

# Biomass Bio-oil and Biochar for Sustainable Bioenergy Production System

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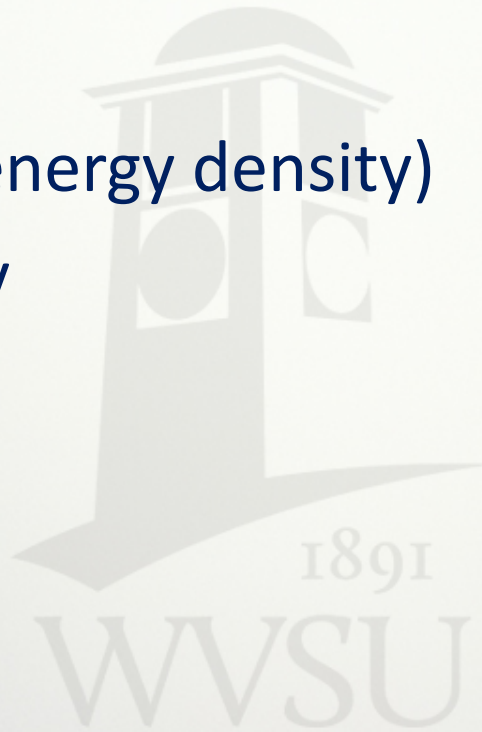


Renewable Energy Conference, Flatwoods, WV  
June 5<sup>th</sup> 2014

# Biomass to Bioenergy

## Main Hindering Factors

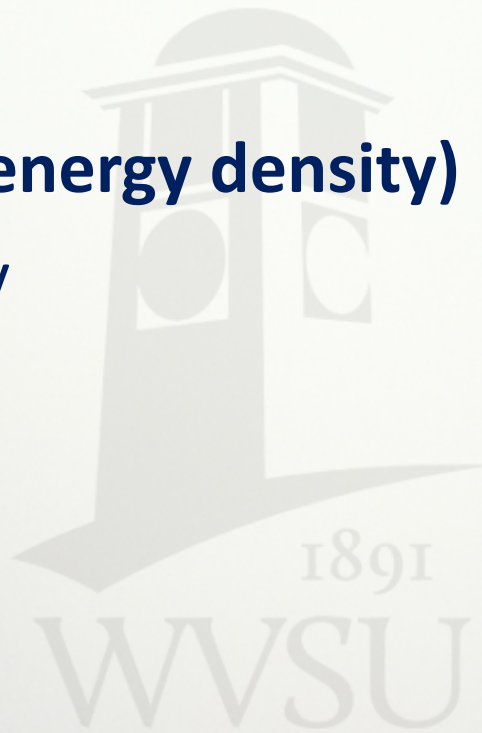
- Transportation (energy density)
- Land Productivity
- Water



# Biomass to Bioenergy

## Main Hindering Factors

- **Transportation (energy density)**
- Land Productivity
- Water



# Woody Biomass in WV

**Total Forest Area: 12,000,000 acres**

**Harvest Area: 240,000 acres/year**

**Logging Residue: 10.4 ton/acres**

**Biomass Left Behind > 2,000,000 ton/year**

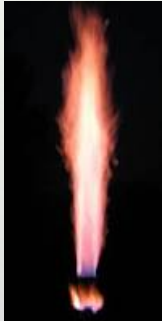
Wang et al., 2007

# Pyrolysis Products

**Biomass**  
( $\approx 19\text{MJ/Kg}$ ;  $0.5\text{ kg/l}$ )



**Syngas**  
( $20\%$ ;  $11\text{ MJ/m}^3$ )



**Biochar**  
( $20\%$ ;  $\approx 22\text{ MJ/kg}$ ;  $0.45\text{ kg/l}$ )



**Bio-oil**  
( $60\%$ ;  $\approx 20\text{ MJ/kg}$ ;  $1.2\text{ kg/l}$ )



# Pyrolysis Products

Typical properties of wood pyrolysis bio-oil and of heavy fuel oil [59].

Physical property	Bio-oil	Heavy fuel oil
Moisture content (wt.%)	15–30	0.1
pH	2.5	–
Specific gravity	1.2	0.94
Elemental composition (wt.%)		
C	54–58	85
H	5.5–7.0	11
O	35–40	1.0
N	0–0.2	0.3
Ash	0–0.2	0.1
HHV (MJ/kg)	16–19	40
Viscosity (at 50 °C, cP)	40–100	180
Solids (wt.%)	0.2–1	1
Distillation residue (wt.%)	Up to 50	1

Zhang et al., 2010



Agri-Therm Ltd.





