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Effects of an advanced land-use scheme and dynamic vegetation on the terrestrial carbon cycle in EC-Earth

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With human land-use activities expected to increase in the future it is important to understand how LULCC (Land-Use Land-Cover Change) activities affect the Earth's surface, climate and biogeochemical cycles. Here we use the CMIP6 version of the EC-Earth3 Earth System Model (ESM) to assess the impacts of LULCC on surface fluxes of carbon (C) and nitrogen (N). EC-Earth is one of the first ESMs to interactively couple a 2nd generation dynamical vegetation model (LPJ-GUESS) with mechanistic C-N dynamics in soil and vegetation to an atmospheric model. The size, age structure, temporal dynamics and spatial heterogeneity of the vegetated landscape are represented and simulated dynamically in LPJ-GUESS. Such functionality has been argued to be essential to correctly capture biogeochemical and biophysical land-atmosphere interactions on longer timescales and has been shown to improve their representation compared to more common area-based vegetation schemes. The patch based structure of LPJ-GUESS also makes it possible to represent the history (soil, litter status) of a single patch as it might have been involved in several land-use transitions. We focus on the effects of gross land-use transitions ("land-hist"), net land-use transitions ("land-noShiftcultivate") and fixing land-use at 1850 levels ("land-noLu").

Global carbon pools increase in simulations without LUC while they decline in those applying LUC, with gross-transitions resulting in values around 3% (or 75 Pg) lower than simulations with net-transitions. This is mainly driven by vegetation carbon changes in the tropical to mid-latitude regions where gross-transitions lead to a significantly higher decrease in high vegetation cover. Furthermore, this is reflected differently for different species, e.g. while there is no change in the LAI of boreal needleleaf trees in net-transitions, their presence is significantly reduced in gross transition scenarios giving way to the growth of fast-growing shade-intolerant species. Moreover, fire-fluxes, which in these experiments are mainly driven by fuel-availability, are also lowest in the gross-transition simulations.

Finally, we will show that the level of complexity with which shifting cultivation is treated has implications for the biogeophysical feedbacks in ESMs resulting from changes to surface albedo

and latent heat exchange.

The experiments we conducted clearly indicate the benefits of dynamic vegetation and the importance of using gross transitions in land use-change (LUC) studies.