FY12 BIOAg Planning Grant Final Report

Title: Use of Oxidized Bio-chars to Reduce Greenhouse Gas Emissions and Attenuate the Transport of *Escherichia Coli* in Soils

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Key words: Bio-char, Soil Amendment

Abstract:

This project generated preliminary data on the production and characterization of oxidized bio-chars and the effects of these chars on the hydrophysical properties of Quincy sandy soils. In the first study, 36 biochar samples were produced via pyrolysis of three feedstocks (hybrid poplar, pine wood, and pine bark) using a lab scale spoon reactor to study the effect of pyrolysis temperature (between 350 and 600 ^{o}C) on the yield and composition of the bio-char produced. Some of the biochar properties measured were: BET surface area, surface topology by SEM, elemental analyses (CHN-O), proximate analysis (fix carbon, volatile and ash), surface composition by XPS , Boehm titration, and cation exchange capacity (CEC). It was found that as the pyrolysis temperature increases the surface area also increases, and reaches up to 408 m^2/g at 600 ^{o}C. However, an advantageous property of the biochar produced at 350 ^{o}C was that it was more oxidizable than the bio-char produced at 600 ^{o}C. Biochars with cation exchange capacity as high as 70 meq/100 g were produced when a hybrid poplar bio-char produced at 350 ^{o}C was oxidized at 250 ^{o}C in the presence of air. The bio-char produced from pine wood showed stronger resistance to oxidation. The study on the effect of the chars produced on the hydro-physical properties of Quincy sandy soils demonstrates that bio-char amendments have the potential to improve the agricultural characteristics of sandy soil. We determined bulk density, pH, EC, porosity, CEC, field capacity, plant available water, and permanent wilting point in biochar amendment sandy microcosms. It was found that biochar application significantly decreased soil bulk density, increasing porosity, and significantly increased water content at both field capacity and the permanent wilting point, increasing the amount of water available to plants. We also studied the release of greenhouse gases from biochar-amended soils and the migration of *Escherichia coli* through saturated soils. Our preliminary results on the transport of *E. coli* indicate no significant difference between the types of bio-char used (produced at various temperatures and oxidation conditions).

Project Description

Outputs:

Work completed: Three major studies were concluded: (1) Production, oxidation and characterization of biochars produced from pine and hybrid poplar, (2) Changes in hydro-physical properties of Quincy sandy soil following bio-char applications, and (3) Effects of bio-char amendment on transport of *Escherichia coli* through saturated soil. Some preliminary results were also obtained on the released of greenhouse gases in the presence of bio-char.

Publications, handouts, Other Text & Web Products:

Smith M, Garcia-Perez M: Developing the phosphate retention capacity of biochar: effect of alkaline oxides (In Preparation, to be submitted to Environmental Science and Technology 2013).

Smith M, Garcia-Perez M: Formation of surface acidic sites on char by air oxidation (In Preparation, to be submitted to Environmental Science and Technology 2013).

Suliman W, Garcia-Perez M: Effect of Pyrolysis temperature on the susceptibility of bio-chars to be oxidized with air at 250 ^{o}C (In Preparation, to be submitted to Environmental Science and Technology 2013).

Outreach & Education Activities:

Smith M., Liaw S-S. Garcia-Perez M. "Integrating Pyrolysis and Anaerobic Digestion" NW bioenergy Symposium. Seattle, WA; November 13, 2012

Smith M, Garcia-Perez M. "Biochar: Applications and Modification" International seminar on advanced biofuels and bioproducts. Institute of Chemical Technology, Mumbai, India. March 8, 2013.

Smith M. Garcia-Perez M."Integration of pyrolysis, char upgrading and anaerobic digestion in a novel bio-refinery concept" Bioenergy IV: Innovations in heat, power, fuels and chemicals. Otranto, Italy; June 12, 2013.

