Slide 1

Thanks to the organizers for the invitation to contribute to the 2020 Ag Sustainability Expo. This is my second presentation at the Ag Expo, the first in 2014 was on soil management in vineyards. So this presentation is a good follow up to that one. Today I will present 2 seasons of data from a trial designed to evaluate the impact of biochar and compost as soil amendments on wine grape growth, water use, yields, and fruit quality. What? Bury charcoal in the vineyard?

Slide 2

I came to the California vineyard scene in the late 90s, after spending 15 years working as a soil scientist in various cropping systems in Asia, Africa, and S. America. The overriding theme of those years was that successful cropping systems had a critical level of soil organic matter, and building soil OM led to healthier more productive crops. This picture is of Hans Jeny, really the first soil ecologist, who long ago came to the same conclusions. I guess this is where he wanted to be… up to his neck in OM!

Slide 3

Comparison of Soil Characteristics Following 3 Seasons of No-Till Cover Crop vs. Clean Cultivation. Monterey Co.

Treatment	Percent OM	Soil pH	Soil Ca ppm	Soil Ca %	CEC	EC mmhos/cm
No-Till Cover Crop	1.3	7.2	1,713	73	12	0.43
Clean-Cult No Cover Crop	1.1	6.3	1,234	67	9	0.62

When I began looking at vineyard soils in Monterey Co, I was really surprised by the low levels of OM in the vineyards where I was working. Soil OM levels below 1% were common, and levels as low as 0.5% were not unusual. To bring vineyards into health and productivity, I thought that 1.2% would be a minimum, and 1.5% would ensure best profitability in the vineyard. So my first task was to figure out how to improve organic matter levels in existing vineyards. Cover crops that were being disked in and replanted annually were modified to no-till permanent cover to build OM in middles. The soil % OM rapidly increased, soil pH came into balance, calcium availability and CEC went up, salts went down.

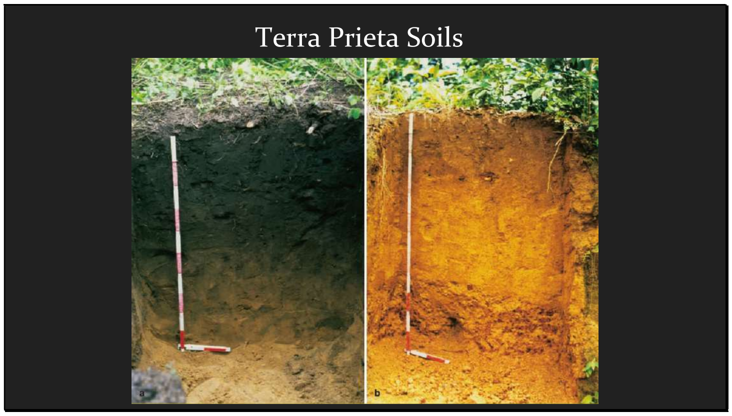
Slide 4

That took care of the middles, but how to get higher OM near vine roots where they would positively impact vine growth? Compost was applied at 3 tons per acre every other row on a yearly basis, sidedressed along the vinerow and disked in 12-14" deep. Three tons per acre applied to about ¼ of the vineyard surface area comes out to about 12 t/a in the area of application. This is enough to positively impact vine growth and productivity, especially when added over many seasons.

Slide 5

The best time to impact vineyard soils with organic matter additions is at planting. The first pass of a gps-controlled deep winged ripper shatters compacted soil to over 3 ft deep and leaves a groove or delve where compost is applied down the ripped row. The final ripping pass to maximum depth of 3.5-4 ft is then made to mix the amendment with the soil at depth. Here you see the area where compost has been mixed, and the total shattered area of soil. Shovel is a little over 4 ft long.

Slide 6

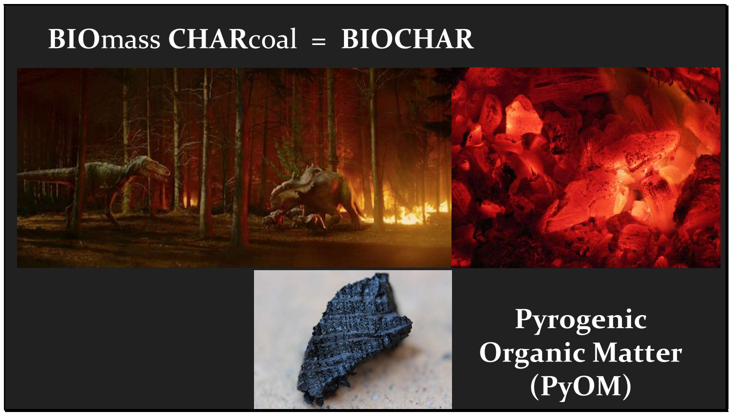


I became interested in biochar in the early 90s, when I had the opportunity to see these dark soils used in agricultural production in S. America. This soil rich in organic matter is attributed to the prehistoric civilizations that once thrived in the Amazon. It may be that Terra Prieta soils are what in part sustained ag productivity in harmony with their ecosystems. We have yet to figure out exactly how ancient civilizations made these dark soils mixtures, but what we do know is that the soils contain high amounts of char-wood (also referred to as biochar). Char-wood is basically a form of charcoal produced by burning wood or agricultural residues in an environment very low in oxygen.

Slide 7

Not too incredible to consider their ability to construct tierra prieta, when you look at prehistoric constructions in the region, granite boulders weighing 10-100s of tons were somehow carved with incredible precision with multiple angles, not even a sheet of paper fits between them.   It actually looks like they were melted into place. Hard granite supposedly carved with copper balls and chisels…

Slide 8



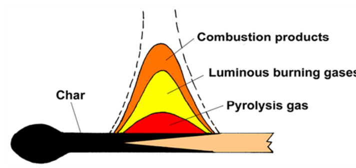
I am no expert on biochar, but there are certain to be questions so I will take a couple of minutes to describe what is biochar. Basically, it is biomass charcoal. And it was not necessarily formed by dinosaurs when they were fighting wildfires….

Slide 9

How is Biochar Made?

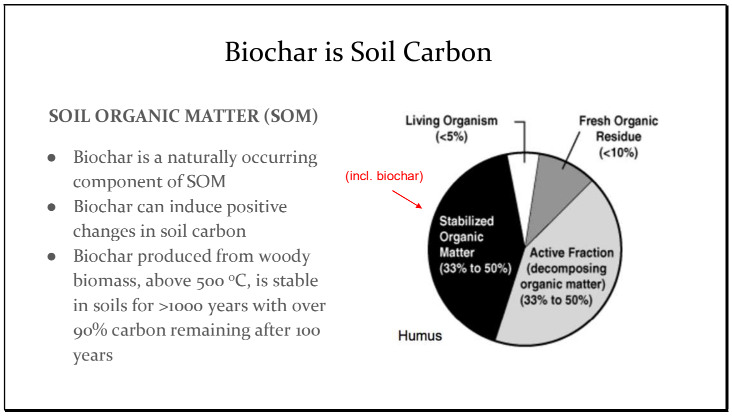
PYROLYSIS & CARBONIZATION

- During pyrolysis biomass is heated in a low-oxygen environment (>500°C)
- Carbon rich gases released can be burned for energy or condensed for bio-oil and wood vinegar
- Remaining carbon is transformed into char - carbonization
- Different feedstocks will produce biochars with varying properties (i.e. wood, nut shells, straw, manure, etc.)



