UB#7: How Does Biochar Sequester Atmospheric Carbon Dioxide in Growing Systems

By Hugh McLaughlin, PhD, PE – CTO – NextChar.com January 9, 2017

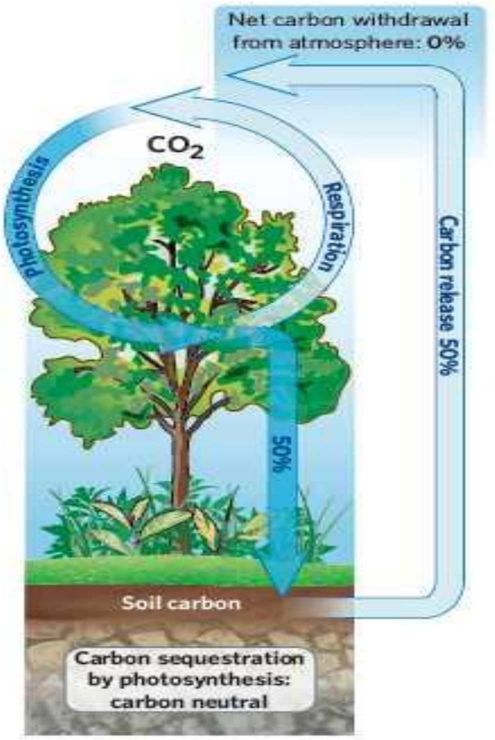
Biochar is central to the climate debate and efforts to limit, and potentially lower, the level of carbon dioxide in the atmosphere. The concepts are straightforward about how biochar represents carbon dioxide removed from the atmosphere as the plant grew and how biochar represents a portion of the plant's carbon that is converted to a stable form that resists degradation by soil microbes for millennia. There are, however, additional beneficial impacts or contributions coming from the creation and use of biochar. This discussion will summarize qualitatively these additional pathways without attempting to rigorously quantify the actual carbon capture amounts, which tend to be site-specific and data intensive.

In 2007, Dr. Johannes Lehmann, a leading biochar academic, published a 2-page Commentary in *Nature* magazine (*Nature* 2007 May 10; 447(7141):143-4 – the entire piece can be downloaded by searching the web for the title; *A handful of carbon*). The discussion included a pair of graphics, shown on the next page, which have been often reproduced, but seldom appreciated for the significance of the depicted phenomena. This may be due to the complete absence of any discussion of the images in the text, with just two instances of "see graphic". We will review the concepts at this time.

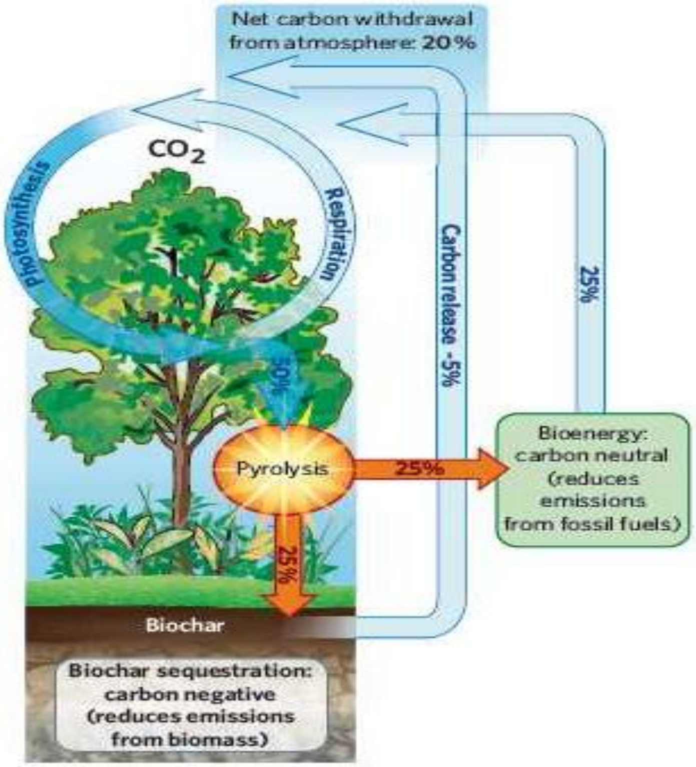
The cycle depicted on the left is the predominate carbon cycle on earth, also known as the "short-term carbon cycle", where carbon dioxide is removed from the atmosphere via photosynthesis by plants as they grow and returned to the atmosphere by microbial degradation in the soil after the plants die, with the overall cycle being carbon neutral with respect to the inventory of carbon dioxide in the atmosphere. The short-term carbon cycle results in the vast majority of the biomass carbon being returned to the atmosphere within one to two decades after the biomass dies and typically within one year for seasonal crops.

