NC Farm Center for Innovation & Sustainability

Conservation Innovation Grant (CIG) Final Report

Cover Page

Project Title: A Field Demonstration for Mobile Torrefaction Technology to Produce Biochar and Evaluate Its Value to North Carolina Farmers.

Location: North Carolina Farm Center for Innovation and Sustainability (NCFCIS), cooperating with Beaver Dam Farms, Clinton, NC

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Executive Summary

Brief Overview: The North Carolina Farm Center for Innovation and Sustainability (NCFCIS), White Oak, NC, with matching funding support by the NRCS-CIG program, has conducted a three- year field project to produce and determine the value of pine-based biochar, locally produced, as an agricultural soil amendment for farmers in Southeastern North Carolina. Cooperating with Beaver Dam Farms, Roseboro, NC, a series of soil treatment and crop combinations (winter wheat/soybeans double cropped, soybeans, corn and cotton) were imposed, and crop yields measured, on marginal, non-irrigated soil and fertile, irrigated soil (Lakeland Sandy Loam, both locations). Commercial blended fertilizer, turkey litter and composted swine waste solids were included as treatments, with and without biochar, in a design to enable main treatment effects to be measured as well as additive effects of combinations.

The results of those studies demonstrated that addition of biochar at rates of 4.5, 9, 10 and 13.5 tons per acre, equally distributed over two consecutive years, resulted in a biochar stimulated increase in yields of all crops, at both locations, with increases in the range of from 11-20%, and with two exceptions (one very high and one negative). A third was impacted by an unusually high response in a single plot, which cannot be excluded from the data. The maximum increase was achieved at the 9-10 ton application rate, incorporated at a depth of 4-6 inches. Above that application rate, yield declined in all crops. The greatest yield response was achieved when turkey litter was included with biochar, and strongly suggests that biochar plays a role in improving the efficacy of nutrient utilization by crops. Swine waste compost did not result in a response. While the microstructure of the biochar was not evaluated, the probability that enhanced soil microbe growth, either due to colonization support or nutrient (especially nitrogen) retention or both, suggests the need for follow up study, incorporating appropriate location relative to plant root zone.

The data lead to the conclusion that application of biochar to soils of the type studied, at 10 tons per acre (a single, one-time application is recommended), and incorporated at a depth of 4-6 inches, is recommended. This results in the incorporation of about 6 tons of carbon as biochar, which was also an objective of the project. The development of a viable carbon credit program will determine the viability of that aspect of biochar use. Other amendments and fertilizers should be applied regularly according to nutrient management and recommendation plans.

The evaluation of a mobile biochar production unit was a part of the project. The unit that was brought to the site with intention to produce the biochar for the project was not satisfactory. Slower than “designed” through-put of feedstock and excessive maintenance requirements resulted in abandoning of that aspect and securing biochar produced by a unit located at North Carolina State University. An operating cost analysis of that unit is included in the report. That experience suggests that mobile biochar technology is still in its infancy and significant work is needed to achieve economically viable, reliable mobile units for farm-scale use.

Biochar management observations from this project are important. Particle size of biochar, if "too fine," results in difficulty in application and placement. Also, in the soils used in this study, the biochar tended to migrate to the surface of the ground over time, with larger particles being more mobile. More work is needed on this, to make recommendations on feedstock preparation and management across various soil types, including depth of incorporation and subsequent application rates.

The impact of biochar application to the soils studied on soil water retention was initiated on the non-irrigation site. Early data suggested that there was no effect of biochar on water retention and that work was discontinued.

What are the major recommendations resulting from this project?

Recommendation 1. That applications between 5 and no more than 10 tons per acre be used as the target for biochar when applied to the top 4-6 inches of soil, and that subsequent research fine-tune the application rate and appropriate depth of incorporation (for each soil type), as well as evaluate the benefits of a single application compared to serial applications over two or more years. In addition, where greater applications of biochar are to be practiced, in an attempt to sequester more carbon in the soil, that a significantly greater total depth of incorporation would be needed. Future work is needed to evaluate acre application rate for biochar, depth of incorporation, soil type and structure and plant response.

Recommendation 2. That biochar be used primarily as an agricultural soil amendment to enhance soil nutrient utilization in crops, rather than as a soil moisture retention aid, until data on many types of soils are available. In addition, the cost of biochar, the cost of incorporation and the extent (value) of crop response achieved are important considerations in the decision to use biochar on soils for which moisture is limiting, as it was in one of the sites used in this study.

Recommendation 3. That future research focus on the role of soil microbes in the production response and nutrient utilization associated with biochar application, and that consideration be made for combining appropriate microbial cultures with biochar for most consistent results. This will involve further evaluation of the appropriate depth and extent of biochar incorporation relative to the active root zone of the crops involved.

Recommendation 4. That standards for production and characterization of biochar include physical characteristics consistent with the most effective methods for application and incorporation of the biochar in soil in such a way that its migration in the soil is minimal.

Recommendation 5. That manufacturers of biochar production units focus on development of reliable, cost-effective and efficient farm scale or mobile devices.

Recommendation 6. That USDA/REE/NIFA and NRCS develop a National Biochar Research and Development "National Project" modeled after the highly successful "regional research projects" of the past (USDA/CSRS/CSREES/REE), with coordinated participation and project development, using funds allocated to the states for Regional Research, to produce a comprehensive program for biochar use in American agriculture.

The report and the appendices below contain detailed discussion and information on the elements of these studies.

Below are a series of questions to which answers were requested by NRCS, along with answers.

1. What NRCS designated priorities were met with this grant?
The use of biochar as a soil amendment and as a means for sequestration of atmospheric (non-fossil) carbon in soil was a main motivation for this work. The expected very stable and long duration of carbon added as biochar could not be evaluated in a three-year study, but the important management observations that emerged are critical in the application of this technology on a practical basis. The development of a sustainable, and viable carbon credit marketing system will be required to advance that aspect of the use of biochar.

2. What were the goals and objectives for this project?
The evaluation of biochar as an agricultural soil amendment, as a mechanism for carbon sequestration in soil, and the evaluation of a mobile biochar production unit were the goals of the project, with the long-term objective of establishing recommended practices for farmers to put into use.

3. What were the accomplishments?
The accomplishments of this project were the determination that biochar is a potentially important soil amendment for agricultural application, with resulting crop production and yield responses indicative of improved use of soil nutrients. In addition, the apparent synergy between biochar and turkey litter suggests that waste management and environmental benefits can be achieved by turkey and possibly all poultry or even other livestock producers when biochar is used in local cropping practices. The observation of optimization in crop yield response to graded levels of biochar application is important in helping establish management practices for other applications, on different soils, and at different biochar incorporation depths for. These results will also help in establishing biochar carbon loading rates for agricultural soils while maintaining productivity, as carbon credits for sequestration become economically viable.

4. Were the goals and objectives met? If not, what were the barriers to completion?
With the exception of the mobile biochar production unit, the objectives were met. The barrier was that the unit did not perform. The failure to demonstrate that biochar resulted in water retention under these conditions was not a failure, but simply a negative result that actually has value.

5. Was the project completed on time? If not, what were the reasons for extending the timeframe?
The project was completed on time.

6. Who are the customers that benefit from this grant?
Farmers and agricultural producers in Southeastern North Carolina, initially. Once the use of biochar is evaluated on a wide array of soils, farmers in all regions may benefit.

7. Were project funds spent as anticipated? If not, describe major changes in the budget.
The funds were expended as reported and as anticipated.

8. What methods were employed to demonstrate alternative technology in this project?
Biochar production was accomplished by treating chipped wood in a continuous feed torrefaction unit located at NCState University. It was incorporated into the soil with a mechanical tractor-mounted tiller after spreading by hand or with a poultry litter spreader. All other methods were routine agronomic and crop production practices used in the area, under the supervision of a professional agronomist.

9. What were the economic results?
There are no economic results, because at this time the commercial market value of biochar is not established. Once that is done, the economic value of the production response can be evaluated. The economic viability of mobile biochar production units depends on advances in development of reliable technology.

10. Are there Federal, State and local programs that may be used to implement this project?
Depends on the allocation of funds at Federal, State and local levels, public and private, in support of alternative practices in agriculture, and the development of a carbon credit system (at all levels) that is sustainable and viable in the United States.

11. Discuss data reduction, analysis, review, and reporting: How raw data is converted and presented, who reviewed it, and how the final presentation was derived.
Data as collected were provided to the project leaders, summarized in tabular and narrative form, and presented without modification or alteration. The individual who wrote the report has published well in excess of 200 scientific publications, grant project reports, book chapters and books, using accepted methods for handling such data. The draft report was reviewed by the Board of Directors of the NCFarm Center and edited for content prior to final copy completion. That was especially important since the writer was not involved in the design and conduct of the project.

Introduction and Background

The North Carolina Farm Center for Innovation and Sustainability (NCFCIS), a 501(c) (3) nonprofit sustainable farming organization has developed and employed one of the larger scale farming models in the US which focuses on the effects of biochar use on the sandy soils found throughout the Southeast coastal plain region (Southeastern North Carolina). Efficient and strategic introduction of biochar for agricultural use requires farm-scale production using locally available feedstocks.

Biochar has received a lot of interest and press as a soil amendment due to the apparent ability of the material to enhance crop productivity and sequester carbon in soil (biochar normally contains in excess of 60% carbon on a dry basis, with a very long and stable soil retention time, suggested to be in thousands of years!). While an ancient product, dating back thousands of years to use in South America, called "***terra preta***", the functional and critically important characteristics of biochar are only recently beginning to be identified and understood. The refinement in the understanding of this very interesting material is literally in its infancy, and thus almost any new data can play a critical role in building an understanding that can enable this ancient product to emerge once again as an important tool in our efforts to achieve ever improving environmental sustainability for the future.

Use of biochar along with other complimentary technologies and processes relating to its use have the potential to impact the local and national economy in a positive manner, by allowing what once was deemed unusable or underutilized farmland to become productive. Economic stimulation begins with the creation of jobs and the influx of expendable income into the marketplace. As a land-area scale-neutral component, biochar has the potential to become a catalyst that could jump start that process by helping farm operations to expand and become more profitable, creating a need for more labor and opening the door to new business opportunities related to the production, application, and marketing of amendment-based materials. It may also serve to help regulate the availability of nutrients for crops, resulting in the possibility of achieving excellent yields with reduced inputs, a point that will be made subsequently in this report.

The landscape of agriculture, especially in the Southeastern United States, is changing rapidly. Smaller family owned farms are not as prevalent as they once were, giving way to larger units depending on economies of scale to compete in commodity-based agriculture. The demise and waning popularity of tobacco production within the state of North Carolina, especially, has significantly changed the patterns of land use as well as economic viability of the rural communities in the region.

What follows is the final report of the three-year study involving field trials utilizing biochar and presents results and insights that relate to potential benefits from biochar application as a soil amendment. **This project should be considered a starting point in what should to be a modern national effort, modeled after the**

historically successful "Regional Research Project System" in USDA/CSRS (subsequently CSREES/REE), to apply a national need to an integrated and coordinated effort to understand and subsequently provide recommendations for when and where to most effectively use biochar as an AGRICULTURAL soil amendment. NRCS is encouraged to take the lead in developing this initiative, and the budgetary support to fund it.

Experimental Design, Methods and Analytical Procedures

This project was designed to produce and gather field plot test results involving biochar over the course of a three-year period (2010, 2011, 2012) and was supported by funding and in-kind support provided by the NCFCIS and a national USDA-NCRS Conservation Innovation Grant (CIG). The NCFCIS received a tremendous amount of assistance in various capacities from the private farm owners where the trials were conducted. The locations of the trials are as follows: Privateer Farm (owned by Ms. Sharon Valentine and referred to herein as the NC Farm Center) and Beaver Dam Farm (owned by Mr. Scott Weathington, a professional agronomist and certified crop advisor), located southeast of Fayetteville, NC.

One goal of this project was to explore and develop sustainable farming practices through the use of biochar and other potentially complimentary products such as a stable compost produced from locally produced hog waste and turkey litter, also an abundant local product. The trial has been designed to evaluate biochar alone and in conjunction with other amendments, both at varying rates, to determine practicality and access potential yield enhancing properties that can be applied to practical farming applications, small as well as large, and lend itself to sustainability.

Another goal of the project was to evaluate and quantify the effects biochar has on soil composition and fertility as it relates to row crop production and yield enhancement. The study was designed to monitor a number of components such as crop yields, soil data and plant tissue data (as indicators of any potentially negative effects on plant physiology) in an attempt to identify the type of response that can be expected when biochar is incorporated into the soils found in the region (Lakeland Sandy Loam soil on both farms used). The results are intended to help subsequent evaluations of biochar effectiveness when used in other types of soils and/or producing other types of crops. The project has been designed to follow a normal row crop rotation for this area that includes winter wheat, soybeans, cotton, and corn. Using data that have been collected over the three years of work in this project, the objective is to establish a set of working parameters to help identify situations where biochar can be used to aide in agricultural production on a sustainable and commercial scale. The elements of consideration include efficient use of nutrients (potentially reduced application needs), more effective use of chemicals such as pesticides or herbicides, and improved profitability, allowing all types of land to become more productive.

