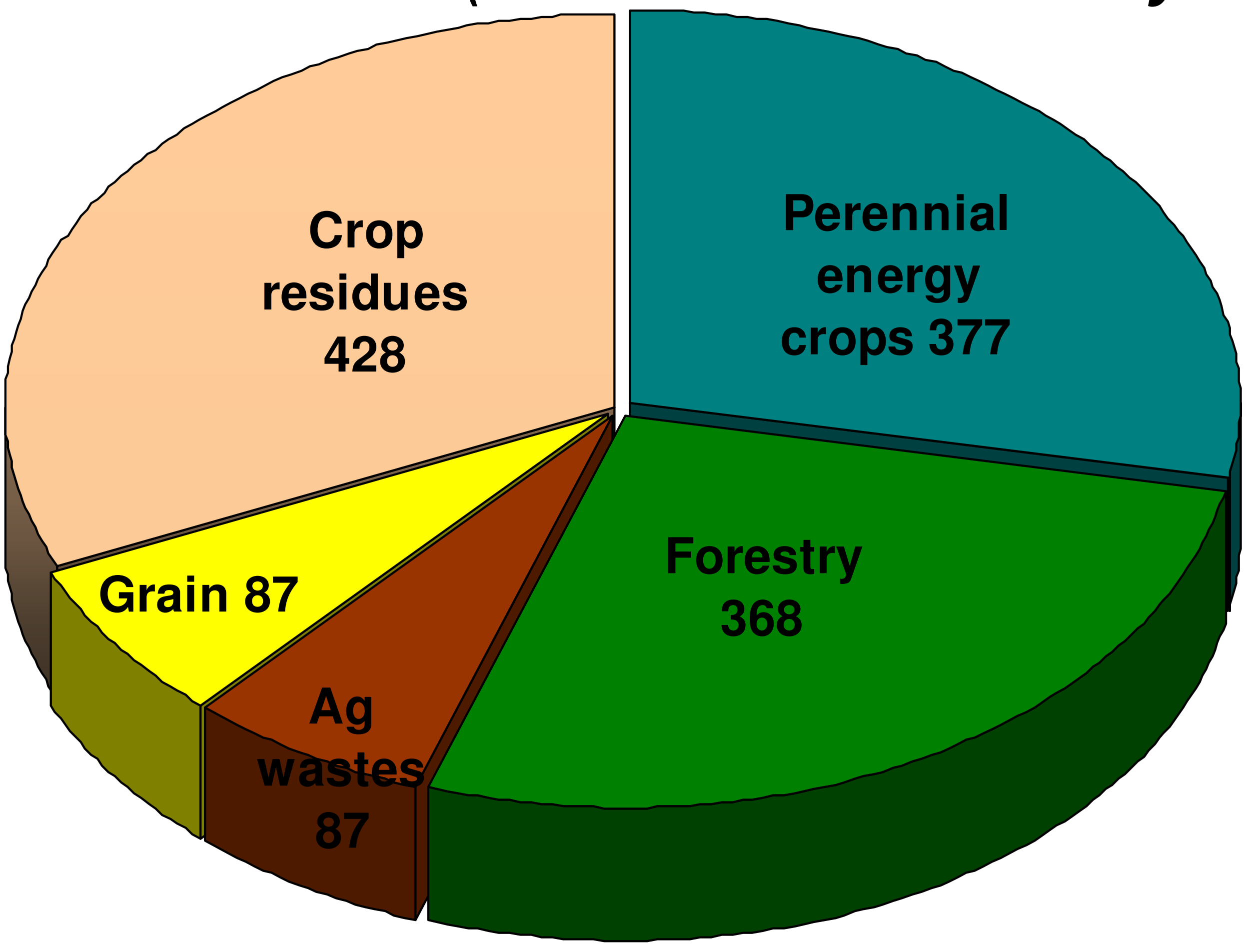


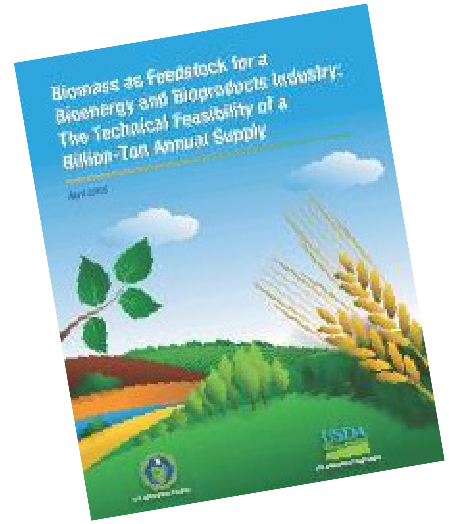
*RFA, http://www.ethanolrfa.org/industry/statistics/#C
**NCGA, http://www.ncga.com/ethanol/pdfs/2007/HowMuchEthanolCanComeFromCorn0207.pdf

REAP

Billion Ton Report

(1.366 billion tons/year)



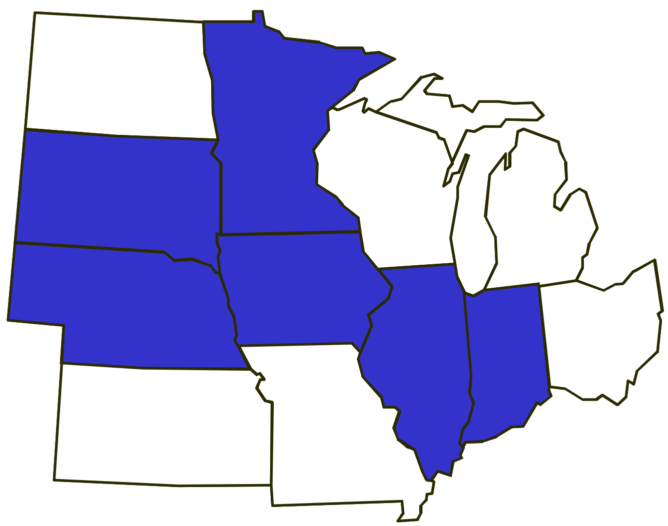


Estimated biomass (million tons/year) contribution by 2030

Perlack et al., 2005; http://bioenergy.ornl.gov

What is ONE BILLION tons?

- Agricultural land (cropland plus hay and pasture)
  - 5 ton ac^{-1}
  - 200,000,000 acres
    - All of the agricultural land in the 6 leading corn producing states of Iowa, Illinois, Nebraska, Minnesota, Indiana, and South Dakota (195.5 x 10^6 ac)

