Land-use patterns for climate and socio-economic forcing data – Update (ISIMIP3b Group III-PROCLIAS TG 1.1)

Edna Molina Bacca, Miodrag Stevanović, Jonathan Doelman, Michael Wögerer, Tamás Krisztin, Louise Parsons Chini, Christopher Reyer, Benjamin Leon Bodirsky, Katja Frieler, Jan Volkholtz Petr Havlik, George Hurtt, Hermann Lotze-Campen, Alexander Popp, Elke Stehfest

Potsdam, April 24th, 2024

Content

1. **Introduction & Methodology**
   Outputs, scenarios, and analyses
2. **First results**
   New projections and comparisons with previous ones, high-resolution maps (Mean and CV), ANOVA (multiple resolutions)
3. **Recap**
4. **First tests** – Biosphere integrity meassurements (Fabian Stenzel)

Group III (LUMs): LU and Management maps 2015-2100

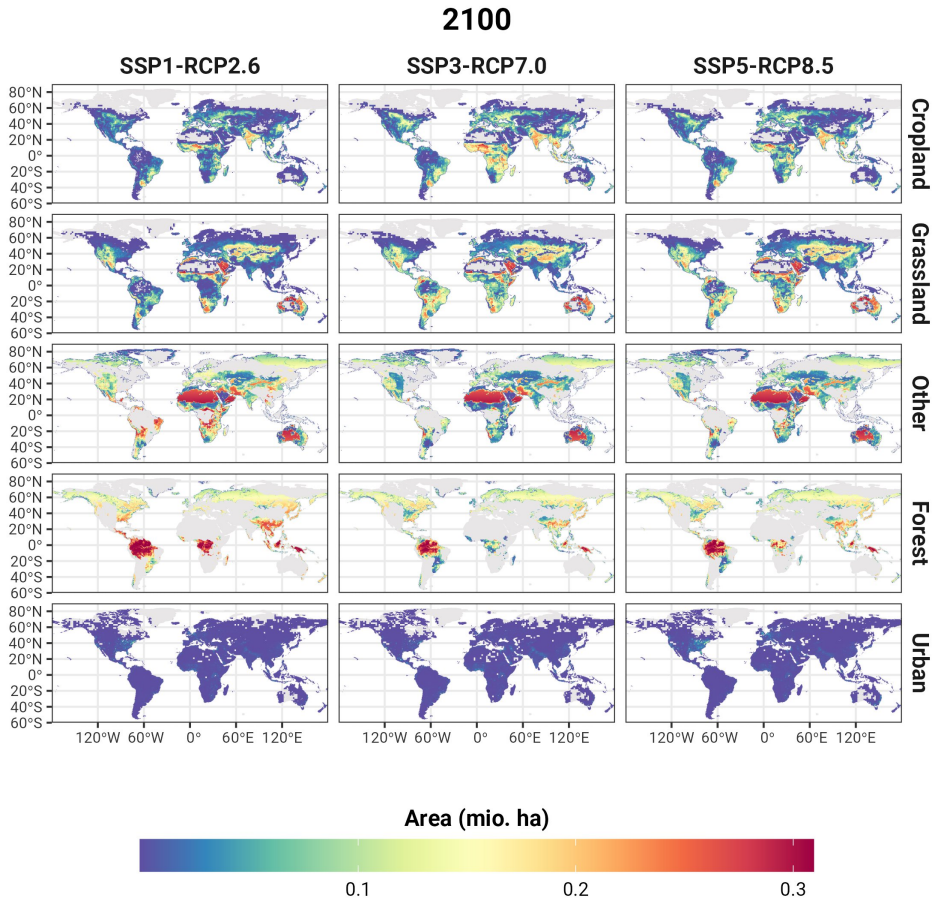
Harmonized (LUH2) land-use and agricultural management projections driven by global change **(0.25° x 0.25° resolution)**

