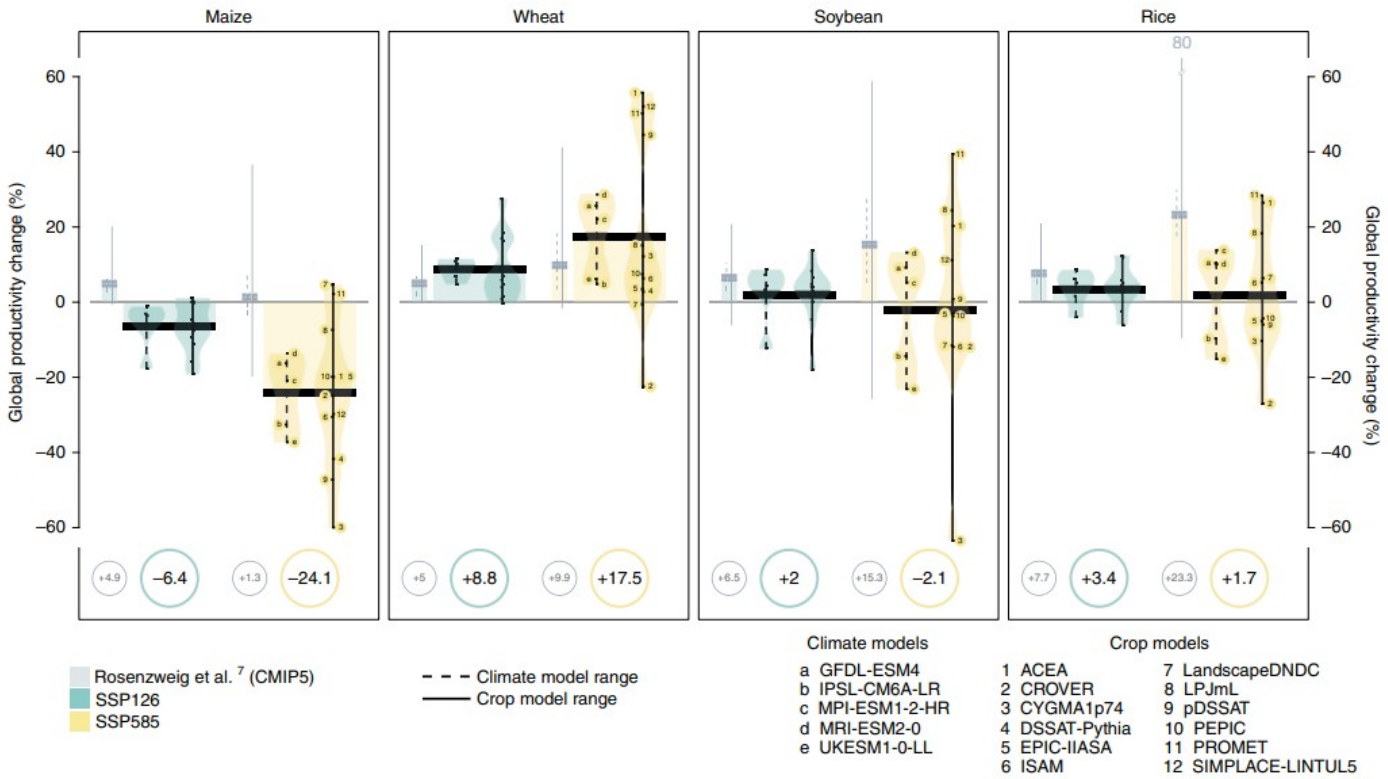
Quantifying food security and mitigation risks consequential to climate change impacts on crop yields

ISIMIP/PROCLIAS workshop 2023

Hermen Luchtenbelt - PBL

Background



Ensemble end-of-century crop productivity response (Jägermeyr et. al, 2021)

- Global crop productivity likely to be impacted under climate change
  - Changing precipitation / extreme temperatures (IPCC 2022)
  - CO_2 fertilization
- Recent GGCMI–CMIP6 model comparison show large uncertainty
- Yield impacts emerge before 2040
- Effects on food security and mitigation targets?