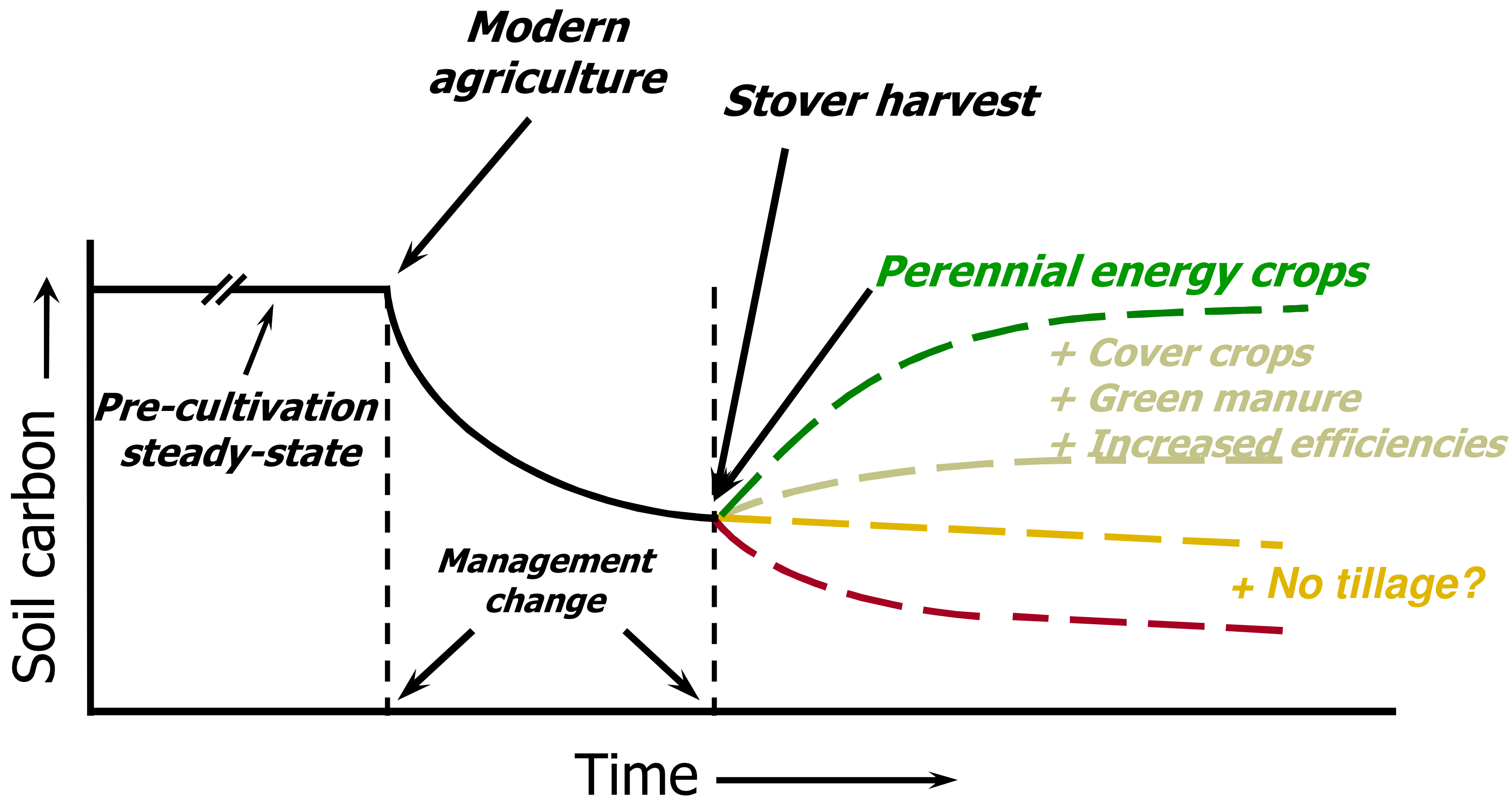


Sustainability

- Meeting current needs in a manner that does not jeopardize the capacity of future generations to have their needs met.



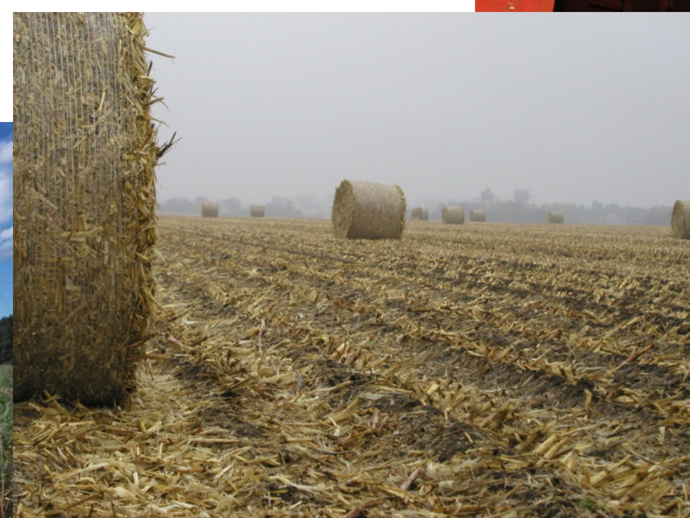

Meeting expectations sustainably



Δ SOC = Σ (inputs – outputs)

Fuel from agriculture

- Grain
- Crop residue
- Dedicated energy crops



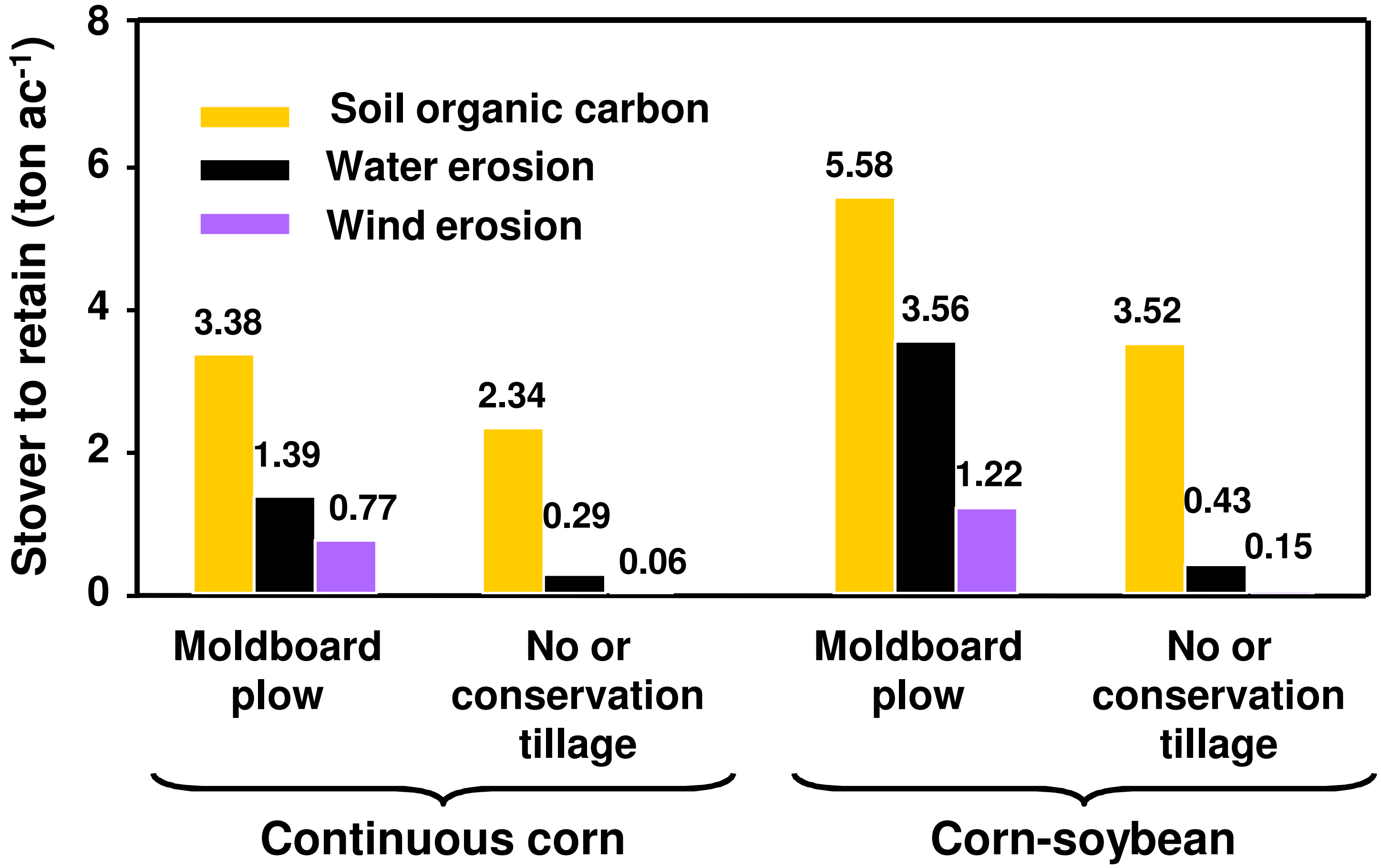
Grain

- Advantages
  - Current feedstock (largely corn)
  - Production, storage, transport, marketing, and conversion technology and expertise exist
- Liabilities
  - High market price increasing production area
    - Land use shift-marginal land returned to production
    - Less rotations, more monoculture, less landscape and species diversity
  - Demand met by increased yield per unit land
  - Improved genetics, improved practices

Crop residues

- Advantages
  - Production technology and expertise exist
  - Biomass increases with grain yield
    - Harvest index
    - Cultural practices
    - Breeding emphasis shift to biomass
- Liabilities/Limitations
  - Numerous current uses
    - Erosion control
    - SOC maintenance
    - Livestock feed, increasing with DDGs

Factors limiting crop biomass removal



Wilhelm et al., 2007. Agron. J. 99:1665-1667.

Energy Grains Biomass

Launching a new industry for stover!

Contract Your Stover

***Contract your stover - corn stover or soybean stubble-* for processing into stover pellets to be marketed to end users such as coal-fired power plants.**

NEW! THREE Contract Options:

7-Year Contract = $20 / ton ($60 per acre) + 2% annual price increase

***5-Year Contract = $17.50 / ton ($52.50 per acre) + 1% annual price increase**

***3-Year Contract = $15.00 / ton ($45 per acre)**

*** Once EGB obtains 100,000 tons of stover, it will be able to accept five and three-year contracts.**

http://www.contractyourstover.com

Key Contract Elements

1. Only 3/5ths of the stover is removed; leaving more than USDA's standard of 30% for moisture retention and erosion protection, plus maintaining some nutrients.

