Adding value to ethanol production byproducts through production of biochar and bio-oil

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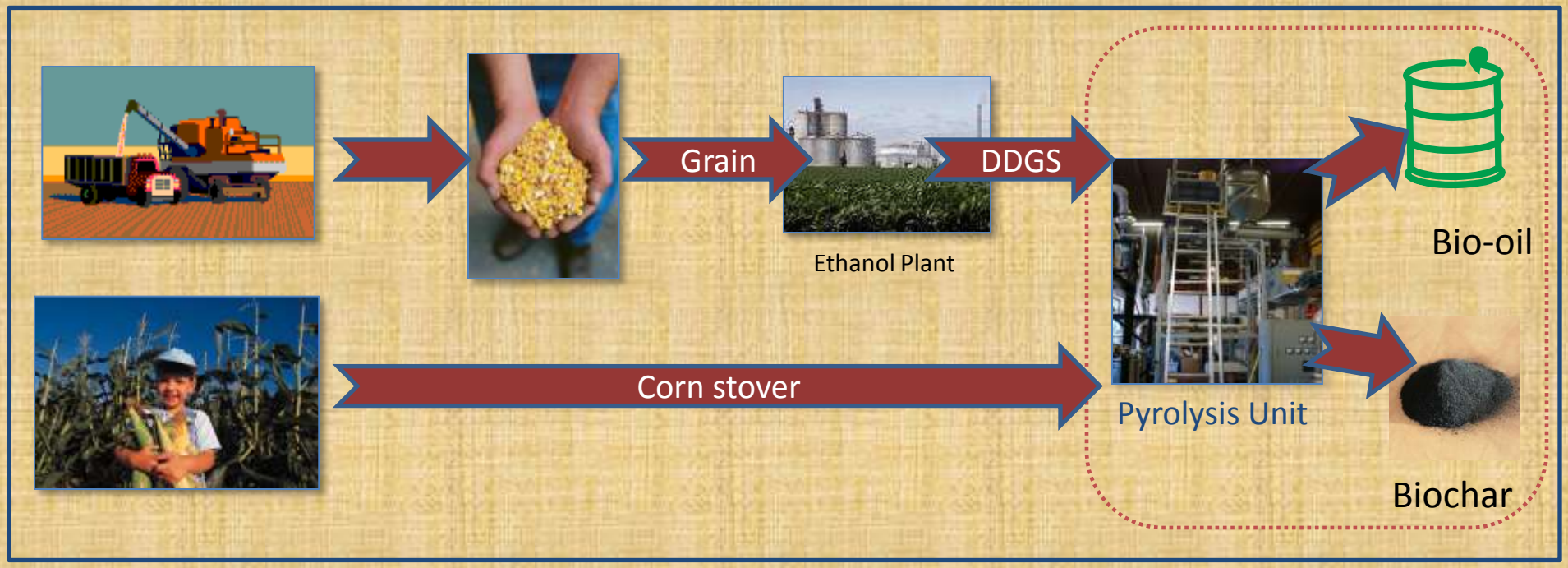

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Project Objectives

1. Examine the production of **biochar** and **bio-oil** from distillers grain and corn stover mixtures from **microwave pyrolysis**

2. Examine the potential role of this biochar in **C sequestration** and improvements in the **sustainability** of corn production

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Current Ethanol Production

>30% in MN

Ethanol

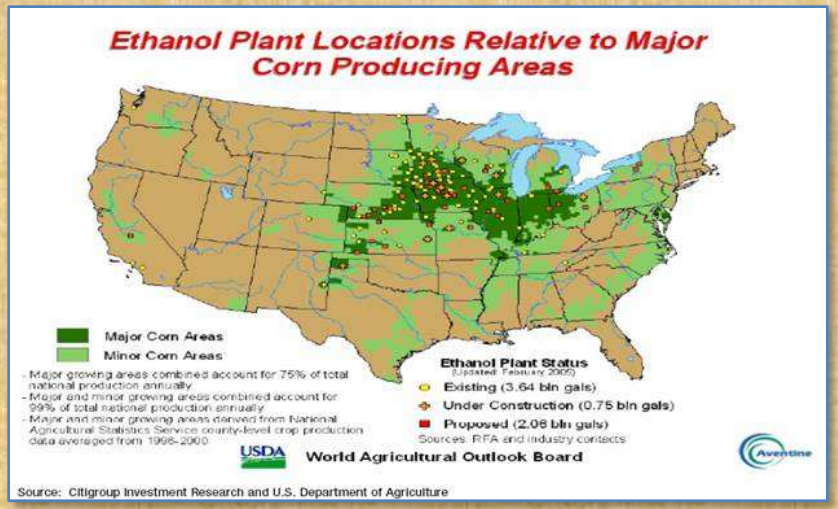
Ethanol → market

Future?