Battelle Biofuels and Bioproducts

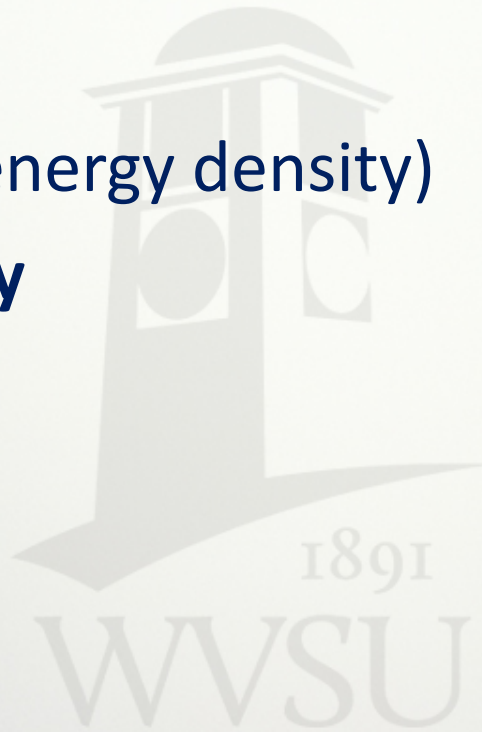




# Biomass to Bioenergy

## Main Hindering Factors

- Transportation (energy density)
- **Land Productivity**
- Water



# Land Productivity



# Land Productivity



# Land Productivity



**Yield Gap (Actual)**

NO FERT  
NO LIME

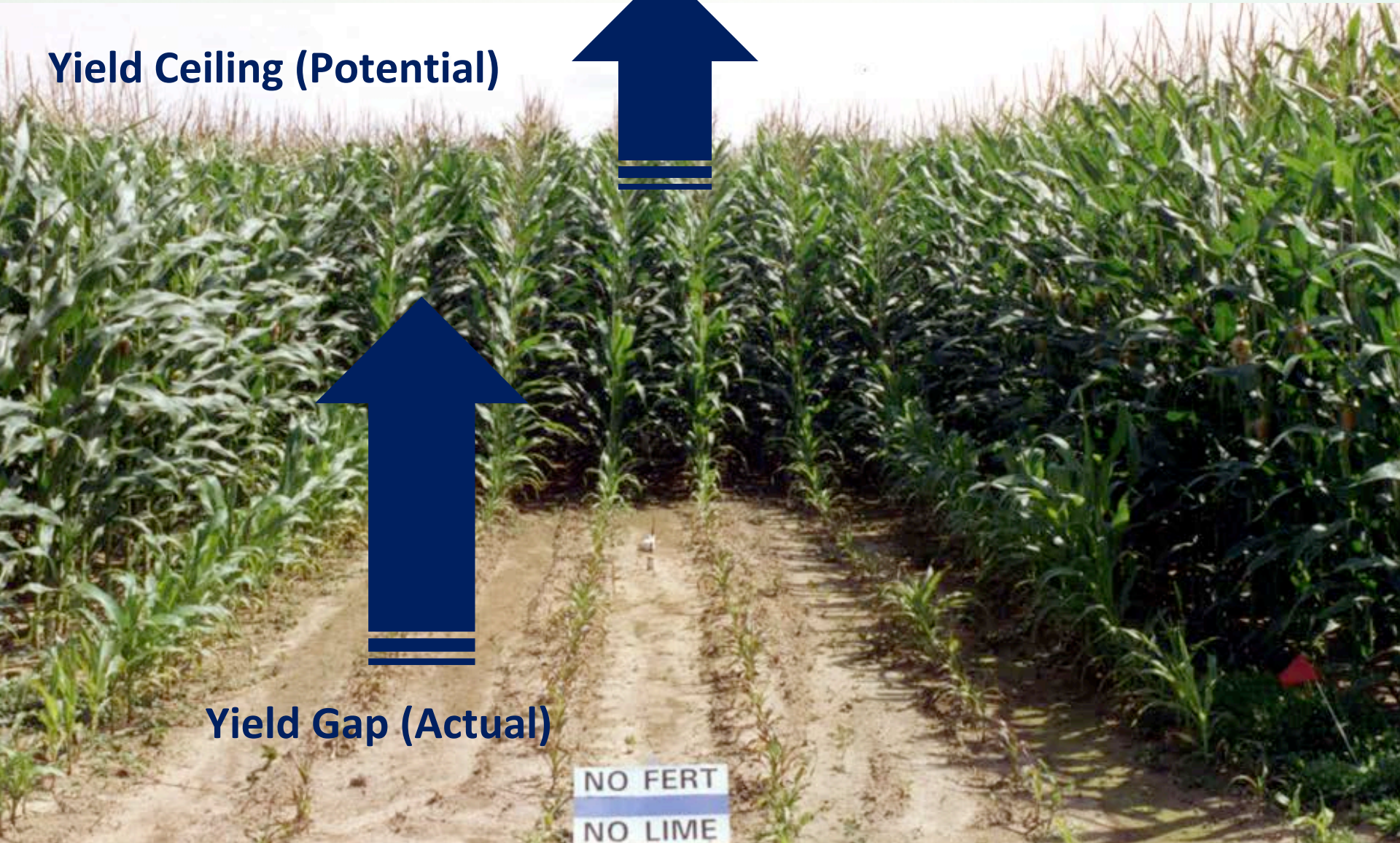
# Land Productivity

Yield Ceiling (Potential)



Yield Gap (Actual)

NO FERT  
NO LIME



An aerial photograph showing a landscape with a river on the left side, winding through agricultural fields. The fields are divided into various plots, some of which appear to be planted with crops. The terrain is a mix of green vegetation and brownish soil. The text "Productive Land Inventory" is overlaid in yellow on the right side of the image.

