Potsdam Institute for Climate Impact Research

Uncertainty in land-use adaptation persists despite crop model projections showing lower impacts under high warming

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Content

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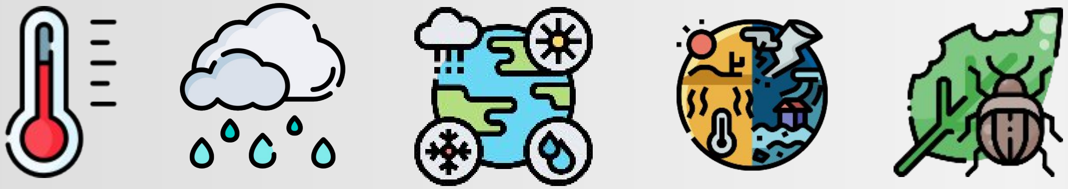
Introduction – Climate change and Agriculture

"…adaptation **is a fundamental** and ongoing activity in the **agricultural sector**"[1]

"Human-induced climate change is expected to push these managed ecosystems beyond their natural climatic boundaries"[2]



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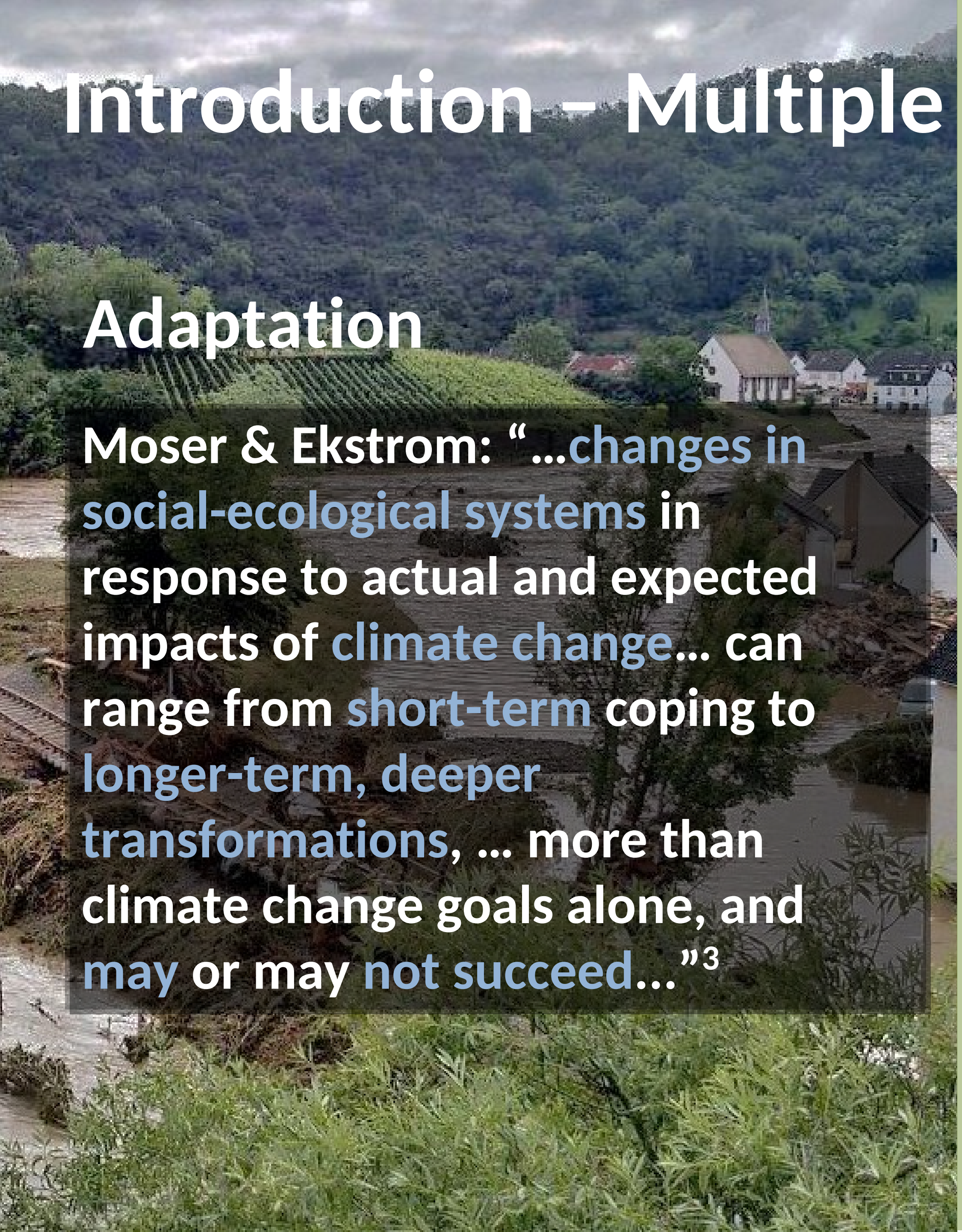
Introduction – Multiple perspectives of adaptation



Adaptation

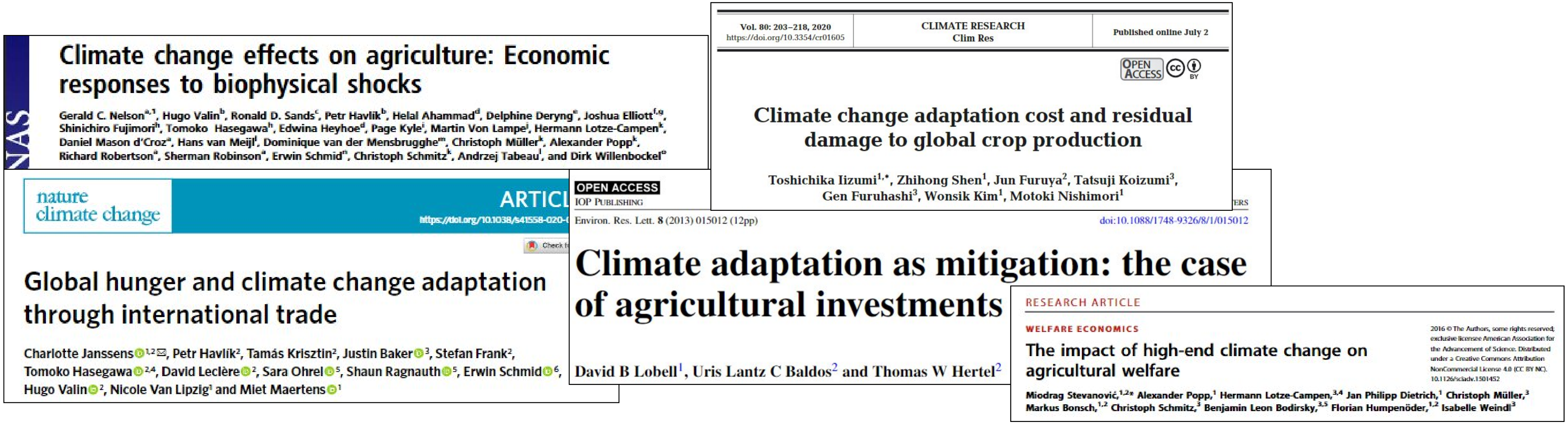
Moser & Ekstrom: "…changes in social-ecological systems in response to actual and expected impacts of climate change… can range from short-term coping to longer-term, deeper transformations, … more than climate change goals alone, and may or may not succeed…"[3]