Background

- SDG 2: *By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round*
- *SDG 13: Take urgent action to combat climate change and its impacts*
- *Paris agreement: avoid dangerous climate change by limiting global warming to well below 2°C and pursuing efforts to limit it to 1.5°C*

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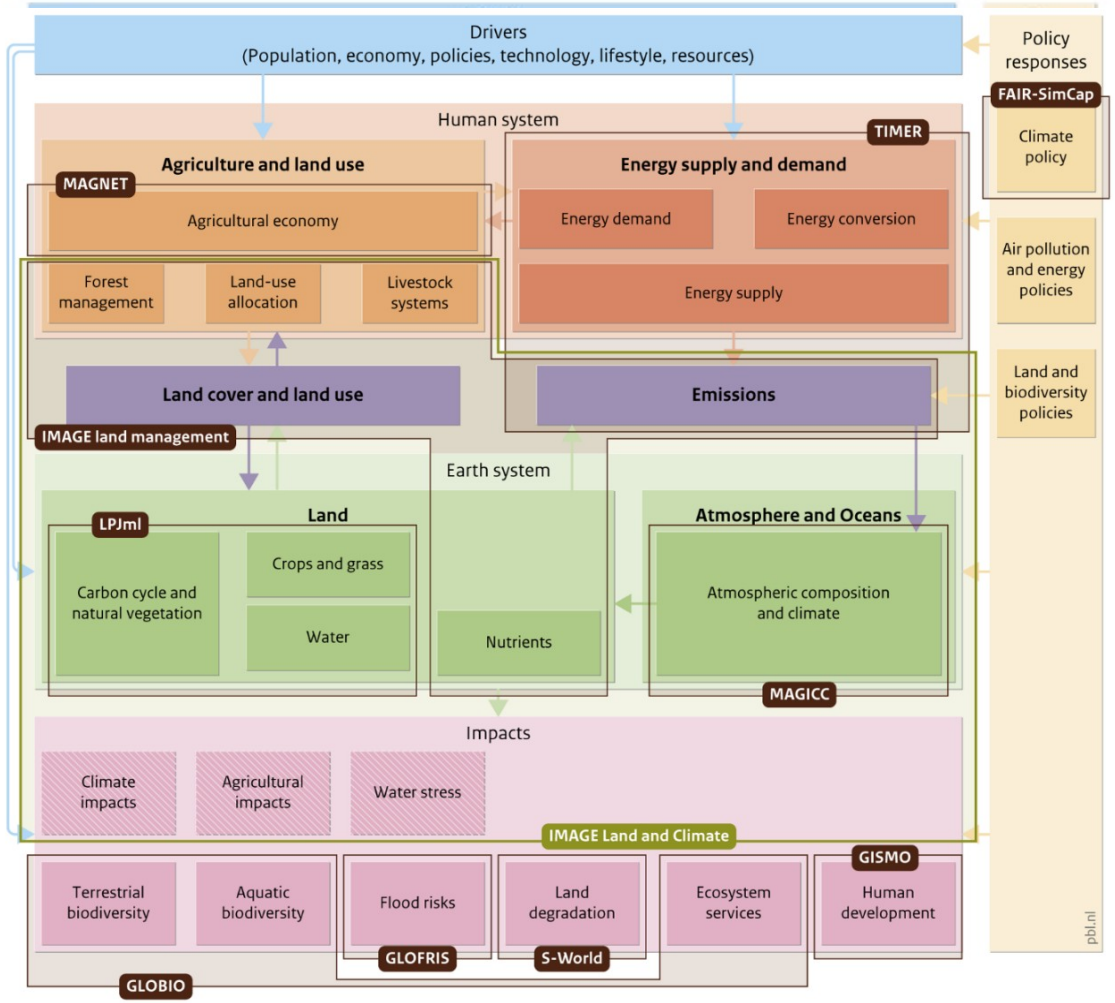
Integrated Assessment Model IMAGE

