REDWOOD FOREST FOUNDATION, INC

PO BOX 12 MENDOCINO, CALIFORNIA 95460 PHONE: 707-409-5144 EMAIL: INFO@RFFI.ORG WWW.RFFI.ORG

Biochar Research- 2018

This report was prepared by Raymond Baltar of the Sonoma Ecology Center in conjunction with completing Outcome # Four of the Weyerhaeuser Family Foundation funded "From Forest to Farm and Beyond" project.

Outcome 4: The partnership continued to work with researchers and representatives in emerging markets and incorporated their results into developing a business plan.

According to a recent report by the US Biochar Initiative, annual biochar production in the US alone was estimated at 45,000 tons in the 2017-2018 time period, and could be as high as 70,000 tons.[1] It was also estimated that in order to produce that volume of biochar, the industry used between 125,000 and 200,000 bone dry tons of biomass feedstock. However, the market production potential for the use of biochar in agriculture alone was estimated to be over 3 billion tons.[2] So clearly, there is ample room for growth and entrepreneurial activity in biochar production and use in coming decades.

This USBI report also broke down current markets and the percentage of producers that are selling to these markets:

Garden	62%
Horticulture, specialty crops	47%
Field crops	42%
Orchard and tree Crops	29%
Turf	20%
Landscaping	36%
Stormwater filtration	33%

---

[1] http://www.dovetailinc.org/report_pdfs/2018/DovetailBiochar118.pdf

[2] The USDA's National Agricultural Statistical Service reported there were 318 million planted cropland acres in 2010. It takes 9.4 tons of carbon per acre to increase soil carbon content by 1%; therefore, almost 3 billion tons (6.1 million railcars) of biochar would be needed to enhance all U.S. cropland. For background information on biochar see past Dovetail reports:

Biochar 101: An Introduction to an Ancient Product Offering Modern Opportunities www.dovetailinc.org/report_pdfs/2016/dovetailbiochar0316.pdf and Biochar as an Innovative Wood Product: A Look at Barriers to Realization of its Full Potential http://www.dovetailinc.org/report_pdfs/2017/dovetailbiocharpotential0517.pdf

Odor control	27%
Other(heavy metal remediation, concrete additive, etc)	18%

Within the U.S., California is the largest and most important agricultural state, and coupled with its progressive political governance and leading climate change policies, its massive tree die-off, surplus biomass and water scarcity issues, and its push for healthy soils, it has become in many ways ground zero for interest in biochar. Pyrolysis and gasification technology companies from around the world are actively looking for opportunities to gain a foothold within the state, forestry managers and communities are looking for ways to better utilize the massive amounts of partially burned or non-merchantable slash material they have available. So California is poised to both produce and use a large percentage of the biochar produced over the next 6 years.

But agriculture is only one of many markets for biochar, and there is growing interest in a number of other uses for it. Hans Peter Schmidt, a biochar researcher from Europe, and Kelpie Wilson, a well-known biochar author, teacher, and researcher from Oregon, have written a compelling article called the 55 Uses of Biochar[3], wherein they illustrate many additional applications other than direct field application for this carbon-rich material. These additional agricultural uses include as a feed supplement for cattle to reduce enteric methane release, to improve composting operations, to reduce odors in dairy operations, and as a poultry litter additive. But there are many environmental, commercial and industrial uses as well. A sampling of these include as an air and water filtration medium, as a building insulation material, as protection against electromagnetic radiation, for soil remediation of heavy metals and pesticides and herbicides, and in composting toilets. Biochar could be remanufactured to be used in cosmetics, as a food colorant, as a deodorant in shoes, and even as a material to produce semiconductors as a replacement for silica.

While most of these uses are not yet mainstream (other than in cosmetics and pollution remediation), the interest and experimentation in the use of biochar for many of the aforementioned applications is rapidly expanding. We are at the very beginning of a long-term trend involving better and more sustainable uses for our surplus resources, and since biochar production and use addresses a number of pressing issues, including improved forest management and reduced fire danger, better waste management, renewable energy production, improved agricultural practices and food security, and carbon sequestration, the significant increased availability and large variety of uses for this material will no doubt spark many new entrepreneurial ventures.