# Productive Land Inventory



# Productive Land Inventory

Low fertility High Heterogeneity

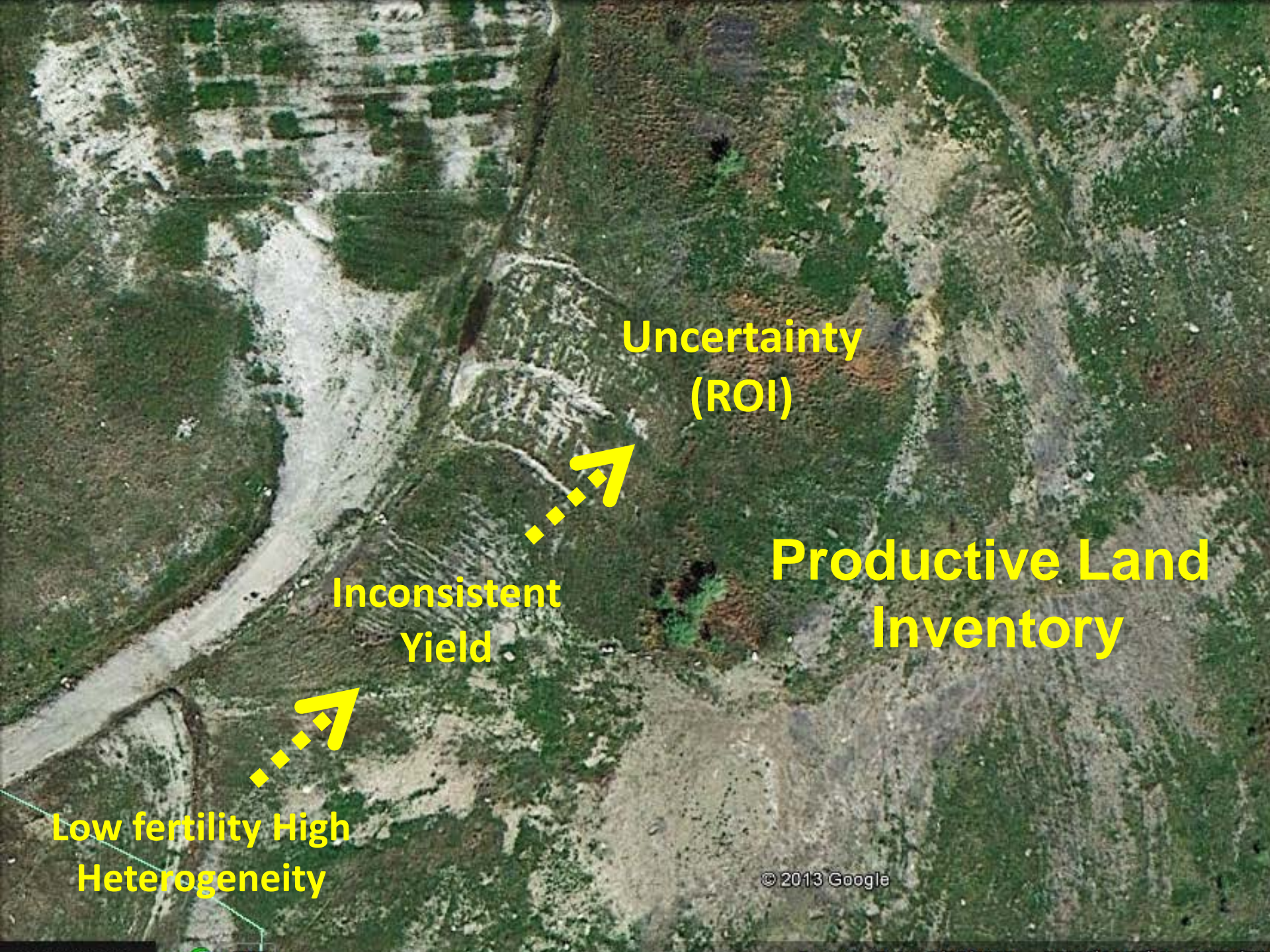


**Inconsistent  
Yield**

**Productive Land  
Inventory**

**Low fertility High  
Heterogeneity**





**Uncertainty  
(ROI)**

**Inconsistent  
Yield**

**Productive Land  
Inventory**

**Low fertility High  
Heterogeneity**



**Risk**

**Uncertainty  
(ROI)**

**Productive Land  
Inventory**

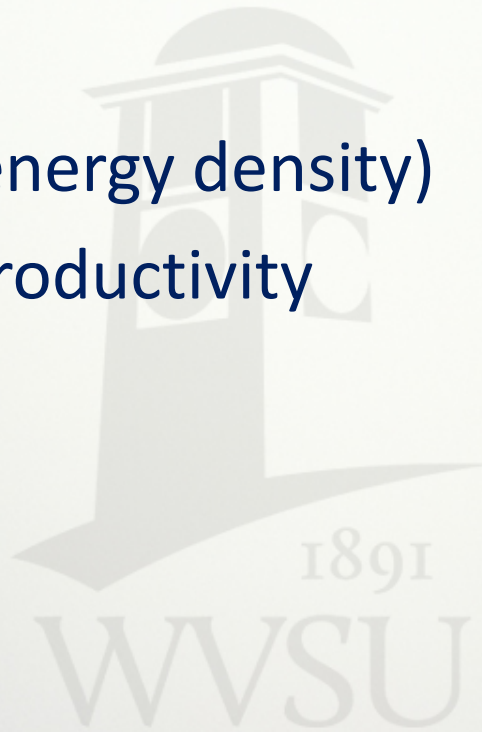
**Inconsistent  
Yield**

**Low fertility High  
Heterogeneity**

# Biomass to Bioenergy

## Main Hindering Factors

- Transportation (energy density)
- Plant and Land Productivity
- **Water**



# Water Use & Resources

**2 g P, 15 g N per kg of dry-weight vegetative biomass**



# Water Use & Resources

2 g P, 15 g N per kg of dry-weight vegetative biomass

> 300 x water

## Evapotranspiration, above-ground biomass

<i>Miscanthus</i>	7.8-9.5 g/kg
<i>Spartina</i>	5.1-8.2 g/kg
<i>Cynara</i>	3.1-5.5 g/kg
<i>Miscanthus</i>	3.4-4.1 g/kg
