Biochar as a CDR technology: where does it stand and can it be combined with other CDR methods?

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My presentation will touch X fields within the broad topic of biochar / pyrolysis: (1) Its use, status and inclusion as a negative emission technology for carbon dioxide removal (CDR), why we need the latter, and where volun-tary markets, trading platforms and Measurement, Reporting and Verification (MRV) schemes stand today; (2) An overview over the results from > 200 metastudies on biochar-CDR, largely on biochar's use in agriculture, and what we have learned via research over the past 15 years; and (3) results from some of my own projects some of which are part of Germany's national research efforts to gain knowledge and understanding of differ-ent CDR technologies, their economic and environmental chances, challenges and drawbacks, and, in our case, synergies between two of them, the use of biochar and rock powder (enhanced weathering) in soils.

In the following, I give some insights into (1) and (3).

Biochar use in agriculture, landscape architecture and in building materials can deliver net CDR when the bio-mass used for pyrolysis is sustainably sourced. Currently, a new IPCC methodology is developed where bio-char will be included to develop national inventory methods (comparable to the national GHG inventory meth-ods) for quantifying national CDR budgets. Countries such as Denmark have included biochar-CDR (PyCCS, pyrolysis for carbon capture and storage) into their national strategies. For CDR trading, five well-adopted vol-untary MRV schemes exist that grow rapidly, which I will compare based on a study carried out by the Intera-tional Biochar Initiative (IBI). Moreover, trading platforms and C-sink accounting has developed rapidly so that Biochar-CDR currently dominates the worlds' leaderboards on actually delivered (and not just promised) CDR.

The German Ministry for Education and Research funds 10 research consortia that deal with exploring different carbon dioxide removal (CDR) techniques, their potentials and side effects, under the umbrella of the CDRterra research program (https://cdrterra.de/). Our consortium "PyMiCCS" (Pyrolysis and Mineral Weathering for Carbon Capture and Storage) explores the synergetic potential of combining (1) pyrogenic carbon capture (bi-ochar) and (2) enhanced weathering (EW); both can theoretically (3) enhance soil organic carbon (SOC besides the C in biochar), and thus increase (4) biomass carbon capture (BCC). These nature-based solutions have high TRLs and can be implemented globally by using low- as well as high-tech approaches. PyMiCCS focuses on potential synergies or cancelling-out effects of combining biochar and rock powder (EW), either pre- or post-pyrolysis. Co-pyrolysis may increase the C-yield in rock-enhanced biochar (RE-biochar) when a feedstock is pyrolyzed with rock powder [1, 2] while biochar has overall positive effects on several agronomically relevant soil parameters [3, 4]. PyMiCCS applies a cascade of iterative experiments and analyses from the lab to the field scale, with and without soils and plants, to produce the data needed to parameterize global models for C-sink potential analyses and to assess the economic feasibility. Experiments investigate the separate and com-bined CDR potential of EW (i) under controlled conditions; (ii) in soils without plants and (iii) in soils with plants (greenhouse and under controlled field

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conditions) and in (iv) field experiments in the tropics (Kenya). Experi-ments in (iii) include measurements of environmental side effects (nitrate leaching, N2O emissions) that can impact the net CDR balance compared to the use of single applications of both rock powder or biochar. I will report results from the first 1.5 to 2 years from the four experimentally-working subgroups of the PyMiCCS consortium (University of Hamburg with two consortium subgroups on EW and soil processes), Ithaka Institute (PyMiCCS-products, C-fixation, tropical field experiments in Kenya), and Geisenheim University (greenhouse and controlled-field experiments in the presence of crop plants including N losses)..

Keywords: Carbon Dioxide Removal, biochar, enhanced weathering, nitrate leaching, Nitrous oxide

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