CONSERVATION INNOVATION GRANTS
Final Report

Grantee Name: Louisiana State University Agricultural Center	
Project Title: Use of crop residue as biochar soil amendment to reduce greenhouse gas emission, enhance soil carbon sequestration, and improve water quality in sugarcane and rice production	
Agreement Number: NRCS #69-3A75-10-156	
Project Director: Jim Wang	
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Period Covered by Report: October 1, 2010 – September 23, 2014	
Project End Date: September 23, 2014	

A) Summarize the work performed during the project period covered by this report:

The overall goal of this project was to use sugarcane and rice harvest residues to convert to biochar and apply back to the respective fields so the process can conserve carbon by eliminating the open- field burning of harvest residue, which has been in practice especially in sugarcane production. This project was carried out in three different stages: laboratory experiments, potting tests, and field trials. This was necessary due to the fact that various pyrolysis conditions were used in biochar production and these conditional differences affect biochar properties.

1. Laboratory experiments

The objective of the laboratory experiments was quickly to determine what pyrolysis condition would serve the purpose of conserving carbon, enhancing soil fertility, and improving water quality using sugarcane and rice harvest residue. In doing so, harvest residues from sugarcane and rice fields were collected. In addition, milling by-products such as sugarcane bagasse and rice husk were also collected. Biochars from these residues and byproducts were produced at pyrolysis temperatures at 450, 550, 650 and 750 ^{o}C, respectively. A range of characterizations including elemental and molecular composition, surface chemical characteristics, available nutrients and water holding capacity were carried out to better understand the biochar products we produced. Biochar surface functionality was characterized using FTIR and Py-GC/MS, and morphology by electron microscope (SEM). In addition, we conducted initial assessment of these materials on adsorption properties of pesticides and emissions of greenhouse gases through laboratory experiments.

2. Greenhouse potting tests

Potting experiments were conducted in greenhouse to assess the effect of sugarcane residue biochar on sugarcane crop growth based on the results of biochar properties evaluated in the laboratory before field trials. In doing so, sugarcane billets were used to germinate sugarcane in pots and different treatments of biochar and fertilizer applications were evaluated for sugarcane growth. In addition, direct effects of biochar made by different pyrolysis temperatures on rice germination were assessed.

3. Field trials

The ultimate goal of this project for using sugarcane and rice residue for conserving carbon and improving water quality was expected to be demonstrated through field trials. In doing so, two tons each of sugarcane harvest residue and rice straw were collected and shipped to the Genesis Industries located in California, which indicated that they would convert biochar according to our recommended 500-550 ^{o}C pyrolysis temperature (based on our laboratory and potting experiments). The biochar was produced with a continuous feed operation. A 2-stage reactor chamber to separate heavy condensable gaseous compounds from syngas waste gases was used to dry feed stock which increases the overall efficiency while reducing CO_2 emissions. The feedstock capacity of the unit was 200 kg hr^{-1} (20-25% of moisture content in feedstocks) and biochar output was 50 kg hr^{-1}. Additional processing procedures (grounding) of the feedstocks were carried out before the conversion. Approximately a total 400 kg of biochar each from sugarcane harvest residue and rice straw, respectively, were produced for our field trials. In addition, we purchased biochar produced from yellow pine woods and applied in sugarcane fields for comparison purpose. Three years of field trials were conducted from the beginning season of 2013 at the same fields with the last year ended in December, 2015 (even after the project was officially ended in September, 2014). One delay was due to the unsuccessful contact of a biochar producer that would make the biochar based on our recommendation in 2011 and the delayed handling of our feedstocks for large quantity production in 2012 by the commercial company. In addition, the last year we wish to evaluate the residual effect of biochar application on agronomic yield and soil properties.

Rice field trials were established in a silt loam soil located at the Rice Research Station, LSU Agricultural Center, Rayne, LA 70578 after realizing rice farmers were not able to accommodate the small plot requirement due to the specific water management in rice production. Rice straw biochar was applied at rates of 0 and 11.2 Mg ha^{-1} with and without N fertilizer at rates of 0 and 134 kg ha^{-1}.

Both biochar and N fertilizer were broadcasted and incorporated into 10 cm depth of soil. Rice seeds were sowed after biochar and fertilizer application. All field treatments consisted of 4 replications. After flooding, metal frames were installed at the individual plots for easy collection of water samples during the growth season. Greenhouse gases were monitored using a static gas chamber method for collection at 3-4 days interval in the first two weeks and then weekly after.

