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Scenarios of global agricultural biomass harvest reveal conflicts and trade-offs for bioenergy with CCS

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We assess the quantitative potential for future land management to help rebalance the global carbon cycle by actively removing carbon dioxide (CO_2) from the atmosphere with simultaneous bio-energy offsets of CO_2 emissions, whilst meeting global food demand, preserving natural ecosystems and minimising CO_2 emissions from land use change. Four alternative future scenarios are considered out to 2050 with different combinations of high or low technology food production and high or low meat diets. Natural ecosystems are protected except when additional land is necessary to fulfil the dietary demands of the global population. Dedicated bio-energy crops can only be grown on land that is already under management but is no longer needed for food production. We find that there is only room for dedicated bio-energy crops if there is a marked increase in the efficiency of food production (sustained annual yield growth of 1%, shifts towards more efficient animals like pigs and poultry, and increased recycling of wastes and residues). If there is also a return to lower meat diets, biomass energy with carbon storage (BECS) as CO_2 and biochar could remove up to 4.0 Pg C per year in 2050. With the current trend to higher meat diets there is only room for limited expansion of bio-energy crops after 2035 and instead BECS must be based largely on biomass residues, removing up to 1.5 Pg C per year in. A high-meat, low-efficiency future would be a catastrophe for natural ecosystems (and thus for the humans that depend on their services) with around 8.5 Gha under cultivation in 2050. When included in a simple earth system model with a technological mitigation CO_2 emission baseline these produce atmospheric CO_2 concentrations of $\sim$ 450-525ppm in 2050.
In addition we assess the potential for future biodiversity loss under the scenarios due to three interacting factors; energy withdrawal from ecosystems due to biomass harvest, habitat loss due to land-use change, and climate change. Forecasts of committed global biodiversity loss in 2050 (from 2000 levels) vary by more than a factor of two across the scenarios. The greatest biodiversity loss is forecast in the ‘high meat low efficiency’ scenario with roughly equal contributions from biomass harvest and climate change, and a smaller land-use change contribution. The smallest biodiversity loss is forecast in the ‘high meat high efficiency’ scenario and is mostly due to biomass harvest, followed by climate change. Climate change is lowest in the ‘low meat high efficiency’ efficiency scenario thanks to BECCS based on bio-energy crops, but the resulting withdrawal of energy from ecosystems has a greater negative impact on biodiversity than the positive effect of less climate change. This suggests that using bio-energy to tackle climate change in order to limit biodiversity loss would instead have the opposite effect.