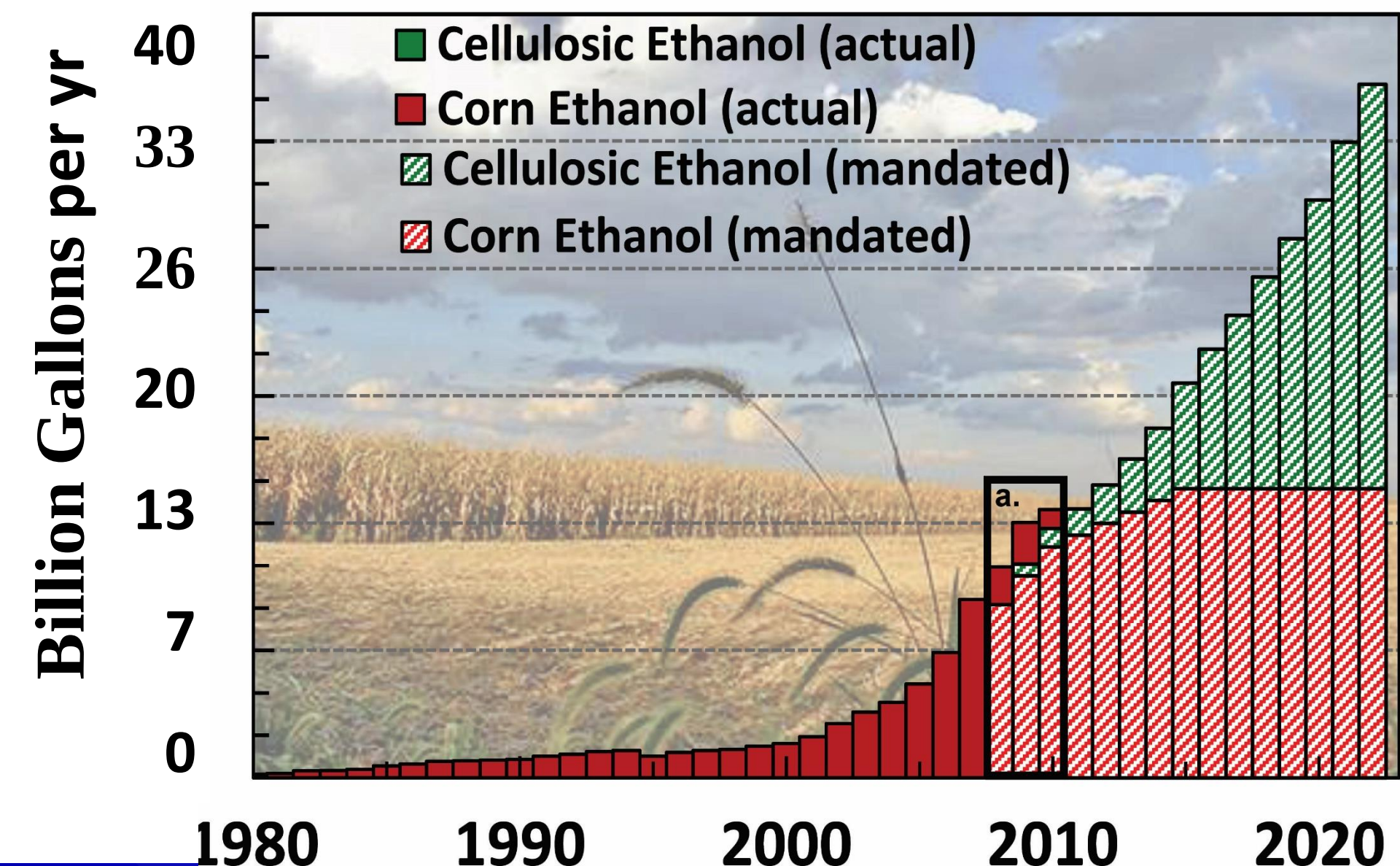
SWITCHGRASS AND MISCANTHUS BIOMASS ON RECLAIMED MINED LANDS

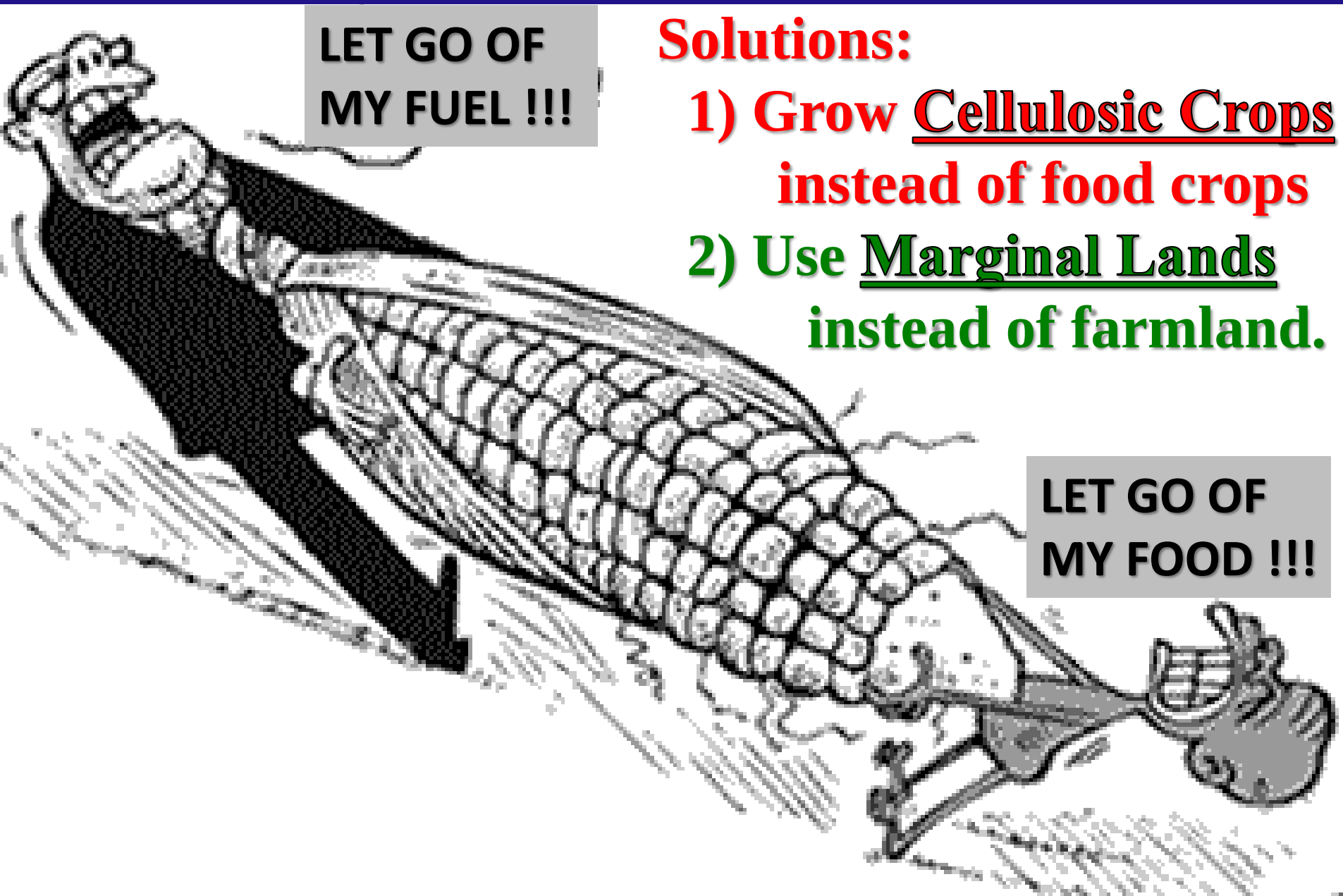
Jeff Skousen, Steffany Scagline-Mellor, Carol Brown, Thomas Griggs, Travis Keene, Mike Marra
Division of Plant and Soil Sciences
West Virginia University

Corn - Ethanol

12 Billion Gallons now (8%)
36 Billion Gallons in 2022 (26%)



Food vs. Fuel Debate



Solutions:

1) Grow **Cellulosic Crops** instead of food crops

2) Use **Marginal Lands** instead of farmland.