In agriculture:

Farm scale: Management practices (e.g., **Irrigation**[4,5], climate-resilient cultivars[6], modification planting dates[7], nitrogen input[5], others[8])

Land-use scale: Change of production patterns (e.g., **transformation between land-use types[9], shift in crops cultivated and cultivation sites, investments in R&D**[10,11], changes in trade flows[12])

Introduction – Previous studies and contribution



Climate change effects on agriculture: Economic responses to biophysical shocks

Gerald C. Nelson[a,1], Hugo Valin[b], Ronald D. Sands[c], Petr Havlík[b], Helal Ahammad[d], Delphine Deryng[e], Joshua Elliott[f,g], Shinichiro Fujimori[h], Tomoko Hasegawa[h], Edwina Heyhoe[d], Page Kyle[i], Martin Von Lampe[j], Hermann Lotze-Campen[k], Daniel Mason d'Croz[a], Hans van Meijl[l], Dominique van der Mensbrugghe[m], Christoph Müller[k], Alexander Popp[k], Richard Robertson[a], Sherman Robinson[a], Erwin Schmid[n], Christoph Schmitz[k], Andrzej Tabeau[l], and Dirk Willenbockel[o]

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Climate change adaptation cost and residual damage to global crop production

Toshichika Iizumi[1,*], Zhihong Shen[1], Jun Furuya[2], Tatsuji Koizumi[3], Gen Furuhashi[3], Wonsik Kim[1], Motoki Nishimori[1]

nature climate change

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Global hunger and climate change adaptation through international trade

Charlotte Janssens[1,2], Petr Havlík[2], Tamás Krisztin[2], Justin Baker[3], Stefan Frank[2], Tomoko Hasegawa[2,4], David Leclère[2], Sara Ohrel[5], Shaun Ragnauth[5], Erwin Schmid[6], Hugo Valin[2], Nicole Van Lipzig[1] and Miet Maertens[1]

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Environ. Res. Lett. 8 (2013) 015012 (12pp) doi:10.1088/1748-9326/8/1/015012

Climate adaptation as mitigation: the case of agricultural investments

David B Lobell[1], Uris Lantz C Baldos[2] and Thomas W Hertel[2]

RESEARCH ARTICLE

WELFARE ECONOMICS

The impact of high-end climate change on agricultural welfare

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Miodrag Stevanović,[1,2*] Alexander Popp,[1] Hermann Lotze-Campen,[3,4] Jan Philipp Dietrich,[1] Christoph Müller,[3] Markus Bonsch,[1,2] Christoph Schmitz,[3] Benjamin Leon Bodirsky,[3,5] Florian Humpenöder,[1,2] Isabelle Weindl[3]

What is our contribution?

- Evaluated the individual and combined effect of multiple adaptation strategies using MAgPIE (Model of Agricultural Production and its Impact on the Environment).
- Used the latest multi-model crop yield impact data generated with CMIP6.
- Included CO_2 fertilization effects.

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Modeling chain, scenarios and analyses

Scenarios:
SSP1-RCP2.6 (SSP1-NoCC)
SSP5-RCP8.5 (SSP5-NoCC)

Socio-economic assumptions (SSPs)

- Population
- GDP
- Bioen. and carbon price policies
- …

Climate (RCPs)

General Circulation / Earth System Models (GCMs)

- Temperature
- Precipitation
- …

Biophysical

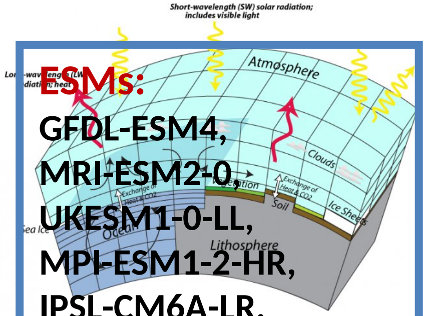
Global Gridded Crop Models (GGCMs)

- Crop potential yields
- Water
- Soil

MAgPIE

- Land-use and crop patterns
- Crop yields (MAgPIE)
- Technological Change factor (TC)
- Self-sufficiency
- Production
- Production costs

Results:
- Global effects
- Regional adaptation
- Adaptation costs



ESMs:
GFDL-ESM4,
MRI-ESM2-0,
UKESM1-0-LL,
MPI-ESM1-2-HR,
IPSL-CM6A-LR,

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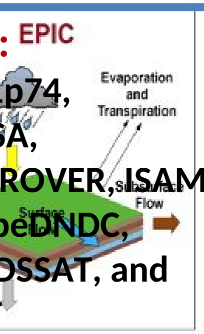
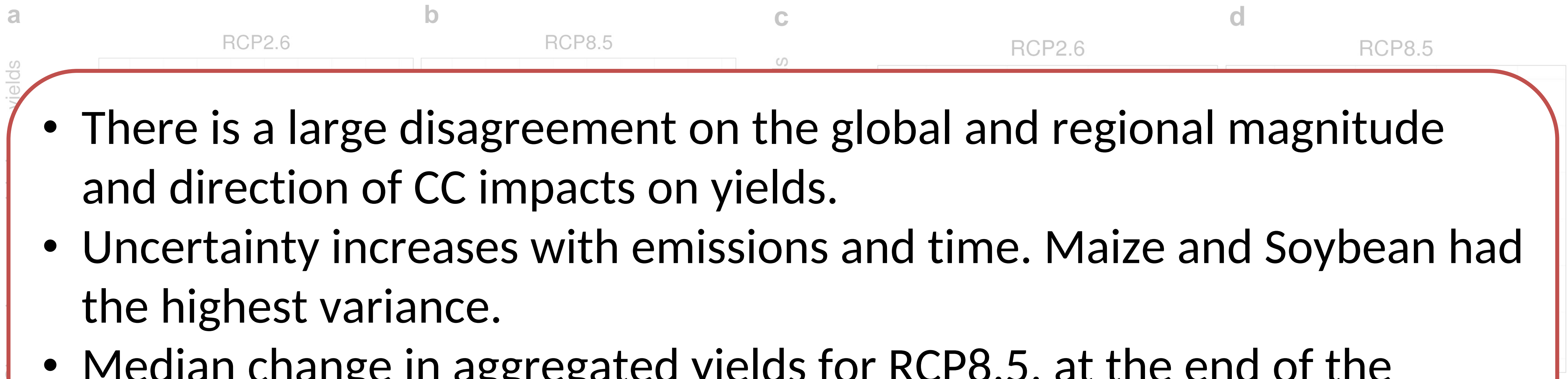