---

[3] https://www.biochar-journal.org/en/ct/2

Over the last 10 years thousands of biochar-related lab studies and field trials have been undertaken by university and private researchers around the world. While most of this research has focused on crop agriculture, a number of other important areas of study have been emerging that could rapidly accelerate the use of biochar by industry, municipalities, and entrepreneurs. These include water and air filtration at water treatment facilities, stormwater filtration, heavy metal pollution mitigation at mine and industrial cleanup sites, phosphate and/or nitrogen filtration from polluted waterways, animal agriculture, and as a construction material.

Here are some links to a few of these articles, white papers or studies:

Phosphate removal from Florida waterways
https://eponline.com/articles/2011/05/18/biochar-more-effective-cheaper-at-removing-phosphate-from-water.aspx

Heavy metal removal from stormwater in Port Townsand Washington:
http://www.ptleader.com/news/paper-mill-biochar-may-help-filter-port-water/article_3b8e78f6-8583-11e4-8e37-eb4b861b936b.htm

The use of biochar in cattle farming:
http://www.biochar-journal.org/en/ct/9-The-use-of-biochar-in-cattle-farming

Canadian study using biochar as a feed supplement:
https://www.feednavigator.com/Article/2017/08/29/Canada-to-invest-1.75m-in-feeding-study-to-reduce-GHG-improve-cattle-production

Biochar in poultry farming:
http://www.biochar-journal.org/en/ct/10-Biochar-in-poultry-farming

Biochar for mine lands remediation:
http://biochar-us.org/presentation/biochar-mine-lands-reclamation

An emerging market solution for legacy mine remediation:
https://www.law.du.edu/documents/registrar/adv-assign/Keske_Economicsof%20Natural%20Resources%20and%20the%20Environment_Attachment%201_79_2.pdf

PO BOX 12 MENDOCINO, CALIFORNIA 95460 PHONE: 707-409-5144 EMAIL: INFO@RFFI.ORG WWW.RFFI.ORG

The following article by well-known European biochar researcher Hans Peter Schmidt and Oregon author, educator and biochar advocate Kelpie Wilson outlines the wide range of potential markets for biochar as the industry develops. Each application is ripe for entrepreneurial development and the sheer number of different uses in different industries illustrates how large the future market for biochar will likely be.

The 55 uses of biochar:
http://www.biochar-journal.org/en/ct/2-The-55-uses-of-biochar

---

Sonoma Ecology Center/Sonoma Biochar Initiative

The Sonoma Ecology Center and Sonoma Biochar Initiative, RFFI's collaborators in the first two WFF grant projects, have been involved in a number of biochar-related research projects since 2014, including an NRCS Conservation Innovation grant study titled, "The Sonoma County Biochar Project", the "Citizen Science Biochar Project", a winery wastewater filtration project, and water efficiency field trials funded by the Department of Water Resources that is currently underway.

The Sonoma County Biochar Project produced biochar using an Adam-Retort pyrolysis unit and then analyzed its effects after application at three farms in the county. The most significant results were shown at Oak Hill Farm, and a short synopsis of the results are shown below:

On June 20, 2015, Oak Hill Farm (OHF) planted a winter squash crop here. Preparation simply involved tilling before seeding rows and setting out drip tape for irrigation. An equal number of rows of two squash varieties (Delicato and Butternut) were planted in each plot. Irrigation came from centerlines of the squash rows. Irrigation duration, and thus total water applied, was identical for both test and control plots. Irrigation frequency and duration were adjusted by the farm manager to meet moisture requirements of the drier of the two plots, rather than differentially from one plot to the other. The farm manager reported that on extremely hot days, the test plot with its biochar was under visibly less stress than was the control plot. Irrigation ceased about September 1, after which the crop began about a month of drying and curing. The greater soil moisture retained in the test plot due to biochar impacts actually became a concern for the farm manager at this point as it forced him to delay harvest to allow more curing time for the squash there.

