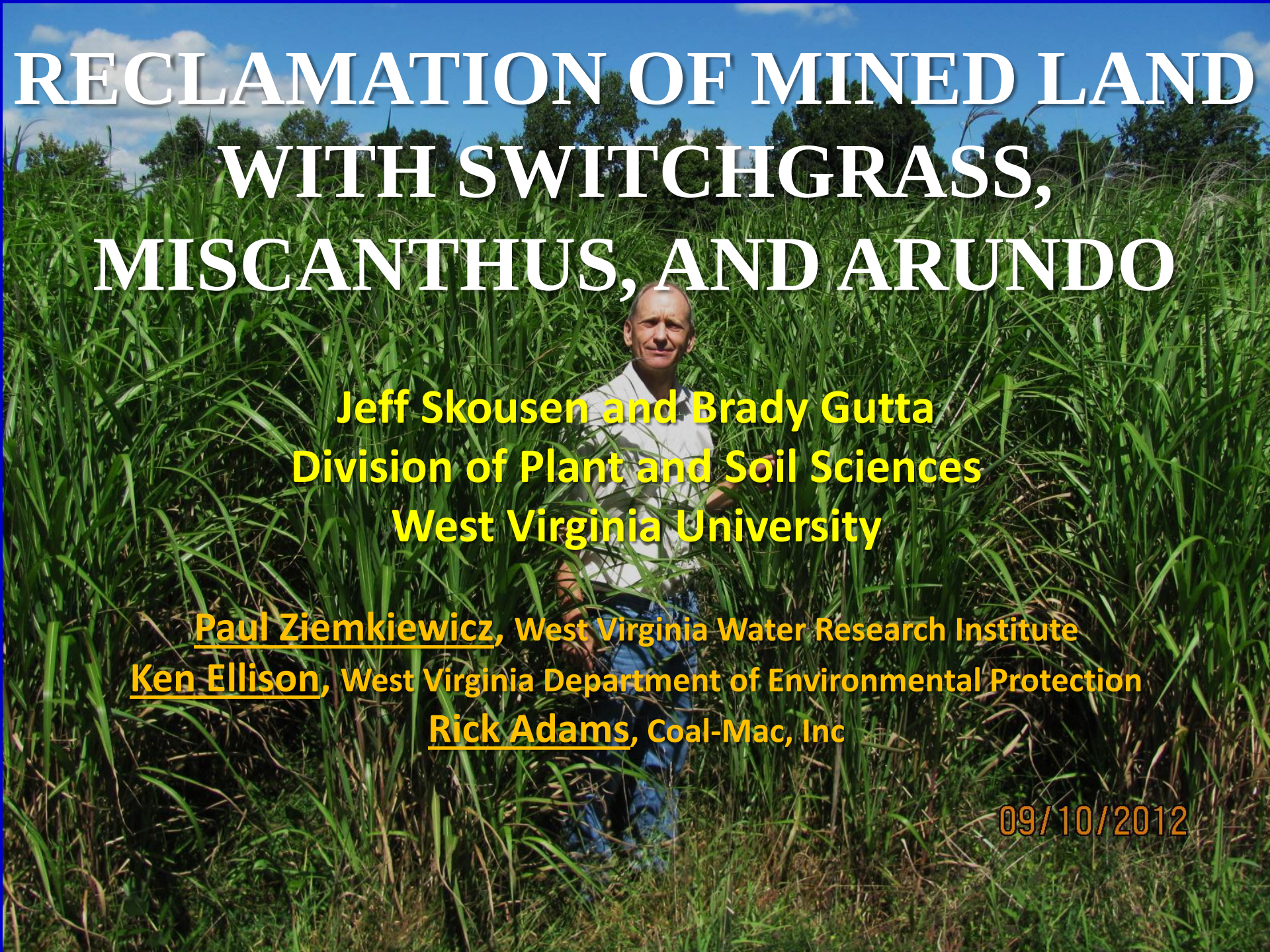
RECLAMATION OF MINED LAND WITH SWITCHGRASS, MISCANTHUS, AND ARUNDO



Jeff Skousen and Brady Gutta
Division of Plant and Soil Sciences
West Virginia University

Paul Ziemkiewicz, West Virginia Water Research Institute
Ken Ellison, West Virginia Department of Environmental Protection
Rick Adams, Coal-Mac, Inc

09/10/2012

Reasons for turning to Biofuel:

High Energy Prices

Increasing Energy Imports

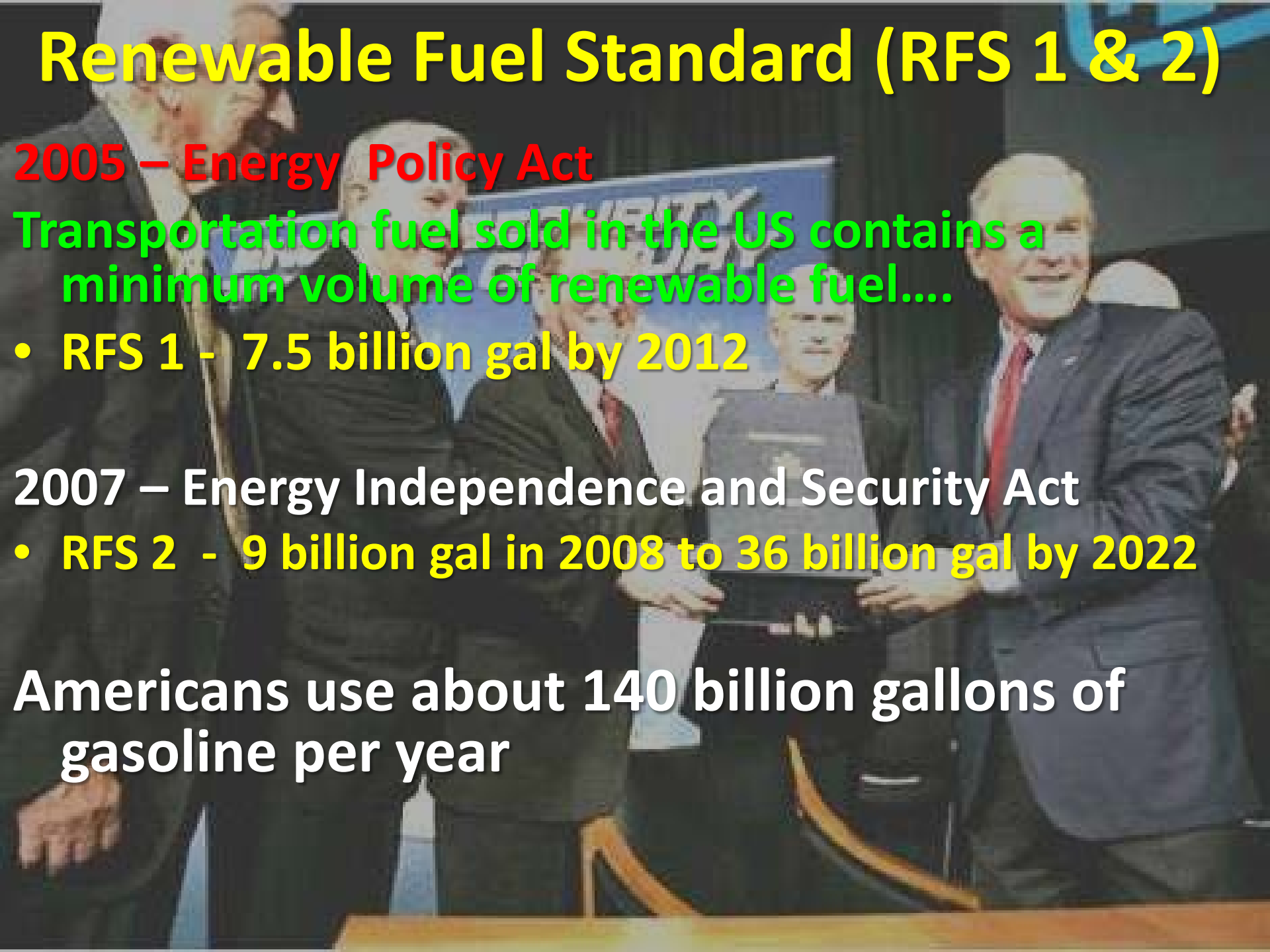
Concerns About Petroleum Supplies

Greater Recognition of Environmental Consequences

Bioenergy

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

Renewable Fuel Standard (RFS 1 & 2)



2005 – Energy Policy Act

Transportation fuel sold in the US contains a minimum volume of renewable fuel….

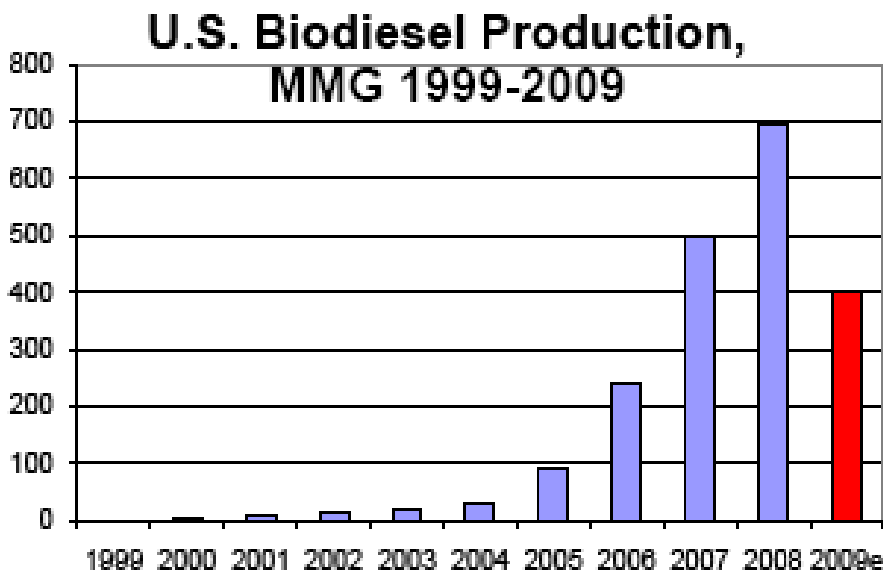
- RFS 1 - 7.5 billion gal by 2012

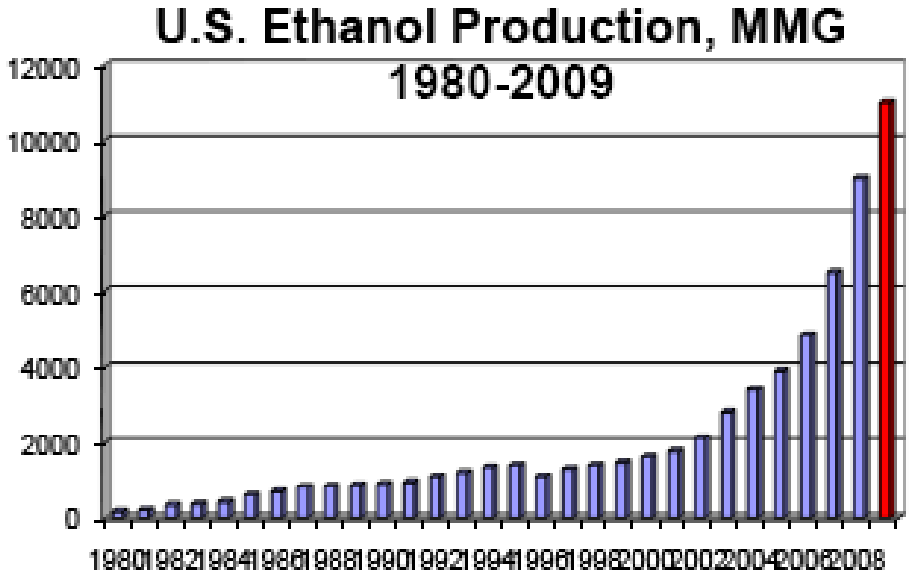
2007 – Energy Independence and Security Act