wet cake separated

DDGS → market

Syrup/thin silage → market



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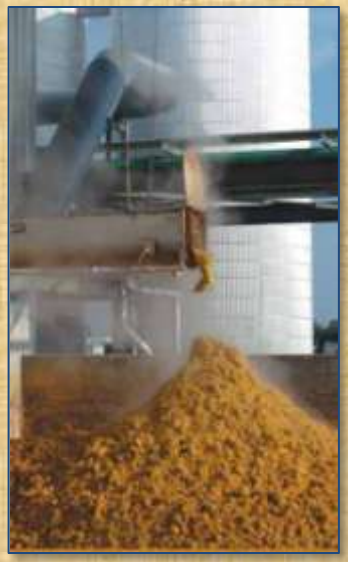
Why Distillers Grain?



- ~25% of US ethanol plants are in MN
- Emerging issues related to distillers grain as livestock feed:

Food security

  - Pharmaceutical residues (antibiotics)
  - Mycotoxins (e.g. vomitoxin)
  - Other pathogens (*E. Coli*)
  - Feeding limits

- **Distillers grain is an important income source for ethanol plants**
  - Desire to keep and enhance economic value of distillers grain and other co-products

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Proposed New Vision of Ethanol Plant Production

Syn-gas – Reduce natural gas use

DDGS/Wet cake

Ethanol Production

Pyrolysis

Heating Oil

Ethanol → market (unaffected)

(reduced quantities)

DDGS → market

Syrup/thin silage → market

Bio-oil

Corn Production

Biochar

Soil Applied Biochar

Increased soil quality and fertility

- Improved sustainability
- Improved nutrient utilization
- Decreased nitrate leaching
- Reduced fertilization requirements
- Reduced N_2O production

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What is biochar?

- Definition:
  - **Black carbon** that is created from biomass for the purposes of atmospheric ***carbon sequestration***

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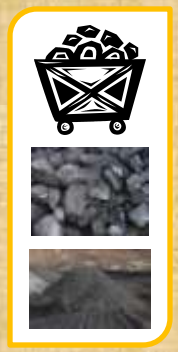

- ***Black carbon***: Range of solid residual products resulting from the chemical and/or thermal conversion of any carbon containing material (e.g., fossil fuels and biomass) (Jones et al., 1997)
  - Names used for this spectrum of products:
    - » Charcoal, graphite, chars, bone black, carbon blacks, soots, etc.

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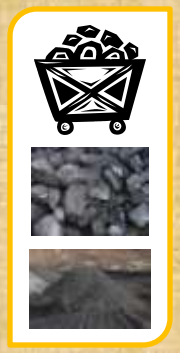


- ***Black carbon***: Range of solid residual products resulting from the chemical and/or thermal conversion of any carbon containing material (e.g., fossil fuels and biomass) (Jones et al., 1997)

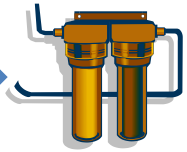
- ***Carbon Sequestration***: Transfer of carbon from a quick (fast) cycling C-pool (atmospheric-plant) to a slower C-pool (more resistant to microbial mineralization).

Biochar: Not a new material….

Purpose for the creation of black carbon has changed with time:

Cave Drawings
(>10,000 to 30,000 BC)

Energy Source (fuel)
(3000-4000 BC)



Water filtration
(3000-4000 BC)

Charcoal production
(15th century)

Climate Change Mitigation
(1980's)

Properties of Biochar leading to surge in recent interest:

* Carbon Storage
  - Biochar can store atmospheric carbon, potentially providing a mechanism for reduction in atmospheric CO_2 levels
* Soil Improvements
  - Improve water quality
  - Improve soil fertility
  - Reduce soil greenhouse gas emissions (N_2O, CH_4)
* Bio-energy Source