Read points

Slide 10



Biochar occurs naturally in soils in small amounts, and is a (normally small) part of the stabilized OM that makes up around half of soil humus. Biochar produced from woody biomass is stable for a thousand years or more… so you have to think long term when using it as an amendment! It also appears that biochar is formative for making more stable OM.

Slide 11

(August 2019) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.

Chapter 4, Land Degradation

4.9.5.2 Role of biochar in management of land degradation

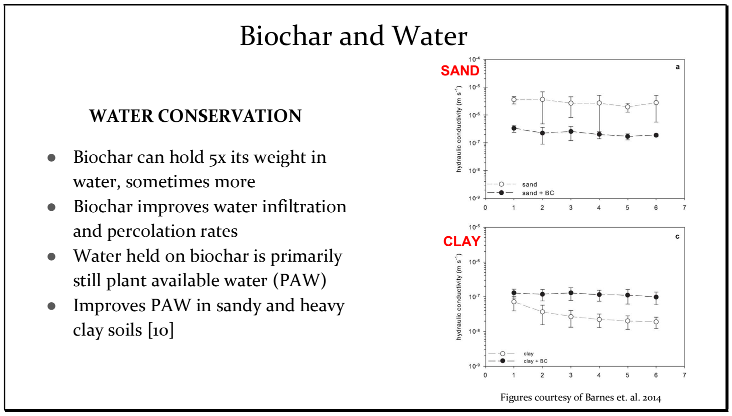
Biochars generally have high porosity, high surface area and surface-active properties that lead to high absorptive and adsorptive capacity, especially after interaction in soil (Joseph et al. 2010). As a result of these properties, biochar could contribute to avoiding, reducing and reversing land degradation through the following documented benefits:

- **Improved nutrient use efficiency** due to reduced leaching of nitrate and ammonium (e.g., Haider et al. 2017) and increased availability of phosphorus in soils with high phosphorus fixation capacity (Liu et al. 2018c), potentially reducing nitrogen and phosphorus fertiliser requirements.
- **Management of heavy metals and organic pollutants**: through reduced bioavailability of toxic elements (O'Connor et al. 2018; Peng et al. 2018), by reducing availability, through immobilisation due to increased pH and redox effects (Rizwan et al. 2016) and adsorption on biochar surfaces (Zhang et al. 2013) thus providing a means of remediating contaminated soils, and enabling their utilisation for food production.
- **Stimulation of beneficial soil organisms**, including earthworms and mycorrhizal fungi (Thies et al. 2015).
- **Improved porosity and water-holding capacity** (Quin et al. 2014), particularly in sandy soils (Omondi et al. 2016), enhancing microbial function during drought (Paetsch et al. 2018).

ipcc

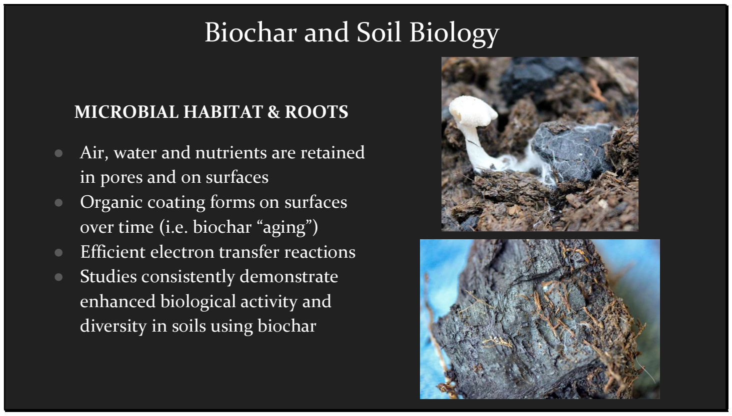
The IPCC has defined biochar as delivering improved nutrient efficiency, management of heavy metals like Cd or lead and organic pollutants like pesticides, stimulation of beneficial soil organisms, and improved porosity and water holding capacity

Slide 12



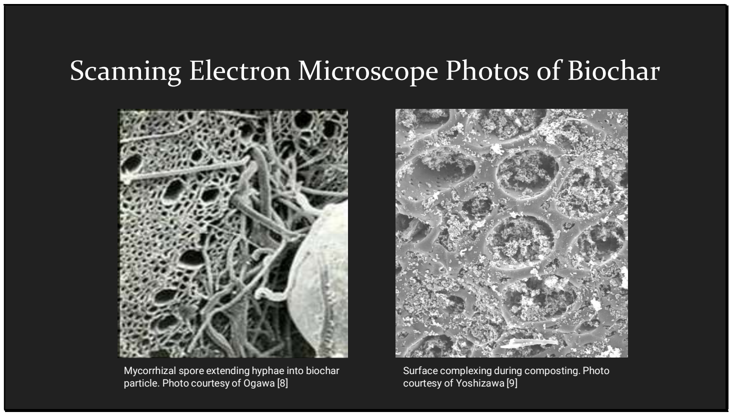
Biochar has positive effects for water use efficiency in both sandy soils and heavy soils. In clays, it improves water infiltration, percoloation, and availability to plants by improving soil structure and increasing hydraulic conductivity. In sand it provides additional water holding capacity and prevents leaching of nutrients by reducing water loss from the soil system.

Slide 13



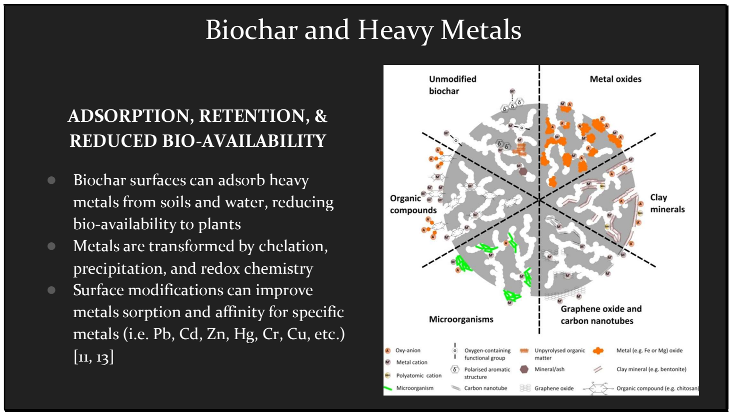
Biochar makes an ideal habitat for soil microbes, fungi, and arthropods. Studies consistently demonstrate enhanced biological activity and diversity in soils using biochar. Air, water, and nutrients are retained in the pores and on surfaces, providing perfect habitat support for all kinds of beneficial organisms. An organic coating forms on biochar over time, enhancing its positive properties.