- RFS 2 - 9 billion gal in 2008 to 36 billion gal by 2022

Americans use about 140 billion gallons of gasoline per year

USDA Office of the Chief Economist
Office of Energy Policy and New Uses





Ethanol

11 Billion Gallons now (8%)

36 Billion Gallons in 2022 (26%)

Marcellus Shale Gas Wells

Biomass Feedstocks

Starch & Sugar based Feedstocks

- Corn
- Wheat
- Sugarcane

Cellulosic Feedstocks

Ag Plant Wastes:

- Corn Stover
- Cereal Straws
- Forest Residues

Plant Wastes from Industrial Processes

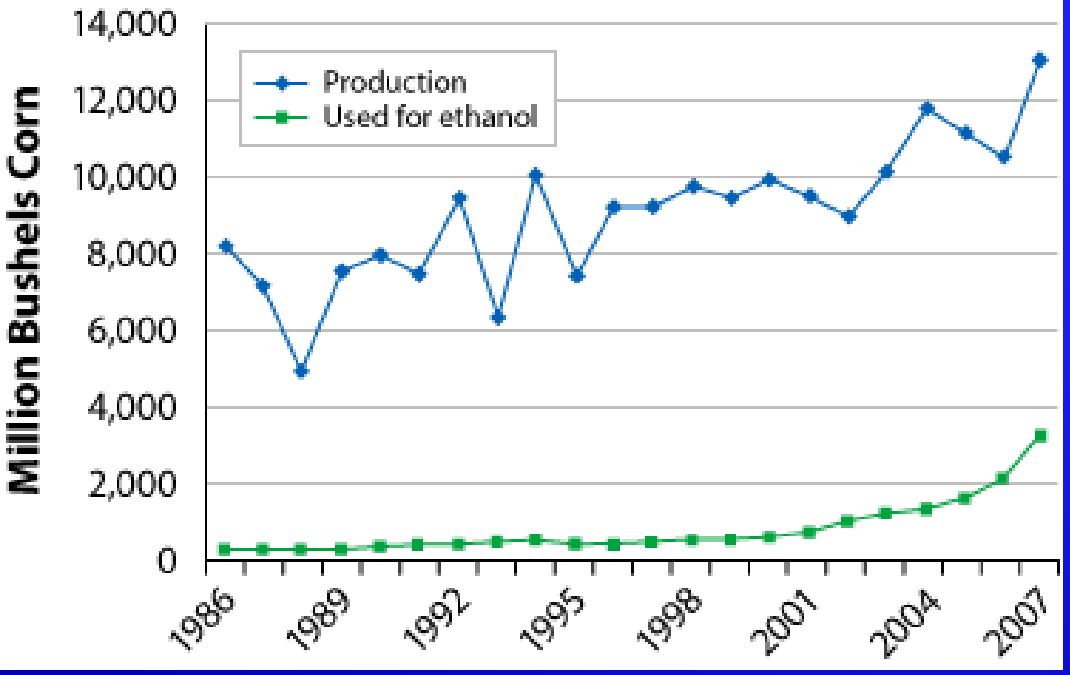
- Sawdust
- Paper Pulp

Energy Crops

- Switchgrass
- Miscanthus, Arundo

Food vs. Fuel

U.S. Corn Production and Use for Fuel Ethanol

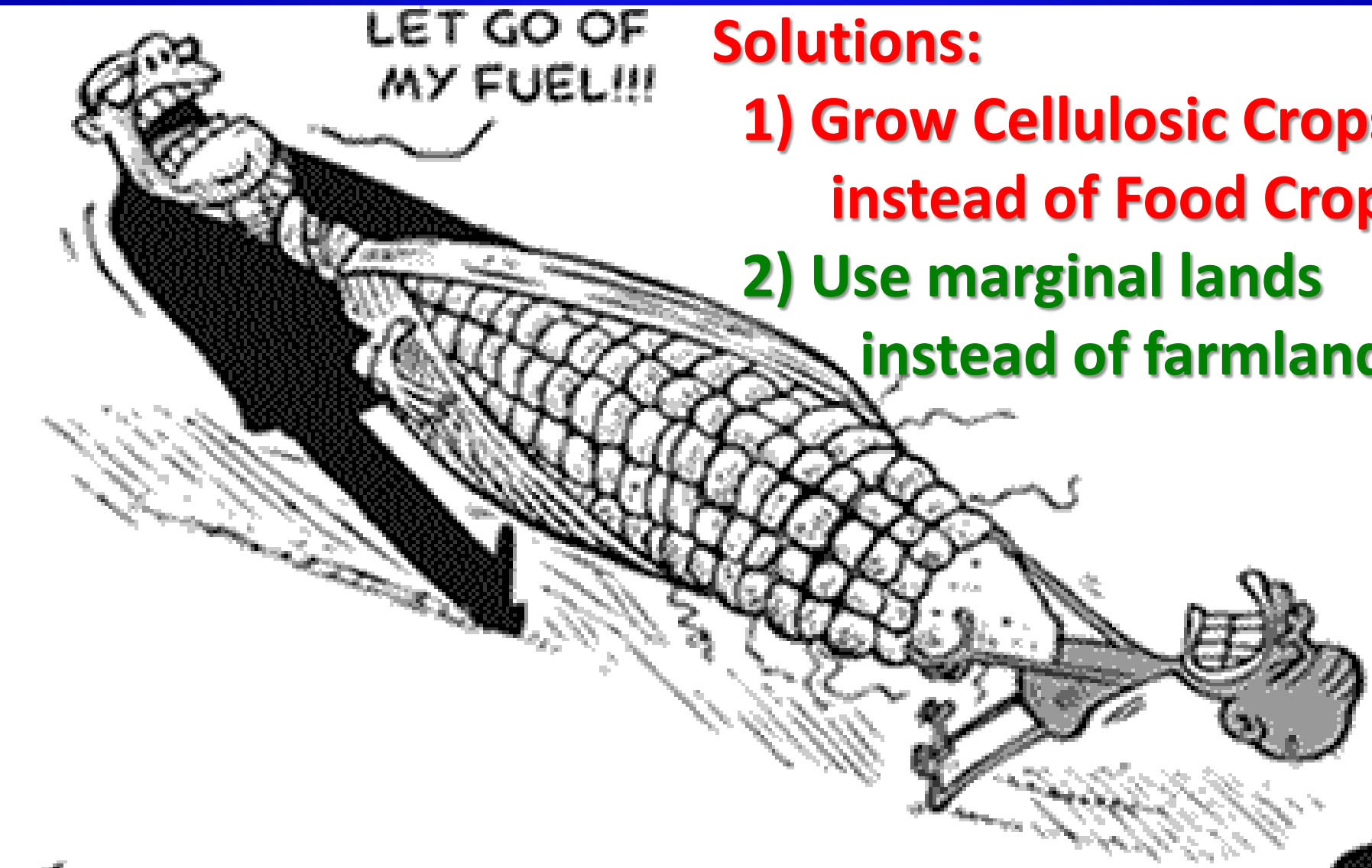


U.S. Department of Energy

World pop. > 7 billion
Malnutrition: approx. 800 million

SOLUTION =
Cellulosic Feedstocks

Food vs. Fuel Debate



Solutions:

1) Grow Cellulosic Crops instead of Food Crops

2) Use marginal lands instead of farmland.