Another aspect of the project was the intended incorporation and evaluation of a mobile pyrolysis unit that would allow biochar to be produced on site. While that was not accomplished with the results as intended, significant valuable information was gathered in the process and is included in the report for use in subsequent applications.

As noted, this project was designed around a series of field plot studies. The primary source of biochar used was Loblolly pine harvested as chips, on site at the NC Farm Center, during an ongoing forestry management operation. The biochar was produced by a pyrolysis unit located at the North Carolina State University (NCSU), Animal and Poultry Waste Management Center (APWMC), Raleigh, NC, and designed by Mr. Christopher Hopkins, College of Natural Resources, NCSU along with staff from the APWMC. The the operating conditions used to produce the biochar from the chipped wood feedstock were: end temperature, 350C, residence time in char unit, 4 minutes. The biochar was analyzed by the North Carolina Department of Agriculture and Consumer Services, Agronomic Division, Raleigh, NC. The composition of the biochar is found in the Appendix of this report. Biochar was incorporated into the plot soil at a depth of from 4-6 inches, using a Befco power tiller following distribution using a Hardee 3 point hitch fertilizer spreader.

Quality assurance was maintained by third party analysis if all samples. All soil and plant tissue (early flower) samples were taken based on standard and industry accepted sampling protocols and analyses were conducted by the Agronomic Division Laboratory, North Carolina Department of Agriculture and Consumer Services. Plant tissue was taken at the early flower stage, and primary interest was focused on tissue nitrogen and potassium, and analyzed in the same laboratory as the soil samples. Because there were no remarkable differences observed in any of the plant tissue samples taken from the various crops grown in this study, indicating that treatments, specifically biochar incorporation in the soil, did not stress or impact plant composition unrelated to yield, those data are not included in this report. Soil analyses are included in the Appendix.

Crops were harvested at appropriate stage of maturity, and yields were measured based on weight and/or volume. All yields were expressed on an acre basis, and where necessary, conversions to or from weight to volume were based on standard equivalencies.

Tables 1 and 2 below show the design of the field test plot array used in this work. Table 1 includes the plots and description of treatments used at the NC Farm Center, and Table 2 shows the same for the plots located at the Beaver Dam Farm. each case, treatment of the soil was done according to accepted agronomic practices used in the area and with the crop rotations employed. That included application of appropriate amounts of nitrogen, as shown in the tables, for all except the “check” (untreated) plots. In addition, biochar, balanced fertilizer, turkey litter and composted swine waste solids were only applied in years one and two, with only nitrogen in year three, to assess the carryover effects of the biochar on the crops used.

Table 1. NC Farm Center, Plot Soil Treatment Grid

	Year	
Plots	2010-11	2012
1A-D	400 lb 5-15-30 fertilizer	none
	140 lb N	140 lb
2A-D	5 tons turkey litter	none
	160 lb N	160 lb N
3A-D	2.5 tons turkey litter	none
	160 lb N	160 lb N
4A-D	none	none
	none	none
1A-4A	0 biochar	0 biochar
1B-4B	2.25 tons biochar	0 biochar
1C-4C	4.50 tons biochar	0 biochar
1D-4D	6.75 tons biochar	0 biochar

Note 1: See Table 3 for crop sequence and yield data.
Note 2: Plots not irrigated.
Note 3: Plot size was 50 x 100 ft.
Note 4: All applications expressed in tons or lb/ac; N application was as ammonium nitrate.

Table 2. Beaver Dam Farm, Plot Soil Treatment Grid

	Year	
Plots	2010-11	2012
1A-1D	none	none
2A	400 lb 5-15-30, 140 lb N	140 lb N
2B	400 lb 5-15-30	none
2C	400 lb 5-15-30, 200 lb N	200 lb N
2D	400 lb 5-15-30, 75 lb N	75 lb N
3A	5 tons biochar, 140 lb N	140 lb N
3B	5 tons biochar, 3 tons compost	
	140 lb N	140 lb N
3C	3 tons compost, 140 lb N	140 lb N
3D	5 tons biochar, 3 tons t. litter,	
	140 lb N	140 lb N
3E	3 tons t. litter, 140 lb N	140 lb N
4A	5 tons biochar, 3 tons compost	none
4B	5 tons biochar	none

4C	3 tons compost	none
4D	5 tons biochar, 3 tons t. litter	none
4E	3 tons t. litter	none
5A	5 tons biochar, 200 lb N	200 lb N
5B	5 tons biochar, 3 tons compost , 200 lb N	200 lb N
5C	3 tons compost, 200 lb N	200 lb N
5D	5 tons biochar, 3 tons t. litter , 200 lb N	200 lb N
5E	3 tons t. litter, 200 lb N	200 lb N
6A	5 tons biochar, 75 lb N	75 lb N
6B	5 tons biochar, 3 tons compost, 75 lb N	75lb N
6C	3 tons compost, 75 lb N	75 lb N
6D	5 tons biochar, 3 tons t. litter, 75 lb N	75 lb N
6E	3 tons t. litter, 75 lb N	75 lb N

Note 1: See Table 5 for crop sequence and yield data.
Note 2: Plots were irrigated to result in 1 inch of moisture added per week (including rainfall)
Note 3: Plot size was 15 x 40 feet.
Note 4: All applications expressed as lb or tons/ac; N application was in form of ammonium nitrate.

The rotation of crops, which included double cropping of winter wheat and soybeans, soybeans grown full season (Beaver Dam Farm only), corn and cotton, was imposed over the plots shown for both locations. At the NCFarm Center, only one given cropping group was grown each year (wheat/soybeans, corn and cotton), while at Beaver Dam Farm there were rotations of the full group of crops within each year. The plot x crop matrix is shown in the tables that contain the results and will be discussed in that part of the report.

Results and Discussion

Carbon Sequestration: One of the deliverables included in this project was to test biochar's effects on sequestering carbon en route to its role in assisting greenhouse gas mitigation. Biochar was added to several of the test plots, at rates ranging from 2.25 to 6.75 tons per acre, applied for two consecutive years, thus adding a two year total ranging from 4.5 to 13.5 tons. While it is not known precisely what the rate of release of carbon from biochar addition to soil is, it is reported to be "very slow" (estimated, without data, in hundreds or thousands of years). In that case, measurements taken in a three-year study would not be expected to establish any meaningful trend but could provide a confirmation of the extent of addition of carbon.

It is very important to note that the biochar in these trials was applied and incorporated into the soil at approximately from the surface to a depth of 4-6 inches. When discussions of potential addition of biochar are made and the possibility of addition of up to 100 tons of carbon as biochar per acre, the depth of incorporation would need to be considerably greater to avoid impairment of crop production. That source of confusion will be addressed in the Conclusions and Recommendations section of this report.

In addition to very slow chemical release of carbon from biochar, one would expect physical impacts on migration of the material within the soil layer (mechanical tillage, water leaching, etc., and probably most significantly by tillage-induced particle size reduction and enhanced movement of small particles). As well, soil type will have a major impact on rate and type of movement. For example, sandy, well-drained soils such as those in this study, would be expected to have migration extent and rate greater than, for example, fine, clay-based soils with a tight clay "hardpan" underlay. (*In fact, migration of biochar toward the surface of the treated plots was observed in this study, especially larger particles. This is an observation that warrants additional careful study, as it has a number of implications.)*

The carbon content of the biochar that was applied in these studies (found in the Appendix) was approximately 66% (dry basis), and the moisture content was 10.2%. The biochar as applied was determined to be in the range of 10% moisture. Therefore, using the carbon content of 59% (66% dry basis, 10% moisture as applied) as a working estimate, the addition to the soils in these trials was in the range of 2.7 to 8.0 tons per acre on those plots to which biochar was applied, in the top approximately 6 inches of soil volume described above.

Based on the crop production data obtained (discussed below), and the slight decline in production where the highest levels of biochar were applied, the application of 10 tons during two years, and a carbon application of 5.9 tons, would appear to be optimal for the soil layer used in this project. This is assuming that there was **NO** loss of biochar from the growth zone due to the factors noted above, an assumption that requires follow-up study.

In these trials, application of biochar was done in consecutive years, to sandy, very well drained soils (Lakeland sandy loam). It is to be determined if the most appropriate application should be in a single year or in subsequent years to achieve the total addition, based on crop performance results. These results suggest a single year application.

Subsequent work is also needed to determine the stability and mobility of biochar and its carbon when added to all types of soils, suggesting the need for a nationally coordinated effort, as will be proposed below.

Physical Characteristics and Behavior of Biochar: There were several other observations during the conduct of the trials that are important for future consideration. First, because the particles size of the chips that were converted to biochar in 2010 were qualitatively "larger" than those used in the 2011 application, two important observations were made: a. the small particle size of the 2011 biochar resulted in difficulty in land application with a strong tendency of the fine char to be blown around during application, and even the formation of bothersome "biochar dust clouds". The char used in 2010 was far easier to handle and did not result in the dust encountered in 2011. Second, there was an observed tendency for the larger particle size biochar to migrate toward the surface of the plots during the three years of the project, as noted above. While no measurements were made of the quantity of the char that moved to the surface, it is something that should be considered in future trials aimed at optimum biochar particle size production. The fine particle dustiness observation needs to be addressed also, because such behavior may result in air quality issues that limit biochar application.

Table 3. NC Farm Center, All Data, 2010, 2011, 2012

		Year		
Plot	Biochar	2010	2011	2012
		wheat/soybeans	cotton	corn
		(bu/ac)	(lb/ac)	(bu/ac)
1A	0	4.10/6.90	500	33.3
1B	2.25	5.80/6.20	476	43.3
1C	4.50	7.00/8.50	505	57.6
1D	6.75	5.22/2.90	442	39.9
2A	0	4.60/4.70	755	34.4
2B	2.25	5.64/10.10	598	30.2
2C	4.50	7.80/13.10	505	28.8
2D	6.75	5.52/18.00	459	33.3
3A	0	6.90/6.10	622	35.1
3B	2.25	4.65/14.00	366	35.7
3C	4.50	5.40/10.60	430	30.0
3D	6.75	5.65/12.10	412	27.6
4A	0	8.05/11.10	349	31.4
4B	2.25	8.50/8.50	279	18.0
4C	4.50	6.74/12.30	459	41.6
4D	6.75	9.40/11.20	453	30.7

Note 1: For treatment protocol additional to biochar, see Table 1.
Note 2: Biochar added at indicated rate in 2010, 2011 only.
Note 3: Wheat/soybeans double cropped.

Biochar impact on crop production: Crop rotation sequence, and yield are shown for each location and each year, in Tables 3 and 4. There are a number of critical and important points to be made from these data and those follow. **There is a very clear and consistent response to biochar addition to the soil at the NC Farm Center up to an application of 4.5 tons per acre per year for two consecutive years.**

Water retention: There was no indication that biochar had a specific impact on soil water retention, in these plots, which were subject to periods of drought (not irrigated). The NCFCIS, through a generous non-funded Cooperative Agreement with the USDA-ARS Coastal Soil and Water Research Center, Florence, SC was able to test biochar embedded soils for effects on improving water retention capacity. This work entailed taking samples from biochar stand-alone test plots, four months after the initial application. A team of ARS staff headed by Dr. Jeff Novak performed the laboratory analysis. After two weeks, the tests indicated that the NCFCIS biochar did not significantly increase water holding capacity or water retention levels in the project soils. However, there was less variability between plots receiving similar treatment, when biochar was included in the amendments, suggesting a sustainability effect that needs to be further evaluated. It may be that moisture plays a role at a micro level in the biochar, or that there is a complex interaction between moisture, microbes and nutrients. Further information on this work can be found in the Appendix

When summarized as a biochar-supported response effect, the data presented below emerge:

Table 4. NC Farm Center, Response to Biochar

Biochar Addition	Wheat + Soybeans	Corn	Cotton
(tons/ac)	(bu/ac double crop)	(bu/ac)	(lb/ac)
0	5.91/7.20	33.5	556
2.25	6.15/9.70	31.8	425
4.50	6.74/11.13	39.4	475
6.75	6.46/11.05	32.9	442
Improvement (%)	+14/+55	+18	-15

Note: Biochar addition as application per year, 2010 and 2011; data for all years.

Performance Observations: The optimal performance for each of the crops included in the above table occurs with the addition of a total of 9 tons of biochar per acre, spread over two years (4.5 tons per acre per year). The improvement in performance, as a percentage of the crops without biochar, was impressive, and even with the cotton yields, the yield at the optimum biochar addition was 11% greater than the lowest addition. The fact that the yields were greater without any biochar for cotton cannot be explained from these data. Because crops were not replicated over years in the NC Farm Center trials, and rainfall (total and distribution) as well as temperature differences are confounded with crop, it is not possible to assess the impact of the application pattern for biochar on the results. That observation requires further study.