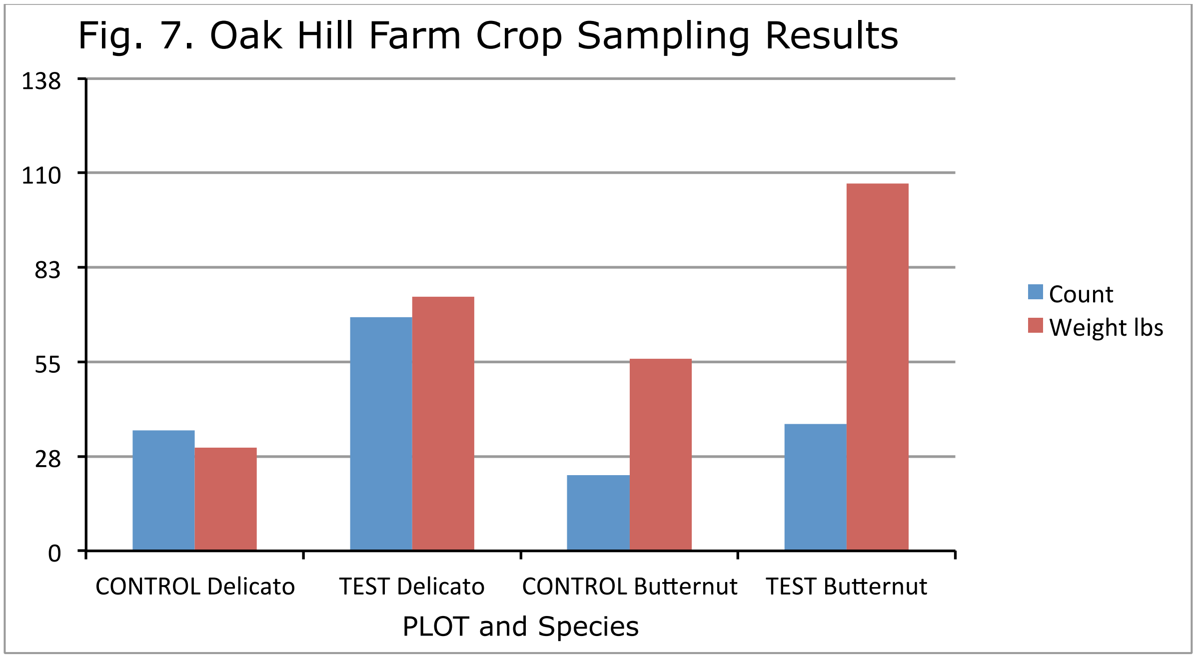
Fig. 3 below illustrates the growing season moisture retention results at our OHF field trial site. Note the wilted squash vines in the row to the left of center (in the control plot) in contrast to the larger squash vines with no wilting on the right (in the biochar test plot). Fig. 4 shows the OHF field trial plots in mid-September, halfway through the curing period (again, control on left, test on right of center pumpkin row). Note smaller biomass and greater wilting in the control plot (left) as compared to the test plot.

Figure 3

The results of this sampling showed, for both varieties, that the test plot yielded significantly higher numbers of squash and had a significantly higher total weight of squash as compared to the control plot. Table 1 presents the data, depicted in Fig. 7.

Table 1. Crop Weight and Number Comparisons, Oak Hill Farm

OHF Crop Sampling	Control Plot	Test Plot	Difference	Pct. Difference
Delicato Squash - Count	35	68	33	194%
Delicato Squash - Weight in lbs.	30	74	44	247%
Butternut Squash-Count	22	37	15	168%
Butternut Squash-Weight lbs	56	107	51	191%



In 2017, the Sonoma Ecology Center was approached by a biology professor at Sonoma State University named Michael Cohen who wanted to use biochar in a winery wastewater filtration experiment he had received funding for. Through their relationship with the Redwood Forest Foundation the Ecology Center received a donation of 4 cubic feet of North Coast Biochar for this purpose, and professor Cohen integrated the biochar into the experiments. A short synopsis describing the results is below:

Summary

- Addition of a biochar-containing compartment to a sand filter appears to increase the removal of organics from microbial fuel cell-treated winery wastewater (WW).
- In greenhouse experiments plants in farm soil amended at 10% or 20% (vol/vol) with biochar performed significantly better than those in soil amended with an equivalent volume of sand.
- Treated WW-saturated sand taken from the biochar/sand filter was inhibitory to buckwheat germination when used as a 20% farm soil amendment whereas an equivalent volume of biochar taken from the filter was not.
- Passage of winery WW through the microbial fuel cell and biochar/sand filter improves its value for use in crop irrigation but phytoinhibitory components still remain at the end of the treatment process.