Plants to Fuel

The Basic Steps…

1. **Convert feedstocks to simple sugars**

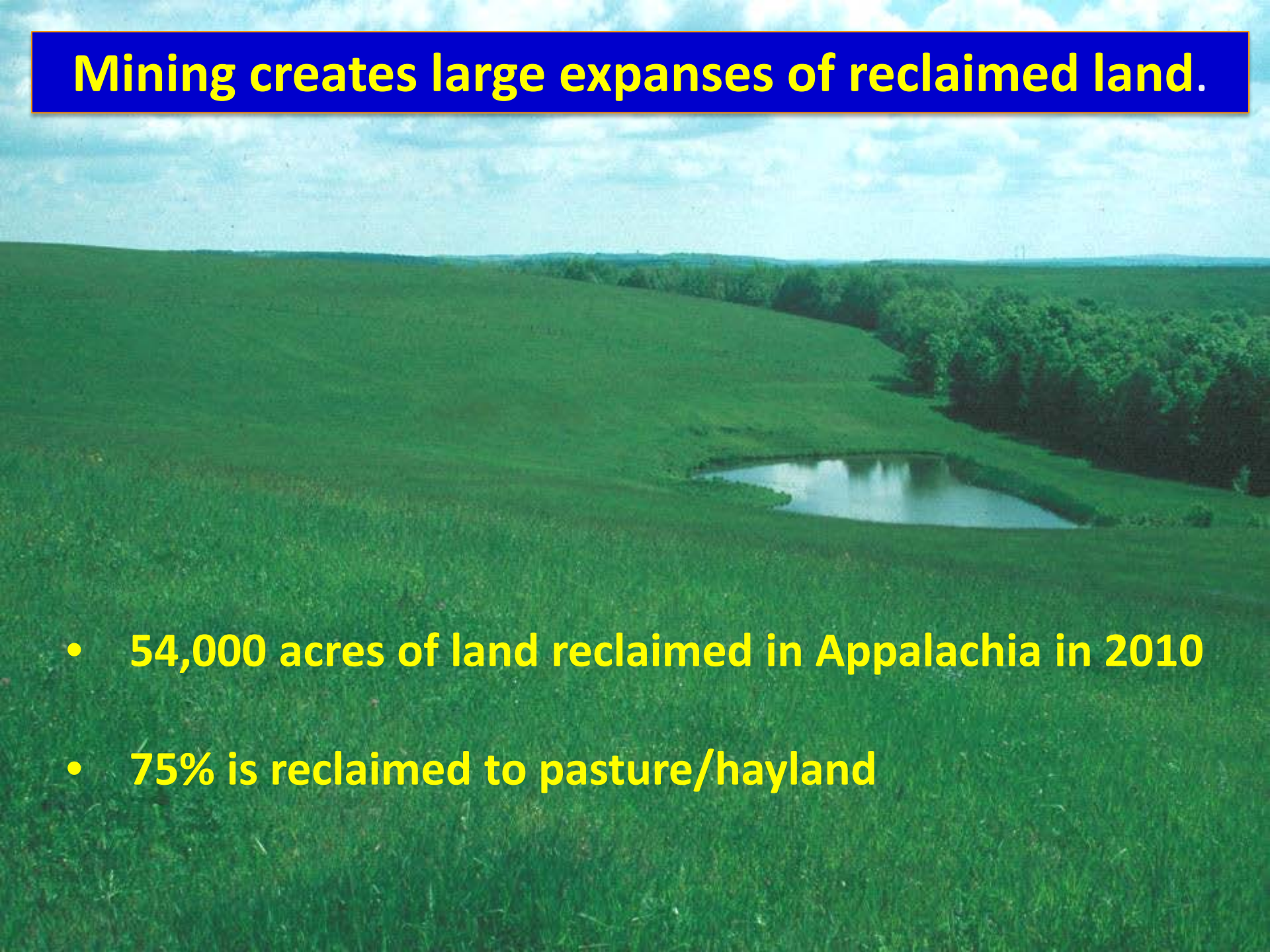
2. **Fermentation (???)**

3. **Recovery of Ethanol**

West Virginia's traditional energy production…

COAL

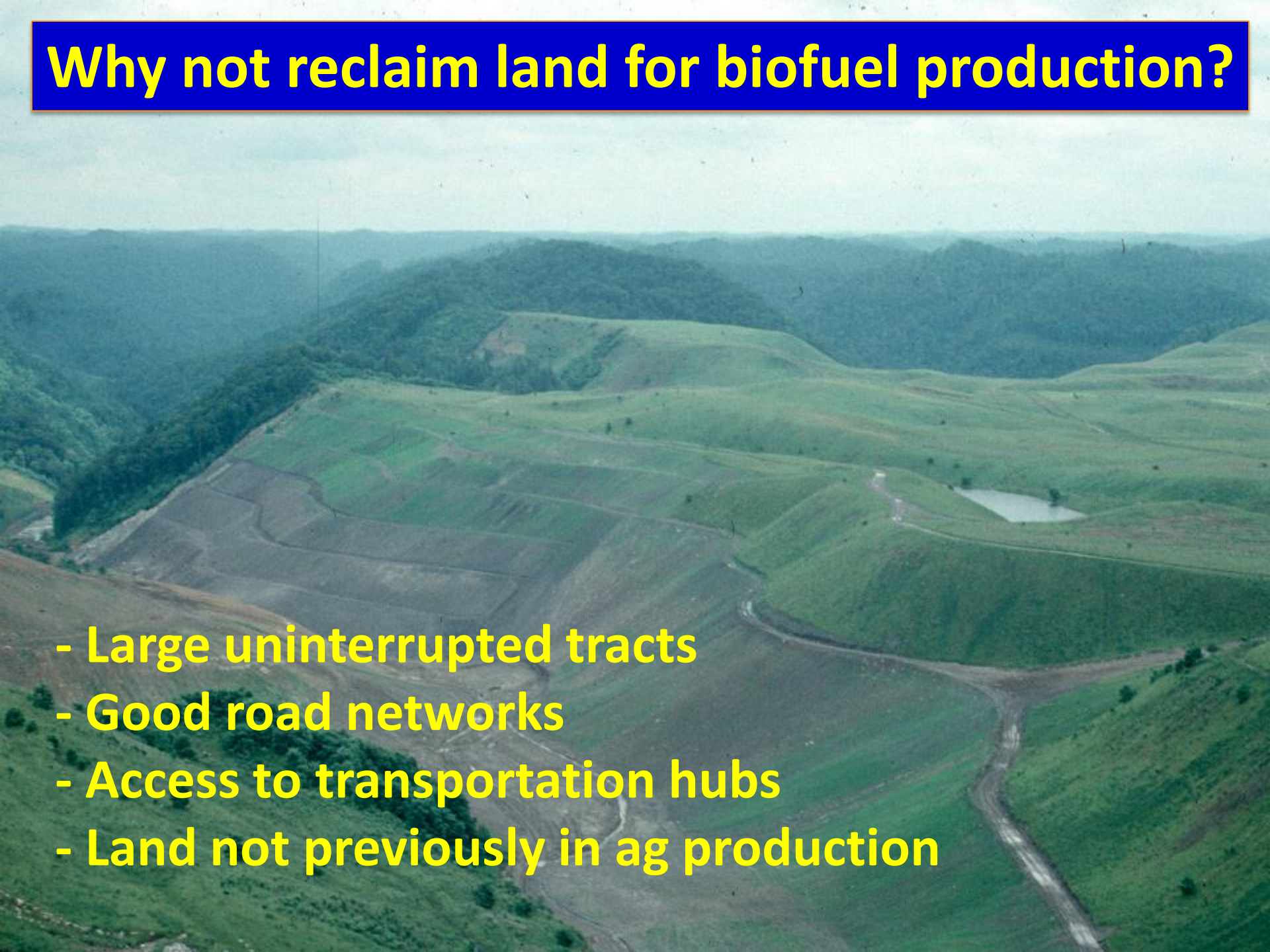
Mining creates large expanses of reclaimed land.



- 54,000 acres of land reclaimed in Appalachia in 2010
- 75% is reclaimed to pasture/hayland

…much is underutilized and unmanaged

Why not reclaim land for biofuel production?



- Large uninterrupted tracts
- Good road networks
- Access to transportation hubs
- Land not previously in ag production

Switchgrass: a viable biofuel?

SWITCHGRASS

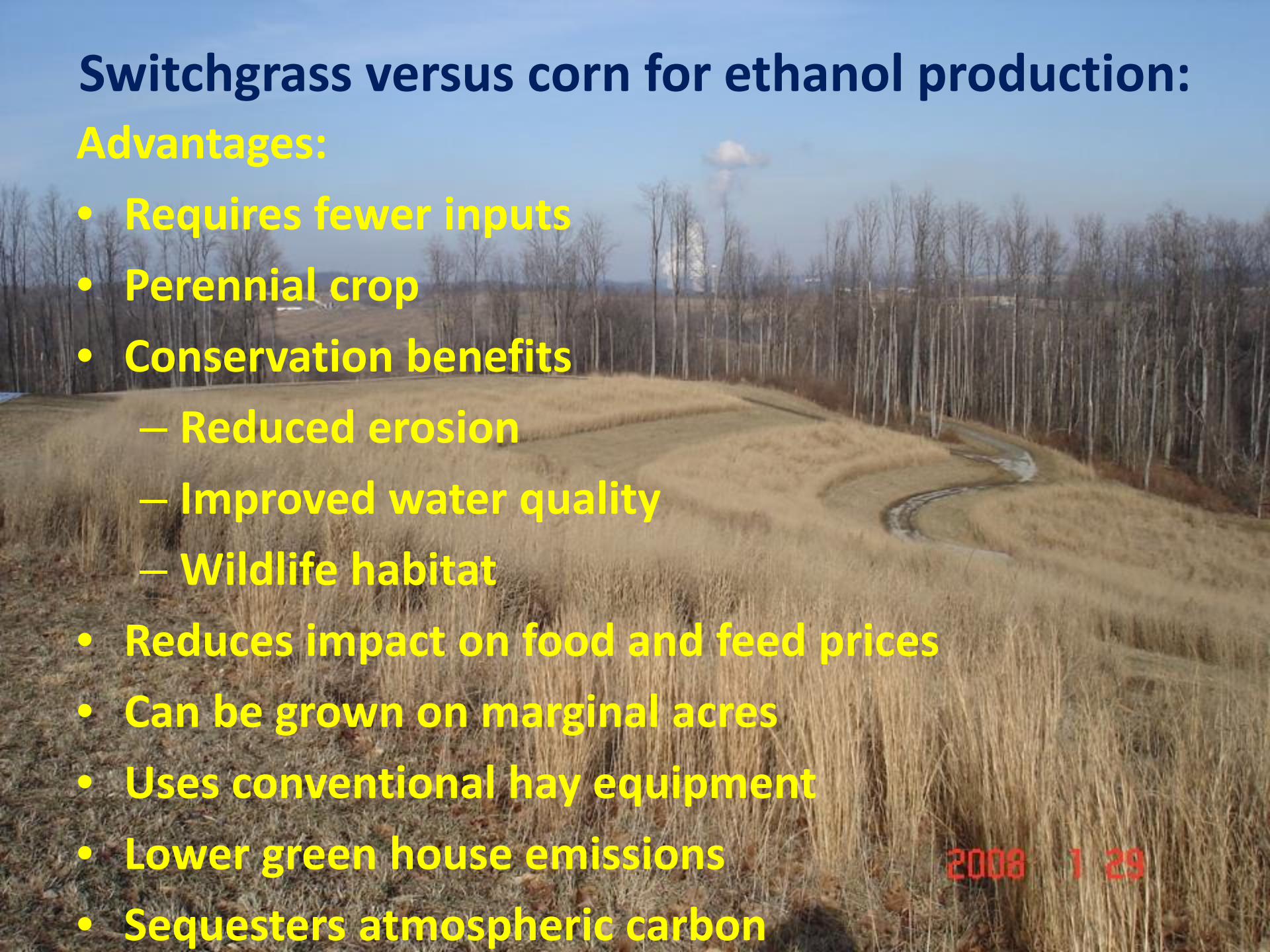
***Panicum virgatum* L.**

- Warm season, perennial, bunch grass
- Native to North America
- Well adapted to a variety of sites:
  - pH 4.9 to 7.5
  - soils ranging from sand to loam
  - little to no fertilization or mgt
  - extensive root system
  - two ecotype

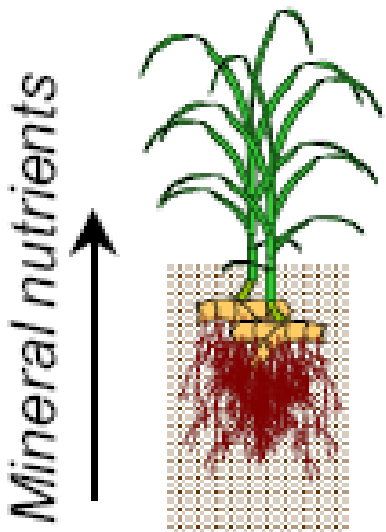
Switchgrass versus corn for ethanol production:

Advantages:

- Requires fewer inputs
- Perennial crop
- Conservation benefits
  - Reduced erosion
  - Improved water quality
  - Wildlife habitat
- Reduces impact on food and feed prices
- Can be grown on marginal acres
- Uses conventional hay equipment
- Lower green house emissions
- Sequesters atmospheric carbon