Sugarcane field demonstration trials were carried out in plots of 5.5 m x 12.2 m (18 ft x 40 ft) at a EQIP eligible farmer’s field in Duson, Louisiana and the experimental site was a silt loam soil. The soil properties of the site were: pH (H_2O) 5.9, total carbon 1.5%, and total nitrogen 0.08%. Sugarcane residue biochar and yellow pine wood biochar were applied to the field plots at rates of 0 and 8.9 Mg ha^{-1} with and without N fertilizer as urea at rates of 0 and 134 kg ha^{-1}. All field treatments were replicated for 3 times.

For field monitoring of greenhouse gas emissions following biochar and fertilizer application, static gas chambers were installed in fields for monitoring CO_2, CH_4, and N_2O gases. Gas samples were taken using a 15-ml syringe at 0, 30 and 60 min interval and were measured for CO_2, CH_4 and N_2O using a Varian CP-3800 gas chromatograph equipped with flame ionization detector (FID) and electron capture detector (ECD), respectively.

For water quality monitoring from sugarcane fields, the runoff water samples were collected at treatment plot edges using an automatic refrigerated sampler (ISCO model 6700FR, Lincoln, NE) operated with battery with water pressure sensors. Similar water quality parameters were analyzed for collected runoff samples following every rainfall event. For rice fields, flooding water samples were collected periodically to measure various water quality parameters.

B) Describe significant results, accomplishments, and lessons learned. Compare actual accomplishments to the project goals in your proposal:

Laboratory results:

Laboratory evaluation of biochars produced from different pyrolysis temperatures showed significant effects on elemental and molecular compositions. Increasing pyrolysis temperature from 450 ℃ to 750 ℃ elevated C contents from 395 to 570 g kg^{-1} but the increase in C content of biochars appeared, however, to be the highest between 650 ℃ and 750 ℃. There was a general decrease in biochar contents of H, N, S, and O corresponding to an increasing pyrolysis temperature. The magnitude of loss in these elements varied with source materials. Approximately, 80% and 40% of N were lost in sugarcane residue biochars as compared to 50% and 20% in rice straw biochars, respectively, at 750 °C. On the other hand, 64% and 80% S were lost at the same temperature for sugarcane biochars as compared to 44% and 51% for rice straw biochars, respectively. Water extractable organic C (WEOC), an indicator of labile organic carbon (LOC) was decreased significantly with the conversion of raw materials into biochars with increasing pyrolysis temperature. The WEOC was in the order of sugarcane harvest residue and rice straw biochars > the biochars made from milling sugarcane bagasse and rice husk, suggesting stronger prime effect of the former two biochars on CO_2 emissions if they are applied to the field, which was supported by the short-term laboratory incubation conducted in our laboratory.

Biochars were dominated with pore size around 20 nm although high pyrolysis temperatures generally increased both smaller and larger than 50 nm pores, and surface area. Water holding capacity (WHC) was found more impacted by raw material rather pyrolysis temperature and other factors such as hydrophobicity rather than just pore size and volume appeared to also affect WHC of a biochar (Figure 1). The latter was supported by much higher molecular composition of BTX and PAH compounds as revealed by Pyrolysis-GC/MS analysis besides pore volume properties. All biochars exhibited a maximum cation exchange capacity (CEC) at 550 ℃ with sugarcane residue biochars being generally greater than rice residue biochars.

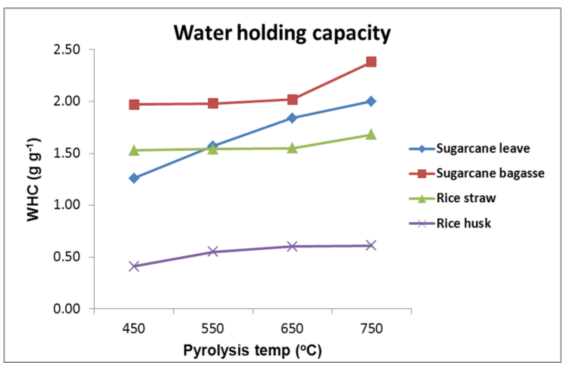

Figure 1. Water holding capacity (WHC) of biochars made from four different feedstocks

In addition, the biochar produced from rice husk had generally higher total N and P content whereas the rice straw biochar had greater K content than the sugarcane residue biochar, Soil test extraction indicated that as much of 50% total P in the biochar could be plant-available but only 8-12% total K would be available.

Greenhouse potting test results:

Potting tests showed that biochar treatment enhanced sugarcane regeneration from sugarcane billet planting and enhanced stalk population. Biochar application at 5% on weight basis enhanced the length of both sugarcane leave and roots as compared to the control, and this effect was even greater when N and K fertilizers were applied along with biochar. Biochar increased sugarcane dry weight by 26% (Figure 2). Clearly there was a synergy effect of biochar and fertilizer application. In addition, biochar produced from different temperatures showed no significant effect on rice germination (Figure 3), suggesting that the toxicity impact of free radical damage of the biochar was minimal.

