

Updated January 2, 2017

Barn Raiser Project -

On-Farm Allothermal (dual chamber) Biochar Kiln for Daily Production of charcoal and energy

The Happy Berry is a highly diversified, direct marketing small fruit farm on 22 acres since 1979. We want to increase our carbon sequestration and improve soil health by adding annual applications of biochar to our fields. Healthy soils produce healthy plants and a healthy planet. We have woody pruning's annually from our five acres of blueberries and from our pine trees (loblolly, Italian stone pine and long leaf pine) growing in our fields as an adaptation to global warming and to mitigate the problem by sequestering more carbon dioxide. It is visualized that we would use a 55 gallon stainless steel sealable drum inside a fire brick lined kiln at 400-600 degrees centigrade. Also in the kiln tortuous exhaust is a stainless steel coil that is connected to a steam engine that would run a variable speed wind mill electric generator(see figure)that is connected to the grid.

Reasons for doing biochar kiln

Pruning disposal problem - Currently blueberry pruning's are annual disposal problem. One fifth of a fifteen to twenty stem bush are removed each year from a thirty to thirty five year old bush or younger. The twiggy tops are removed from 12 to 15,000 blueberry stems that are removed at the root crown and the tops are mulched with a side delivery finishing mower. The remaining stems ranging from half inch to two inches in diameter are collected and put in nearby woods. If left under the bush wild pigs push them towards middles where they either jam or break the finishing mower. Even with active biota under the bush or in the woods it is estimated that less than a few percent is converted to recalcitrant soil carbon. The current net result is that this carbon is being sequestered maybe five years or less and carbon dioxide is return to the atmosphere. This project could turn it into recalcitrant carbon with a life of hundreds if not thousands of years.

Soil health and fertility - Soils in the Piedmont of South Carolina are old, highly weather and eroded from hundred plus years of plowing for cotton production. The cationic exchange capacity ranges from three to five and has virtually no anion exchange capacity. The addition of properly prepared biochar, even in small doses would slowly increase both as well increase recalcitrant carbon in the soil. This carbon has highly adsorptive capacity that would create greater water holding capacity. Historical research has used massive biochar doses from a few tons to 50 - 100 tons per hectare. For the small (subsistence) farmers like The Happy Berry this is very expensive (capital intensive) in terms of purchase, transport and application in

an ongoing perennial system.

The basic goals for soil health are to improve physical and chemical properties of the soil. Improvement in these properties would promote better nutrient cycling, improved biological properties, increased water holding capacity, better soil aggregation, increased rate of water percolation and thus reduced soil erosion.

It is proposed here that ground biochar composted with 30 to 50% on-farm produced poultry litter would be applied in small micro doses using standard tractor mounted fertilizer spreader as a directed in row application under the bush. A bicycle mounted grinder would be used to deposit the charcoal from the stainless steel drum on a concave pad for hydration and addition of nutrients/poultry litter over time for activation.

Energy return on investment - Currently there is little or no return on pruning stems other than health, vigor and management of the blueberry bush. Adding a small steam engine and wind mill electric generator (thus continues to generate at variable speeds) offers the opportunity to store energy on line. A 10 horse unit is available that generates 6.5 kilowatts at 125 psi from www.greensteamengine.com for \$2260. Our electric coop (Blue Ridge Electric) provides net metering and no payment for annual generation that exceeds usage.

Energy generation using waste heat generated -

How much energy would be generated? White oak at 20% moisture yields 5800 btu's per pound of wood. Perhaps blueberry pruning's are more dense ... density needs to be determined. One kilo watt (kW) is equivalent to 3400 btu's. Thus if one pound of blueberry pruning equals 6000 btu's that pound is equivalent to 1.76 kWh. If the system is 20% efficient, then 0.35 kWh would be generated from each pound of wood. A 55 gallon drum holds about 93-95 pounds of dry blueberry branches. Therefore one load would generate approximately 33 kWh of power. There are at least 150 barrel loads of pruning stems potentially generated each year or 4950 kWh of power. The typical percent moisture of blueberry wood that has been allowed to dry from February to November when it would typically be used in the system is about 11%.

What is the payback rate? The cost per kilo watt hour (kWh) from Blue Ridge Electric coop is 0.12 cents per kWh. The farm uses approximately 50 kWh per day so 33 kWh would be over half the daily usage. This would be equivalent to \$3.96 per day and assuming 180 days a year it would be \$712.80 per year. The payback period on the steam generator would be 3.17 years. If the system is run 150 days it would be \$594 per year or the payback period is 3.8 years. If these number are correct this would make the investment in the steam generator feasible.