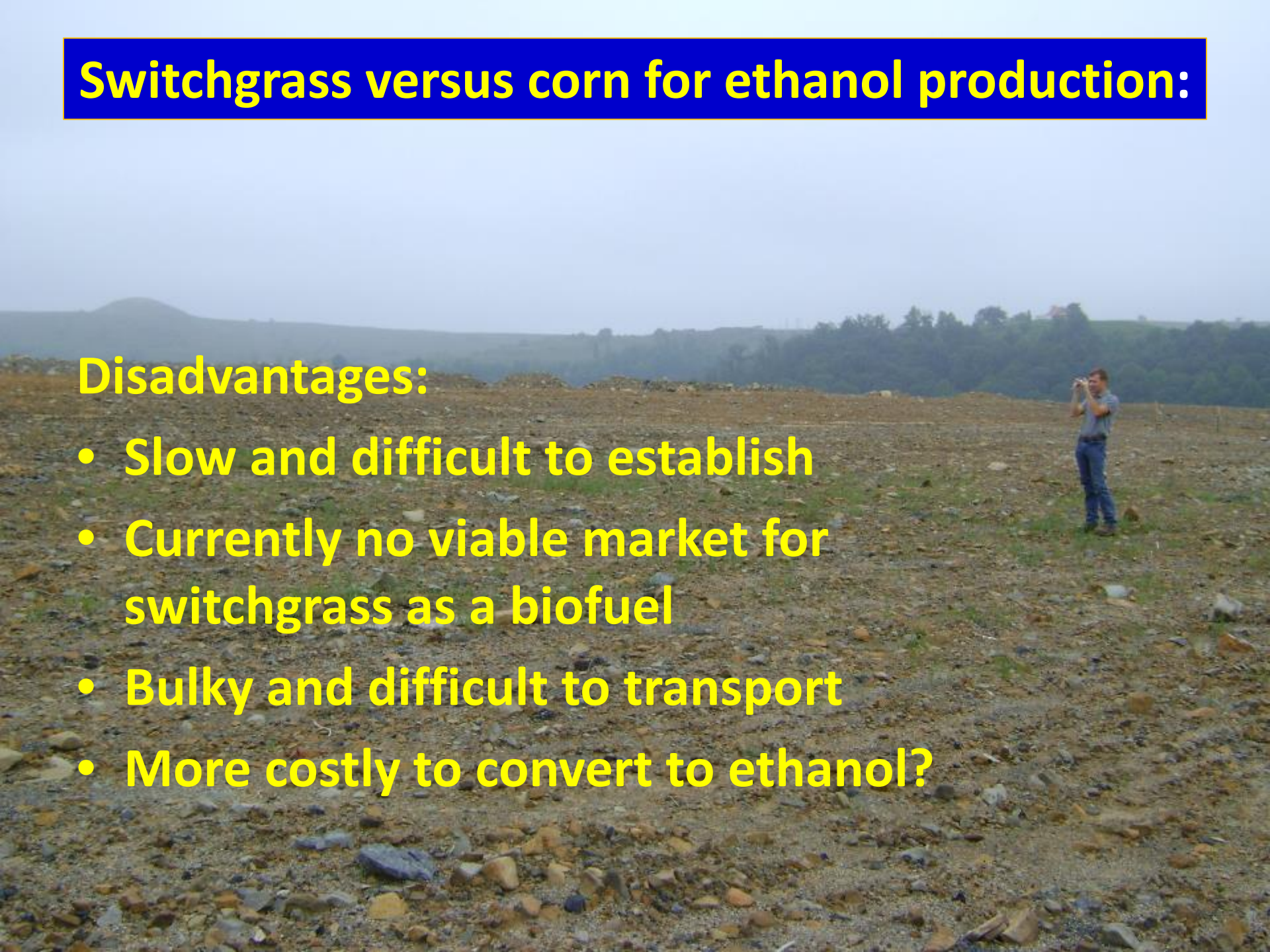
Example of "Ideal" biofuel crop

SPRING/ SUMMER	FALL	WINTER
		
Translocation from rhizomes to growing shoot	Translocation to rhizome as shoot senesces	Lignocellulose dry shoots harvested, nutrients stay in rhizomes

Just Reviewed a Paper for a journal…

Source Dr. Steve Long, UIUC 2005

Switchgrass versus corn for ethanol production:



Disadvantages:

- **Slow and difficult to establish**
- **Currently no viable market for switchgrass as a biofuel**
- **Bulky and difficult to transport**
- **More costly to convert to ethanol?**

Pelletizing switchgrass

- Reduces shipping costs
- Prepares crop for utilization as a feed stock

Other uses for switchgrass:

- Can be co-fired in coal plants
- Create synthesis gas through pyrolysis
- Burned outright for heat generation
- Carbon sequestration credits

Switchgrass Yields

Study	DM Yield (Mt ha^{-1})	Description
Fike et al., 2006a	14.1	4 cultivars, 8 sites, 5 states (including WV)
Vogel & Masters (1998)	14.9	3 states in Midwestern US
Fike et al., 2006b	14.2	Years 6 - 9 of production
USDOE (McLauglin & Kszoz 2005)	11 – 19	Cave-in-Rock; 10-year study in 13 states
Schmer et al., 2008	5.2 – 11.1	Marginal cropland
Mulkey et al., 2006	< 7.5	CRP land in South Dakota

Goal would be 5.0 Mt ha^{-1}

What we know….

- Need cellulosic feedstocks (FOOD VS FUEL)
- Switchgrass can produce good yields on agricultural land and even on marginal croplands
- Ethanol production and fermentation process from switchgrass is ongoing and under research

Could switchgrass grow on land even poorer quality than marginal cropland?