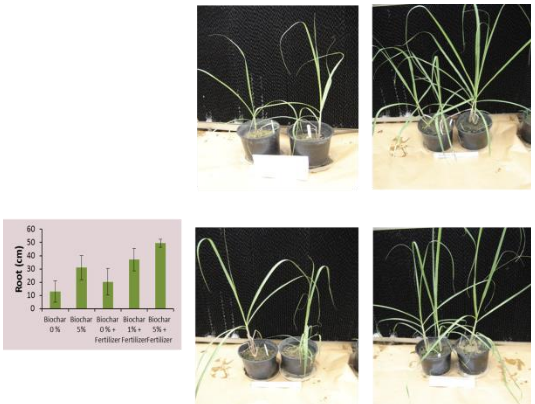

Figure 2. Biochar effects on sugarcane growth with and without N and K fertilizers

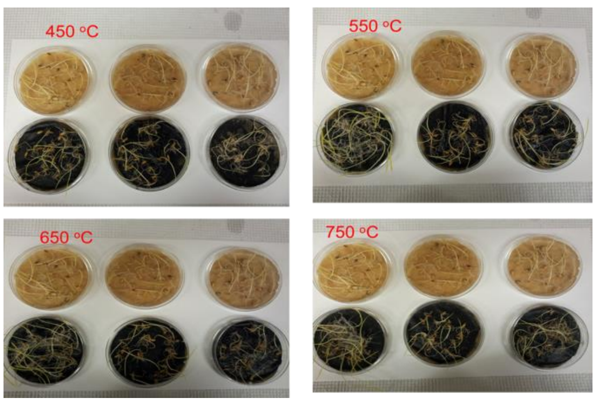

Figure 3. Comparison of rice seed germination by biochars produced at different temperatures

Field trial results:

Greenhouse gas emission: Rice field monitoring of the biochar impact on greenhouse gas emission showed that CH_4 emission was significantly reduced by rice biochar application (Figure 4). Overall the reduction of CH_4 emission by biochar application was 16% and 27 % for treatment plots without and with N fertilizer, respectively, as compared to the control plots. Also N_2O-N emission was decreased by 43 % with biochar application in N fertilizer-treated plots.

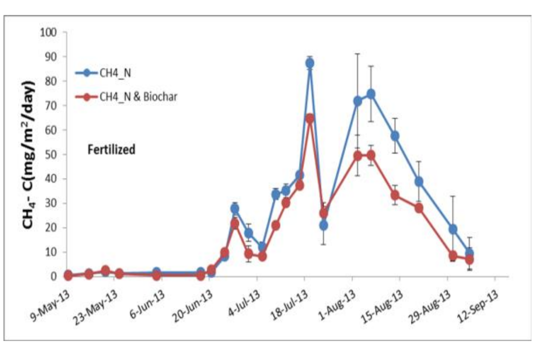

Figure 4. Effect of biochar application on methane emission from rice field

Biochar application also significantly reduced total N_2O emission from sugarcane plots by 18% as compared to the control (Figure 5). However, the effect was not evident in the second year. There was no statistically significant difference in overall CO_2 emission among different treatments.

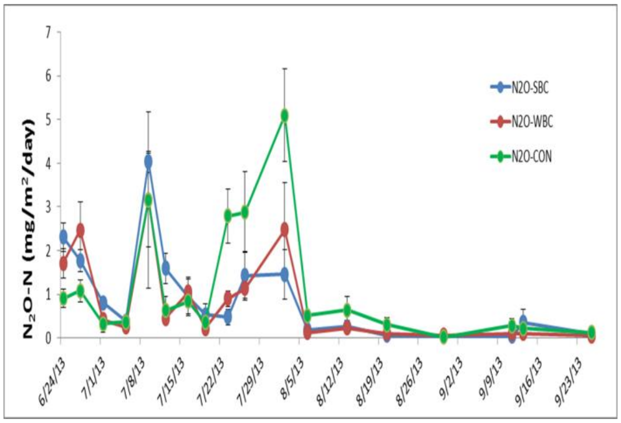

Figure 5. Effect of sugarcane residue biochar on nitrous oxide emission from sugarcane field

Water quality parameters: The monitoring of surface runoff water from the sugarcane trials, in which the experiments were only conducted on N-fertilized fields, showed that biochar application generally increased total suspended solids (TSS) and biological oxygen demand (BOD) than the control overall two years (Figure 6). The higher BOD was also corresponding to a higher TOC level in the surface runoff, which was expected, due to that biochar did contain a fraction of water soluble C. For the rice trials, similar results were also observed for BOD of the pond water in the N-fertilized plots. On the other hand, for the rice trials on N-unfertilized plots, biochar application decreased the BOD in the ponded water. Biochar application also reduced nitrate concentration in the rice pond water. In addition, there was no significant change in the runoff or pond water pH, suggesting that soil was able to buffer much of residual alkalinity of biochar.