Slide 14



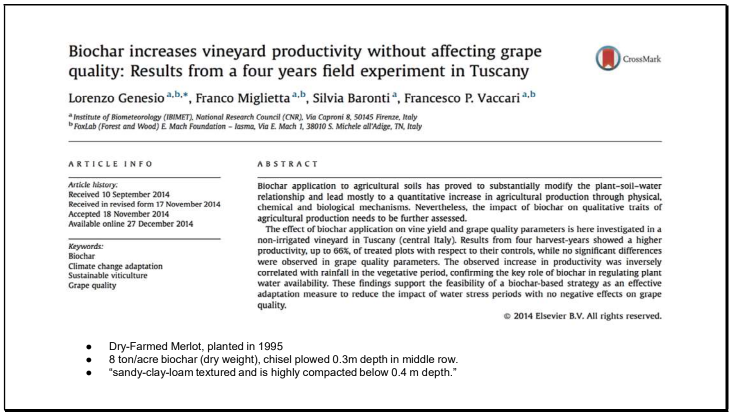
The key to its characteristics is the porous charged structure that increases surface area and provides pockets for water, microorganisms and nutrients. Here on the right you can see the surface complexes formed during the composting process – biochar and compost together.

Slide 15



Because of their charge, biochar surfaces can adsorb heavy metals like lead and cadmium so that plants don’t take it up. Metals are transformed by chelation, precipitation, and redox chemistry. It could be of great benefit in contaminated soils, enabling ag when it would be otherwise not be productive or economical.

Slide 16



Biochar increases vineyard productivity without affecting grape quality: Results from a four years field experiment in Tuscany

Lorenzo Genesio [a,b,*], Franco Miglietta [a,b], Silvia Baronti [a], Francesco P. Vaccari [a,b]

[a] Institute of Biometeorology (IBIMET), National Research Council (CNR), Via Caproni 8, 50145 Firenze, Italy
[b] FoxLab (Forest and Wood) E. Mach Foundation – Iasma, Via E. Mach 1, 38010 S. Michele all'Adige, TN, Italy

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ABSTRACT

Biochar application to agricultural soils has proved to substantially modify the plant–soil–water relationship and lead mostly to a quantitative increase in agricultural production through physical, chemical and biological mechanisms. Nevertheless, the impact of biochar on qualitative traits of agricultural production needs to be further assessed.

The effect of biochar application on vine yield and grape quality parameters is here investigated in a non-irrigated vineyard in Tuscany (central Italy). Results from four harvest-years showed a higher productivity, up to 66%, of treated plots with respect to their controls, while no significant differences were observed in grape quality parameters. The observed increase in productivity was inversely correlated with rainfall in the vegetative period, confirming the key role of biochar in regulating plant water availability. These findings support the feasibility of a biochar-based strategy as an effective adaptation measure to reduce the impact of water stress periods with no negative effects on grape quality.

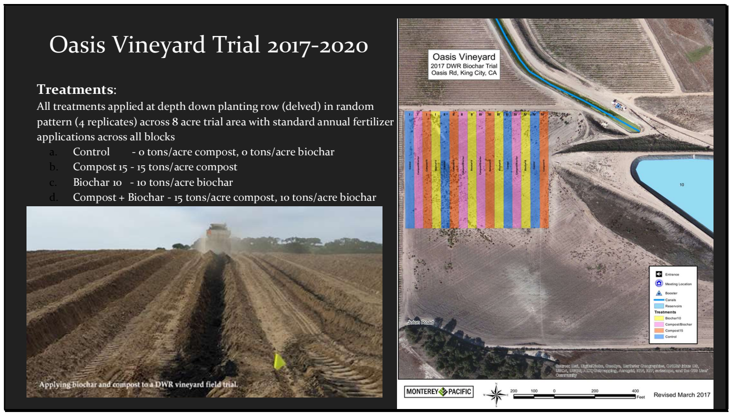
- Dry-Farmed Merlot, planted in 1995
- 8 ton/acre biochar (dry weight), chisel plowed 0.3m depth in middle row.
- “sandy-clay-loam textured and is highly compacted below 0.4 m depth.”

So the big question for us was how do applications of biochar to the soil impact wine grape productivity and quality? In theory it should provide considerable benefits, and Indications have been positive… But you sure wouldn’t want to put biochar in the ground under your vines, lasting the life of the vineyard, if yields or grape quality were decreased

Slide 17

As part of the California Department of Water Resources' efforts to increase agricultural water use efficiency throughout California, DWR funded research by Sonoma Ecology Center and its subcontractor University of California – Riverside on the effects on crop water usage of adding biochar and compost to soils. We at MPI decided to host a trial at our Oasis Vineyard in S Monterey county. The old San Bernabe vineyard south of King City

Slide 18

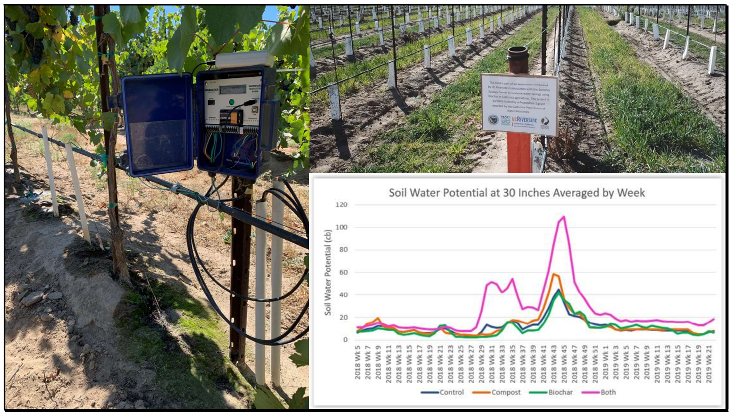


Soil type is mostly Oceano Sand with organic matter content of 0.7%. Trial amendment treatments include: control (no compost, no biochar), compost (15 tons compost/ac, no biochar), biochar (no compost, 10 tons biochar/ac), and biochar and compost (15 tons compost + 10 tons biochar), each replicated four times. The picture of amendment being applied shows how much material we were incorporating! This is the biochar-compost mix being applied in the trial, following the first ripping pass that left the delve.

The ground was prepped late 2016 and the block planted in March 2017.