The graphic on the right depicts the introduction of pyrolysis, which is the heating of dead biomass in a limited supply of oxygen, to convert the biomass into equal amounts of vapor and biochar. The vapor's combustible gases can then be converted to carbon neutral bio-energy and the biochar can be utilized as carbon negative sequestration, either securely buried or into soils in growing systems.

Situations where the left graphic is the end result may represent net removal of carbon dioxide from the atmosphere if the ending condition supported more total biomass, above and below ground. Under the Kyoto protocol, these practices were allowed as tradable "carbon offsets", being termed afforestation if the initial condition was barren land and reforestation if the land was previously deforested. Over time, the accumulated biomass approaches the steady-state of stable supportable growth, where there is diminishing additional long-term carbon sequestration. Furthermore, both afforestation and reforestation are not secure from natural forest fires and future intentional land clearing for farming.



Short-term Carbon Cycle: 0% removal



Pyrolysis yielding Biochar Cycle: 20% net removal

In contrast, the creation of biochar results in a material which, once distributed in the soil, is protected from conditions that would convert the stable (graphitic) carbon back to carbon dioxide. Furthermore, the creation of biochar provides additional opportunities for an endless sequence of reforestation cycles, with the harvesting of the resulting biomass and conversion to additional biochar. Lehmann’s *Nature* article provide some estimates of representative rates of excess biomass generation by several typical growing systems: forest residues with 3.5 tonnes biomass per hectare per year; fast-growing vegetation (switch grass, short rotation trees, etc) with 20 tonnes biomass per hectare per year; and crop residues with 5.5 tonnes biomass per hectare per year. Based on the material balance outlined in the pyrolysis graphic, roughly 40 percent (25% less 5% of the 50% entering pyrolysis) of the carbon in every one of these biomass sources can be converted to stable biochar. This is in addition to receiving the entire energy content of the pyrolysis gases that become available for bio-energy production or domestic activities such as cooking.

To demonstrate the amplifying impact of systematic harvesting and creating additional biochar, consider a single hectare of land planted with fast-growing vegetation (20 tonnes excess biomass per hectare per year) and yielding 40% biochar from the harvested residues. After a century, the additional sequestered carbon, in the form of biochar, would be (20 tonnes x 40% yield x 100 years from just a single hectare =) 800 tons of biochar, equivalent to over 2500 tonnes of carbon dioxide removed from the atmosphere. If one hectare of non-productive or marginal land could be returned to similar productivity by the one-time addition of 8 tons of biochar per hectare, the first year's biochar from that one hectare would develop a second hectare, and the next year, those two hectares would yield 16 tons of biochar, upgrading 2 additional hectares of unproductive land in year three. As can be imagined, if this geometric conversion to productive land can be continued, biochar would provide a straightforward method of returning marginal land to agricultural productivity while removing atmospheric carbon dioxide.

While biochar represents carbon that has been removed from the atmosphere as the plants grew and stabilized by pyrolysis prior to storage in the soil, an additional benefit of biochar relates to its role in improving soil properties and facilitating biomass growth and accumulation, termed "Net Primary Productivity". By improving water retention, decreasing nutrient leaching, and increasing soil biota levels and diversity, biochar improves both the quantity and quality of the above-ground crops and accumulated biomass. And this occurs every single growing season on the biochar-augmented land for the foreseeable future.

There is one additional and very pivotal role of biochar in carbon sequestration, and that is the role of remediation of marginal soils that suffer from residual toxicity. Toxicity and the presence of undesirable soil chemicals that result in lower Net Primary Productivity can result from accumulation of chemicals intentionally applied to the land, such as glyphosate, or by competition between crops that emit phyto-toxins, or by the accumulation of slowly degrading residues of the intended crop when mono-cropping is practiced. Biochar, which shares the unique property of adsorption with activated carbon, can preferentially cleanse a wide range of synthetic and natural toxins from the soil groundwater and effectively "quarantine" chemicals that are antagonistic and inhibitory to soil biota and the plants supported by the soil. Furthermore, the biochar makes these chemicals accessible to the microbes at greatly reduced concentrations, rendering them a non-toxic source of soil organic carbon that can be metabolized and destroyed over time by soil biota.

In summary, biochar removes carbon dioxide from the atmosphere and stores it securely in the soil, but it also improves the productivity of the entire soil-food web. Biochar stabilizes life in the soil and allows the soil to create more life by providing a better growing environment. In conclusion, the benefit of biochar is not accurately represented by the amount of carbon buried when it is put in the ground on *day One*. The benefit of biochar is the cumulative series of carbon sequestration opportunities due to increased Net Primary Productivity through *day One-hundred-thousand* and beyond.