GGCMs:
CYGMA1p74,
EPIC-IIASA,
LPJmL, CROVER, ISAM,
LandscapeDNDC,
PEPIC, pDSSAT, and
PROMET

Credit: © IIASA

Harmonized GGCM crop yields median values show only slight losses due to climate change but high uncertainty



- There is a large disagreement on the global and regional magnitude and direction of CC impacts on yields.
- Uncertainty increases with emissions and time. Maize and Soybean had the highest variance.
- Median change in aggregated yields for RCP8.5, at the end of the century, is around -4%.

Fig. 1 Global climate change impacts on crop yields under two different emission scenarios.

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Global results - Projections where yields grow lead to reduced input requirements

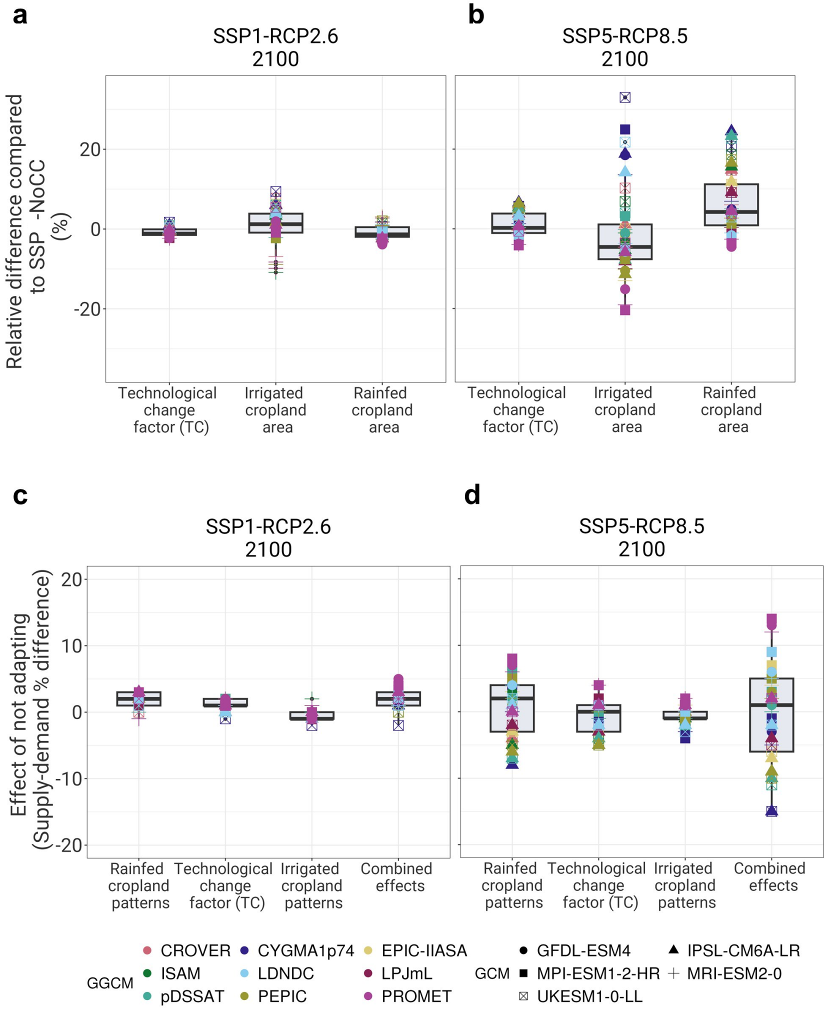

Fig. 2 Global land-use adaptation responses in the MAgPIE model under SSP1-RCP2.6 (low emissions) and SSP5-RCP8.5 (high emissions) scenarios.

- Lower needed cropland expansion than previously reported.
- Climate change impacts on yields are buffered through rainfed cropland patterns and TC adjustments.
- Overproduction if the system did not adapt to climate change in optimistic projections.

Regional results - large disparity in the projected regional distribution of impacts

