SWITCHGRASS AND GIANT MISCANTHUS BIOMASS PRODUCTION ON RECLAIMED MINED LANDS

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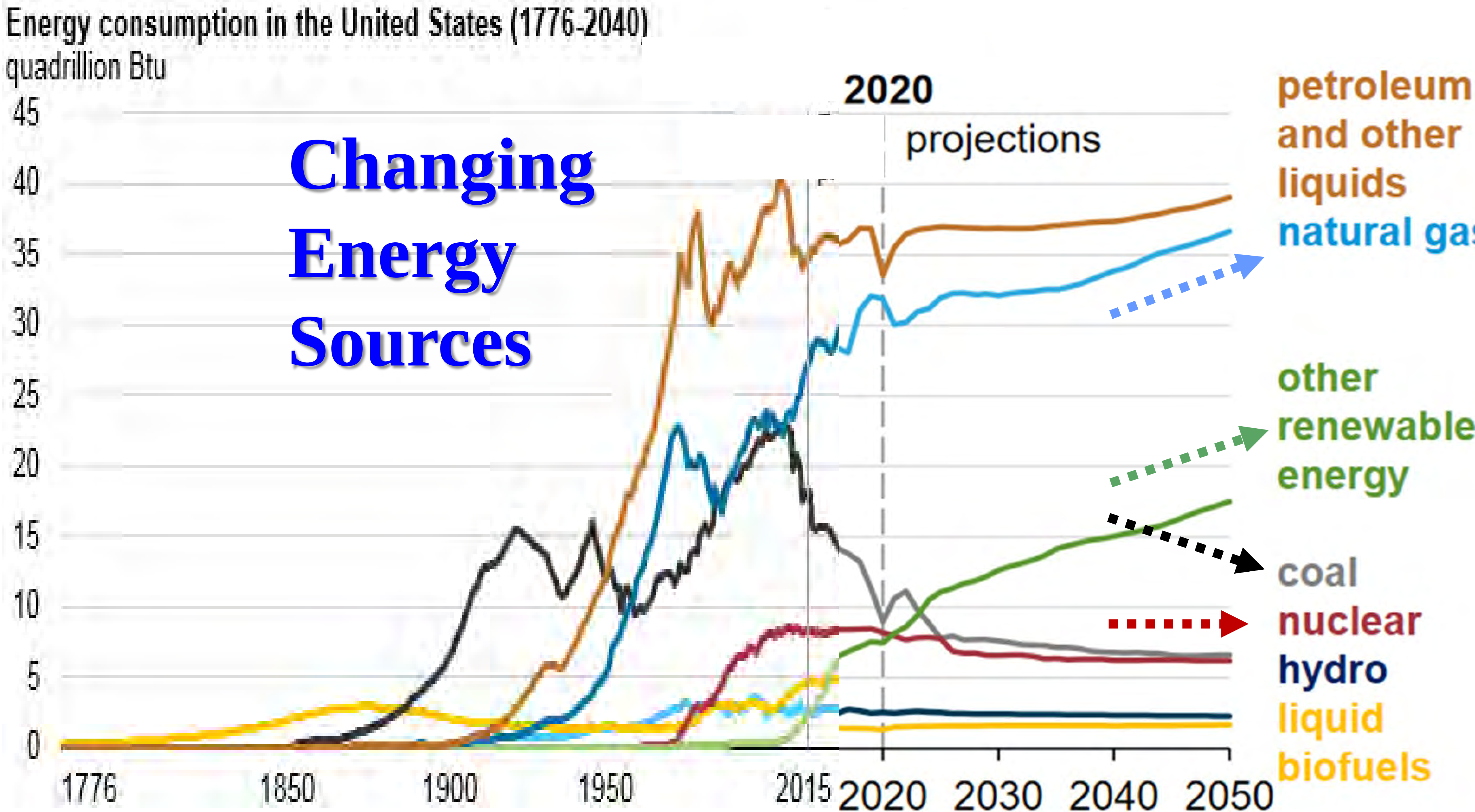
Vitae

Biomass for Biofuel

Switchgrass and Miscanthus



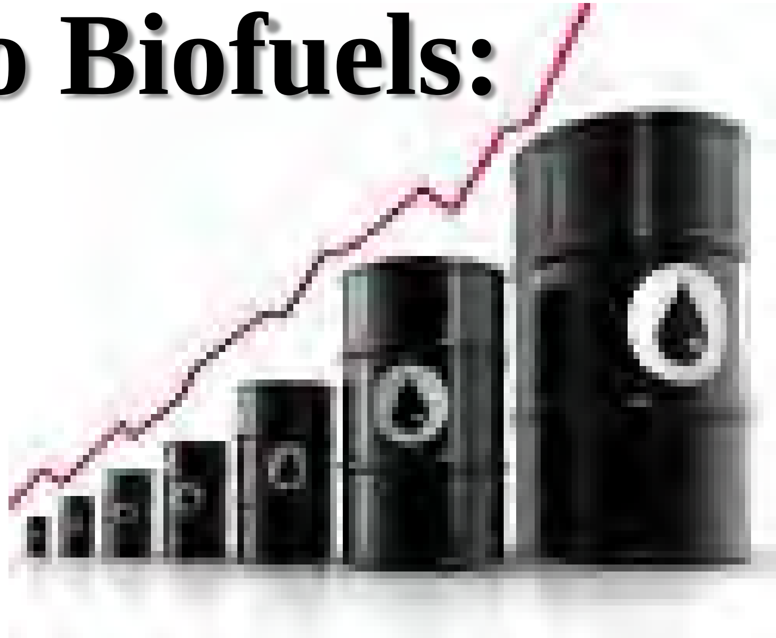
Energy consumption in the United States (1776-2040)
quadrillion Btu
Changing
Energy
Sources
2020
projections
45
40
35
30
25
20
15
10
5
0
1776
1850
1900
1950
2015
2020
2030
2040
2050
petroleum
and other
liquids
natural gas
other
renewable
energy
coal
nuclear
hydro
liquid
biofuels


Nuclear
Solar
Coal
Oil
Energy
Wind
Natural gas
Biomass
Water

If you could choose, which…?

Equal in Availability?
Equal in Price?
Where?

Reasons for turning to Biofuels:



High Energy Prices ?

Concerns About Petroleum Supplies ?

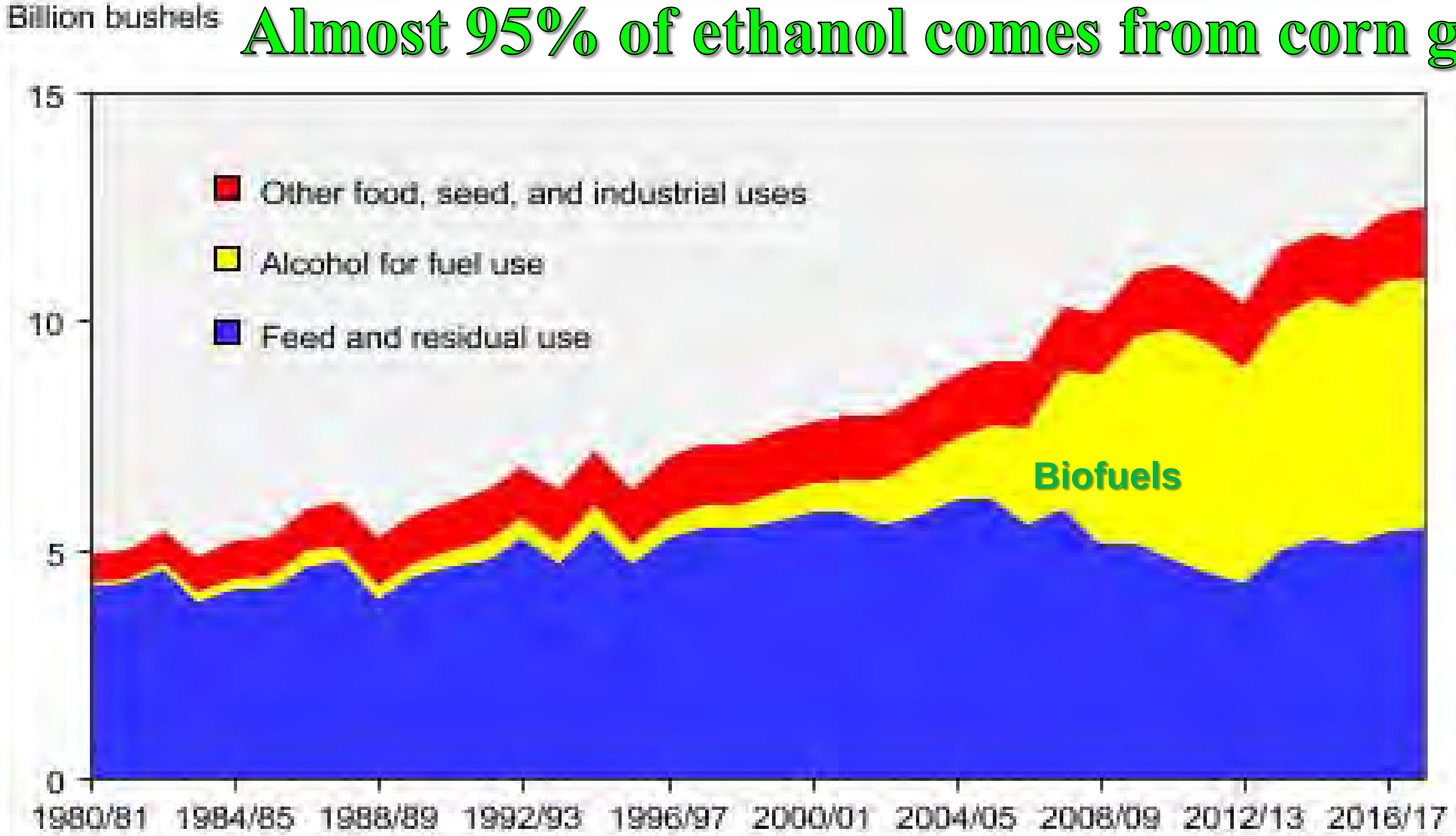
Greater Recognition of Environmental Consequences

Biofuels

- Carbon sources derived from photosynthesis
- Less green house gas emissions
- Less dependence on foreign sources for energy
- Supports rural economies
- Currently mandated by Congress