Key outputs

- **LU projections** (Cropland, forest, grassland, urban land, natural vegetation, crop types)
- **Bioenergy crops**
- **Irrigated crop area**
- **Industrial N Fertilizer use**
- **Others**

Scenarios

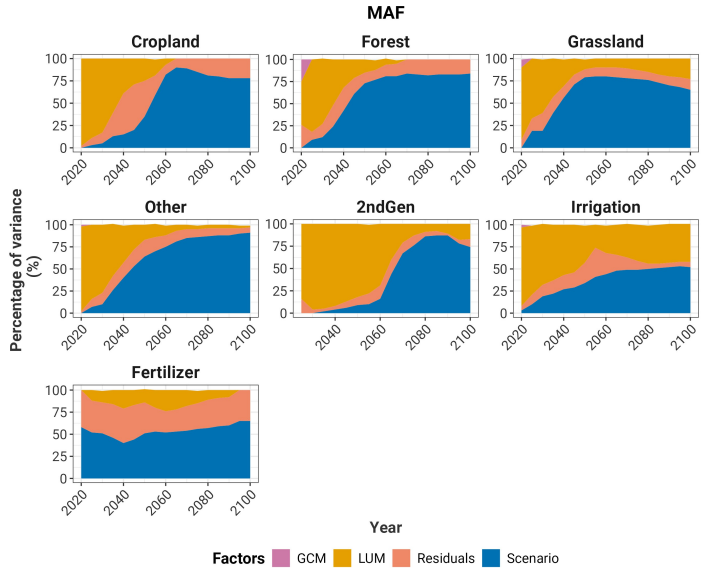
GCM/ESM	CO2 fert.	SSPs-RCPs	GGCMs-IAMs
IPSL-MC6A-LR	+		
MPI-ESM1-2-HR	+	SSP1-RCP2.6	EPIC-GLOBIOM-MESSAGE
UKESM1-0-LL	+	SSP3-RCP7.0	**LPJmL-IMAGE-MAGNET**
MRI-ESM2-0	+	SSP5-RCP8.5	**LPJmL-MAgPIE-REMIND**
GFDL-ESM4	+		
noadapt	Const	SSPx-NoCC	
GFDL-ESM4	-	SSP5-RCP8.5	



Comparison to old projections and analysis of variance

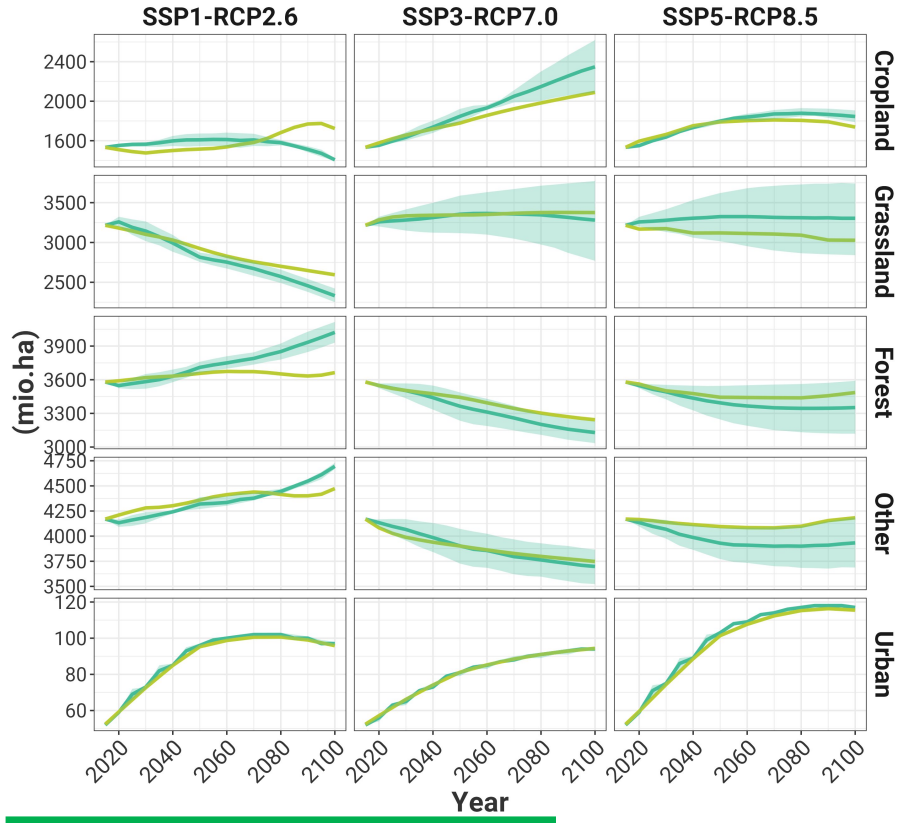
Together with the protocol paper, we are working on a results paper (harmonized maps):

