Profitable Use of Biochar in Agricultural Soils

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Abstract

Biochar and black carbon production and use are at the intersection of agricultural productivity, food security, climate change, and energy. We evaluated available research on: 1) the impacts of the addition of inorganic carbon on agricultural productivity and soils (e.g. crop yield, transport and leaching, and chemical modifications), 2) industrial conversion of 'carbon black' into forms that share properties with biochar, and 3) possible carbon markets and business opportunities that can incentivize and expand use of Monolith technology to transfer carbon from natural gas to agricultural soils. Biochar was produced using homemade methods.

Biochar Production

Apparatus, homemade

Biochar from deciduous wood

Biochar, crushed

Biochar combustion

Residence Times

There is ample evidence that biochar is very stable in the environment. In soil, it typically has the longest age of any C fraction [5]. Biochar that was created from forest fires is typically found to be more than 10,000 years old in various ecosystems. In laboratory experiments .3 and .8 percent of $C0_2$-C was observed to be lost when biochar was incubated for a 60 day period at 800 and 350ºC respectively[4]. A similar study reported a loss of less than 2% in a 120 day incubation period.

Effects in Agricultural Soils

Biochar has long been used for its ability to increase soil fertility, crop yields, and decrease leaching of nutrients that are beneficial for plant growth. Biochar has been shown to significantly increase the Cation Exchange Capacity (CEC) of soils. One specific study done at the Iowa State University Agronomy and Agricultural Engineering Research Farm in Boone County Iowa showed that soil that had added 5, 10, and 20 g kg^{-1} of biochar showed an increase in Soil Organic Carbon (SOC) by 17.6%, 37.6%, and 68.6%, respectively [2]. SOC has long been identified as a key indicator of overall soil quality and fertility [8]. Another key indicator of overall soil quality is the ability for soils to retain water. Soils with 5, 10, and 20 g kg^{-1} of biochar added retained 10, 12, and 15% more water respectively than soils with no biochar added [2]

References

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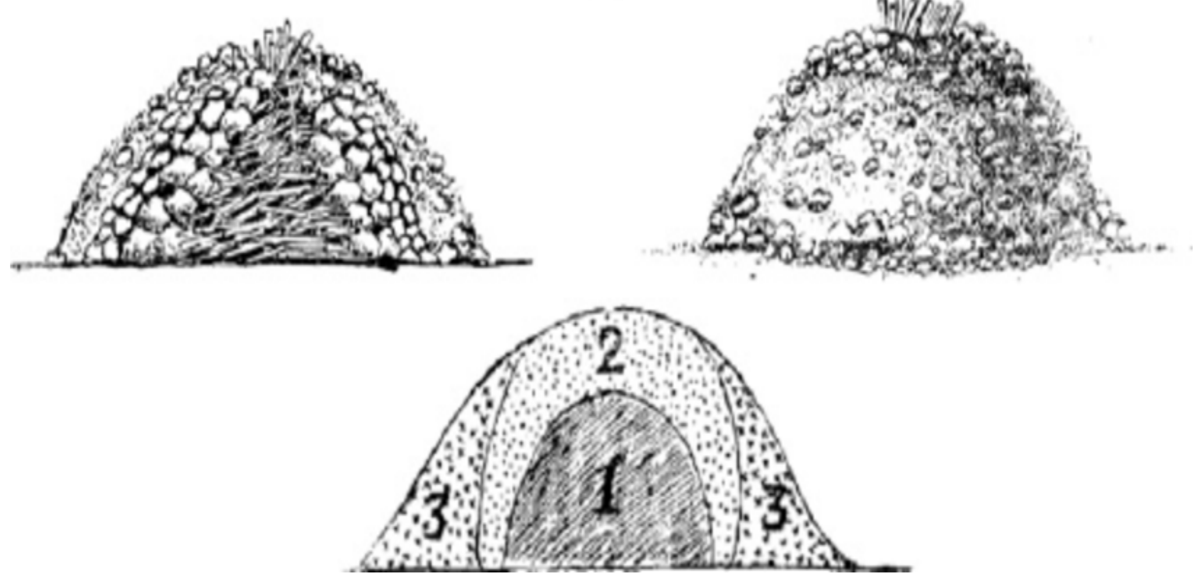
Production of Biochar/Carbon Black

Biochar has been used by ancient civilizations as a soil additive since the dawn of mankind. Most famously are the Terra Preta De Indios soils that are found in the amazon basis. For centuries, these soils have amazed scientists and geologists alike due to their high concentrations of nutrients such as nitrogen, phosphorus, potassium and calcium, but also greater amounts of stable soil organic matter (SOM) and SOC [3]. "Biochar" is a modern term often used along with charcoal, pyrogenic C, or black carbon (BC), but they are not fully interchangeable or synonymous [4]. There are 6 main biochar production methods.

Historic biochar production method that uses soil to restrict oxygen



Method	Temp C	Other Defining Parameters	Gas %	Liquid %	Solid %	Intended Use for Final Product
Carbonization	300-1200	Air access, residence time, materials	60-75	3-5	10-35	Charcoal for solid fuel and industrial input
Pyrolysis (for bio – oil)	400-600	residence time, particle size, gas flow	20-40	40-70	10-25	Bio-oil; chemical products and fuels
Pyrolysis (for bio-char)	300-700	Residence time	40-75	0-15	20-50	Soil amendment, carbon sequestration and bioremediation
Gasification	500-1500	Oxidizing media, equivalence ratio	85-95	0-5	5-15	Syngas; gaseous fuel for heat and power, and gas to liquid
Hydrothermal Processing	200-400	Pressure, Solvent type and ratio	0-90	0-80	0-60	Various chemical products
Combustion	1000-1500	Air access	95	0	5	Energy converted to heat and power

In the partial or total absence of oxygen, the thermal decomposition of plant-derived biomass (pyrolysis) can be manipulated to yield, and in addition to CO_2 and in variable ratio, combustible gases (chiefly H_2, CO, CH_4), volatile oils, tarry vapors, and a solid C-rich residue generically referred to as char. As distinct from char in general, biochar remains ill-defined [6]. Black carbon (BC, used synonymously with 'carbon black'), produced by incomplete combustion of fossil fuels, is relatively resistant to degradation (but is combustible) and occurs ubiquitously in natural environments, including soils, sediments , seawater, and the atmosphere.

Markets and Business Incentives

Biochar technologies are currently in the early stages of development and the true cost of producing biochar and the associated products are not completely known. This uncertainty makes it very difficult to estimate the costs and benefits of biochar and since the technology is still evolving and there is yet to be one 'dominant design' for which to most efficiently produce this product [7]. A representative from Monolith materials informed us that phase one of the plant will have the capacity to produce 14,000 tons/year, while phase two will be able to produce 200,000 tons of BC a year. Monolith Materials sells their Carbon Black at a price ranging from $1,000 from up to $10,000 depending on the certain grades of the finished product. Annual net emissions of carbon dioxide (CO_2), methane and nitrous oxide could be reduced by a maximum of 1.8 Petagram (Pg) CO_2-C equivalent (CO_2-C) per year (12% of current anthropogenic CO_2-Ce emissions; 1Pg=1Gt), and total net emissions over the course of a century by 130 Pg CO_2-Ce, without endangering food security, habitat or soil conservation [1].

Projected biochar production in US (kilotons)