Colorado State University
Extension

Biochar in Colorado

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Introduction

Biochar has been promoted as a soil amendment for gardening, agriculture, forestry, and mine reclamation. Biochar can also capture and sequester greenhouse gases, and its use may contribute to slowing global climate change. Biochar is commercially produced and sold in Colorado, but at this time quantities and distribution channels are limited. Small scale experiments suggest that biochar could be applied beneficially as a soil amendment in Colorado, although field trials are necessary to test its effectiveness and economic viability of applying it.

The purpose of this article is to educate interested readers about the potential uses of biochar in Colorado. The article summarizes the general scientific literature and recent developments in Colorado biochar research. Links to other resources are also provided.

What is Biochar?

Biochar is charred organic matter used deliberately as a soil amendment, with the intent to improve soil properties[1]. Technically speaking, biochar is made from organic matter that has been transformed through pyrolysis. Pyrolysis is the process of heating an organic substance, in the absence of oxygen, at 250-700 degrees Celsius, or approximately 480-1200 degrees Fahrenheit[2]. Pyrolysis alters the feedstock and yields a charcoal-like substance called biochar[1], as well as by-product liquids and gases. A wide variety of feedstocks can be used to make biochar, including sawmill scraps and wood chips, municipal solid waste and compost material, animal manure, yard waste, and forest residues.

Not all biochar is the same. Characteristics of the feedstock and parameters of the pyrolysis process determine biochar properties. Biochar behavior in soils is dependent on the specific biochar and soil properties. For example, wood-derived biochar pyrolyzed at high temperatures is optimal for carbon sequestration. Grass or animal waste derived biochar have a higher pH and function better to improve soil fertility in poor, acidic soils. The next section describes the main applications for biochar.

Biochar Applications

1) Carbon sequestration & climate change mitigation: Biochar has recently received attention in the research community, and consequently in the media, as a way to mitigate global climate change by capturing carbon and reducing greenhouse gas emissions[3-5]. Any plant naturally sequesters carbon in its biomass as a living organism. When the feedstock is burnt, 15-40% of the biomass remains in the char, depending on pyrolysis conditions. Compared to open burning, the fraction of the burned C converted to biochar is estimated to range from less than 1% - 9.5%[6].

Biochar is a very stable form of carbon and when it is incorporated into soils can remain there for hundreds of years. Therefore, biochar is considered a 'carbon sink'[7]. Biochar can also reduce N_2O emissions from soils, possibly as a result of increasing soil pH[8].

Preliminary findings from lab experiments at Colorado State University show a high carbon sink capacity. However, the time it remains in soil before being respired by microbes and returned back to the atmosphere as carbon dioxide (CO_2) also depends on content of soil organic matter. After 606 days of incubation under optimum

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Quick Facts

- Biochar shows promise for several different applications—such as utilizing organic residues from overcrowded and beetle-infested forests, soil reclamation and mining remediation, and as a soil amendment in gardening—but more research is necessary.
- A commercial biochar market has begun to develop in the U.S. despite the fact that scientific results are only emerging and primarily confined to laboratories and experimental field sites.
- The race is on between soil scientists to document and quantify the bio-physical impacts of biochar on soil chemistry and the entrepreneurs to promote a product that yields uncertain positive bio-physical outcomes.

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conditions, only 0.6% of the biochar had been respired from a relatively carbon-rich agricultural soil (1.5% C) while 4.5% of the carbon in biochar was mineralized in a steppe soil (0.7% C)(9).

At the time of this writing, environmental damages from CO_2 emissions have not been fully quantified or monetized in the U.S.(10). U.S. carbon markets are not currently viable, although this could change in the future(11). Should the demand for carbon emission credits rise, interest in using biochar to offset carbon emissions from other industries may increase.

2) Forestry: One of the most appealing aspects of biochar production in Colorado is that it could provide a means to utilize organic residues from overcrowded and beetle-infested forests. In the Western United States where wildfire prevention and mitigation is a top environmental and safety priority of the U.S. Forest Service, management of millions acres of dead trees killed by pine beetle infestation could serve multiple environmental goals. Most likely the trees would be disposed through controlled burning or by using mechanical harvest and slash piling. Such slash piles are typically burned onsite, rather than used as a value-added product. In either case, large amounts of CO_2 would be released into the atmosphere, accompanied by smoke and particulates. While the use of forestry residues as feedstock for biochar production appears to be a win-win strategy for the economy and the environment, the effectiveness of the use of biochar for forest soil applications needs to be established. Biochar research is underway at U.S. Forest Service sites in Colorado and Idaho.

3) Mine Reclamation: Biochar shows promise for soil reclamation and mining remediation due to its sorption characteristics and relatively high pH, which have been linked to re-establishment of vegetative cover(12). Preliminary results indicate that biochar has the ability to take up heavy metals from legacy mines, 'capturing' the metals, potentially reducing toxic runoff, and protecting water quality.