Cellulose – It's Everywhere!

Biomass Feedstocks

Starch/Sugar Feedstocks

- Corn
- Sugarcane

Cellulosic Feedstocks

Ag Plant Wastes:

- Corn/Grain Stover
- Forest Residues
- Sawdust
- Paper Pulp

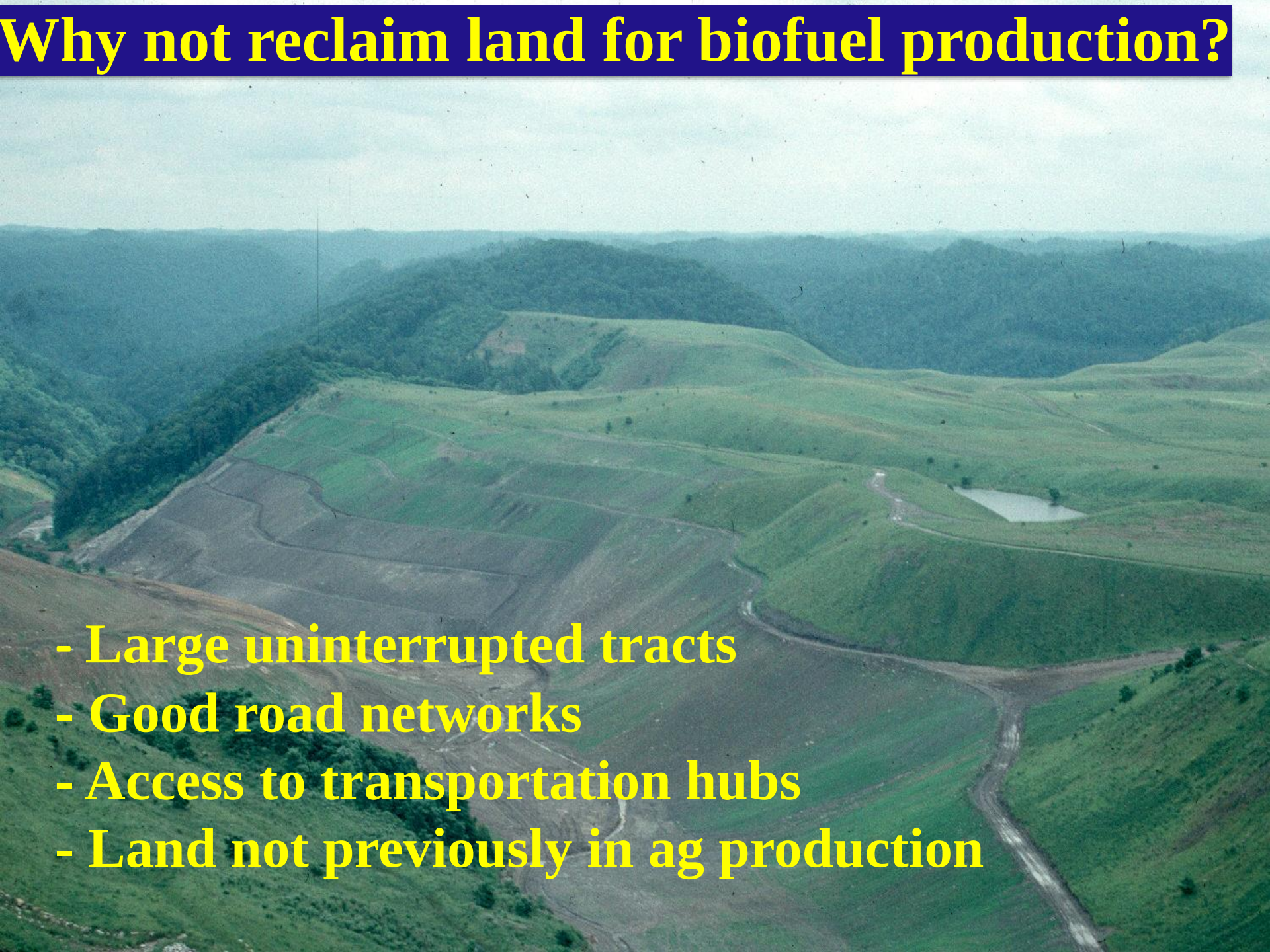
Energy Crops

- Switchgrass
- Miscanthus

Coal Mining disturbs landscapes and forests

These lands can be reclaimed to productive uses

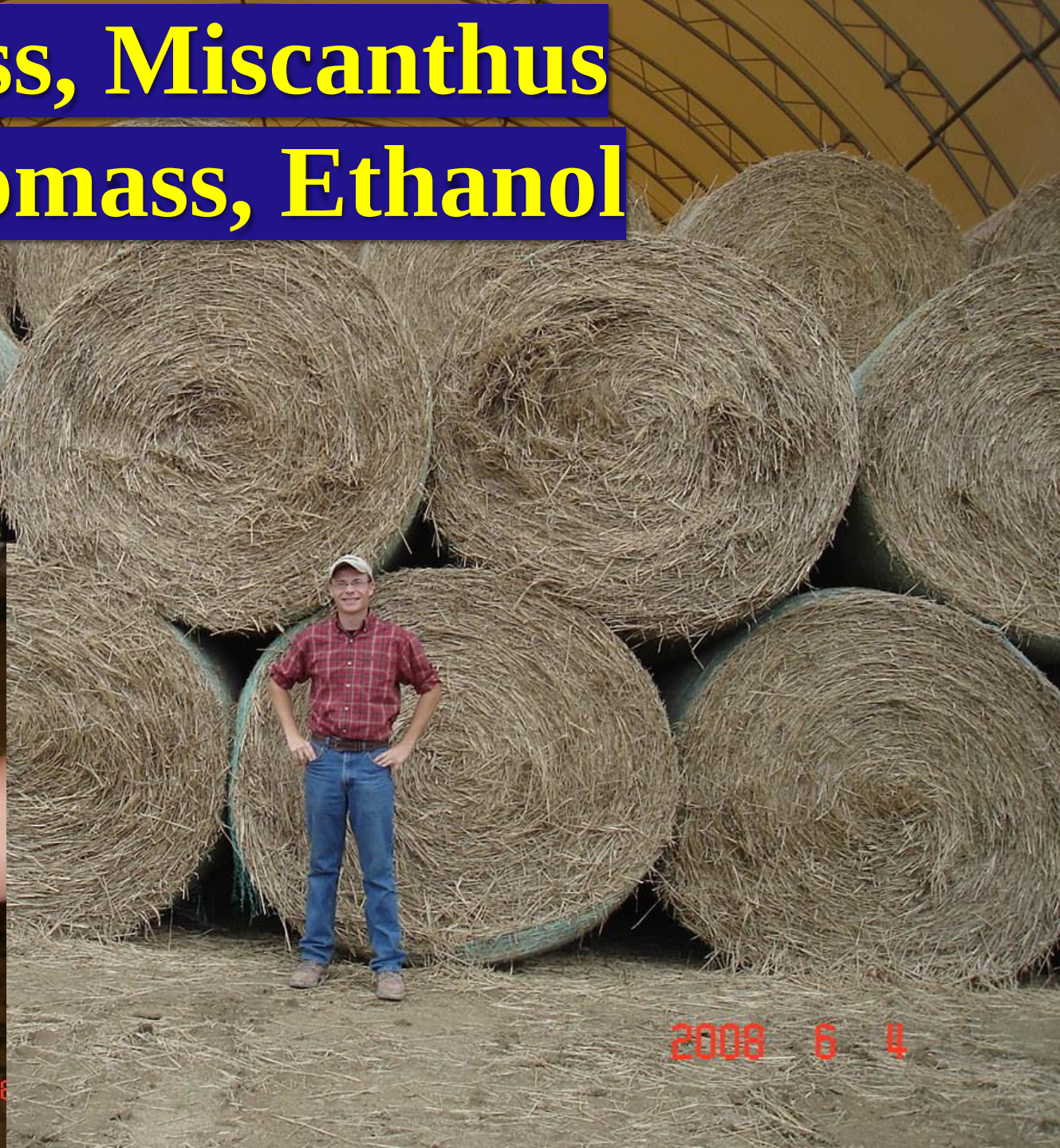
Why not reclaim land for biofuel production?