Research and outreach - If the system provides the benefits hoped for perhaps it could be a model for others to follow. It is proposed here that university extension and researchers be involved in documenting energy considerations, baseline soil health characteristics and possible changes in those characteristics over time. They would be welcomed to establish plots with variables of their choosing.

Initially it is proposed that soil aggregate stability, thus better soil structure, would be evaluated by annual evaluation of soil slaking in the fall of each year (a normal post harvest slower work time after lay-by operations). Second, a crude evaluation of bulk density measuring the weight of a known volume of soil each year. Third, the rate of water infiltration be measured every other year using a tube and measuring the time for a known volume of water to disappear.

Annually evaluate soil chemical properties by having Clemson University run a soil test and organic matter test. Cost \$11 per sample.

Annually it is proposed to evaluate biological properties by doing midden counts on 1/4 meter of soil surface and doing earth worm counts after a powdered mustard stimulation (2 Tablespoons per quart of water). Also annually run a soil test for plant parasitic nematodes and total nematodes including saprophytes as indicators of soil health.

It is proposed that for the observations above that one sample be taken from each management zone for each planting date and put in a spread sheet. Eight locations have been selected(see Appendix 1). Each management area would be append with brief historical description of land management prior to the initiation of the plan.

Other considerations

Where to put Coil? If the steam generating coil is placed in the kiln how much energy would it remove from the kiln, thus lower the temperature of the kiln thus impacting the temperature at which the charcoal is formed. Based on reading to date charcoal formed at 500+ or - 100 C is perhaps the best for agricultural use. Perhaps the coil should be placed in a tortuous exhausted system of the kiln where it would not draw energy needed to make charcoal???

Yield of charcoal? When the wood is loaded in the barrel there will be oxygenated air in the container. The amount of estimated air is the volume of 40 gallons as estimated using water at about 70 degrees F. How will that amount of air impact the amount converted to ash verses charcoal? Allothermal biochar cook stoves have yields of biochar from 20 to 30%. At 30% yield and 90 pounds of pruning's at 11% moisture per batch would yield 24 pounds of charcoal. 150 batches would create 3600 pounds. One of the advantages of a allotherrmal (dual chamber) kiln is that it is self extinguishing thus the inner biochar chamber does not continue to smolder creating more ash.

Field application? Initially it was visualized that the biochar would be applied as a slurry to escape dust issues. For 3600 pound and 16 pounds per 50 gallon tank it would take 200 slurry tanks to make the application. At one hour per tank it would take 5 weeks to apply it. *A better on-farm method of application is needed.*

Suggestions? Composting it with 30 to 50%chicken litter and using perhaps a standard fertilized spreader??

Currently there are about 10 acres of crop at mostly 10 feet row spacing. If the biochar is applied in a 4 foot band over the row and there is 4356 linear feet of row

per acre this would mean the actual application rate ($3600\text{lbs}/10\text{acres} = 360\text{lbs}/\text{broadcast acre}$ applied to just 0.4 acre of crop or $1/0.4=2.5 \times 360 = 900$ lbs per applied acre) and would be 900 lbs of biochar applied per acre per year. Ten year would be 4.5 tons per acre.

Time considerations - It takes about 20 to 30 minutes to load 55 gallon drum with branches. Current branches were just trimmed to enable grinding with a finishing mower. With the knowledge that a barrel takes a 40 inch branch, then pruners during the pruning process will make the large branches not appropriate for side delivery finishing mower closer to the right size.

What would be the typical run time for a single barrel from load up to cool down?... so the system could be reloaded. 24 hours?

It takes about 3 months man hours working 6 days a week to do the pruning. And currently takes about 10 day man hours to haul branches to the nearest woods. This might increase as we would be taking them all to one spot.

Many of the bushes are 35 plus years old and have 15- 30 plus branches per bush. The pruning involves removing 1/5 to 1/6 of these branches each year and takes 10 to 15 minutes per bush. There is about 3500 bushes in all at this time or about 12-15000 thousand branches to be converted to biochar. We can get 60 to 80 branches in a barrel (90 plus pounds) depending on size that could be about 150 barrels or more given other on-farm carbon sources. If the project is feasible perhaps a second kiln would need to be added or that may mean running virtually every day for 6.25 months using a six day week from November to May.

Automation - Given the figures above to reduce the labor time input a little automation with draft control based on temperature might be helpful. Initially it would direct exhaust to get the external fire going. Once the external fire is going the first change in draft would be to semi tortuous. Then when the sealed container has reached the point that the container/kiln reaches 300 plus degrees Celsius and the reaction (pyrolysis) becomes endothermic the draft could be changed from semi direct tortuous exhaust to full tortuous system for improved waste heat capture by the steam engine.

