September 18, 2009

Colorado Department of Agriculture
700 Kipling Street, Suite 4000
Lakewood, Colorado 80215-8000

Interim report for: Carbon negative bioenergy through the soil sequestration of pyrolysis bio-char on Colorado pastureland: measuring the effects on forage yield, soil chemical properties, and microbial activity.

CLIN# 09BAA00162

Dear ACRE Board:

Flux Farm Foundation is happy to offer this interim report to the Colorado Department of Agriculture for the western Colorado biochar demonstration project. Three of our proposed application techniques have been tested, and soil chemical and microbial analyses are currently underway. Biochar has received great notoriety over the past six months since our project began. The first annual North American Biochar conference was recently held in Boulder, Colorado at which The Secretary of Agriculture, Tom Vilsack, gave the keynote address. Our project is timely and important and aims to address one of the critical unknowns that remain: how does one effectively apply biochar to agricultural soils in a scalable fashion.

WHAT IS BIOCHAR?

Biochar is the carbon-rich product obtained when biomass (such as wood, manure or crop residues) is heated in a closed container with little or no available air. It can be used to improve agriculture and the environment in several ways, and its stability in soil and superior nutrient-retention properties make it an ideal soil amendment to increase crop yields. Biochar has been shown to serve as a habitat for microorganisms and increase soil microbial diversity, reduce emissions of non-CO_2 greenhouse gasses from soil (notably CH_4, NO_x), reduce soil nutrient leaching (notably N, P, and K), and increase soil water retention. In addition to agronomic benefits, biochar sequestration, in combination with sustainable biomass production, can be carbon-negative and therefore used to actively remove carbon dioxide from the atmosphere, with major implications for mitigation of climate change. Biochar production can also be combined with bioenergy production through the use of the gases and liquids that are given off in the pyrolysis process (Lehmann 2009).

STATUS OF TASKS TO COMPLETE:

The following is an overview of the tasks outlined in the "Statement of Work," and a brief narrative of the status to date.

a) **Review of biochar literature**: Flux Farm Foundation has completed a thorough review of the biochar literature. Some of our findings can be found on our website: http://www.fluxfarm.com/reviews/biochar. Much has been documented about the agronomic benefits to biochar application on many soils throughout the world. Currently fourteen USDA-ARS locations are directly involved in biochar studies, and most major agricultural colleges have at least one faculty member or post-doctoral student involved in biochar research. However, a critical review of potential biochar application methods remains elusive. We intend on filling this void.

b) **Sieving biochar by size**: We initially believed that the particle size of biochar could have a great effect on the agronomic properties of the product and proposed to separate our biochar treatments into various sizes. After receiving our biochar samples from

Dynamotive Energy and Best Energies, and attempting to sieve biochar into size classes, we quickly realized that the practice was not viable. Excessive dust was produced during sieving trials and concerns over air pollution forced us to re-think our presumptions. The existing particle size of Dynamotive's CQuest biochar approaches a low of 5 μm in size and a high of roughly 50 μm, while Best Energies Agrichar has a greater particle distribution ranging from 20 μm to 1.5 cm. We remain interested in looking further into larger biochar aggregates (i.e. pelletized biochar roughly the size of rabbit food), but sieving is not viable.

c) **Defining research plots**:

Flux Farm Biochar Plot Layout

P-1 CQ (B) 12.5	P-2 CQ (T) 12.5	P-3 CQ (T) 25	P-4 CQ (T) 75
P-5 CQ (B) 25	P-6 NONE (T)	P-7 CQ (T) 25	
P-8 Agri (B) 5	P-9 NONE (T)	P-10 CQ (T) 12.5	
P-11 NONE	P-12 NONE	P-13 CQ (T) 50	
P-14 CQ (T) 12.5	P-15 CQ (B) 12.5	P-16 Agri (B) 5	
P-17 CQ (B) 12.5	P-18 CQ (B) 25	P-19 CQ (T) 50	
P-20 CQ (I) 12.5	P-21 CQ (I) 12.5	P-22 NONE	
P-23 CQ(T) 50	P-24 CQ (T) 75		
P-25 CQ (I) 12.5	P-26 CQ (B) 25		
P-27 NONE	P-28 CQ (T) 75		
P-29 NONE	P-30 Agri (B) 5		
P-31 CQ (T) 25	P-32 NONE (T)		
P-33 NONE			

1) Plot size = 20 ft x 6 ft (0.00275482094 acres)

2) Complete randomized plot arrangement (generated in Microsoft Excel)

3) In trenched plots, full soil microbial and chemical analysis will be conducted. Samples will be taken along a gradient with a sample set collected from within the trench, a sample set 6 inches to either side of the trench, a sample set 12 inches to either side of the trench, and a sample set 18 inches to either side of the trench. Each sample set will contain no fewer than six individual samples totaling 250 g of sample each.

4) All plots will undergo full chemical analysis with 250 g of sample being collected at random from no fewer than six sites within each plot.

5) Soil sampling will be conducted summer 2009, fall 2009, summer 2010, and fall 2010.

6) Crops will be harvested once each year. Dry matter yield will be measured (48 hrs air dry)

7) Trenches are roughly 24 inches deep, 6 inches wide, and 20 feet long.