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

BioEnergy Crops – 2nd Yr Switchgrass on Reclaimed Mine

Switchgrass, Miscanthus Pellets, Biomass, Ethanol



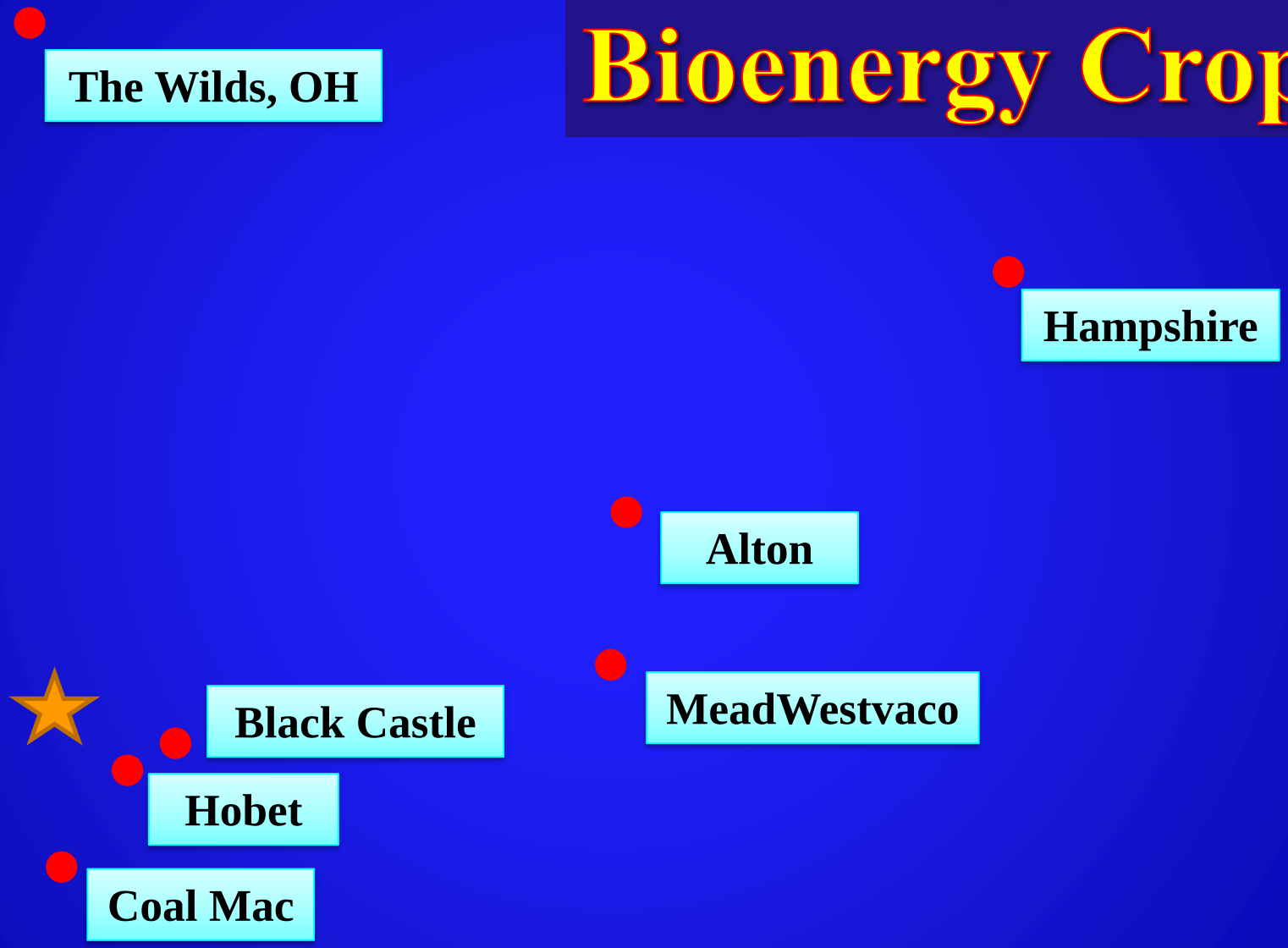
Switchgrass Yields

Study	Yield Mt ha^{-1}	Description
Fike et al. (2017)	14 – 19	4 cultivars, 8 sites, 5 states
Vogel & Masters (1998)	15 – 17	3 states in Midwestern USA
Fike et al. (2006b)	14 – 18	Years 6 - 9 of production
McLauglin (2005)	11 – 19	CIR; 10 years, 13 states
Schmer et al. (2014)	5 – 12	Marginal cropland
Brown et al. (2015)	5 – 10	Reclaimed land in WV

Goal would be 5.0 Mt ha^{-1}

What yields of switchgrass can grow on reclaimed mine lands ?