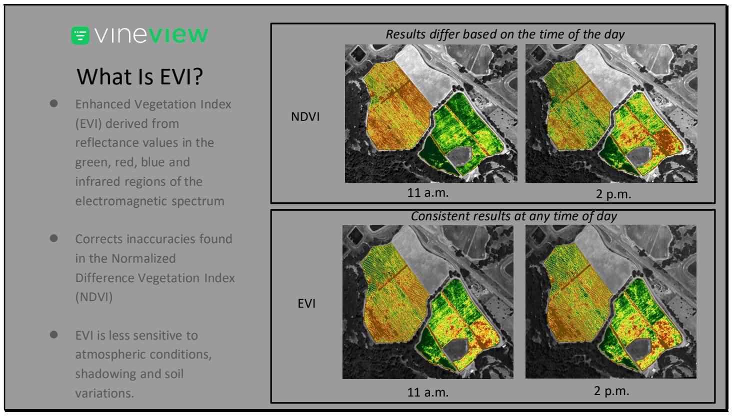
With the second pass of the ripper the amendments were mixed with the soil in the vine row to about 2.5 ft deep. We figured the concentration of biochar at 10 tons per acre, given the volume of soil with which it was mixed, worked out to about 1% biochar by weight. The calculated increase in soil OM from the biochar addition was 0.4%, taking the soil from 0.7 to 1.1 % under the vines.

Slide 19



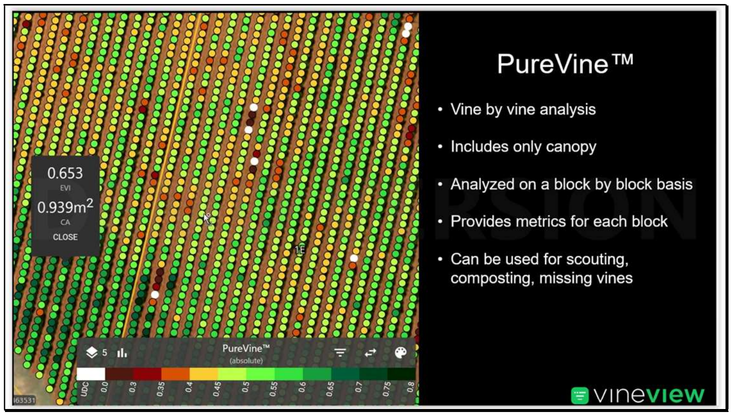
Vines are Pinot noir clone 456 on 1103P, planted at 9x5 spacing and using the high wire box pruned style of trellis. We installed Watermark soil moisture sensors in each of the 16 subblocks at 18" and 30" deep, with data recorded on 4 Watermark dataloggers. Seemed like we buried miles of cables 3 ft deep during the install!

Slide 20



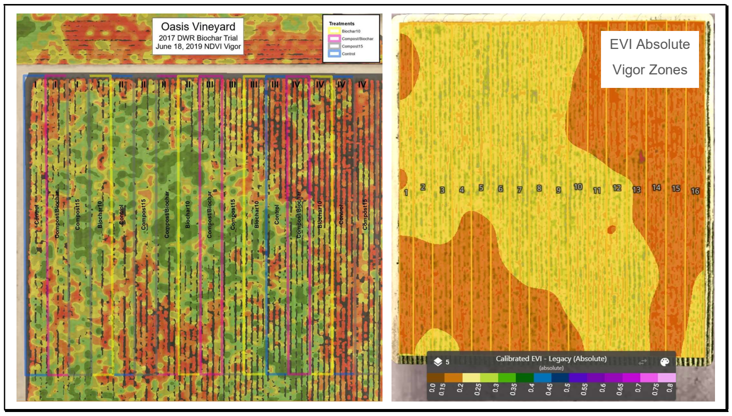
We tried a new way to evaluate the treatments, using aerial imagery provided by VineView VineView's PureVine Enhanced Vegetation Index (EVI) is an index developed to correct inaccuracies found in the Normalized Difference Vegetation Index (NDVI). EVI is less sensitive to atmospheric conditions, shadowing and soil variations. And because it is calibrated, you can compare blocks, seasons, treatments… like in a trial.

Slide 21



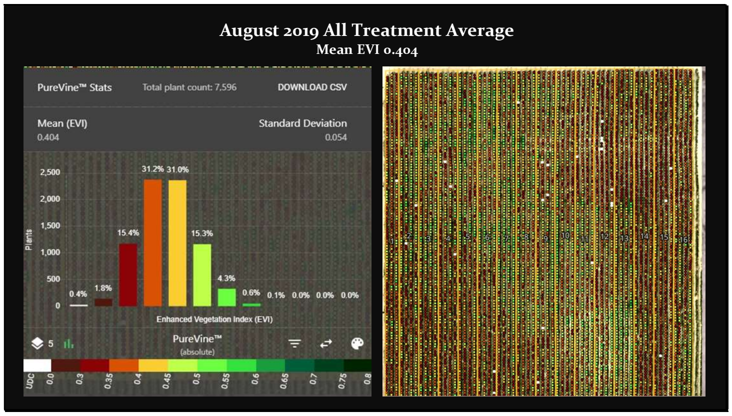
Basically you get a vine by vine analysis, EVI and canopy area for each vine. See arrow. The scale goes from dark red weak to dark green high vigor, each vine has its vigor represented by the colored circle. Missing vines and replants stand out, as do very vigorous vines. You also get metrics for each block, I'll show in a minute.

Slide 22



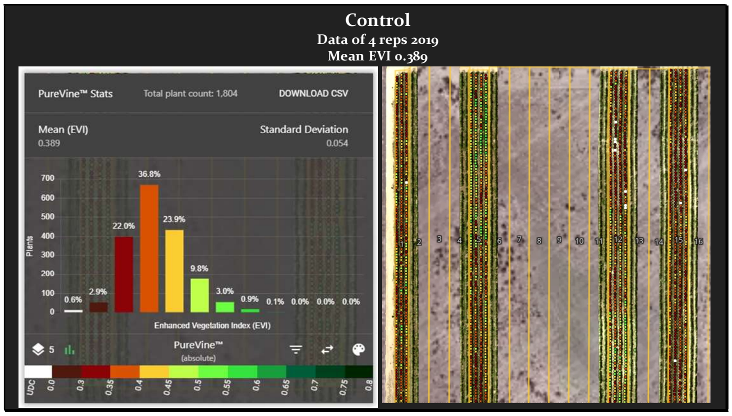
The variability in the trial area was fairly high. On the right you see the vigor zones in the trial area, on the left is individual vine vigor at low res

Slide 23



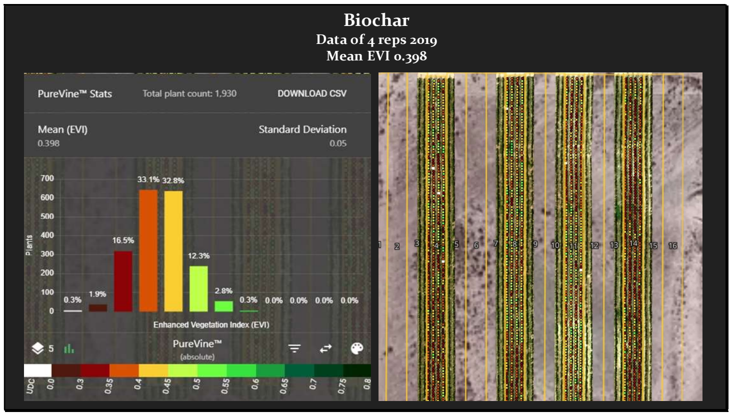
Imagery was taken in August 2019, nearing the first harvest in this block. Describe graph and components. These are the statistics and distribution of vigor for the whole trial. Nice bell curve…