Suliman W, Smith M, Garcia-Perez M: Effect of Pyrolysis Temperature on Oxidability and Surface Chemistry of Bio-char. Bioenergy IV: Innovations in Biomass Conversion for Heat, Power, Fuels and Chemicals. June 9-14, 2013, Otranto, Italy

Impacts:

Short term: (1) Advanced our understanding on the effect of bio-char physicochemical properties on soil fertility, **(2)** Generated data for manuscripts to be published in peer reviewed journals, **(3)** Helped to develop engineered bio-chars with commercial potential, **(4)** The data collected is part of the PhD thesis of a graduate student

Intermediate Term: The main hurdle for the success of slow pyrolysis systems is our capacity to develop higher valued engineered bio-chars for environmental services. Today it is not possible to find

companies that offer the service of designing, producing and testing engineered bio-chars for environmental services from local feedstocks. This proposal contributes to a research and development program at WSU to design and test engineered bio-chars.

Long Term: The new R&D program we are building at WSU will contribute to the development of engineered bio-chars for storm water cleaning, for the removal of P and N from aqueous effluents of anaerobic digesters, and soil amendments and will be made from wastes available in the region. These new materials could contribute to the growth of a slow pyrolysis industry which will create jobs in rural areas, and help solve environmental problems through its inherent atmospheric carbon sequestration.

Additional funding Applied/Secured:

Current:

Frear C, Collins H, Garcia-Perez M, Kruger C, Shumway C, Stockle C: US Dairy Adoption of Anaerobic Digestion Systems Integrating Multiple Emerging Clean Technologies: Climate, Environmental & Economic Impacts. PIs: Funding Agency: USDA-NIFA-AFRI Climate Variability. July 2012 – July 2015 Total Award: *$749,920*

Garcia-Perez M: CAREER: An Integrated Research and Educational Plan to Develop Selective Pyrolysis Reactors and improve the Capacity of Students to Work in Multidisciplinary Teams. Funding Agency: US National Science Foundation Period: May, 2012 – May 2017, Total Award: $ 400,000

Pending:

Garcia-Perez M, McEwen J-S: Understanding the Formation Mechanisms of Carbonaceous Adsorbents from Lignocellulosic Materials for Environmental Applications. Funding Agency: NSF, Period: 8/16/2013 to 8/15/2016

Kruger C, Benedict C, Desta K, Frear C, Garcia-Perez M, Killinger K, Ndegwa P, Peters R: Evaluate the efficacy and Regional Environmental Benefit of using Manure-Derived Soil Amendments. Funding Agency: USDA-NRCS Period: 9/1/2013 – 8/31/2016, Funds requested: $ 879,582

Frear C, Garcia-Perez M: Bio-char for Digestion and Pyrolysis Media for Hydrogen Sulfide Scrubbing, Adsorption of Nutrients, and production of Value added Peat Moss Replacement. Funding Agency: Sun Grant Period: 9/1/2013-9/1/2015, Funds requested: $ 200,000

Unfunded:

Garcia-Perez M, Frear C: Production of Green Energy and Bio-char by the Pyrolysis of Solid Waste in Colombian Palm Oil Mills (POMs). Funding Agency: USAID Funds requested: $ 860,210

Graduate students funded:

Waled Suliman (PhD student in Soil Sciences)

Matthew Smith (PhD student in Chemical Engineering)

Recommendations for future research:

In the next years we will continue developing engineered bio-char from anaerobically digested fiber (AD) for nitrogen and phosphorous removal from AD liquid effluents and test its performance as a soil amendment. So far, we have been working on the removal of ionic phosphate but a large fraction of the phosphorous AD effluents is in the colloidal form. So, in the next years we will study new approaches for colloidal phosphorous removal. It is also very important to study how to integrate the methods tested at lab scale to produce engineered bio-char with existing technologies for nutrient recovery and to study the behavior of the resulting bio-chars loaded with N and P as soil amendments. The effects of engineered bio-chars loaded with N and P in AD liquid effluents on the physico-chemical and microbiological properties of sandy soil need to be more thoroughly studied. The capacity of these bio-chars to reduce N, and P as well as *E.coli* movement and leaching in amended soils needs to be further investigated.