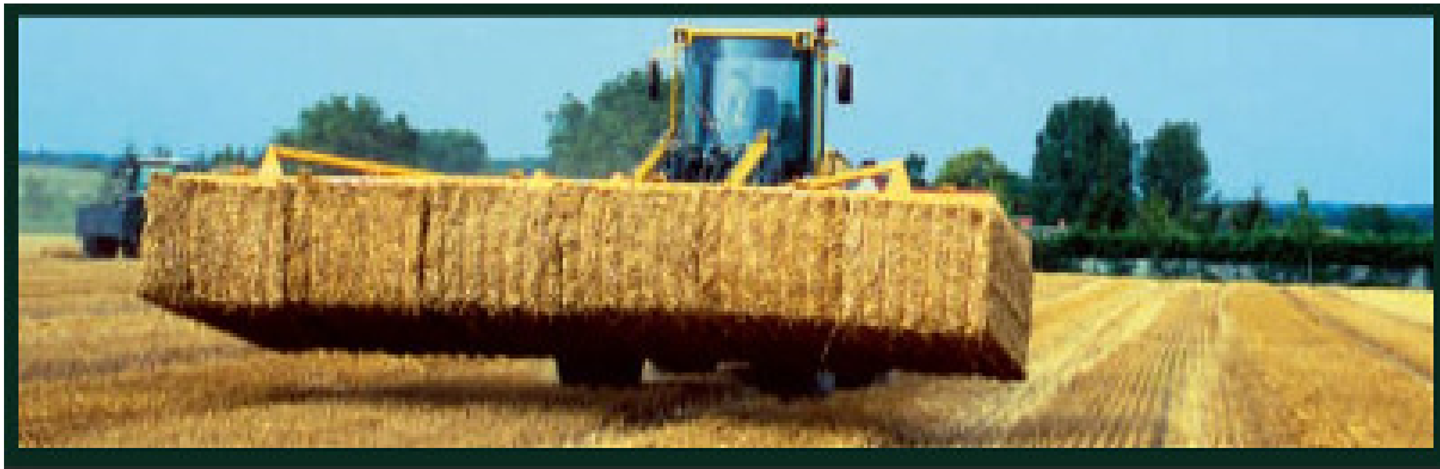
2. The price being paid is $20 per ton for the 7-year contract -- $60 per acre for fields with average corn yields. This is NET income. The harvesting, collection, and hauling is <u>not</u> the producer's expense, but rather that of Energy Grains Biomass, LLC.

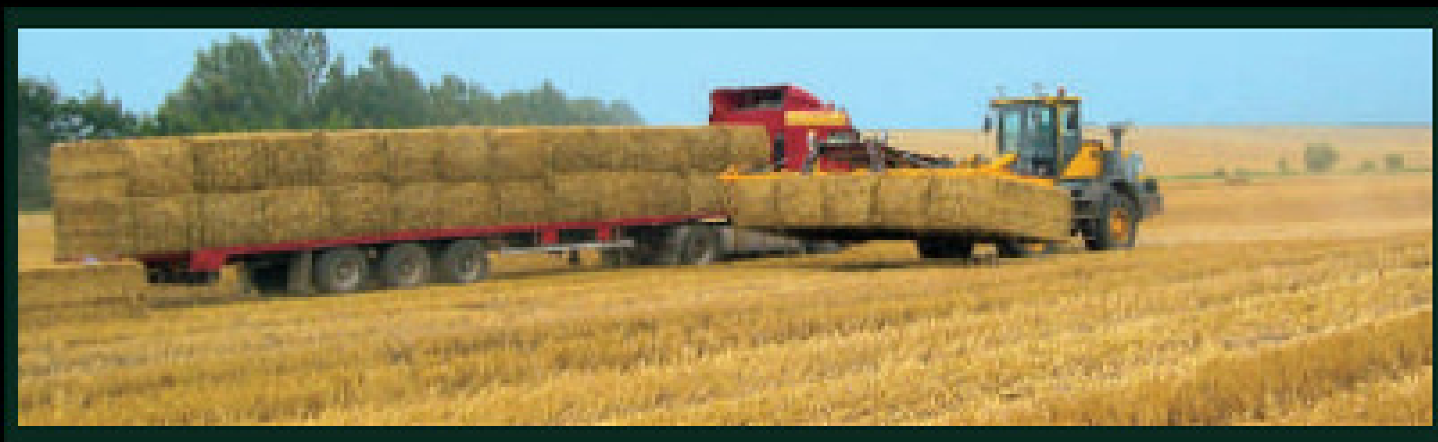
3. The contract is for a <u>set number of tons</u> -- NOT a certain field -- thereby encouraging rotation of harvest sites each year to maintain proper soil organic material.

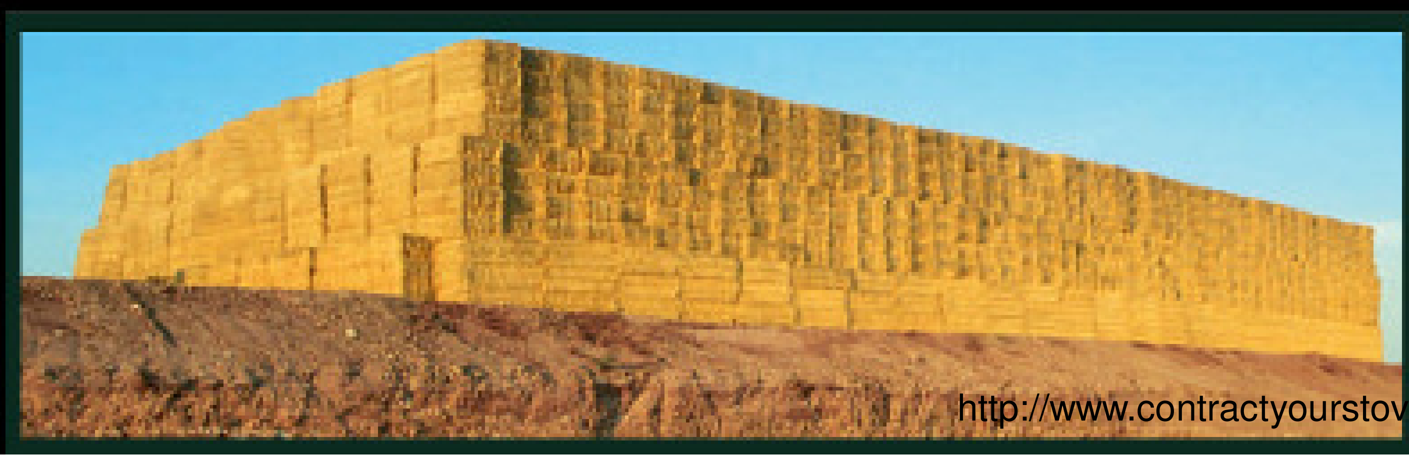
4. The producer need not notify Energy Grains Biomass as to which field(s) is to be harvested until August 1; thereby eliminating concerns about hail damage or other situations that may reduce the quantity of stover. The producer may select the field(s) that are most appropriate for his farming operations.

Exclusive to this Project:

- Energy Grains Biomass (EGB) **has submitted a patent** for a new process that converts loose stover into easy-to-store, easy-to-transport pellets.
- **The initial pellet tests have shown that it burns hotter than Wyoming coal**--which opens the doors for new market opportunities including burning the pellets at coal-fired power plants, thereby potentially reducing emissions of mercury and carbon.
- As a renewable, "green" product, and now one that can be stored and transported with greater efficiencies and cost-effectiveness, excess corn stover has the potential to **generate substantial revenue** for Nebraska producers.







http://www.contractyourstover.com

Dedicated energy crops

Annuals (triticale, sudan grass, tropical maize)

- Advantages
  - Fit into existing crop rotation
  - Large production of biomass in one season
  - Add species diversity
  - C_3 and C_4 species
- Disadvantages
  - Annual planting
  - Grower expertise lacking
  - Harvest technology
  - Biomass storage


Courtesy NRCS

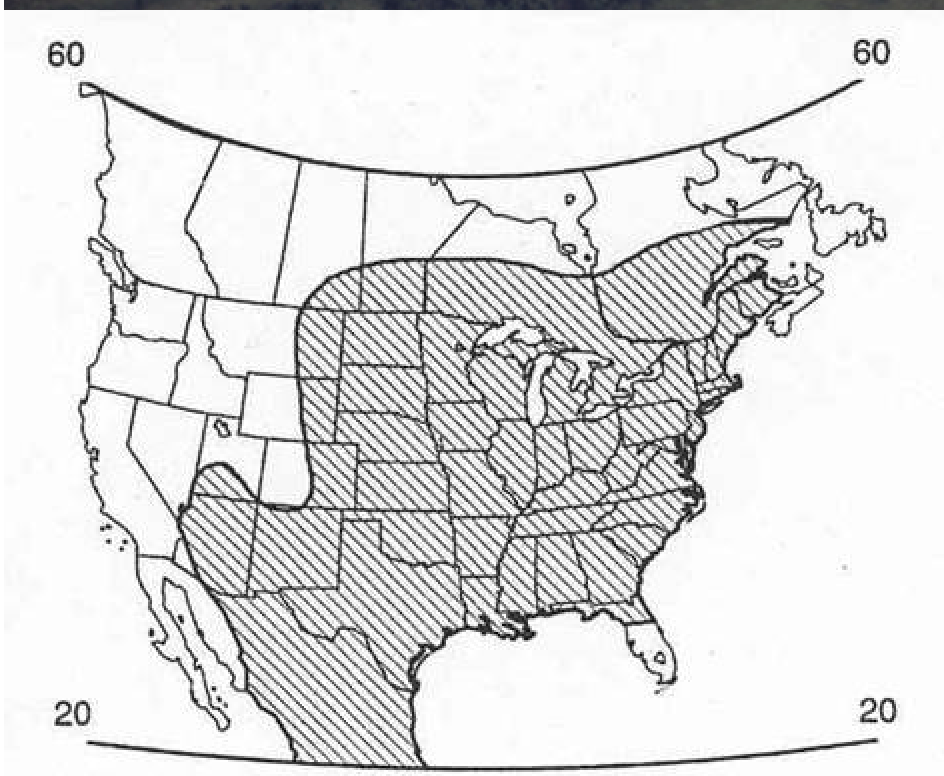
Dedicated energy crops

Perennials (switchgrass, alfalfa, Miscanthus)

