Project: **891**
Project title: **Forest management in the Earth system**
Principal investigator: **Julia Pongratz**
Report period: **2020-11-01 to 2021-08-31**

1. Introduction

The main aim of this project is to better understand the role of land use for and in a changing climate. Land use affects about three quarters of the ice-free land surface. One previously often neglected form of land use – land management (such as forestry harvest) – has been increasingly identified to matter substantially for climate and biogeochemical cycles even on global scale. The importance of land-based mitigation and adaptation to climate change contributes to this increase in awareness. Our group therefore fosters the development of the MPI Earth system model, as well as of the ICON model, towards including land management practices and required structural land representations to better understand and quantify the human impact on the Earth system (see sections 3 and 5). But it also deals with fundamental gaps in our process understanding in general (section 2 and 4). We report here on the progress of the projects proposed in the request for DKRZ resources for end of 2020 to first half of 2021.

2. Drought mortality effect

The Amazon forests are one of the largest ecosystem carbon pools on Earth. However, climate projections predict more frequent and prolonged droughts in the Amazon basin (Joetzjer et al., 2013), and most vegetation models are shown unable to capture the observed drought responses there (Powell et al., 2013, Joetzjer et al., 2014). In 2019 we conducted simulations with a modified JSBACH version that incorporated new formulations of leaf phenology and litter production based on intensive data from the throughfall exclusion experiments in the Amazon (Nepstad et al., 2006, Fisher et al., 2007). We conducted simulations with the improved MPI-ESM to quantify the climate feedback of future direct (soil drying) and LAI (leaf shedding) effects separately. In 2020, further ensemble simulations were conducted with both the standard and modified versions, and we found that the leaf shedding plays an important role in reducing future carbon uptake in the Amazon (Wey et al., submitted). In addition, we implemented an empirical-based formulation for drought-enhanced tree mortality and found that with the drought-enhanced mortality, the vegetation carbon growth will be reduced by more than 60% by the end of the 21st century (Wey, 2021).

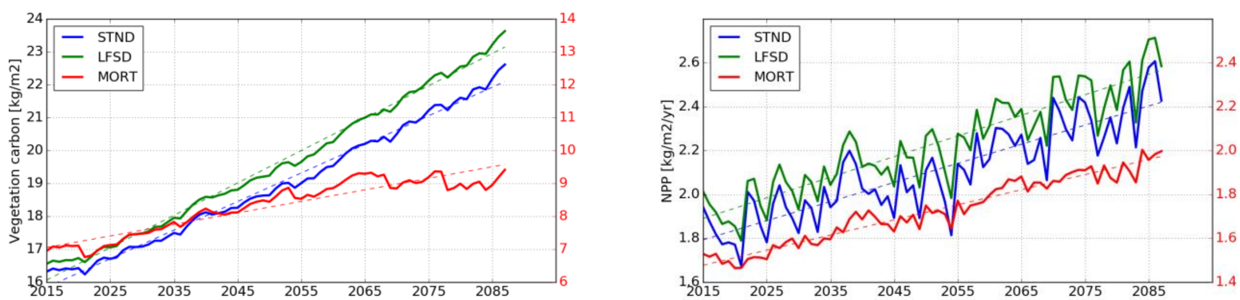

Fig 1. Comparisons between simulations of standard version (STND), leaf-shedding-only version (LFSD) and version incorporating both leaf shedding and mortality (MORT). (Left panel) vegetation carbon. (Right panel) net primary production (NPP). Note that MORT has a shifted y-axis shown at the right-hand side in red.

3. Development of a common area concept for ICON-L towards simulations with the forest age structure

Land use, particularly de- and reforestation and forest management, alter the forest age structure. Although biogeochemical as well as biophysical effects of such structural changes are known to be strong (Erb et al., 2016), many land surface models neglect age effects (Pongratz et al., 2017) and assume ageless or mean-age forests. As described in previous reports, we approached this fundamental gap in JSBACH4 and developed an efficient forest age class module (Nabel et al., 2018, 2020).

