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Before the
House Select Committee on
Energy Independence and Global Warming

Thursday, June 18, 2009

2175 Rayburn House Office Building
Washington, DC

Biochar for sustainable carbon sequestration and global soil enhancement

Chairman Markey, Members of the Committee:

Thank you for the opportunity to provide scientific information about biochar carbon sequestration for sustainable climate change mitigation and global soil enhancement. Biochar is a fine-grained charcoal-like material that is produced through the heating of biomass under air-deprived conditions. This process is called pyrolysis. A wide variety of organic matter sources can be used as a feedstock for this process, including residues from forests or crop production, from animal production (manures), and from green waste streams, such as yard wastes. Upon pyrolysis at relatively low temperatures of 300-600°C, the chemical properties of biomass carbon change to form structures that are much more resistant to microbial degradation in comparison to the original organic matter. Thus, materials that would rapidly release carbon dioxide and other potent greenhouse gases as they decompose, are transformed into a material that degrades much more slowly, thereby creating a long-term carbon sink (Figure 1). Such thermally altered material is about 1.5 to 2 orders of magnitude more stable in soils than uncharred organic matter.[1,2] Biochar has mean residence times of several hundreds to several thousands of years in soils.[3,4]

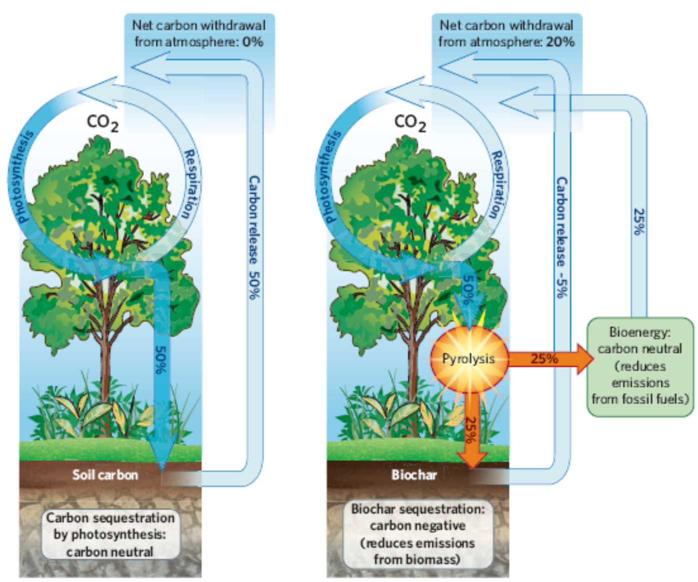

Figure 1: Schematic showing how biochar would achieve an increase of soil carbon stocks by decreasing the carbon dioxide return to the atmosphere.[5]

The mechanism behind carbon sequestration through biochar in soils is very straightforward because stabilization is to a large extent a function of its intrinsic chemical stability. This is in contrast to uncharred organic matter, where soil carbon accrual primarily relies on a range of interactions between the mineral matrix and the organic matter.[6,7] Therefore, the level at which soil carbon stores saturate[8] and cease to sequester additional carbon is greater for biochar than for uncharred crop or forestry residues.

Biochar is a familiar substance in soil. Most soils already contain char that was generated during vegetation fires throughout the past several thousand years. These chars are estimated to make up several percent of total soil organic carbon worldwide,[9,10] which, in turn, is about twice the size of the atmospheric carbon pool.[11] Biochar soil management increases the amount of such naturally existing chars, which have been found to provide beneficial health and productivity properties to soil.

Biochar production and its application to soil provide several additional important value streams beyond direct climate change mitigation. These include waste management, energy production, and soil improvement (Figure 2). As a waste management strategy, biochar can be produced from a variety of feedstocks that would otherwise constitute a financial and environmental liability.[12] For example, in agricultural regions with high phosphorus and nitrogen levels in the soils and water, animal manures could be pyrolysed as a waste management strategy to prevent eutrophication. In many situations, compost, landfill or animal manure operations often generate large amounts of methane and nitrous oxide. By pyrolysing materials such as lawn clippings or biomass from forest thinning for fire prevention, the production of these even more potent non-CO_2 greenhouse gases would be effectively mitigated at the same time as the carbon is sequestered in soil.