- **Global and regional analysis** – Trends and comparison with previous projections
- **High-resolution results (0.5° x 0.5° resolution)** – Mean and CV
- **Analysis of variance on different resolutions** – ANOVA of harmonized data
- **Effect of harmonization** – ANOVA of unharmonized and harmonized data

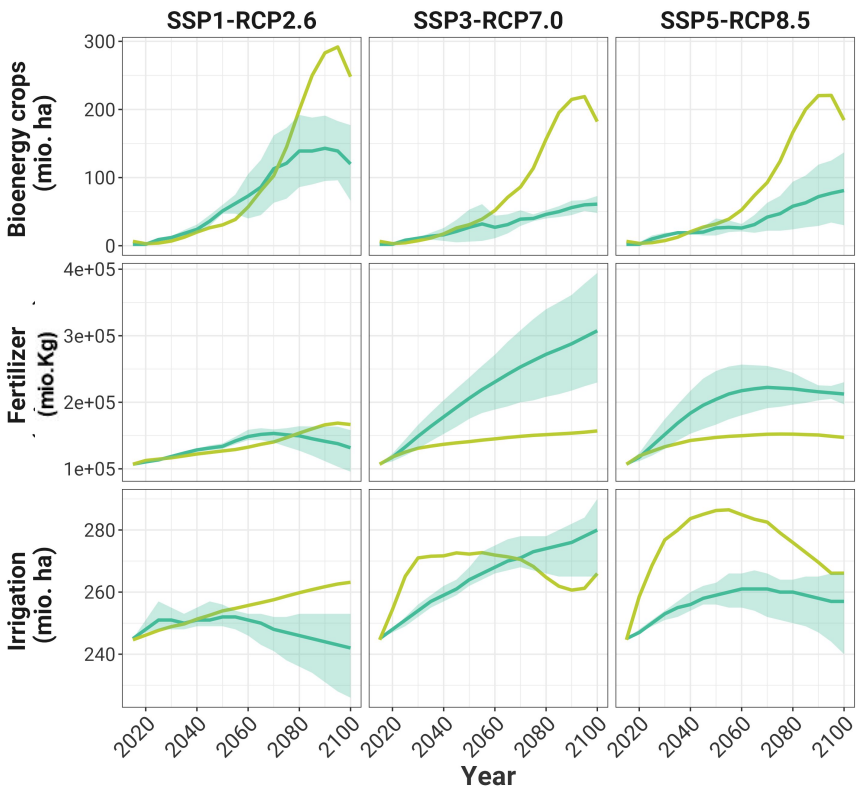


Grasslands trends for high emissions differ among the LUMs

Land use



Management