The Citizen Science Biochar project involved blending biochar and compost and giving away 5-gallon bags to over 180 participating hobby gardeners and school and community gardens. The goal was to measure, using monthly photos of plant growth progress, differences between treated and untreated garden plots. Overall, the biochar-treated plots showed increased plant growth of between 135% and 143% over the control plots, depending on the month the plants were measured.

More information on this project can be found here:
http://sonomabiocharinitiative.org/?page_id=617

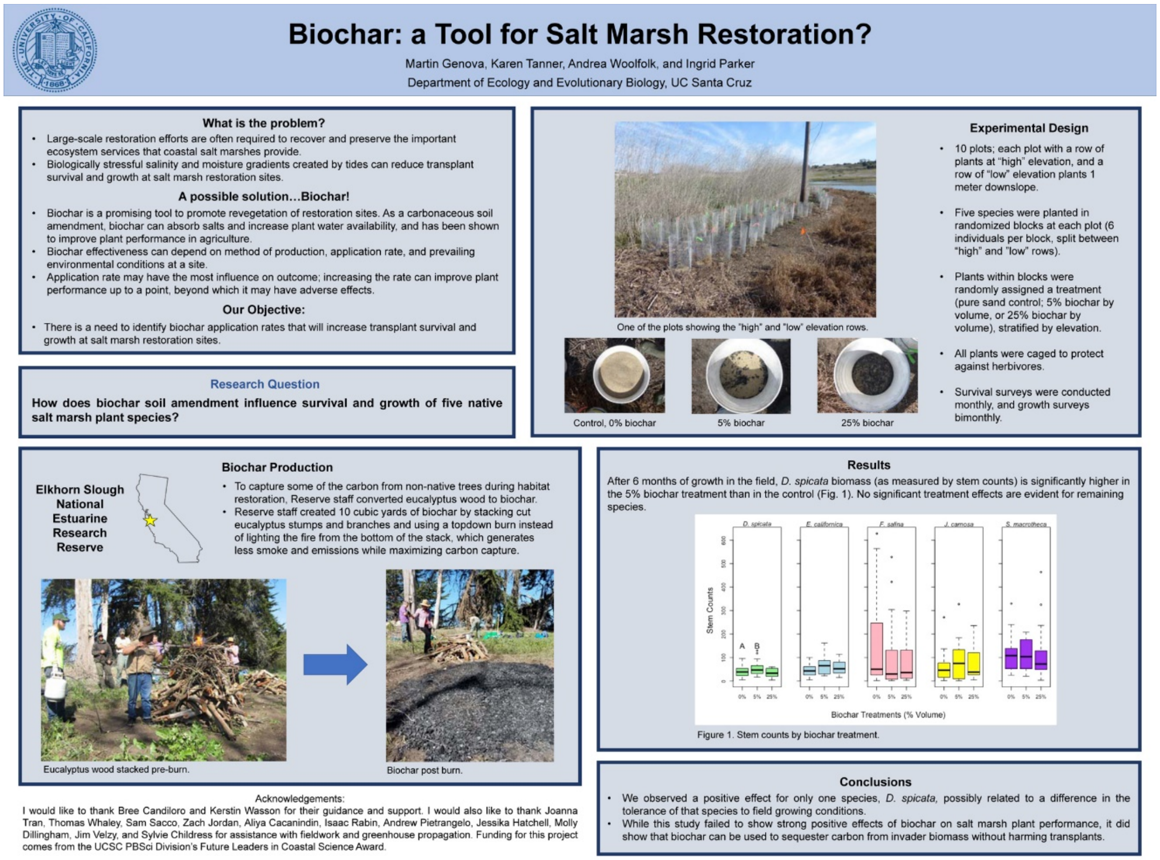
In 2017 the Sonoma Ecology Center received a grant from the California Department of Water Resources to measure biochar's ability to reduce water use at three farms, one in the Central Valley near King City, one on the central coast near Monterey, and one in the desert near Indio. In collaboration with the University of California Riverside, different blends of biochar and compost were integrated in replicated plots along with moisture sensors set at 18" and 30" depths, and dataloggers.

