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Analysis of trade-offs between bio-energy demand, food production, and carbon management in global land-use change scenarios

E. Kato and Y. Yamagata
Center for Global Environmental Research, National Institute for Environmental Studies, Japan (kato.etsushi@nies.go.jp)

For the simulation of long-term future climate changes in the CMIP5 experiments, Representative Concentration Pathways (RCPs) are used as input data. The RCPs provide spatially explicit land-use change scenarios along with the emissions and concentrations of greenhouse gases and aerosols. CO_2 emissions from land-use change are provided as a second largest anthropogenic source of CO_2 along with the emissions from fossil fuel combustion in these scenarios. And CO_2 concentration paths for each RCPs, which is the primary forcing of the concentration-driven simulations of CMIP5, have been constructed with those two CO_2 emissions by a simple climate-carbon model.

However, in CMIP5, Earth System Models (ESMs) are simulating the land-use change carbon dynamics explicitly within their land surface model forced by the gridded land-use transition data of RCPs instead, and this likely induces inconsistency in the CO_2 emissions and concentrations paths in the model compared to the assumption of the original RCPs. Relative importance of the inconsistency may be large in the lower radiative forcing with lower carbon emission scenarios which use large amount of biomass-based carbon capture and storage (CCS), and should be examined in the process of parallel approach in the climate scenario construction. Also, effects of climate change onto the land-use through the changes in food and biomass crop yield should be considered in the updated process.

In this study, we first evaluated the CO_2 emissions by land-use change in 21st century for each RCPs scenarios using an offline terrestrial biogeochemical model VISIT, considering the carbon emission from deforested biomass and the regrowing uptake from abandoned cropland and pasture using the gridded transition data of RCPs. Effect of CO_2 fertilization, land-use transition itself, and climate change are considered in the analysis. We found that constructing consistent land-use change carbon emission scenario with the gridded land-use change data requires precise considerations of effects of CO_2 fertilization and climate change on to the deforested emission and regrowing absorption, particularly for the regrowing uptake. Also, our result showed the possibility of emitting more CO_2 by the land-use change required in RCP2.6 scenario.

Then, we evaluated the land-use area required to sustain the demanded food crop in each RCPs, and also biofuel production to match the assumption of requirement in bio-energy and CCS (BECCS) using a process based crop model. With the evaluation, we estimated the further changes in carbon emissions by the land-use change due to differences in crop yield assumptions which also take into account of climate change. The trade-offs between land-use for crop, biocrop, and natural vegetation in low-carbon scenario are discussed.