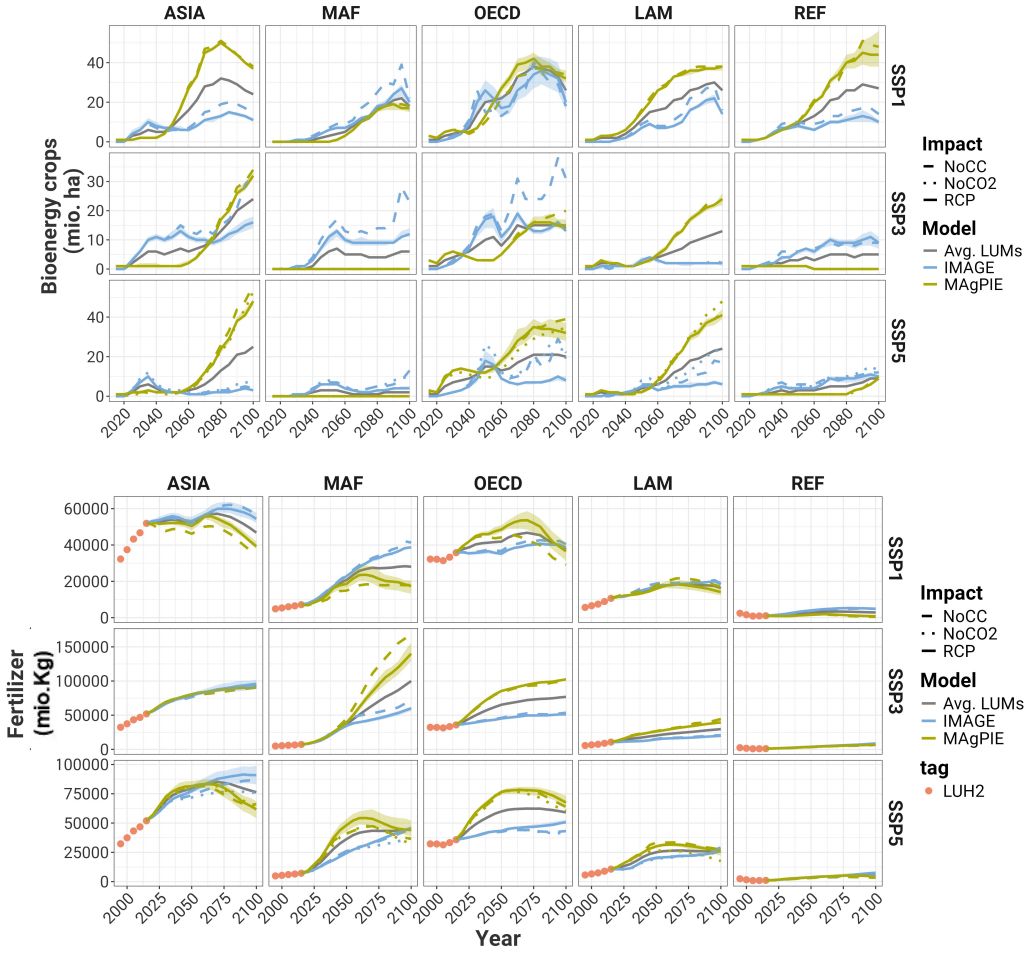
Also large differences in management trends for all scenarios

LUH2- 2017

- **SSP1-RCP2.6** – IMAGE
- **SSP3-RCP7.0** – AIM
- **SSP5-RCP8.5** – MAgPIE

For SSP1-2.6, larger growth of natural vegetation and reduction of grasslands and cropland compared to LUH2-2017

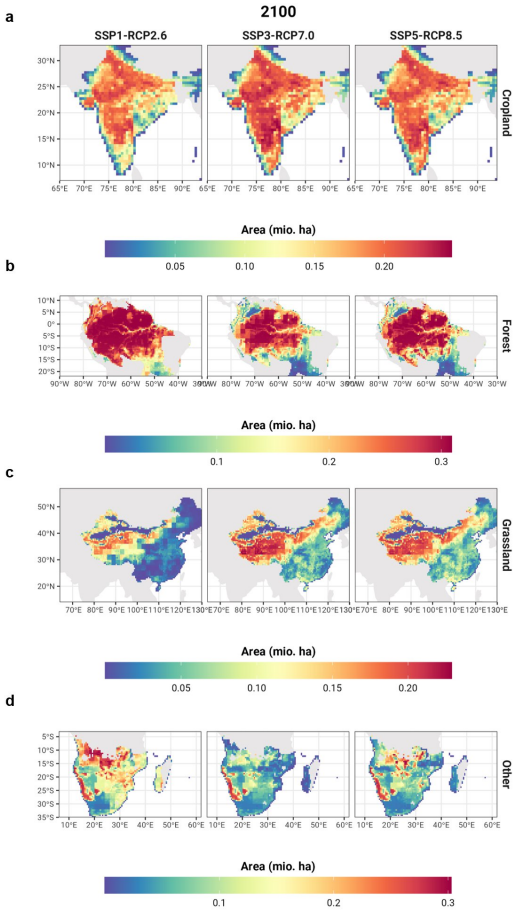
Regional size and direction of land-use and management change show differences among LUMs