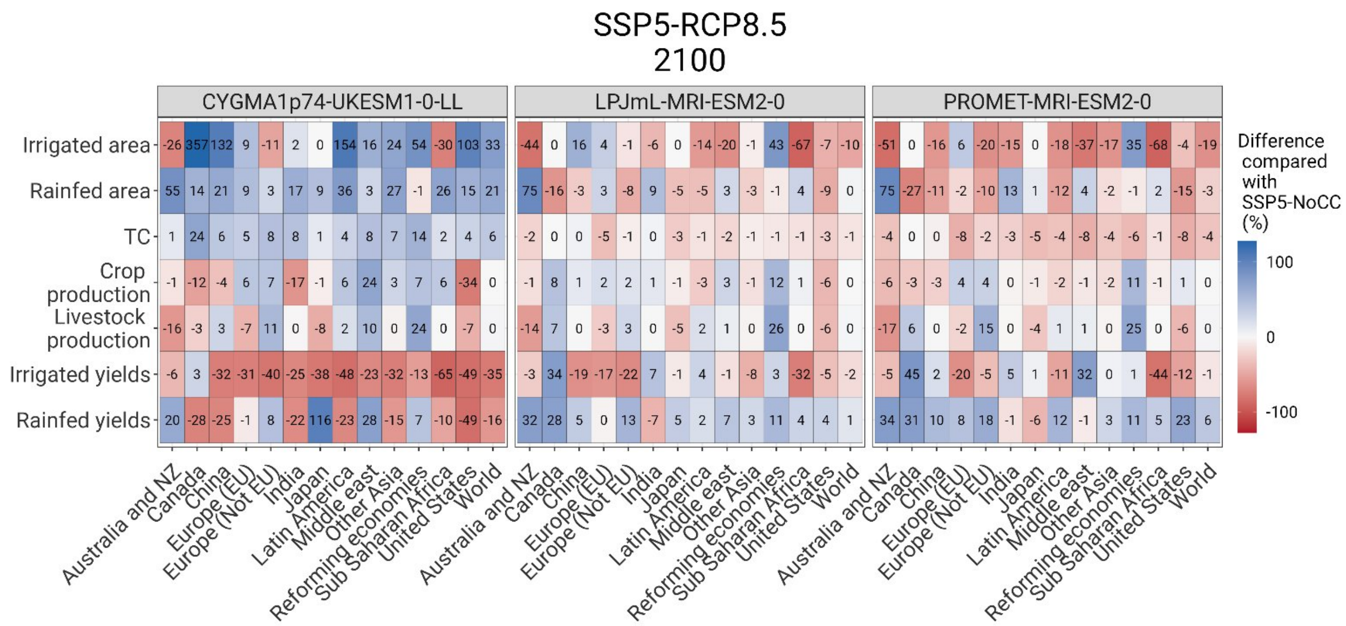

Fig. 3 Regional relative difference of adaptation-related variables estimated by MAgPIE in the year 2100 for three different GCM-GGCM combinations, compared to the SSP5-NoCC scenario (without climate impacts).

- Regions with gains in rainfed yields see less benefit from irrigating land.
- Interdependence between livestock production and competition for land.
- Expansion of production within regions with low land and crop production costs in scenarios with overall losses in yields.

- For optimistic projections, less cropland and TC are needed. Adaptation is also important for a more cost-efficient and less intensified production system.

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Regional results - Climate impacts are experienced mostly at the local level

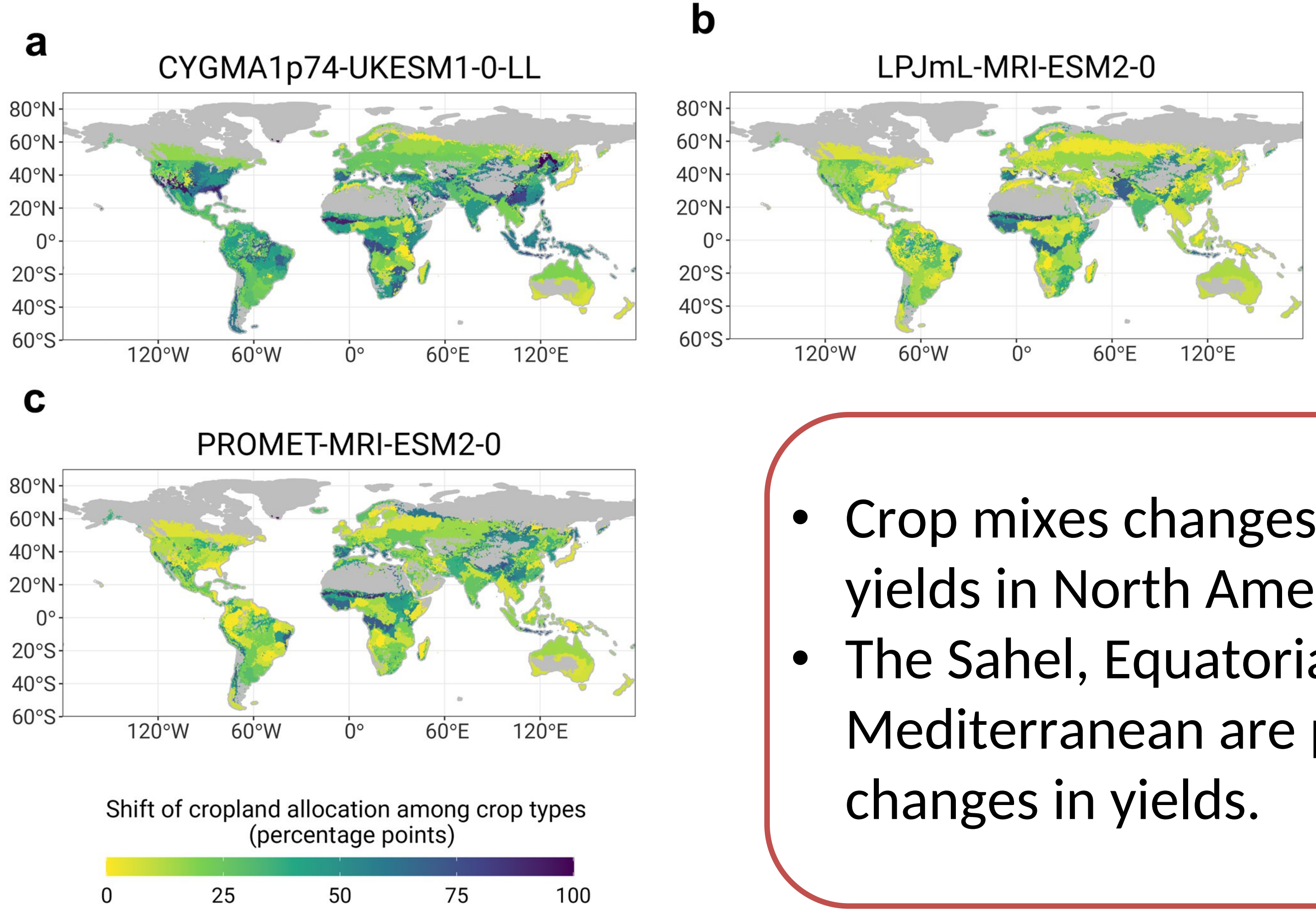

Fig. 5 Shift (in percentage points) of allocation of cropland among different crop types for the SSP5-RCP8.5 scenario, three different GCM-GGCM combinations and compared to the baseline scenario SSP5-NoCC (no climate impacts) in 2100.

- Crop mixes changes driven by the changes in maize yields in North America.
- The Sahel, Equatorial Africa, and the Mediterranean are particularly sensitive to the changes in yields.

Adaptation costs range from positive to negative values

- Uncertainty in SSP1-RCP 2.6 highest around 2050. It is related to population decrease.
- Differences in costs mostly due to investments in R&D and land conversion.
- Regional climate change impact dynamics have a larger effect than the global impacts.