During this study, an effort was made to develop an indicator of biomass production indexed on an area of land basis ("Dry Mass Per Area") by Dr. Deborah Hanmer, UNC Pembroke. While some preliminary data were gathered at the NC Farm Center plots, Dr. Hanmer did not feel that there were adequate data to make definitive conclusions. For that reason, those data are not included. However, the Appendix contains the methodology that was developed, in order to give appropriate scientific credit to those efforts. Work continues in the development of this simple method for assessing biomass yield in conjunction with other tests.

It is also noteworthy that the biochar-mediated response appears to be greatest with the use of organic fertilizer (turkey litter in this case), although there was also slightly more supplemental nitrogen added in addition to the litter. The impact of nitrogen mineralization rate and extent in the litter is not known, and may be related to the positive results. It is possible, and will be discussed subsequently in this report, that biochar is providing at least two important enhancements. It is possible that biochar provides ionic binding sites to adsorb, bind and hold nutrients in the plant root zone for improved efficiency of use and extended availability, and/or that soil microbes, which would be expected to play a major role in nutrient utilization, are able to colonize effectively on or in the biochar structure, to assist in that process. Regardless, it appears that biochar mediates and enhances the use of nutrients from the litter in a beneficial combination, and this is a very important and valuable role for biochar in agricultural crop production.

The crop rotation and performance data gathered from the Beaver Dam Farm plots are shown in Table 5 below. There is a very large and complex array of data included in that table. As is shown in Table 2, there are additional amendment combinations used in these plots as well (composted swine waste solids, alone and in combination with turkey litter), and crops are replicated across all years. The fact that irrigation is used to eliminate differences in moisture provides an additional stabilization to assist in the assessment of treatment impacts.

Table 5. Beaver Dam Farm, All Data, 2010, 2011, 2012

		Year					
Plot	Biochar	Crop	2010	Crop	2011	Crop	2012
1A	0	w/s	15.2/25.3	cn	30.0	w/s	72.6/43.0
1B	0	s	28.1	ct	559	s	34.0
1C	0	cn	56.7	w/s	22.0/34.0	cn	48.0
1D	0	ct	455	s	48.0	ct	358
2A	0	w/s	41.2/36.7	cn	87.0	w/s	82.0/40.0
2B	0	s	44.4	ct	641	s	13.0
2C	0	cn	183.7	w/s	60.0/27.0	cn	91.0
2D	0	ct	608	s	46.0	ct	462
3A	5	w/s	61.2/28.6	cn	58.0	w/s	91.0/35.0

3B	5	w/s	77.8/30.3	cn	71.0	w/s	55.7/32.0
3C	0	w/s	73.8/21.6	cn	75.0	w/s	60.0/47.0
3D	5	w/s	76.7/41.4	cn	100.0.	w/s	90.7/39.0
3E	0	w/s	70.3/47.3	cn	85.0	w/s	46.3/40.0
4A	5	s	31.6	ct	489	s	28.0
4B	5	s	30.9	ct	824	s	33.0
4C	0	s	29.8	ct	764	s	31.0
4D	5	s	35.4	ct	1033	s	27.0
4E	0	s	28.9	ct	766	s	18.0
5A	5	cn	115.3	w/s	38.0/27.0	cn	76.0
5B	5	cn	148.6	w/s	42.0/24.0	cn	114.0
5C	0	cn	144.8	w/s	48.0/35.0	cn	87.0
5D	5	cn	183.7	w/s	44.0/48.0	cn	132.0
5E	0	cn	161.8	w/s	51.0/34.0	cn	111.0
6A	5	ct	716	s	21.0	ct	501
6B	5	ct	854	s	29.0	ct	979
6C	0	ct	776	s	37.0	ct	1139
6D	5	ct	716	s	37.0	ct	1623
6E	0	ct	850	s	29.0	ct	1095

Note 1: See Table 2 for plot treatments .
Note 2: Biochar addition, tons/ac, 2010, 2011
Note 3: w/s = wheat and soybeans , double cropped (bu/ac); s = soybeans, full season (bu/ac); cn = corn (bu/ac); ct = cotton (lb/ac).

As with the results from the NC Farm Center, the addition of biochar to the soils at Beaver Dam Farm resulted in a positive crop production response. Unlike the NC Farm Center results, the fact that only one level of biochar was used do not allow an optimum to be determined from these data. That optimum might be higher because of “better” soil and higher fertility, as well as greater moisture availability, but subsequent work is needed to confirm if that is true.

The data in Table 6 are very encouraging, and are consistent with the results reported from the NC Farm Center. Positive responses of the magnitude noted in Table 6, for all crops except the soybeans grown in a double cropping system following winter wheat, are significant. Within year direct comparisons of all combinations at Beaver Dam with and without biochar resulted in 82% of cases where crop yields for plots with biochar exceeded numerically those without biochar, and where turkey litter comparisons were made alone, with and without biochar, the biochar plots exceeded the non-biochar plots 87% of the time. Biochar in combination with turkey litter also gave the greatest magnitude of response for all of the crops, consistent with the results at NC Farm Center.

The above data give further basis to the important possibility that the biochar is providing a surface for binding or holding nutrients in these very well drained soils that would otherwise leach away, until used by the growing plants. The additional high probability that the process is intimately involved with microbial colonization in the fine tubules of or on the biochar is extremely important. This will require soil microbiologists including some who are experts at microbial attachment such as takes place in feed particles in the anaerobic fore-stomach of ruminants. The lack of response in crop performance to the composted swine waste used is assumed to be due to the fact that that material does not deliver significant nutrients and its structure is unlike that of biochar. (An analysis of the swine waste compost is not available).

Table 6. Beaver Dam Farm, Response to Biochar

Biochar Addition	Wheat +	Soybeans	Soybeans	Corn	Cotton
(tons/ac)	(bu/ac double crop)		(bu/ac)	(bu/ac)	(lb/ac)
5	75.2	35.7	31.6	126	1006
0	62.6	39.0	26.9	117	898
Difference (%)	+20	-9	+17	+7	+12

Note: Biochar added, 2010, 2011, data for all years. Soybeans alone were full-season.

Evaluation of mobile biochar production equipment: The implementation of biochar use on most farms is going to require the ability to produce the material near the site of production of the feedstock and use of biochar. Otherwise, transportation of feedstock to a larger unit will render the process infeasible. One of the deliverables in this project was the intent to evaluate a mobile, farm-scale biochar production unit that would be transportable to the site of the feedstock availability. The unit that was evaluated was a BEC-1000 biochar processing unit, produced by Biochar Systems. The unit was intended to process about 1000 pounds of raw feedstock per hour, into a final product of about 250 pounds biochar. Operating temperature was designated to be in the range of 450- 600C. The economic feasibility of this unit (runtime cost analysis) was evaluated by the Appalachian Energy Center, Appalachian State University, Dr. Jason Hoyle. The description of the evaluation model is found in the Appendix of this report.

The BEC -1000 unit did not operate effectively during the attempts to evaluate its performance and operating costs. Frequent maintenance issues and a thru put that was significantly less than the design predicted resulted in the conclusion that there is still much to be done in the development of a reliable, cost-effective mobile biochar production unit, that can be commercially and effectively deployed.

Summarized Comments Provided by W. Scott Weathington, CCA, Professional Agronomist and Owner, Beaver Dam Farm

I have a few comments here for your consideration and to use as you like.

As you know from our conversations when you were there visiting we did not apply any additional biochar or compost or litter in year three. We only added nitrogen except for the grower standard.

My clear observation now is that if I were a commercial grower I would engage in a one time application of char and a yearly application of litter, either composted or raw is fine. I feel that the major benefit of the char is not in water retention but in improved mineralization and improved efficiency of the nutrients.

I would also love to see biochar used in a waste management situation to prevent nutrients from moving into the aquifer. It also has merit as a biofilter and I would love to have the opportunity to engage in this.

As for the Beaver Dam trials I feel the extreme heat paid a large roll in low yields of some crops this year even though we received extreme rainfall near the end of the season this was more detrimental to the yield than beneficial except for the double crop soybeans.

In White Oak the absence of irrigation more or less made the trial over there non effective overall. Once I realized that the char was having little to no effect in improving water holding capacity this made me firmly believe that the key is to keep some moisture in the root zone at all times so the root/soil exchange was more effective. The wetting and subsequent drying out is not beneficial in any scenario I can think of.

I also have drawn the conclusion that biochar plus manure is more beneficial than biochar plus conventional fertilizer, thus making me believe that animal producers made benefit more than other growers and that they could possibly produce biochar and then top it off with raw or composted manure yearly with some supplemental commercial fertilizer and reduce or eliminate the majority of their inherent waste problems.

Conclusions and Recommendations Going Forward

A. **<u>Biochar Impact:</u>** Loblolly pine based biochar, when added to well drained sandy loam soils (Lakeland) in southeastern North Carolina, at increasing rates up to approximately 10 tons per acre, equally applied in two consecutive years and incorporated in the top 4-6 inches of soil, resulted in increased crop yields for winter wheat double cropped with soybeans, full-season soybeans, corn and cotton.

Application at lower and higher rates resulted in lower yields, and same-plot, same-crop comparisons with 5 and 10 tons per acre suggested that the optimum is less than 10 but more than 5 tons per acre. **Recommendation**: that applications between 5 and no more than 10 tons per acre be used as the target for biochar when applied to the top 4-6 inches of soil, and that subsequent research fine-tune the application rate and appropriate depth of incorporation (for each soil type), as well as evaluate the benefits of a single application compared to serial applications over two or more years. In addition, where greater applications of biochar are to be practiced, in an attempt to sequester more carbon in the soil, that a significantly greater total depth of incorporation would be needed. Future work is needed to evaluate acre application rate for biochar, depth of incorporation, soil type and structure and plant response.

B. Biochar/Moisture: Similar crop performance response was observed in both irrigated and dry land production systems, indicating that the biochar response was not directly related to beneficial retention of moisture in these soils. **Recommendation**: that biochar be used primarily as an agricultural soil amendment to enhance soil nutrient utilization in crops, rather than as a soil moisture retention aid, until data on many types of soils are available. In addition, the cost of biochar , the cost of incorporation and the extent (value) of crop response achieved are important considerations in the decision to use biochar on soils for which moisture is limiting, as it was in one of the sites used in this study.

C. Biochar and Poultry Litter or Similar Organic Products: Best crop production performance was achieved when biochar was combined with an organic fertilizer (turkey litter in this case). It is concluded that this may be a combination of availability and management of nitrogen (and other nutrients) and inclusion of beneficial microbes in the litter that result in colonization in or on the microstructure of the biochar to enhance nutrient availability to the crop roots. **Recommendation**: that future research focus on the role of soil microbes in the production response and nutrient utilization associated with biochar application, and that consideration be made for combining appropriate microbial cultures with biochar for most consistent results. This will involve further evaluation of the appropriate depth and extent of biochar incorporation relative to the active root zone of the crops involved.

D. **Biochar Physical Properties**: Physical properties of biochar that are of concern in soil application and retention include particle size (finer particles were easily airborne and difficult to contain and apply, while larger particles tended to “float” to the soil surface in response to rainfall or irrigation after incorporation). These observations suggest that consideration as a carbon sequestration mechanism for long duration will depend on establishing the optimum particle size and application/incorporation technologies to maintain location stability of the biochar in the soil, and that this will probably be soil type and profile dependent. Long-term stable carbon addition to the soils in these trials at the optimum biochar addition range was in the order of 3-6 tons per acre. **Recommendation**: that standards for production and characterization of biochar include physical characteristics consistent with the most effective methods for application and incorporation of the biochar in soil in such a way that its migration in the soil is minimal.

E. **Farm-Scale Biochar Production Units**: Based on experiences in this project, significant development is still required to produce a farm-scale biochar production unit that is mechanically reliable, cost effective, and labor efficient. **Recommendation**: that manufacturers of biochar production units focus on development of reliable, cost-effective and efficient farm scale or mobile devices.

F. **The Need for a Nationally Coordinated Biochar Initiative**: It is hoped that this series of trials will provide a significant base for subsequent research to build on in the development of recommended practices for the extensive use of biochar in agricultural and horticultural soils, and as a way to significantly engage agriculture, through the sequestration of atmospheric carbon, in climate change mitigation. **Recommendation**: that USDA/REE/NIFA and NRCS develop a National Biochar Research and Development "National Project" modeled after the highly successful "regional research projects" of the past (USDA/CSRS/CSREES/REE), with coordinated participation and project development, using funds allocated to the states for Regional Research, to produce a comprehensive program for biochar use in American agriculture.