Summary of Sites Bioenergy Crops



First 2 Sites – planted 2008

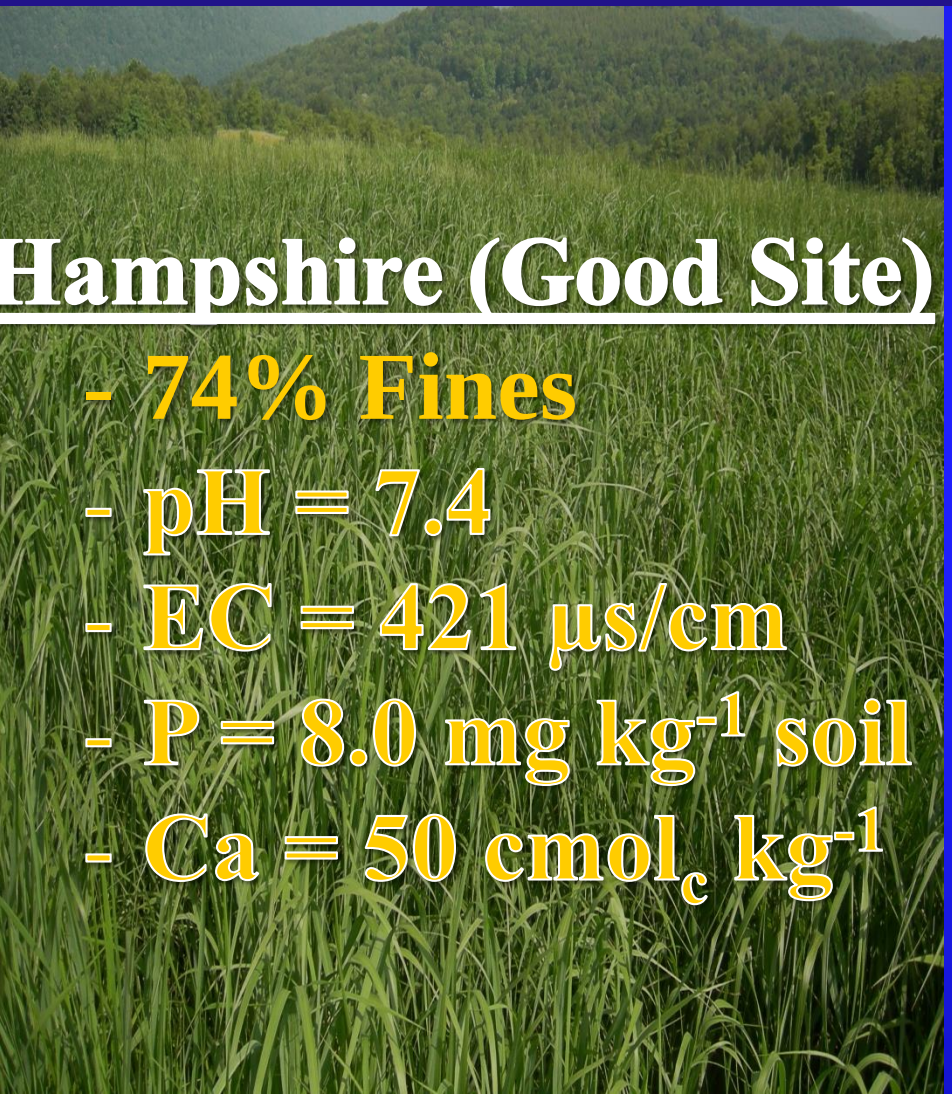
Varieties

- Three varieties of switchgrass
  - Carthage
  - Cave-in-Rock
  - Shawnee

Hand seeding at Hobet

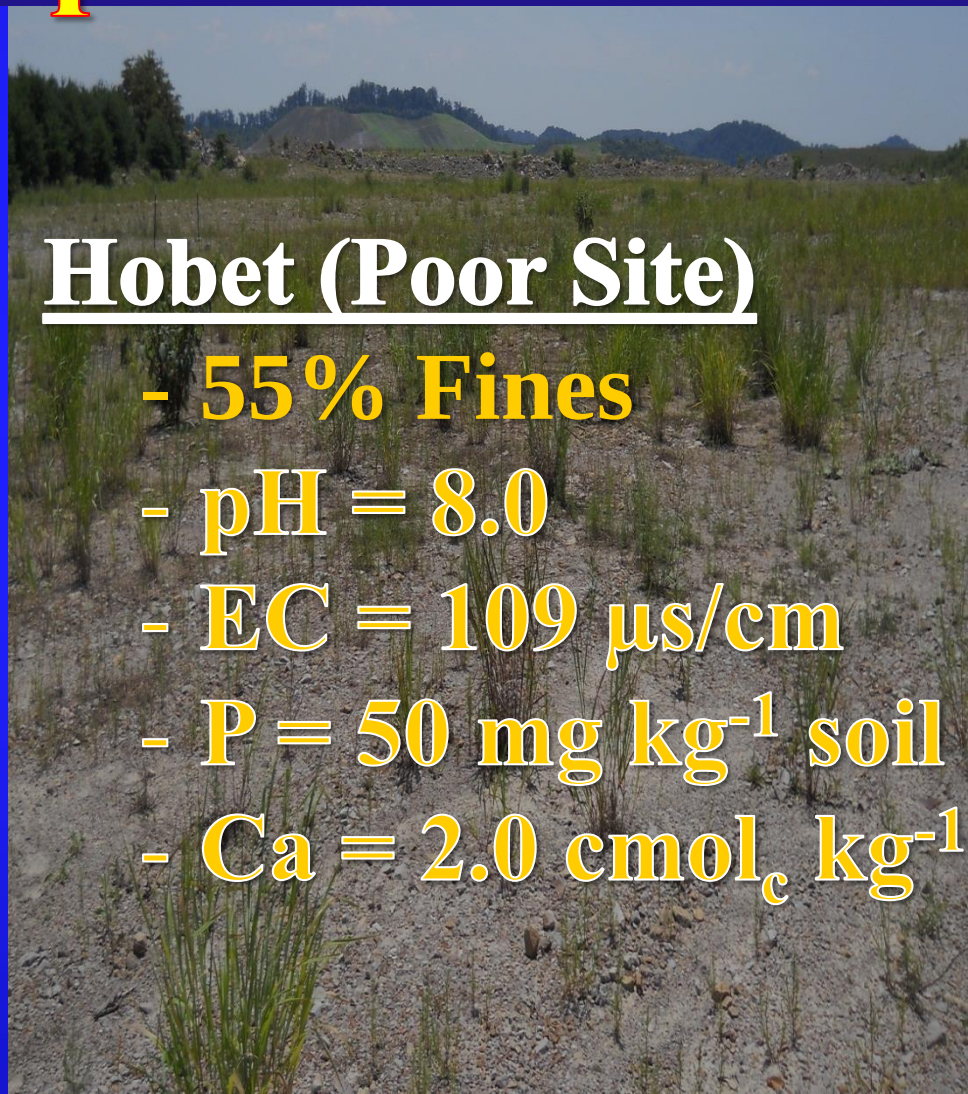
Results

Soil Properties



Hampshire (Good Site)

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



Hobet (Poor Site)

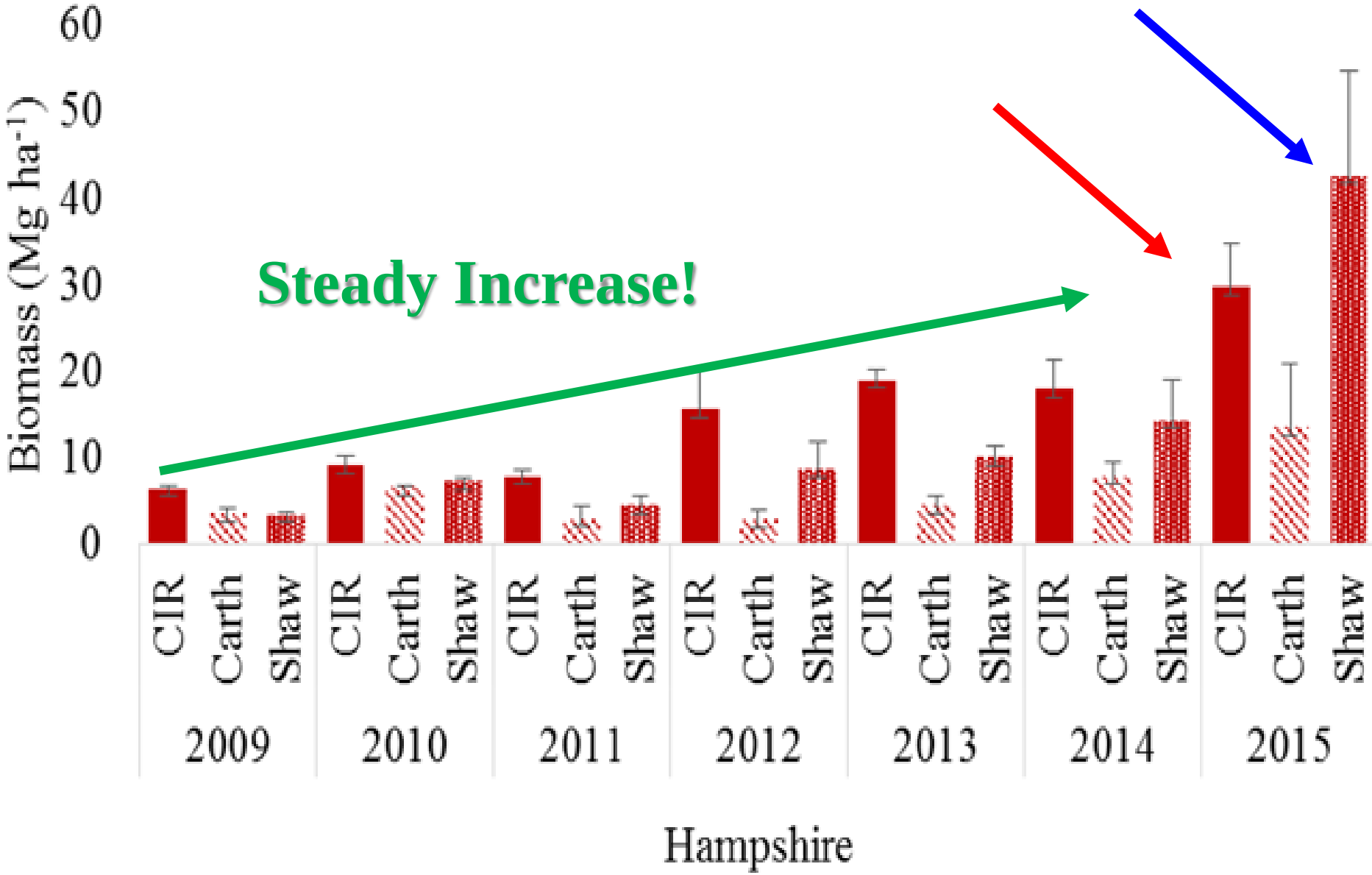
- 55% Fines
- pH = 8.0
- EC = 109 µs/cm
- P = 50 mg kg^{-1} soil
- Ca = 2.0 $cmol_c$ kg^{-1}