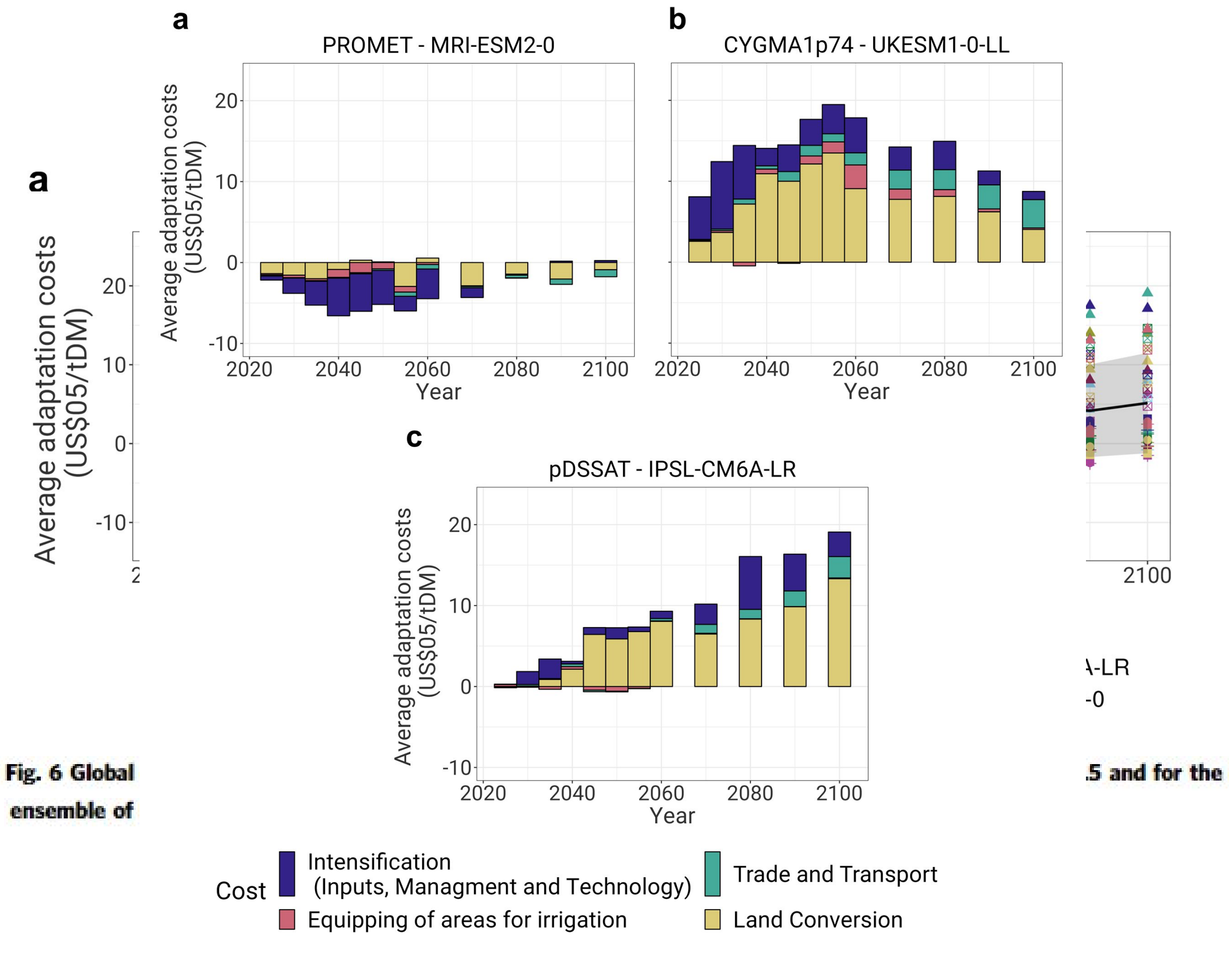

Fig. 7 Details of Climate change-driven adaptation costs for crop production.

Concluding remarks

- Including CO_2 fertilization effects results in lower global cropland expansion, intensification, and cost than previously reported.
- A high level of uncertainty remains at global and local regional scales. This highlights the importance of increasing and improving the flexibility of the food system.
- Costs depend more on regional dynamics (climate and socioeconomic-related adjustments) than global ones.

Thank you!

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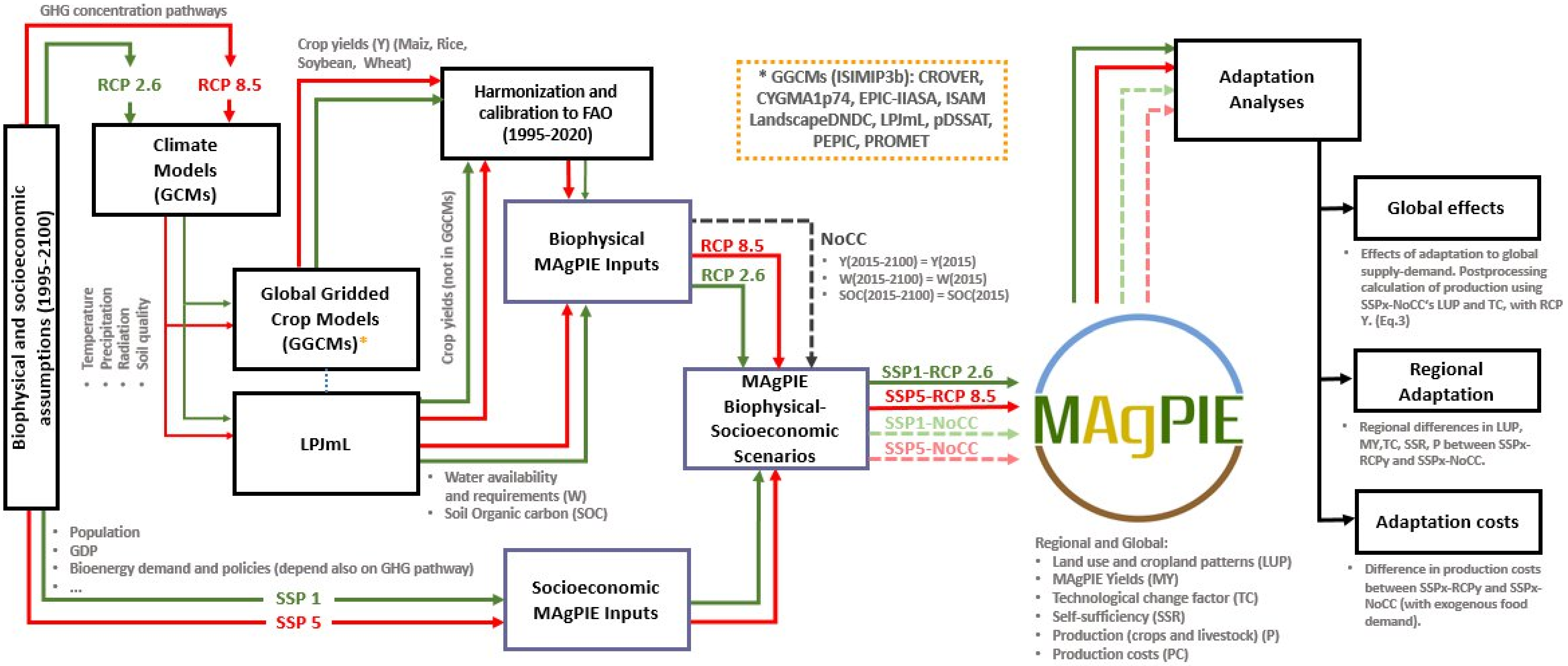
Methodology – Pre-processing of data and analyses



Details Scenarios

Table 1 Assumptions made in MAgPIE for Shared Socioeconomic Pathways SSP1 (Sustainability) and SSP5 (Fossil-Fueled development).