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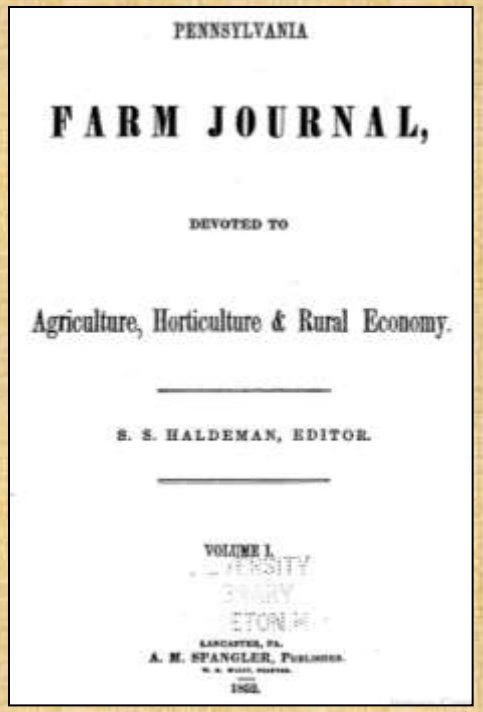
Biochar

"The use of charcoal (*biochar*) as a fertilizer is not a new thing, but only in the last few years that agriculturists have taken notice of it."

Biochar: Not new for soil additions….

"The use of charcoal (*biochar*) as a fertilizer is not a new thing, but only in the last few years that agriculturists have taken notice of it."

-- Pennsylvania Farm Journal (1852)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A. M. SPANGLER, PUBLISHER.

1852.

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MAP Pyrolysis Products





Feedstock	Char (%)	Liquid		Gas (%)
		Organic Phase (%)	Water Phase (%)	
100% Corn stover	27.8	38.9		33.3
DDGS:Corn stover 25:75	26.2	43.7		30.1
DDGS:Corn stover 50:50	25.4	41.8		32.8
DDGS:Corn stover 75:25*	27.0	17.2	28.6	27.2
100% DDGS*	25.0	18.3	27.5	29.2

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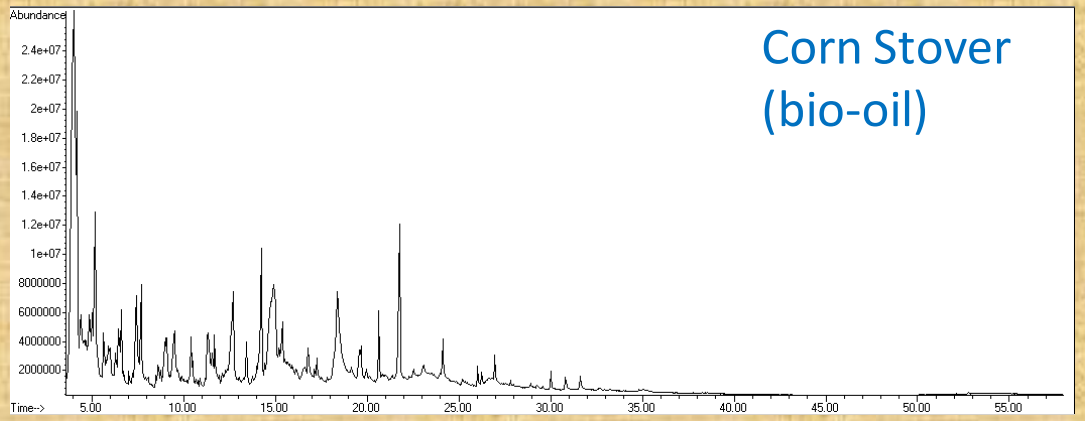
Quality of Bio-oil

- Variable nature of bio-oil – variable composition

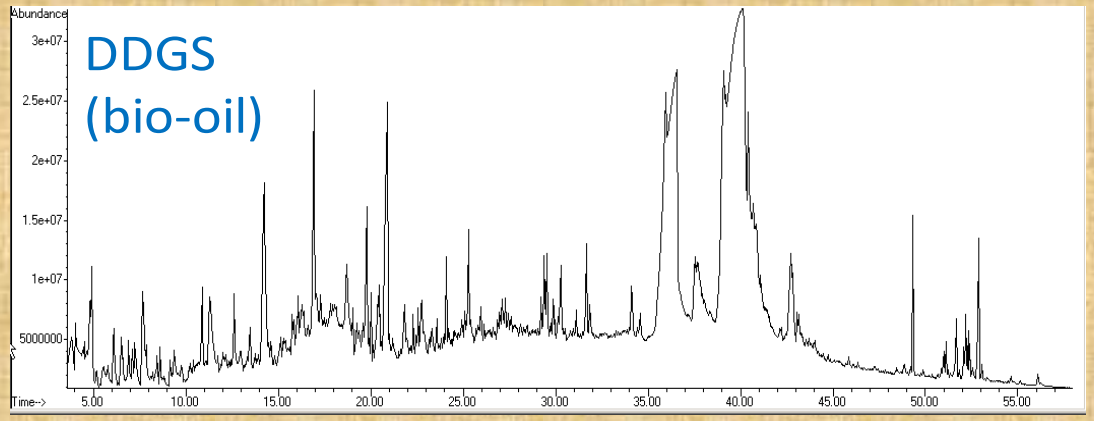
The number and distribution of the various organic compounds in the bio-oil can be altered through feedstock ratios



