Land-use patterns for climate and socio-economic forcing data to ISIMIP3b group III simulation round

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Land-Use Patterns Simulations

- ISIMIP3b, group III: future impacts projections based on the newest set of climate and socio-economic forcing data.
- Land-use pattern projections:
    - Climate change impacts and adaptation in the agriculture and other land use sector.
    - Future socio-economic development.
    - Climate change mitigation efforts from land-based mitigation policies.
- => to reflect a consistent treatment of climate change adaptation and mitigation measures and remaining sectoral impacts

ISIMIP2b vs. ISIMIP3b LU patterns data

	ISIMIP2b	ISIMIP3b
Scenarios	SSP2-RCP6.0 SSP2-RCP2.6	SSP1-RCP2.6 SSP3-RCP7.0 SSP5-RCP8.5
Landuse models	MAgPIE	MAgPIE GLOBIOM IMAGE
Crop models (GGCMs)	LPJmL	LPJmL EPIC IMAGE-LPJmL
Climate Models (GCMs)	CIMIP5	CIMIP6
Scope	Impacts Mitigation	Impacts Mitigation Adaptation

Available Scenarios of Landuse Patterns

GCMs*	CO_2 fert.	SSPs-RCPs*	GGCMs-IAMs*
IPSL-MC6A-LR	+		
MPI-ESM1-2-HR	+	SSP1-RCP2.6	LPJmL-MAgPIE-REMIND
UKESM1-0-LL	+	SSP3-RCP7.0	EPIC-GLOBIOM-MESSAGE
MRI-ESM2-0	+	SSP5-RCP8.5	LPJmL-IMAGE-MAGNET
GFDL-ESM4	+		
soc2015	const.		
GFDL-ESM4	-	SSP5-RCP8.5	

*
GCM: Global Circulation Models
SSP: Shared Socio-economic Pathways
RCP: Representative Concentration Pathways
GGCM: Global Gridded Crop Models
IAM: Integrated Assessment Models

Integrated Assessment Models - IAMs

- **Integrated Assessment Models** of climate change include biophysical and socio-economic data and assumptions across all economic sectors that generate Greenhouse Gas emissions (GHG) for modeling of different GHG concentration pathways.
- For ISIMIP3b the focus is on application of models of agricultural, forestry and other land-use (AFOLU) sectors for projection LU patters for different future scenarios.
- Three Landuse Models (LUMs):
    - **MAgPIE** - Model of Agricultural Production and its Impact on the Environment
      Potsdam Institute for Climate Impacts Research - PIK
    - **GLOBIOM** - Global Biosphere Management Model
      International Institute for Applied Systems Analysis
    - **IMAGE** - Integrated Model to Assess the Global Environment
   *Netherlands Environmental Assessment Agency - PBL*

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MAgPIE

- **M**odel of **Ag**ricultural **P**roduction and its **I**mpact on the **E**nvironment
- **Socio-economic** model of land-use and agricultural sector with **spatial explicit** and **dynamic** features.

- Balance of biophysical and (agro)economic sides:
  - Biophysical: crop yields, terrestrial carbon stocks, nutrients, water.
  - Economic: costs, prices, demand, policies
- 4 spatial geographic layers:
  - Global — 13 world regions — 1000 spatial clusters — 0.5°×0.5° grid
- Dynamic recursive optimization
  - Cost minimization of consecutive times slices with a length of 5-10 years until 2100

https://github.com/magpiemodel/magpie
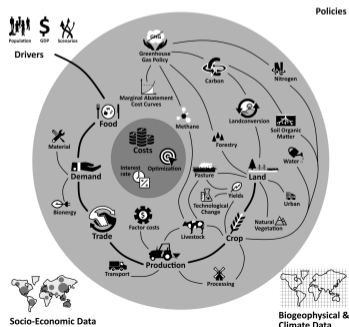
Impacts and Adaptation to climate change in MAgPIE
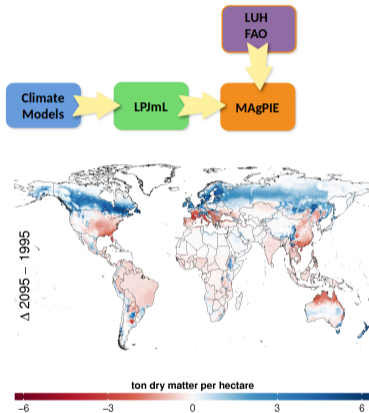
- **Climate Change Impacts**
  - Climate models (GCMs): temperature, precipitation...
  - Crop model LPJmL: crop yields, available water and carbon fluxes
  - Global land data (LUH, FAO): cropland, pasture, forest, natural vegetation