Scenario Setting	SSP1 (Sustainability)	SSP5 (Fossil-Fueled development)
Population[71]	Global population grows slowly and peaks in 2050	Global population grows slowly and peaks in 2050
GDP[72]	Rather rapid income growth	Fast income growth and development
Food Scenario[26]	Healthy and low meat diets, reduced food waste	Unhealthy and high meat consumption diets, high shares of food waste
Trade liberalization (% freely located in more competitive regions)	Reaches 20% for livestock and secondary products, and 30% for all other traded commodities in 2050, until 2100	Reaches 20% for livestock and secondary products, and 30% for all other traded commodities in 2050, until 2100
Land protection and afforestation policies	Compatible with the Paris Agreement and the Nationally Determined Contributions (NDCs)	Current National Policies Implemented (NPIs)
Depreciation rate for capital	5%	5%
Bioenergy demand, emissions budget and carbon price[73]	GHG emissions tax emissions and bioenergy demand consistent with an SSP1-RCP2.6 scenario and an emissions budget of 1300 GtCO2 (below 2.0°C) in 2100	Slow incorporation of a uniform carbon price

Self-sufficiency

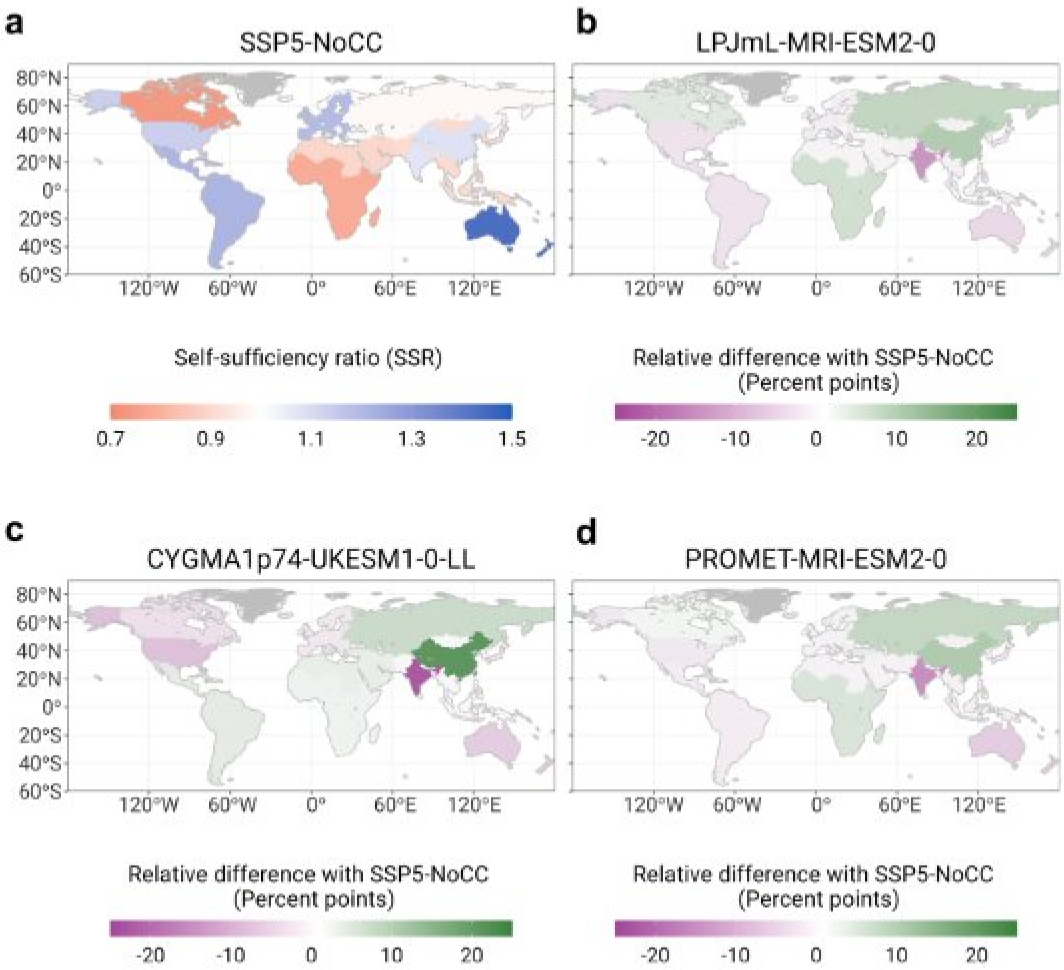


Fig. 4 Aggregated self-sufficiency ratio of traded agricultural products and their relative percentual change compared with the SSP5-NoCC scenario. Values are plotted by world region for the year 2100 under the most divergent scenarios in SSP5-RCP8.5, and LPJmL-MRI-ESM2-0. **a** SSP5-NoCC self-sufficiency ratio, **b** LPJmL-MRI-ESM2-0, **c** CYGMA1p74-UKESM1-0-LL, **d** PROMET-MRI-ESM2-0 represent the difference in percentage points of the self-sufficiency ratio between the SSP5-RCP8.5 simulations and SSP5-NoCC.

