Biochar for mitigating climate change: carbon sequestration in the black

Bioenergy is experiencing a renaissance as a strategy for substituting fossil energy and reducing greenhouse gas emissions but is still facing significant challenges in delivering sufficient amounts of energy in an environmentally friendly and cost-effective way. The return of biochar, a by-product of low-temperature pyrolysis bioenergy, to soil does not only avoid adverse environmental impact but also constitutes a net sink of atmospheric carbon dioxide. Biochar sequestration drives the carbon budget of bioenergy into the black.

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Introduction

Climate change has taken a remarkable share of popular media headlines during recent months, not the least because of the reports published by the Intergovernmental Panel on Climate Change (IPCC) in the first half of 2007. The most effective strategy to mitigate anthropogenic climate change still remains the substantial reduction of greenhouse gas emissions. Since the use of fossil fuels is by far the main culprit of these emissions, reduction in energy use is a reasonable first target for a comprehensive mitigation plan. In addition to energy conservation, the use of alternative energies holds much promise, not only because of their favorable greenhouse gas balances but also because of the associated emancipation from the dependency on fossil energy sources. Liquid biofuels appear to be especially attractive as they fuel the mobile modern economy.

Corn Ethanol – a dead end?

In spite of their attractiveness, biofuels, particularly ethanol production from corn, have come under increased scrutiny. First of all, it is not clear whether ethanol production from maize really yields more energy than was invested into the production process. Estimates of the energy ratio of output to input have a wide range: from 0.7 to 2.2 kg C kg^{-1} C (Pimentel & Patzek 2005; Metzger 2006). A ratio below 1 would indicate that more energy is needed to produce the ethanol than is contained in it. Much hope is associated with so-called cellulosic ethanol production. Here it is not sugar which is fermented to ethanol, but cellulose, which is much more abundant in all plants. Precisely when this alternative will be available on an industrial scale is still a matter of speculation. Estimates show nothing earlier than in 10 to 15 years from now (Stephanopoulos 2007). And under any scenario of bioengineering microorganisms that can indeed break down cellulose, the unavoidable distillations step will always consume a large proportion in the order of 79% of the energy that the final ethanol product contains (calculated after Pimentel & Patzek 2005). Whether ethanol production from corn biomass will be energetically, not to mention economically and environmentally, sound is highly questionable.

Secondly, bioenergy may have significant environmental drawbacks. Bioenergy production inevitably increases the biomass withdrawal from agricultural land. Some fear justifiably that such a massive withdrawal of biomass will deplete soils, and that the required fertilization will also have significant off-site impacts such as ground water pollution and eutrophication of lakes and streams (Dalgaard et al. 2006; Koonin 2006; Ragauskas et al. 2006).

Bioenergy with organic matter return

A relatively recent approach to bioenergy production is low-temperature pyrolysis which is a thermal degradation process reminiscent of charcoal making. During thermal degradation, a whole suite of different gases are emitted which can be captured and used as energy carriers. The energy products include thermal energy, hydrogen, biooils, and electricity (Bridgwater 2003). The residue resulting from low-temperature pyrolysis is a form of charcoal called biochar, which is a fuel in itself. What sets pyrolysis apart from other bioenergy technologies, and even other renewable energy sources, is that this biochar residue can be returned to soil, affording a range of environmental benefits (Lehmann 2007a). About 50% of the organic carbon found in bioenergy crops can in this way be returned to the place where they were harvested from. Biochar has a remarkable potential for soil improvement and may avoid many of the large-scale negative impacts of biomass removal. The ratio of energy obtained to energy invested is most likely much greater than with ethanol production, even when the biochar is used as a soil amendment and not as a fuel (Lehmann 2007b).

Carbon-negative energy

The most important characteristic of biochar is its very long half life in comparison with uncharred organic matter (Baldock & Smernik 2002). This has two important implications: Biochar additions to soil not only reduce carbon dioxide emissions from energy production but this carbon burial also constitutes a net withdrawal of carbon dioxide from the atmosphere. Such a net sequestration is only achieved in combination with regrowing the biomass that was used to produce the bioenergy in the first place. This net withdrawal makes pyrolysis a carbon-negative bioenergy production technique. In contrast to bioenergy production techniques that rely on landuse conversion to increase the amount of carbon accrual in aggrading soil under fast-growing vegetation (Tilman et al. 2006), pyrolysis bioenergy combined with biochar return does not face a sink limit.

There is a high theoretical potential to reduce global greenhouse gas emissions through the use of biochar sequestration in combination with bioenergy, but this needs to be vetted against economic realities (Lehmann 2007b). The basic principle for evaluating its potential is quite simple. Globally, there is a large amount of carbon that annually cycles from the atmosphere into plants and soils and back again into the atmosphere. This pool is about 1-2 orders of magnitude larger than global annual emissions from fossil fuels (IPCC 2007). Even if only a fraction of one percent of that annually cycling pool of carbon can be diverted into a much slower biochar cycle, a considerable reduction of atmospheric carbon dioxide content could be achieved.

What are the alternatives?

Other photosynthetic approaches such as no-tillage or afforestation are all constrained by their limited carbon storage capacity (Lackner 2003), which is not the case for biochar sequestration. A general ques-

Modern pyrolysis power plants such as the one built by BEST Energies (Somersby, Australia) have, from the outside, little in common with the traditional way of making charcoal.

tion also remains as to whether no-tillage constitutes a net greenhouse gas sink at all. Many studies have indeed shown a low or nonexistent increase in carbon storage after conversion from conventional to no-tillage, especially if subsoils were included in the calculation (Baker et al. 2007). Greater emissions of the more potent greenhouse gas nitrous oxide are feared to actually increase the net greenhouse gas balance of no-tillage (Li et al. 2005).

The heavily investigated carbon dioxide capture and storage (CCS) may offer a large-scale solution to reduce emissions by diverting carbon dioxide from coal power plants and injecting it into geological formations or ocean bottoms (IPCC 2005). It certainly is not a net sequestration of carbon dioxide. Even if all carbon dioxide emissions from a coal power plant were captured and net emissions were reduced to zero, not a single ton of carbon would be sequestered and the carbon balance of such an operation would be neutral, at best.

Biochar has undeniable advantages over many alternative approaches. Will it play a major role in mitigating global warming? With the financial challenges of acquiring land and biomass resources, the rising costs of energy, and the ever increasing environmental challenges, the production and implementation of biochar is a technology too promising to be overlooked.

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Link

Biochar home:

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