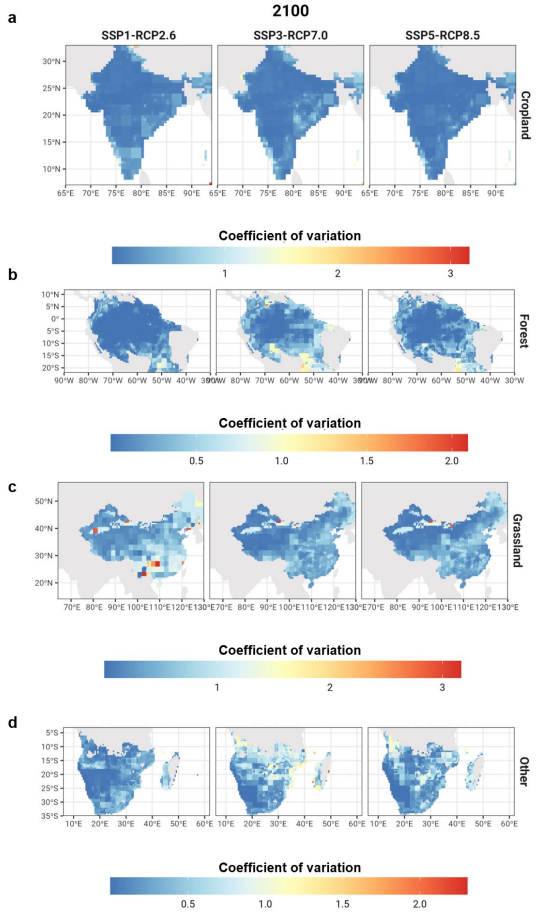
especially in grasslands, bioenergy crops, and fertilizer use at high emissions

In highly concentrated areas where land-use types have typically been located, the coefficient of variation (CV) is lower than elsewhere

