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Projecting optimal land-use and -management strategies under population growth and climate change using a coupled ecosystem & land use model framework

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A major question facing humanity is how well agricultural production systems will be able to feed the world in a future of rapid climate change, population growth, and demand shifts—all while minimizing our impact on the natural world. Global modeling has frequently been used to investigate certain aspects of this question, but in order to properly address the challenge, no one part of the human-environmental system can be assessed in isolation. It is especially critical that the effect on agricultural yields of changing temperature and precipitation regimes (including seasonal timing and frequency and intensity of extreme events), as well as rising atmospheric carbon dioxide levels, be taken into account when planning for future food security. Coupled modeling efforts, where changes in various parts of the Earth system are allowed to feed back onto one another, represent a powerful strategy in this regard.

This presentation describes the structure and initial results of an effort to couple a biologically-representative vegetation and crop production simulator, LPJ-GUESS, with the climate emulator IMOGEN and the land-use model PLUMv2. With IMOGEN providing detailed future weather simulations, LPJ-GUESS simulates natural vegetation as well as cropland and pasture/rangeland; the simulated exchange of greenhouse gases between the land and atmosphere feeds back into IMOGEN's predictions. LPJ-GUESS also produces potential vegetation yields for irrigated vs. rainfed crops under three levels of nitrogen fertilizer addition. PLUMv2 combines these potential yields with endogenous demand and agricultural commodity price to calculate an optimal set of land use distributions and management strategies across the world for the next five years of simulation, based on socio-economic scenario data. These land uses are then fed back into LPJ-GUESS, and the cycle of climate, greenhouse gas emissions, crop yields, and land-use change continues.

The globally gridded nature of the model—at 0.5-degree resolution across the world—generates spatially explicit projections at a sub-national scale relevant to individual land managers. Here, we present the results of using the LPJ-GUESS-PLUM-IMOGEN coupled model to project agricultural production and management strategies under several scenarios of greenhouse gas emissions (the Representative Concentration Pathways) and socioeconomic futures (the Shared Socioeconomic Pathways) through the year 2100. In the future, the coupled model could be used to generate projections for alternative scenarios: for example, to consider the implications from land-based climate change mitigation policies, or changes to international trade tariffs regimes.