Results - Yield

Ave – 2009 to 2015

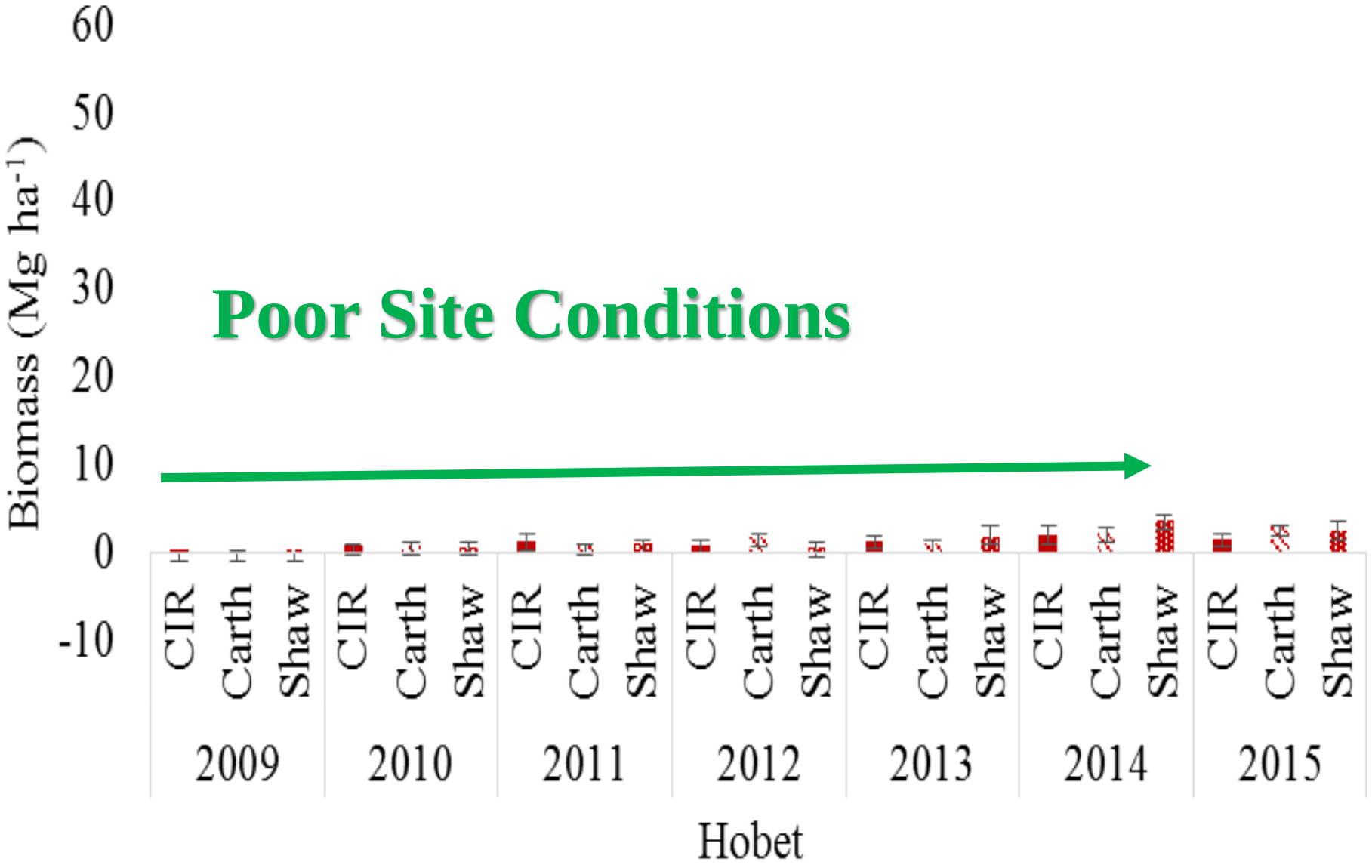
Variety	Hampshire	Hobet
	----- Mt ha^{-1} ----	
Cave in Rock	15.1	1.5
Carthage	8.0	1.3
Shawnee	13.2	1.5

Hampshire – 8th Year – 2015



Hampshire – 8th Year – 25 Mt ha-1

Hobet – 8th Year – 2015



Hobet – 8th Year – 1.5 Mt ha-1

Where do our numbers stand?

Agricultural Land: **15 - 20 Mt ha^{-1}**

Cave-in-Rock at Hampshire: **15 Mt ha^{-1}**

Shawnee at Hobet: **1.5 Mt ha^{-1}**

Goal of 5.0 Mt ha^{-1}

What about other crops?

Switchgrass

Kanlow and BoMaster

Miscanthus

Illinois and MBX-002

Planted in 2010


Each 0.4 ha or 1 acre
5 plots Kanlow
5 plots BoMaster
5 plots Miscanthus – MBX
5 plots Miscanthus – Illinois
5 plots Arundo
Aru
Aru
Aru
Bow
Pub
Pri
Pri
Pub
Kan
Kan
Bow
Pri
Pri
Pub
Pub
Kan
Bow
Kan
Bow
Kan
Bow
Pub
Pri
200 ft
100 m


