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WHITEPAPER

Biochar Analysis

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Biochar Analysis

OVERVIEW

Biochar is charcoal generated from biomass by pyrolysis in the absence of oxygen, but it also a naturally occurring phenomenon in some areas of the world, particularly in the Amazon basin where it was termed "Amazon Dark Earth" or "Terra Pretas". It is a stable solid that is generally rich in Carbon. Some claim that biochar can increase soil fertility of acidic soil, increase agricultural productivity, and provide some protection against foliar and soil-borne diseases. (Source: Wikipedia)

PRODUCTION

Biochar is one of the residues of the biomass pyrolysis process (along with bio-oil and syngas). Biochar is produced mostly at lower temperatures of pyrolysis (400-500 degrees C) in slower processes and typically yields about 20% of the total process output (up to 50% in ideal conditions).

"Application rates of 2.5–20 tons per hectare (1.0–8.1 t/acre) appear to be required to produce significant improvements in plant yields. Biochar costs in developed countries vary from $300–7000/ton, generally too high for the farmer/horticulturalist and prohibitive for low-input field crops."

POTENTIAL BENEFITS (CLAIMED)

Carbon Sequestration and Environmental Benefit: Biochar is very stable, and can effectively sequester carbon in soil for hundreds of thousands of years (similar in this way to coal), which means that in the right circumstances, pyrolysis is one of the few energy generation technologies that can actually have net negative GHG emissions. The theory is that since the soil will sequester the original biomass' carbon, additional tree regrowth would absorb additional carbon from the air, creating net negative GHG Emissions. Some also claim that biochar addition to soil can reduce N2O emissions by up to 80% and eliminate methane emissions directly from soil.

Water and Nutrient Retention: Biochar is generally quite porous, and has a high surface area, and it has been suggested that the structure retains water and water-soluble nutrients at a greater rate than regular soil. This also reduces the negative effect of fertilizer leaching as well.

Improving Acidic Soil and Disease Resistance: Some scientists have suggested that for plants requiring elevated pH/high potash, biochar can improve yield as a soil amendment. Others have suggested that it also improves resistance to specific folias fungal diseases or soil borne pathogens.

What the Research Says: Summary

Biochar is good for carbon sequestration in soil, and also helps reduce N emissions and water losses. These are all great for California, with the regretful caveat that biochar production increases can only come at the cost of producing less biogas. However, claims made about agricultural benefit, such as increased crop yield, nutrient retention, pH stabilization, disease and pest resistance etc, are at best cherry picked from highly inconsistent data, and sometimes are not applicable given biochars diverse potential chemical and biological makeup.

Challenges and Existing Research: Detail

There is an inherent tradeoff to using biomass to produce biochar and to produce energy. You can only produce one at the cost of another (Zero Sum). More biochar comes at the cost of biogas production.

MACRO CHALLENGES (NEGATIVE):

- There is an inherent tradeoff to using biomass to produce biochar and to produce energy. You can only produce one at the cost of another. According to one ambitious article, avoided emissions through biochar could max out at 1.8 Pg CO2-Ce annually, and 130 Pg CO2-Ce over the course of a century, with current feedstock availability, preserving biodiversity, ecosystem stability and food security.[1] This is almost certainly a vast overestimation and may require other compromises such as purpose grown

[1] Woolf, D. et al. Sustainable biochar to mitigate global climate change. Nat. Commun. 1:56 doi: 10.1038/ncomms1053 (2010).

biomass or deforestation etc. However, the same article points out that, "The biochar scenarios described here, with their very high levels of biomass utilization, are not compatible with simultaneous implementation of an ambitious biomass energy strategy."[2] Problematic at best.

- Many of the claims made about Biochar are derived from the very positive studies on Terra Preta, soils from the indigenous peoples in the Amazon, but modern biochar is not always chemically or biologically comparable.
- Good critical review of biochar claims: http://www.biofuelwatch.org.uk/wp-content/uploads/Biochar-Report-Executive-Summary3.pdf

Biochar is basically a catch-all term for black carbon. It can refer to naturally occurring Terra Preta in the Amazon basin, to pyrolyzed wood, to a substance similar to coal and every variant in between. Therefore, the true benefits of these biochars are inconsistent in the scientific literature and one cannot advocate confidently for demonstrated benefits without cherry picking evidence.