A second value stream arises from bioenergy generated during biochar production. Between 2 and 7 units of energy can be produced for each unit of energy invested during the life cycle of various biochar systems.[13] Biochar production can be paired with local heat generation such as a system where poultry manure is pyrolysed on-farm to heat barns and the resulting biochar is applied to fields.

The third value stream is the improvement of soil quality upon biochar additions. Crop yields can be significantly increased in soils that have productivity constraints. These may arise from degradation of soil organic matter or years of nutrient extraction through cultivation. The resulting losses of agrochemicals such as fertilizer nutrients, herbicides and pesticides can be mitigated by biochar's ability to retain these compounds.[14,15,16,17,18] Subsequently, fertilizer use efficiency is increased.[19] In its ability to improve several key properties of soils, biochar is particularly effective not only because it delivers these values for a longer period of time, but also because it has a greater effect per unit of carbon added to soil.[20] Improved soil fertility also provides better resilience against climate change. Taken together, these three sources of value have the potential to enhance food and energy security while also combating climate change.

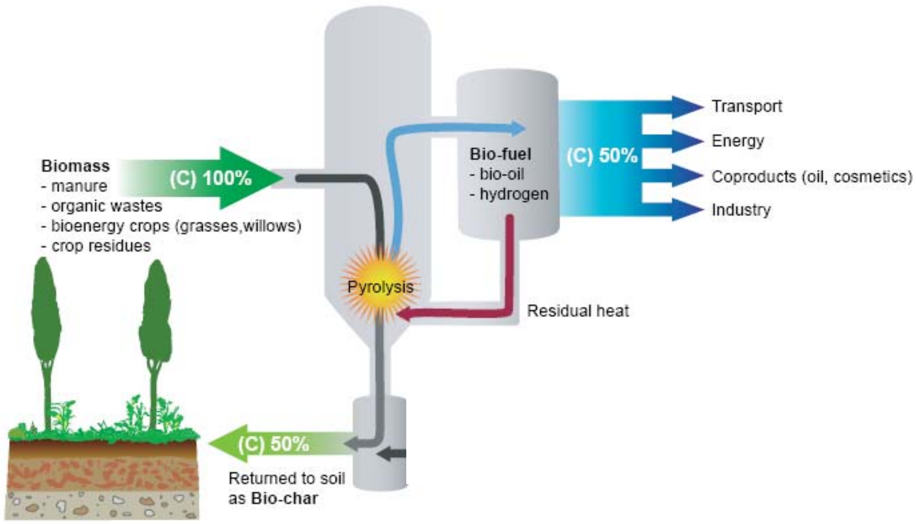

Figure 2: Biochar value streams including biomass use, energy generation and soil enhancement.[21]

Deliberate biochar additions to soils have a number of implications for carbon trading. Additionality can be demonstrated because biochar is currently not actively produced or added to soils to any appreciable extent (less than 1% global penetration). However, it would still be critical to determine what the carbon stocks and flows would have been under the baseline system and to ensure that no greenhouse gas “leakage” would occur. For example, the land-use effects of large-scale biofuel-style plantations[22] for biochar production or the removal and use of crop residues necessary to protect soil from erosion would likely make such systems inappropriate for biochar production to achieve net carbon sequestration. Measurement and verification of biochar sequestration is facilitated by the fact that the amount of carbon added at any one time is easily measured or calculated, and does not need to accumulate over time. Verification of lasting sequestration is possible because biochars bear a chemical signature that can be distinguished from other organic matter in soils. Furthermore, sequestered biochar carbon would not be released to the atmosphere due to changes in land management, fires, or deforestation, making it a strong candidate as a reliable carbon sequestration agent, with a mean residence time of several hundred to thousands of years.