Must Herbicide!
06/14/2013

Switchgrass drilled into killed sod

Miscanthus sprigs planting at Alton

Planted sprigs like tree seedlings

Alton Soils

70% Fines

pH = 7.5

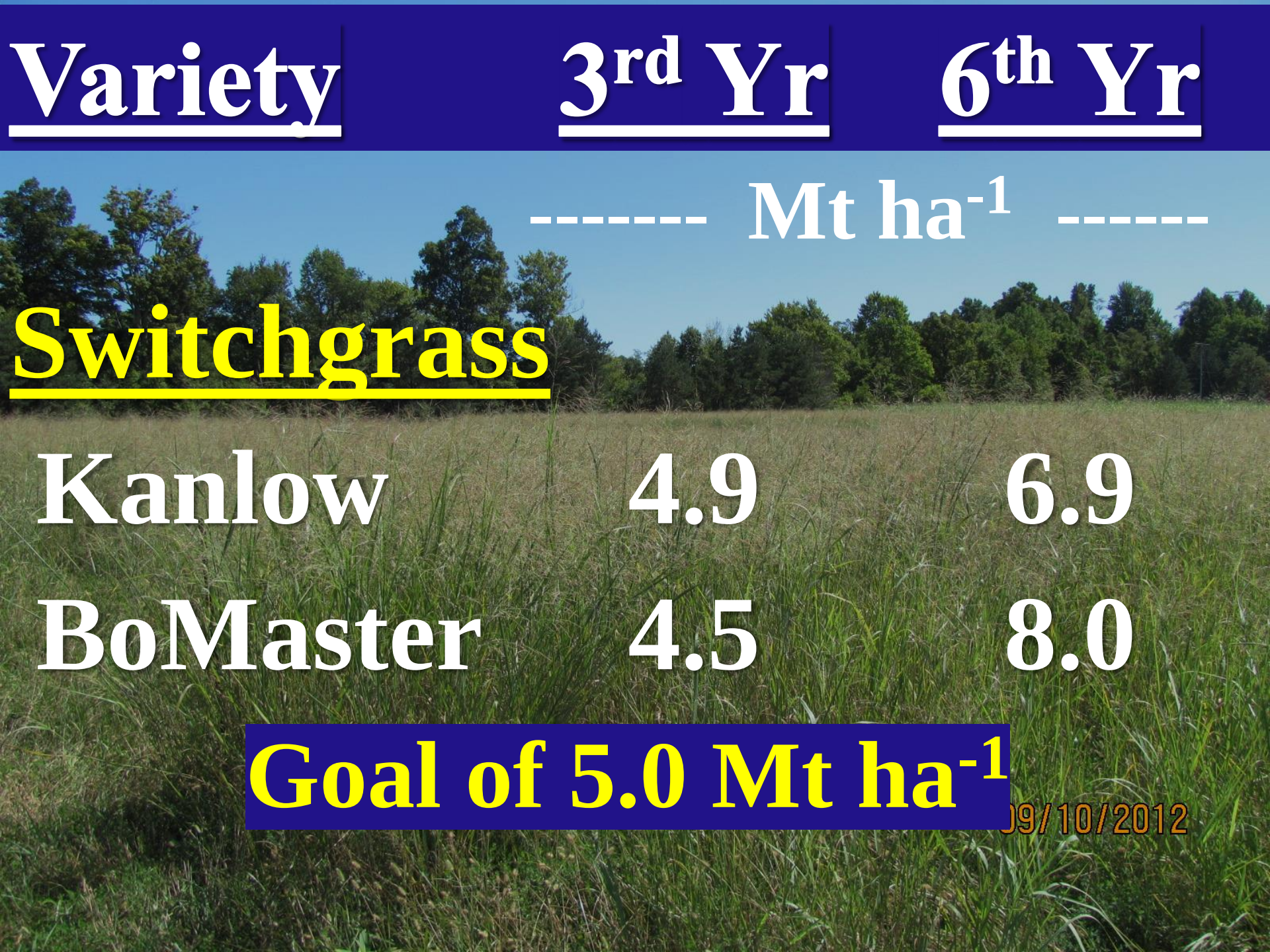
EC = 368 µs/cm

P = 40 mg kg^{-1} soil

K = 0.2 $cmol_c$ kg^{-1}

Ca = 3.2 $cmol_c$ kg^{-1}

10/26/2012

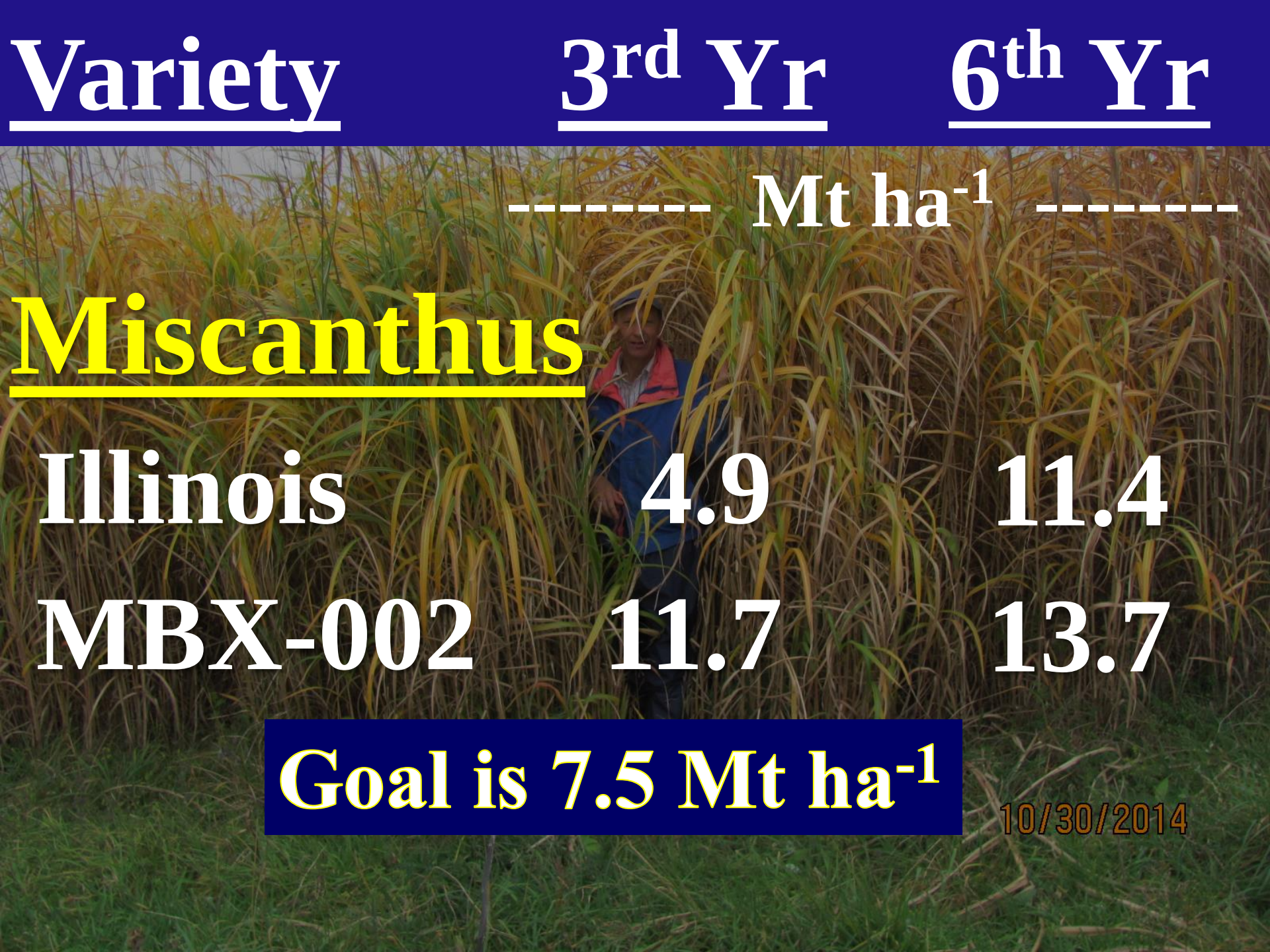

Variety
3rd Yr
6th Yr
------- Mt ha-1 ------
Switchgrass
Kanlow 4.9 6.9
BoMaster 4.5 8.0
Goal of 5.0 Mt ha-1
09/10/2012