- Advantages
  - Plant once, harvest for many years
  - Suited to more fragile or marginal lands
  - Fewer inputs
    - Knowledge from livestock systems
    - Systems with low expected production (CRP)
- Disadvantages
  - Grower expertise lacking
  - Harvest technology
  - Biomass storage
  - May be monocultures to meet demand

Switchgrass: North American Native

Ecologically functions as a monoculture

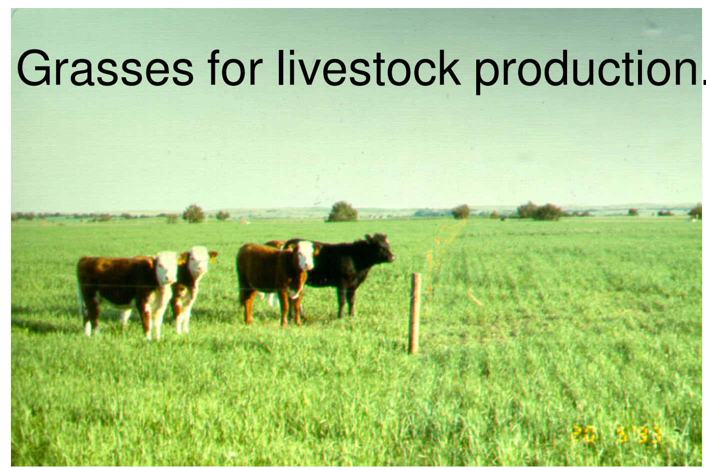


USDA Plant Research for Conservation and Grassland Agriculture

1930's to present

- Germplasm collection, assessment, breeding, and management research on switchgrass and other native grasses
- Lincoln ARS program, 1935 to present. Work started by pioneering breeder, L.C. Newell
- Emphasized use by livestock
- Currently 50% of research at Lincoln still on grasses for use in grazing systems


L.C. Newell


Grasses for livestock production.

Switchgrass Biomass Energy
Current Goals & Research

Goals

- Full establishment in 1 year with 50% yield
- Be at full production (5 t/a) second year
- Goal of 10 t/a in Midwest; increase ethanol yield/ton
- Fully document environmental benefits

Tools and Products

- Weed control, no-till planting, seed quality
- Breeding - Biomass specific cultivars & F1 hybrids, improved conversion, NIRS
- Molecular biology, cell walls, conversion & seed quality
- C sequestration, entomology

Well-suited to Marginal Lands

Switchgrass Establishment

- If an area is suitable for dryland corn it's suitable for switchgrass
    - Plant 2 to 3 weeks either side of optimum corn planting date
- Establishment protocols developed for much of the USA
- Spend money on quality seed & weed control to ensure success

Switchgrass Growth

31 July 2007
4 tons/acre

27 September 2007
4 tons/acre
2 tons/acre regrowth

Switchgrass Growth

7 August 2008
6 tons/acre

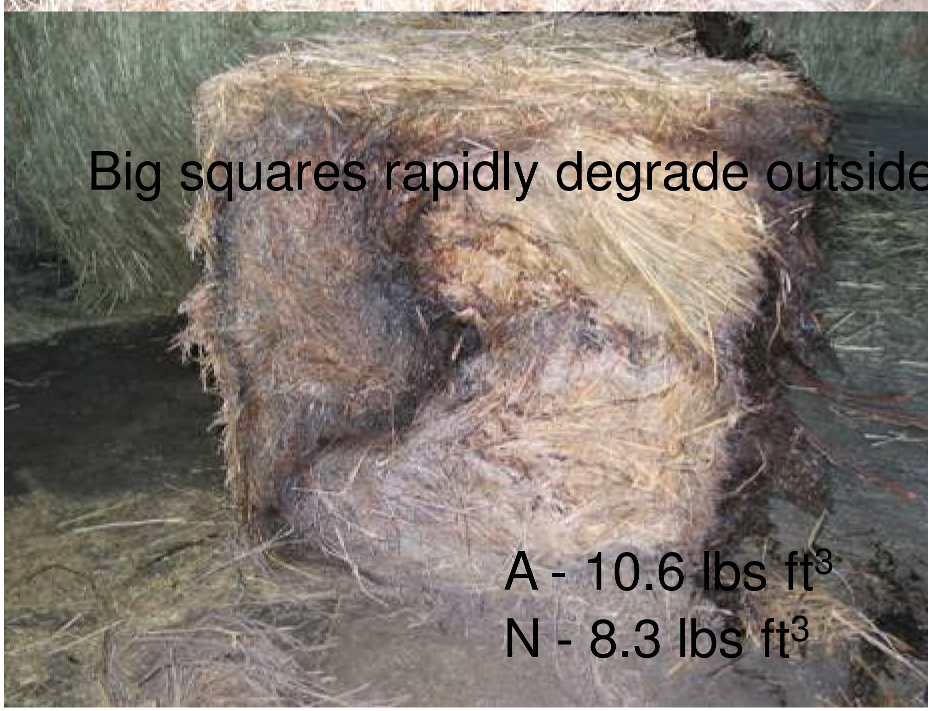
8 December 2008
4 tons/acre
~1 ton/acre regrowth