Willow ( <i>Salix</i> )	3.0-3.7 g/kg
Maize ( <i>Zea</i> )	3.0 g/kg
Willow ( <i>Salix</i> ) stems only	2.2-2.9 g/kg
Willow ( <i>Salix</i> ) stems only 2. rotation	1.7-1.9 g/kg
Willow ( <i>Salix</i> ) stems only 1. rotation	0.3-1.7 g/kg

Jorgensen & Schelde, 2001



# Water Use & Resources

**TABLE 1. Water Requirements for Energy Production by Different Processes (20)**

Process	L/MWh
petroleum extraction	10–40
oil refining	80–150
oil shale surface retort	170–681
NGCC <sup>a</sup> power plant, closed loop cooling	230–30,300
coal IGCC <sup>b</sup>	~900
nuclear power plant, closed loop cooling	~950
geothermal power plant, closed loop tower	1900–4200
EOR <sup>c</sup>	~7600
NGCC, open loop cooling	28,400–75,700
nuclear power plant, open loop cooling	94,600–227,100
corn ethanol irrigation	2,270,000–8,670,000
soybean biodiesel irrigation	13,900,000–27,900,000

<sup>a</sup> Natural gas combined cycle. <sup>b</sup> Integrated gasification combined-cycle. <sup>c</sup> Enhanced oil recovery.