- Tailoring of economics:
  Produce higher value bio-oil components

Example:

- ❑ Bio-oil : $ 50-80/ton from NREL (2010)
- ❑ Acetic acid : $ 800/ton



- Further research needed to fully examine the economic potential

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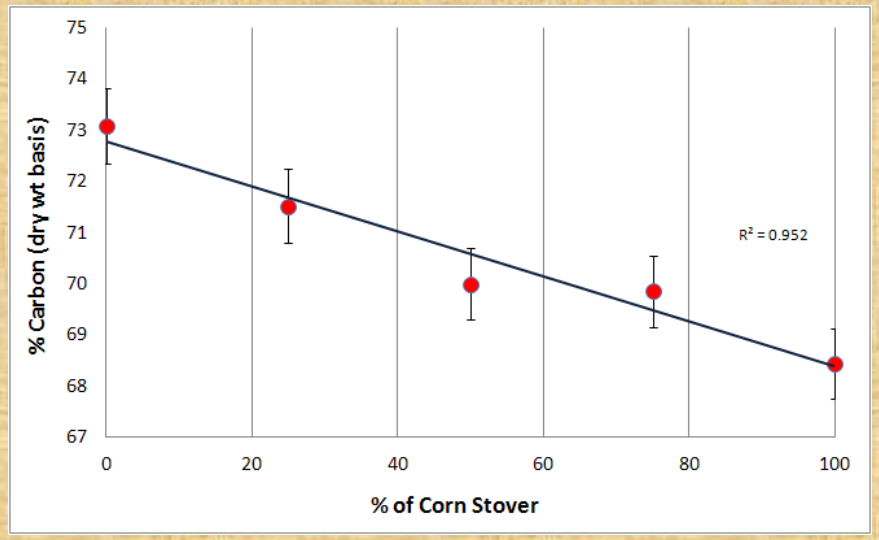
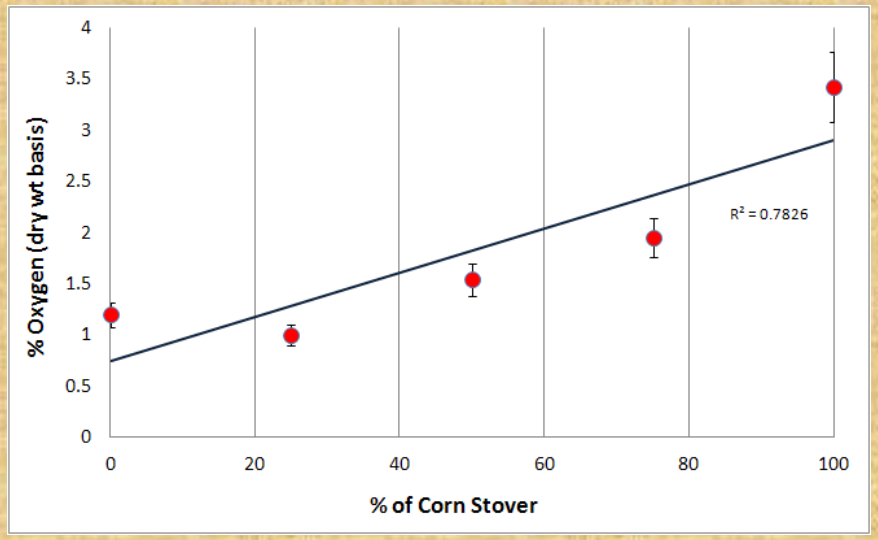
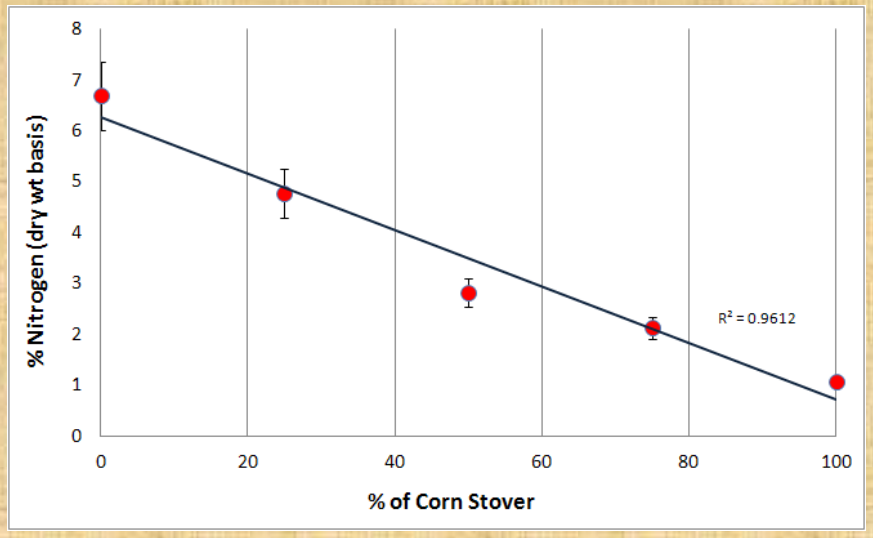
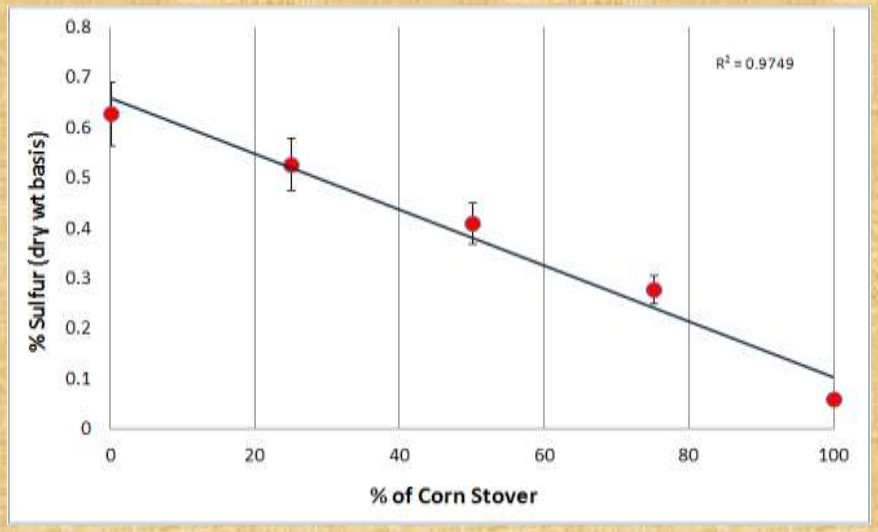
Chemical Quality of MAP Biochars