Average per grid cell



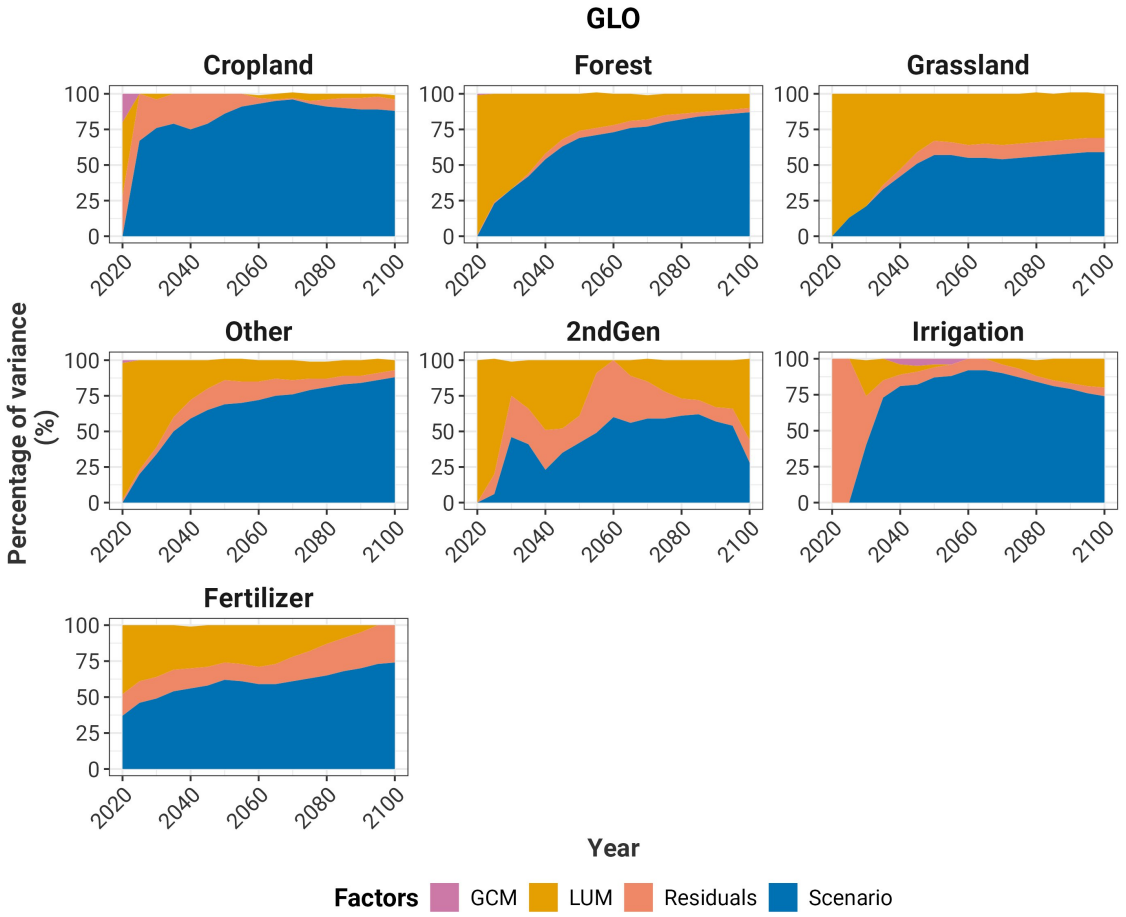
Coefficient of variance per grid cell



- Forest and other natural vegetation have lower CV (on average).
- CV increases with time in all scenarios but not with emissions
- SSP1-RCP2.6's CV is higher for different land-use types.

Different dynamics of LUMs related to where the reduction of cropland and grasslands occurs

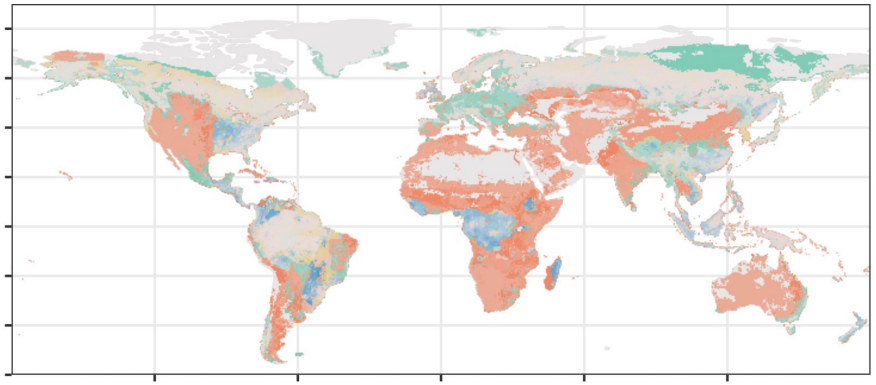
On the global scale, after 2030, the variance of the projections can be explained mostly by the socioeconomic-climate change scenarios



