Future land-use and -management projections under population growth and climate change using a coupled ecosystem & land use model framework

To investigate how land use and its impacts on the terrestrial biosphere might evolve over time, we are coupling the LPJ-GUESS dynamic vegetation model with the PLUMv2 land use model.

LPJ-GUESS simulates soil and vegetation. It provides PLUM with potential yield for crops under different fertilization and irrigation levels, as well as pasture productivity, at 0.5° resolution.

PLUM projects demand for 6 agricultural commodities (4 crop types and 2 livestock types) based on population and economic change projections. It then combines these demand projections with potential yields from LPJ-GUESS to produce maps of suggested land use and management inputs, considering both domestic and international trade.


Results

LPJ-GUESS-PLUM generates realistic maps of cropland and pasture area at the end of the validation run (2010). Below, the LPJ-GUESS-PLUM output for 2010 is compared with the LUH2 dataset (Hurt et al., 2011).

LPJ-GUESS-PLUM also simulates realistic trajectories of change in agriculture area (LUH2) and management inputs (FAO, IFA).

For most commodities in most SSPs, PLUM projects peak global demand around mid-century. SSP3 is the exception, with all demand increasing through 2100. This "rocky road" trajectory presents strong challenges to mitigation (e.g., high population growth) and to adaptation (e.g., decreased international cooperation).

Although global commodity demand mostly peaks around mid-century, the land required to satisfy that demand continually increases. The rate of increase in global cropland area slows after ~2040, at which point fertilizer and irrigation begin to decrease.

Generally, increasing intensity of climate change (and higher CO₂ concentration) results in decreasing management inputs— but there is much overlap among RCPs when considering parameter uncertainty (not shown).

Example: Pasture can replace cropland in SSP1 ("sustainability") but not SSP3 ("rocky road"). Not labelled outputs. ↓

Next steps

Continue to analyze and interpret output.

Quantify impacts of land use (change) and management on ecosystem services.

Complete coupling by feeding PLUMv2 outputs back into LPJ-GUESS.

Couple with IMOGEN climate emulator to capture ecosystem-society-atmosphere interactions.

Extend LPJ-GUESS crops to eliminate calibration step.

Incorporate forestry & products trade.

References available at https://openphil.org/