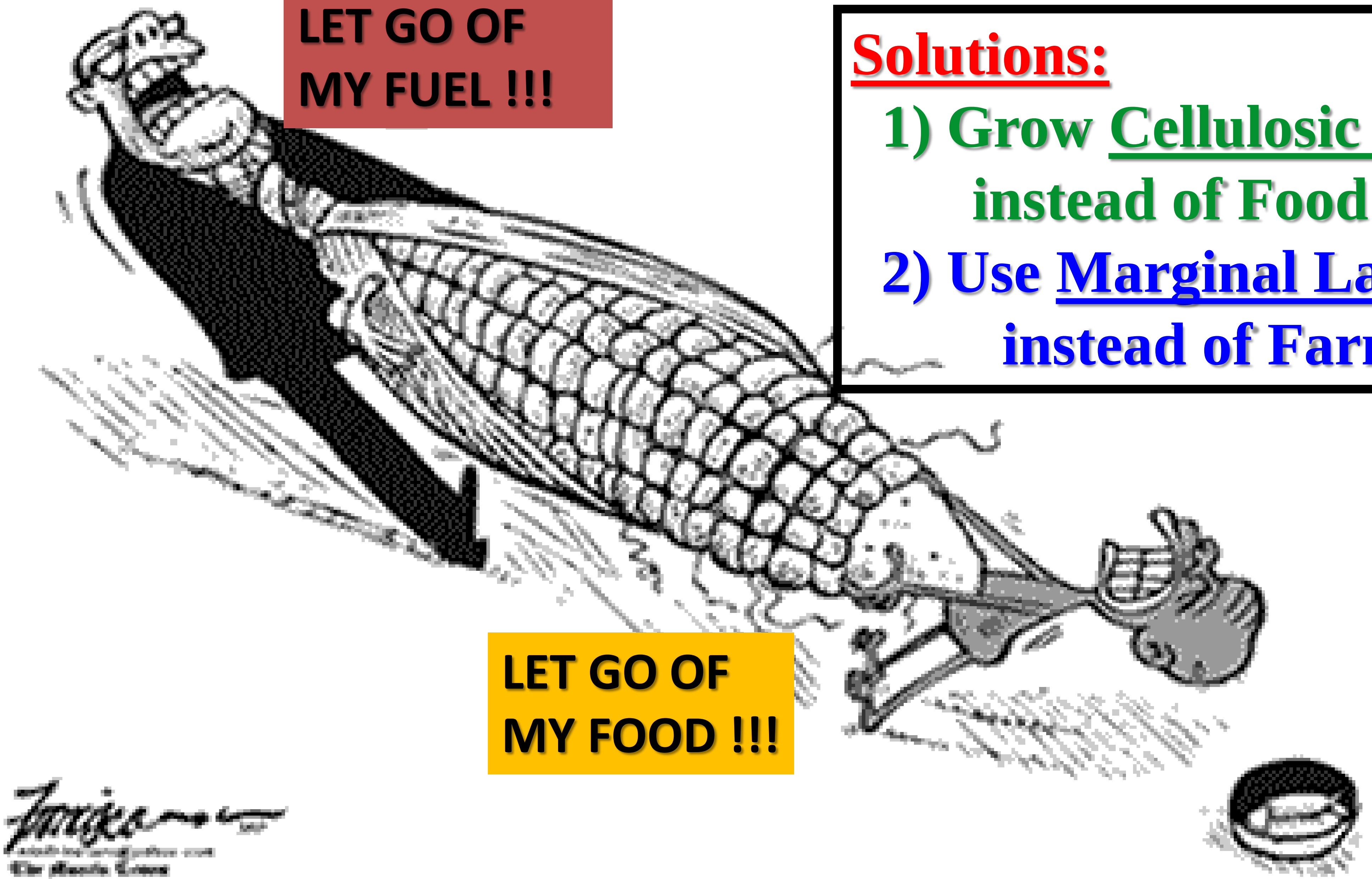
Biofuel Ethanol – Corn

Almost 95% of ethanol comes from corn grain!



Source: Calculated by USDA, Economic Research Service.
Updated: August 2017.

Food vs. Fuel Debate



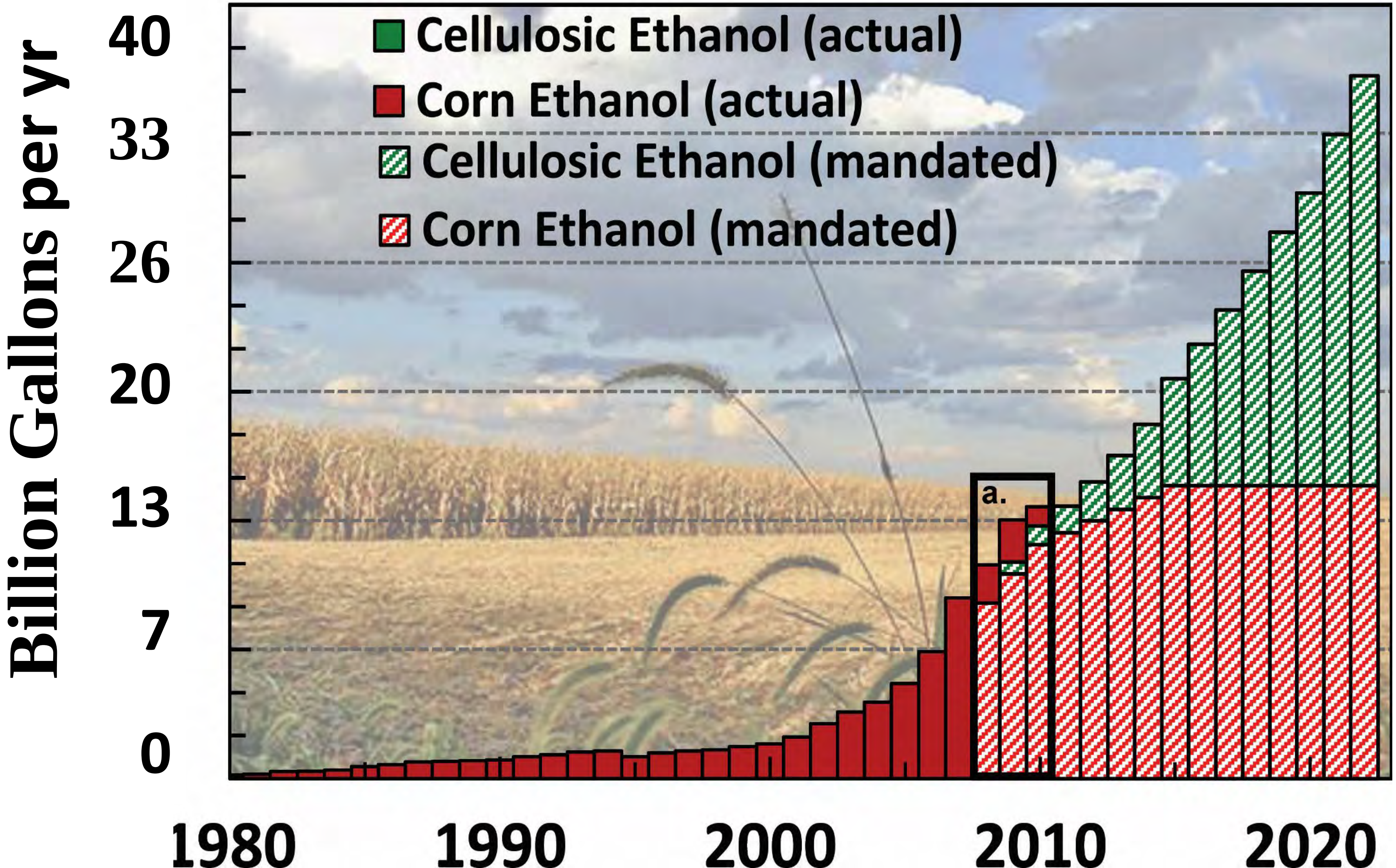
Solutions:

1) Grow **Cellulosic Crops** instead of Food Crops
2) Use **Marginal Lands** instead of Farmland