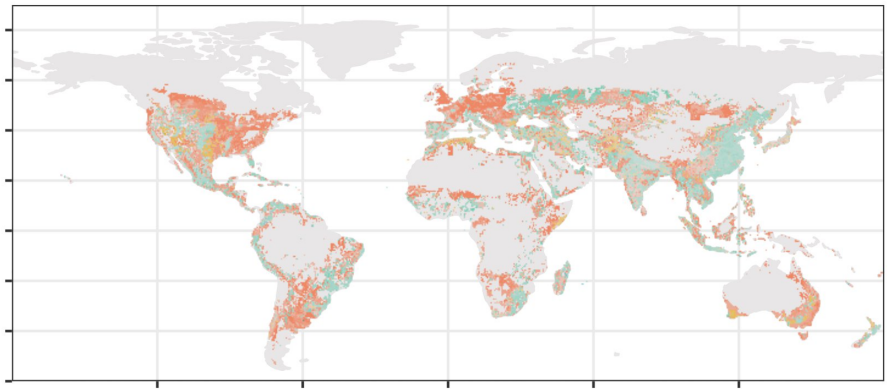
- GCMs have little to no share in explaining the variance among projections (only in REF).
- Before 2030, variance comes from differences among the LUMs (also for ASIA, MAF, and OECD).
- 2nd Generation bioenergy crops, after 2060-2070 LUMs, have a larger contribution to variance.

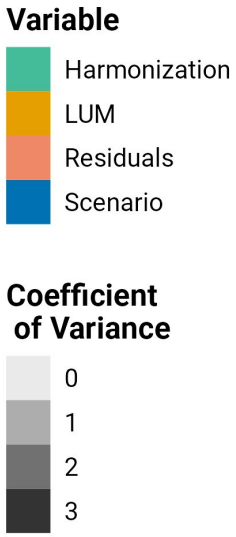
Compared to 2050, in 2100, the number of cells where the Scenarios factor explains the variance grows for all variables

Forest



Irrigation





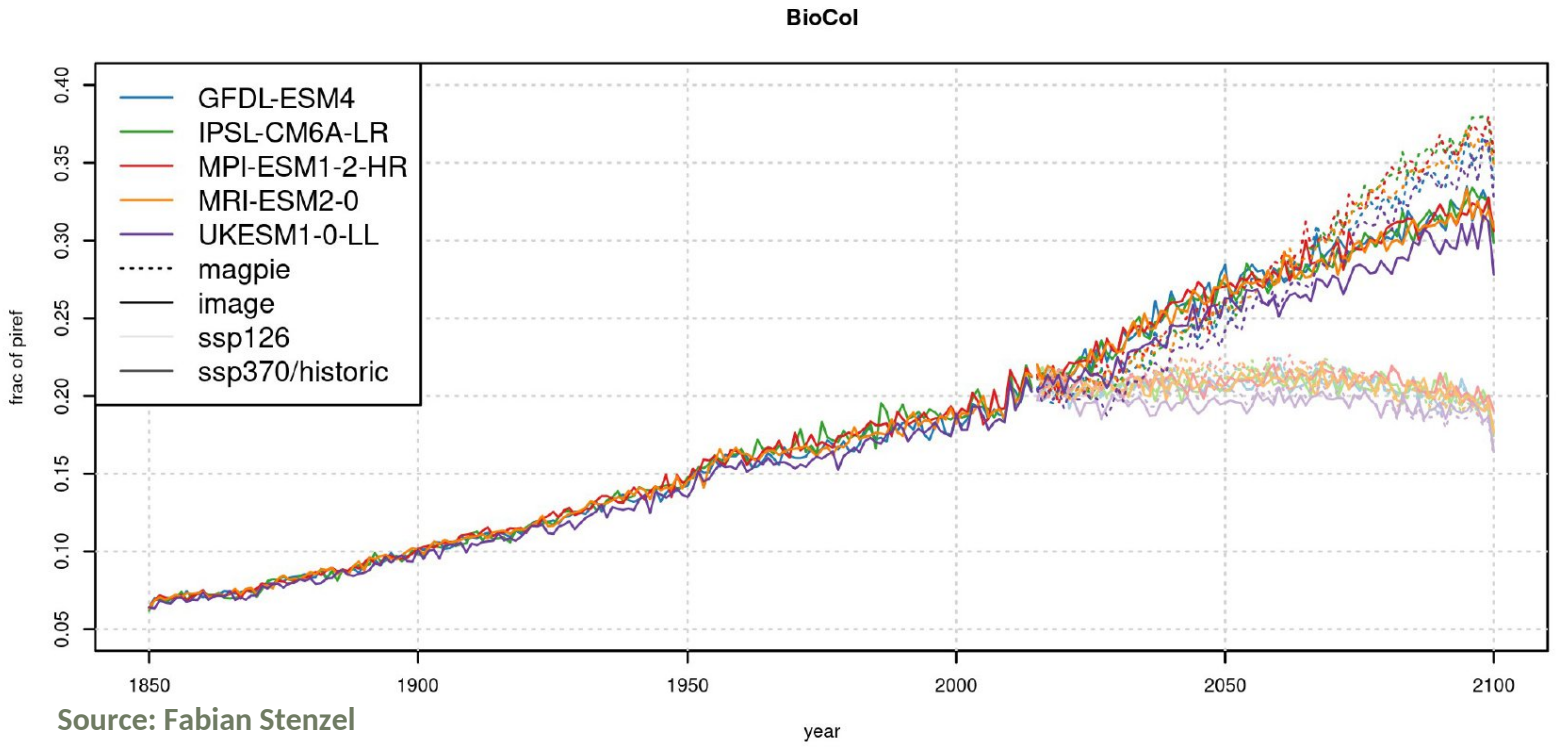
- In high-producing regions, the variance per grid cell can be explained by the Scenarios factor in cropland
- For grassland, fertilizer use, irrigation, and especially second-generation bioenergy crops, residuals explain the variance for most grid cells in 2050 and 2100.
- Harmonization has a large impact on irrigation and forest projections in 2100.

