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

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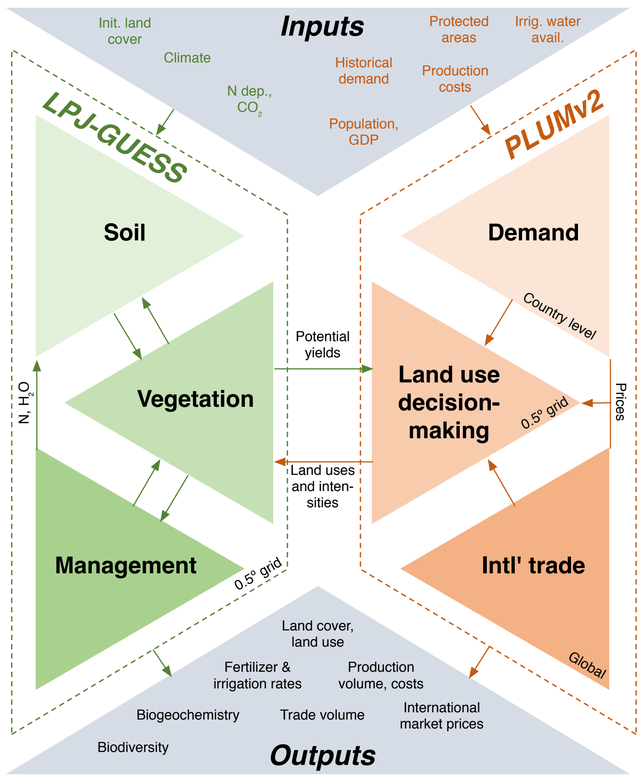
Introduction

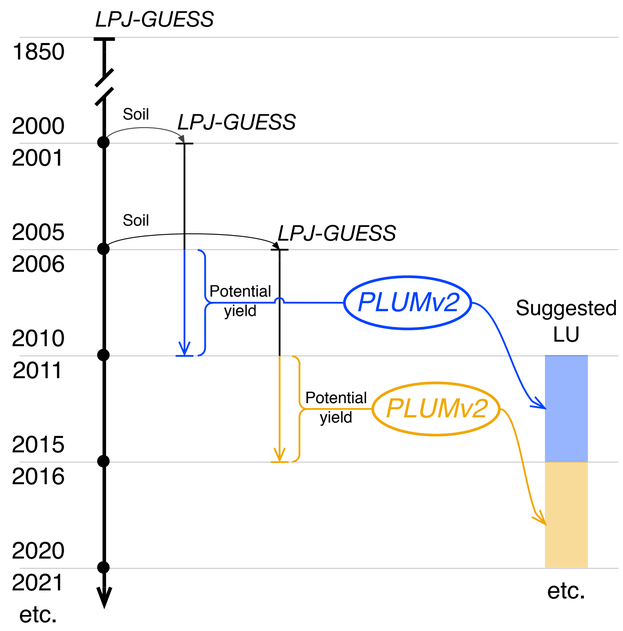
To investigate **how land use and its impacts on the terrestrial biosphere might evolve over time**, we are coupling the LPJ-GUESS dynamic vegetation model with the PLUMv2 land use model.

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.

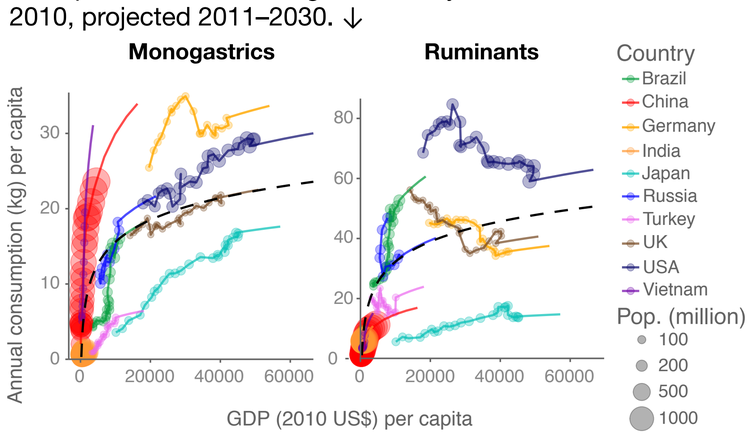
PLUM **projects demand** for 6 agricultural commodities (4 crop types and 2 livestock types) based on population and economic change projections. It then combines these demand projections with potential yields from LPJ-GUESS to produce **maps of suggested land use and management inputs**, considering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



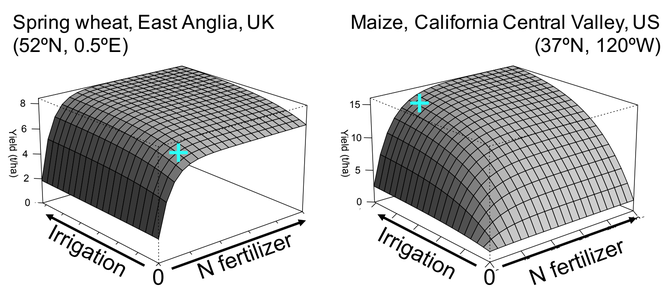
Structure of "one-way" coupled runs presented here. ↓