Other on-farm carbon sources - There is still land to be cleared and currently we use slash and burn. If this project looks feasible, In future we will use slash and conversion to biochar. This will increase time to haul to the wood yard near the kiln.

We lose on average two to three large trees, mostly Oak, pine and Hickory to lightning strikes each year. These could also be converted to biochar. Bi weekly we have chicken litter which could also be converted to biochar.

We are changing cultural practice... using pines as evaporative cooling for adapting to global warming. Branch removal to allow photo synthetic saturation (i.e. 50 - 60 % sunlight) would contribute more wood for conversion to biochar.

Safety - The pyrolysis process can result in oil like liquids which if they catch fire cannot be put out with water. A sufficiently sized dry chemical fire extinguisher

should be present. The location of the kiln should be near water for other types of fires. The same water can be used for the hydration process.

Door to kiln - The door to the kiln should be vented for the pyrolysis starter fire and burning of the gas manifold under the drum as well as big enough to move the drum in and out of the kiln after the pyrolysis process is complete...Further the top of the door or the whole door should insulated so kiln can reach temperature. Where to get a kiln door?...perhaps Vermont casting.

Rack for managing drum - The rack should facilitate loading of the drum in semi upright position and dumping in a semi downward position. The rack should be mobile for putting in and out of the kiln....perhaps some sort of mini rail system could withstand the conditions of the kiln. Looking around the internet perhaps \$200 for wheels??but not sure of their heat tolerance??

Cost for kiln -??? *Where to put exhaust chimney? How to construct the exhaust chimney for efficient extraction of heat by the steam coil?* Will it need draft control, i.e. direct exhaust during starter fire period but tortuous exhaust once pyrolysis is started? How hard would it be to automate draft change? We anticipate we would build it ourselves.

Clemson researchers with possible interest -

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APPENDIX I

Soil tests results, organic matter determinations, slaking, Midden counts, worm counts and nematode counts and water percolation rates will be kept in spread sheet and made accessible on our website. This will be done in 8 different areas enumerated below and the numbers will be used for sample submission.

1. Grapes above drive way including Zoe's Yard
2. Grapes, blackberries, gojii berries, seedless muscadines, and persimmons in south facing valley

3. Blackberries in west facing valley
4. Muscadines in west facing valley
5. Blueberries on "sleeping women" ridges including south ridge
6. Blueberries in north facing valley - Centurions
7. Figs and persimmons on east facing hill east side of farm
8. Mulberries and other to be planted on east facing hill on west side of Farm

Historical description - General background for approximately 10,000 years prior to 1600 the land was managed by the woodland people and then 1800 Cherokee as a grassland savannah using fire. The grass sword was tall and when it burned it char as a result of no or very little oxygen near ground when burning. the result was very fertile savannah from years of accumulation of char. during the late 1600s and 1700's Drovers of cattle/pigs were main industry so the savannah continued in a modified cooperation. In the early 1800's cotton was introduced along with plow. For 100 years cotton was king and all the fertile top soil washed down the rivers. The result was by the early 1900's was exploited soil that in general was abandoned to subsistence farmers that supplement their income by working in the mills. The land was cheap and frequently given as a donation by parishioners' at local church's. Generally that is true of much what is 22 acres we call the happy berry.

Zone one, "the grapes above the drive way", the top of hill was such piece that was donated and used to support a community school before the current public school system. It abandoned and trees return on much of it starting about 1914 other was kept free of trees for grazing animal power for plowing for vegetable and local transportation. Our management about 2000. Part was cleared by heavy equipment and limed and planted to grapes.

Zone two, "grapes below the drive way and persimmons", Was terrace prior to abandonment for cotton and may have seen cotton as late 1940. Some was used for grazing especially the persimmon area. Was kept clear by the power company for power lines. the grape area was limed about 2000 similar to zone one. The persimmon area was heavily limed prior to planting about 2010. While making the parking area in zone one the tree stumps from 2014 were buried in lowest part of zone three.

Zone three, "blackberries and Goji berries below the driveway" also includes the Razzmatazz seedless muscadines, This land abandoned in the 70's from grazing which include goats was cleared 2012 -13 by cutting vegetation off at ground line and leaving roots in the ground was kept by mowing. It was limed heavily in 2014 and planted 2014 and 2015.

Zone four "blackberries west valley also abandoned from grazing including lastly goats about 1965 and was cleared by dozer early 1989 smoothed up fertilized and grass encouraged and mowed for three years before being planted to blackberries in 1992-1995. It has never been limed. The area around the stream was planted to

elderberries in the late 90's Then changed to willows about 2007.