REPORT ACKNOWLEDGEMENTS

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Agri-Technologies, Clinton, NC

Appendices

1. **Raw Rata and Laboratory Reports:**

A. Analysis of Biochar:

NCDA&CS Agronomic Division | Phone: (919) 733-2655 | Website: www.ncagr.gov/agronomi/ | Report No. FY11-W002902

Agri-Technologies Inc. | Page 3 of 3

Sample Information

Sample ID: MC
Waste Code: NBS
Description: Non-Composted Bark/Sawdust
Comments:

Nutrient and Other Measurements

Nitrogen (N) (ppm): *Total N*, *Total Kjeldahl N*, *Inorganic N* (*NH4-N*, *NO3-N*), *Organic N* (*Urea*)

P (ppm)	*K (ppm)*	*Ca (ppm)*	*Mg (ppm)*	*S (ppm)*	*Fe (ppm)*	*Mn (ppm)*	*Zn (ppm)*	*Cu (ppm)*	*B (ppm)*	*Na (ppm)*	*C (ppm)*
2100	3730	18300	3180	754	3940	460	125	16.9	31.7	352	669000

pH	*DM (%)*	*SS (10^{-5}S/cm)*	*EC (mS/cm)*	*CCE (%)*	*ALE (tons)*	*C:N*
8.01	89.8					57.4 : 1

Ni (ppm)	*Cd (ppm)*	*Pb (ppm)*	*Al (ppm)*	*Se (ppm)*	*Li (ppm)*	*As (ppm)*	*Cr (ppm)*	*Co (ppm)*	*Cl (ppm)*	*Mo (ppm)*

Estimate of Nutrients Available for First Crop (lb / ton)

Application Method	*N*	*P_2O_5*	*K_2O*	*Ca*	*Mg*	*S*	*Fe*	*Mn*	*Zn*	*Cu*	*B*	*Mo*
Soil Incorporated	8.38	4.31	7.23	16.4	2.86	0.68	3.54	0.41	0.11	0.02	0.03	

Other Elements (lb / ton)

Cl	*Na*	*Ni*	*Cd*	*Pb*	*Al*	*Se*	*Li*
	0.63						

B. Analysis of Turkey Litter:

Sample Information

Sample ID: TL-1
Waste Code: HLT
Description: Turkey House
Comments:

Nutrient and Other Measurements

Nitrogen (N) (ppm): *Total N*, *Total Kjeldahl N*, *Inorganic N* (*NH4-N*, *NO3-N*), *Organic N* (*Urea*)

P (ppm)	*K (ppm)*	*Ca (ppm)*	*Mg (ppm)*	*S (ppm)*	*Fe (ppm)*	*Mn (ppm)*	*Zn (ppm)*	*Cu (ppm)*	*B (ppm)*	*Na (ppm)*	*C (ppm)*
34500	15300	65400	16100	4040	2190	1280	928	740	57.7	4420	

pH	*DM (%)*	*SS (10^{-5}S/cm)*	*EC (mS/cm)*	*CCE (%)*	*ALE (tons)*	*C:N*
	63.1					

Ni (ppm)	*Cd (ppm)*	*Pb (ppm)*	*Al (ppm)*	*Se (ppm)*	*Li (ppm)*	*As (ppm)*	*Cr (ppm)*	*Co (ppm)*	*Cl (ppm)*	*Mo (ppm)*

Estimate of Nutrients Available for First Crop (lb / ton)

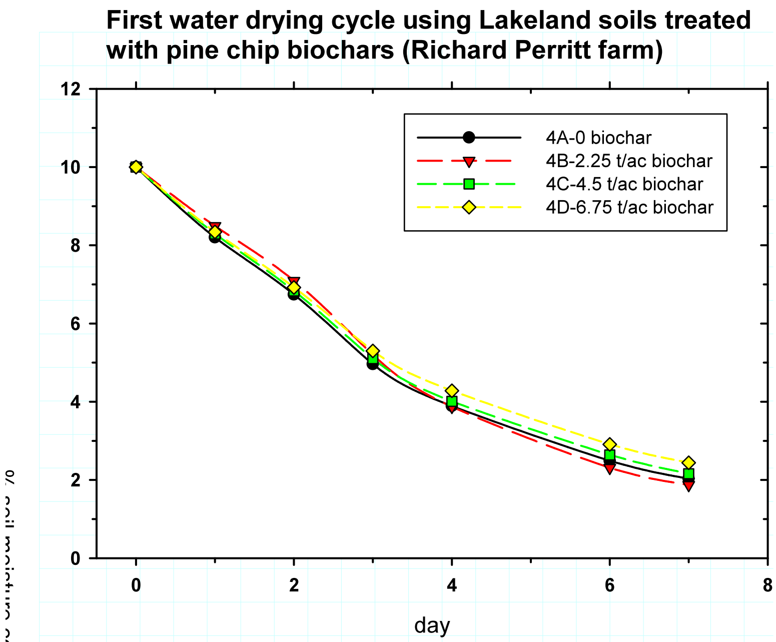
Application Method	*N*	*P_2O_5*	*K_2O*	*Ca*	*Mg*	*S*	*Fe*	*Mn*	*Zn*	*Cu*	*B*	*Mo*
Soil Incorporated	24.8	74.7	20.9	61.9	15.3	3.82	2.07	1.21	1.05	0.84	0.05	

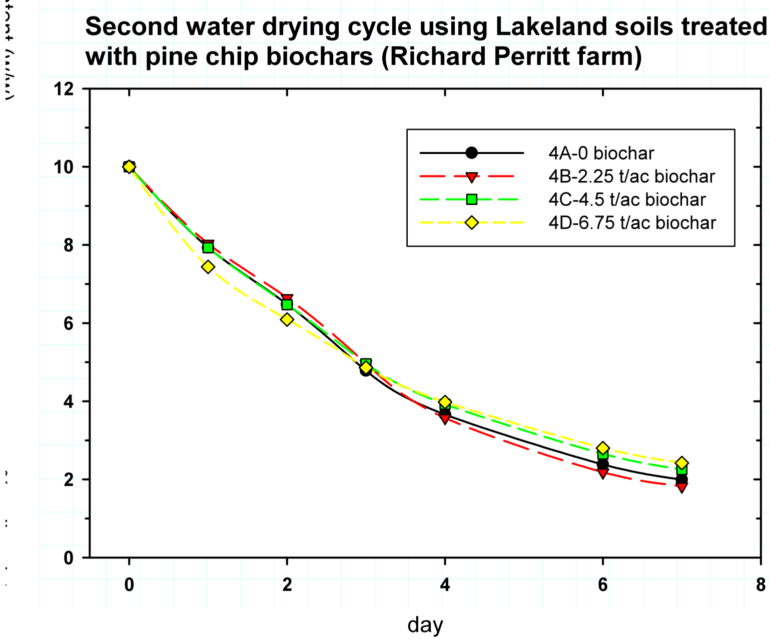
Other Elements (lb / ton)

Cl	*Na*	*Ni*	*Cd*	*Pb*	*Al*	*Se*	*Li*
	5.57						

C. Water Retention Measurements (sent by Dr. Jeff Novak, USDA)

"We did collect a Lakeland soil from some test plots that were treated with and without pine chip biochars. We placed the soils in pots and conduced a soil moisture retention study. We simply wetted the soils and monitored the % moisture content over a time period. We found no improvement in soil moisture contents using the pine chip biochars compared to the controls. I have enclosed two graphs for your review. The pine chip biochars were simply too large (1 to 3 inches) in size to make a difference. I suggested to Dr. Perritt that he use a biochar made from switchgrass. We have found that this feedstock improves soil water retention. We did not publish this work because there was no improvement adding the pine chip biochar." Jeff Novak, Soil Scientist, USDA,


First water drying cycle using Lakeland soils treated with pine chip biochars (Richard Perritt farm)
4A-0 biochar
4B-2.25 t/ac biochar
4C-4.5 t/ac biochar
4D-6.75 t/ac biochar
0
2
4
6
8
10
12
day


Second water drying cycle using Lakeland soils treated with pine chip biochars (Richard Perritt farm)
4A-0 biochar
4B-2.25 t/ac biochar
4C-4.5 t/ac biochar
4D-6.75 t/ac biochar
0
2
4
6
8
10
12
day

D. Soil Analysis Data:

Report by John Ray, District Conservationist (ret), Fayetteville, NC

The report has the soil series Lakeland sand shown for Scott Weathington's test plot area. The soil that is mapped in the official published Cumberland Hoke Counties Soil Survey as an Autryville loamy sand, 0 - 2 percent slopes. Since published soil surveys are mapped at a scale that may not show smaller (less that 3 acres) soils I requested that Vincent Lewis, Soil Scientist, NC Division of Soil and Water, visit the farm and remap the soils at Scott's test plot. We mapped the site as Candor sand. I have attached the mapping information for your information.

The report has the soil series Lakeland sand shown for the Privateer Farm test plot area. The soil that is mapped in the official published Bladen County soil survey as a Lakeland sand, 1-2 per cent slopes. I requested that Vincent map the Privateer test plot area. We mapped the test plot area as Wakulla sand. The report is attached for the Wakulla mapping also.

The remapping would not influence the test results but this information is more accurate for the conditions found in the field. It may make a difference if the water retention was an issue.

Scott's test plot is located in Cumberland County and for the detail folks the Lat/Long is 34 degrees, 52' 56"N and 78 degrees, 34', 08" W.

The Privateer test plots are in Bladen County and the Lat/Long is 34 degrees, 50', 48"N and 78 degrees, 45', 56" W.

Classification by Vicent E. Lewis, Soil Scientist,
Division of Soil and Water Conservation,
Department of Environment, and Natural Resources

Date of Classification – 1/2/2010
Location – Bio Char Test Plot on Scott Weathington Farm, Cumberland County, NC
Soil Classification - Candor Sands

Setting
Landform: Uplands of the Sandhills and Coastal Plains
Landscape position: Broad ridges
Shape of areas: Broad and irregular

Profile 1: Center
Ap 0 to17 inches; dark brown (10YR 4/3) sand; weak fine granular structure; very friable; common fine roots; abrupt smooth boundary.
Bt1 17 to 30 inches; brownish yellow (10YR 6/6) loamy sand; weak fine granular; very friable; few fine roots; gradual wavy boundary.
C 30 to 65 inches; light yellowish brown (10YR 6/4) sand; single grained; loose.

Profile 2: East
Ap 0 to 14 inches; dark brown (10YR 4/3) sand; weak fine granular structure; very friable; common fine roots; abrupt smooth boundary.
C1 14 to 40 inches; brownish yellow (10YR 6/8) sand; single grained; loose; gradual wavy boundary
C2 40 to 63 inches; brownish yellow (10YR 6/6) sand; single grained; loose.

Profile 3: West
Ap 0 to 8 inches; dark brown (10YR 4/3) sand; weak fine granular structure; very friable; common fine roots; abrupt smooth boundary.
E 8 to 20 inches; pale brown (10YR 6/3) sand; weak fine granular structure; very friable; few fine roots; gradual wavy boundary.
Bt 20 to 35 inches; brownish yellow (10YR 6/8) sandy loam; weak medium subangular blocky structure; friable; gradual wavy boundary.
C 35 to 63 inches; brownish yellow (10YR 6/6) sand; single grained; loose.

Classification by Vicent E. Lewis, Soil Scientist,
Division of Soil and Water Conservation,
Department of Environment, and Natural Resources

Date of Classification – 1/2/2010
Location – Bio Char Test Plot on Privateer Farm, Bladen County, NC
Soil Classification – Wakulla sand

Setting:
Landform: Uplands of the Coastal Plains
Landscape Position: Broad ridges
Shape of areas: Broad and irregular

Profile:
Ap 0 to 12 inches; dark brown (10YR 3/3) sand; single grained; loose; few fine roots; clear smooth boundary.
Bt 12 to 30 inches; brownish yellow (10YR 6/6) loamy sand; weak medium granular structure; very friable; few fine roots; gradual wavy boundary.
C 30 to 63 inches; brownish yellow (10YR 6/8) sand; single grained; loose.