These field trials are now into their second year and a final report is due in August of 2019. The most interesting results we have had so far have been gleaned from the Monterey Vineyard plots, where significantly more vine and leaf growth has been occurring in the biochar plots, which causes LESS moisture to be measured at both the 18" and 30" depths than in the control plots. This is because more of the moisture is contained in the leaves and stems. Much more analysis will be done once all the data has been collected over the two-year trial period, including measuring microbial differences in the test plots, but the results thus far are promising.

In 2018 the Sonoma Ecology Center conducted a biochar and conservation burn training for staff at the Elkhorn Slough National Estuarine Research Reserve. Their property includes many stands of non-native Eucalyptus trees and their goal was to transform the Eucalyptus into biochar, then using the biochar in a number of different ways. Here is a breakdown of current research they are doing:

Some of our biochar research is done, some is in the field but not monitored yet, and some is still in the planning phases. Here's a recap of that from an email communication with Andrea Woolfolk, Stewardship Coordinator for the Elkhorn Slough:

- *Martin's experiment using our eucalyptus biochar in salt marsh ecotone plantings is done. He did not find a significant effect of biochar on planted ecotone species. He has presented this work at two symposiums (Cal IPC and Restore America's Estuaries). The most recent poster is shown below:*



- *Beth Watson's experiment using biochar in a salt marsh/greenhouse experiment (not eucalyptus biochar - purchased from Pacific Biochar). I don't have her charts in front of me, but the take home was that biochar did not affect marsh plant growth, but she's doing some more complex analyses about the fate of the carbon under tidal conditions, and she is asking me to mail her our eucalyptus biochar so she can track that, too. More to come. . .*

- *Biochar addition (not eucalyptus biochar - from Pacific Biochar) in our thin layer sediment addition experiment at 3 Reserves around the country. So far we haven't seen an effect of biochar on salt marsh plant recruitment, but we only have preliminary data so far.*

- *Large scale eucalyptus biochar addition in our newly restored Hester marsh plain are in progress - to sequester carbon and see if it helps with pickleweed recruitment. I think Beth will analyze the fate of carbon here, too, but we don't have data yet. And pickleweed won't start growing for several more weeks, so stay tuned for that. But an aerial with scale bars is attached so you can see the scope of that project. We have 3 blocks: each block has two different biochar plots (different amounts) and an added granite fines treatment.*

- *Next week we will plant thousands of high marsh/ecotone plants at Hester with eucalyptus biochar, to compare to thousands of others that were planted last week and this week without biochar. We'll do that again in a second marsh restoration area next year, too.*

Major funding for biochar research through the California Strategic Growth Council

The California Strategic Growth Council has awarded two significant grants for biochar-related research. Ken Alex, Director of the Governor's Office of Planning and Research and SGC Chair said, "The SGC research grants are designed to fill gaps in our knowledge about some of the most promising climate change solutions, and move them more quickly to fruition."

Biochar production and use was highlighted in the most recent IPCC climate change report as one of the least expensive and easily scaled methods of drawing down carbon from the atmosphere, and this recognition has helped bring the biochar story to the forefront of many climate change mitigation discussions and actions. There is, however, much research that still needs to be done to better characterize which types of biochar will persist the longest in varying agricultural soils, under what type of farming protocols, as well as creation of a standardized system for rating biochars based on a set of common criteria and characteristics. Gaining acceptance from the farming community for biochar production and use using surplus biomass will also be critical for scaling its use, and this will also be studied. These are some of the gaps in our knowledge about biochars that should be better understood and hopefully answered once this climate-change focused research and field trials are completed.

Congratulations to Benjamin Z. Houlton of the UC Davis Muir Institute and collaborators who will be working on a $4.7 million grant project entitled

"CALIFORNIA COLLABORATIVE ON CLIMATE CHANGE SOLUTIONS: WORKING LANDS INNOVATION CENTER—CATALYZING NEGATIVE CARBON EMISSIONS."