- Biochar elemental properties varied as a function of feedstock ratios









Laboratory Soil Incubations

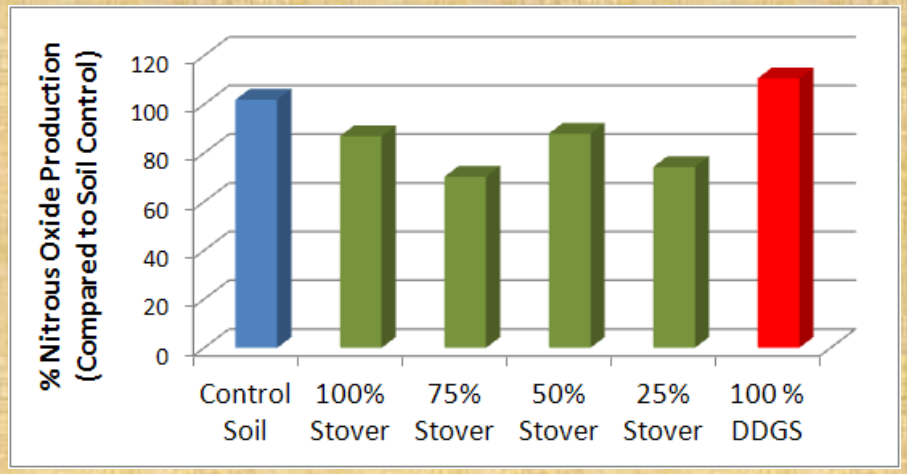
Laboratory soil incubations:

- Monitor the production/consumption of greenhouse gases (CO_2, N_2O, and CH_4)

- Monitor nutrient cycling
  Inorganic N-forms

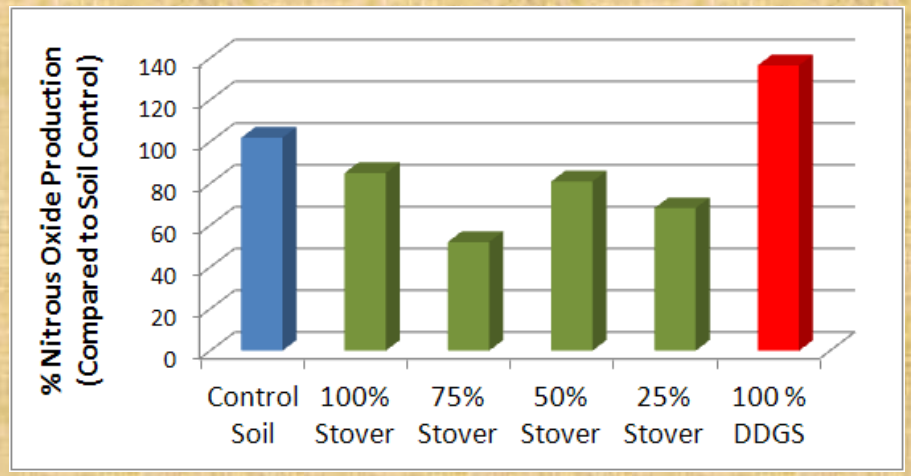
Soil : N_2O Impacts

- Morris, MN Soil – Barnes-Aastad clay loam



2% w/w addition

- *Despite linear trends in chemical composition; no similar linear trends in the response of the soil microbial system*



10 % w/w addition

- *Benefit to feedstock mixtures:*
  Corn stover + DDGS mixtures suppressed the N_2O production observed with the 100% DDGS biochar addition

Biochar feedstock mixing ratios

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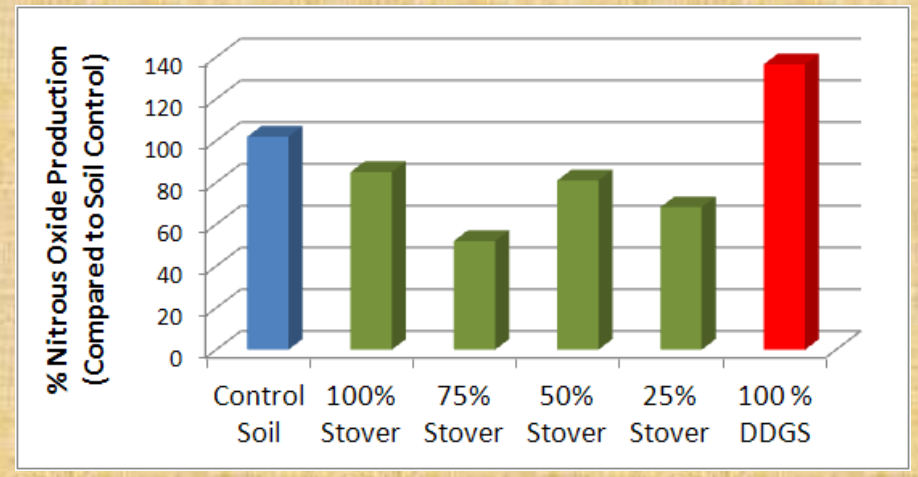
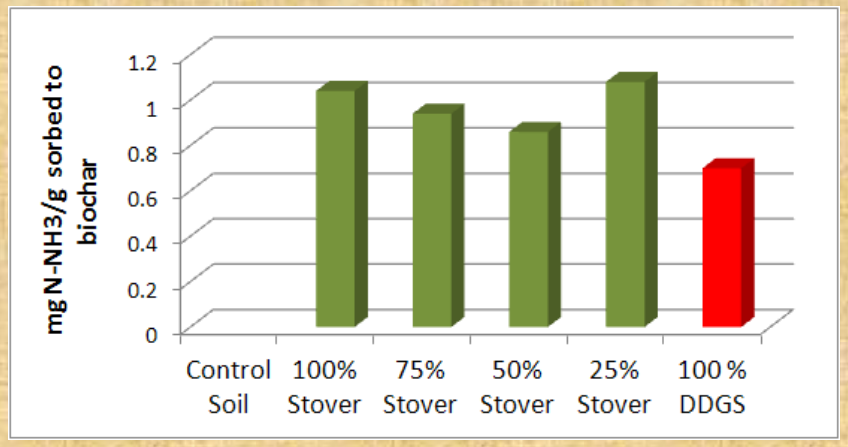
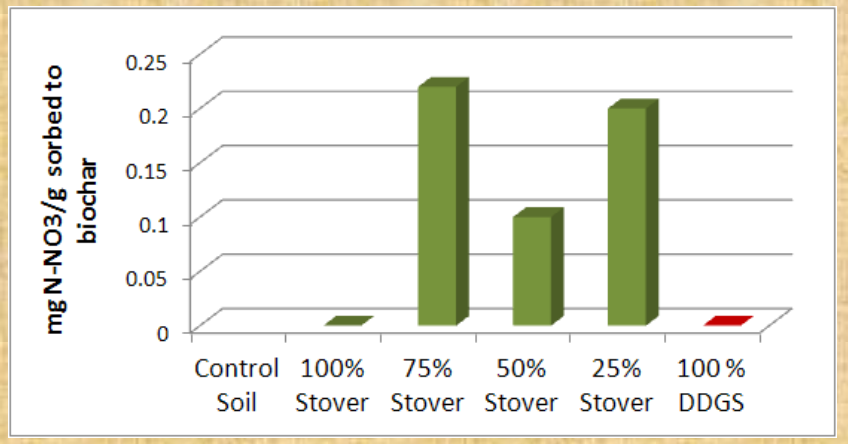
Nitrate/Ammonia Sorption