… like reclaimed mine lands…

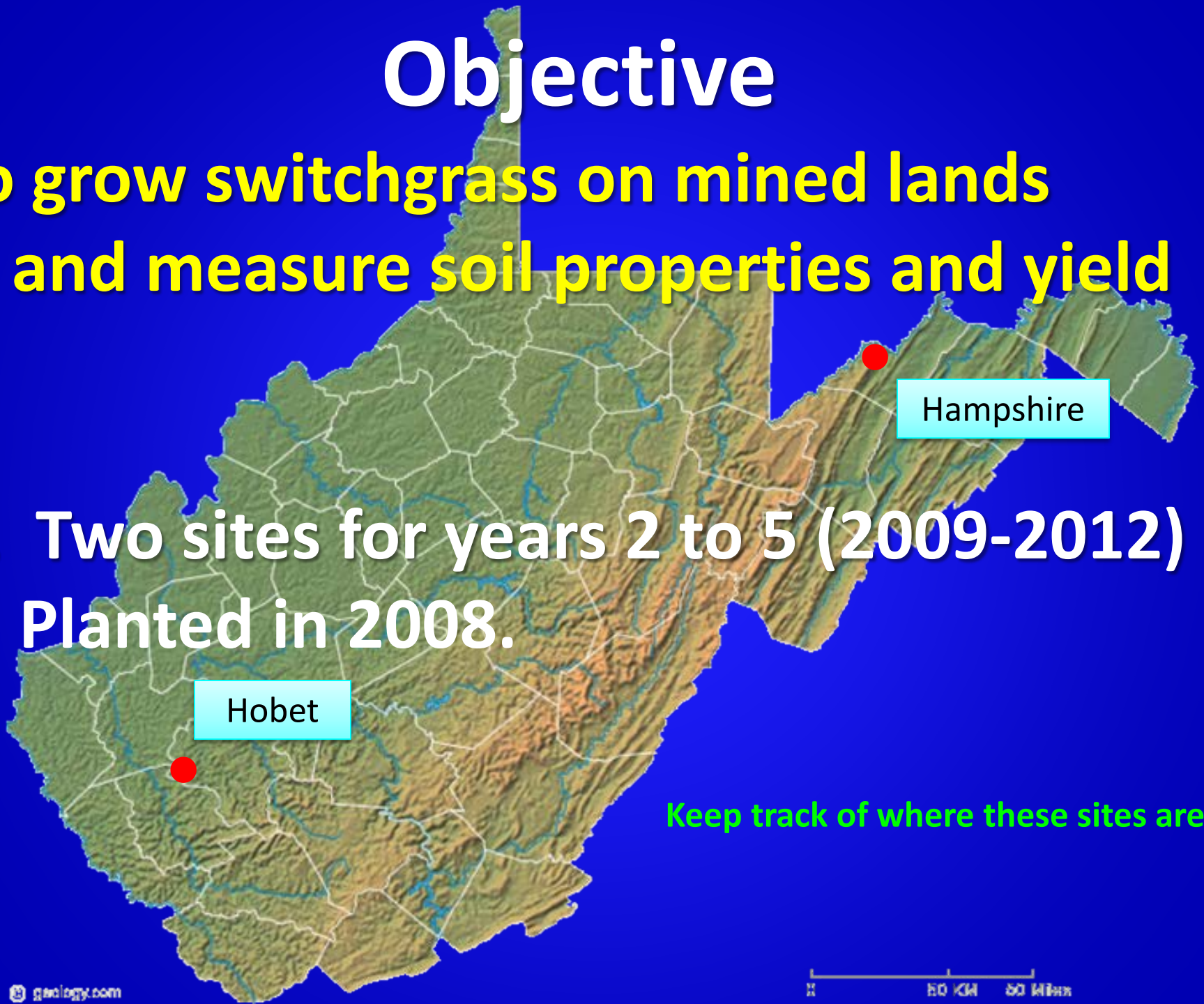

1984
Reclaimed land
TX - Alamo


2008 – Marginal
Agric Lands


65
2000 – WV Highways

Objective

To grow switchgrass on mined lands and measure soil properties and yield

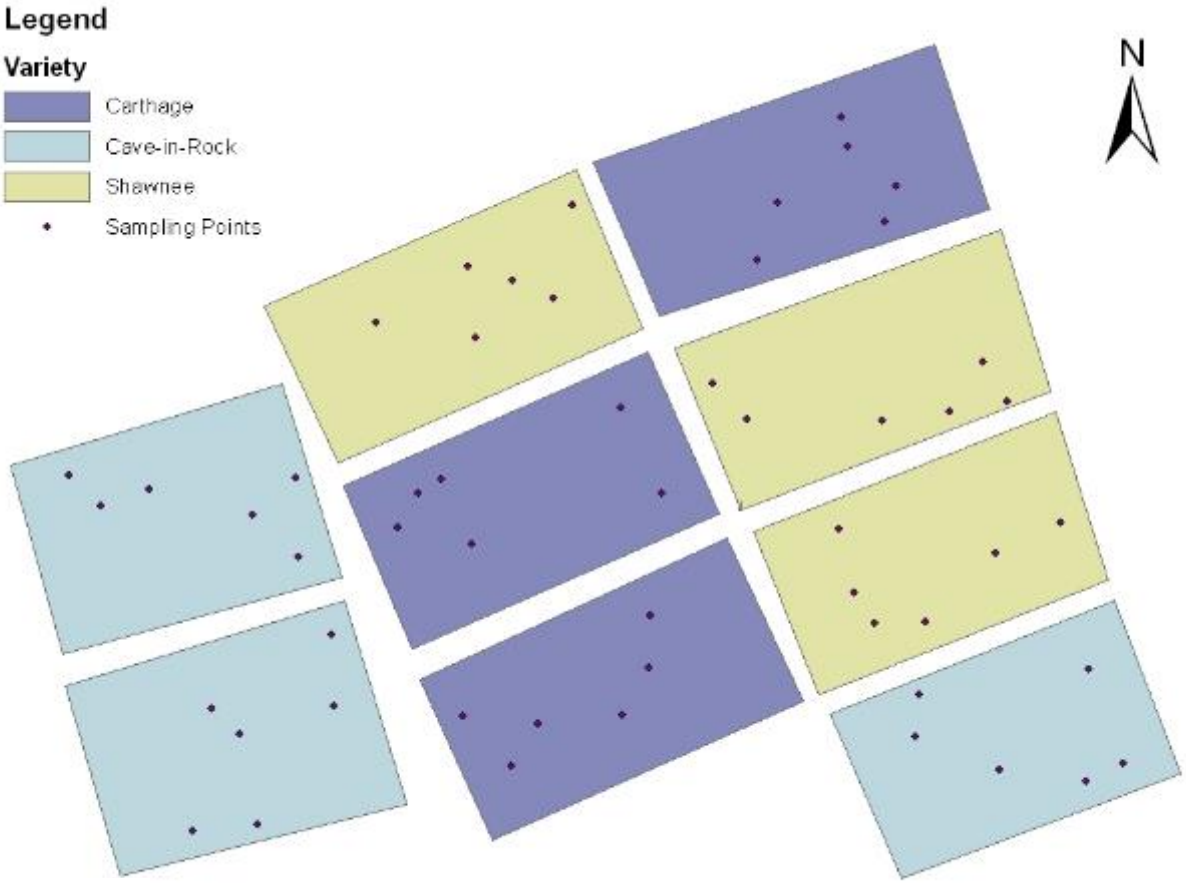


1. Two sites for years 2 to 5 (2009-2012)
2. Planted in 2008.

Experimental design

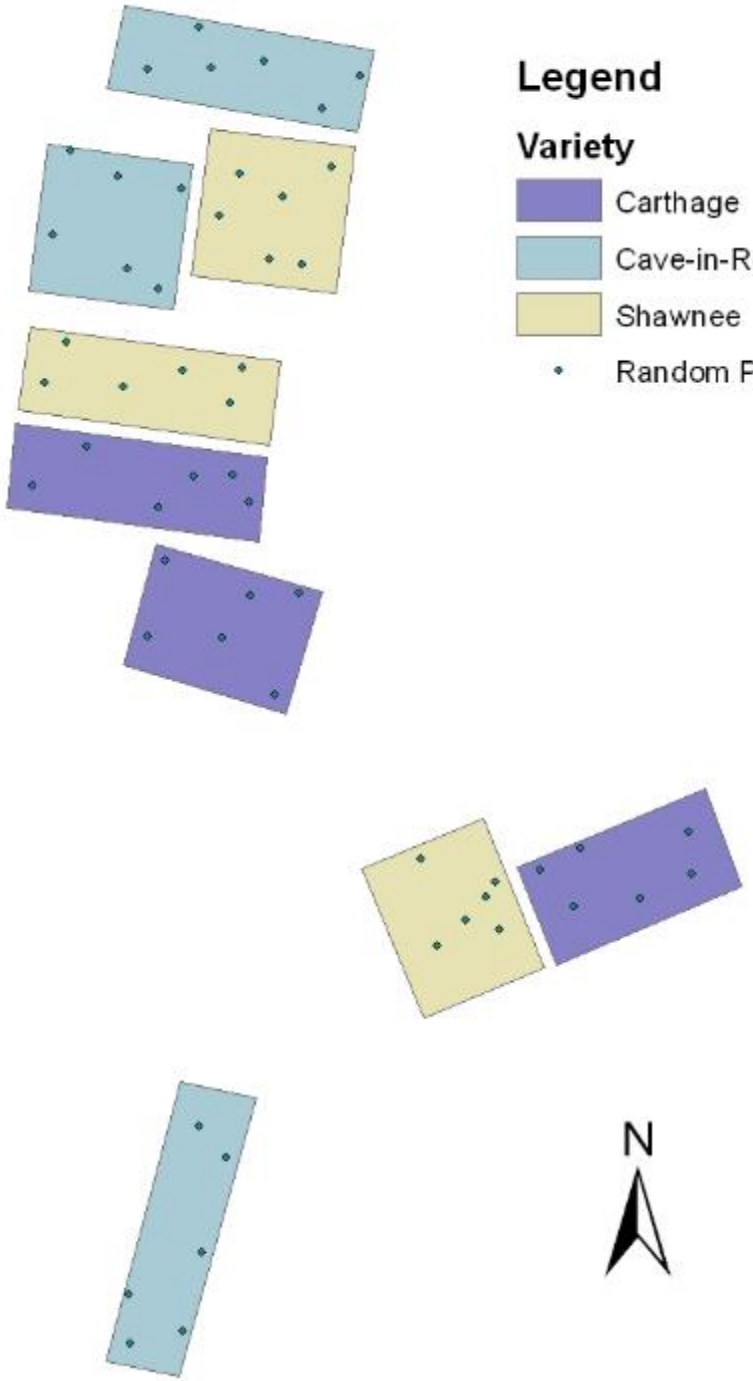
- Three upland varieties of switchgrass
  - Carthage
  - Cave-in-Rock
  - Shawnee
- Three, 1-ac replications of each variety at each site (Hobet and Hampshire)