NC Farm Center, Pre-trial

NCDA&CS Agronomic Division **Phone: (919)733-2655** **Web site: www.ncagr.gov/agronomi/** **Report No: 17175**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC TEST PLOT

Sampson County

Received: 11/30/2009 Completed: 12/17/2009

Agronomist Comments 3,5

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4A					1st Crop: Cotton	1T	50-70	0	80-100	$	0	0	0	1.0	0	3
					2nd Crop:						0					
4B					1st Crop: Cotton	.5T	50-70	0	50-70	0	0	0	0	1.0	0	3
					2nd Crop:						0					
4C					1st Crop: Cotton	.7T	50-70	0	70-90	0	0	0	0	1.0	0	3
					2nd Crop:						0					
4D					1st Crop: Cotton	1.1T	50-70	0	80-100	$	0	0	0	1.0	0	3
					2nd Crop:						0					

Test Results

Sample No.	Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
4A	MIN	0.46	1.47	7.4	73.0	2.0	5.8	519	31	65.0	6.0	238	150		818	818	595	28				0.1
4B	MIN	0.56	1.44	9.5	83.0	1.6	6.0	659	42	76.0	6.0	250	157		1068	1068	805	31				0.1
4C	MIN	0.60	1.43	10.1	84.0	1.6	5.9	807	36	76.0	6.0	265	166		1260	1260	835	33				0.1
4D	MIN	0.76	1.42	8.8	77.0	2.0	5.7	653	31	70.0	5.0	322	200		1039	1039	704	31				0.1

NC Farm Center, 2010

NCDA&CS Agronomic Division Phone: (919)733-2655 Web site: www.ncagr.gov/agronomi/ **Report No: 09831**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC#1

Sampson County

Received: 10/07/2010 Completed: 10/18/2010 Links to Helpful Information

Agronomist Comments 3, 5

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1A					1st Crop:	Cotton	1T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.44	5.7	74.0	1.5	5.5	448	24	67.0	5.0	219	138		654	654	478	38				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1B					1st Crop:	Cotton	1.3T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.71	1.42	7.0	71.0	2.0	5.4	552	19	66.0	4.0	283	177		792	792	539	38				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1C					1st Crop:	Cotton	1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.51	1.46	7.1	77.0	1.6	5.6	576	19	73.0	4.0	258	162		898	898	559	40				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1D					1st Crop:	Cotton	1.2T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.71	1.43	7.8	76.0	1.9	5.5	644	19	70.0	5.0	250	157		984	984	609	35				0.1

NCDA&CS Agronomic Division Phone: (919)733-2655 Web site: www.ncagr.gov/agronomi/ **Report No: 09832**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To: Agri-Technologies Inc

Farm: NCFC#2

Sampson County

Received: 10/07/2010 Completed: 10/18/2010 Links to Helpful Information

Agronomist Comments

3.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2A					1st Crop: Cotton	1.1T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.48	8.0	78.0	1.8	5.5	650	24	71.0	5.0	253	159		1038	1038	731	45				0.2

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2B					1st Crop: Cotton	1.2T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.42	6.5	72.0	1.8	5.4	557	23	65.0	5.0	208	132		743	743	579	45				0.2

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2C					1st Crop: Cotton	1.1T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.41	7.6	78.0	1.7	5.5	621	23	71.0	5.0	289	180		1008	1008	606	37				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year	Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2D					1st Crop: Cotton	1.2T	50-70	0	80-100	$	0	0	0	1.0	0	3
					2nd Crop:						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.43	8.3	77.0	1.9	5.5	705	31	70.0	6.0	297	185		1077	1077	666	38				0.1

NCDA&CS Agronomic Division **Phone: (919)733-2655** **Web site: www.ncagr.gov/agronomi/** **Report No: 09833**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC#3

Sampson County

Received: 10/07/2010 Completed: 10/18/2010 Links to Helpful Information

Agronomist Comments

3, $

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3A					1st Crop:	Cotton	.8T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					
3B					1st Crop:	Cotton	1T	50-70	0	70-90	$	0	0	0	1.0	0	3
					2nd Crop:							0					
3C					1st Crop:	Cotton	1.2T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					
3D					1st Crop:	Cotton	1.1T	50-70	0	80-100	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Sample No.	Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
3A	MIN	0.51	1.46	7.9	81.0	1.5	5.7	606	24	74.0	5.0	282	176		1021	1021	734	49				0.2
3B	MIN	0.51	1.41	7.6	79.0	1.6	5.6	667	32	72.0	6.0	249	156		1017	1017	702	46				0.2
3C	MIN	0.51	1.42	7.9	77.0	1.8	5.4	677	25	71.0	5.0	272	170		1113	1113	647	38				0.1
3D	MIN	0.51	1.42	8.9	81.0	1.7	5.4	836	28	75.0	5.0	301	188		1289	1289	788	45				0.1

NCDA&CS Agronomic Division **Phone: (919)733-2655** **Web site: www.ncagr.gov/agronomi/** **Report No: 09834**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

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Farm: NCFC#4

Sampson County

Received: 10/07/2010 Completed: 10/18/2010 Links to Helpful Information

Agronomist Comments 3, 8

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4A					1st Crop:	Cotton	.8T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.43	7.0	80.0	1.4	5.6	564	17	75.0	5.0	254	159		913	913	643	40				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4B					1st Crop:	Cotton	.6T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.44	7.7	83.0	1.3	5.9	584	24	76.0	5.0	243	153		885	885	673	37				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4C					1st Crop:	Cotton	.8T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.51	1.43	8.0	81.0	1.5	5.7	632	19	76.0	5.0	267	167		1039	1039	603	39				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4D					1st Crop:	Cotton	1.1T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.71	1.40	7.2	75.0	1.8	5.5	534	17	69.0	5.0	279	174		821	821	534	30				0.1

NC Farm Center, 2011

NCDA&CS Agronomic Division **Phone: (919)733-2655** **Web site: www.ncagr.gov/agronomi/** **Report No: 30918**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC #1

Received: 02/09/2011 Completed: 04/01/2011 Links to Helpful Information **Sampson County**

Agronomist Comments 3, $

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1A					1st Crop:	Cotton	1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.45	5.4	70.0	1.6	5.6	393	20	63.0	6.0	196	125		559	559	420	30				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1B					1st Crop:	Cotton	1.3T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.44	6.0	67.0	2.0	5.4	431	16	61.0	5.0	243	153		594	594	440	33				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1C					1st Crop:	Cotton	1T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.43	6.0	72.0	1.7	5.6	439	15	65.0	5.0	210	133		638	638	428	28				0.1

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1D					1st Crop:	Cotton	1T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.44	6.3	73.0	1.7	5.6	471	17	66.0	6.0	208	132		726	726	453	31				0.1

NCDA&CS Agronomic Division Phone: (919)733-2655 Web site: www.ncagr.gov/agronomi/ **Report No: 30919**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC #2

Sampson County

Received: 02/09/2011 Completed: 04/01/2011 Links to Helpful Information

Agronomist Comments

3, $

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2A					1st Crop:	Cotton	.9T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.41	1.45	6.9	78.0	1.5	5.6	539	25	71.0	6.0	238	150		857	857	619	41				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2B					1st Crop:	Cotton	1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.43	6.1	74.0	1.6	5.5	516	19	66.0	6.0	201	128		699	699	535	38				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2C					1st Crop:	Cotton	1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.51	1.44	7.0	76.0	1.7	5.6	539	21	69.0	5.0	265	166		857	857	533	39				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2D					1st Crop:	Cotton	1.1T	50-70	0	80-100	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.43	7.8	78.0	1.7	5.5	647	28	71.0	6.0	285	178		961	961	596	40				0.1

NCDA&CS Agronomic Division	Phone: (919)733-2655	Web site: www.ncagr.gov/agronomi/	Report No: 30824

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC #3

Received: 02/08/2011   Completed: 03/31/2011   Links to Helpful Information   Sampson County

Agronomist Comments

3, 5

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3A					1st Crop:	Cotton	1.1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.46	7.5	73.0	2.0	5.7	491	20	66.0	6.0	256	161		834	834	629	33				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3B					1st Crop:	Cotton	1.1T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.41	1.46	6.6	73.0	1.8	5.5	537	21	66.0	5.0	215	136		808	808	580	33				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3C					1st Crop:	Cotton	1.3T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.41	7.7	74.0	2.0	5.5	642	21	69.0	5.0	257	161		1072	1072	625	33				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3D					1st Crop:	Cotton	1.5T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.41	1.47	7.3	68.0	2.3	5.4	600	19	62.0	5.0	261	164		901	901	581	32				0.1

NCDA&CS Agronomic Division   Phone: (919)733-2655   Web site: www.ncagr.gov/agronomi/   **Report No: 30825**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: NCFC #4

Sampson County

Received: 02/08/2011   Completed: 03/31/2011   Links to Helpful Information

Agronomist Comments

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Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4A					1st Crop:	Cotton	1.2T	50-70	0	120-140	$	0	0	0	1.0	0	3
					2nd Crop:							0					
4B					1st Crop:	Cotton	.7T	50-70	0	90-110	$	0	0	0	1.0	0	3
					2nd Crop:							0					
4C					1st Crop:	Cotton	.9T	50-70	0	100-120	$	0	0	0	1.0	0	3
					2nd Crop:							0					
4D					1st Crop:	Cotton	1.8T	50-70	0	110-130	$	0	0	0	1.0	0	3
					2nd Crop:							0					

Test Results

Sample No.	Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
4A	MIN	0.32	1.46	6.5	69.0	2.0	5.6	442	13	64.0	4.0	227	143		732	732	522	30				0.1
4B	MIN	0.41	1.45	8.0	80.0	1.6	5.9	533	26	73.0	6.0	231	146		831	831	635	29				0.1
4C	MIN	0.46	1.43	8.8	82.0	1.6	5.7	645	19	76.0	5.0	257	161		1128	1128	650	36				0.1
4D	MIN	0.66	1.46	8.4	67.0	2.8	5.5	520	17	60.0	5.0	273	171		827	827	536	28				0.1

NC Farm Center, 2012

NCDA&CS Agronomic Division   Phone: (919)733-2655   Web site: www.ncagr.gov/agronomi/   Report No: 37712

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: BIOCHAR-WHITE OAK 1

Received: 03/11/2012   Completed: 03/30/2012   Links to Helpful Information

Sampson County

Agronomist Comments

3, 8

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1A					1st Crop:	Corn Grain	.9T	120-160	0	20-40	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.45	6.4	73.0	1.7	5.4	509	59	59.0	10.0	224	151		823	823	475	31				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1B					1st Crop:	Corn Grain	.9T	120-160	0	60-80	$	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.51	1.41	5.9	73.0	1.6	5.2	521	35	63.0	6.0	234	157		721	721	441	37				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1C					1st Crop:	Corn Grain	.7T	120-160	0	40-60	$	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.43	7.1	77.0	1.6	5.5	570	47	68.0	6.0	274	181		857	857	479	34				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
1D					1st Crop:	Corn Grain	.9T	120-160	0	40-60	$	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.41	7.2	76.0	1.7	5.3	607	42	68.0	6.0	262	174		964	964	520	37				0.1

NCDA&CS Agronomic Division Phone: (919)733-2655 Web site: www.ncagr.gov/agronomi/ Report No: 37713

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Farm: BIOCHAR-WHITE OAK 2

Received: 03/11/2012 Completed: 03/30/2012 Links to Helpful Information **Sampson County**

Agronomist Comments

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2A					1st Crop:	Corn Grain	.6T	120-160	0	40-60	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.76	1.42	9.3	83.0	1.6	5.6	764	45	74.0	6.0	298	196		1378	1378	808	36				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2B					1st Crop:	Corn Grain	.9T	120-160	0	20-40	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.41	7.6	75.0	1.9	5.5	649	56	64.0	8.0	271	180		945	945	598	33				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2C					1st Crop:	Corn Grain	.7T	120-160	0	20-40	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.39	7.6	79.0	1.6	5.5	708	55	68.0	8.0	311	204		1060	1060	629	35				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
2D					1st Crop:	Corn Grain	.7T	120-160	0	0-20	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.37	9.2	80.0	1.8	5.6	822	74	68.0	9.0	341	222		1279	1279	712	37				0.1

NCDA&CS Agronomic Division | Phone: (919)733-2655 | Web site: www.ncagr.gov/agronomi/ | **Report No: 37714**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: BIOCHAR-WHITE OAK 3

Received: 03/11/2012 | Completed: 03/30/2012 | Links to Helpful Information | **Sampson County**

Agronomist Comments

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3A					1st Crop:	Corn Grain	.5T	120-160	0	60-80	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.46	1.44	8.1	81.0	1.5	5.7	613	36	73.0	7.0	284	187		1053	1053	663	32				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3B					1st Crop:	Corn Grain	1T	120-160	0	40-60	$	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.56	1.36	7.1	75.0	1.8	5.2	678	44	65.0	6.0	243	163		970	970	706	35				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3C					1st Crop:	Corn Grain	.9T	120-160	0	50-70	$	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.60	1.39	7.9	77.0	1.8	5.4	739	37	70.0	6.0	287	189		1175	1175	600	31				0.1

Field Information | **Applied Lime** | **Recommendations**

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
3D					1st Crop:	Corn Grain	1T	120-160	0	40-60	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
MIN	0.71	1.40	8.9	78.0	2.0	5.4	845	47	69.0	7.0	321	210		1332	1332	716	33				0.1

NCDA&CS Agronomic Division **Phone: (919)733-2655** **Web site: www.ncagr.gov/agronomi/** **Report No: 37715**

Soil Test Report

SERVING N.C. RESIDENTS FOR OVER 60 YEARS

Grower: **Agri-Technologies Inc.**
3164 Governor Moore Rd
Clinton, NC 28328

Copies To:

Farm: BIOCHAR-WHITE OAK 4

Sampson County

Received: 03/11/2012 **Completed:** 03/30/2012 Links to Helpful Information

Agronomist Comments

3,3

Field Information / Applied Lime / Recommendations

Sample No.	Last Crop	Mo	Yr	T/A	Crop or Year		Lime	N	P_2O_5	K_2O	Mg	S	Cu	Zn	B	Mn	See Note
4A					1st Crop:	Corn Grain	1T	120-160	0	80-100	5	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					
4B					1st Crop:	Corn Grain	.5T	120-160	0	70-90	0	0	0	0	.0	0	2
					2nd Crop:	No Crop						0					
4C					1st Crop:	Corn Grain	.6T	120-160	0	80-100	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					
4D					1st Crop:	Corn Grain	1T	120-160	0	80-100	0	0	0	0	.0	0	3
					2nd Crop:	No Crop						0					