- **Adaptation to Climate Change Impacts**
  - Inputs of crop yields with *adjustment to growing season*
  - *Autonomous adaptation* under simulated cost-optimal landuse objective: landuse change, technological investments, production system change, or spatial relocation (trade)

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Stevanovic et al. Sci. Adv. 2016

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## Mitigation of climate change in MAgPIE
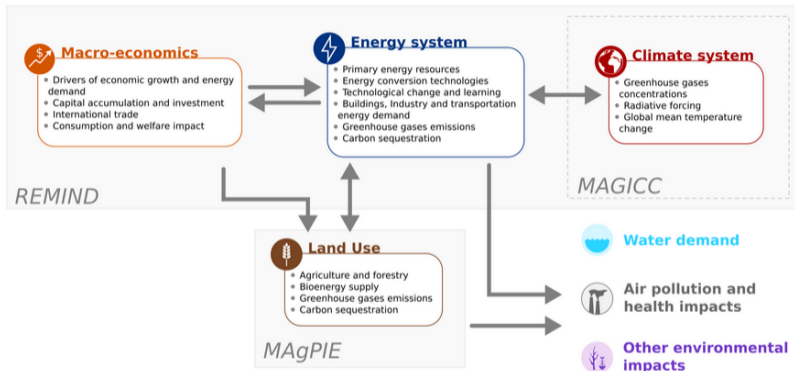
- Energy-economy and land-use systems are interlinked
- For ISIMIP3b, group III, SSP-RCP scenarios are consistent with mitigation policies with given targets, in defining necessary large-scale land-based measures (bioenergy, carbon sequestration)
- Standalone scenarios

Global Cropland Expansion

Cropland expansion
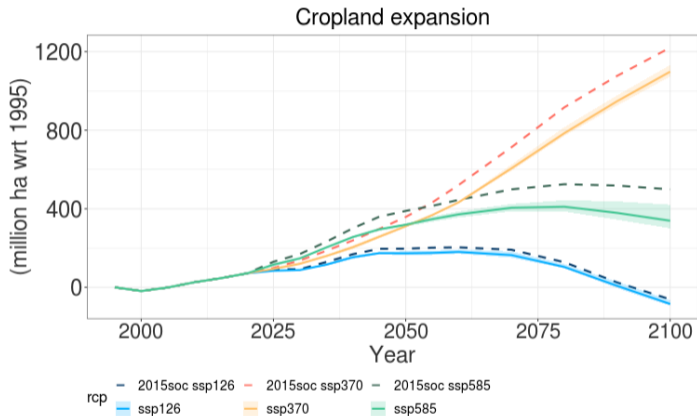
- Declining cropland areas in the climate change (adaptation) scenarios.

Global Average Yield
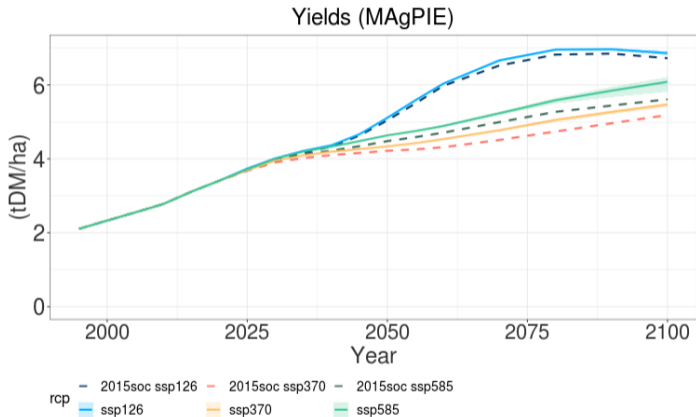
- CO_2 fertilization and adjustment of growing season make positive effect on average yields globally.