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Postprocessing calculation of effects of not adapting

$$Pr_{i,y} = \sum_{i,w,kr} Y_{i,w,kr,y} * C_{i,w,kr,y} * TC_{i,y}$$

GGCM
GGCM

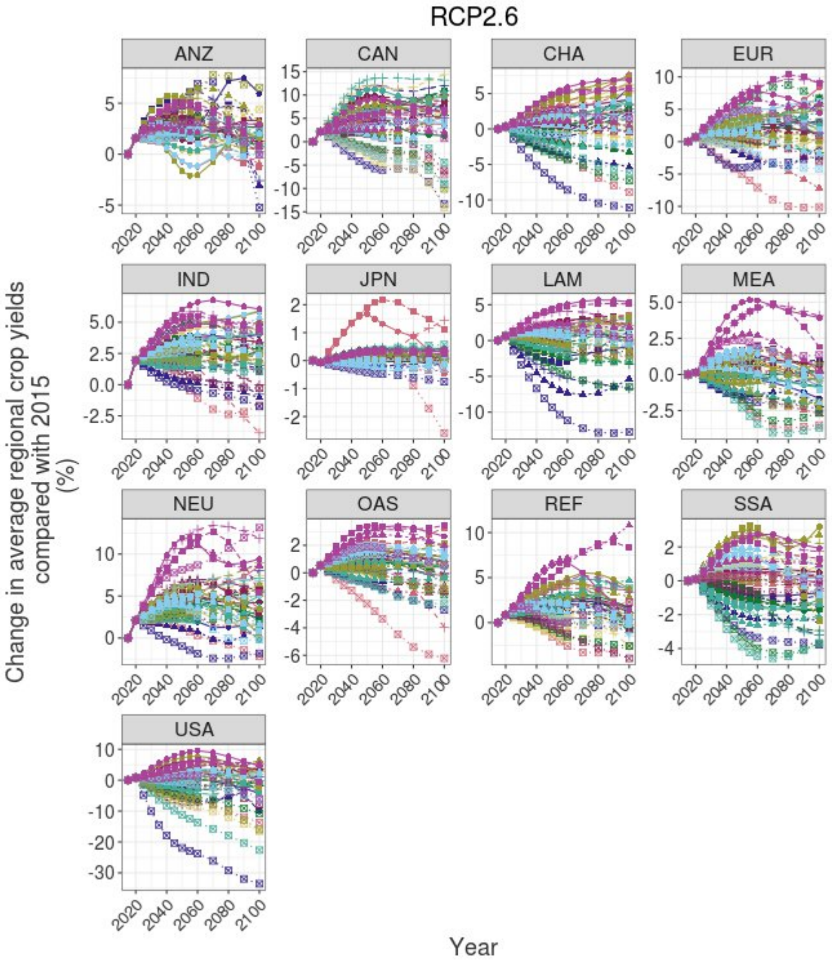
SSPx-RCPy

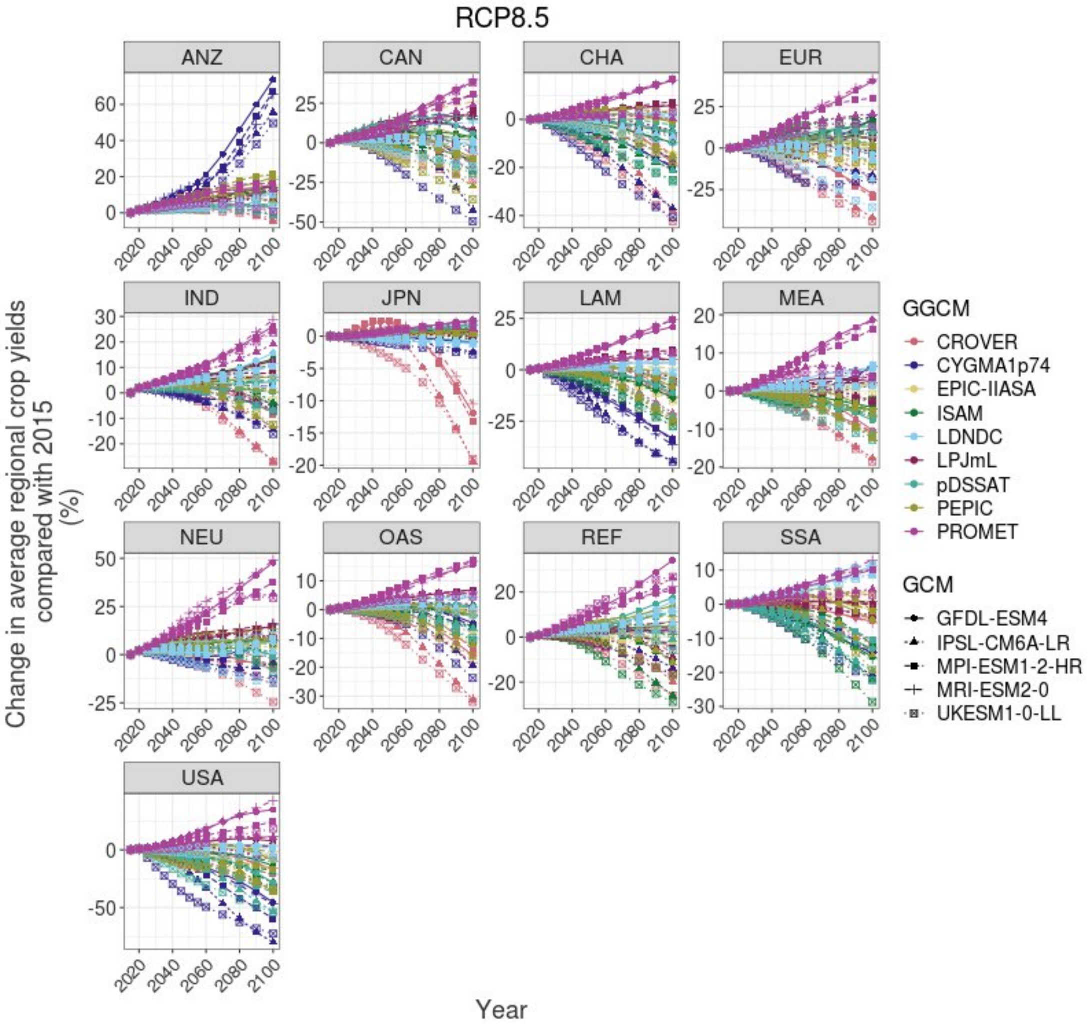
SSPx-NoCC
SSPx-NoCC

Combined effects (TC example)