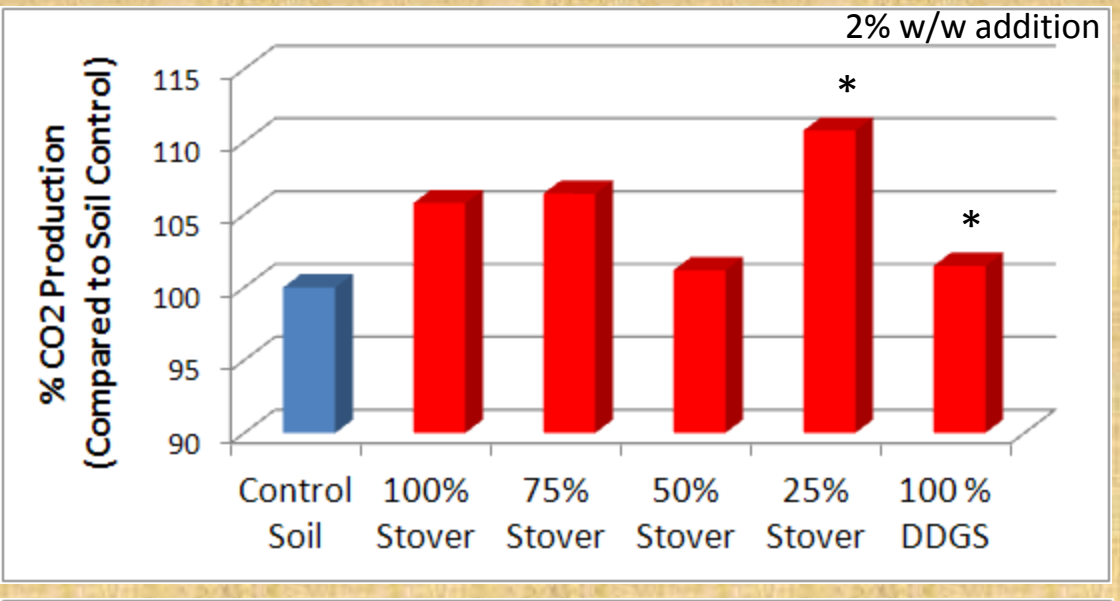
- Direct nutrient sorption to biochar?