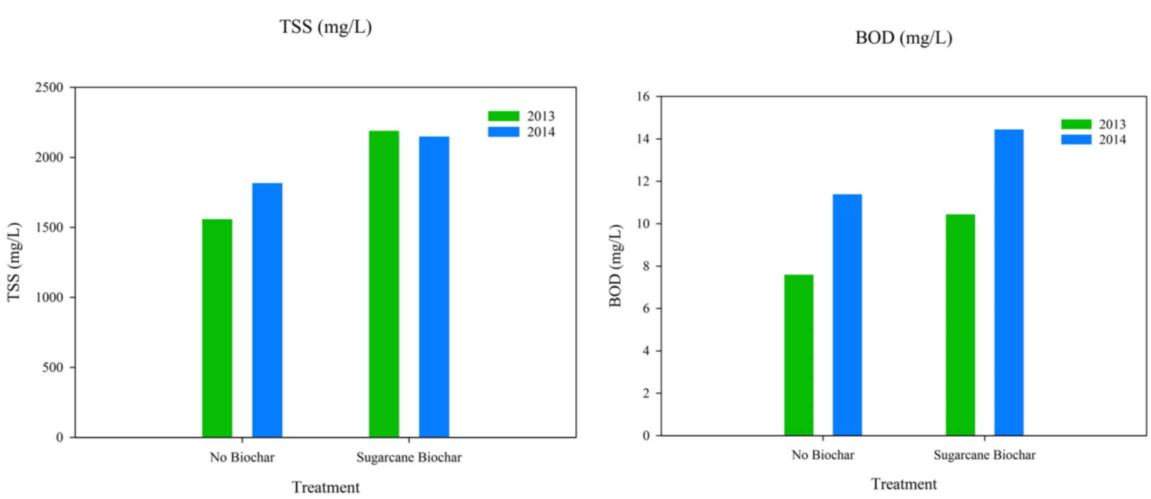

Figure. 6. Effect of biochar application on runoff water TSS and BOD

Soil parameters: There was no statistically significant difference in soil total organic carbon between the biochar treatment and control plots. While it generally takes time to increase soil organic C, the rate of biochar application in these trials was unable to enhance immediate soil organic C content. However the results did show increasing soil test- extractable P with the biochar application, which was likely due to that as much as about 50% of total biochar P was plant-available as mentioned in previously.

Agronomic yields: Rice field trials showed that biochar application could improve agronomic yields by approximately 10-11% without N fertilizer applied and about 5-7% with N fertilizer applied over two years of field trials (2013 and 2014) although these differences were not statistically different. Sugarcane field trials showed that biochar application had significant sugarcane tonnage increase by as much as 20% in the plant cane (2013) but no difference for the first (2014) and second stubble (2015, residual effect) crops.

The lesson learned and positive impact of the project:

Speaking about the actual accomplishments as opposed to the project goals, there were two major lessons learned. As we needed to have the biochar made based on our specific requirement for the carbon conservation at field scale trials, it was to our surprising to find out that none of the available commercial biochar producers were able or willing to accommodate our suggested temperature for biochar production at the beginning of this project. So often we find the biochar was made at too low (<400 ^{o}C) or very high temperatures (>900 ^{o}C), which would produce instable biochar or the by-product materials that often have low carbon contents. One initially arranged Louisiana entity delayed the conversion due to an unexpected failure of their logistics and relocation. Nonetheless, we believe that our project did have a positive role in facilitating the integration of biochar conversion unit into a regular sugar mill processing facility in Louisiana.

Another lesson we learned from this project was that, due to the relative small field plots, it was relatively difficult to collect enough runoff samples for water quality parameter measurement, which was limited by precipitation events. Nonetheless, we did observe difference in ponded water in rice production, which was not limited by the amount of precipitation but by the distance of the field plots from the input of flooding water source.

C) Describe the work that you anticipate completing in the next period:

N/A. Final report

D) Provide the following in accordance with the Environmental Quality Incentives Program (EQIP) and CIG grant agreement provisions:

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