Project: **1147**

Project title: **LAnd MAnagement for CLImate Mitigation and Adaptation**

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1. Overview and simulation description

Until the end of the reporting period and during the entire project time starting in the year 2020 we created large and diverse data sets consisting of several historic, present-day, and future scenario simulations from three different Earth system models (ESMs, MPI-ESM-1.2-LR, CESM2, EC-Earth3-Veg and -CC). MPI-ESM-1.2-LR was run on mistral and last year on levante, model output of all three ESMs is storend on levante archive project in order to ensure data exchange between all project partners. The first set of present-day condition scenarios applying different land cover changes and land management practices were conducted during the years 2020 and 2021 are already described in detail in the report for the period of 2020 and 2021. Due to different research foci within the BMBF funded LAMACLIMA project we are still making use of these simulation results and are in exchange with scientists outside the LAMACLIMA project who want to make use of the data. Section 2 describes our current study in preparation, in which we highlight the combined effects of climate change adaptation and mitigation practices on land on both, biogeoechmistry (i.e. C-cycle) and biogeopyhscis on the local and non-local scale. During the year 2023 we additionally conducted in total four fully coupled (land, atmosphere, and ocean) emission-driven scenario simulations consisting of the following transient historical and transient future scenarios: (1) Historical control scenario (histCTL) from 1980-2014 with a 5 years spin-up and a 30 years period using transient fossil fuel emissions forcing with constant present-day land-use; (2) Future control scenario (futCTL) from 2015-2100 using transient fossil fuel emissions forcing (SSP1-1.9) and constant present-day land-use; (3) Future sustainability scenario (futSust) from 2015-2100 using transient fossil fuel emissions forcing (SSP1-19) and transient MAgPIE global sustainability land-use scenario (Humpenöder et al., 2022); (4) Future inequality scenario (futIneq) from 2015-2100 using transient fossil fuel emissions forcing (SSP1-19) with transient MAgPIE global inequality land-use scenario (Humpenöder et al., 2022). All scenario runs were simulated as an ensemble of three model runs. The histCTL scenario (1) branches off from three different realizations of CMIP6 historical emission-driven runs (esm-hist). All future ensemble simulations (2)-(4) were initialized from the three simulations of histCTL scenario (1). We summarize our first analyses in Section 3.

2. Land use impact on climate and C-cycle from local, regional and global perspective

What makes this analysis unique is the calculation of the local biogeochemical (BGC) effect as a consequence of the local biogeophysical (BGP) effect. To our knowledge, this local BGC effect has not yet been demonstrated in any scientific publication before. Different than the previously used and adapted approach of the publication by Winckler et al, 2017 (doi: 10.1175/JCLI-D-16-0067.1), the separation between local and non-local signal needs to be conducted within an ESM grid cell separately for each land class defined in the model. Local effects of land-use change on surface air temperature and the terrestrial carbon pool can be compared by the decreased or enhanced greenhouse gas effect by uptake or emission of CO_2 by land use. In some regions, this greenhouse gas effect due to regional land-use change is comparable in magnitude to the BGP effect, and thus can contribute to local climate adaptation. In addition, the BGP effect may contribute to climate mitigation. The non-local effect of land-use change on the surface air temperature becomes significant under intense land-use change and has rates of change similar to the local effects. The same is observed for changes in terrestrial carbon content: non-local effects with local changes can thus be of similar magnitude, particularly for influences due to irrigation of agricultural land. In summary we will quantify:

1. How do local land-use changes affect us? By induced climate change via water and energy flux changes (local biogeophysical effect) and direct change of the terrestrial carbon stock (local carbon cycle effect), which alters global and local temperature by greenhouse gas effect.
2. How do remote land-use changes affect us? By changed global temperatures via the

greenhouse gas effect (temperature impact of local carbon cycle effect), changed climate via teleconnection and advection (remote biogeophysical effect), and remarkably and unintendedly alter carbon cycle of remote regions via climate change (non-local carbon cycle effect). 3. How do land-use changes contribute to global mitigation? By altering the global carbon stock change, non-local BGP effects, and the global effects of local BGP effects.

3. Land use and temperature development of future sustainability and inequality scenarios

After two conversion steps and by applying the land-use change transition scheme, the simulated land-use area changes by MPI-ESM-1.2-LR (Fig. 1) still correspond well to those of the original data-set from the MAgPIE model (Humpenöder et al., 2022) at the global scale.