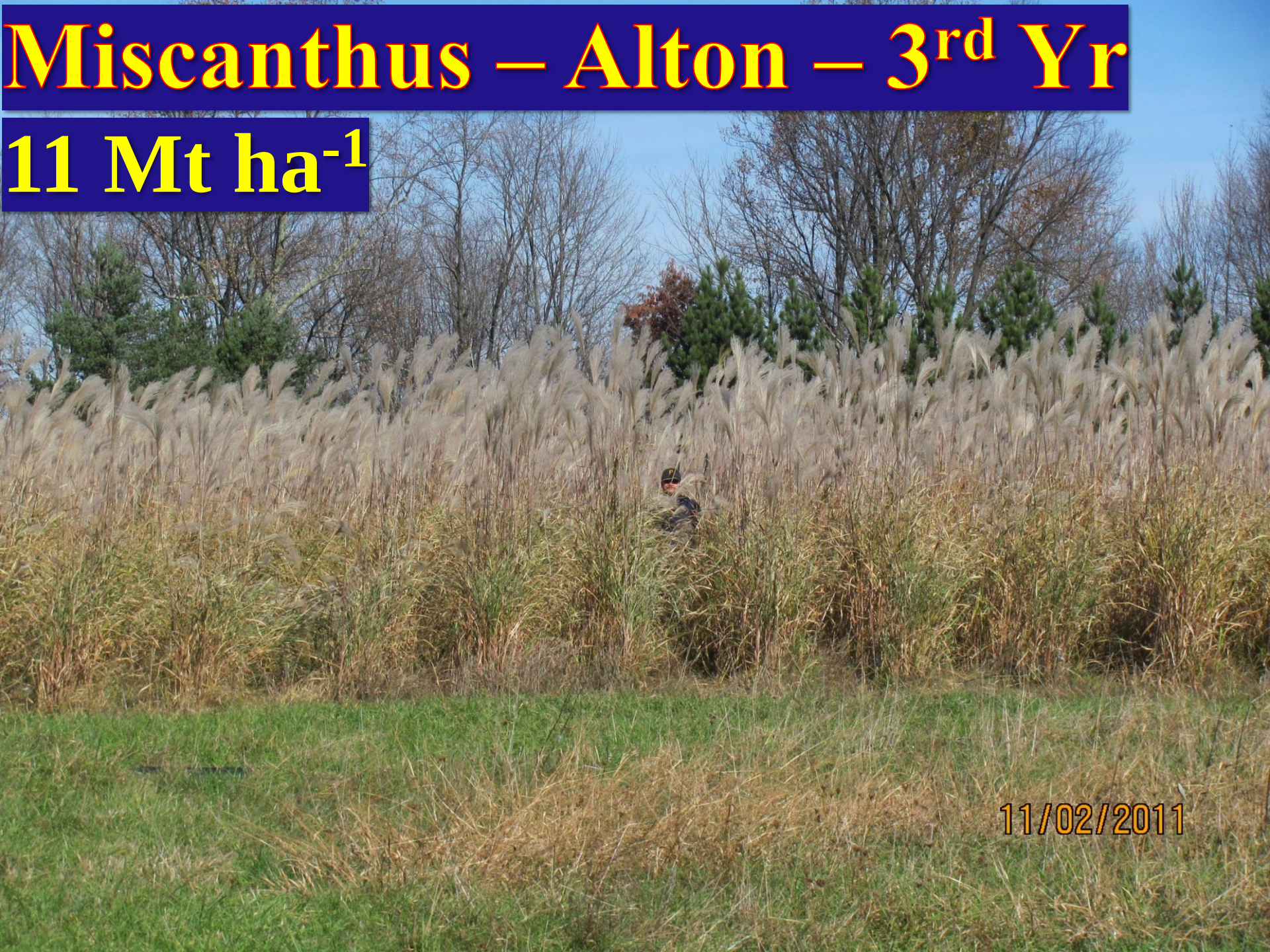
Switchgrass – Alton – 3rd Yr

5 Mt ha^{-1}

Switchgrass – Alton – 6th Yr

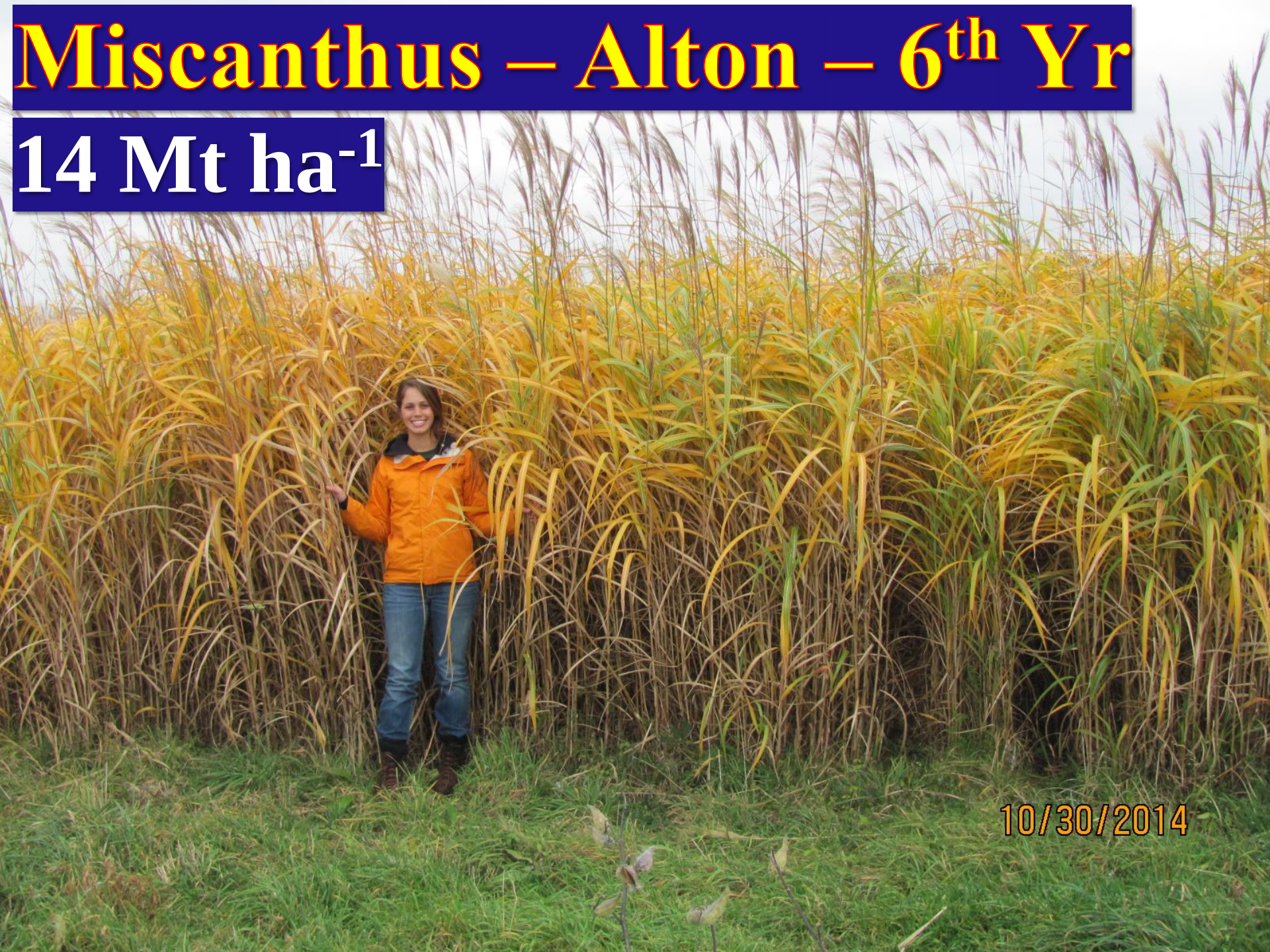
8 Mt ha^{-1}


Variety
3rd Yr
6th Yr
--------- Mt ha-1 ---------
Miscanthus
Illinois 4.9 11.4
MBX-002 11.7 13.7
Goal is 7.5 Mt ha-1
10/30/2014