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Global Demand for Bioenergy

Production of 2nd generation bioenergy
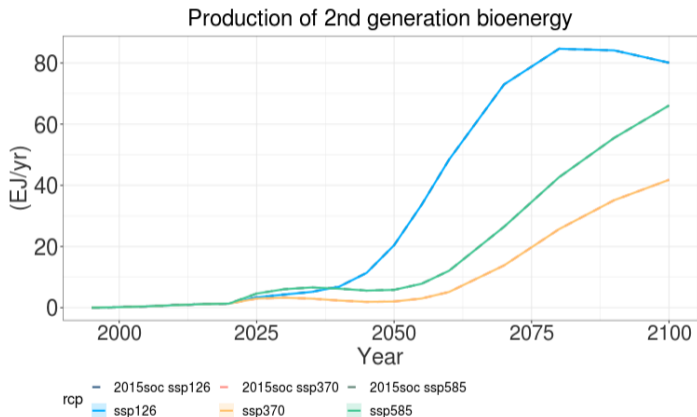
- Highest demand for 2nd generation bioenergy in the SSP1-RCP2.6 scenarios which has most mitigation efforts in the selected scenarios.

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Global Forest Expansion

Forest expansion
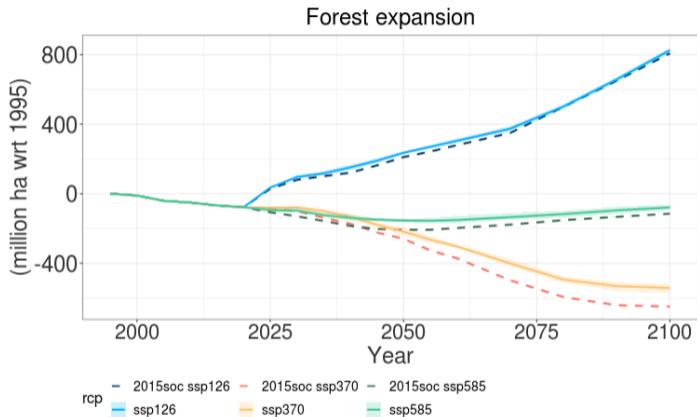
- Similarly, forest increases in SSP1-RCP2.6 due to demand for carbon sequestration, but also due to other socio-economic development (lower population increase and shift in diets).
- Deforestation in SSP3-RCP7.0 scenario.

Landuse Patterns Harmonization

- Land-Use Harmonization (LUH) algorithm:
  - minimizing the differences at the transition between the historical reconstruction ending conditions and IAM initial conditions
  - to preserve changes depicted by the IAMs in the future.

  - outputs at 0.25°×0.25° resolution, at annual level
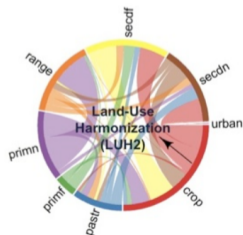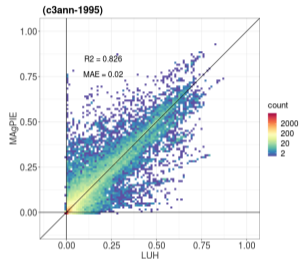
Landuse Patterns Final Data Product

- Dataset:
    - cropland (rainfed and irrigated)
    - C3 annual crops (rainfed and irrigated)
    - C3 perennial crops (rainfed and irrigated)
    - C4 annual crops (rainfed and irrigated)
    - C4 perennial crops (rainfed and irrigated)
    - C3 nitrogen-fixing crops (rainfed and irrigated)
    - bioenergy grass (rainfed and irrigated)
    - bioenergy trees (rainfed and irrigated)
    - fertilizer application (organic and inorganic)
    - managed pastures
    - rangelands
    - forests
    - urban land