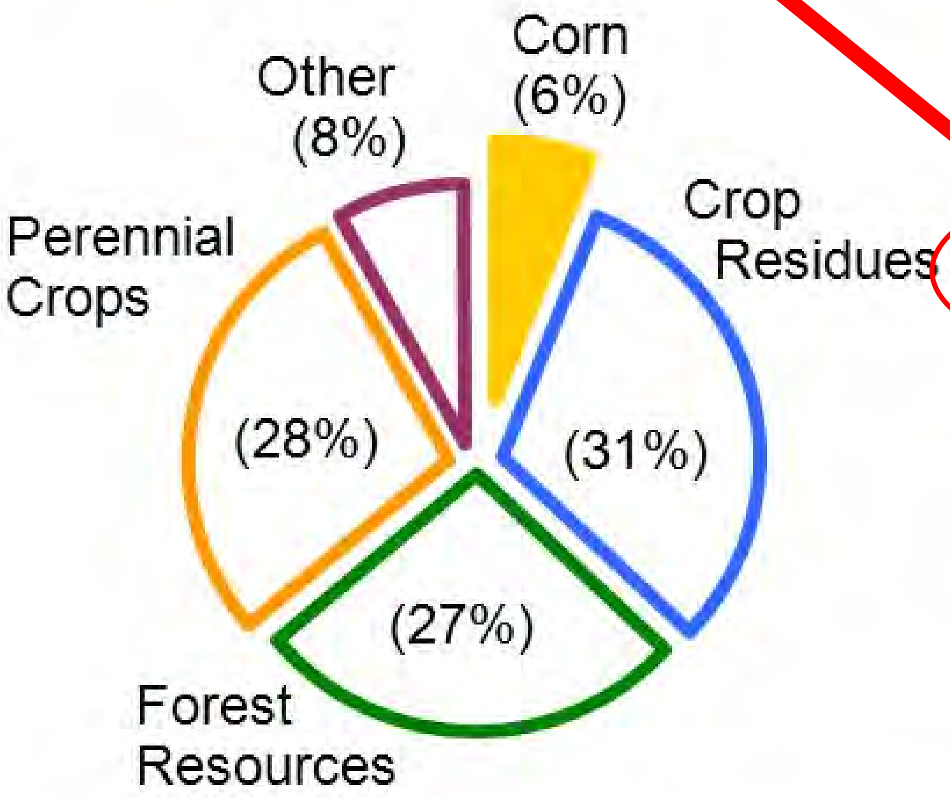
Ethanol Mandates

Renewable Fuel Standard

14 Billion Gallons now (10%)
36 Billion Gallons in 2022 (26%)



Future Production of Biofuels: Sources



Projected U.S. Biofuel Sources

Today: Nearly all ethanol is made from corn grain

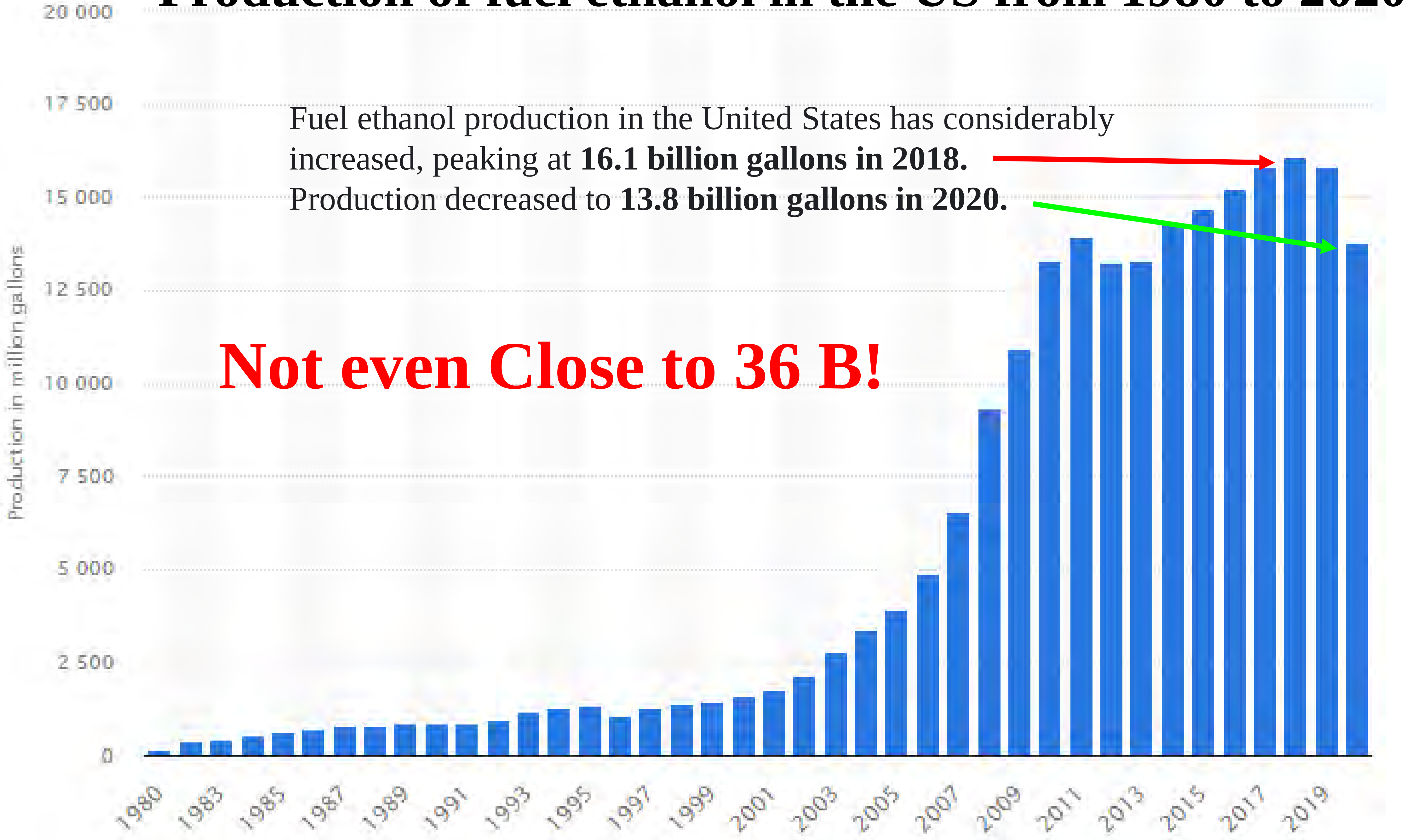
The Future: Cellulosic biomass will be the primary source for fuel ethanol

Benefits of Cellulosic Ethanol

- Emits up to 86% less greenhouse gases than reformulated gasoline
- Relies on non-food and waste resources

Source: *Biomass as Feedstock for a Bioenergy and Bioproducts Industry:*

Production of fuel ethanol in the US from 1980 to 2020



Plants to Fuel

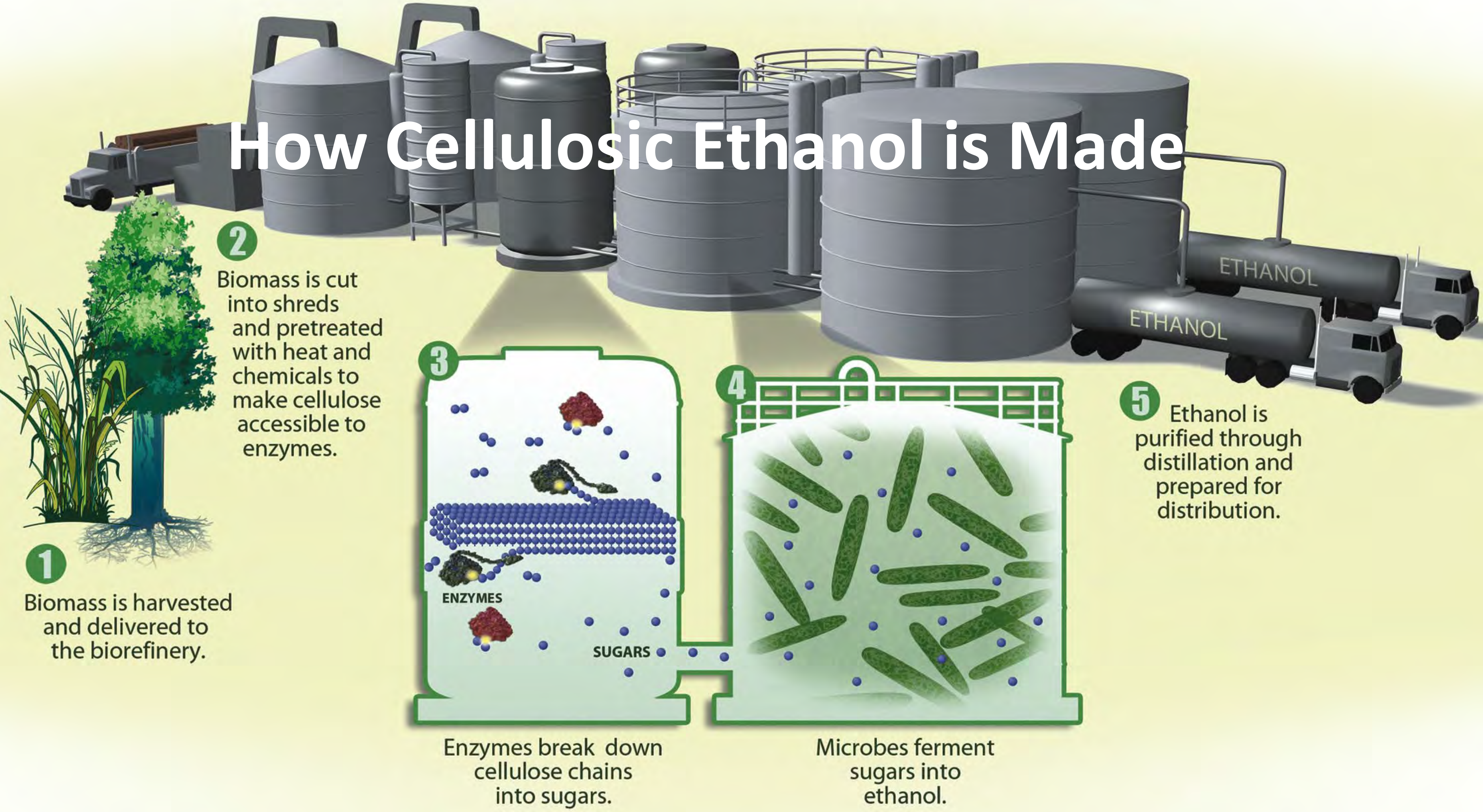
The Basic Steps…

1. Convert feedstocks to simple sugars

2. Fermentation

3. Recovery of Ethanol

How Cellulosic Ethanol is Made



Ethanol Plants

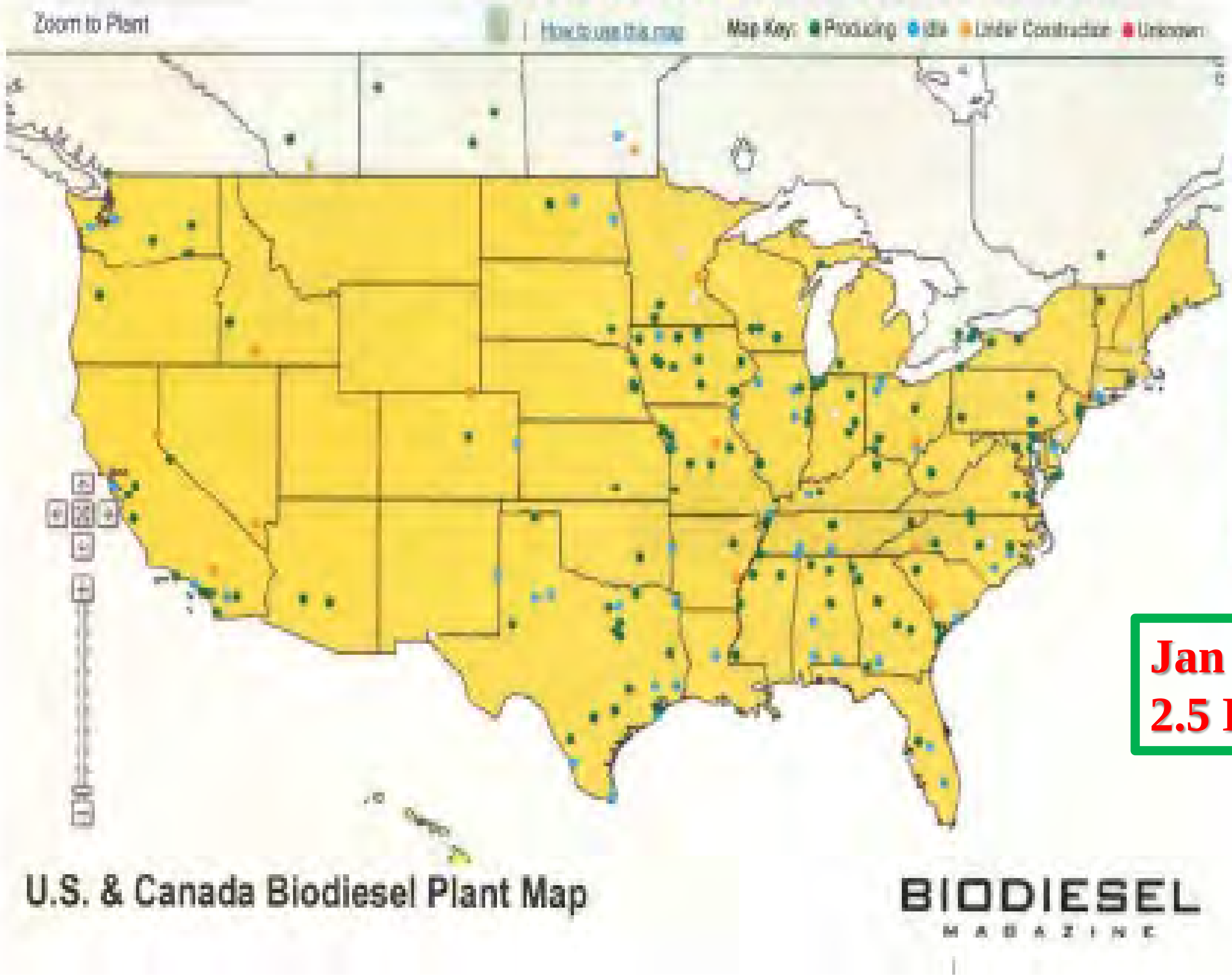
Operating plants
134 Plants in USA
in 26 states 11.7 BGY
40 Plants in Iowa 3.2 BGY

Construction/expansion
21 Plants in USA 1.4 BGY
2 Plants in Iowa 0.4 BGY

June 2022, 195 plants
17.7 BGY capacity

4 being built, ND, SD, KS, IN

Biodiesel Plants in USA



Operating Plants
173 Plants in USA
2.7 bgy capacity
15 operating in Iowa
322.5 mgy production

Jan 2020, 124 plants
2.5 BGY capacity

So what do we need to do to encourage biomass for fuel?