Recap

- There are differences between the LUMs projections and LUH2-2017.
- At high emissions, differences between LUMs on the regional level.
- In general, Forests and Other natural vegetation have the lowest average coefficient of variation (CV) per grid cell.
- Low emissions scenarios show a higher average CV than in high emission scenarios per grid cell for multiple variables.
- Variance on the global and regional levels after 2030, mainly explained by the scenarios' differences.

LUMs projections to calculate metrics for functional biosphere integrity

BioCol global sum wrt NPP$_{preind.}$



Source: Fabian Stenzel

BioCol (human colonization of the biosphere)

Flow of biomass extracted in the form of[1]:

- **Crop, residue, other biomass harvest**
- **Inhibited biomass production due to LUC, management, and fires**

[1]*Stenzel, Fabian, et al. "biospheremetrics v1. 0.1: An R package to calculate two complementary terrestrial biosphere integrity indicators: human colonization of the biosphere (BioCol) and risk of ecosystem destabilization (EcoRisk)." EGUsphere 2023 (2023): 1-36.*

Thank you!

Contact: mbacca@pik-potsdam.de

Differences among LUMs

Uncertainty in land-use projections among models can be attributed to[1]:

- **Differences in inputs**
- **Definitions of variables definition (e.g., definition of land use types)**
- **Differences regarding the parametrization and representation of socioeconomic and biophysical processes (e.g., due to factor substitutability, CGE models show higher yield gains compared with partial equilibrium models)**
- **Sensitivity to change**

[1] C. Schmitz, H. van Meijl, P. Kyle, G. C. Nelson, S. Fujimori, A. Gurgel, P. Havlik, E. Heyhoe, D. M. d'Croz, A. Popp, R. Sands, A. Tabeau, D. van der Mensbrugghe, M. von Lampe, M. Wise, E. Blanc, T. Hasegawa, A. Kavallari, and H. Valin, "Land-use change trajectories up to 2050: Insights from a global agro-economic model comparison," Agricultural Economics (United Kingdom), vol. 45, no. 1, 2014