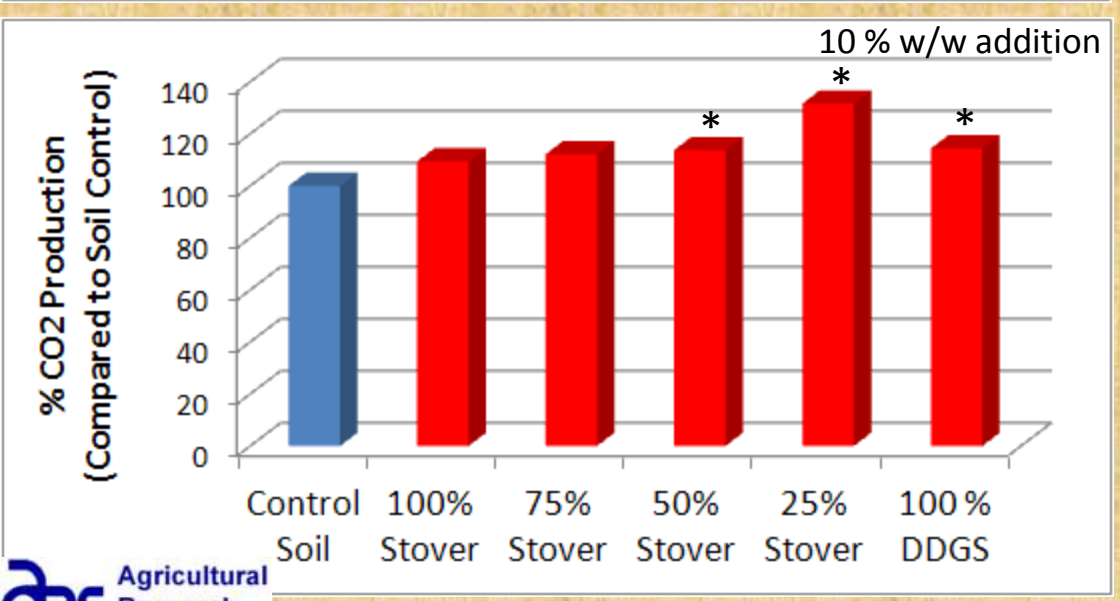






CO_2 Production – C mineralization





- All biochar additions stimulated soil CO_2 production
- Assumption is that the biochar provided some source of additional degradable substrates
- However - Not all statistically significant

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CO_2 effects – C mineralization

- Assumption: The extra CO_2 production is of biochar origin

- Max observed mineralization rate of biochar-C :
  - 0.9 µg C/g_soil/day -or – <0.1% mineralized after 1 yr
  - 99.9% of C remains in the soil after 1 yr

- For comparison:
  - Non-pyrolyzed DDGS: 80% C lost in 60 d (Cayuela et al., 2010)
  - Non-pyrolyzed corn stover: 55% C lost in 180 d

Next Steps….

- Biggest hurdle for biochar applications: Economics
  - Known since the early 1800's that biochar applications were *too expensive for wide spread use*

    Holbrook, F., 1849. "Improvements of lands by green manuring", The Cultivator (Albany, NY: New York State Agricultural Society, Luther Tucker and Sanford Howard (eds)), vol. 6(7), pp. 201-232.

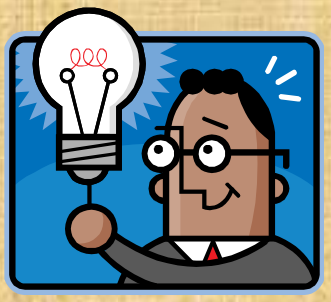
What has changed?

- Precision agriculture
- New biobased (renewable) energy emphasis
- New knowledge on mechanisms of charcoal's interaction
  - Allows targeting for specific needs in agricultural soils (e.g. nitrification inhibition)

- Still an immediate need to have more field plot based research

Conclusions of the Project to Date

- **Additional bio-energy sources**
  - Expanded end-uses of DDGS/wet cake
    - Bio-oil source: Heating oil replacement (boilers)
    - Syngas: Replacement for natural gas use
    - Biochar



- **Improved and alternative uses of co-products**
  - Potential use of prior classified "*contaminated*" grain
  - New potential market for co-products → bio-oil & syngas
    - Reuse at ethanol plant – optimization of energy conversion
  - Not only DDGS/wet cake, other coproducts could be utilized
    - e.g., corn syrup, rejected grain, etc.

- **Improving sustainability of corn production through biochar applications**
  - Improve soil quality
  - Reducing soil greenhouse gas emissions (N_2O)
  - Reduced nitrate leaching (decreased nitrate formation)
  - Potential soil carbon sequestration

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Acknowledgements

- Minnesota Corn Growers Association
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"The nation that destroys its soil destroys itself." --Franklin D. Roosevelt