Preface

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Moving forward from "biochar revolution" to "biochar evolution": Shaping a promising mitigation tool demands future research efforts

In February 2013, the 2nd Nordic Biochar Seminar was successfully held in Helsinki, Finland. The fruitful meeting, well organized by Priit Tammeorg, offered a broad kaleidoscope of new insights into the novel interdisciplinary research topic of biochar. The seminar proceedings are available on http://www.biochar-hy.blogspot.fi/p/2nd-nordic-biochar-seminar-proceedings.html.

First of all, what is "biochar"? To date the term is widely used to describe the pyrogenic solid product of pyrolysis made from various biogenic feedstocks and intended for beneficial soil amendment. Why is "biochar" so exciting for many scientists from quite different disciplines? As often in human history, research ignited when the time had come, and the need for it grew: The atmospheric loading with CO_2 accelerates, fueled by continued transfer of fossil carbon into the atmosphere. In addition, the fertile land area for food production is declining but humankind is growing, in number as well as in per-capita resource consumption. Moreover, mankind introduces each year more reactive N into the global N cycle than natural processes do (Galloway et al. 2008), resulting in increasing emissions of the potent greenhouse gas nitrous oxide (N_2O). To meet these challenges soil degradation must be reversed, soil fertility improved and the greenhouse gas "costs" associated with agricultural production must be reduced. Recent research revealed that fertile black-earth soils contain considerable amounts of pyrogenic carbon; the most prominent example are the fertile Amazonian dark earth (ADE, or Terra preta) soils in Brazil (Glaser and Birk 2012).

Lately the "biochar idea" gathered speed, attracting considerable research attention: It seems so logical and attractive to first withdraw CO_2 from the atmosphere by photosynthesis, then to transfer the biomass-C into a recalcitrant form by pyrolysis (using the products heat and bio-oil), and finally to improve soil fertility and reduce the GHG "costs" of agricultural production by amending soils with biochar (Lehmann 2007, Woolf et al. 2010). However, biochars can be tremendously different, and temperate or boreal soils may respond completely different compared to tropical soils where the majority of biochar research has been conducted until recently. Thus, the presentations held at the 2nd Nordic Biochar Seminar and the papers reported in this issue help to close such knowledge gaps.

In this issue, Kettunen and Saarnio investigated the possibility to reduce GHG emissions by biochar amendment to soils. A recent meta-analysis revealed that biochars made from low-nutrient feedstock can be expected to significantly reduce N_2O emissions from soils (Cayuela et al. 2014). Freezing and thawing often leads to large N_2O emission peaks; freeze-thaw periods can contribute more than 50% of the annual N_2O-emission balance. However so far it has not been investigated if biochar can reduce N_2O emissions during thawing: Kettunen and Saarnio found that it did, and, moreover it also reduced the leaching of nitrate and ammonium, providing another important environmental benefit.

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The enigmatic Amazonian dark earths (ADE) or Terra preta soils still hold many secrets. They are not only enriched in pyrogenic carbon, but also in humus and nutrient contents, cation exchange- and water holding capacity, and they have distinctively different soil microbial communities. More research is clearly needed. Thus, “finding Terra preta” is the topic of Söderström et al. In this issue they report on their efforts to develop new non-invasive scanning and detection techniques using proximal soil sensing and fuzzy classification for identifying Amazon dark earths at *terra firme* upland sites.

The contribution of Karer et al. aims at reducing a considerable gap in biochar research, i.e. the sparseness of larger-scale European field trials. They added two amounts of biochar up to a high dosage to two field sites with different soil properties and fertility, and investigated plant yields and nutrient dynamics over two years. No negative effects of biochar were observed up to the rather large application rate of 72 t ha^{-1} when all treatments received the same amount of N fertilizer. However, significant yield increases of 10% only occurred once, during drought conditions, and Karer et al. assume that biochar addition may have increased the amount of plant-available water. Using the same field sites and additional mesocosms in the greenhouse, Anders et al. investigated the soil microbial community dynamics over more than one year after biochar amendment, thus providing more than just a single snapshot in time. The authors report distinct shifts in the microbial community structure rather than an increase in the total microbial biomass which was increased only when a low-temperature biochar was added.

The papers in this issue, as well as the presentations at the 2nd Nordic biochar seminar clearly show that biochar use in agriculture can deliver benefits such as reductions in N_2O emissions or N leaching (Kettunen and Saarnio), in addition to soil C storage without negative effects (Karer et al. , Anders et al.). However, they also demonstrate that just one biochar addition does not turn each temperate fertile soil into a fertility miracle. In Terra preta sites, the pyrogenic carbon was likely an important ingredient, but it was combined with organic waste inputs and not used pure. Thus, yield-increasing pure-biochar effects in temperate soils are likely not a low-hanging fruit to be harvested without further ado. Rather, problematic soils should be the primary target; combined biochar-organics usage also deserves further research. However, considering the lack of political efforts to restore our planet’s radiative balance, or tackle the challenges associated with soil degradation and resource consumption, no emerging chances should be missed. “Biochar” is such a chance – not more, but also not less. Shaping “biochar use in agriculture” into a safe, sustainable and economically feasible tool will only come at the cost of good hard research efforts; but it offers the unique chance to turn agricultural practices from being part of the problem into being part of the solution.

References

Cayuela, M.L., van Zwieten, L., Singh, B.P., Jeffery, S., Roig, A. & Sánchez-Monedero, M.A. 2014. Biochar’s role in mitigating soil nitrous oxide emissions: A review and meta-analysis. *Agriculture, Ecosystems & Environment*, in press.

Galloway, J.N., Townsend, A.R., Erisman, J.W., Bekunda, M., Cai, Z., Freney, J.R., Martinelli, L.A., Seitzinger, S.P. & Sutton, M.A. 2008. Transformation of the Nitrogen Cycle: Recent Trends, Questions, and Potential Solutions. *Science* 320: 889−892.

Glaser, B. & Birk, J.J. 2012. State of the scientific knowledge on properties and genesis of Anthropogenic Dark Earths in Central Amazonia (terra preta de Índio). *Geochimica et Cosmochimica Acta*. 82: 39−51.

Lehmann, J. 2007. Bio-energy in the black. *Frontiers in Ecology and the Environment.* 5: 381−387.

Woolf, D., Amonette, J.E., Street-Perrott, F.A., Lehmann, J. & Joseph, S. 2010. Sustainable biochar to mitigate global climate change. *Nature Communications* 1: 56.