"The Working Lands Innovation Center's objective is to scale and sustain CO2 capture and GHG emissions reductions by deploying a suite of cutting-edge soil amendment technologies, driving substantial co-benefits for California growers, ranchers, Tribes, communities, the economy, and environment. This project will increase understanding of the mechanisms and potential for carbon sequestration in soil."

More information on this grant can be found here: http://sgc.ca.gov/programs/climate-research/docs/20181221-CCR_Summary_2019CCR20007.pdf

And congratulations to Gerardo Diaz of UC Merced and collaborators who will be working on the $3 million grant project entitled **"MOBILE BIOCHAR PRODUCTION FOR METHANE EMISSION REDUCTION AND SOIL AMENDMENT."**

"The overall goal of this proposal is to determine how biochar can be produced and used in a closed cycle agricultural application to reduce GHG emissions, ameliorate agricultural waste disposal problems, improve the quality of life in low-income and disadvantaged farming and

adjacent communities, and identify means to gain acceptance among farmers of small-scale biochar production and use as a sustainable best practice for California agriculture."
More information on this grant can be found here: http://sgc.ca.gov/programs/climate-research/docs/20181221-CCR_Summary_2019CCR20014.pdf

Returning carbon to forest environments
As previously shown there are positive applications and potential markets for biochar in food agriculture as well as for environmental restoration and industrial uses. However, there may also be major ecosystem benefits in returning these charred materials back into forestry soils as a form of carbon sequestration. Most terrestrial ecosystems have co-evolved with fire, with some even depending on it for reproduction. But given mankind's increasing population and our relatively recent policies of putting fires out to protect the human infrastructure that continues to creep further and further into the urban/wildland interface, the carbonaceous residues that would normally be present have become missing in many of our forest environments. This lack or carbon could be adversely affecting forest ecosystems, and this has become an interesting new area of research. Only a handful of studies have been done thus far on the efficacy and safety of using biochar as a carbon sequestration medium in forest soils, but given the increased interest in biochar by scientists from the Forest Service and ARS, along with CalFire's and private landowners' seeking to thin the forests of ladder fuels in the wake of ever more catastrophic wildfires, there will be ample opportunities and surplus biomass available to increase this research.
Here are a few studies related to biochar and forests::

Biochar Amendments to Forest Soils: Effects on Soil Properties and Tree Growth:
https://forest.moscowfsl.wsu.edu/smp/solo/documents/GTs/McElligott-Kristin_Thesis.pdf

Tree growth response to biochar amendment:
https://www.researchgate.net/publication/329976104_Soil_greenhouse_gas_carbon_content_and_tree_growth_response_to_biochar_amendment_in_western_United_States_forests

Biochar and Forests http://biochar-us.org/pdf%20files/4IPBiocharandForests_v5.pdf
Biochar as a replacement for Sphagnum Peat in tree nurseries:
https://www.researchgate.net/publication/324812008_Biochar_Can_Be_a_Suitable_Replacement_for_Sphagnum_Peat_in_Nursery_Production_of_Pinus_ponderosa_Seedlings

Additional research has been done by Mark Coleman at the University of Idaho, and Debbie Dumroese with the USFS in Moscow, ID. Debbie's email address is: ddumroese@fs.fed.us. Mark's email is: mcoleman@uidaho.edu.

Opportunities and Uses of Biochar on Forest Sites in North America
https://www.fs.fed.us/rm/pubs_journals/2017/rmrs_2017_page_dumroese_d002.pdf

Short-term growth and soil biological responses to post-thinning biomass removal and complementary soil amendments
https://www.uidaho.edu/-/media/UIdaho-Responsive/Files/cnr/ifc/2018-annual-meeting/5_coleman_presentation.pdf?la=en&hash=3C97020501507F38BEE550B198AA9DE2CE612C24

Other biochar-related studies at the University of Idaho
https://www.uidaho.edu/search?q=biochar&cof=FORID:9&cref=http://www.uidaho.edu/search?xml=1&ticks=635409346879695626