1. Cellulosic biomass feedstocks
2. Marginal lands
3. Cost incentives
4. Consumer desire

Biomass Feedstocks

Starch & Sugar based Feedstocks

- Corn
- Sugarcane
- Sugar beets

From Here

to There

Cellulosic Feedstocks

Ag Plant Wastes:

- Corn Stover
- Cereal Straws
- Forest Residues

Plant Wastes from Industrial Processes:

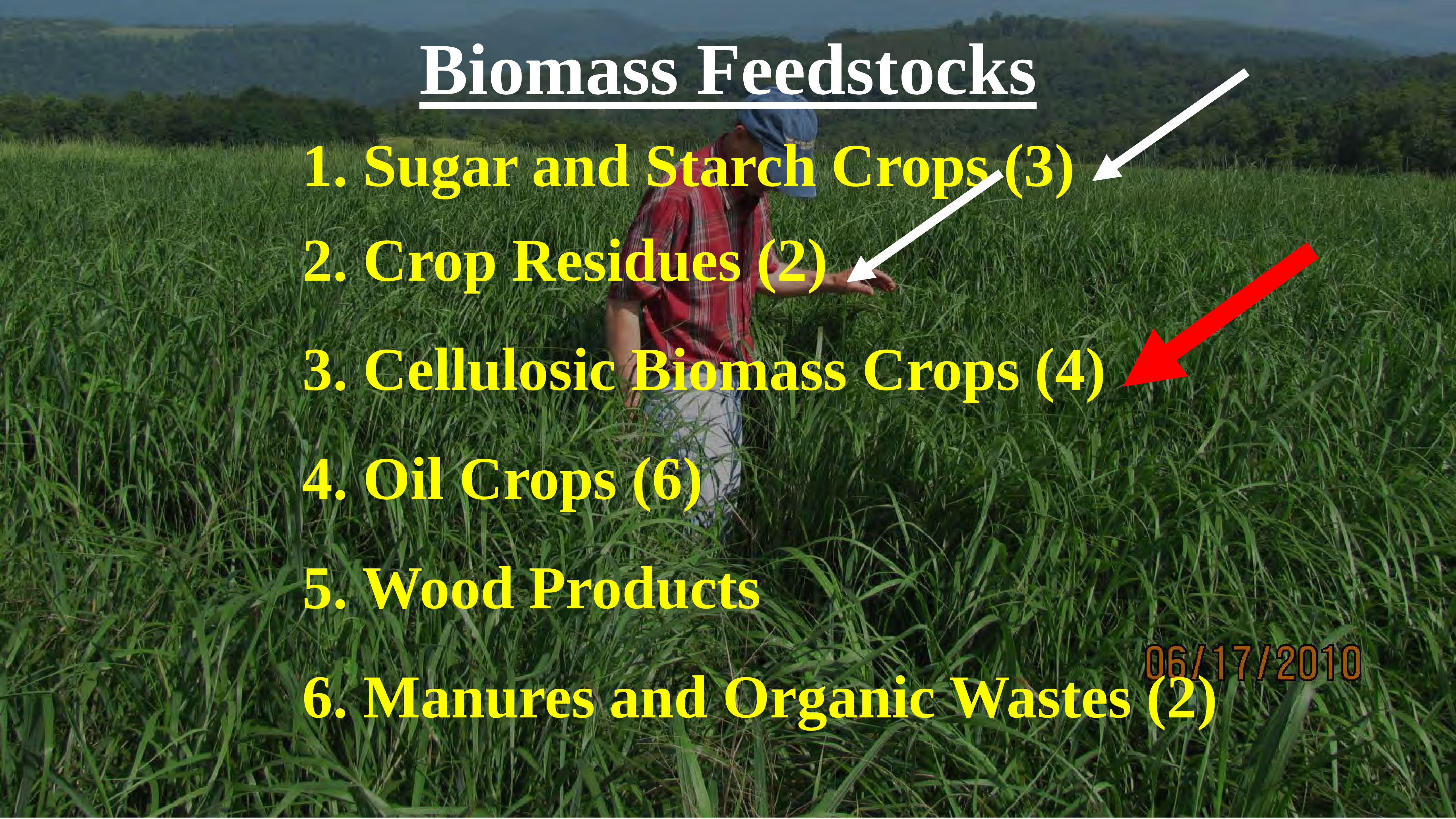
- Sawdust
- Paper Pulp

Energy Crops:

- Switchgrass
- Miscanthus, Willow

Biomass Feedstocks

1. Sugar and Starch Crops (3)
2. Crop Residues (2)
3. Cellulosic Biomass Crops (4)
4. Oil Crops (6)
5. Wood Products
6. Manures and Organic Wastes (2)



BIOMASS FEEDSTOCKS

1. Sugar Crops: Corn, Sugarcane, Sugar Beets
2. Crop Residues: Corn Stover, Straws, Hay
3. Cellulosic Crops:
   Switchgrass, Miscanthus,
   Biomass Sorghum, Giant cane,
   Willows, Hybrid Poplar

3a. Cellulosic Crops: Switchgrass

- Warm season perennial grass **native** to North America
- Adapted to a wide variety of growing conditions including **marginal acres** unsuited for row crop production, **seed**
- High biomass production with very **few inputs**
- Cellulose converted to simple sugars and then fermented

Ideal traits of a biomass energy crop

- C_4 photosynthesis
- Long canopy duration
- Accessible cellulose in shoots
- Recalcitrant carbon in roots
- Perennial
- Ease of rotation
- No known pests or diseases
- Provide wildlife habitat
- Rapid spring growth (out compete weeds)
- Rapid fall drydown
- Sterility
- Partitions nutrients to roots in fall
- Aggressive root system sequesters carbon
- High water use efficiency
- Multiple use (animal feed)
- Use existing farm equipment

Source: modified from Raghu et al. Science 313:1742

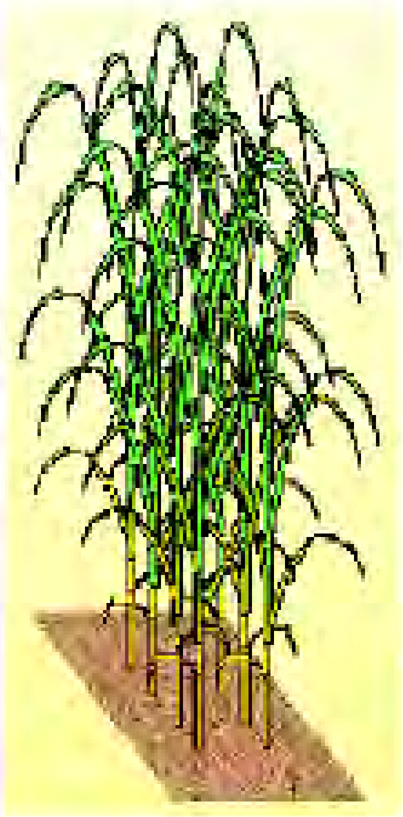
Switchgrass (*Panicum virgatum*)

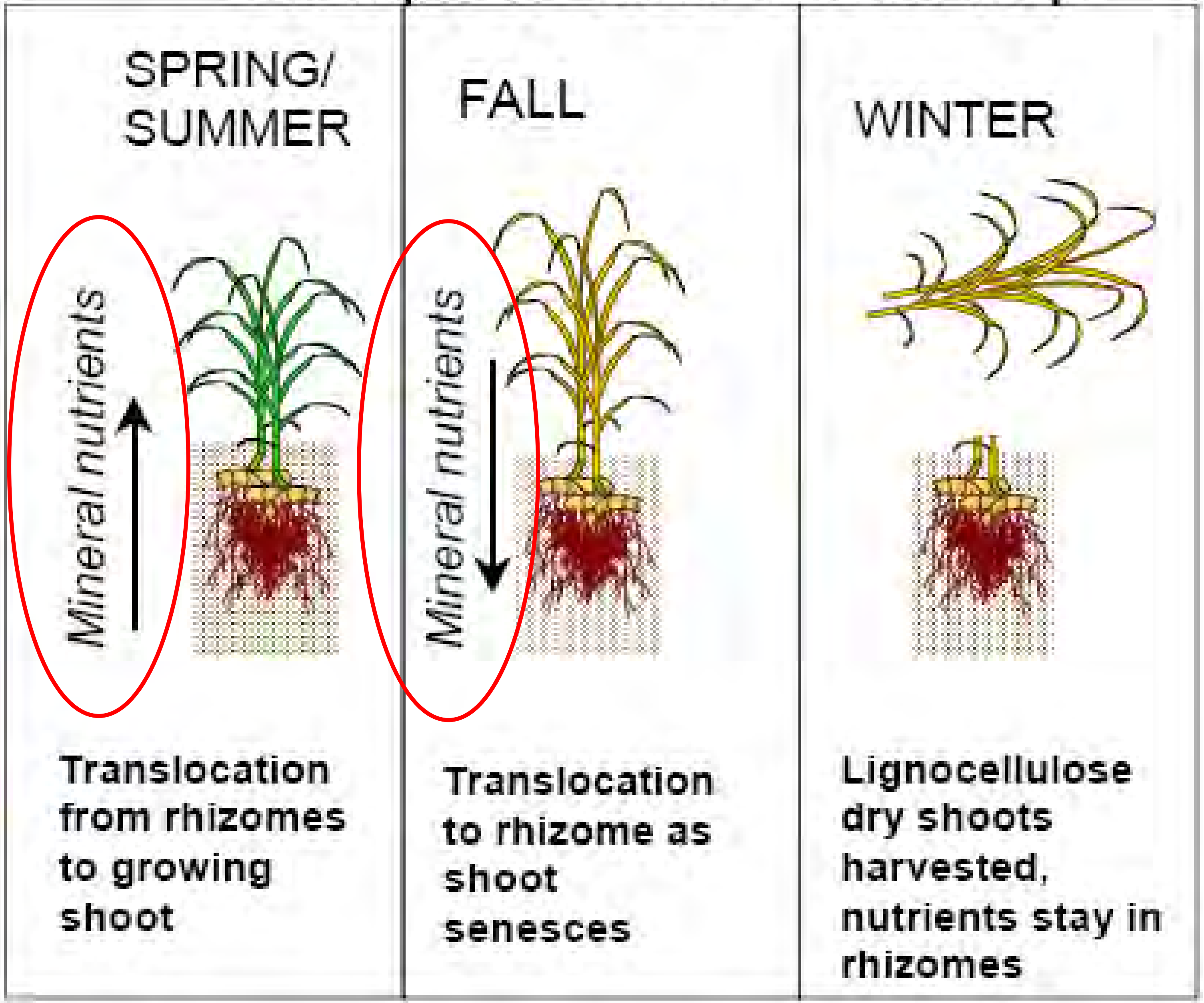
1991 the decision to pursue switchgrass as a "model" or "prototype" bioenergy crop was made based on the economic and environmental assessments by the Oak Ridge National Laboratory's Biofuels Feedstock Development Program (1984-1991)

– C_4 - High Water and Nitrogen Use Efficiency
– High yields potential even on relative poor quality sites, deep rooting characteristics
– Significant capacity to improve soil quality by sequestering carbon & reduced soil erosion
– Reduced fertilizer and pesticide requirements relative to conventional annual crops.