Averaged over 4 tons/acre for the planting year and the first 2 production years

Switchgrass Harvest & Storage



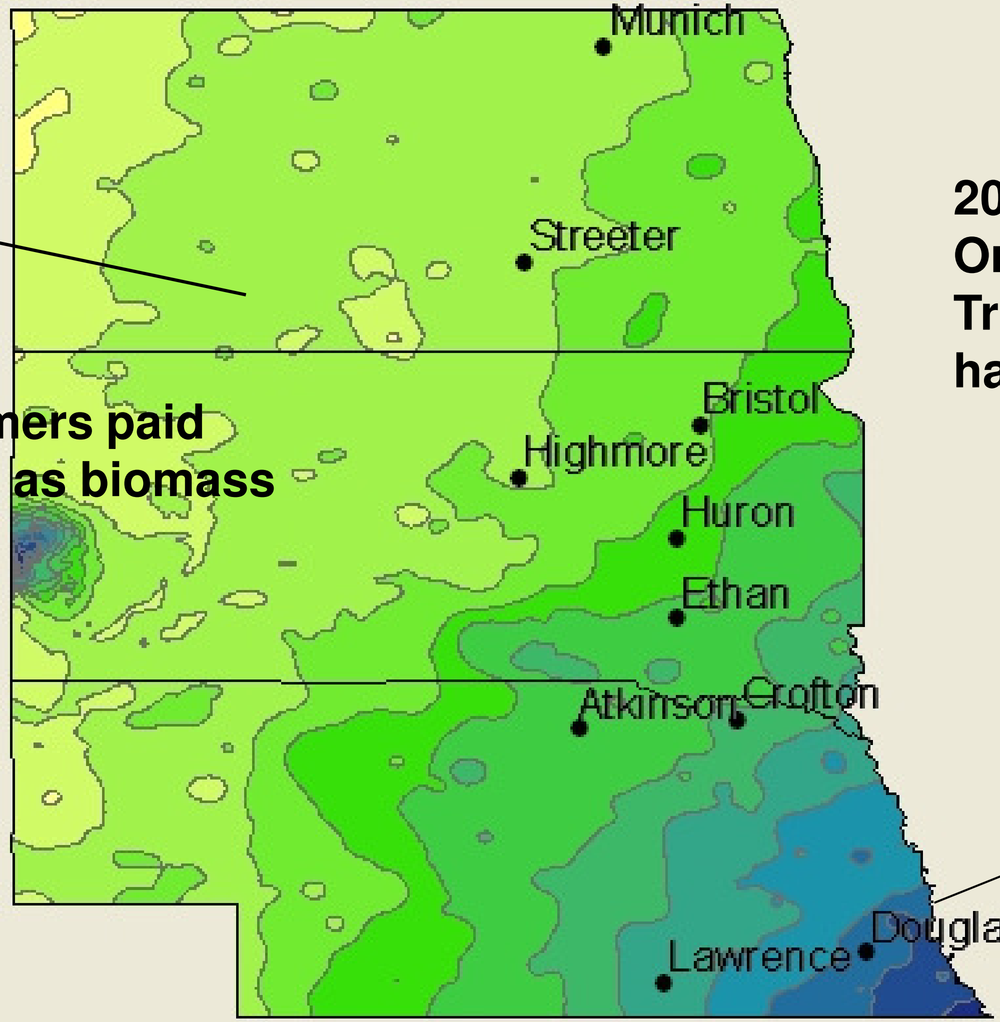
Switchgrass Harvest & Storage



Northern Plains Field Scale Production and Economics Trial

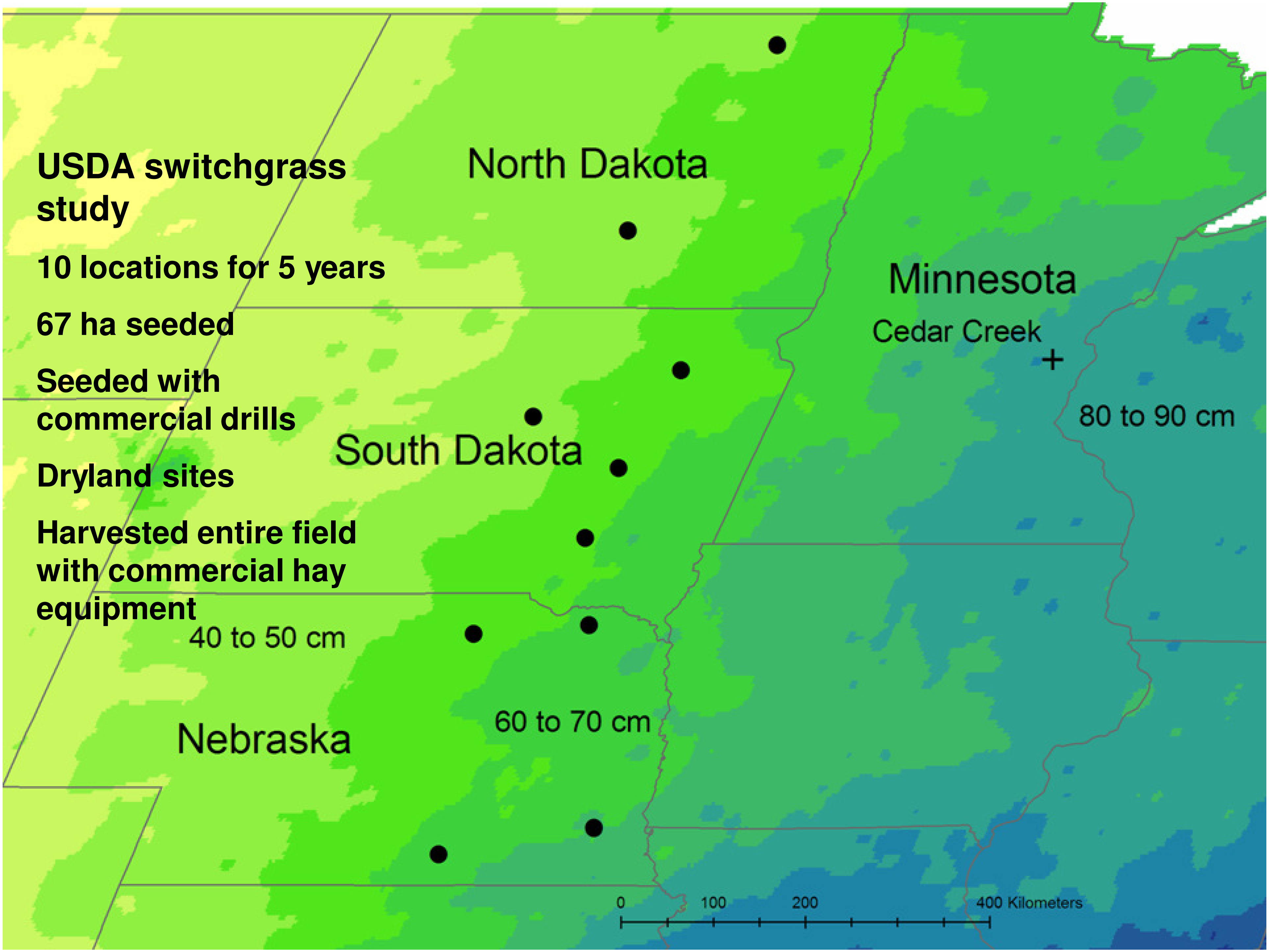
15”-17”
Annual
Precipitation

Cooperating farmers paid to manage fields as biomass energy crops.



2000-2005 On-Farm Production Trials: 15-20 acre (6-9 ha) fields

31”-33”
Annual
Precipitation


USDA switchgrass study
10 locations for 5 years
67 ha seeded
Seeded with commercial drills
Dryland sites
Harvested entire field with commercial hay equipment
North Dakota
South Dakota
Nebraska
Minnesota
Cedar Creek
40 to 50 cm
60 to 70 cm
80 to 90 cm
0
100
200
400 Kilometers

Switchgrass Average Annual Production Costs

Cost Item	$/ha	$/Mg
Planting	30.21	6.06
Herbicide Applied	33.42	6.70
Fertilizer Applied	37.15	7.45
Harvest	80.25	16.09
Total Operating Costs	**181.03**	**36.30**
Land Rent	147.45	29.56
Total Cost	**328.48**	**65.86**

Costs are annualized at 10%.

Perrin et al. 2008

Previous Switchgrass Producer vs. New Crop Producer

Five Year Average Cumulative Costs	
	Total costs $/ton ($/Mg)
Experienced (2)	$43.13 (47.44)
New crop producer (8)	$69.16 (76.08)

Experience helped producers reduce production costs (minus land costs) by $10.86/ton during the 5 production years.

Perrin et al. 2008

Extension Efforts Will Pay Dividends

Field of Jerry Roitsch near Bristol, South Dakota

- 5-year average yield of 9.4 Mg/ha
- Average cost of $42/Mg including land & labor
- Farm gate feedstock cost was $0.13/l
- Based on 80 gallons of ethanol per ton, each big bale equals 50 gallons of ethanol

Paramount Herbicide vs. No Paramount in Establishment Year

Five Year Average Cumulative Costs	
	Total costs $/ton ($/Mg)
Paramount used (4)	$44.06 (48.47)
No Paramount (6)	$77.22 (84.94)

Applying Paramount at establishment reduced production costs (minus land costs) by 43%.

Perrin et al. 2008

Year 1 Harvests vs.
No Year 1 Harvest Comparisons

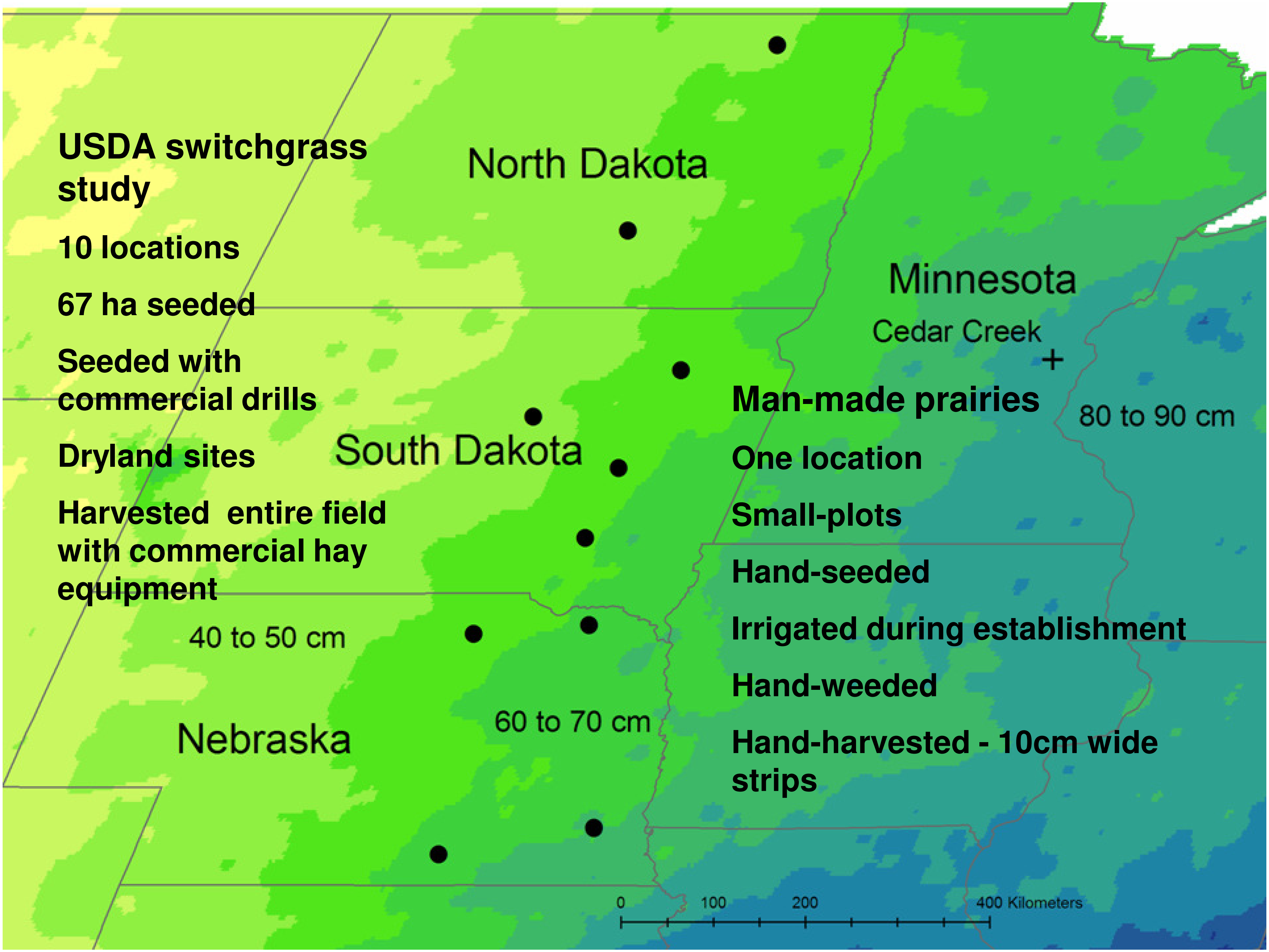
Five Year Average Cumulative Costs	
	Total costs $/ton ($/Mg)
Year 1 Harvest (3)	$44.22 (48.64)
No Year 1 Harvest (7)	$72.41 (79.65)

