Geophysical Research Abstracts
Vol. 21, EGU2019-5219, 2019
EGU General Assembly 2019

Pyrogenic Carbon Capture and Storage (PyCCS) – potentials, trade-offs and co-benefits

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Negative emission (NE) technologies are recognized to play an increasingly relevant role in strategies limiting mean global warming to 1.5°C as specified in the Paris Agreement. The potentially significant contribution of pyrogenic carbon capture and storage (PyCCS) is, however, highly underrepresented in the discussion. PyCCS is a NE technology based on pyrolysis, the thermal treatment of biomass at temperatures of 350–900°C in an oxygen-deficient to anoxic atmosphere. Three main carbonaceous products are generated in this conversion, which can subsequently be stored in different ways to produce NE: a solid biochar, a pyrolytic liquid (bio-oil), and permanent pyrogases. The storage of the recalcitrant biochar in arable soils is particularly worthy of consideration within NE strategies due to its technological adaptability and co-benefits for agricultural productivity. Applying biochar to arable soils has been shown to improve soil fertility and increase crop yields significantly in many regions around the world.

In the BioCAP-CCS project, we conducted the first quantitative assessment of the global potential of PyCCS as a NE technology based on biomass plantations. Using the process-based biosphere model LPJmL, we calculated the land use change required to reach specific climate mitigation goals while observing biodiversity protection guardrails.

The results indicated that meeting the 1.5°C target through mitigation strategies including large-scale NE with plantation-based PyCCS may require conversion of natural vegetation to biomass plantations in the order of 146–3,328 Mha globally, depending on the applied technology (storage of biochar only or bio-oil and permanent pyrogases additionally) and the NE demand (a range given by socioeconomic projections). Advancing towards additional bio-oil sequestration reduces land demand considerably by potentially up to 60%. In addition, we analyzed how the gain in land induced by biochar-mediated yield increases on tropical cropland may reduce the pressure on land. These benefits account for another 17–46% area reduction (equaling 142–410 Mha).

However, any land conversion needs to be considered thoroughly, as land use change is estimated one of Anthropocene's most destructive forces in the Earth system. Sacrificing biosphere integrity for climate change mitigation will most likely cause further uncontrollable dynamics threatening humanity's basis of life. Thus, the conversion from natural to cultivated land should be reduced to a minimum.

In our second study, we address the potential of PyCCS as a NE technology relying solely on arable land that is already cultivated. We quantify the NE potential of a PyCCS scheme that uses 20% of the tropical cropland for feedstock production (fast-growing grasses) based on the assumption that biochar-mediated yield increases enable food production on less land. In a meta-analysis, Jeffery et al. (2017) calculated an average yield increase of 25% in the tropics that would potentially "clear" 20% of the cropland. We furthermore evaluate to what degree this scheme helps to save land and water resources, protect biodiversity and support healthy soils.

In this EGU session, we will jointly present the results of the first study evaluating the maximum potential of PyCCS and the latest findings for the impact-reduced scheme of the second analysis.