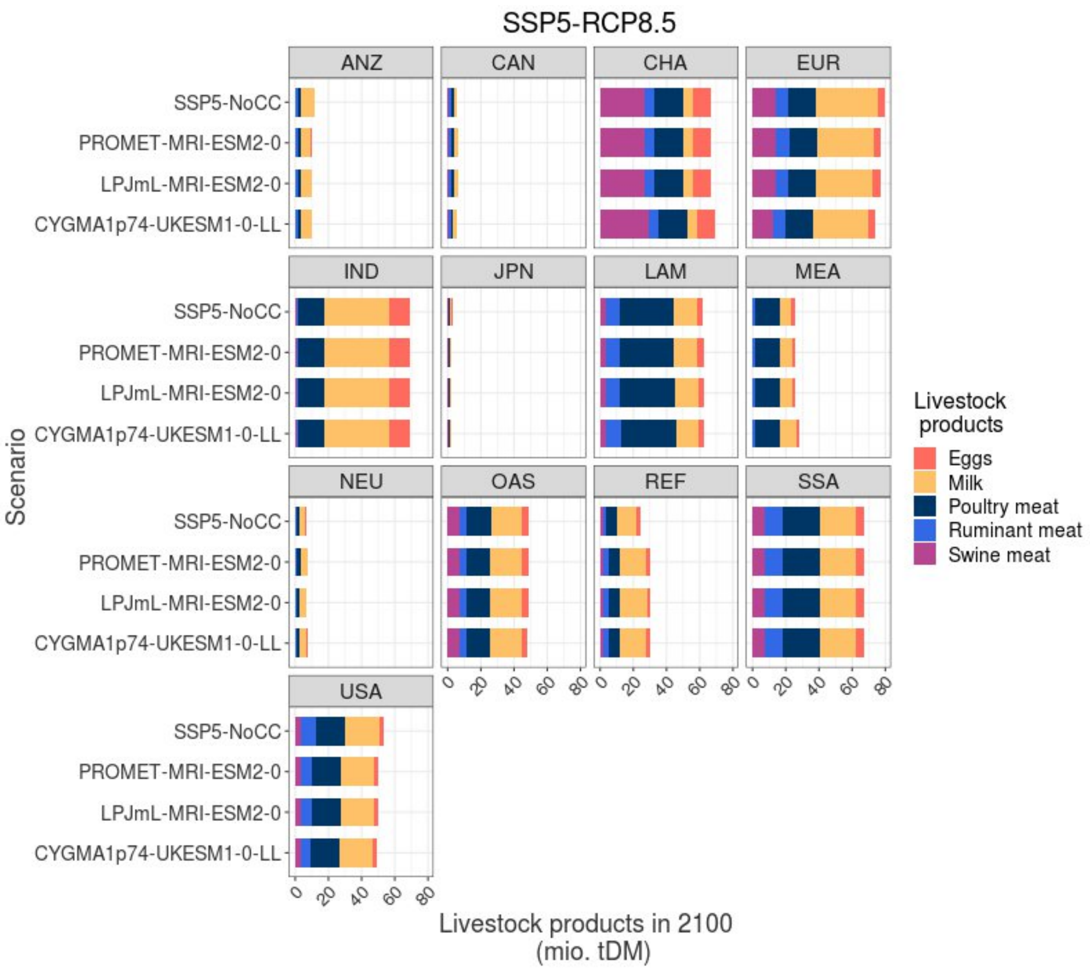
Individual effects

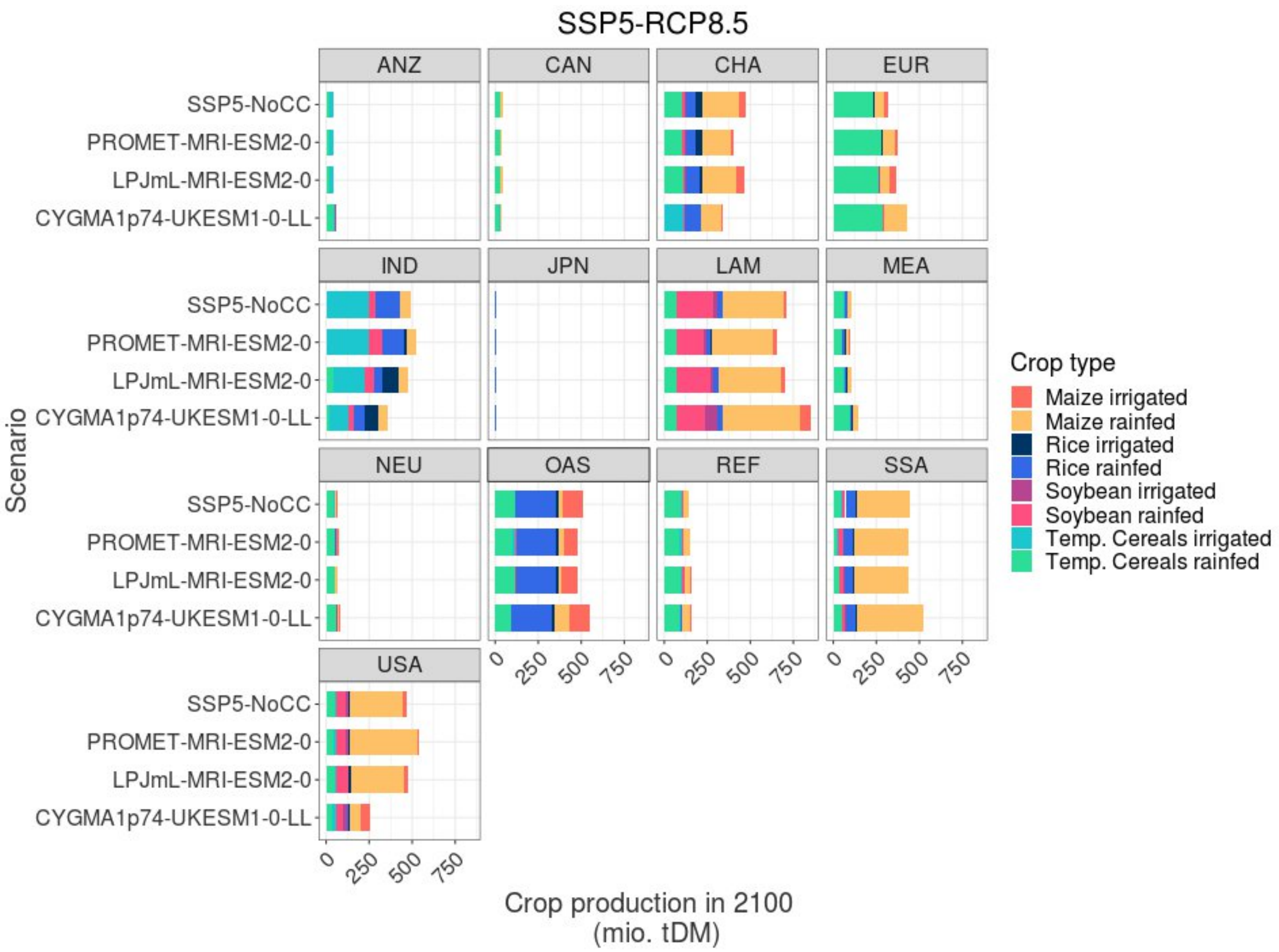
Regional input yields





Regional production





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