Source: ORNL/TM-2007/109

Example of "Ideal" biofuel crop





Source Dr. Steve Long, UIUC 2005

Switchgrass Yields

Study	Yield $Mt\ ha^{-1}$	Description
Fike et al. (2006a)	14	4 cultivars, 8 sites, 5 states (including WV)
Vogel & Masters (1998)	15	3 states in Midwestern US
Fike et al. (2006b)	14	Years 6 - 9 of production
McLauglin & Kszoz (2005)	11 – 19	Cave-in-Rock; 10-year study in 13 states
Schmer et al. (2008)	5 – 11	Marginal cropland
Mulkey et al. (2006)	< 7.5	CRP land in South Dakota

Goal would be 5.0 $Mt\ ha^{-1}$

3b. Cellulosic Crops: Miscanthus

- Warm season **perennial** grass native to Asia
- Biomass variety sterile so limited chance of invasive weed, **rhizomes**
- Very high biomass production for 15 years **with few inputs**
- Cellulose converted to simple sugars and then fermented

Miscanthus giganteus: life cycle

- *Miscanthus x giganteus is a perennial,* warm-season grass with a C4 photosynthetic pathway. Unlike most C4 species, photosynthesis and leaf growth can be sustained at relatively low temperatures (as low as 43°F).
- Because *Miscanthus x giganteus is sterile it* must be propagated vegetatively from rootstock.
- *Miscanthus x giganteus grows as a*bunchgrass and will spread slowly with short rhizomes. It has erect stems, 5 to12 feet tall.
- Dry matter accumulation increases rapidly during June, July, and August,reaching its maximum dry matter yield in late-summer.
- Autumn frost stops annual growth of miscanthus. Regrowth in Michigan begins in May.
- Miscanthus has a lengthy stand life. Replanting is necessary after 15 years.


Incredible growth potential
After only 2 years! 15 tons/ac


After 6 and 8 years



A variety of conventional hay forage equipment is suitable for harvesting both switchgrass and Miscanthus


3c. Cellulosic Crops: Biomass Sorghum

- Warm season annual grass
- Very high biomass production, seed annually
- Cellulose converted to simple sugars and then fermented
- Harvested with traditional forage equipment – can be pelletized

3d. Cellulosic Crops: Willow and Poplar

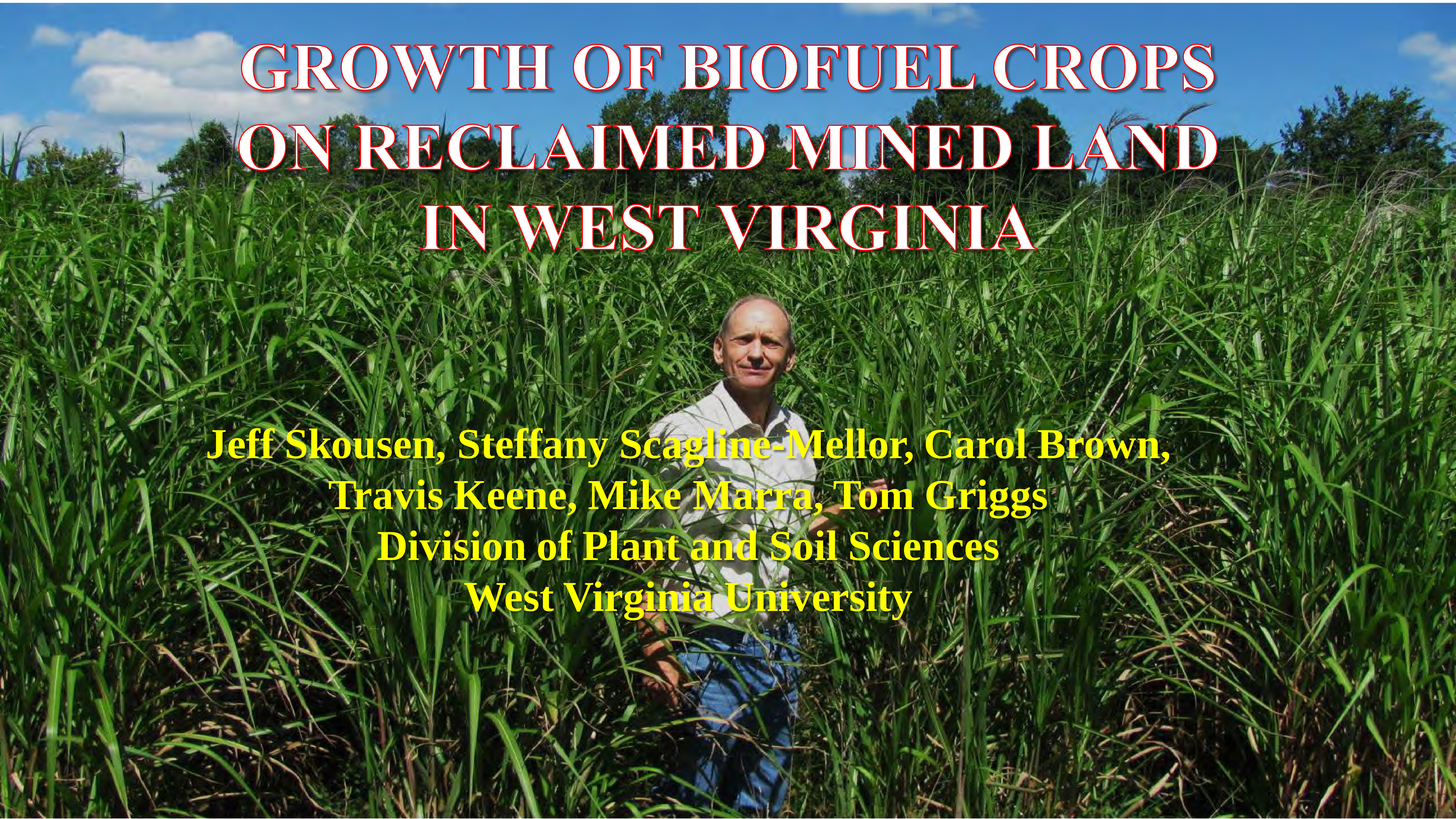
Willow trial in New York

Projected biofuel yield

Crop	Ps	Bu/wt	Crop Yield	Biofuel	EtOH or oil/bu	EtOH or oil yield/A
Corn	C4	56 lb	150 bu/a	EtOH	2.8 gal	420 gal
**Corn + Stover		56 lb	150 bu/a 3.5 ton	EtOH	2.8 gal 72 gal/ton	420 252 672 gal
Switchgrass	C4	NA	8 ton/a	EtOH	72 gal/ton	576 gal
Miscanthus	C4	NA	10 ton/a	EtOH	72 gal/ton	720 gal
Sugarcane	C4	NA		EtOH		600 gal
Soybean	C3	60 lb	40 bu/a	Diesel	1.5 gal	62 gal
Sunflower	C3	27 lb	50 bu/a	Diesel	1.5 gal	77 gal
Canola	C3	50 lb	42 bu/a	Diesel	2.9 gal	120 gal
Palm trees	C3			Diesel		587 gal
Jatropha	C3			Diesel		250 gal

Similar to Corn

GROWTH OF BIOFUEL CROPS ON RECLAIMED MINED LAND IN WEST VIRGINIA



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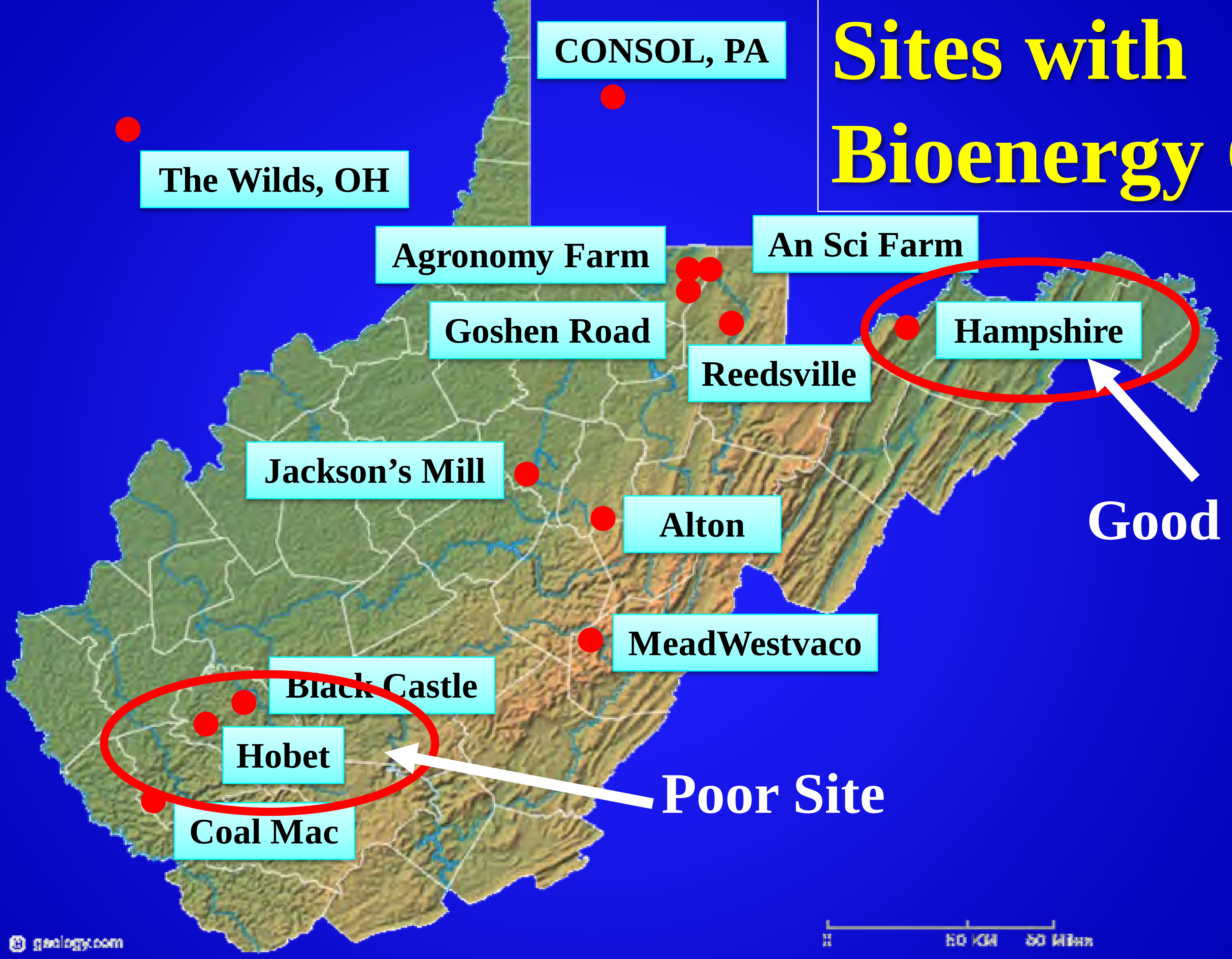
Sites with Bioenergy Crops