Perrin et al. 2008

On-farm Switchgrass Production in the Great Plains – Energy

- Previous models over-estimated the energy inputs for switchgrass production by as much as 2X
- Switchgrass produced 13X more energy as ethanol than was required as energy from petroleum
- Switchgrass produced 540% more renewable than non-renewable energy consumed on marginal land when properly managed
- Switchgrass biofuel production systems are economically feasible, and energetically positive on marginal cropland in the central USA

Schmer et al. 2008 – PNAS 105:464-469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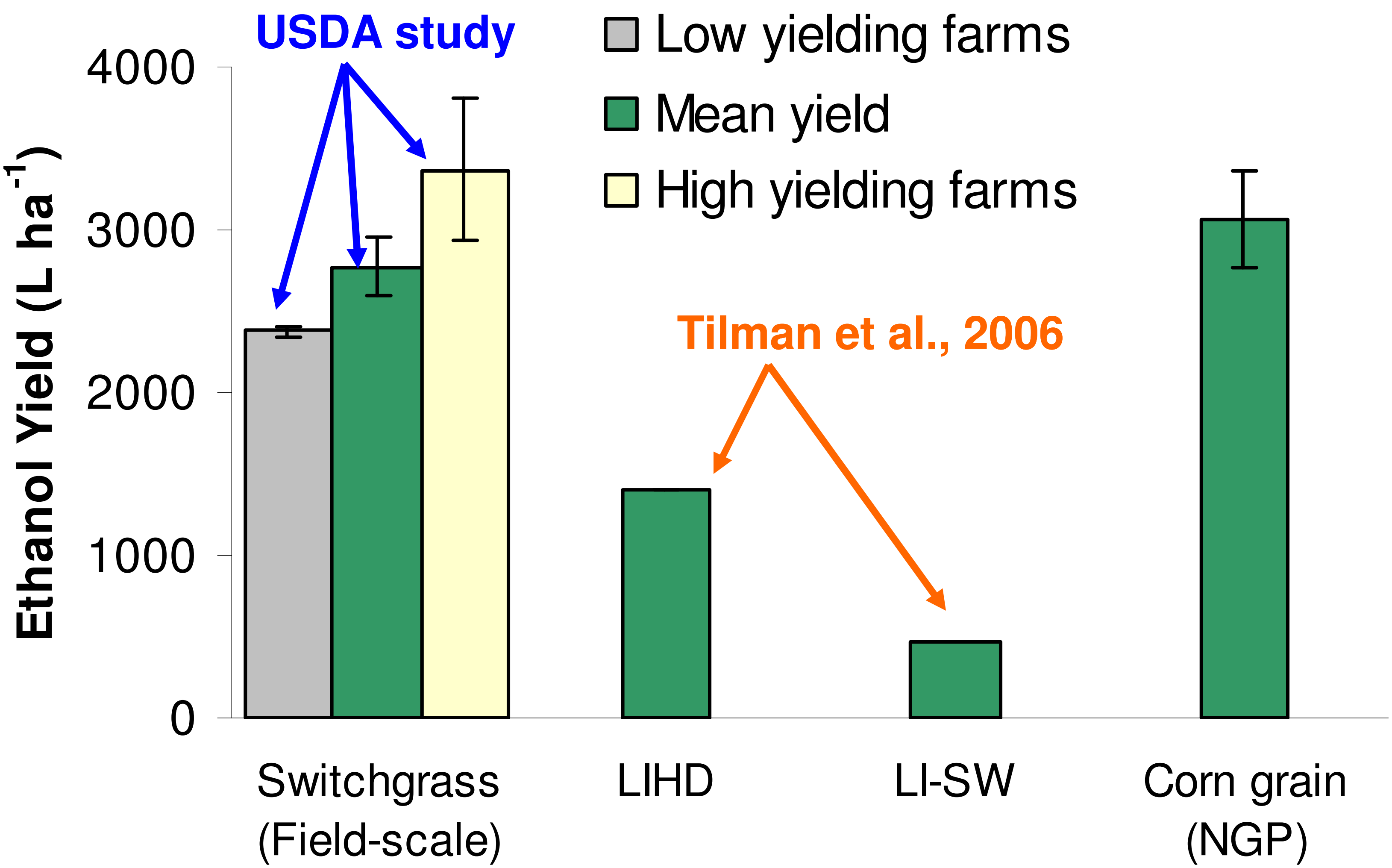
10 locations
67 ha seeded
Seeded with commercial drills
Dryland sites
Harvested entire field with commercial hay equipment
North Dakota
South Dakota
Nebraska
Minnesota
Cedar Creek
40 to 50 cm
60 to 70 cm
80 to 90 cm
Man-made prairies
One location
Small-plots
Hand-seeded
Irrigated during establishment
Hand-weeded
Hand-harvested - 10cm wide strips
0
100
200
400 Kilometers

Managed switchgrass produced 97% more ethanol yield than man-made prairies



What about soil carbon?

Switchgrass Soil Carbon Sequestration when grown and managed as a biomass energy crop

C storage at Douglas, NE for 5-year period:

- 4.9 Mg/ha increase in soil carbon in the top 30 cm of soil
  - 1 Mg C/ha/year
- 18.4 Mg/ha increase in soil carbon in the top 1.2 m of soil
  - 3.7 Mg C/ha/year

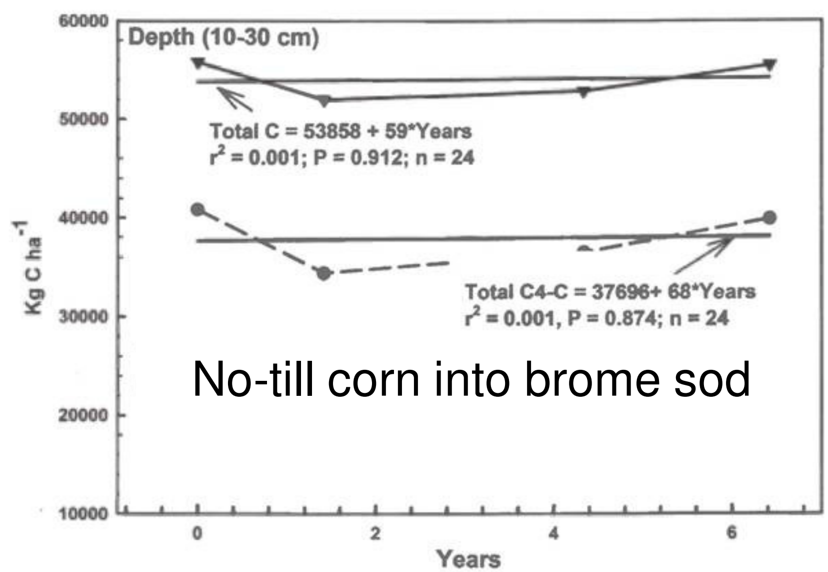
- In the top 1.2 m of soil at 4 NE sites, SOC increased at a rate of 2900 kg of C/ha/year.

Liebig et al. 2008 Bioenergy Research

Grass to crops – What happens to the soil carbon?