Zone 5 "Muscadines West Valley" Was originally part of zone four till viruses destroyed the blackberries in that area. Muscadines were planted using the blackberry flip trellis system bolted into an upright position. It was planted 2005-6 and later limed.

Zone six "blueberries sleeping women ridge" was 30 years grown up when the property was first bought. Three acres cleared by hand 1979/80 fertilized and kept mowed. It was planted to blueberries in 1981. In 1983 and additional acre was cleared by dozer fertilized and kept mowed. It was planted in 1985/6 to blueberries. Balanced fertilizers were used for about 9 years and then switched to 16-4-8. At one point in 1988/89 because pH was about 3.9 one quarter ton of lime was used per acre and half ton of gypsum was applied in the fall.

Zone seven "blueberries Centurion Valley" 90 plus years grown up was cleared by dozer in the 1994/5. Fertilized and kept mowed and planted to blueberries in 1997/98.

Zone eight "figs east hill" was cleared of 35 year grown up in 1983 and initially planted to raspberries that failed after 8-10 years. It was then converted to blackberries 95-97 but difficulty in care because of steepness of slope, they were removed in stages and planted fig in 2015/16 and a small area of persimmons 2017. the area lightly limed in the 80'S.

Zone 9 is being cleared slowly starting 2014 of 45 year grown up by cutting off at the ground line and control by mowing. Mulberries were planted in the earliest part cleared spring of 2016. No fertility has been added to date.

APPENDIX 2 Methods

Earthworm counts:

Earthworm "mustard" extraction based on work from Cindy Hale, et al. ([website](#)). In fall or spring when soil is still cool and wet:

-Materials:

40g mustard powder (~1/3 cup)

4 L water (or 1 gall)

-Mix well by shaking in a gallon jug.

-Define 1' x 1' area to pour over, preferably with metal flashing (see photo on website)

-Pour 1/3 wait 2 minutes & repeat until solution is all poured out.

-Wait 10 minutes. Collect earthworms as they emerge, but be sure they're all the way out before removing them, otherwise they hold on to the ground.

Water infiltration into soil:

From the NRCS's soil test kit/methods literature ([website](#))

- Materials:

6 inch diameter tube - firmed into soil

500 mL water

Stop watch

- Pour gently into tube

- Time from start to finish (finish = no more water puddled on surface)

- Take a soil sample at the same time to measure soil moisture:

Weigh soil to x.x grams

Dry in oven at 150F

Weigh dry soil (dry time varies)

$\% \text{ water} = ((\text{wet wt} - \text{dry wt}) / \text{dry wt}) \times 100$

- Soil moisture can then be used as a covariate to see if water infiltration rates differ according to starting moisture.

APPENDIX 3 Data Baseline 11/2016

Nematodes

	Grapes (AD)	Grapes persi(SV)	Blackberries (SV)	Blackberries(WV)	Muscadines(WV)
Spiral	60	90		20	50
Ring	100	70		70	
Root knot		10			

Organic matter was done without removing/sieving fresh roots - the samples were just ground and organic matter determined by furnace method. This I believe is misleadingly high.

Mulberry west hill samples were not collected 11-2016

APPENDIX 4 - Background reading - The brief synopsis's are my opinions and you are encouraged to form your own. I have ranked the items directly related to biochar first in no special order.

Biochar

1. Lehmann, Johannes and Stephen Joseph, 2015, Biochar for Environmental Management, science, technology and implementation, Second edition.

This text goes deeply into the available information details of physical and structural properties of biochar including macro/micro-molecular level and how biochar influences nutrient retention, water retention, soil influence on biochar properties including persistence, movement, effects on crop yield, effects on N and methane emissions and influence on soil biota. The approach is very technical and not a "quick read."

2. Loudermilk, W.C. 1953, Revised 1975 reissued 1994 Conquest of the land through seven thousand years, USDA technical bulletin.

This text is an interesting "quick read" of how soil destruction resulted in the demise of civilizations

3. Jeff Schahczenski, 2010 Biochar and sustainable agriculture, National Center for Appropriate Technology

An easy read covering what is biochar, why it is important, including fertility, moisture retention, pH balancing, bio-energy production, carbon sequestration and perceived future.

4. Bates, Albert, 2010. The biochar Solution: Carbon Farming and Climate Change. New society Publishers.

Another easy read that covers the historical use of biochar in civilizations for 5000 plus years before the advent of spread of invasive diseases plants, animals and man around the world. How man has exploited soils around the world by bad technology and the rediscovery of carbon farming and a glimpse of a possible future.