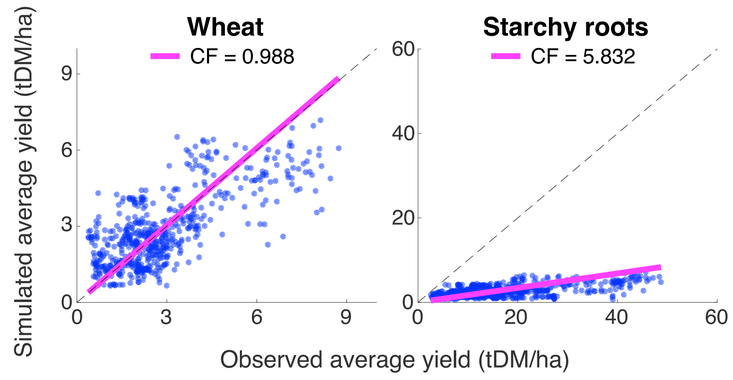
Example demand curves generated by PLUM: Historical 1961–2010, projected 2011–2030. ↓



Example PLUM potential yield surfaces. + indicates yield at optimal inputs. ↓

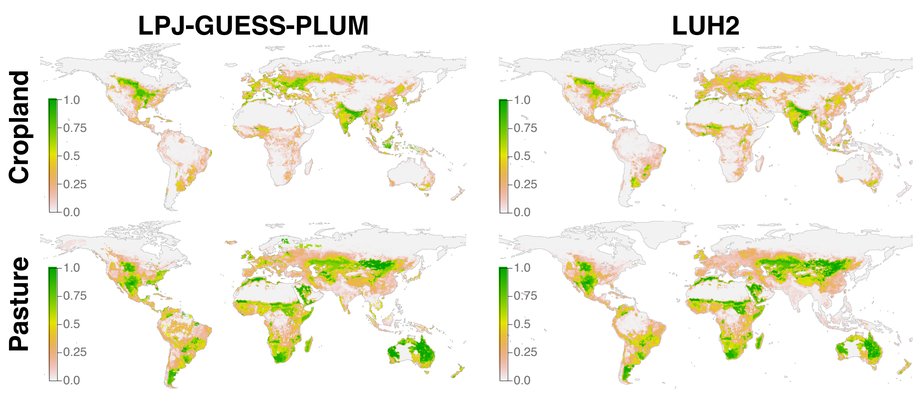


Calibration example:
LPJ-GUESS wheat to PLUMv2 wheat, starchy roots. ↓

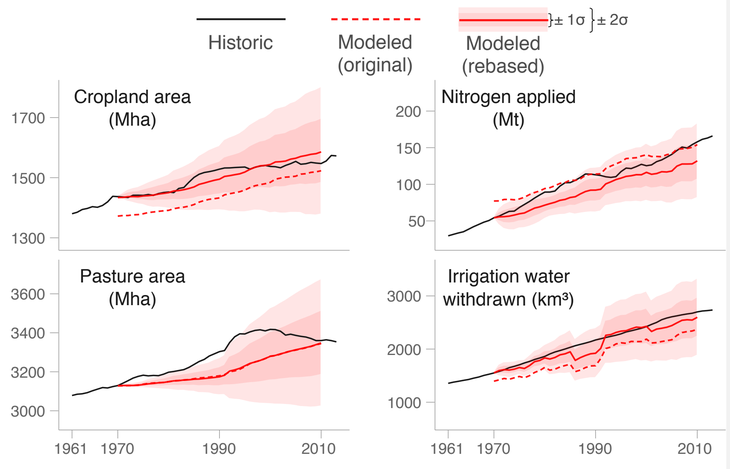


Validation

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 (Hurtt et al., 2011). ↓



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



Future runs

Perform simulations with a variety of scenarios for climate change and societal development over 2010–2100.

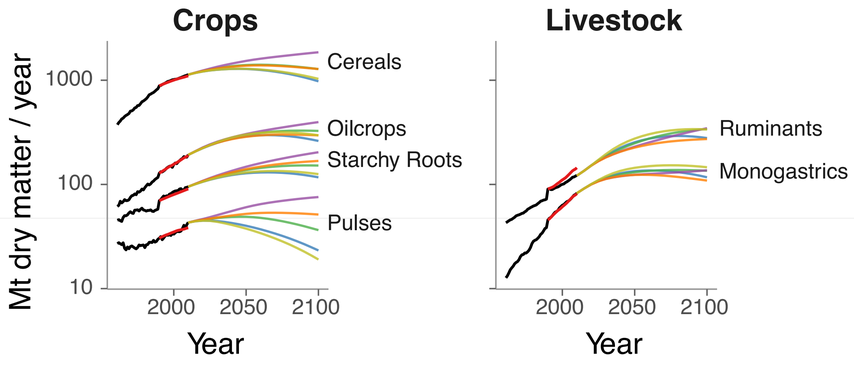
Climate: 4 Representative Concentration Pathways (RCPs; Taylor et al., 2012). Output from IPSL-CM5A-MR ESM (Dufresne et al., 2013).