Slide 24



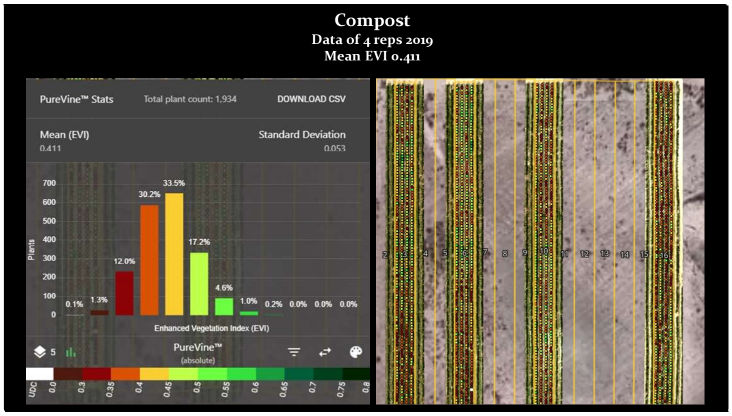
Here you see the distribution shift toward lower vigor in the Control… Subblocks that are included are shown on the right

Slide 25



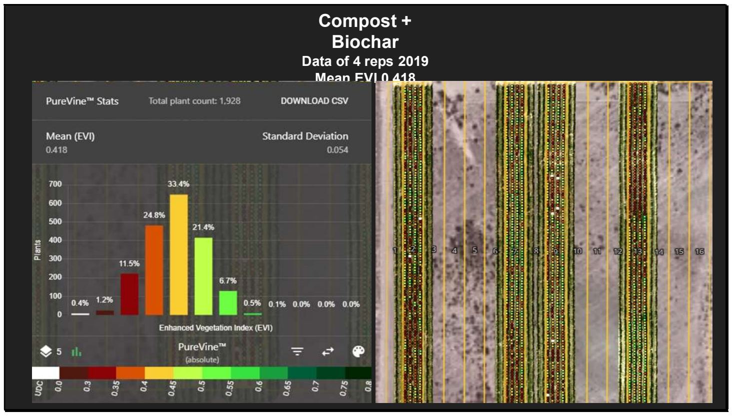
With the biochar treatment, you can see the distribution shift slightly toward higher vigor…

Slide 26



With the Compost treatment, vigor shifts further to the right, with over 20% now in the green (above 0.45)

Slide 27



The compost biochar mix had the highest overall vigor with nearly 30% in the green (>.45)

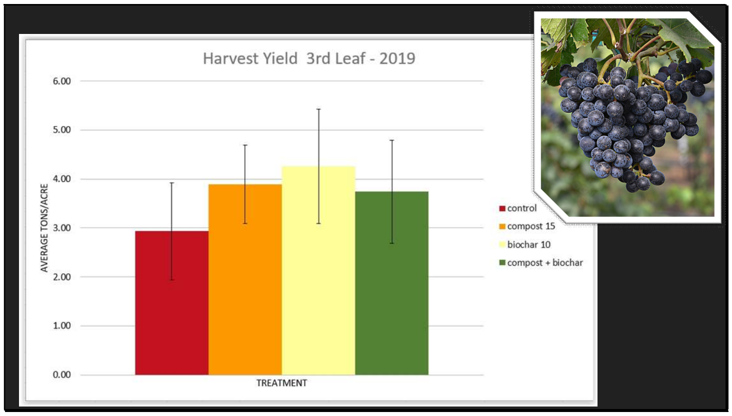
Slide 28

It was gratifying to see that Pruning weights for the 3^{rd} leaf crop followed the imagery trends, though there was too much variation in PW to determine the differences as significant. Our thinking is that compost is a ready source of N P K , releasing about 10% of its N the first and second seasons, and produced more growth the blocks receiving compost.

Slide 29

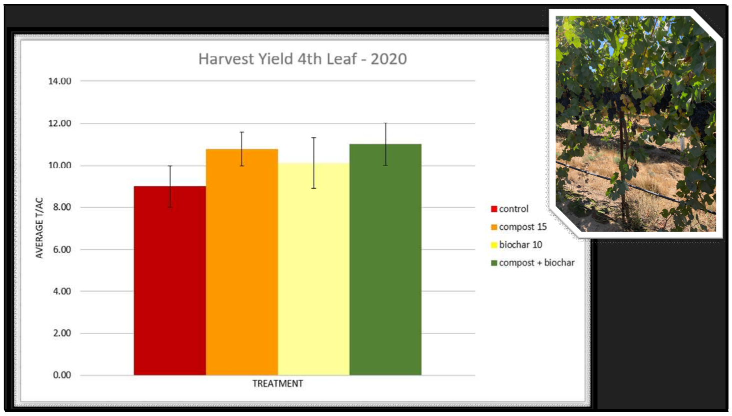
Here is a VineView comparison of the two seasons side by side. You can see the range of variability has decreased from 3rd leaf to 4th, as you would expect. Notice that the scales on the vigor bar graphs are different for 2019 and 2020. Less vines on the low and high sides in 2020, and more in the middle where they should be.

Slide 30



So for 3rd leaf in 2019, the biochar only treatment gave significantly better yields than the control with 1.3 tons/ac increase. It also had the highest yield of all treatments.

Slide 31



Fourth leaf harvest from a couple weeks ago gave even more encouraging yield results, with all amendment treatments significantly beating the control. The biochar only treatment increased fruit yield as it did in 2019 by a little over a ton/ac, while compost only increased yields by 1.8 tons per acre. And the compost + biochar treatment increased yields significantly by 2 tons/ac. *Maximum carbon equals maximum growth?*

