Project: **891**

Project title: **Forest management in the Earth system**

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1. Introduction

The main aim of this project is to better understand the role of land use change for and in a changing climate. Land use change affects about three quarters of the ice-free land surface. Land management (such as crop or forestry harvest) has been increasingly identified to matter substantially for climate and biogeochemical cycles even on global scale. Our group therefore fosters the development of the MPI Earth system model towards including management practices to better understand and quantify the human impact on the Earth system (see sections 3, 4, 6 below). But it also deals with fundamental gaps in our process understanding of land use change effects on climate in general (section 2 and 5). We report here on the progress of the projects proposed in the request for DKRZ resources for 2017.

2. Local and nonlocal effects of deforestation

Land use change affects local climate directly by changes in surface properties, such as altering surface albedo, but also affects climate remotely via changes in atmospheric composition and circulation, in particular for scenarios of global land use change. The work of the last allocation periods dealt mostly with the local effects and used AMIP-type simulations. Now, the nonlocal effects were addressed. These required MPI-ESM simulations to capture the full climatic response including far-reaching effects and ocean feedbacks. Nonlocal effects are not included in the observation-based datasets that recently were published and are applied to policy-relevant questions of using land use change for climate mitigation. The nonlocal effects therefore prevent a consistent comparison between the total deforestation effects simulated by climate models and those captured by observations. We show that separating local and nonlocal effects makes climate simulation results more comparable to observations and that the nonlocal effects of deforestation contribute a global cooling signal that is stronger than the local warming, questioning the applicability of observations alone for policy-relevant statements (Winckler, 2017; Winckler et al., 2017).

3. Soil carbon responses to land-use changes

Historical changes in soil carbon associated with land-use change result mainly from the changes in the quantity of litter inputs to the soil and the turnover of carbon in soils. We use a factor separation technique to assess how the input-driven and turnover-driven controls, as well as their synergies, have contributed to historical changes in soil carbon associated with land-use change. We apply this approach to equilibrium simulations of present-day and pre-industrial land use performed with JSBACH. Our results show that historical losses in soil carbon due to land use change were mostly driven by a reduction in input rather than a change in turnover. Further, omitting land management through crop and wood harvest substantially reduces the global losses through the input-driven changes, to about half. Our study thus suggests that the dominating control of soil carbon losses is via the input-driven changes, which are more directly accessible to human management than the turnover-driven ones, and that land management has substantial effects on the global carbon balance (Nyawira 2017; Nyawira et al., 2017). The latter has also been confirmed by observational studies for vegetation carbon (Erb et al., in press).

4. CO2-fertilization hypothesis

All Earth system models account for the effect of increasing CO2 on photosynthesis under optimal growth conditions, but observational evidence from close-to-natural ecosystems is still inconclusive with respect of the persistence of this effect in forest growth, with several studies indicating increased water use efficiency, but not growth in mature ecosystems (e.g. Penuelas et al. 2011; van der Sleen 2014). The new representation of forest regrowth in JSBACH (see last year's report) allows us to test the hypothesis of no growth stimulation in mature forest (irrespective of the underlying causes) in terms of its consistency with our current understanding of the global carbon cycle. We derive rotational cycles for managed and disturbance cycles for unmanaged forests typical for present-day conditions from global forest age maps. Then we perform two sets of C4MIP-type simulations in which CO2 is increased by 1% each year: The first keeps the current implementation of CO2 effects on plant photosynthesis, in the second the CO2- fertilization effect was limited as soon as the forest reaches maturity (Körner, 2006). We find that the cumulative loss of carbon over the 21st century is about 200 PgC when assuming old-growth forests stop to react to increasing CO2 levels. This is the order of magnitude that the IPCC AR5 model mean suggests as terrestrial carbon sink for the RCP8.5 future scenario. The resulting temperature anomaly yields an increase of 0.21 to 0.64 K for limited CO2 fertilization at the time of CO2 quadrupling (Vogt, 2017). Both results suggest that our climate-carbon cycle models are challenged in their quantitative results should the hypothesis of limited growth stimulation prove true.

5. Participation in TRENDY

JSBACH has again participated in the long-standing MIP of the Global Carbon Project, TRENDY ("Trends in the global carbon cycle"), which delivers annual updates of the global carbon budget (Le Quéré et al., 2016; Le Quéré et al., subm.). This year, the FOM group also contributed with a second model, the bookkeeping of land-use emissions model BLUE (updated version of Hansis et al., 2015), which is used as one of two models to quantify the net land use change flux (fLuc). Extension of the budget analysis beyond one single model to quantify fLuc is a major methodological novelty.

6. Test and first application simulations for cohort structure

This part of the project has been delayed due to unforeseen delays in the MPI-M providing the JSBACH4 base version including a carbon cycle, which is required to implement cohorts. It can partly be tackled in the last months of the year.

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