- Additional distribution of LU patterns on the crop specific level:
    - maize
    - groundnut
    - rapeseed
    - soybean
    - sunflower
    - rice
    - sugarcane
    - pulses
    - temperate cereals
    - temperate roots
    - tropical cereals
    - tropical roots
    - others annual
    - others perennial
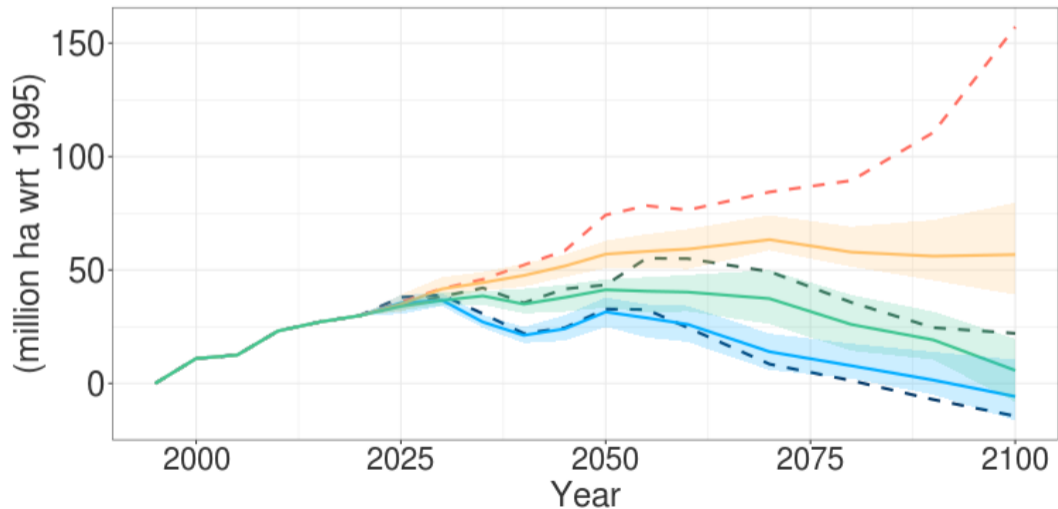   - other N-fixing

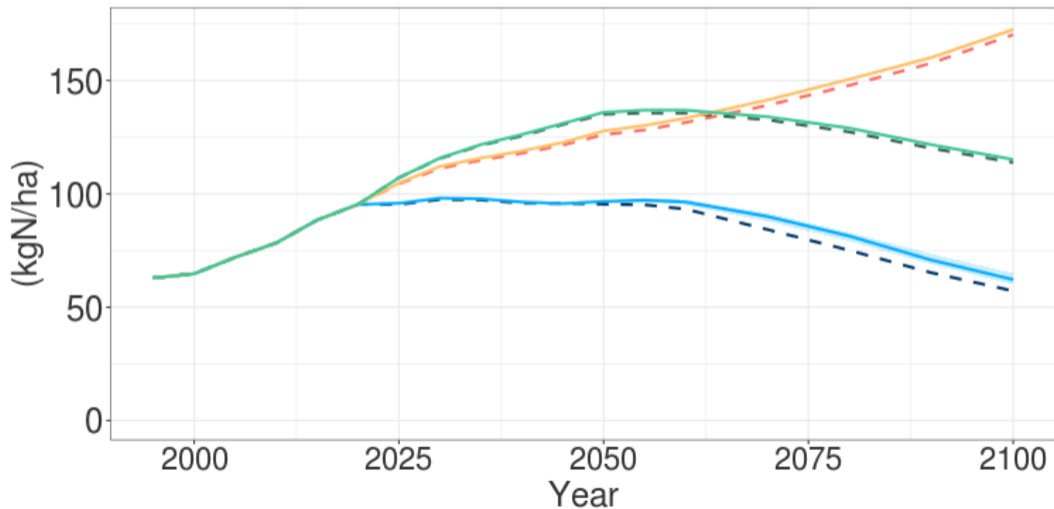## Breakout Group TG1.1 ISIMIP Land use patterns