Faus et al., 2009

# Water Use & Resources



# Water Use & Resources



**Clean Water Act Sec. 402. Surface Water  
Runoff Analysis (SWROA) regulations,  
TMDL's for Selenium, TSS, ...**

**National Pollution Discharge Elimination  
System (NPDES), MS4's permit, etc.**



# The Road Ahead:

- **Yield Ceiling / Potential** (Improving genetic stock)
- **Yield Gap / Actual yield** (Improving management practices / biochar as soil amendment)
- **Storm Water / Runoff Management** (landscape hydrology)
- **Productive Land Inventory** (marginal/mine land productivity / biochar as soil amendment)
- **Feedstock Densification / On-Site Conversion** (e.g. pyrolysis/bio-oil)



# Surface Application of Biochar



(Husk & Major 2010)

1891  
WV  
SU



# Surface Application of Biochar



(Husk & Major 2010)

**Feedstock**



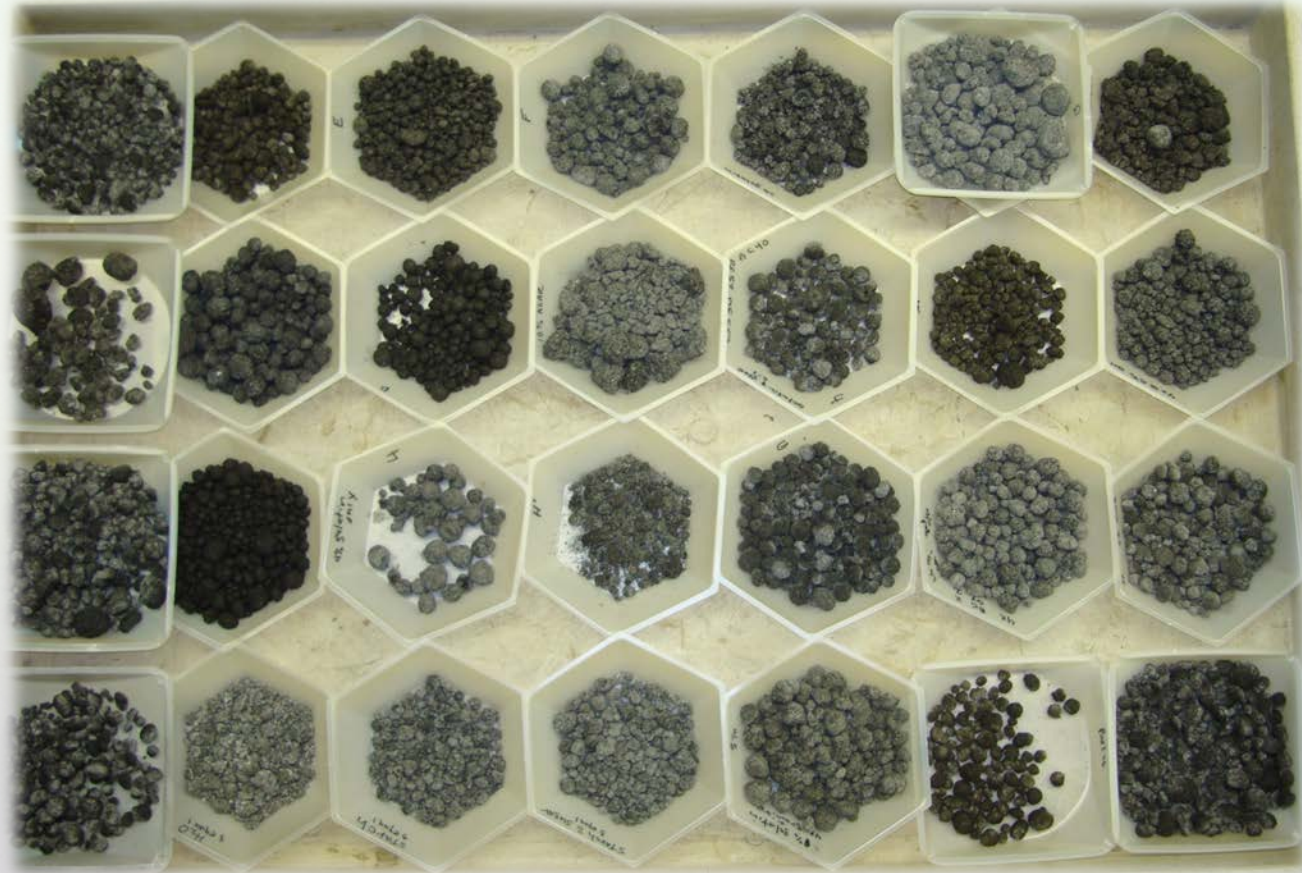
**Co-product Biochar**



**Agglomerated Biochar**



# Biochar Agglomeration



# Biochar Augmentation



**Control**  
AgLime, + nutrients x 2

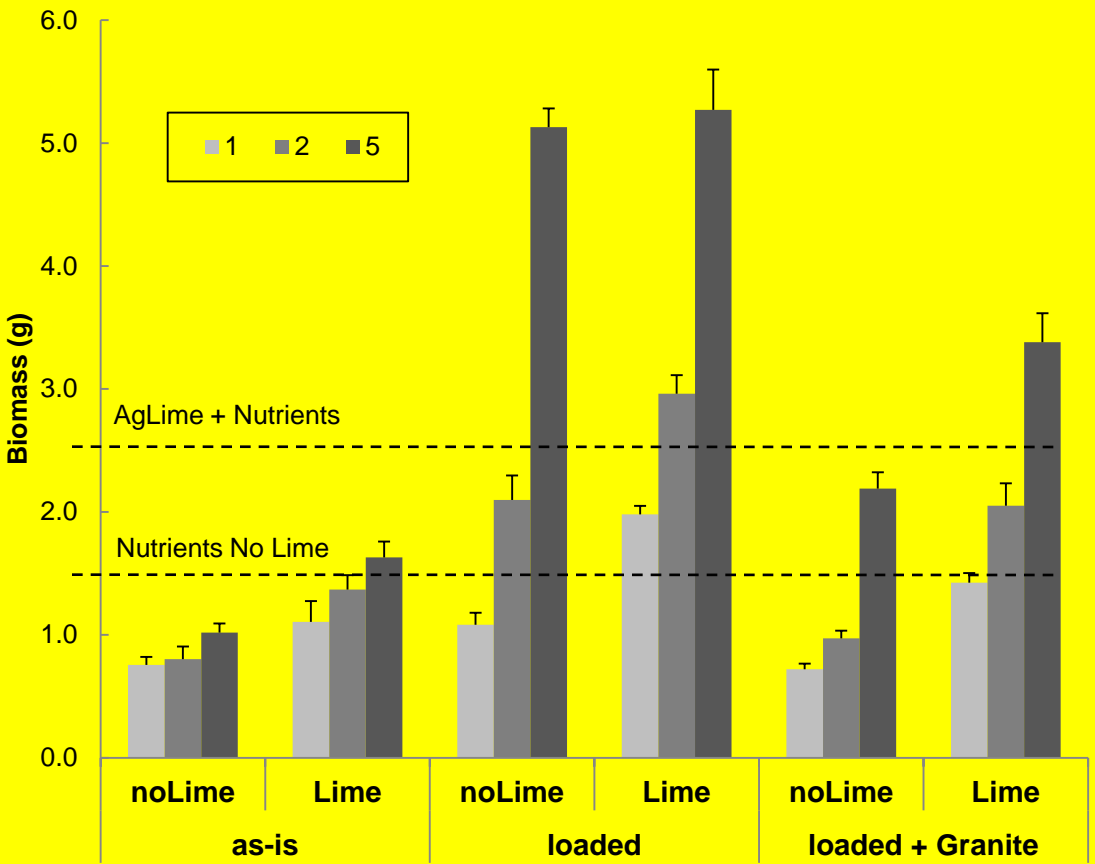
**Biochar**  
5% Loaded

**Biochar**  
5% as is

**Biochar**  
2% Loaded

**Biochar**  
2% as is

# Biochar Augmentation



**Control**  
AgLime, + nutrients x 2

**Biochar**  
5% Loaded

**Biochar**  
5% as is

**Biochar**  
2% Loaded

**Biochar**  
2% as is