Results – Yield

7th Yr

Variety	Good Hampshire	Poor Hobet
	Mt ha^{-1}	
Cave in Rock	19.0	1.8
Carthage	5.7	1.5
Shawnee	10.0	1.5

Hampshire – 2nd Yr Switchgrass on Reclaimed Mine


Hampshire – Switchgrass
7th Year
About 19 Mt ha-1
10.16.2015

Hobet – Switchgrass

7th Year

< 2.0 Mt ha^{-1}

Journal of Environmental Quality
TECHNICAL REPORTS
ECOSYSTEM RESTORATION

Switchgrass Yield on Reclaimed Surface Mines for Bioenergy Production

Michael Marra, Travis Keene, Jeff Skousen,* and Thomas Griggs

The high cost of transportation fuels and the environmental risks associated with acquiring and using nonrenewable energy sources have created a demand for developing renewable bioenergy crops. Switchgrass (*Panicum virgatum* L.), a warm-season perennial grass, is a promising feedstock due to its high biomass production under a wide range of growing conditions and its satisfactory forage quality

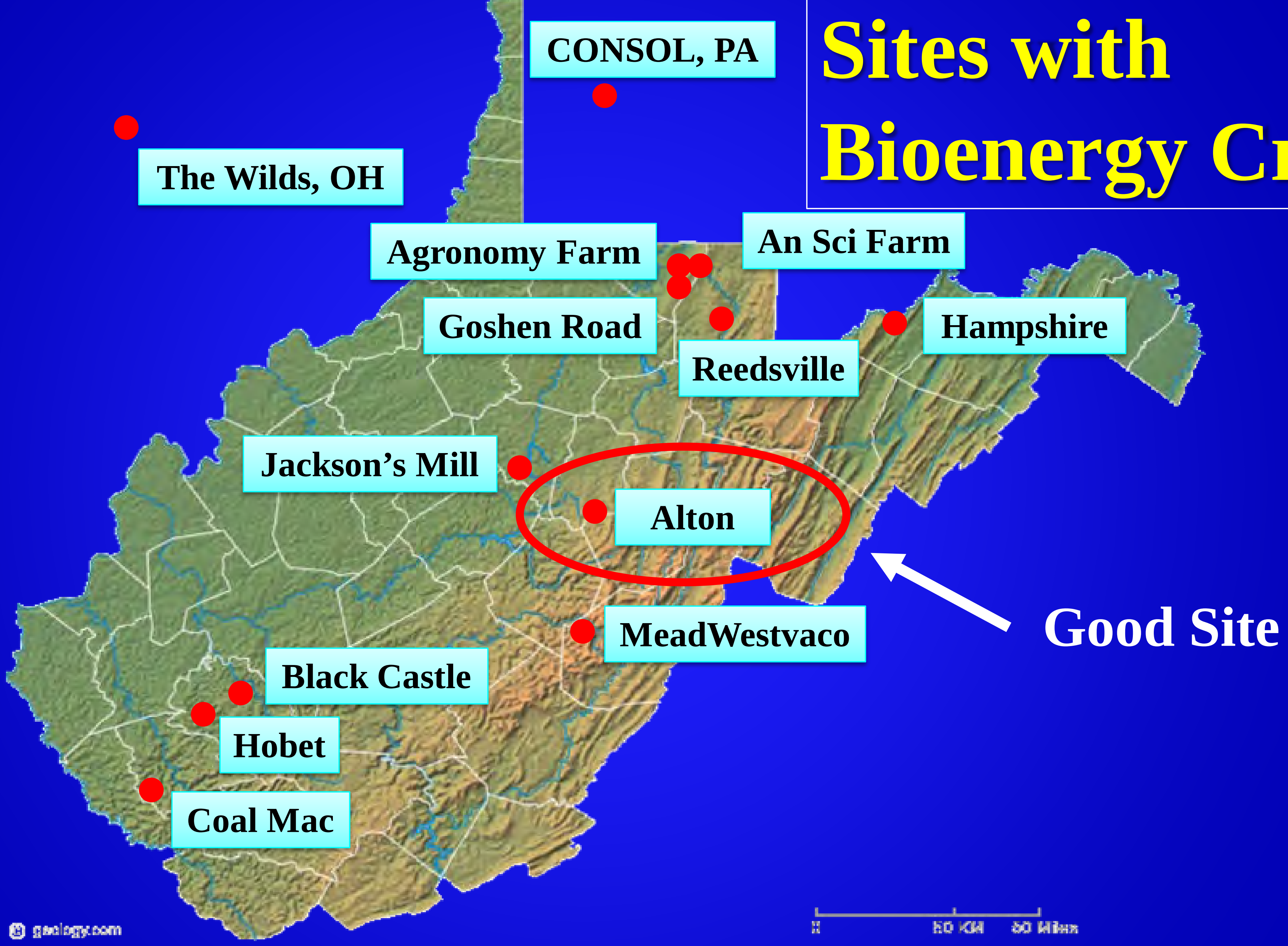
CHANGES IN ENERGY USAGE from fossil fuels (oil, coal, and gas) to biomass (recent plant-based organic materials) has gained considerable interest with climate change legislative mandates, rising oil prices, and world market uncertainty (Ragauskas et al., 2006; Tilman et al., 2009). This change in the use of petroleum products, which make up 94% of

Bioenerg. Res. (2016) 9:40–49
DOI 10.1007/s12155-015-9657-3

Switchgrass Biofuel Production on Reclaimed Surface Mines: II. Feedstock Quality and Theoretical Ethanol Production

Carol Brown[1] · Thomas Griggs[1] · Ida Holaskova[1] · Jeff Skousen[1]

Sites with Bioenergy Crops

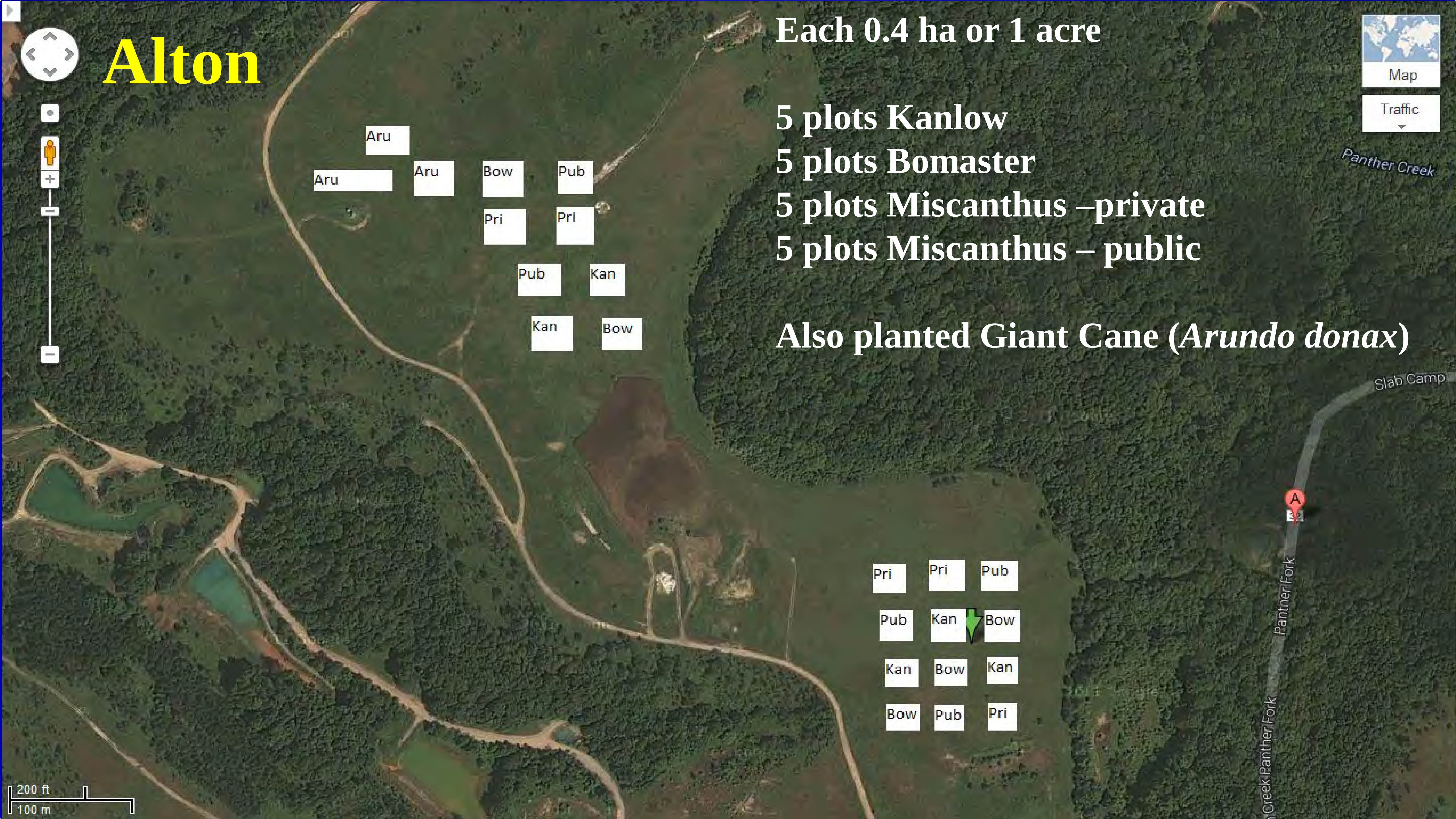


Alton

Each 0.4 ha or 1 acre

5 plots Kanlow
5 plots Bomaster
5 plots Miscanthus –private
5 plots Miscanthus – public

Also planted Giant Cane (*Arundo donax*)