- Further clarify questions from plenary presentation.
- What assumptions behind scenarios are key for you to know about?
- Want kind of modeled processes do you need to know more about (e.g. mitigation, deforestation, afforestation etc.)?
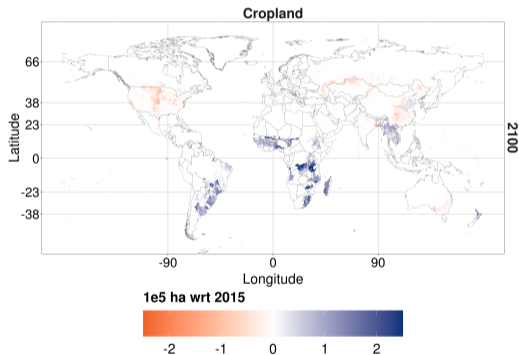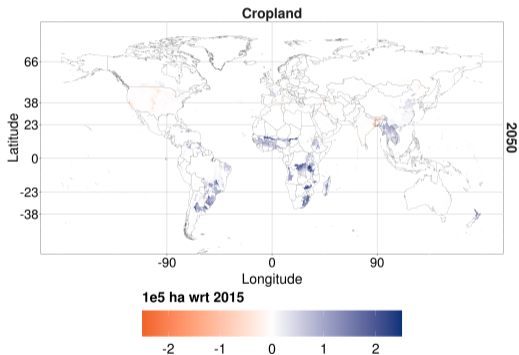- What fact sheet would be necessary for you papers?
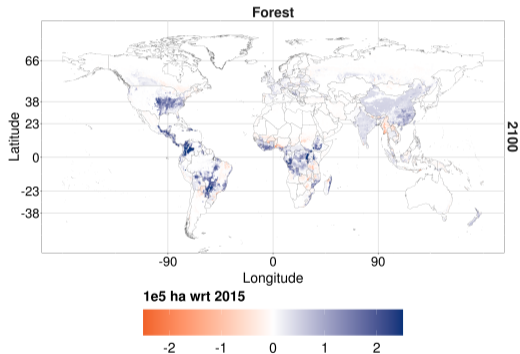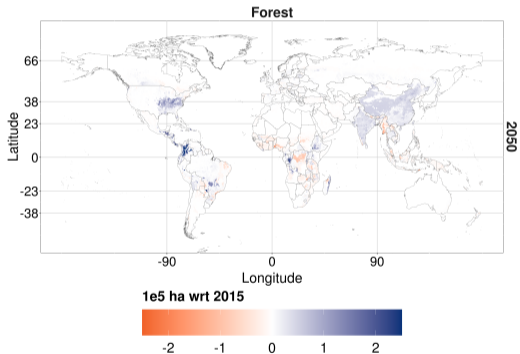
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Thank you!

Irrigated area expasion

Nitrogen (inorganic fertilizer and Manure)

Spatial Dynamics Cropland GFDL-ESM4 SSP5-RCP8.5

Forest

Spatial Dynamics Forest GFDL-ESM4 SSP3-RCP7.0

		MAgPIE
Trade		Endogenous. Historical patterns are preserved until 2015 (FAO), after which the trade barriers are relaxed to different degree across commodity classes.
	SSP1	liberalized
	SSP3	regionalized
	SSP5	liberaliezed
Demand		Endogenous. Driven by per capita income and the demography of the world population accoriding to SSP assumptions (including sex and age classes at the country level). Responsive to the prices for agricultural products in the optimization.
	SSP1	SSP1
	SSP3	SSP3
	SSP5	SSP5
Agricultural management		Endogenous irrigated versus rainfed crop production management. Endogenous intensification of inputs in the production.
	SSP1	SSP1
	SSP3	SSP3
	SSP5	SSP5
Livestock husbendry		Exogenous. SSP dependent scenarios for animal waste management.
	SSP1	SSP1
	SSP3	SSP3
	SSP5	SSP5

Modeled Processes in MAgPIE part 2/2

		MAgPIE
Technological progress		Endogenous. Different levels of cost based on the SSP dependent assumptions on public investment in R&D in agriculture.
	SSP1 SSP3 SSP5	SSP1 SSP3 SSP5
Spatial relocation		Endogenous, inert/sticky capital investments for crop produciton.
	SSP1 SSP3 SSP5	SSP1 SSP3 SSP5
Forestry		Endogenous. Production of timber products i.e., wood and woodfuel from plantation forests while still accounting for afforestation policies.
	SSP1 SSP3 SSP5	SSP1 SSP3 SSP5
Protected areas		Exogenous. Land protection based on the World Database on Protected Areas (WDPA), with different fade-in protection policies.
	SSP1 SSP3 SSP5	SSP1 SSP3 SSP5

	soc15 (no adaptation)	SSP1-RCP2.6, SSP3-RCP7.0, SSP5-RCP8.5 (adaptation)
Climate	historical observations (W5E5)	ISIMIP bias-adjusted GCM data
Agricultural management	historic and SSP-based adjustments of irrigation, fertilizer input, and technological progress. No changes in growing seasons.	as no-adapt but additionally accounting for climate and CO2 impacts on crops allowing for purely climate induced growing season adjustments
Land-based mitigation effort (bioenergy demand and CO2 removal from the atmosphere by afforestation)	provided by the IAM	provided by the IAM, same as in the no-adaptation set-up
...	...	...