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From land use to land cover: Restoring the afforestation signal in a coupled integrated assessment - earth system model and the implications for CMIP5 RCP simulations

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Climate projections depend on scenarios of fossil fuel emissions and land use change, and the IPCC AR5 parallel process assumes consistent climate scenarios across Integrated Assessment and Earth System Models (IAMs and ESMs). The CMIP5 project used a novel "land use harmonization" based on the Global Land use Model (GLM) to provide ESMs with consistent 1500-2100 land use trajectories generated by historical data and four IAMs. A direct coupling of the Global Change Assessment Model (GCAM), GLM, and the Community ESM (CESM) has allowed us to characterize and partially address a major gap in the CMIP5 land coupling design: the lack of a corresponding land cover harmonization. For RCP4.5, CESM global afforestation is only 22% of GCAM's 2005 to 2100 afforestation. Likewise, only 17% of GCAM's 2040 afforestation, and zero pasture loss, were transmitted to CESM within the directly coupled model. This is a problem because GCAM relied on afforestation to achieve RCP4.5 climate stabilization. GLM modifications and sharing forest area between GCAM and GLM within the directly coupled model did not increase CESM afforestation. Modifying the land use translator in addition to GLM, however, enabled CESM to include 66% of GCAM's afforestation in 2040, and 94% of GCAM's pasture loss as grassland and shrubland losses. This additional afforestation increases CESM vegetation carbon gain by 19 PgC and decreases atmospheric CO_2 gain by 8 ppmv from 2005 to 2040, which demonstrates that CESM without additional afforestation simulates a different RCP4.5 scenario than prescribed by GCAM. Similar land cover inconsistencies exist in other CMIP5 model results, primarily because land cover information is not shared between models. Further work to harmonize land cover among models will be required to increase fidelity between IAM scenarios and ESM simulations and realize the full potential of scenario-based earth system simulations.