Test Results

Sample No.	Soil Class	HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	Mn-I	Mn-AI(1)	Mn-AI(2)	Zn-I	Zn-AI	Cu-I	S-I	SS-I	NO_3-N	NH_4-N	Na
4A	MIN	0.66	1.44	7.7	74.0	2.0	5.4	596	24	67.0	6.0	289	190		1050	1050	638	31				0.1
4B	MIN	0.81	1.45	9.1	82.0	1.6	5.7	690	31	74.0	6.0	281	186		1116	1116	767	38				0.1
4C	MIN	0.81	1.44	9.8	83.0	1.7	5.7	705	24	76.0	6.0	264	175		1193	1193	663	37				0.1
4D	MIN	1.08	1.41	7.7	77.0	1.8	5.3	554	24	68.0	7.0	351	228		893	893	570	55				0.1

Beaver Dam, 2012

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No.	FY13-SL003128

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc., 3164 Governor Moore Rd, Clinton, NC 28328

Advisor:

County: Sampson

Farm: biochar #1

Links to Helpful Information

Sampled: Received: 08/21/2012 Completed: 08/23/2012

Sample ID	Lime History	Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1A		1 - Soybeans 2 -	0.0	0	0	100	0	25	pH$ $pH	0	0	0	Note: 3 Note: $

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.18	1.42	3.7	97	0.1	6.8	90	20	69	25	11	55	30		76	76	64	0.1	3		

Sample ID	Lime History	Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1B		1 - Soybeans 2 -	0.0	0	0	130	0	25	pH$ $pH	0	0	0	Note: 3 Note: $

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.18	1.44	2.7	92	0.2	6.7	67	9	71	20	11	65	39		89	89	39	0.1	4		

Sample ID	Lime History	Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1C		1 - Corn Grain 2 -	0.0	120 - 160	20	100	0	25	pH$ $pH	0	0	0	Note: 3 Note: $

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.13	1.35	3.5	98	0.1	7.2	55	18	75	20	14	55	31		53	53	30	0.1	3		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No.	FY13-SL003128

Agri-Technologies Inc. Page 2 of 3

Sample ID	Lime History	Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1D		1 - Cotton 2 -	0.0	50-70	0	100	0	25	pH$ $pH	0	0	1.0	Note: 3 Note: $

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.13	1.33	3.7	89	0.4	6.7	64	23	61	25	12	58	34		71	71	49	0.2	5		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003129

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Advisor:

County: Sampson

Farm: Biochar #2

Links to Helpful Information

Sampled: Received: 08/21/2012 Completed: 08/23/2012

Sample ID: 2a

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.7	0	0	90	0	25	0	0	0	0	Note: 3
2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.71	1.41	3.6	55	1.6	5.5	273	24	41	11	21	179	117		138	138	114	0.1	3		

Sample ID: 2b

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.4	0	0	110		25	0	0	0	0	Note: 3
2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.60	1.41	3.5	66	1.2	5.7	253	14	54	10	19	241	155		165	165	100	0.2	6		

Sample ID: 2c

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Corn Grain	0.8	120 - 160	0	120	25	25	0	0	0	0	Note: 3
2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.41	1.40	2.8	48	1.4	5.3	208	10	38	8	19	205	140		129	129	81	0.1	4		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003129

Agri-Technologies Inc.

Sample ID: 2d

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Cotton	0.6	50-70	0	130	0	25	0	0	0	1.0	Note: 3
2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.46	1.42	3.1	65	1.1	5.7	179	13	52	12	16	241	152		162	162	78	0.1	3		

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Advisor:

County: Sampson

Sampled: Received: 08/21/2012 Completed: 09/05/2012 Farm: BIOCHAR #3

Links to Helpful Information

Sample ID: 3a

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.0	0	0	120	0	25	0 $pH	0	0	0	Note: 3
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.22	1.37	2.5	84	0.4	6.3	86	13	63	19	11	58	40		60	60	42	0.1	4		

Sample ID: 3b

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.0	0	0	120	0	25	pH$ $pH	0	0	0	Note: 3 Note: $
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.45	3.7	96	0.2	6.8	119	12	74	20	11	68	38		175	175	127	0.1	3		

Sample ID: 3c

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.0	0	0	120	0	25	pH$ $pH	0	0	0	Note: 3 Note: $
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.41	1.44	4.0	92	0.3	6.6	197	11	70	21	14	91	55		200	200	128	0.1	3		

Sample ID: 3d

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.0	0	0	120	0	25	0 $pH	0	0	0	Note: 3
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.40	3.2	83	0.6	6.2	157	12	64	17	14	101	68		123	123	77	0.1	3		

Sample ID: 3e

Lime History:

Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
1 - Soybeans	0.0	0	0	120	0	25	0 $pH	0	0	0	Note: 3
2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.41	1.37	3.4	76	0.8	5.9	191	12	58	16	16	137	92		170	170	87	0.1	3		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003131

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Advisor:

County: Sampson

Farm: BIOCHAR #4

Links to Helpful Information

Sampled: Received: 08/21/2012 Completed: 08/23/2012

Sample ID: 4A	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Soybeans	0.0	0	0	100	0	20	pH$	0	0	0	Note: 3 Note: $
	2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.36	1.27	4.7	90	0.5	6.7	157	21	71	16	14	124	75		138	138	58	0.1	2		

Sample ID: 4B	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Soybeans	0.0	0	0	120	0	25	pH$	0	0	0	Note: 3 Note: $
	2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.36	4.6	90	0.4	6.5	199	13	72	17	14	100	62		367	367	220	0.1	2		

Sample ID: 4C	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Soybeans	0.0	0	0	120	0	25	pH$	0	0	0	Note: 3 Note: $
	2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.38	3.9	89	0.4	6.5	172	10	70	17	16	90	56		297	297	175	0.2	5		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003131

Agri-Technologies Inc.

Sample ID: 4D	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Soybeans	0.0	0	0	120	0	20	0	0	0	0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.27	1.26	3.8	83	0.6	6.3	148	10	67	15	17	118	76		234	234	121	0.2	5		

Sample ID: 4E	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Soybeans	0.0	0	0	120	0	25	0	0	0	0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm^3; CEC and Na in meq/100 cm^3; NO_3-N in mg/dm^3]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.27	1.38	3.3	78	0.7	6.1	160	11	63	13	15	122	82		178	178	102	0.2	6		

NCDA&CS Agronomic Division Phone: (919) 733-2655 Website: www.ncagr.gov/agronomi/ Report No. FY13-SL003132

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Advisor:

County: Sampson

Farm: BIOCHAR #5

Links to Helpful Information

Sampled: Received: 08/21/2012 Completed: 08/23/2012

Sample ID: 5A	Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.0	120 - 160	0	120	0	25	0 $pH	0	0	0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.41	1.40	3.4	81	1.4	6.0	185	11	66	14	14	104	79		174	174	116	0.1	3		

Sample ID: 5B	Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.0	120 - 160	0	120	0	25	0 $pH	0	0	0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.36	1.37	3.1	72	0.9	5.9	169	11	58	13	17	123	91		211	211	143	0.2	6		

Sample ID: 5C	Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.0	120 - 160	0	110	0	25	0 $pH	0	0	0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.36	1.39	3.5	78	0.8	6.1	165	15	61	15	14	98	75		224	224	121	0.1	3		

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Agri-Technologies Inc.

Sample ID: 5D	Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.0	120 - 160	0	130	0	25	0 $pH	0	0	0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.32	1.40	3.0	78	0.6	6.0	171	8	64	13	17	107	81		148	148	85	0.1	3		

Sample ID: 5E	Recommendations: Crop	Lime (tons/acre)	N	P_2O_5	K_2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.5	120 - 160	0	130		25	0 $pH	0	0	0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO_3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO_3-N
0.32	1.38	2.5	61	1.0	5.4	183	7	50	10	17	164	115		137	137	88	0.1	4		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003133

Predictive

Soil Report

Mehlich-3 Extraction

Client: Agri-Technologies Inc.
3164 Governor Moore Rd
Clinton, NC 28328

Advisor:

County: Sampson

Farm: BICHAR #6

Links to Helpful Information

Sampled: Received: 08/21/2012 Completed: 08/23/2012

Sample ID: 6A	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Cotton	0.0	50-70	0	130	0	25	0	0	0	1.0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.36	1.35	3.5	82	0.6	6.1	167	12	65	15	16	101	68		148	148	73	0.1	3		

Sample ID: 6B	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Cotton	0.3	50-70	0	130	0	25	0	0	0	1.0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.31	3.6	77	0.8	5.9	181	11	62	13	16	107	71		226	226	141	0.1	3		

Sample ID: 6C	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Cotton	0.0	50-70	0	130	0	25	0	0	0	1.0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.36	1.36	3.8	80	0.8	6.0	172	11	65	14	15	106	71		293	293	164	0.1	3		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003132

Agri-Technologies Inc.

Sample ID: 5D	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.0	120 - 160	0	130	0	25	0	0	0	0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.40	3.0	78	0.6	6.0	171	8	64	13	17	107	81		148	148	85	0.1	3		

Sample ID: 5E	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Corn Grain	0.5	120 - 160	0	130		25	0	0	0	0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.32	1.38	2.5	61	1.0	5.4	183	7	50	10	17	164	115		137	137	88	0.1	4		

NCDA&CS Agronomic Division	Phone: (919) 733-2655	Website: www.ncagr.gov/agronomi/	Report No. FY13-SL003133

Agri-Technologies Inc.

Sample ID: 6D	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Cotton	0.5	50-70	0	140	0	25	0	0	0	1.0	Note: 3
	2 -							$pH				

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.36	1.33	3.4	74	0.9	5.7	158	9	60	13	17	108	72		177	177	98	0.1	3		

Sample ID: 6E	Recommendations: Crop	Lime (tons/acre)	N	P2O5	K2O	Mg	S	Mn	Zn	Cu	B	More Information
Lime History:	1 - Cotton	0.6	50-70	0	140	0	25		0	0	1.0	Note: 3
	2 -											

Test Results [units - W/V in g/cm³; CEC and Na in meq/100 cm³; NO3-N in mg/dm³]: Soil Class: Mineral

HM%	W/V	CEC	BS%	Ac	pH	P-I	K-I	Ca%	Mg%	S-I	Mn-I	Mn-AI1	Mn-AI2	Zn-I	Zn-AI	Cu-I	Na	ESP	SS-I	NO3-N
0.36	1.38	3.0	67	1.0	5.5	179	8	54	11	17	145			173	173	99	0.1	3		

E. Methodology Development

Dry Mass Yield per Land Area Methodology (Dr. Deborah Hanmer, UNC Pembroke, Unpublished Data, 2011)

A. Using a ½ meter square made from pvc pipe, toss randomly into the plot;
B. Cut off all vegetation within the frame, at ground level;
C. Put vegetation into a pre-weighed, paper grocery-type bag;
D. Dry the plant material in the bags at 100C for 48 hours;
E. Weigh bag and dry plant material, subtracting bag weight;
F. Net is dry weight measure (DWM);
G. Compute DWM per square meter as: 4 x DWM, g/square meter .

Biochar Equipment Information and Performance and Related Materials

Biochar - A Material with Amazing Potential for North Carolina

Chris Hopkins and Dennis Hazel, School of Natural Resources,
NCState University, Raleigh, NC

Biochar can be charcoal, torrefied biomass or almost any plant material exposed to heat in the absence of oxygen. Biochar is biomass that has undergone heat treatment (pyrolysis) and has had significant changes to its chemical properties. Typically the volatile compounds and hemicellulose are eliminated and the cellulose and lignin remain. While the biochar has value as a fuel (its energy content is similar to that of coal), it also has value as a soil amendment and for carbon sequestration.

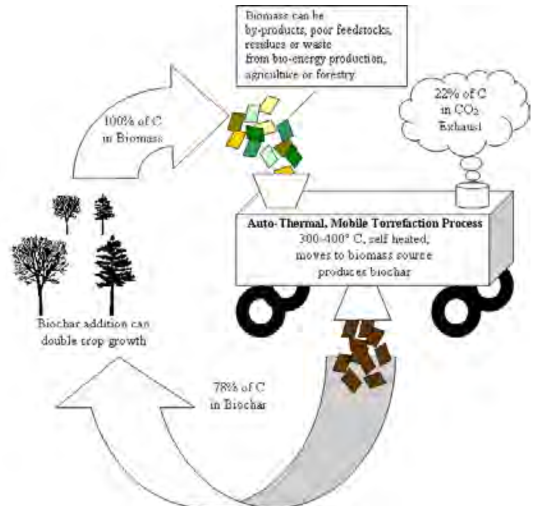
When biochar is added to soil it can dramatically increase crop production and improve soil properties. *Terra preta* or *agrichar* soils are found in former settlement and agricultural areas in the Amazon. The original Amazonians added biochar to these soils to improve soil fertility 500-7000 years ago. These soils still retain their carbon and fertility and even today they are transported and sold as a high quality soil. Biochar has a high pH, an excellent ability to absorb nutrients (cation exchange capacity or CEC), low density, high porosity and can also promote the growth of beneficial soil mycorrhizae.