Miscanthus planting trial at Alton, WV

Sprigs

We had tree planters do the sprig planting


07/29/2010


07/29/2010
Two months later

Or you can plant rhizomes

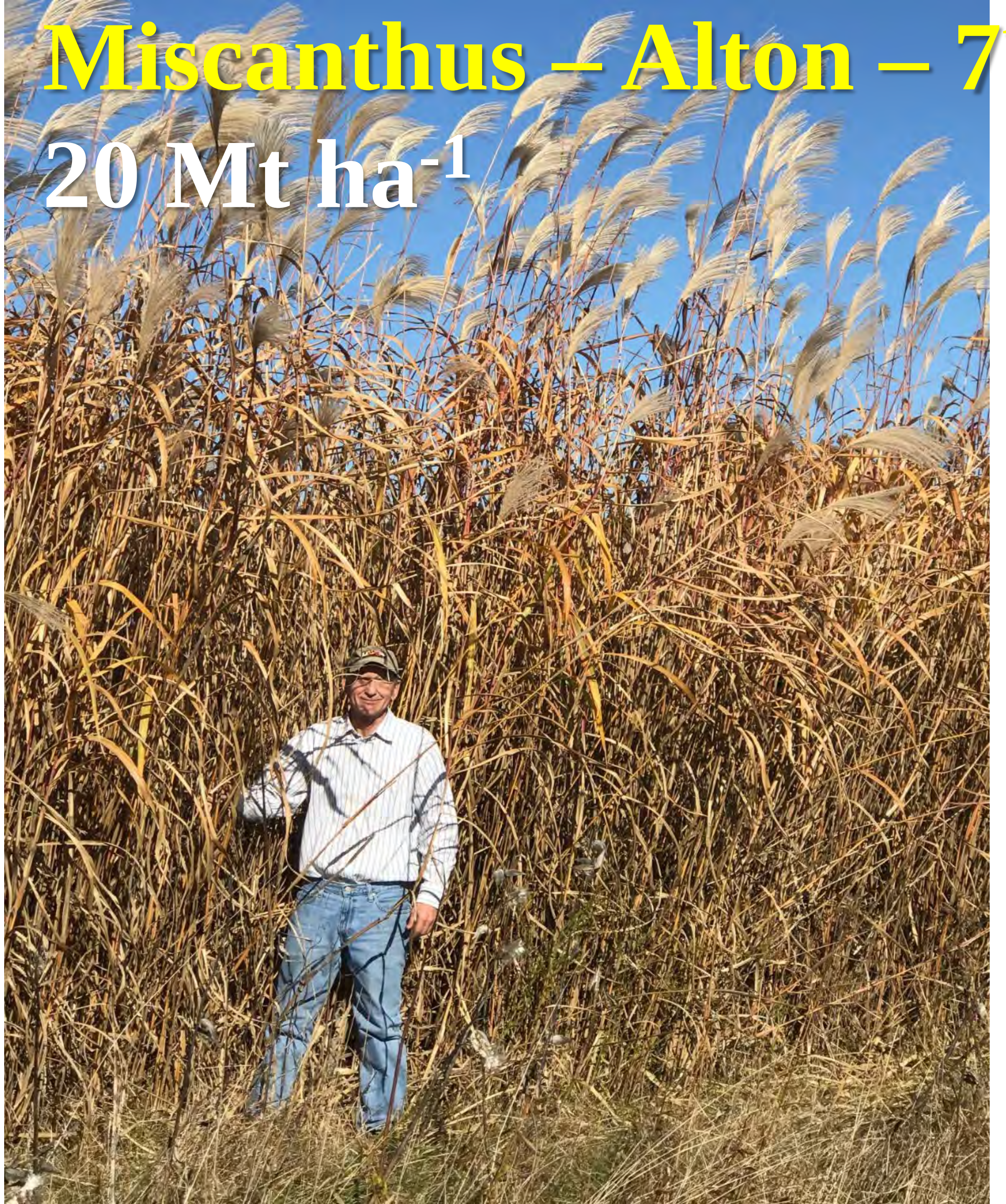
Miscanthus – Alton – 2nd Yr

15 Mt ha^{-1}


Miscanthus – Alton – 5th Yr
13 Mt ha^{-1}

Miscanthus – Alton – 7^{th} Yr

20 Mt ha^{-1}



Variety	3rd Yr	5th Yr
	------------ Mt ha^{-1} ----------	
Miscanthus		
Public	4.9	14.4
Private	15.5	13.7

Goal is 7.5 Mt ha^{-1}

BioEnergy Research (2018) 11:562–573
https://doi.org/10.1007/s12155-018-9915-2

Switchgrass and Giant Miscanthus Biomass and Theoretical Ethanol Production from Reclaimed Mine Lands

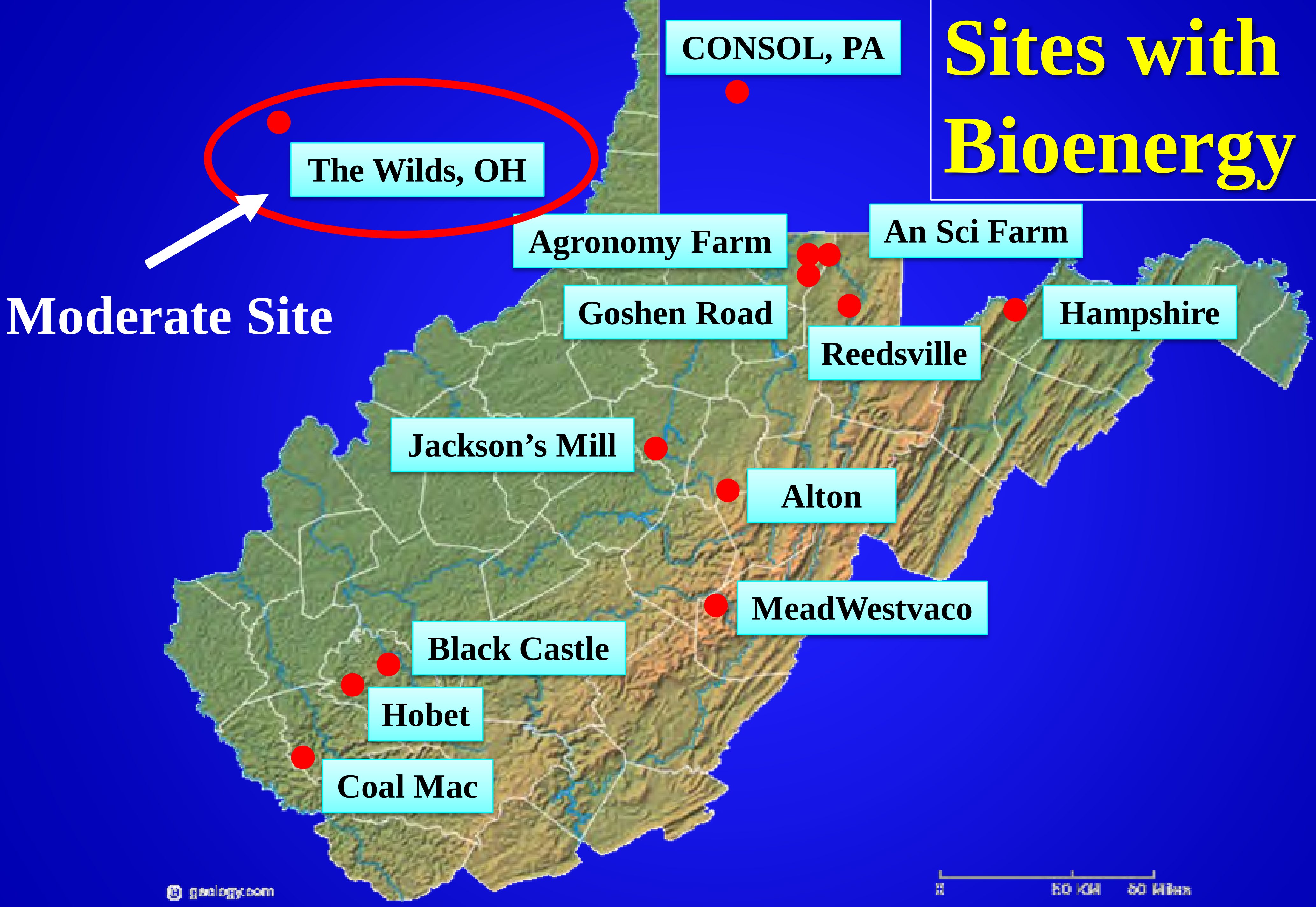
Steffany Scagline-Mellor[1] · Thomas Griggs[2] · Jeffrey Skousen[2] · Edward Wolfrum[3] · Ida Holásková[4]

Published online: 19 May 2018

Abstract

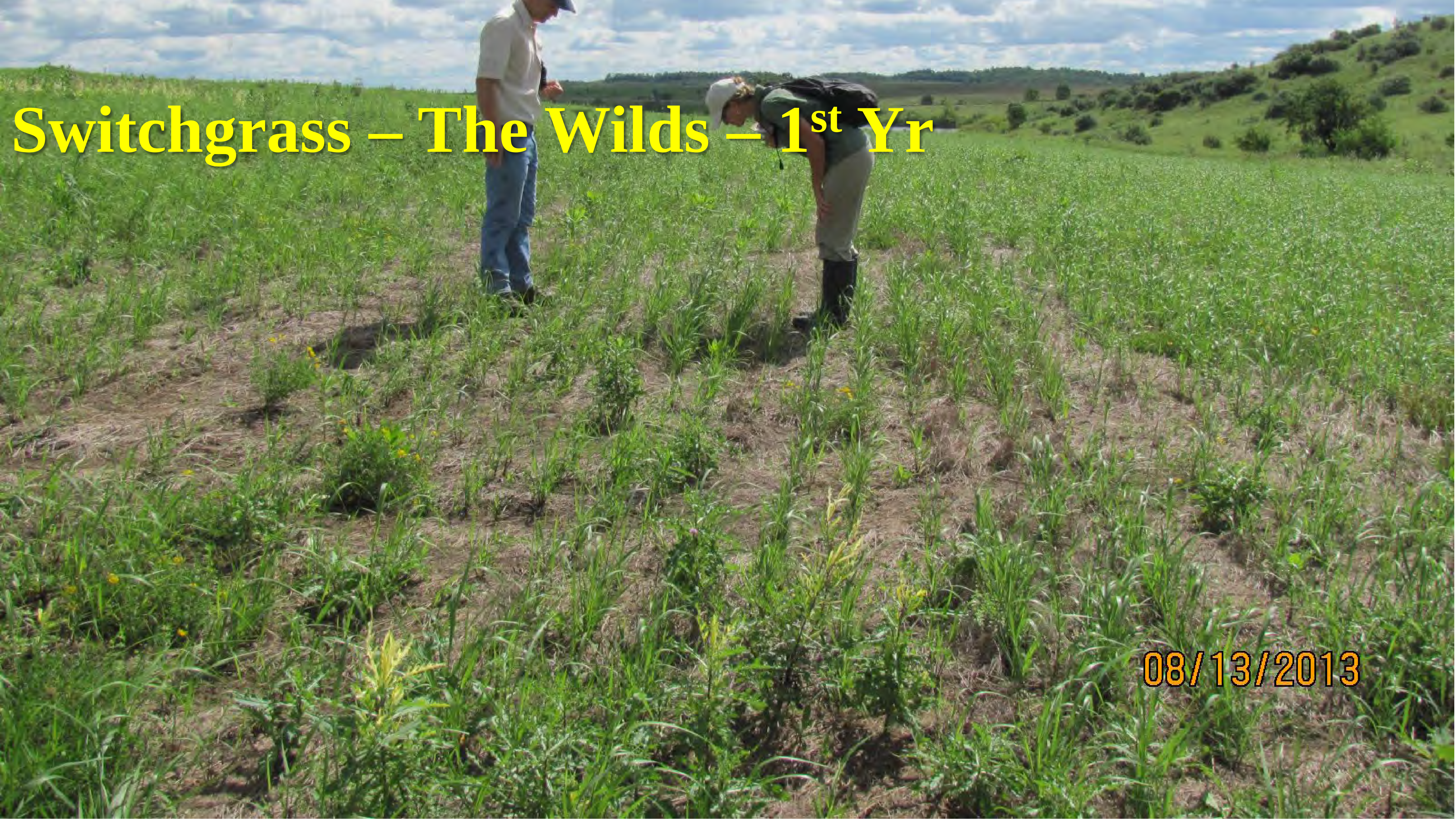
Switchgrass (*Panicum virgatum* L.) and giant miscanthus (*Miscanthus x giganteus* Greef & Deuter ex Hodkinson & Renvoize) are productive on marginal lands in the eastern USA, but their productivity and composition have not been compared on mine lands. Our objectives were to compare biomass production, composition, and theoretical ethanol yield (TEY) and production (TEP) of these grasses on a reclaimed mined site. Following 25 years of herbaceous cover, vegetation was killed and plots of switchgrass cultivars Kanlow and BoMaster and miscanthus lines Illinois and MBX-002 were planted in five replications. Annual switchgrass and miscanthus yields averaged 5.8 and 8.9 Mg dry matter ha^{-1}, respectively, during 2011 to 2015. Cell wall carbohydrate composition was analyzed via near-infrared reflectance spectroscopy with models based on switchgrass or mixed herbaceous samples including switchgrass and miscanthus. Concentrations were higher for glucan and lower for xylan in miscanthus than in switchgrass but TEY did not differ (453 and 450 L Mg^{-1}, respectively). In response to biomass production, total ethanol production was greater for miscanthus than for switchgrass (5594 vs 3699 L ha^{-1}), did not differ between Kanlow and BoMaster switchgrass (3880 and 3517 L ha^{-1}, respectively), and was higher for MBX-002 than for Illinois miscanthus (6496 vs 4692 L ha^{-1}). Relative to the mixed feedstocks model, the switchgrass model slightly underpredicted glucan and slightly overpredicted xylan concentrations. Estimated TEY was slightly lower from the switchgrass model but both models distinguished genotype, year, and interaction effects similarly. Biomass productivity and TEP were similar to those from agricultural sites with marginal soils.