In 2018-2020 and in the current period we conducted various test-simulations with JSBACH4 standalone, as well as JSBACH4 in ECHAM6-AMIP and ICON-AMIP. Delays in the general development of ICON/JSBACH4 and of presupposed applications with this model in other projects (suitable carbon equilibrium not yet available; land-use transitions not yet implemented; still no common infrastructure for land cover change (lcc) processes) prevented planned productive applications. In order to enable the full integration of the forest age structure with other lcc processes we now fostered the development and implementation of a common area concept for ICON-L, implemented anthropogenic lcc using maps within this newly implemented area concept, and tested the new concept in JSBACH4 standalone simulations in ECHAM and ICON environment as well as in short simulations in the ICON-AMIP setup.

4. Participation in TRENDY

In this allocation period 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 (Friedlingstein et al. 2020). TRENDY simulations are not only used in the global carbon budget, but also in the framework of the REgional Carbon Cycle Assessment and Processes (RECCAP; e.g. Bastos et al. 2020) and for other further reaching studies, e.g. studying different approaches to assess and thereby increase the understanding of land-use emissions (Obermeier et al. 2021), or comparison to/ cross-consistency checks with observational data (Chen et al., 2021a,b; O'Sullivan et al. 2020).

5. BLUE simulations at high resolution and adjusted high-resolution harvest dataset

BLUE (Bookkeeping of Land-Use Emissions) is one of three bookkeeping models used in the GCB2020 for estimating ELUC. The default resolution of BLUE is 0.25° x 0.25° degrees. In the past year we were able to incorporate new high-resolution land-use change data (HILDA+) in the BLUE model, create an adjusted high-resolution harvest dataset and semi-parallelised the BLUE model to be able to run it at a 25 times higher resolution (now 0.01° resolution). Results show significant differences in ELUC estimates depending on the resolution of the input data. Globally, ELUC estimates based on the same LULCC data at 0.25° and 0.01° resolution are on average 59 TgC/y lower with the high-resolution data (time period 1960-2019). These differences are due to an effect of "iterating transitions", which implies that - despite having the same transition areas - overall less area remains unchanged at the coarser resolution compared to the finer resolution (Ganzenmüller et al., in prep.). This effect has not been described in the literature so far.

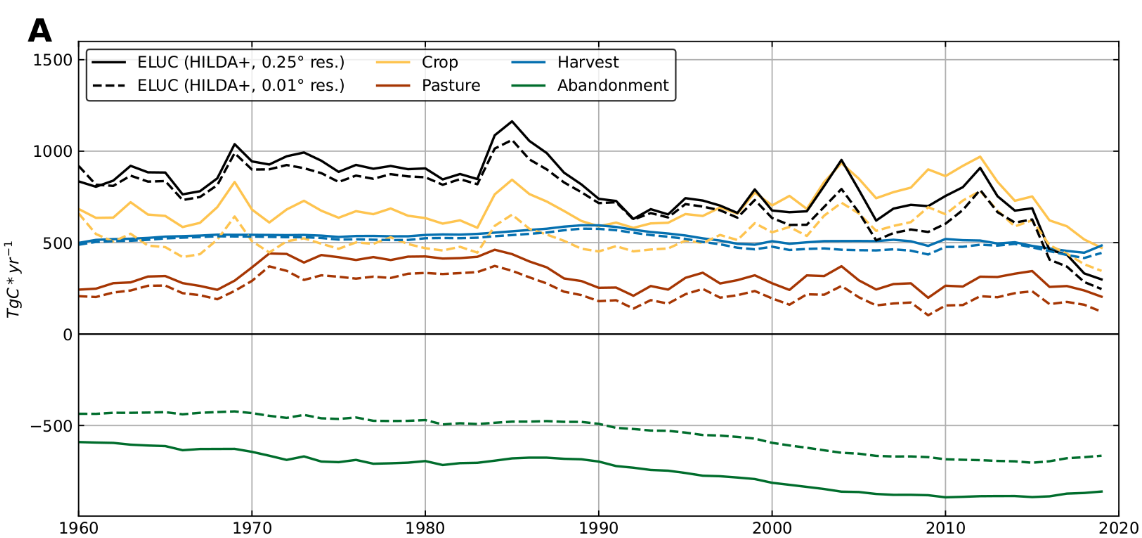

Figure 2: Estimates of ELUC and component fluxes based on HILDA+ at 0.25° and 0.01° resolution.

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