Society: 5 Shared Socioeconomic Pathways (SSPs; O'Neill et al., 2014).

Results

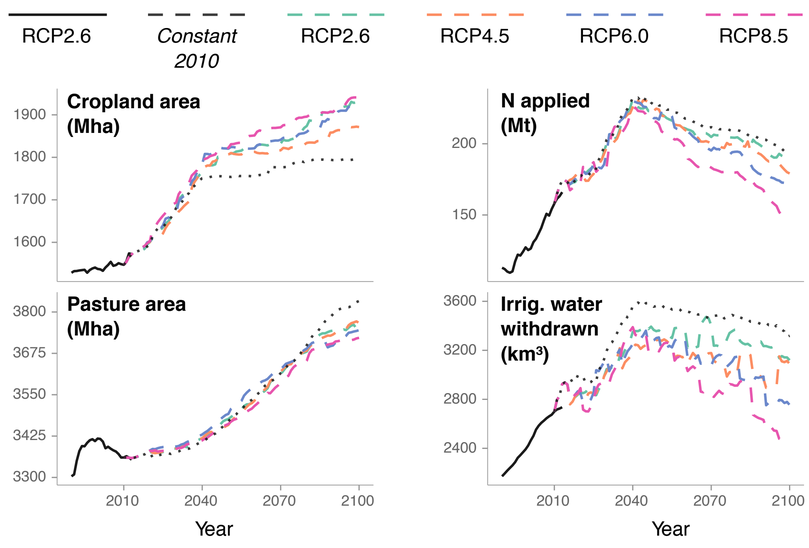
For most commodities in most SSPs, PLUM projects peak global demand around mid-century. SSP3 is the exception, with all demand increasing through 2100. This "rocky road" trajectory presents strong challenges to mitigation (e.g., high population growth) and to adaptation (e.g., decreased international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

Historic (FAOSTAT) (1961–2010) | Validation (1990–2010) | SSP1 | SSP2 | SSP3 | SSP4 | SSP5

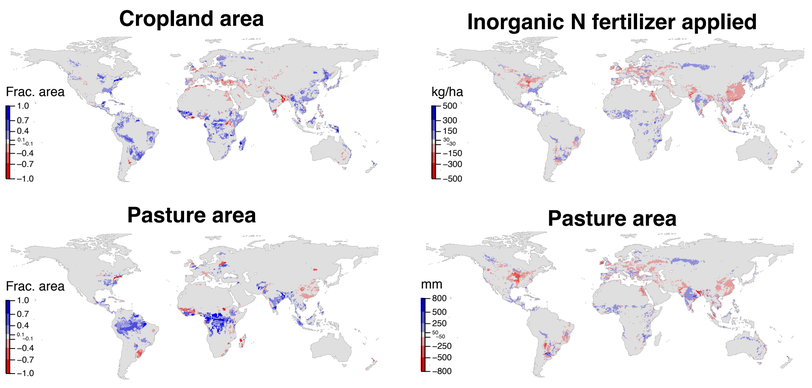


Although global commodity demand mostly peaks around mid-century, the land required to satisfy that demand continually increases. The rate of increase in global cropland area slows after ~2040, at which point fertilizer and irrigation begin to decrease.

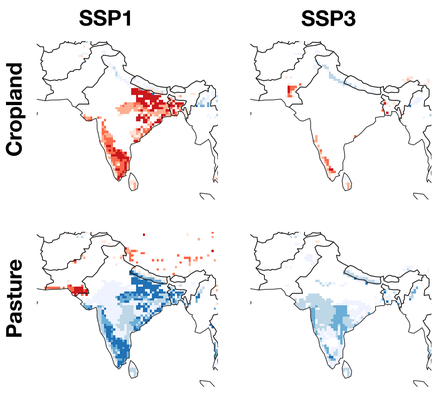
Generally, increasing intensity of climate change (and higher CO_2 concentration) results in decreasing management inputs—but there is much overlap among RCPs when considering parameter uncertainty (not shown).



Example maps of projected change, 2010 to 2100: RCP6.0 + SSP2. ↓



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



Next steps

Continue to analyze and interpret output.

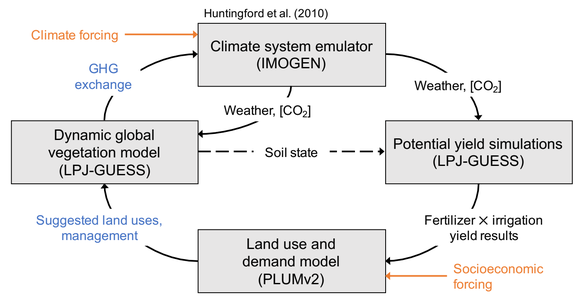
Quantify impacts of land use (change) and management on ecosystem services.

Extend LPJ-GUESS crops to eliminate calibration step.

Incorporate forestry & products trade.

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

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



References available at https://goo.gl/HRrpCU