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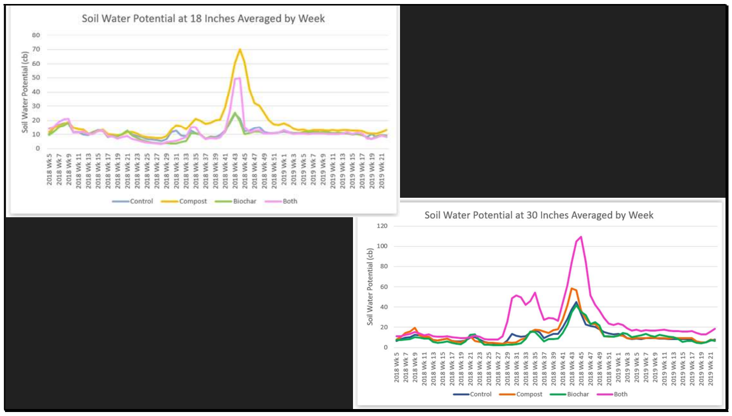
Harvest 2019 3rd Leaf	Yield	Cluster #	Cluster lb
R1	2.78	26.40	0.31
R2 Control	3.73	28.70	0.27
R3	2.82	23.10	0.25
R4	3.92	26.30	0.31
Control Average	**3.31**	**26.13**	**0.29**
R1	4.04	30.60	0.27
R2 Compost	3.30	27.10	0.25
R3	4.20	33.20	0.26
R4	4.02	27.60	0.30
Compost Average	**3.89**	**29.63**	**0.27**
R1	3.94	28.50	0.29
R2 Biochar	4.90	39.60	0.26
R3	3.63	27.30	0.28
R4	4.55	33.30	0.28
Biochar Average	**4.26**	**32.18**	**0.28**
R1	3.78	26.80	0.29
R2 Compost + Biochar	3.58	24.40	0.30
R3	3.83	36.90	0.21
R4	4.08	31.50	0.27
Compost-Bio Average	**3.82**	**29.90**	**0.27**

Harvest 2020 4th Leaf	Yield	Cluster #	Cluster lb
R1	9.22	54.60	0.31
R2 Control	10.12	53.95	0.34
R3	8.66	46.60	0.34
R4	8.00	41.85	0.35
Control Average	**9.00**	**49.25**	**0.34**
R1	10.37	55.25	0.34
R2 Compost	10.72	54.30	0.36
R3	11.39	62.60	0.33
R4	10.68	54.45	0.36
Compost Average	**10.79**	**56.65**	**0.35**
R1	10.71	57.00	0.34
R2 Biochar	10.79	57.40	0.35
R3	10.72	58.50	0.34
R4	8.27	45.55	0.33
Biochar Average	**10.12**	**54.61**	**0.34**
R1	11.21	58.80	0.35
R2 Compost + Biochar	10.23	55.15	0.34
R3	13.09	65.10	0.37
R4	9.57	49.85	0.35
Compost-Bio Average	**11.02**	**57.23**	**0.35**

Getting into the details of the harvest… There were no differences in cluster size/weight either harvest, but cluster numbers did differ and accounted for the yield differences. The biochar treatment had the highest number of clusters in 2019, and the compost-biochar mix had the most clusters in 2020. More clusters look to be the result of larger more vigorous vines, especially in the 2020 harvest.

Slide 33



DWR was looking for decreased water use, and what we saw was greater water use efficiency in some treatments. By that I mean that for the same amount of applied water, more fruit was produced. All blocks received the same irrigation regime based on ET measurement. Blocks that dried soil down more were also those that produced larger vines and more crop. Bigger vines with more grapes and more leaves with greater transpiration and water taken from the soil. This watermark technology measures the tension with which water is held in the soil, so higher numbers mean drier soil.

The compost and compost+biochar treatments both dried the soil more than biochar treatment, which was about equal to the control.

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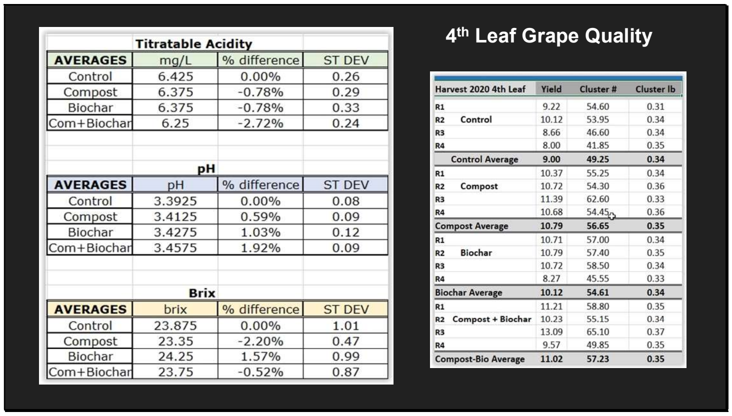


4th Leaf Grape Quality

Titratable Acidity

AVERAGES	mg/L	% difference	ST DEV
Control	6.425	0.00%	0.26
Compost	6.375	-0.78%	0.29
Biochar	6.375	-0.78%	0.33
Com+Biochar	6.25	-2.72%	0.24

pH

AVERAGES	pH	% difference	ST DEV
Control	3.3925	0.00%	0.08
Compost	3.4125	0.59%	0.09
Biochar	3.4275	1.03%	0.12
Com+Biochar	3.4575	1.92%	0.09

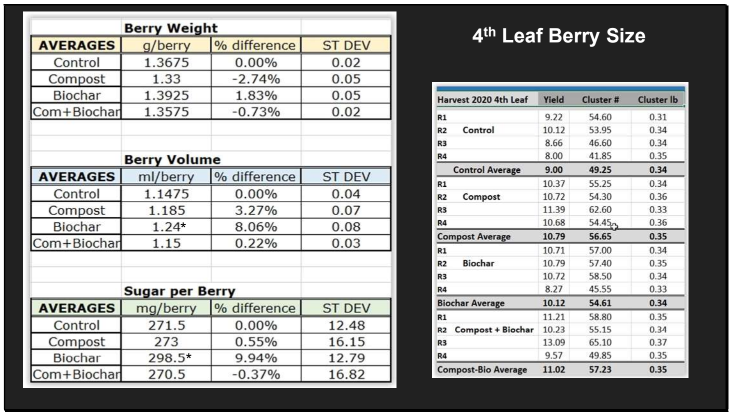
Brix

AVERAGES	brix	% difference	ST DEV
Control	23.875	0.00%	1.01
Compost	23.35	-2.20%	0.47
Biochar	24.25	1.57%	0.99
Com+Biochar	23.75	-0.52%	0.87

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		**9.00**	**49.25**	**0.34**
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		**10.79**	**56.65**	**0.35**
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		**10.12**	**54.61**	**0.34**
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		**11.02**	**57.23**	**0.35**

Finally, we wanted to be sure we had no negative impacts from biochar on fruit quality. So we analyzed 300-berry samples from each of the 16 subblocks so we could determine statistical differences. Samples were tested at commercial lab ETS for the full phenolic panel plus brix and acidity. In the following tables, think its best to look at the % difference column to follow along. Brix in the biochar only blocks was a bit above control, not by much Safe to say that there was little effect of biochar on brix and pH.