Preliminary research by Peltz et al.(13) at field sites near Silverton, Colorado, at elevations of 9,180 to 12,140 feet, showed that—with the addition of 30% biochar by volume—water holding capacity increased by 90-180% in all soils. When compared to seeding alone, vegetative cover increased by 240% when biochar was added to acidic soils, including an additional 192% increase in overall measureable biomass. However, in the alkaline soils (the control condition), little to no difference in vegetative cover was observed. This indicates that the mechanism driving increased vegetative cover may be linked to increased pH in the acidic soils, driven by the biochar addition. Additionally, seed emergence increased in number, at a faster rate, and with taller seedlings in biochar amended soils. Soil leachate results were mixed, with some heavy metal concentrations increasing (copper) while others decreased (aluminum and iron), while the remaining concentrations showed no change overall.

Although many questions remain unanswered by the Peltz et al. study, it provides evidence that biochar's desirable characteristics may be useful for remediating acidic soils affected by mining operations. Specifically, the increase in pH as a result of biochar additions may be linked to increased vegetative cover for acidic soils, which could in-turn decrease soil erosion. Additionally, decreases in leachate concentration, although documented to be minimal, encourage further investigation into the potential for biochar to actually trap and contain these minerals, decreasing their presence within the soil profile.

4) Energy Production: The biochar production process can result in, depending on adjustable parameters of the pyrolysis process, two co-products – synthesis gas (syngas) and bio-oil(14, 15). The amount generated of these co-products varies with adjustments in temperature of the pyrolysis process and residence time in the reactor. The relative production mix of char, syngas, and bio-oil can be optimized depending on the desired outcome. However, if generated, these products can be captured and utilized at the production site to power and heat the facilities there, or to generate electricity that could be sold back to the utility company to be used on the power grid. Syngas and/or bio-oil can also be captured and sold for further processing. At this point, utilizing these co-products is not wide-spread among biochar producing operations, but as production increases and expands the implementation of these options could increase. However, there are costs and benefits to be considered in each stage of production. Pyrolysis can be conducted at various temperatures which will affect the amount of char compared to co-product output. Additionally, there are various technologies available including flared or unflared reactors, which impact the emissions output and can consequently influence the carbon footprint of biochar. Each of these variables needs to be analyzed to optimize the desired output of a given facility.

5) Agriculture: Crop yields commonly increase after biochar application to agricultural soils, with the larger beneficial effects being reported for acidic, arid or coarse textured soils(16). Colorado agricultural soils are generally alkaline, but crop production is limited by water availability. Preliminary results from a CSU greenhouse trial demonstrated an overall beneficial effect of biochar application to Colorado agricultural soils on winter wheat biomass production, likely due to improved soil water retention(17). Should field research demonstrate a correlation between biochar application and increased yield, production economic models will be necessary to determine the economic feasibility of using biochar as a soil amendment.

6) Gardening: In Hawaii and Florida, among other places, biochar has been used with anecdotal success for gardening, where the low pH levels of the tropical, weathered soils require soil amendment. In gardening applications, the biochar is frequently mixed by nurseries as a proprietary, biochar-enriched soil blend. Retail prices of biochar blends are approximately \$22.99-\$24.99/ft^3 in Hawaii and approximately \$28 -\$32/ft^3 biochar in Florida. These prices are based upon relatively small packages distributed for gardening and household use.

In Western states like Colorado, the biochar is typically sold in larger bulk quantities at \$250/yard^3, and in Idaho at \$350/yd^3. In a series of qualitative research interviews conducted by the authors in 2011 with biochar purchasers and home/garden supply stores(18), the majority of char was sold for mine reclamation applications and experimental forest research conducted by government agencies and entrepreneurs. Pine wood chips comprised the typical feedstock, and the average order was approximately 6,400 lbs, or on the order of 25 to 30 cubic yards depending on the density of the specific biochar. Interviews with personnel at 33 nurseries along the Front Range including Fort Collins, Denver, Boulder and Golden confirmed that biochar is not currently available on the commercial market in the state and is not yet a widely recognized product in the agricultural, horticultural and gardening sectors in Colorado. However, as demonstrated by the Hawaii market, there could be considerable interest in the gardening sector if biochar is shown to be an effective soil amendment.

Summary

Biochar shows promise for several different applications, but more research is necessary to establish scientific linkages. A commercial biochar market has begun to develop in the U.S., despite the fact that scientific results are only emerging and primarily confined to laboratories and experimental field sites. Although outcomes and correlations between various biochar parameters are only beginning to emerge, there appears to be considerable amounts of enthusiasm about the potential environmental benefits of using biochar and commercially producing it. The race is on between soil scientists to document and quantify the biophysical impacts of biochar on soil chemistry and the entrepreneurs to promote a product that yields uncertain positive biophysical outcomes.

Should you have the inclination, you could experiment with biochar in your own garden to assess the performance in Colorado soils. The section below contains information for finding biochar producers. Look for more information on biochar as it becomes available from research projects across the state.

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