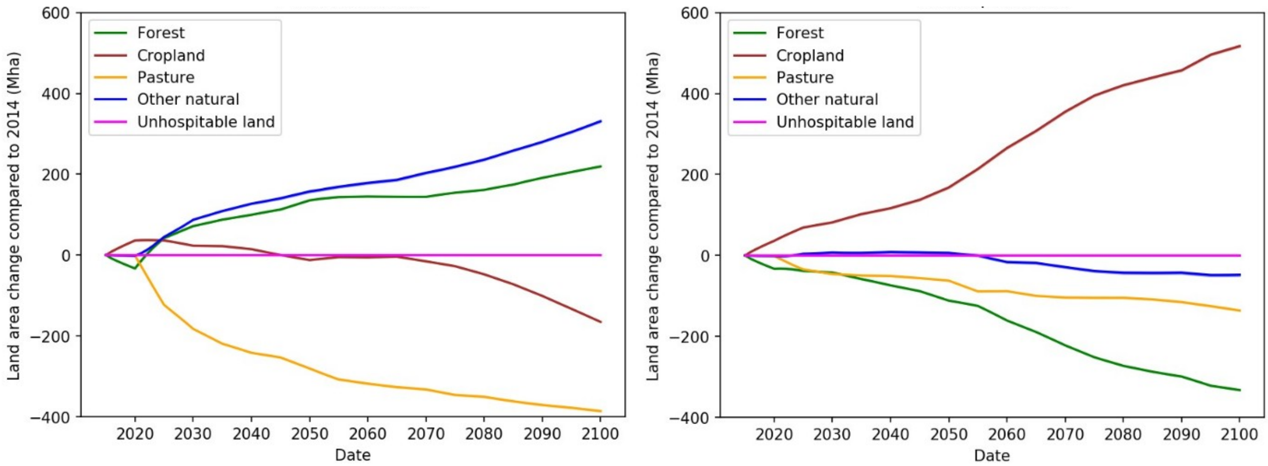

Figure 1: Development of global land use areas based on the categories forest, cropland, pasture, and other non-forest natural land in the two scenarios future sustainability (left) and future inequality (right) simulated with MPI-ESM-1.2-LR.

Results of the global mean temperature with MPI-ESM-1.2-LR (see Fig. 2) show that all three future scenarios are simulated with a relatively similar global mean temperature trend: a temperature difference of 0.2 K is expected by the year 2100. This suggests that in the model, drastic reduction and avoidance of fossil emissions, as described in the SSP1-1.9 scenario, have a large impact on temperature trends. In contrast, rather ambitious global sustainability goals or a world with only low societal cohesion lead to a comparatively small change in global mean temperature due to their influence on the land-use sector. However, the transformation of the land use sector can make a substantial contribution to how well the goals of the Paris Agreement are met. In terms of climate impacts such as extreme weather events and maximum temperature development during the 21st century, every tenth of a degree counts (IPCC Summary for Policy Makers WGI, 2021).This is where sustainable land use development can contribute to global climate change mitigation.

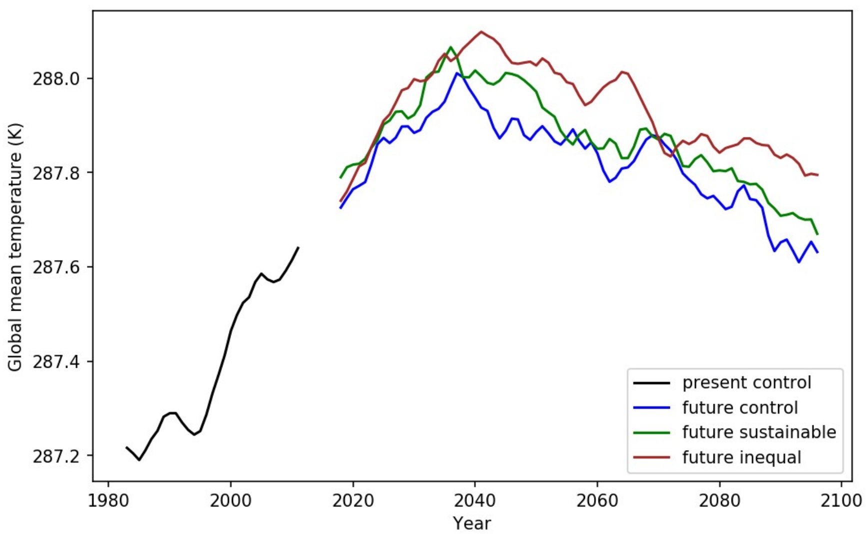

Figure 2: Evolution of the global mean temperature until 2100 based on three different scenarios (future control, future sustainability, and future inequality) simulated with MPI-ESM-1.2-LR.