Southern US soils are sufficiently similar to tropical Oxisols and Ultisols so that the tropical results can be used for North Carolina estimates.[1] Small amounts of biochar (<8 tons carbon/ha) improve overall fertility (20-80% increase in yield) compared to controls. Large amounts of biochar can be added to soil, perhaps as much as 100 tons of carbon per acre, without any negative impacts on plant growth.

[1] Dr. Johannes Lehmann, Cornell University, personal communication.

Biochar is also very stable, with some work suggesting a half-life of 1000 years. Biochar could therefore be means to store huge amounts of carbon and therefore address climate change while providing benefits to agriculture and the environment. The addition of biochar to soils, plus their increased growth on those soils could lead to biochar being a method to sequester large amounts of carbon on very large scales in a relatively short time period.

.As a measure of the scale of biochar's potential, annual biochar applications, in the vicinity of 7 tons of carbon (or 10 tons biochar) per acre to all the cropland in North Carolina (1 ton carbon per acre on the full land base) would offset the state's annual carbon emissions. If one assumes an annual production of 2 dry tons of agricultural waste per acre on North Carolinia cropland, returning the carbon of this biomass to the soil via biochar can yield about 0.78 tons of soil carbon gain per acre per year, achieving a target of 3.5 tons of carbon per acre in 4 to 5 years. In a forestry context, making biochar from the waste biomass from conventional harvests (about 5 tons dry biomass in tops and limbs) would achieve the target of 3.5 tons of carbon per acre after a single thinning and harvest cycle. A doubling of growth potential from the use of existing waste biomass from a few crop cycles would be a valuable addition to the agricultural and natural resource economy of the state.



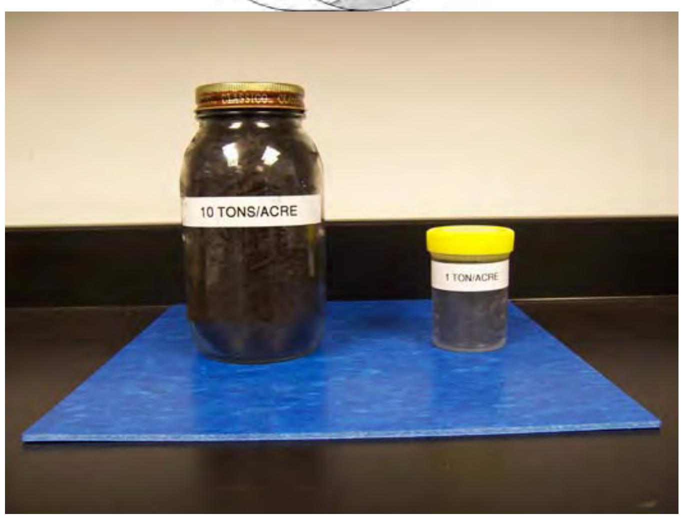


Figure 1: Biochar Cycle returns large amounts of carbon to soil to increase growth and sequester carbon and add value to biofuels processing.
Figure 2: Application rates of 10 tons per acre and 1 ton per acre scaled to 1 square foot.

If, in fact, a doubling of agricultural productivity can be achieved with biochar application, the economic impact to North Carolina could be substantial. The 2005 value of crop harvests in North Carolina was $2.66 billion[2]. If this value could be doubled through increased crop yields it would be a significant impact on both the agricultural economy and the state economy as well. If no increase in productivity were realized but some of the traditional inorganic fertilizer use were offset (North Carolina farmers purchased $238 million of inorganic fertilizer in 2002, ~$59/acre[3]) this would still be a significant impact on the states agricultural economy

[2] http://www.census.gov/compendia/statab/tables/08s0811.pdf
[3] 2002 Census of Agriculture, North Carolina State Data,Table 46 (http://www.nass.usda.gov/census/census02/volume1/nc/st37_1_045_046.pdf)

Carbon sequestration is another aspect of this technology that is potentially valuable but is difficult to price. There is currently not a carbon offset mechanism that directly recognizes biochar as a permanent soil carbon increase. If it were valued on say the Chicago Climate Exchange, carbon would be worth approximately $5 per ton. While not as valuable as the potential crop growth increase or fertilizer offset (perhaps as much as $500 per acre, or about $150/ton carbon added), its value seems sure to increase if carbon is taken seriously as a cause of climate change by our government.

Biochar Application Rates to Offset North Carolina CO_2 Emissions

Application Area by Land Types	Acres	Biochar tons/acre to Offset NC Annual CO_2 Emissions	Biochar tons/acre to Offset NC Share of Anthropogenic CO_2
Cropland	5,065,500	10.8	131.8
Total Agriculture	7,677,800	7.1	87.0
Timberland	17,684,000	3.1	37.8
Forests and Agriculture	25,361,800	2.1	26.3
All Land	31,174,000	1.7	21.4

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Torrefaction for Biomass Energy Applications

Making "Green Coal" from Biomass

Chris Hopkins and Dennis Hazel, School of Natural Resources,
NCState University, Raleigh, NC

Biomass is a Great Energy Source, But…

Biomass has an advantage over renewable energies (such as solar, wind and hydro) in that it can produce both electrical power and liquid transportation fuels. Biomass is also carbon-neutral because, in a broad sense, the CO_2 released in combustion of current vegetation is captured by the next generation of vegetation through photosynthesis. However, biomass feedstocks (both forestry and agricultural) have low energy density and they are bulky, moist, and perishable so that they are relatively expensive to transport and store. Torrefaction solves these problems by making a feedstock that is dry, does not rot, and holds much more energy per unit of volume and mass. Torrefied wood (also known as biochar), when used as a soil amendment, can also be the *foundation of a carbon storage system while increasing overall crop productivity 20-80%.*[4]

The Torrefaction Process

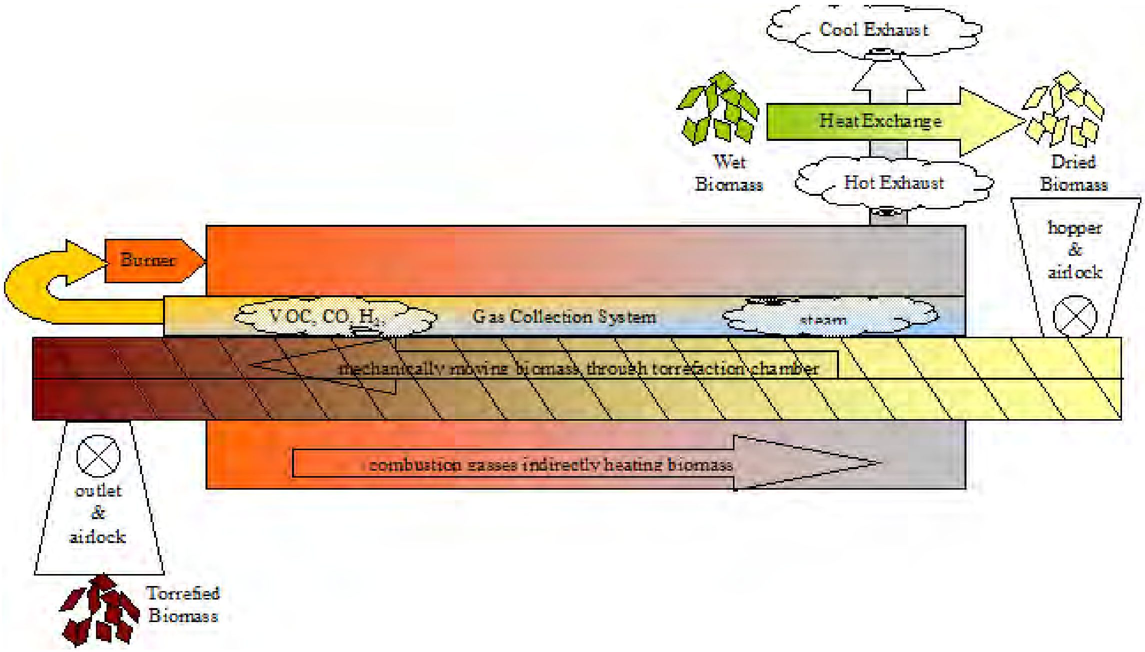
Torrefaction changes plant material from a moist, fibrous, perishable material into a dry, grindable, stable fuel. Torrefaction is carried out under atmospheric pressure in the absence of oxygen at a temperature between 500-800 °F. During torrefaction, all moisture and volatile organic compounds in the biomass are removed and the properties of biomass are changed to obtain a much more energy dense fuel. The gaseous and liquid products of torrefaction are combustible, and depending on the specific process such as our own in NCSU Extension Forestry, can be used to make the process self sustaining, thus minimizing the need for an external energy source to maintain the process.

When green wood chips (approximately 50% water by weight) are torrefied, a portion of the wood energy is used to dry the wood before torrefaction, so about 80% of the original energy is available in the final torrefied product, while only 40% of the initial weight remains. This is a doubling of the energy density from the original wood. Our own NC State University process currently yields product that is 30% of initial weight and retains between 50% to 75% of the energy. We are continuing to develop and refine the process to improve efficiency and increase though-put.

Torrefied Wood is Especially Appealing to the Power Industry

North Carolina annually spends over $2 billion on coal imports to produce electricity. Yet, woody biomass from currently unused forest thinnings, culls and logging waste currently left in the forest after harvest (collectively called woody biomass) could be potentially used to satisfy a major portion of the electricity currently made from coal. However, green wood chips must be dried and pulverized in order to be used in today's modern pulverized coal boilers. Torrefied wood, on the other hand, is easily

[4] Biological Approaches to Sustainable Soil Systems, "Bio-Char Soil Management on Highly Weathered Soils in the Humid Tropics", Johannes Lehmann and Marc Rondon, page 519, Figure 36.1, CRC Press, Taylor & Francis Group, 2006.



Schematic of the NC State University Extension Forestry Torrefaction Process

• Woody Biomass is: – Bulky – Moist – Fibrous – Perishable – Waste – Expensive to transport	• Torrefied Wood (TW) is: – Dense (if pelletized) – Dry, water resistant – Easily crushed – Does not rot – Valuable Fuel – Energy Dense

pulverized and can readily be mixed with coal. Additional benefits of replacing coal with torrefied wood for power production include:

- reduced mercury emissions
- reduced sulfur emissions
- use of a locally derived fuel
- monies spent for fuels stay in the local economy

Torrefied Wood Has Enormous Potential for the Pellet Industry

The fuel pellet industry is one of the fastest-growing uses of biomass for energy. Pellet stoves have been popular, especially in the Northeast, and their popularity is growing. Most consumers purchase pellets as 40-pound bags. However, the last several years have seen the emergence of large wood pellet mills in the Southeast that are targeting the European power and heating industry. For these markets, pellets are shipped via rail to ports for loading bulk-freight based ships. For these markets, energy density and pellet stability are key. Torrefied wood can be made into pellets that are more energy dense than traditional wood pellets and are water resistant unlike wood pellets.

Production Runtime Cost Analysis: B-1000 Biochar System Prototype

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Introduction

The prototype B-1000 biochar processing unit from Biochar Systems was intended to produce biochar from biomass material with high lignin content, including sources such as forestry slash, lumber mill waste, urban wood waste, prunings, and compressed grass. Raw biomass material is prepared as a feedstock for the processing unit by reducing the raw material to particle sizes ranging from 0.5 inch to 2.5 inches – averaging about 1 inch – and reducing moisture content to about 10% or less. The B-1000's operations were modeled for a unit with the capacity to process 1,000 pounds per hour of raw feedstock material, producing an average biochar yield of about 25% by weight, or 250 pounds of biochar per 1,000 pounds of feedstock. Typical processing temperatures ranged between 450°C and 700°C with an approximate average 600°C operating temperature.

Purpose & Scope

This analysis was prepared to provide a preliminary indication of operational costs of biochar production using the B-1000. The operational parameters, cost and quantity factors, and other variables used to develop the model are based on both design information provided by the manufacturer and the experience of the N.C. Farm Center during early operation of the unit.

The scope of the analysis is limited to an examination of the operating costs of B-1000 Biochar System units when the units are operated for between 1-hour and 12-hour processing cycles in a continuous production run processing 1,000 pounds of raw feedstock per hour. Because the model was intended to provide preliminary guidance on the marginal production cost impacts from different lengths of operational run-times and provide some insight into the optimal length of time for each production run – and perhaps frequency of production runs – the model and the resulting analysis doesn't directly reflect on the economic viability of a biochar processing facility, but with the addition of capital investment requirements, maintenance expenses, feedstock processing time requirements, biochar output handling and packaging requirements, feedstock cost, and sales price data, the results of this model could be incorporated into a broader analysis of the economic viability of a regional biochar processing facility or extended to better understand the operational parameters which may bound a vertically integrated biochar processing facility concept.

