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# Low climate potentials but large side-effects of terrestrial $CO_2$ removal – insights from quantitative model assessments

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Terrestrial carbon dioxide removal (tCDR) through dedicated biomass plantations is considered as one climate engineering (CE) option if implemented at large-scale. The Royal Society judged afforestation projects to be of lower risk and more affordable than other CE options. However, tCDR is only moderately effective and its implementation requires both long time horizons and extensive cultivation areas.

The dynamic global vegetation model LPJmL simulates such large-scale, effectively managed biomass plantations and enables us to assess their associated tradeoffs from an earth system-analytic perspective. Therefore, we analyzed 12 scenarios including a range from far-fetched (e.g. conversion of all cropland) to more conservative (e.g. 10% of the agricultural area) assumptions about the transformed areas. Furthermore, the implementation of tCDR takes place immediately at full scale after the 2°C target is crossed around 2050 in an RCP8.5 storyline. The resulting tCDR potentials in year 2100 include changes in all land carbon pools and 50% of the accumulated annual biomass harvests to include leakage effects.

The climate potentials of tCDR are not sufficient to bring global mean temperatures down to the 2° target in 2100 under otherwise RCP8.5 emissions. Even on maximum spatial scales diminish carbon emissions of the massive land use and land cover changes the tCDR effectiveness. Smaller tCDR plantations do not build up enough biomass over this period and high leakage rates substantially lower the potential to achieve global warming reductions of more than 1°C.
Finally, we demonstrate that the (non-economic) costs for the Earth system also include negative impacts on the water cycle and on ecosystems, which are already under pressure due to land use and climate change. Overall, tCDR may lead to a further transgression of land- and water-based planetary boundaries while not being able to set back the crossing of the boundary for climate change.