Slide 35



4th Leaf Berry Size

	Berry Weight		
AVERAGES	g/berry	% difference	ST DEV
Control	1.3675	0.00%	0.02
Compost	1.33	-2.74%	0.05
Biochar	1.3925	1.83%	0.05
Com+Biochar	1.3575	-0.73%	0.02

	Berry Volume		
AVERAGES	ml/berry	% difference	ST DEV
Control	1.1475	0.00%	0.04
Compost	1.185	3.27%	0.07
Biochar	1.24*	8.06%	0.08
Com+Biochar	1.15	0.22%	0.03

	Sugar per Berry		
AVERAGES	mg/berry	% difference	ST DEV
Control	271.5	0.00%	12.48
Compost	273	0.55%	16.15
Biochar	298.5*	9.94%	12.79
Com+Biochar	270.5	-0.37%	16.82

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
R1		9.22	54.60	0.31
R2	Control	10.12	53.95	0.34
R3		8.66	46.60	0.34
R4		8.00	41.85	0.35
Control Average		9.00	49.25	0.34
R1		10.37	55.25	0.34
R2	Compost	10.72	54.30	0.36
R3		11.39	62.60	0.33
R4		10.68	54.45	0.36
Compost Average		10.79	56.65	0.35
R1		10.71	57.00	0.34
R2	Biochar	10.79	57.40	0.35
R3		10.72	58.50	0.34
R4		8.27	45.55	0.33
Biochar Average		10.12	54.61	0.34
R1		11.21	58.80	0.35
R2	Compost + Biochar	10.23	55.15	0.34
R3		13.09	65.10	0.37
R4		9.57	49.85	0.35
Compost-Bio Average		11.02	57.23	0.35

In 2020, cluster weights were similar in all treatments with little variation, but berry weights, berry volume, and sugar per berry were all highest in the biochar treatment, significantly for berry volume and sugar per berry. Larger berries, can sometimes means less color…

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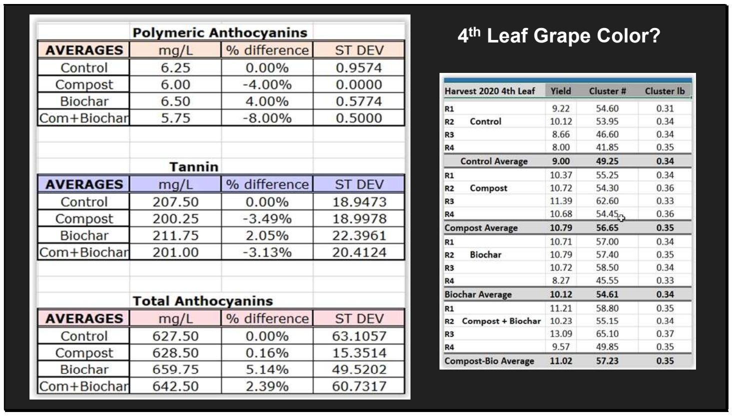

Polymeric Anthocyanins

AVERAGES	mg/L	% difference	ST DEV
Control	6.25	0.00%	0.9574
Compost	6.00	-4.00%	0.0000
Biochar	6.50	4.00%	0.5774
Com+Biochar	5.75	-8.00%	0.5000

Tannin

AVERAGES	mg/L	% difference	ST DEV
Control	207.50	0.00%	18.9473
Compost	200.25	-3.49%	18.9978
Biochar	211.75	2.05%	22.3961
Com+Biochar	201.00	-3.13%	20.4124

Total Anthocyanins

AVERAGES	mg/L	% difference	ST DEV
Control	627.50	0.00%	63.1057
Compost	628.50	0.16%	15.3514
Biochar	659.75	5.14%	49.5202
Com+Biochar	642.50	2.39%	60.7317

Harvest 2020 4th Leaf		Yield	Cluster #	Cluster lb
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But the biochar treatment stands out as having the highest in terms of color… both anthocyanins and tannin, tho differences are not statistically significant.

Many more quality components were measured, but showed only small differences between treatments. All treatments neared 24 brix at the same time. From these results we confirm that biochar did not negatively affect grape quality or time to harvest. There were, in fact, some hints that grape quality may have been improved.

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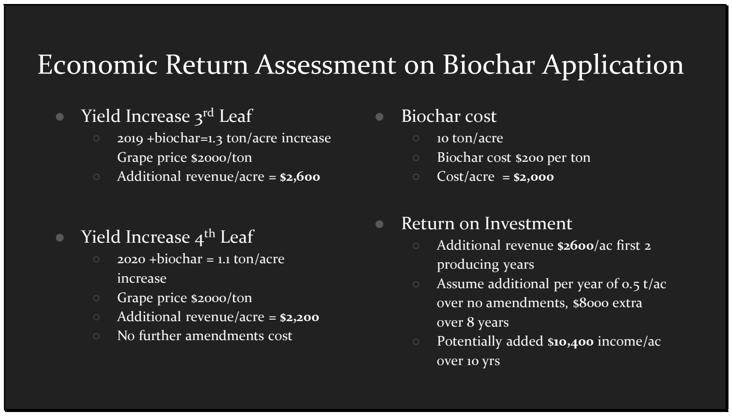

To summarize economic return on investment in biochar only application… the total biochar cost was $2000 per acre,. The yield increase third leaf was 1.3 t/a, and at a price of $2000/ton represents additional revenue of $2600. $600 profit above biochar cost. At harvest this season in fourth leaf the biochar tmt again yielded over a ton more per acre than control, giving additional income of about $2600/acre for the first 2 years of production. If you assume only 0.5 tons/ac increase per season from a single biochar application over future years, the extra income is quite attractive.

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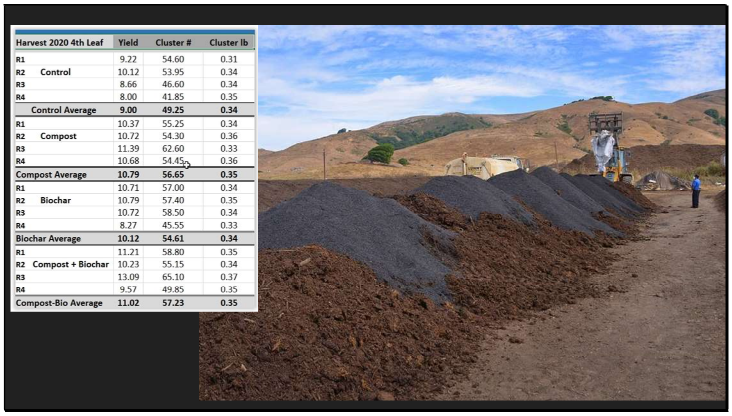

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The most promising treatment in these low OM soils is the compost-biochar mix … apparently a potent mix for vine growth and yields. Provides compost for shorter term OM boost, biochar for long term OM maintenance and carbon sequestration. It has become clear in recent literature that composting the biochar together with the compost substrates gives a mix that is much like a super charged compost. In our case, mixed biochar and compost matured together in a windrow like this one for over 2 months before applying in the winter.