The national or global potential of biochar to help mitigate climate change is only theoretical at this point, because too few biochar systems exist at scale of implementation. Conservative modeling of the technical potential place biochar as an approach to contribute on the order of 1Gt carbon removals annually by 2050 (considering only limited biomass feedstock availability and only carbon sequestration impacts).[23] Such widespread adoption of biochar systems will require sustainability criteria, since the climate change mitigation value of biochar arises from several connected sources including energy and agriculture. The potential for climate mitigation is highly variable from one biochar system to the next due to different feedstocks, scales, and applications[13,24] which requires careful evaluation. Biochar must be integrated into existing food production systems and not be an alternative to food production, make use of already developed best-management practices such as no-tillage or conservation agriculture, and, for efficiency, build on residue collection systems that are already in place.

While few fully implemented modern biochar systems exist worldwide, the necessary engineering and science capacity is available to evaluate a diverse set of biochar systems at scale of implementation in the near term. In fact, biochar science has rapidly evolved even over the past 12 months.[25] Evaluation does not rely on a fundamental advance in science, but on the application and adaptation of existing science. The underlying technology is robust and sufficiently simple to make it applicable to many regions globally.

Current hurdles to implementation are: availability of pyrolysis units at sufficient maturity to allow all necessary research and development, and, as a direct consequence, a lack of demonstrated carbon trading activities; of sufficient development of best biochar practices at scale of implementation, including farm scale; and of demonstration of soil health benefits for the full spectrum of agroecosystems. The distributed nature of biochar systems and the potential for variability between systems create significant opportunities for sustainability, but also hurdles to widespread adoption, regulation, and financial viability.

Establishment of policies at national and international levels is required to remove hurdles to implementation and support full evaluation of biochar systems. Mechanisms for carbon trading that recognize soil carbon sequestration, including biochar sequestration, need to be put into place. Methodologies must include full life cycle accounting of emissions balances to deliver net climate benefits. The entire value chain of mitigation approaches must be recognized, to reward those activities that have multiple environmental and societal benefits. Biochar must not be an alternative to making dramatic reductions in greenhouse gas emissions immediately, but it may be an important tool in our arsenal for combating dangerous climate change.

Thank you, Mr Chairman.

Summary

What is biochar?

- Biochar is a fine-grained charcoal-like material produced through pyrolysis.
- Pyrolysis is the heating of biomass to temperatures of 300-600°C under air-deprived conditions.
- Through pyrolysis, the feedstock changes chemically to form structures that are much more resistant to microbial degradation than the original material.
- Many different sources of organic matter can be used as a feedstock for this process, including residues from forests or crop production, from animal production (manures), and from green waste streams, such as yard wastes.
- Biochar-like materials produced through forest fires are already a significant part of the global soil carbon cycle.

How does biochar sequester carbon?

- Because biochar is much more stable than other forms of biomass-derived carbon in soil, it remains in the soil for much longer.
- Biochar is 1.5-2 orders of magnitude more stable in soils than uncharred material and has mean residence times of hundreds to thousands of years.
- The “saturation point” for biochar additions to soil would be significantly greater compared to other additions from organic matter.

Why is biochar valuable?

- Biochar is a very stable form of carbon and can thus be used to sequester CO_2.
- Biochar can be made from waste materials, including those (e.g., manure or green wastes) that may otherwise produce even more potent non-CO_2 greenhouse gases.
- Biochar production results in energy generation, which can also be integrated into sustainable local-scale operations such as the heating of farm buildings.
- Biochar’s addition to soils can enhance soil fertility and retention of agrochemicals.

What do we need to know/do?

- The technology and scientific knowledge is ready to implement the necessary steps to thoroughly develop biochar systems at a meaningful scale.
- This will be necessary in order to understand biochar best practices, demonstrate field-scale soil health benefits for different agroecosystems.
- Soil carbon sequestration, including biochar carbon sequestration must be recognized under carbon trading schemes.
- Robust guidelines must be developed to ensure that any integration of biochar into carbon trading schemes is truly additional, sustainable, and does not result in the “leakage” of greenhouse gas emissions.
- Biochar must not be seen as a replacement for dramatic reductions in our greenhouse gas emissions.

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