5. Liebig, mark, A.J. Franzluebbers, Ronald F. Follett. Editors, 2012 Managing Agricultural Greenhouse Gases: Coordinated Agricultural Research through GRACEnet to address our changing climate, Elsevier Inc.

This book is a very technical read covering agricultural contribution to the global warming problem. Perhaps it should be in the global warming list below but I have put it here it really addresses soil carbon issue. It fails to use consistent units of weight. The editors are USDA and take a very optimistic view, thus a minimal contribution by agriculture to global warming, especially in the US. The bottom line after you wade through all the chapters is that only a few perennial systems do a good job of actually sequestering carbon. "New" systems, like "no-till," "strip-till" various crop rotations, cover crops, "ridge-till," and various combinations are less exploitive of carbon but really end up doing very little in terms of carbon sequestration for more than a year or two or three. The book covers a wide variety of bioregions. It demonstrates how at the current technological state of agriculture we are moving from exploitive to net zero carbon dioxide and continuing to dump other global warming gases into our atmosphere. If you really want to understand the problem in depth you should read it. What we really need to be doing is putting 30% of the carbon dioxide we put in the atmosphere each year back into the ground and drastically reduce our contribution of other global warming gases.

6.

Energy

1. Richard Heinberg and David Friley, 2015, Our Renewable Future
2. Daniel Yergin, 2011. The quest: Energy, security, and the Remaking of The Modern World
3. Michael J Graetz, 2011. The End Of Energy; The unmaking of America's environment, security, and independence.

Global warming

1. Michael E. Mann, The hockey stick and the climate wars: Dispatches from the front lines.
2. Al Gore, The future: Six Drivers of Global Change.
3. James Hansen, Storms of my grandchildren: the truth about the coming Climate Catastrophe and our last chance to survive.
4. Bill McKibben Oil and Honey: The education of an unlikely activist.
5. Naomi Klein, This changes everything: Capitalism vs. The Climate.
6. Elizabeth Kolbert, The sixth Extinction: an unnatural History.
7. Mark, Maslin, Climate Change: A very short introduction.
8. Mark Lynas Six Degrees: Our Future on a Hotter Planet

9. Mark Hertsgaard Hot: Living Through the Next Fifty Years on Earth.
10. Giles Slade, American Exodus: Climate Change and the coming Fight for Survival
11. Thom Hartmann, The Last Hours of Humanity: Warming the World to Extinction

Economics and community

1. Amy Cortese, Localvesting: The Revolution in Local Investing and How to profit from it.
2. Rob Dietz and Daniel W. O'Neill Enough is Enough: Building a Sustainable Economy in a world of finite resources.
3. Dmitry Orlov, James Bates Truong, Jason Ray Albert and et al, Communities that Abide
4. Rob O'Grady, 150- Strong: a pathway to a different Future .
5. David C. Korten, Change the story, change the future: A living Economy for a Living Earth
6. Bill McKibben, Deep Economy: The wealth of Communities and the Durable Future.
7. Thomas Piketty, Capitalism in the Twenty-first Century
8. Molly Scott Cato, The bioregional Economy: Land, Liberty and The Pursuit of Happiness.
9. Stan Cox, Any Way You Slice It: The Past, Present and Future of Rationing.
10. Naomi Oreskes, Erik M. Conway, The Collapse of western Civilization: A View from the Future

Water

1. See Stan Cox number 9 above
2. The World Economic Forum Water Initiative
3. I served as president of Friends of Lake Keowee Society, a local watershed association in the Savannah river system and had many reads in that position

History

1. Charles C Mann, 1493: Uncovering the new world Columbus Created
2. Ronal Wright A short history of Progress

3. Jared Redman, Collapse

4. Jared Redman, Guns Germs and Steel

5. James Gustave Speth, The bridge at the Edge of the World: Capitalism, the Environment, and Crossing from Crisis to Sustainability

Genetics - This may seem unusual to include it here. Here is why. The potential harvest of energy from the sun is over 3.8 Exajoules. We, the worlds civilization, currently use a little over 500 exajoules. The harvest of this energy is by plant photosynthesis. Photosynthesis and growth of plants is regulated by genetics. To draw an analogy genes are kind of like economic planners. A farmer in planning the farm must work with these genes to balance local energy production in his bioregion for on farm use of energy and energy production to feed his community. Considering the first and second law of thermodynamics the only really renewable energy source with a positive (healthier planet) waste management system(if we don't mess it up!) is the sun.

1. Siddhartha Mukherjee, The Gene: An Intimate History

A recommended read.