The economics are even more attractive with the compost-biochar mix, with an average yield increase of 2 tons per acre over the control in 2020. That's $4000/ac additional income this year, 4 hundred thousand dollars per year additional on 100 acres!!

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In the process of composting biochar and compost substrates together, …..

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In our case, biochar was produced from woody forest waste at a commercial plant in the Sierra foothills and provided by Pacific Biochar in bulk delivered to the compost yard.

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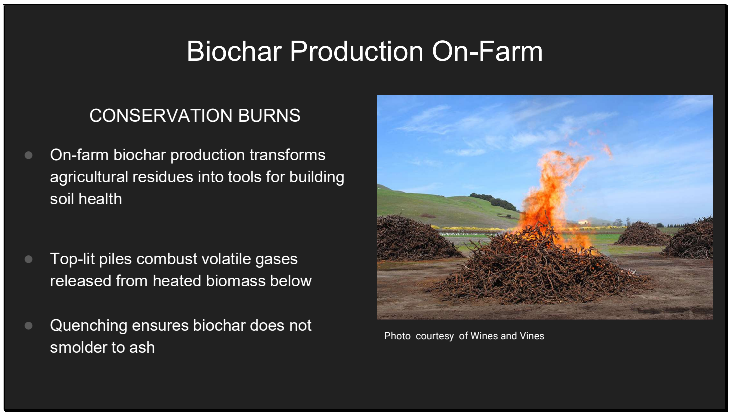


But it is possible to produce biochar from, for example pulled vines, right in your own fields. Most important is to light the piles to burn from the top down, so heated gas goes up without taking the wood all the way to ash

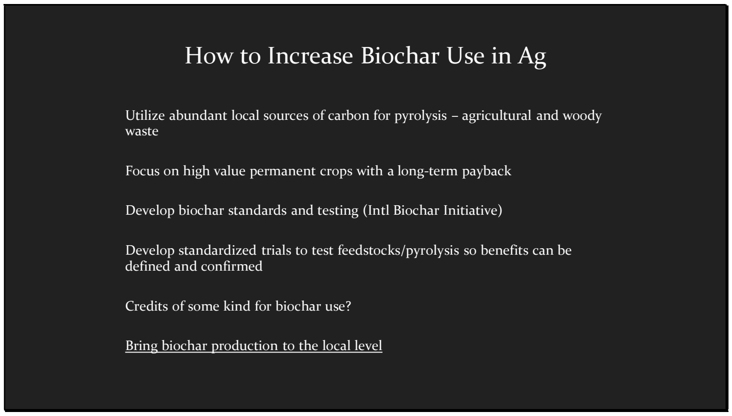
Slide 42

This was a demo burn conducted by Raymond Baltar of the Sonoma Ecology Center in cooperation with Kendall Jackson family wines on one of their Monterey properties. This pile is burning toward the lower center, not far from having to quench with water.

Slide 43

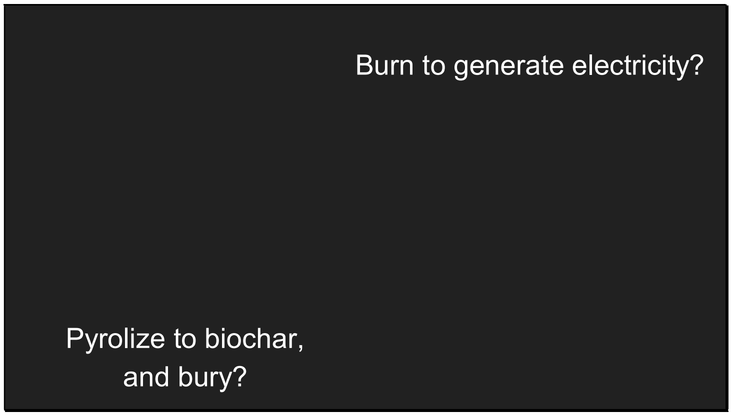
So you'll need a water truck to quench the fire when you get to the charcoal stage… if you let it continue to burn, you end up with ash only. You will also might need a big magnet to remove all the metal mixed with the vine trunks!

Slide 44



I've definitely been converted into a biochar proponent. How to increase its use in Ag? READ POINTS Carbon credits for burying biochar in agricultural fields would be a huge plus. I know discussions are on the table to do this in California, and can imagine that having some of the costs of biochar application offset by payments for sequestration could really accelerate the adoption process.
Maybe portable biochar makers, of which there are many models available. Where you bring it in on a flatbed and run your woody wastes through? Ground biochar goes to your compost pile or directly to the field.

Slide 45



We first had this idea when we saw Salinas Valley eucalyptus windbreaks, planted last century by WPA, being removed one by one. When we heard CalTrans was going to remove a windbreak alongside one of our vineyards along Hwy 101, to be trucked to the Central Valley and burned for electricity, we thought why not turn those trees into biochar, and incorporate that biochar in our adjacent vineyard? We weren’t able to use those trees, decisions had already been made by CalTrans. But in the process of considering this, we saw a clear need to understand the impact of biochar as a soil amendment on vine growth and grape quality. Before we began loading it into the vineyard soil. Storing all that carbon in the ground sure seemed like a positive, especially if we saw benefits to the vines.

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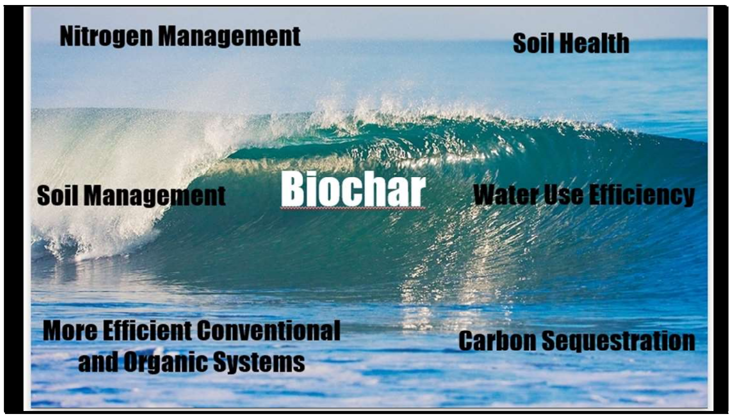

- We see the potential for biochar use in agriculture, with all its benefits with respect to soil health and productivity, GHG savings, and carbon sequestration as a high-potential high-payoff technology "in the curl". Brought to the local level and utilized as a soil amendment especially in poorer soils, it potentially has the power to transform agriculture. Theres a lot of info out there about biochar use. If you are interested, I urge you to look into it.

- Thanks to Elias Chairez, manager of the Oasis Vineyard and willing cooperator. Also to Pete Opatz, his vision enabled this work to go forward. And to all the folks who helped along the way: Jeff, Sara, Alan, Josiah, Raymond, Elizabeth, and Milt McGiffen at UCR. And of course to Kris and the Vineyard team for providing a forum to present this info.