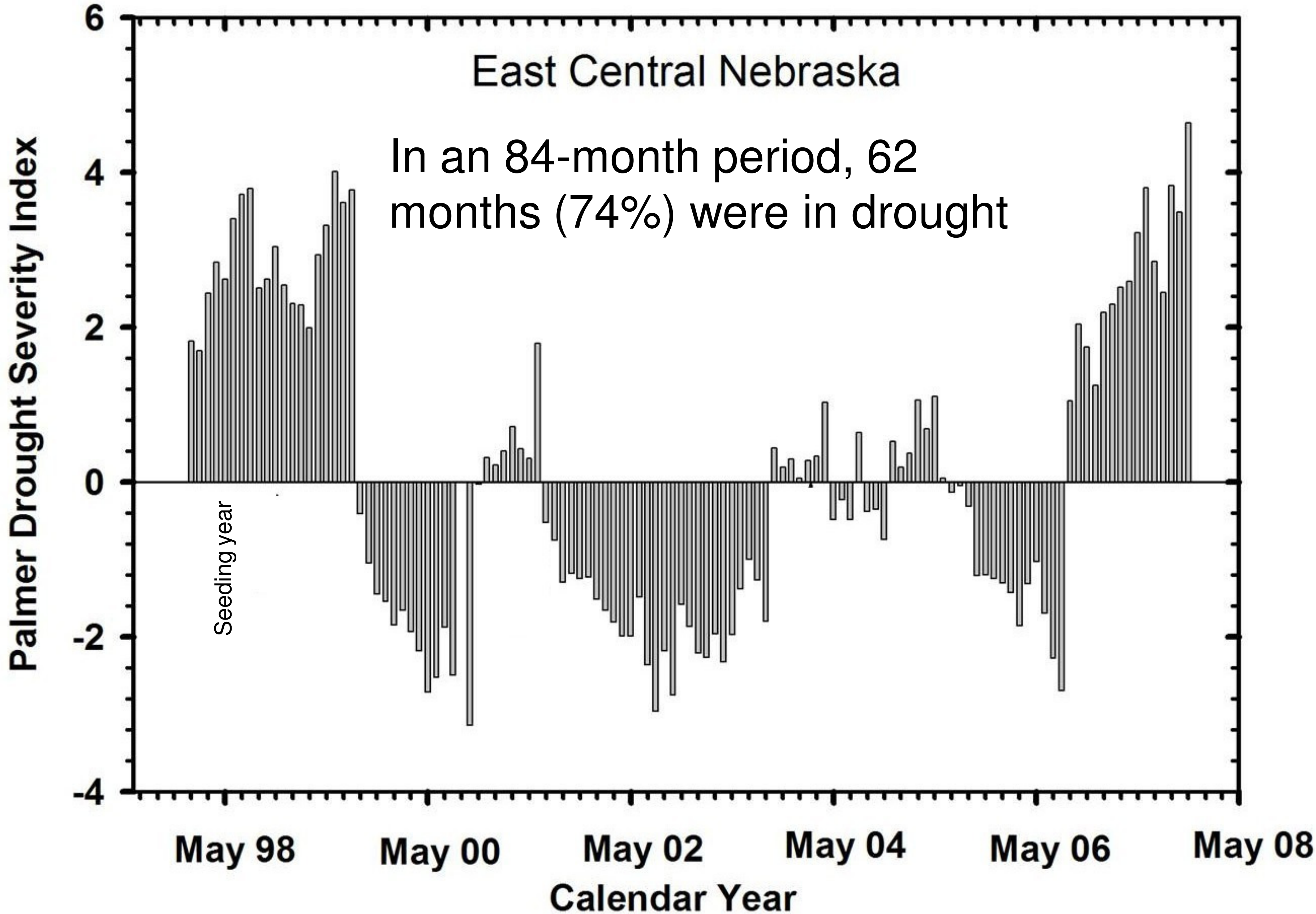
- Searchinger et al. Science 2008 – sequestered carbon from perennial bioenergy crops is lost due to plowing and crop production.
- Fact: plowing is not necessary and not recommended. Too expensive and sod-seeding is easier.
- What happens to sequestered C under no-till farming? No-till corn into bromegrass: no net change in soil C.

- Mitchell et al. 2005. Renovating pastures with glyphosate tolerant soybeans. Online. Forage and Grazinglands doi:10.1094/FG-2005-0428-01-BR.
- Follett et al. 2009. Crop Science.



Long-term Study of Corn & Switchgrass Mead, NE

- 10-year study established in 1998 to evaluate no-till corn & switchgrass on marginal sites in eastern NE
- In 2000, corn plots were split & 50% of stover removed on half of plots
  - Removing ½ of stover for 7 years reduced grain yield by 7.2%.
  - Total corn & switchgrass biomass were similar averaged over 7 years.
  - C sequestration – Longest on-going switchgrass soil C study – will be continued.


East Central Nebraska
In an 84-month period, 62 months (74%) were in drought
Palmer Drought Severity Index
6
4
2
0
-2
-4
Seeding year
May 98
May 00
May 02
May 04
May 06
May 08
Calendar Year

Switchgrass Progress Using Conventional Breeding
Yield Trial Mead, NE 2003-2005

Cultivar	Year released	Biomass yield -Ton/a	IVDMD (%) (mature)
Trailblazer	1984	6.3	52.5
Shawnee	1995	6.5	54.8
NE 2000C1	**In seed increase**	**7.4**	**53.8**
NE Late YD C4	**In seed increase**	**7.0**	**55.2**

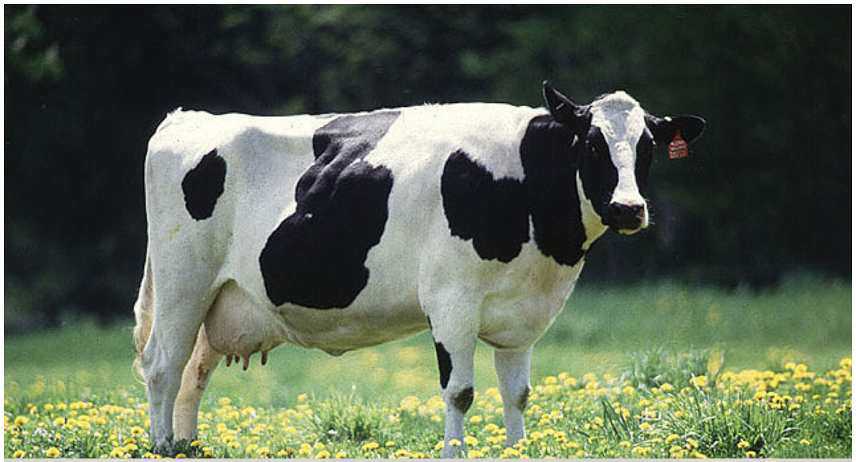
Hybrid Switchgrass

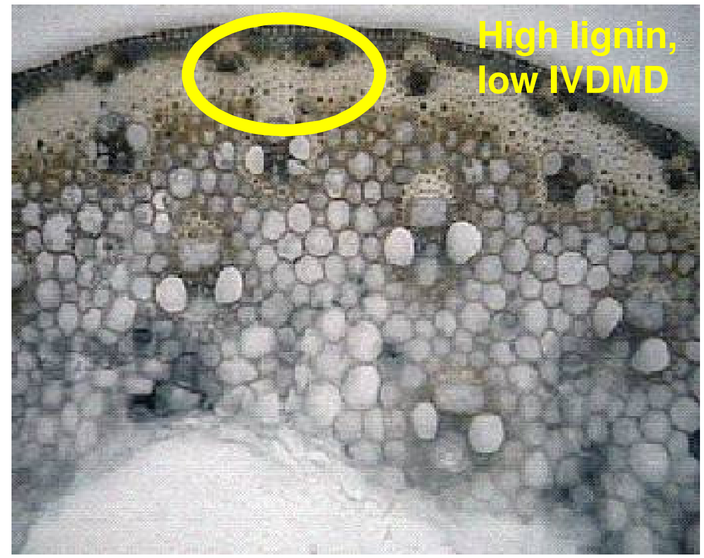
Strain	Yield Tons/A
Kanlow & Summer F1's	9.4
Kanlow	7.1
Summer	6.1

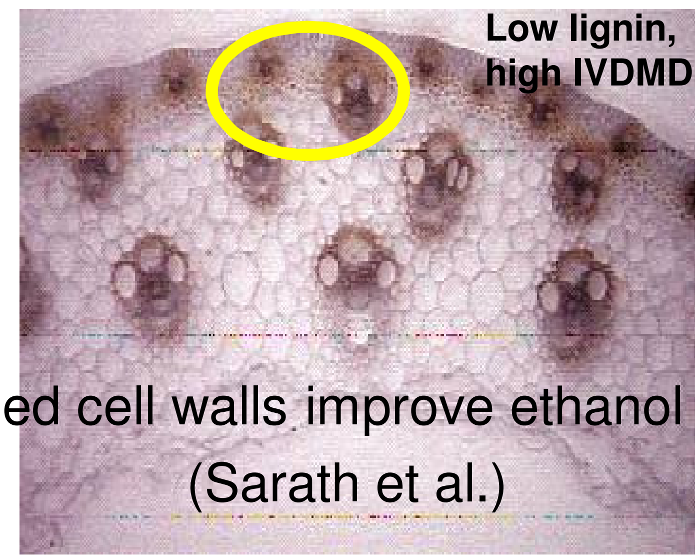
Vogel & Mitchell, Crop Science 48:2159-2164. 2008.