BIOCHAR IS VERY VARIABLE, AND SO ARE ITS REPORTED BENEFITS (NEGATIVE):

'Biochar is part of the black carbon continuum with variable properties due to the net result of production (e.g., feedstock and pyrolysis conditions) and postproduction factors (storage or activation). Therefore, biochar is not a single entity but rather spans a wide range of black carbon forms.' (Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration, USDA) 3

In terms of carbon and other emission mitigation:

- There is evidence to support the fact that biochars DO act as a stable form of carbon sequestration in soil (the fact is not under debate, but the extent to which this is true is). They also do not increase CO2 respiration (natural carbon emissions from soil) in any measurable way.
- Relatively consistent evidence exists to support the claim that Biochars reduce certain Nitrogen emissions (especially N2O) from soil at an average across studies of 50%.

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[2] Ibid.

[3] Spokas, K. A., K. B. Cantrell, J. M. Novak, D. W. Archer, J. A. Ippolito, H. P. Collins, A. A. Boateng, I. M. Lima, M. C. Lamb, A. J. McAloon, R. D. Lentz, and K. A. Nichols. 2012. Biochar: A Synthesis of Its Agronomic Impact beyond Carbon Sequestration. J. Environ. Qual. 41:973-989. doi:10.2134/jeq2011.0069

CARBON SEQUESTRATION AND EMISSIONS REDUCTION (POSITIVE):

Conversion of biomass C to bio-char C leads to sequestration of about 50% of the initial C compared to the low amounts retained after burning (3%) and biological decomposition (< 10–20% after 5–10 years). Biofuel production using modern biomass can produce a bio-char by-product through pyrolysis which results in 30.6 kg C sequestration for each GJ of energy produced. Bio-char soil management systems can deliver tradable C emissions reduction, and C sequestered is easily accountable, and verifiable.

- **CARBON:** It is generally agreed upon that biochar is in fact a stable means of sequestering carbon in soil, and while some might disagree on how much remains sequestered, no one argues that biochar significantly increases the carbon in surrounding soil and does not seem to have any noticeable increase in CO_2 emissions from the same soil. The correlation is positive – what scientists disagree on is by how much.
    - One study indicated that biochar did not increase CO_2 emissions from soil, and increased the carbon in the soil by 38% on average.[4] This study echoed those findings in principal though the numbers differ a bit. [5] This concept of stable carbon sequestration is generally accepted.

- **NITROGEN**: It seems likely that Biochar *does* reduce N_2O emissions – a review study suggests that there is a direct correlation between biochar application to soil and the reduction of N2O emissions by 54% in lab and field studies.[6] [7]

    - The above finding is most reliable because it is a review of several studies. However, a selected individual study found that biochar application had no effect at all.[8] The literature is riddled with these kinds of inconsistent results.

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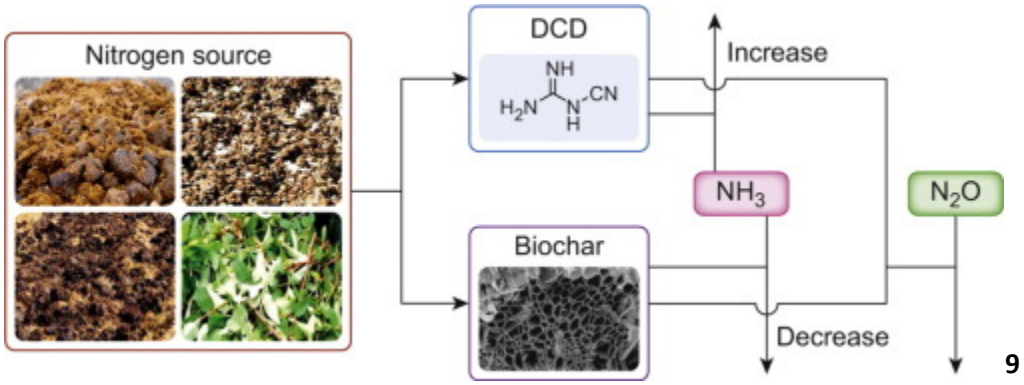
[4] https://www.sciencedirect.com/science/article/pii/S0048969716303904

[5] Long-term effect of biochar on the stabilization of recent carbon: soils with historical inputs of charcoal - https://onlinelibrary.wiley.com/doi/abs/10.1111/gcbb.12250

[6] https://www.sciencedirect.com/science/article/pii/S0167880913003496

[7] https://www.sciencedirect.com/science/article/pii/S0048969717322490?via%3Dihub

[8] https://www.sciencedirect.com/science/article/pii/S0167880914001273



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There is little consistent evidence that biochars have any significant impact on crop yield (or disease or pest impact mitigation).