Hampshire


Legend
Variety
Carthage
Cave-in-Rock
Shawnee
Sampling Points
N


Morgantown
Hampshire Hill
West Virginia
Charleston
Hobet 21
N

Hobet

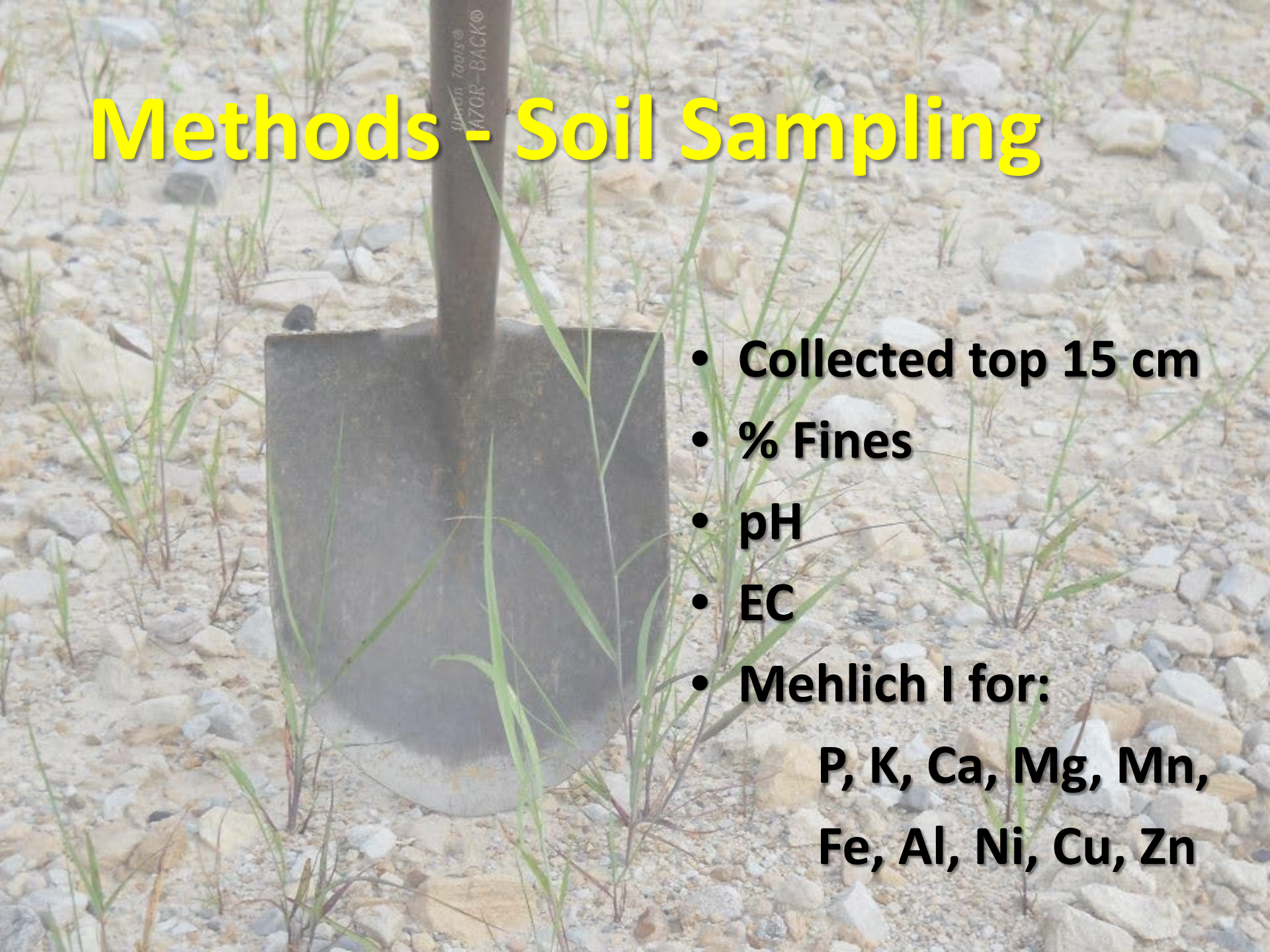

Legend
Variety
Carthage
Cave-in-Rock
Shawnee
Random Points
N


Morgantown
Hampshire Hill
West Virginia
Charleston
Hobet 21
N


10 lbs PLS ac-1
Mister Donut
Seed was carefully measured for each plot

Hand seeding at Hobet

Methods - Soil Sampling



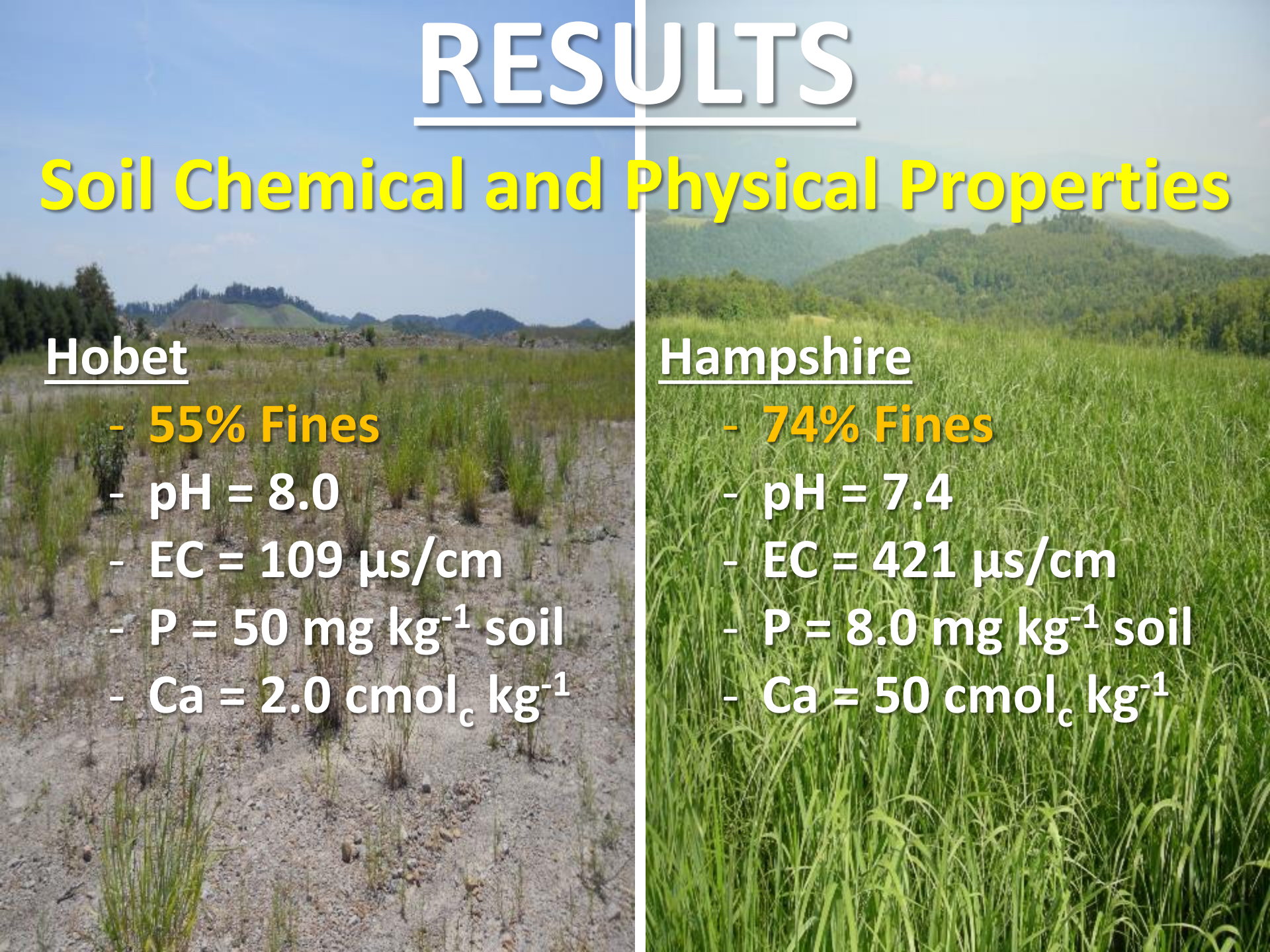
- Collected top 15 cm
- % Fines
- pH
- EC
- Mehlich I for:

  P, K, Ca, Mg, Mn,

  Fe, Al, Ni, Cu, Zn

RESULTS

Soil Chemical and Physical Properties

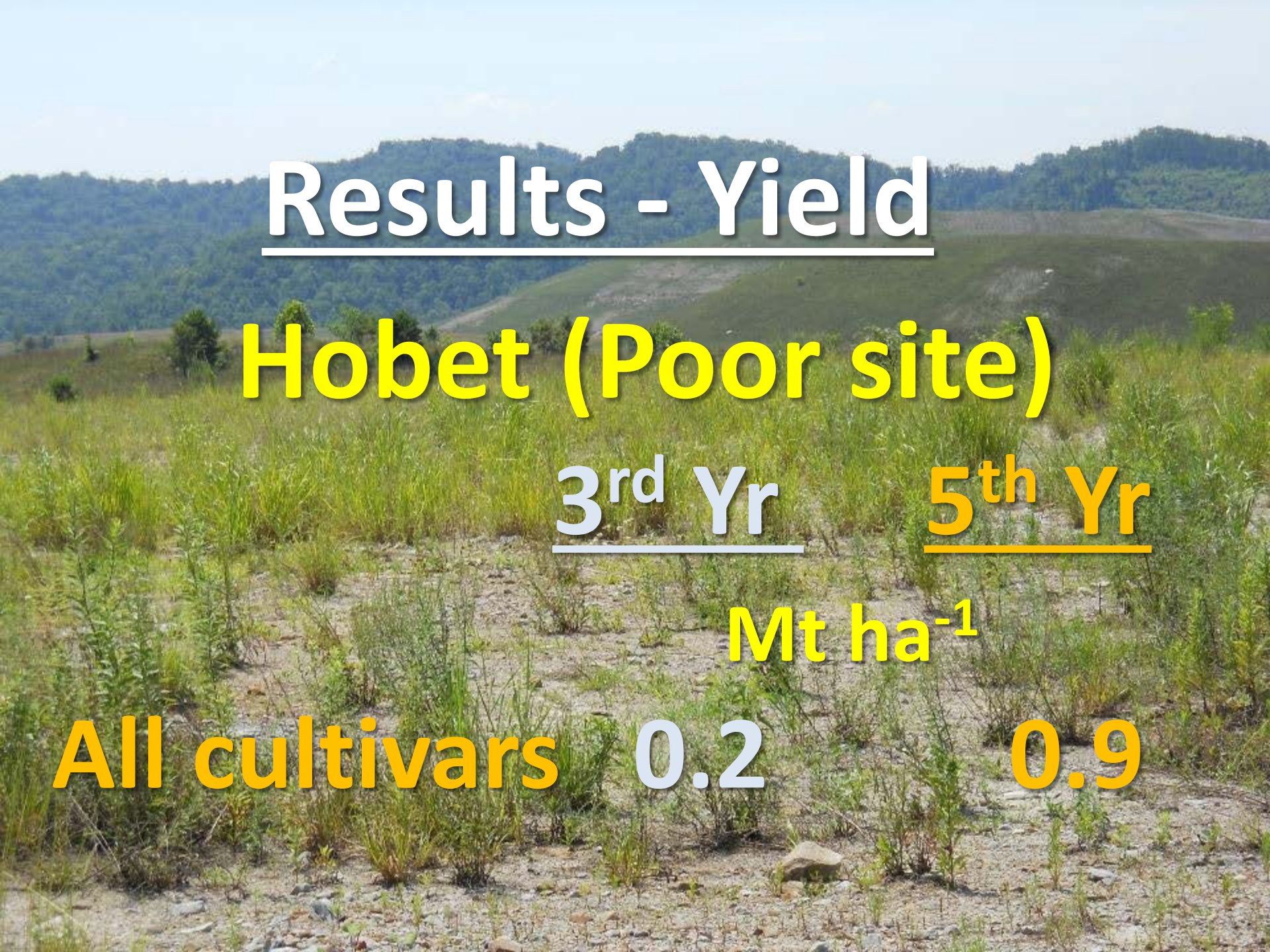


Hobet

- 55% Fines
- pH = 8.0
- EC = 109 µs/cm
- P = 50 mg kg^{-1} soil
- Ca = 2.0 $cmol_c$ kg^{-1}

Hampshire

- 74% Fines
- pH = 7.4
- EC = 421 µs/cm
- P = 8.0 mg kg^{-1} soil
- Ca = 50 $cmol_c$ kg^{-1}


Results - Yield
Hobet (Poor site)
3rd Yr
5th Yr
Mt ha-1
All cultivars
0.2
0.9

Results - Yield

Hampshire (Good site)

	3rd Yr	5th Yr
	Mt ha^{-1}	
All Cultivars	4.5	5.1

Results - Yield

3rd Yr – Hampshire

Variety	Mt ha^{-1}
Cave-in-Rock	6.5
Carthage	3.6
Shawnee	1.9

Results - Yield

5th Yr

Variety	Hampshire	Hobet
	Mt ha^{-1}	
Cave in Rock	7.9	1.1
Carthage	3.0	0.9
Shawnee	4.5	0.8


Hampshire
Oct 2012 - 5th Year
About 9 Mt ha-1
10/05/2012


Hobet
Aug 2011 - 4th Yr
About 1.0 Mt ha-1
HOBET MINING, LLC.
SWITCHGRASS
DEMONSTRATION PLOT
Planted May 2008
Partners with:
West Virginia University
West Virginia Dept. of Environmental Protection
09/01/2011

Research Questions

Can switchgrass be grown on reclaimed surface mines?

Produce yields similar to *agricultural* soils?

Where do our numbers stand?

Agricultural Land: 13 - 16 Mt ha^{-1}

Cave-in-Rock at Hampshire: 9.0 Mt ha^{-1}

Shawnee at Hobet: 1.9 Mt ha^{-1}

Goal of 5.0 Mt ha^{-1}

What about other crops?