8) Injection/spraying will be equally distributed throughout injection plots at 3 - 6 in depths

9) Additional application methods will be developed for technical effectiveness, however no plot trials will be conducted.

d) **Preparing biochar for application:** Various wetting techniques were preformed to minimize the dust produced during application. We found that both CQuest and Agrichar do not like to remain suspended in water, and separate into three distinct layers over time. We are currently looking into potential agricultural surfactants that will aid in the dissolution of biochar into water.

e) **Applying biochar to test plots (biochar application methods of interest)**:

1) Backfilling of line trench: Caterpillar T9B Trenchers for CAT Skid Steer Loaders are designed for cutting narrow straight trenches in the soil prior to laying electrical, telephone and cable lines, or water and gas pipe. At a cutting width of 6 inches and a maximum depth of 54 inches, the CAT T9B trencher has the ability to excavate a great deal of soil while minimizing surface disturbance. For this reason, Flux Farm decided to adapt the method for biochar application. Trenches 24 inches deep by 6 inches wide by 20 feet long were excavated in an existing stand of pasture grass. To calculate application rate, trench spacing was assumed at 6 feet. Using this assumption, a total of 7,350 feet could be trenched in one acre requiring 35 rows. In knowing the volume of space, and the bulk density of the product (31.5 g per 100 mL) biochar was backfilled into trenches at 12.5 ton/ac, 25 ton/ac, 50 ton/ac, and 75 ton/ac rates.

   Note: We selected a sampling method that will assess soil conditions along a gradient perpendicular to the trench to investigate if biochar physically migrates through the soil profile, and if agronomic benefits are observed at a distance from the site of application.

2) Slurry (biochar/water) injection by root feeder: A Rittenhouse 100 US Gallon Skid Mount Sprayer with Honda 5.5 hp gas engine, Hypro D30 pump, and soil injector with flow meter was used to inject a mixture of biochar and water into soils.

   Note: After our initial investigation, it was determined that an agricultural surfactant will be needed to lower the surface tension of water thereby allowing biochar to remain evenly suspended in solution and suitable for pumping. The concentration of biochar in solution, by volume, is also likely to be somewhat low (10 – 20%) and a significant amount of water will be required to apply a relatively small amount of biochar. We are not yet fully convinced that biochar/water soil injection would be a wise use of limited water.

3) Slurry (biochar/water) injection by modified hydraulic injector: Not yet attempted. We are currently designing and building a hydraulic injector and experimenting with suitable surfactants, biochar:water ratios, and other potential mixing agents.

4) Direct slurry top-dressing (biochar/soil/water) with cement sprayer: Not yet attempted. The technique appears intriguing since the sprayer would accommodate a material with lower viscosity and higher particulate size that the Rittenhouse soil injector. We are currently looking for surplus cement spraying equipment, and developing suitable biochar mixtures.

5) Direct top-dressing of solid powder: Top dressing of solid powder was performed at rates of 12.5 tons/ac and 25 tons/ac. Concerns over air quality were significant given the small particle size of biochar (as noted above). A 3M 6000 series full-face respirator fitted with N100 particulate filters was used to protect against harmful exposure and inhalation. We recommend that a fine water mister be used to reduce air particulate pollution if commercial scale topical broadcasting of biochar powder is attempted in the future.

   Note: Given that biochar was not mixed into the soil, significant erosion of material could be experienced over time. Concerns over biochar flammability are also significant and must be addressed.

6) Direct top-dressing of pelletized biochar: Not yet attempted. Looking for rental equipment and suitable binding agents and mixtures.

f) **Physiochemical analysis of biochar**: BestEnergies and Dynamotive Energy Corporation.

g) **Soil chemical and physical analysis**: Being performed by Dr. James Ippolito of the USDA-ARS office in Kimberly, Idaho.

h) **Soil Microbial analysis**: Being performed by Dr. Mary Stromberger of the Soil and Crop sciences department at Colorado State University.

i) **Biochar porosity**: Still unknown.

j) **Forage yield**: Due to the unanticipated long contracting period with the Colorado Department of Agriculture prior to receiving authorization to begin our experiment, and the lag time between ordering equipment and receiving biochar delivery, we were unable to apply biochar on schedule. Because of this, pasture grasses were already established at the time of application, and subsequently damaged (*see Appendix A: pictures*) during application. Inaccurate forage yield measurements would have been produced if collected; therefore we decided to begin collecting yield data in July of 2010. We feel that this is acceptable given that our control treatments will still produce sufficient baseline data for comparison. However, this means that only one year of growth data will be produced during the ACRE project window. We will seek additional funding to continue the growth trails beyond the scope of the ACRE grant this coming year.

k) **Repeated soil testing and forage yield**: Spring 2010 and Fall 2010.

l) **Data analysis**: To be completed winter 2010

m) **Final report**: To be completed winter 2010

Thank you for the opportunity to conduct this important research. We will continue to keep you informed as the project develops. If additional clarification is needed, please do not hesitate to contact me directly.

Sincerely,

Morgan Williams
Executive Director
Flux Farm Foundation

APPENDIX A: PICTURES OF RELEVANCE

Research pasture (April 2009). We had planned on applying biochar when grasses were still not fully established for the season (below 6 inches in height).

Rittenhouse sprayer


CAT Trencher


CQuest Biochar (notice air particulates)

Trenched plots (June 2009). Notice the height of established pasture grass.

Trenched plots (September 2009). Notice remaining disturbance.

Biochar application by hand. Hand application was performed to control the exact amount of biochar applied to each plot. The mechanized backfilling of trenches could be achieved through the use of a commercial Row Mulcher (http://lancoequipment.com/row_mulchers/).

Dynamotive Energy Fast Pyrolysis CQuest Biochar


Best Energies Slow Pyrolysis Agrichar


Prairie dog excavation of biochar.