Sites with Bioenergy Crops



The Wilds – Drilling into herbicided vegetation

Switchgrass – The Wilds – 1st Yr



Switchgrass – The Wilds – 5th Yr

8 Mt ha^{-1}

Miscanthus – The Wilds – 7th Yr

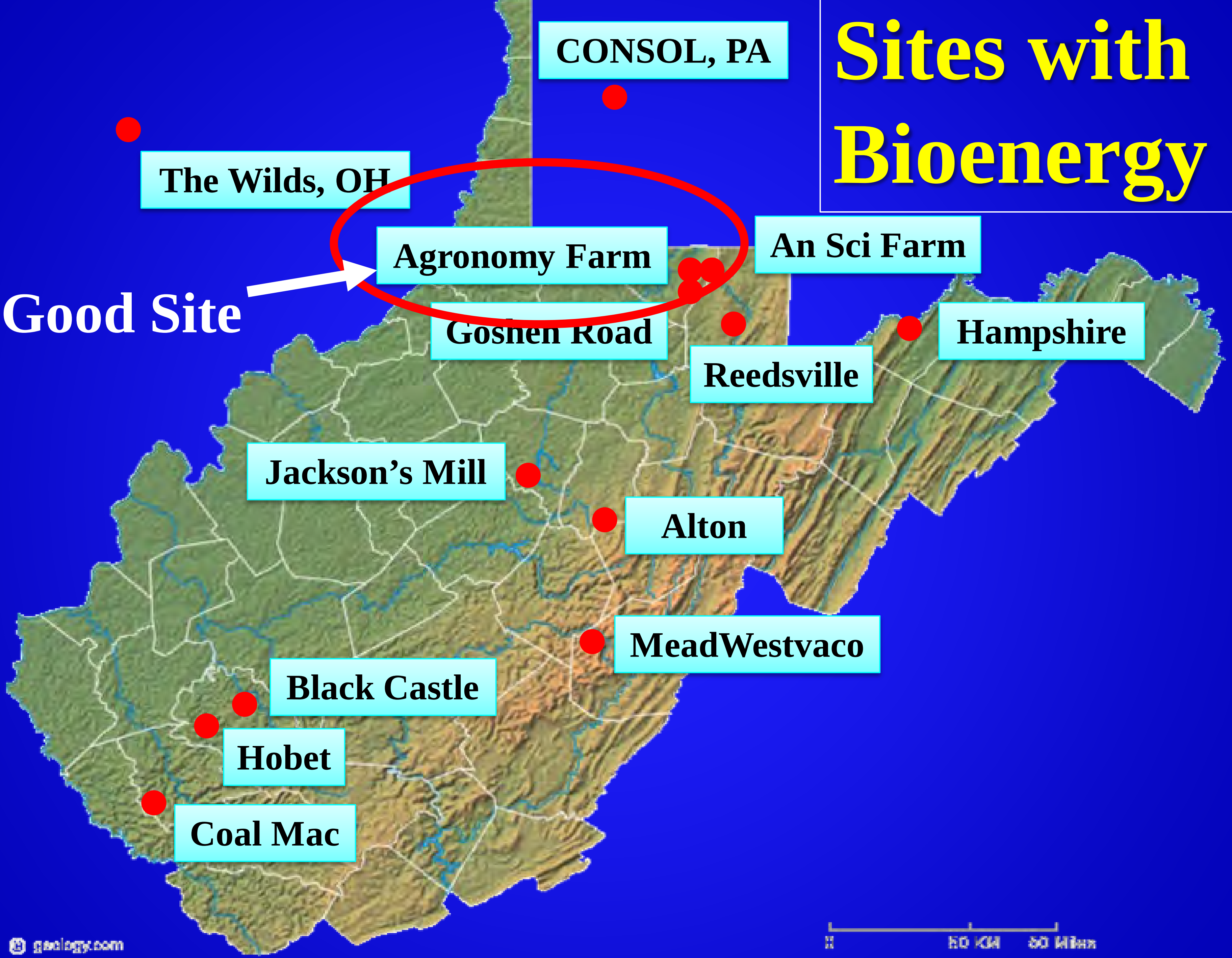
15 Mt ha^{-1}

20-ac Switchgrass field in Ohio at The Wilds

Harvest with conventional haying equipment

Switchgrass Bales

Sites with Bioenergy Crops




Miscanthus
Ag Site


Mine Site

Miscanthus
Rhizosphere microbiome


Biomass Sorghum


Giant Cane
(*Arundo donax*)
10/26/2012

Why Biofuels?

Can we grow them?

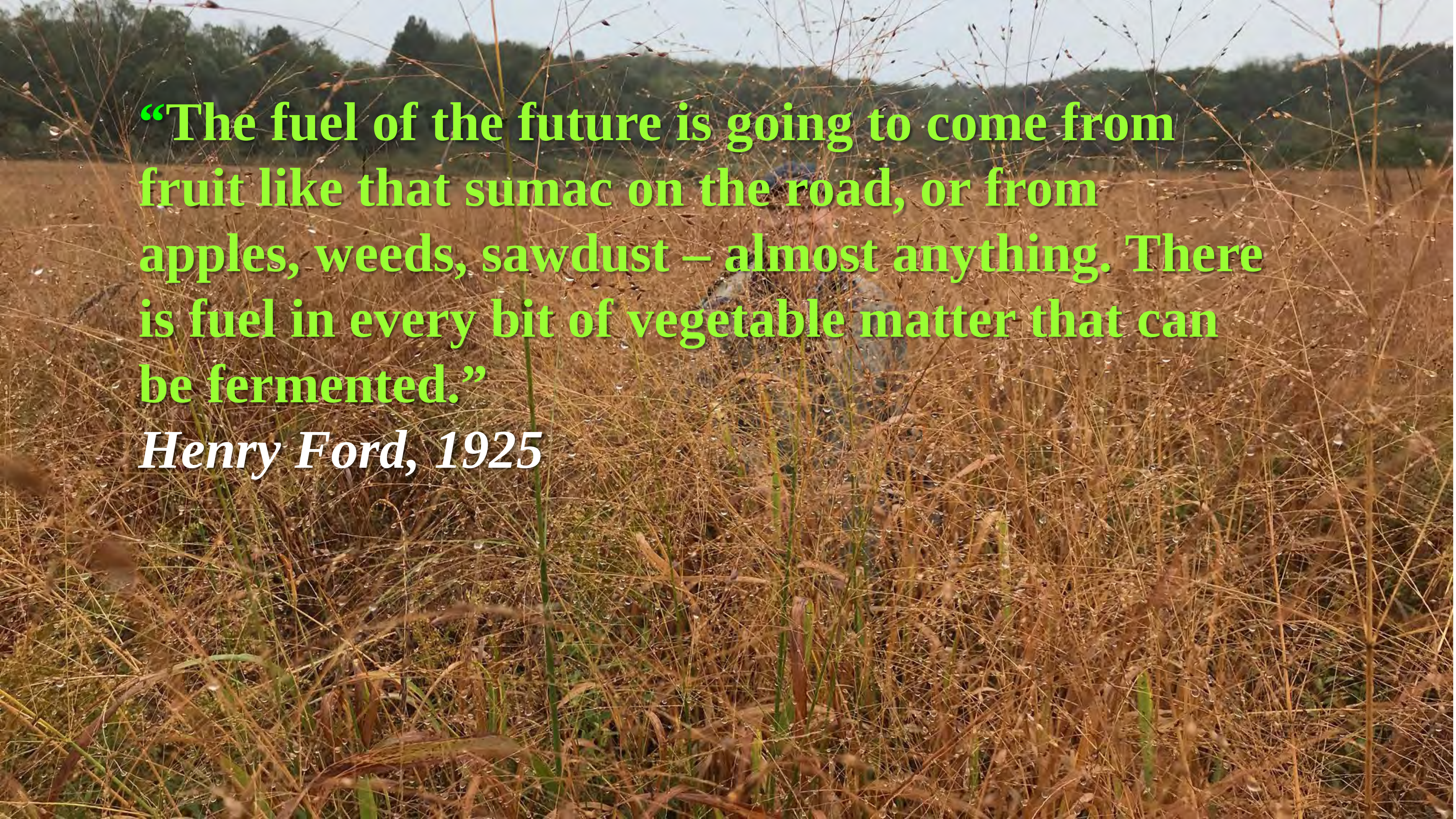
Why hasn’t it happened?

Summary

- **Perennial Grasses show great promise as bioenergy crops for Ethanol.**
- **Switchgrass and Miscanthus have demonstrated high growth potential on marginal lands.**
- **Other grasses are being tested.**

What offers the best ideas for future ethanol production?

1. Use cellulosic crops instead of corn
2. Grow on marginal lands
3. Grow on reclaimed mine lands


"The fuel of the future is going to come from fruit like that sumac on the road, or from apples, weeds, sawdust – almost anything. There is fuel in every bit of vegetable matter that can be fermented."
Henry Ford, 1925

Questions?