Miscanthus

Illinois

Photo credit John Caveny

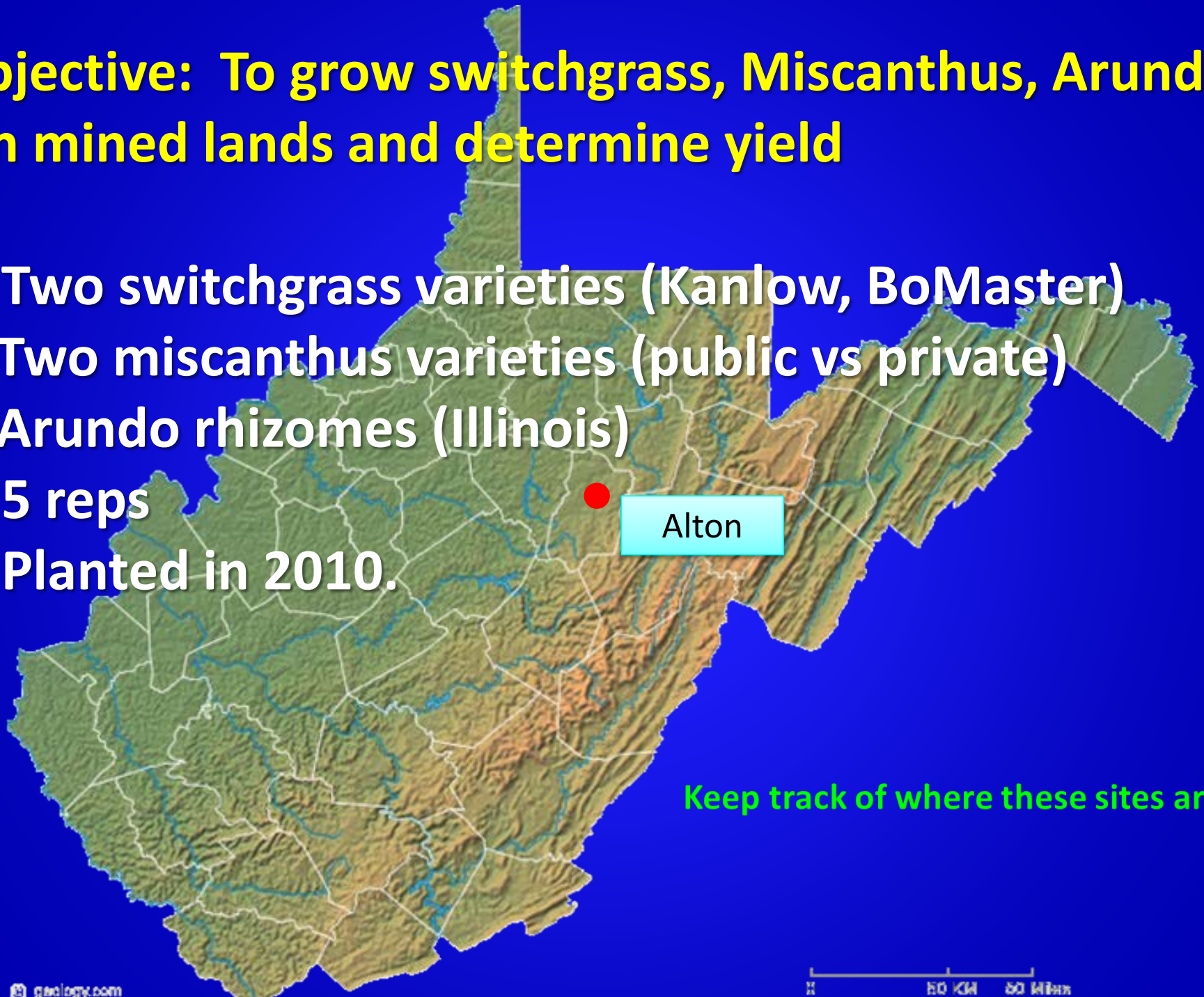
China

Mendel

Giant Cane - *Arundo donax*

Objective: To grow switchgrass, Miscanthus, Arundo on mined lands and determine yield

1. Two switchgrass varieties (Kanlow, BoMaster)
   Two miscanthus varieties (public vs private)
   Arundo rhizomes (Illinois)
2. 5 reps
3. Planted in 2010.



Keep track of where these sites are!

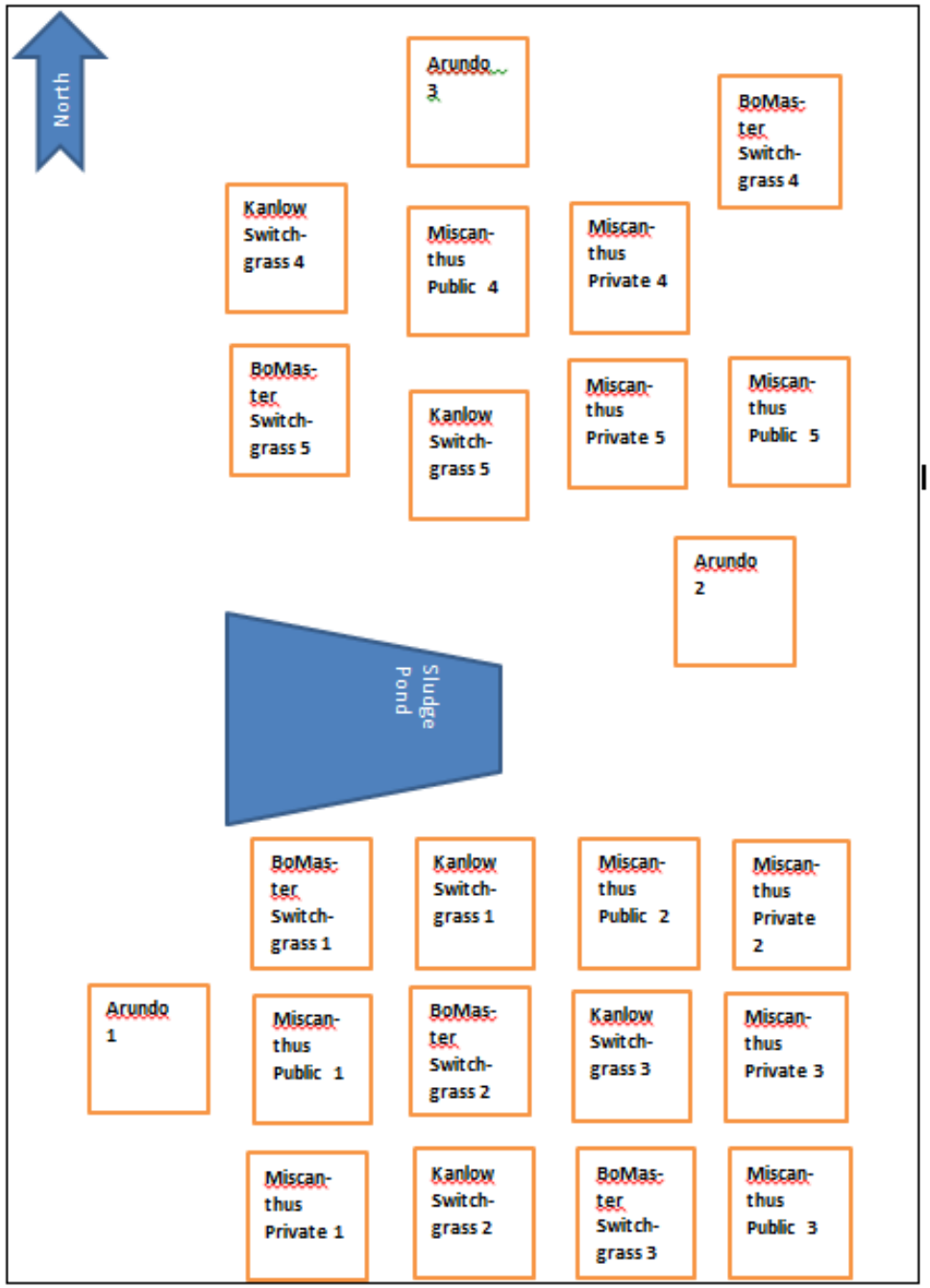
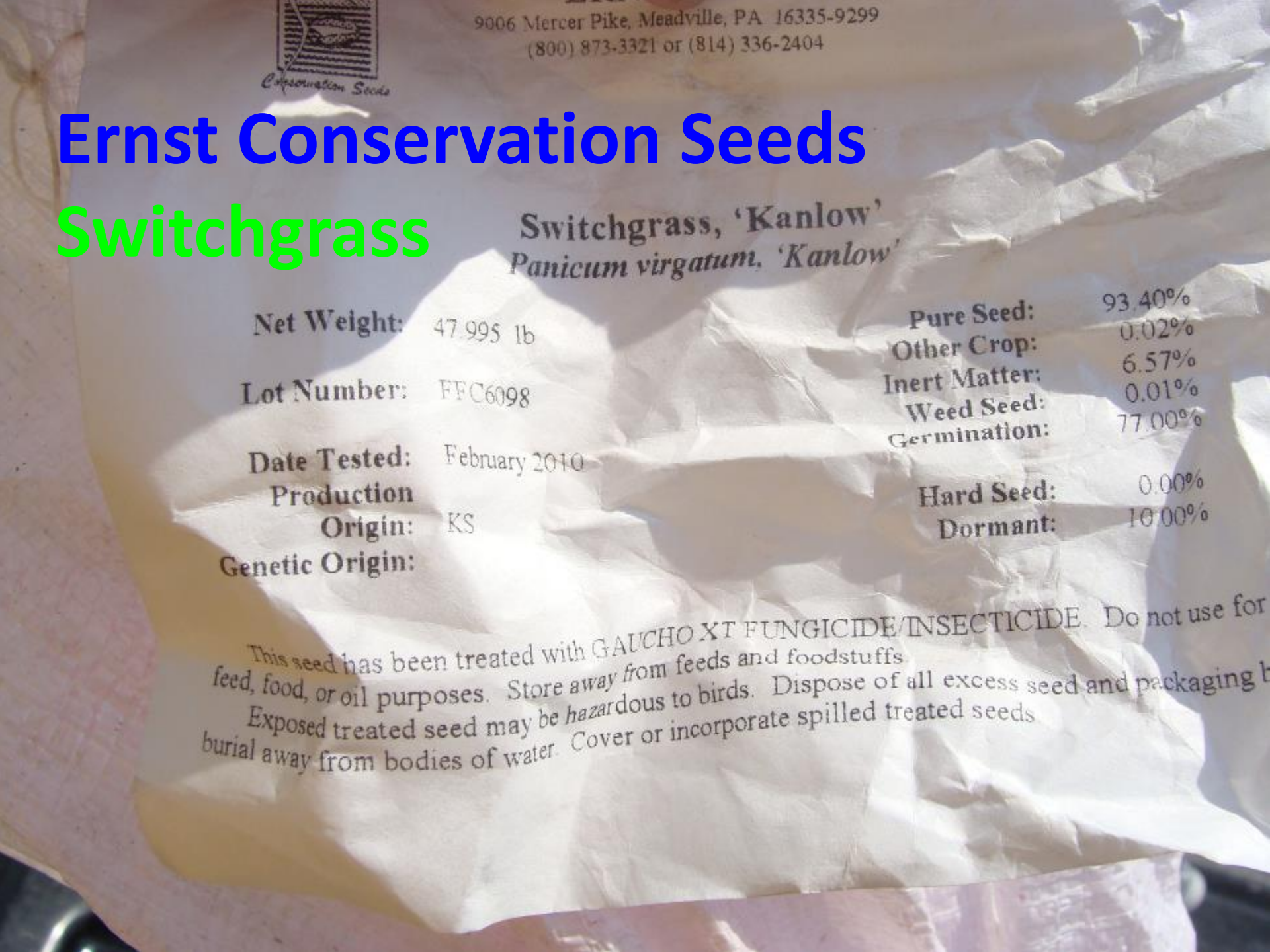


Figure 1. Plot layout for the yield trials at Alton, WV with two varieties of switchgrass, two varieties of miscanthus, and giant cane.

Randomly assigned plots

Each 0.4 ha or 1 acre

5 plots Kanlow
5 plots BoMaster
5 plots Miscanthus –private
5 plots Miscanthus – public
3 plots Arundo


9006 Mercer Pike, Meadville, PA 16335-9299
(800) 873-3321 or (814) 336-2404
Ernst Conservation Seeds
Switchgrass
Switchgrass, 'Kanlow'
Panicum virgatum, 'Kanlow'
Net Weight: 47.995 lb
Lot Number: FFC6098
Date Tested: February 2010
Production Origin: KS
Genetic Origin:
Pure Seed: 93.40%
Other Crop: 0.02%
Inert Matter: 6.57%
Weed Seed: 0.01%
Germination: 77.00%
Hard Seed: 0.00%
Dormant: 10.00%
This seed has been treated with GAUCHO XT FUNGICIDE/INSECTICIDE. Do not use for
feed, food, or oil purposes. Store away from feeds and foodstuffs.
Exposed treated seed may be hazardous to birds. Dispose of all excess seed and packaging b
burial away from bodies of water. Cover or incorporate spilled treated seeds.