- Improved hybrid cultivars with modified cell walls could improve ethanol yields & reduce costs.

Biorefineries and Biomass Feedstock Quality

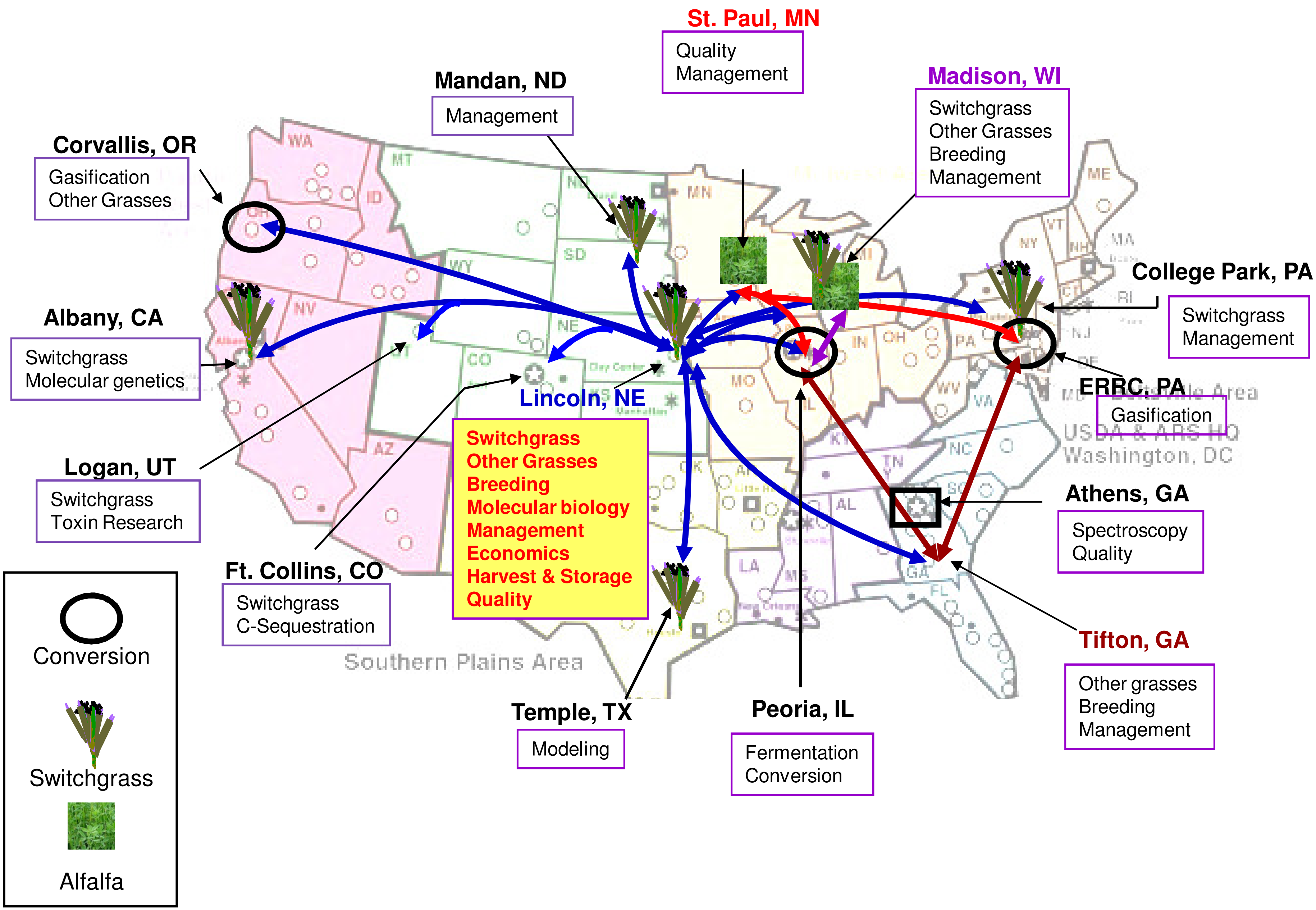




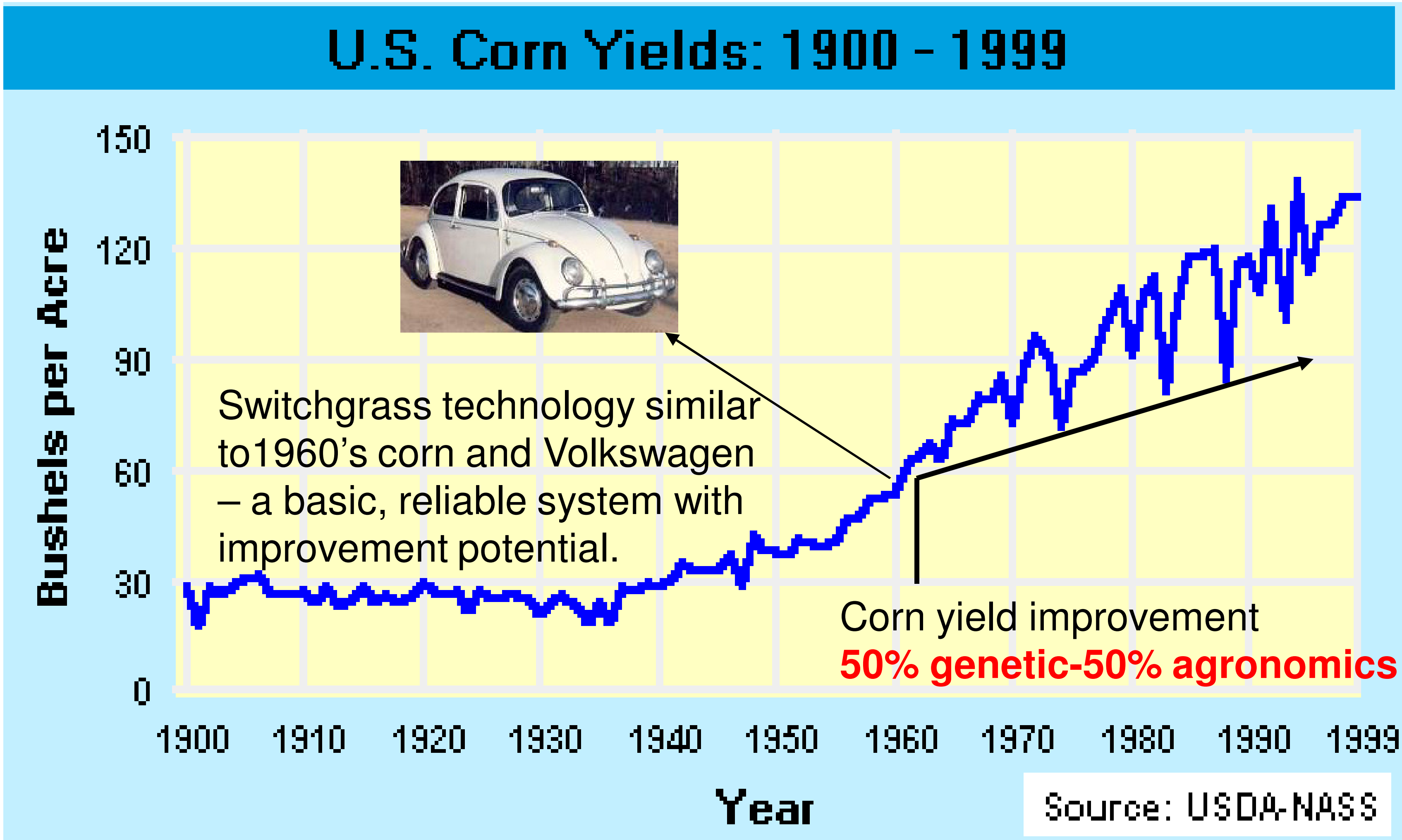


Modified cell walls improve ethanol yields
(Sarath et al.)

Lincoln ARS Switchgrass Bioenergy Crop Cooperative Research



Current switchgrass cultivars & agronomics equivalent to 1960's corn system



1. There is no one-size-fits-all biomass crop
2. Biomass can be produced and delivered to the biorefinery in a timely manner
   a. Crop residue contracts are being signed
   b. Switchgrass could be supplied to biorefineries in as few as 4 years from release
3. Production system information is available, verified and sustainable
4. Bottom line: Agriculture can provide a reliable, affordable & long-term feedstock supply

USDA ARS

The green revolution was successful because of improved genetics and agronomics. Successful large-scale production of sustainable green energy will likewise depend on improved genetics, agronomics, & feedstock combinations.

Questions?