CROP YIELD (NEUTRAL)

Crop yield (neutral) response to biochar application may vary with biochar type/rate, soil, crop, or climate. One study applied various amounts of biochar to cotton, peanut and corn crops and found no correlation with productivity. Overall, there was no positive or negative response to crop yield or quality with increasing biochar rates, implying biochar could be applied for economic purposes (carbon sequestration) without detrimental effects to crop yield.**10**

- Some studies have shown minor disease or pest resistance in crops. The effects were notable in the beginning of the disease development, but the rate of progression became similar towards the end of long term tests.**11**

- Vineyard soils tend to exhibit low soil fertility. They are highly vulnerable to erosion, low in soil organic matter content and, therefore, in water holding capacity and nitrate retention. The applications of biochar and biochar-compost are said to address some of these issues. Like the first study, this study

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9 https://www.sciencedirect.com/science/article/pii/S0048969717322490?via%3Dihub

10 Marshall C. Lamb, Ronald B. Sorensen, Christopher L. Butts. (2018) Crop response to biochar under differing irrigation levels in the southeastern USA. *Journal of Crop Improvement* 32:3, pages 305-317.

11 https://apsjournals.apsnet.org/doi/10.1094/PHYTO-100-9-0913

again concluded that, "Biochar and biochar-compost treatments induced only small, economically irrelevant and mostly non-significant effects over the three years."[12]

- Fifty percent of the reviewed studies reported yield increases after black carbon or biochar additions, with the remainder of the studies reporting alarming decreases to no significant differences.[13]

- Some studies have averaged a potential 20% increase in crop yields (a review of multiple studies) but the component studies are very divers and often study a biochar-compost mixture which makes it hard to isolate the positive properties of biochar alone.[14] Hardwood biochar (black carbon) produced by traditional methods (kilns or soil pits) possessed the most consistent yield increases when added to soils.[15]
- A summary of reports on biochar in agriculture indicates that the scientific literature has claimed both that biochar has benefits or no benefits at all in no understandable pattern.[16]

There IS a relatively strong correlation between the application of biochars and the retention of water. Biochars help the soil retain water than control groups consistently, but best in particular types of soil.

HYDRAULIC RESPONSE (POSITIVE)

Conditioning the soil with biochar has been identified as a possible means on improving water conservation and soil biochemical, physical, i.e. mechanical, and hydraulic characteristics. It is not in debate that biochar has a porous structure and high surface area which would intuitively lend itself to improved hydraulic conditions in soil that does not have those properties.[17]

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12 https://www.sciencedirect.com/science/article/pii/S0167880914001984

13 Ibid

14 https://www.sciencedirect.com/science/article/pii/S0929139316304954

15 Ibid

16 Environmental Benefits and Risks of Biochar Application to Soil – Jounral of Agriculture, Ecosystems & Environment https://www.sciencedirect.com/journal/agriculture-ecosystems-and-environment/vol/191/suppl/C

17 https://www.agronomy.org/files/students/2010-ricigliano-entry.pdf

- Biochar amendments increased water retention in coarse textured sand compared to the unamended soil by making the soil more rigid and stable.[18]

- Another large experiment in China on several staple crops with different biochar-soil mixtures also held a similar conclusion for a significant correlation between biochar application and an increase in moisture content of the soil.[19]

[18] Effect of biochar addition on hydraulic functions of two textural soils - https://www.sciencedirect.com/science/article/pii/S0016706117319092?via%3Dihub

[19] https://aip.scitation.org/doi/10.1063/1.4967706

Some Other Resources (in addition to footnotes):

1. http://www.earthisland.org/journal/index.php/elist/eListRead/biochar_black_gold_or_just_another_snake_oil_scheme/
2. https://www.nature.com/articles/ncomms1053
3. http://www.biofuelwatch.org.uk/2011/a-critical-review-of-biochar-science-and-policy/
4. https://escholarship.org/uc/item/49r8v2b5
5. https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2486.2012.02665.x
6. https://dl.sciencesocieties.org/publications/jeq/abstracts/41/4/973
7. https://www.treehugger.com/sustainable-agriculture/should-you-use-biochar-your-garden.html
8. https://link.springer.com/article/10.1007/s11027-005-9006-5