Switchgrass drilled into killed sod

Miscanthus planting trial at Alton, WV


Sprigs
WVU
FRATERNITY
RECRUITMENT

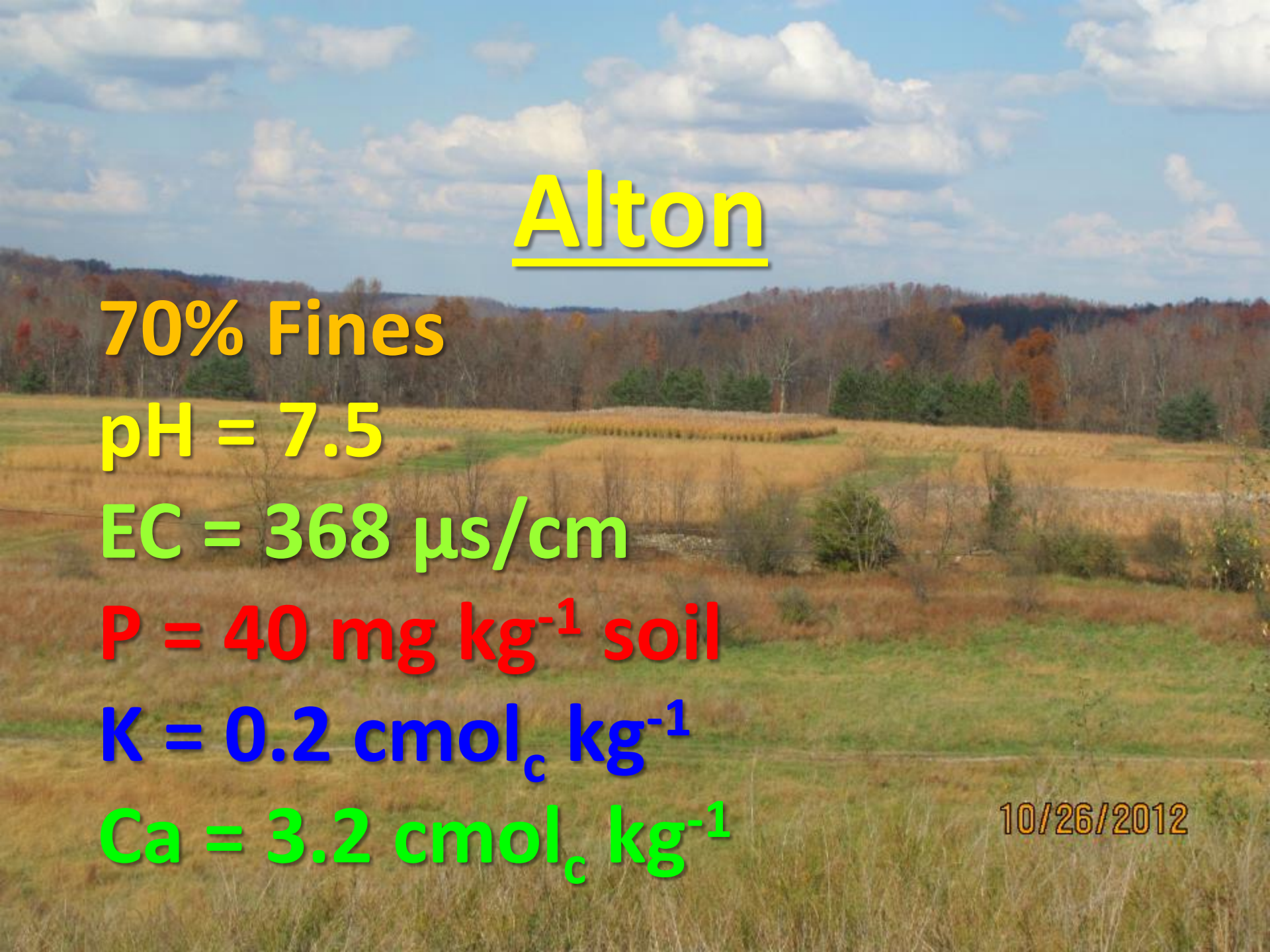

We had tree planters do the sprig planting

Two months later


Arundo Planting at Alton
MAY 26 2011


MAY 26 2011


10/25/2012


Alton
70% Fines
pH = 7.5
EC = 368 µs/cm
P = 40 mg kg-1 soil
K = 0.2 cmolc kg-1
Ca = 3.2 cmolc kg-1
10/26/2012

Plant Species	2011 – 2nd Yr	2012 – 3rd Yr
	---------- Mt ha^{-1} ----------	
Switchgrass		
Kanlow	4.0 (2.64)	4.9 (1.14)
BoMaster	2.7 (1.38)	4.0 (3.14)

Goal of 5.0 Mt ha^{-1}


Kanlow Switchgrass - 3rd Yr
Alton
Looks like over 5 Mt ha-1
09/10/2012

Switchgrass – 2012 - 3rd Yr

Alton


Switchgrass - 3rd Yr
Alton
10/25/2012

Plant Species	2011 – 2nd Yr	2012 – 3rd Yr
	---------- Mt ha^{-1} ----------	
Miscanthus		
Public	7.5 (8.25)	4.9 (3.00)
Private	21.9 (22.84)	15.5 (10.45)
Arundo	NA	0.5 (0.18)

Wide Variation in Yields across plots!


Miscanthus – 2011 – 2nd Yr
Alton
17 Mt ha-1
Average yields are from 12 – 28 Mt ha-1
Reclaimed site for 20 years, so some soil material.
11/02/2011

Miscanthus – 2012 – 3rd Yr

Alton


Miscanthus – 2012 - 3rd Yr
Alton
10/25/2012

Miscanthus – 2012 - 3rd Yr

Alton

Plant Species	2011 – 2nd Yr	2012 – 3rd Yr
	---------- Mt ha^{-1} ----------	
Miscanthus		
Public	7.5 (8.25)	4.9 (3.00)
Private	21.9 (22.84)	15.5 (10.45)
Arundo	NA	0.5 (0.18)

Wide Variation in Yields across plots!

Arundo (Giant Cane) – 2012 – 2nd Yr

Alton


Arundo (Giant Cane) - 2012 – 2nd Yr
Alton
10/26/2012


09/10/2012

Arundo after three months

Coal Mac


Arundo – 2012 - 2nd Yr
Coal Mac
10/11/2012

Conclusions

After the 3rd year on reclaimed land

Switchgrass: 3.0 to 5.0 Mt ha^{-1}

Miscanthus: 5.0 to 20 Mt ha^{-1}

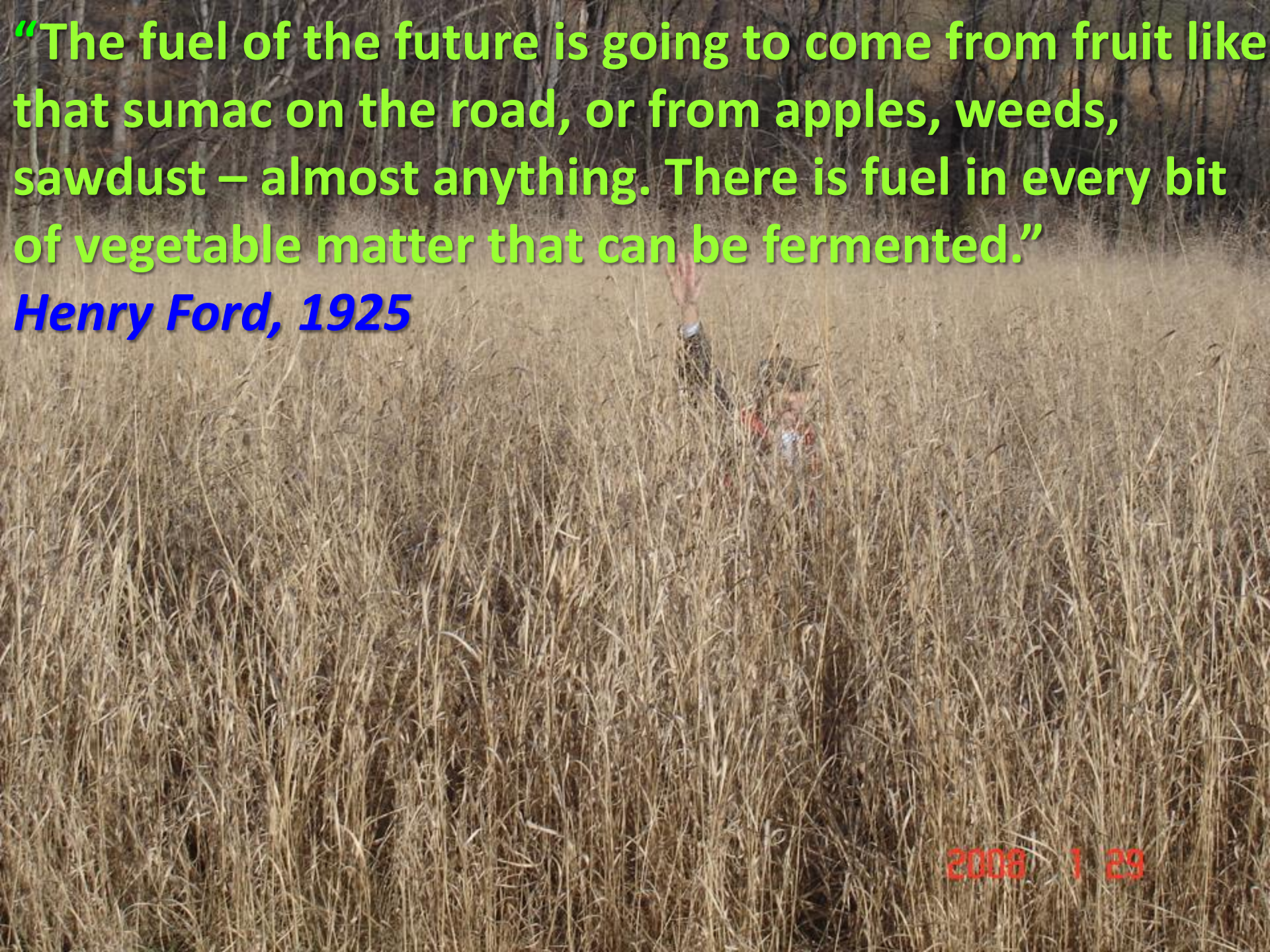
Arundo: < 1.0 Mt ha^{-1}

09/10/2012

Sustainable Energy Parks!

Potential Uses of Reclaimed Land

Coal – Biomass Fired and Wind


"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
2008 1 29

Questions?