Unit Operation Characteristics

The B-1000 unit was modeled with a capacity to process 1,000 pounds of prepared biomass feedstock per hour into biochar. The model only incorporates the B-1000 unit and is based on continuous processing for a specified length of time with limited (if any) automation. In addition to the B-1000 pyrolysis device, a biochar processing facility operating at full commercial scale would also likely include equipment to perform the following functions:

- Biomass Feedstock Preparation – wood chipper/grinder and biomass dryer;
- Feedstock loader or conveyor to provide steady flow of feedstock material into processing unit;
- Biochar product management and packaging system to steadily handle biochar output from the processing unit, allowing cooling, storage and labeling/packaging.

Labor

At a minimum, the presence of one person is generally necessary during operation of the biochar processing unit. However, the actual quantity of "working" labor hours and nature of the work required to be performed depends largely on the manner and the degree of automation with which feedstock input and biochar output are handled. Plus insurance regulations may require the presence of two people during operation of the system. During system start-up and shut-down additional labor is necessary.

Labor in the model was assumed to cost $18.25 per hour. Each production run was estimated to require a fixed quantity of labor at 9 person-hours (estimated at 3 people for 1.5 hours each during both start-up and shut-down) regardless of the length of time the unit operated. During actual processing operations, labor requirements were estimated at 0.5 person-hours per hour, most of which would be spent loading the hopper and managing the biochar output; so, one person working 1 person-hour per hour could theoretically operate two processing units per hour.

Processing Run Fixed Costs

There are two types of costs factored into the operational cost model: fixed and variable. The fixed costs in the model are associated with system start-up and shut-down, and are incurred at the same rate during each discrete operational run of the biochar processing unit regardless of the length of time the unit operates.

In addition to the aforementioned fixed labor expenses associated with starting and stopping the unit, each operational run also consumes an estimated 1 gallon of propane to ignite the flare, heat the unit and warm down the unit. Each start-up is also estimated to consume 2 kWh of electricity for the initial ignition of the biomass material.

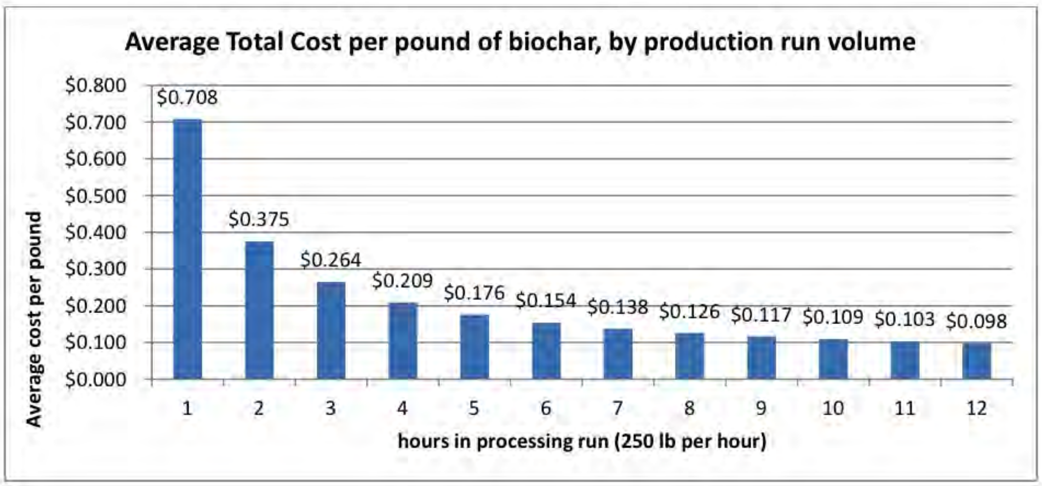
Variable Processing Costs

The portion of the biochar production costs incurred for each hour the system operated are referred to herein as variable processing costs. These per-hour expenses include: 0.25 gallons of propane (between 0 and 0.5 gallons dependent on the feedstock), 10.9 kWh of electricity to operate motors (biomass turner, blower) and auxiliary systems, and 0.5 person-hours of labor as previously discussed.

The model was constructed using approximate then-current prices of $1.83 per gallon of propane, $0.10/kWh of electricity, and the aforementioned $18.25/hour for labor.

Biochar Processing Costs

The first-hour costs of biochar processing include the start-up and shut-down cost as well as costs associated with the first hour of operation. So, the first 250 pounds of biochar can be processed at a cost of $177, or $0.71/lb of biochar. Each additional pound of biochar – processed in 250-pound increments – incurs only the variable operating expenses and is produced at a cost of about $10.67, or at a marginal cost of about $0.0427/pound. As the length of time in the production run increases the average cost per pound decreases from $0.71/lb in the first hour (first 250 pounds) to just under $0.10 per pound in the 12th continuous hour of a single production run, as shown in the figure below.



Implications of Processing Cost Model

The processing cost model is designed to be the core module in the development of a more comprehensive biochar business model. The processing cost model does not include the cost of biomass feedstock since feedstock quality, cost and availability varies. The manner in which this model may be extended and incorporated into a business model evaluation include the following:

- Given a feedstock cost, the full cost of produced biochar can be determined (net of capital and maintenance expenses); the cost of biochar can then be compared with the value or market price to determine the potential unit profitability per pound of biochar;
- Based on the expected profit per unit, the minimum unit production volume for break-even operation can be figured based on the capital investment (purchase price plus any financing cost) and maintenance cost for the production and associated system equipment;
- With the break-even production volume estimate, the availability of feedstock can be evaluated for potential deployment locations.

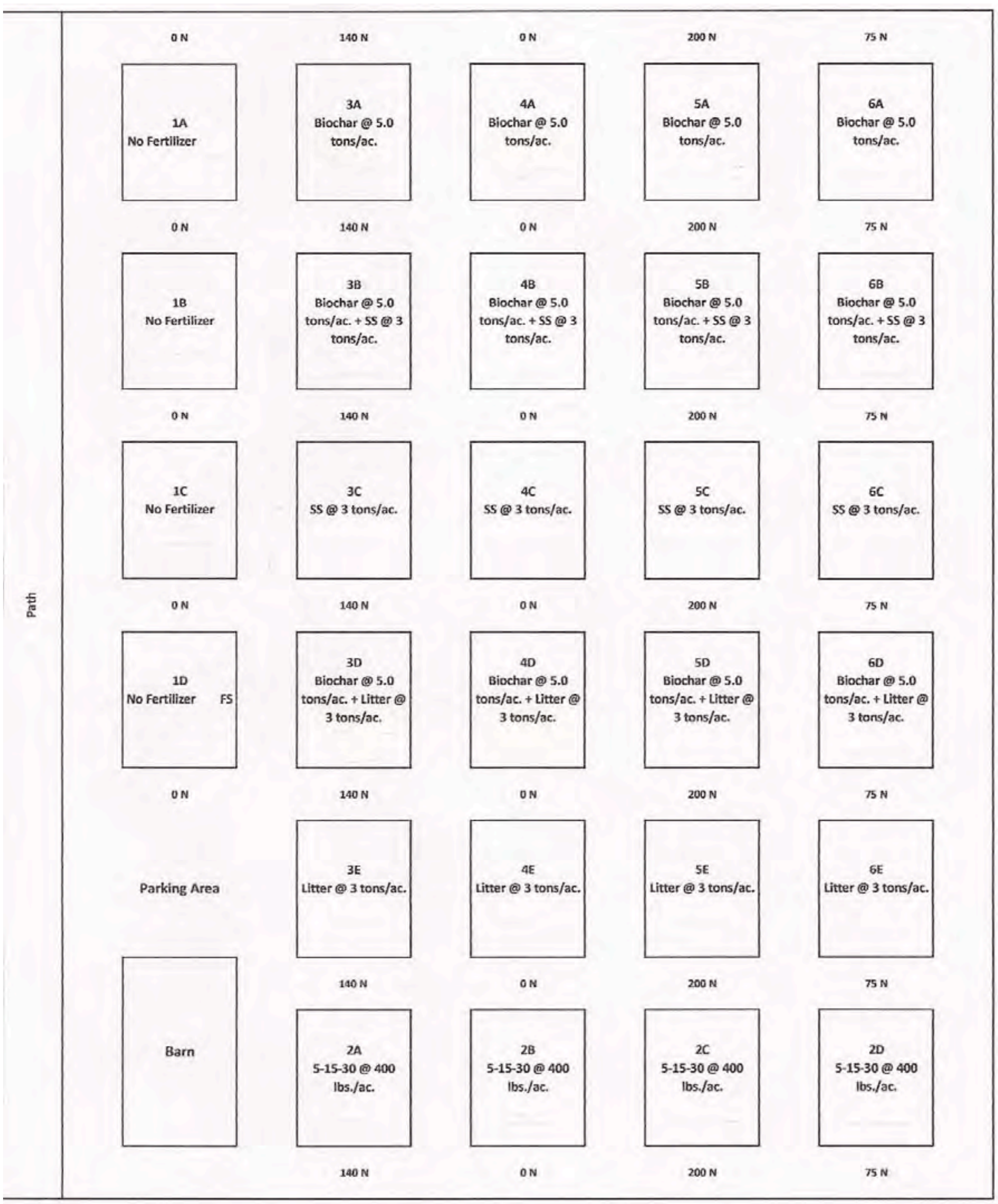
Other feasibility and operational derivatives can also be extrapolated from this basic operational cost model. For instance, the scale of production can be optimized to ensure full utilization of employed labor units (i.e., a person can't work ½ of a person-hour over the course of a whole hour – the person will be paid for the whole hour). Another optimal scale calculation pertinent to consideration of commercial operation is related to the feedstock preparation requirements, such as time [presumably related, in part, to the type of feedstock] – can feedstock materials be prepared for biochar processing in more or less time than the actual biochar processing takes? Also, at a large enough scale of production, the potential advantage of supplementing labor with technology – automated feedstock loading or biochar packaging – would likely be sufficient to support an investment in additional automation, converting some variable processing expenses into fixed or overhead costs and further reducing the average total cost per unit of biochar.

F. Plot Grids and Selected Photographs of Crops

Treatment and Fertility Plot Map, NC Farm Center

No Biochar	2.25 tons Biochar	4.5 tons Biochar	6.75 tons Biochar
1A 5-15-30 @ 400 lbs./ac.	**1B** 5-15-30 @ 400 lbs./ac.	**1C** 5-15-30 @ 400 lbs./ac.	**1D** 5-15-30 @ 400 lbs./ac.
No Biochar	2.25 tons Biochar	4.5 tons Biochar	6.75 tons Biochar
2A Litter @ 5.0 tons/ac.	**2B** Litter @ 5.0 tons/ac.	**2C** Litter @ 5.0 tons/ac.	**2D** Litter @ 5.0 tons/ac.
No Biochar	2.25 tons Biochar	4.5 tons Biochar	6.75 tons Biochar
3A Litter @ 2.5 tons/ac.	**3B** Litter @ 2.5 tons/ac.	**3C** Litter @ 2.5 tons/ac.	**3D** Litter @ 2.5 tons/ac.
No Biochar	2.25 tons Biochar	4.5 tons Biochar	6.75 tons Biochar
4A No fertilizer	**4B** No fertilizer	**4C** No fertilizer	**4D** No fertilizer
No Biochar	2.25 tons Biochar	4.5 tons Biochar	6.75 tons Biochar

Treatment and Fertility Plot Map, Beaver Dam




Soybeans, 3 tons turkey litter, 200 lb N per acre, no biochar- Beaver Dam


Soybeans, 3 tons turkey litter, 75 lb N per acre, no biochar- Beaver Dam

Soybeans, 3 tons hog waste compost, 75 200 lb. N per acre, no biochar- Beaver Dam

Soybeans, 3 tons hog waste compost, 75 lb N per acre, no biochar- Beaver Dam

Soybeans, 3 tons turkey litter, 75 lb. N; 10 tons biochar per ac. (2 yr)- Beaver Dam

Soybeans, 3 tons turkey litter, 200 lb. N; 10 tons biochar per ac. (2 yr)- Beaver Dam

Cotton, 3 tons hog waste compost and 10 tons biochar (years 1 and 2)

Cotton, no fertilizer or biochar (years 1 and 2)

Cotton, 400 lb 5-15-30 per acre, no biochar- Beaver Dam

Cotton, 3 tons turkey litter per acre, no biochar- Beaver Dam

Cotton, 3 tons hog waste compost per acre, no biochar- Beaver Dam

Cotton, 3 tons turkey litter and 10 tons biochar (2 yr) per acre- Beaver Dam


Cotton, 400 lb. 5-15-30 and 140 lb N per acre, no biochar – NCFC


Cotton, 5 tons turkey litter and 160 lb N per acre, no biochar - NCFC

Cotton, 2.5 tons turkey litter and 160 lb N per acre, no biochar – NCFC

Cotton, no fertilizer, no biochar - NCFC

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