Miscanthus – Alton – 3rd Yr
11 Mt ha-1
11/02/2011

Miscanthus – Alton – 6th Yr

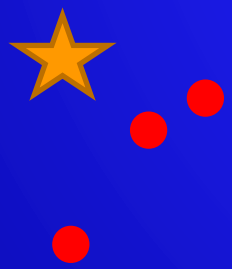
14 Mt ha^{-1}



Large Plots

The Wilds, OH

Planted in 2010



MeadWestvaco


06/14/2013

Switchgrass – MeadWestvaco – 1st Yr

Switchgrass – MeadWestvaco – 2nd Yr

3 Mt ha^{-1}

The Wilds – Drilling into herbicided area

Switchgrass – The Wilds – 1st Yr

Switchgrass – The Wilds – 2nd Yr

5 Mt ha^{-1}

Harvest at The Wilds - 2017

Conventional Haying Equipment

Biomass Conclusions

After 3rd year on reclaimed land

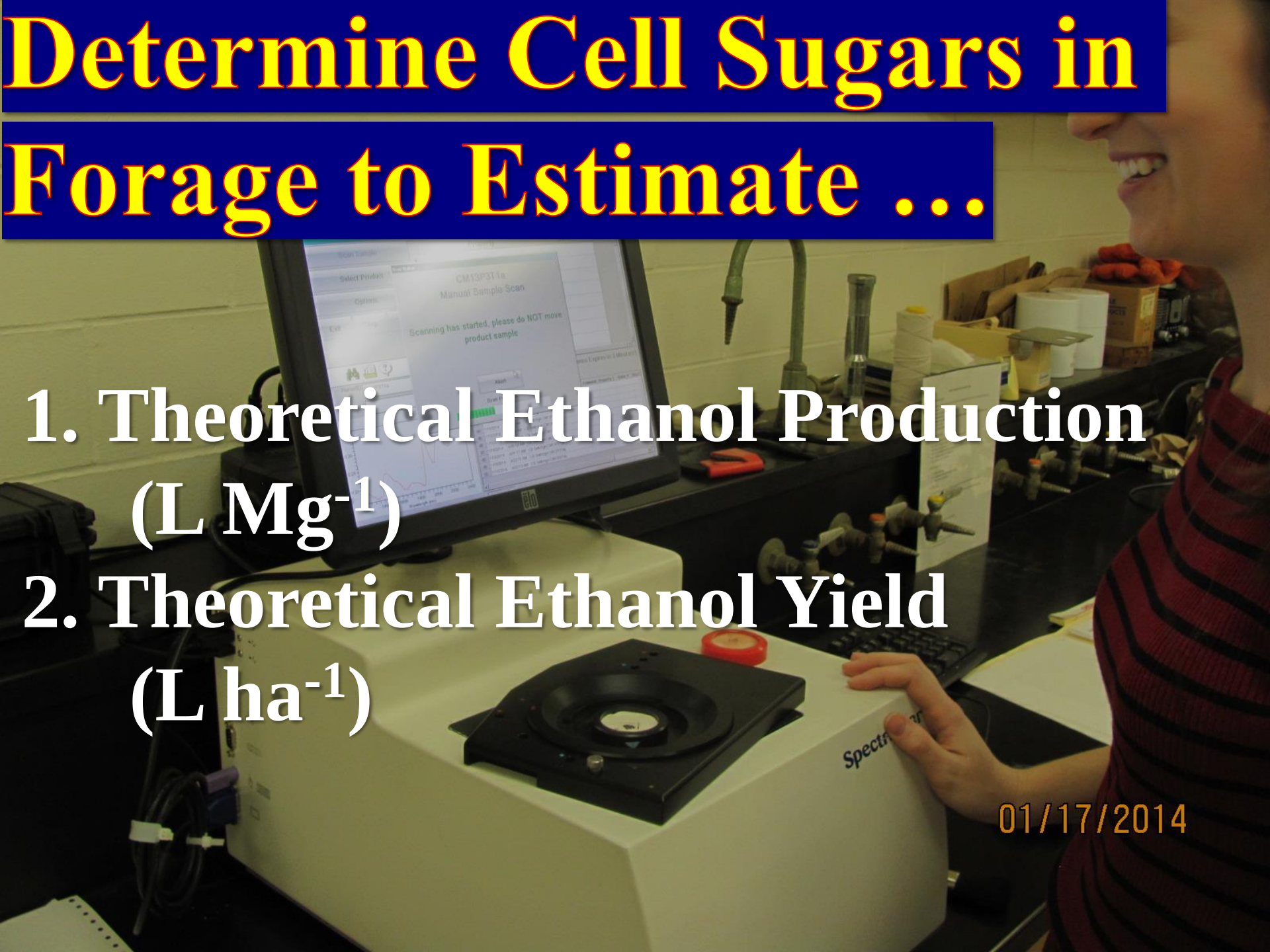
Switchgrass: 5 to 15 Mt ha^{-1}

Miscanthus: 10 to 15 Mt ha^{-1}

Increasing to the 8th year

09/10/2012

Determine Cell Sugars in Forage to Estimate …



1. Theoretical Ethanol Production ($L\ Mg^{-1}$)
2. Theoretical Ethanol Yield ($L\ ha^{-1}$)

Sugars in Biomass to estimate Theoretical Ethanol Yield

Cell Wall Constituents

<u>Hexose:</u>	
Mannan	MAN
Galactan	GAL
Glucan	GLC
Sucran	SUC
Soluble Glucose	GLCS
Fructan	FRU
Starch	STA
<u>Pentose:</u>	
Arabinan	ARA
Xylan	XYL

Prediction of Theoretical Ethanol Yield (TEY) and Production (TEP)

6-carbon sugars

HEX	(((**GLC**+**GAL**+**MAN**+STA)×0.57)+((GLCS+FRU) ×(SUCx0.537)) ×1.267; assuming 100% conversion	L Mg^{-1}
PEN	(**XYL**+**ARA**)×0.579×1.267	L Mg^{-1}
TEY1	HEX+PEN	L Mg^{-1}
TEP1	TEY1×biomass yield (Mg ha^{-1})	L ha^{-1}

Prediction of Theoretical Ethanol Yield (TEY) and Production (TEP)

5-carbon sugars

HEX	(((**GLC**+**GAL**+**MAN**+STA)×0.57)+((GLCS+FRU) ×(SUCx0.537)) ×1.267; assuming 100% conversion	L Mg^{-1}
PEN	(**XYL**+**ARA**)×0.579×1.267	L Mg^{-1}
TEY1	HEX+PEN	L Mg^{-1}
TEP1	TEY1×biomass yield (Mg ha^{-1})	L ha^{-1}

Prediction of Theoretical Ethanol Yield (TEY) and Production (TEP)

HEX	(((**GLC**+**GAL**+**MAN**+STA)×0.57)+((GLCS+FRU) ×(SUCx0.537)) ×1.267; assuming 100% conversion	L Mg^{-1}
PEN	(**XYL**+**ARA**)×0.579×1.267	L Mg^{-1}
TEY1	HEX+PEN	L Mg^{-1}
TEP1	TEY1×biomass yield (Mg ha^{-1})	L ha^{-1}

Switchgrass – Hampshire in 2016

Theoretical Ethanol Yield and Production

	C6[a]	C5	TEY2	TEP2
	--------L Mg^{-1}--------			L ha^{-1}
Cultivar				
CIR	235	183	420	13,274
Carthage	224	180	405	5,623
Shawnee	230	181	412	17,502
SE	2.4	2.5	4.3	3,476

Switchgrass – Hampshire in 2016

Theoretical Ethanol Yield and Production

Cultivar	C6[a]	C5	TEY2	TEP2
	--------L Mg^{-1}--------			L ha^{-1}
				x biomass
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Carthage	224	180	405	5,623
Shawnee	230	181	412	17,502
SE	2.4	2.5	4.3	3,476

Switchgrass vs Miscanthus – 2016

Theoretical Ethanol Yield and Production

	C6[a]	C5	TEY2	TEP2
	--------	L Mg^{-1}	-------	L ha^{-1}
cies				
Switchgrass	259	216	479	4,261
Miscanthus	266	209	467	5,423
SE	1.6	2.6	0.27	581

Switchgrass vs Miscanthus – 2016

Theoretical Ethanol Yield and Production

	C6[a]	C5	TEY2	TEP2
	--------	L Mg^{-1}	-------	L ha^{-1}
cies				**x biomass**
Switchgrass	259	216	479	4,261
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SE	1.6	2.6	0.27	581

Ethanol Conclusions

1. Differences in TEY

CIR > Shawnee, Carthage

Switchgrass > Miscanthus

2. Differences in TEP (x biomass)

Miscanthus > Switchgrass

Questions?