- Model framework
  - *Interaction between the human and earth system*
  - *Stehfest et. al, 2014*
- *MAGNET: agro-economy*
- *TIMER/fair: climate and energy*



Source: PBL 2014 (Stehfest et. al, 2014)

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Integrated Assessment Model IMAGE

- Model framework
  - *Interaction between the human and earth system*
- *MAGNET: agro-economy*
- *TIMER/fair: climate and energy*
- Crop mapping following (Janssens et al., 2020) and (Müller & Robertson, 2014)
  - To convert four main crops to
- Mitigation policies: Limit GW well below *2°C*

Crop type	**IMAGE LPJmL mapping**
Wheat	Wheat productivity changes directly applied
Rice	Rice productivity changes directly applied
Maize	Maize productivity changes directly applied
Tropical Cereals (millet, sorghum)	Modified corn yields where only half of the negative effects are applied due to better drought tolerance
Other temperate cereals (rye, barley)	Modified wheat yields where only half of the negative effects are applied due to better drought tolerance
Soybeans	Soybean productivity changes directly applied
Pulses (field peas), temperate oil crops (rapeseed, sunflower), tropical oil crops (groundnuts), temperate roots & tubers, tropical roots & tubers, sugar crops, oil & palm fruit	C_3 crops are represented by the average of three modelled C_3 crops (wheat, rice and soybean)

Model selection

- To get a good representation of the different climate-crop combinations:
  - two pessimistic, optimistic model and average climate-crop model combinations are used (from Jägermeyr et. al, 2021)

RCP	Climate model (GCM)	Crop model (GGCM)
RCP26	Mri-esm2-0	Promet
RCP26	Mri-esm2-0	Crover
RCP26	Ukesm1-0-ll	Simplace-Lintul5
RCP26	Mri-esm2-0	Lpjml
RCP26	Ukesm1-0-ll	Crover
RCP26	Mpi-esm-1-2-hr	Dssat-pythia
RCP85	Ukesm1-0-ll	Acea
RCP85	Ukesm1-0-ll	Simplace-Lintul5
RCP85	Gfdl-esm4	Epic-iiasa
RCP85	Mri-esm2-0	Epic-iiasa
RCP85	Ipsl-cm6a-lr	Pepic
RCP85	Gfdl-esm4	Dssat-pythia

Scenario setup

- To get a good representation of the different climate-crop combinations:
  - two pessimistic, optimistic model and average climate-crop model combinations are used
- Socio-economics: SSP2 for all scenario's
- Climate mitigation policy based on RCP2.6!
  - To limit GW well below 2°C

RCP	Climate model (GCM)	Crop model (GGCM)	Socio-economics	Climate Policy-target
RCP26	Mri-esm2-0	Promet	SSP2	2.6
RCP26	Mri-esm2-0	Crover	SSP2	2.6
RCP26	Ukesm1-0-ll	Simplace-Lintul5	SSP2	2.6
RCP26	Mri-esm2-0	Lpjml	SSP2	2.6
RCP26	Ukesm1-0-ll	Crover	SSP2	2.6
RCP26	Mpi-esm-1-2-hr	Dssat-pythia	SSP2	2.6
RCP85	Ukesm1-0-ll	Acea	SSP2	2.6
RCP85	Ukesm1-0-ll	Simplace-Lintul5	SSP2	2.6
RCP85	Gfdl-esm4	Epic-iiasa	SSP2	2.6
RCP85	Mri-esm2-0	Epic-iiasa	SSP2	2.6
RCP85	Ipsl-cm6a-lr	Pepic	SSP2	2.6
RCP85	Gfdl-esm4	Dssat-pythia	SSP2	2.6

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Preliminary results

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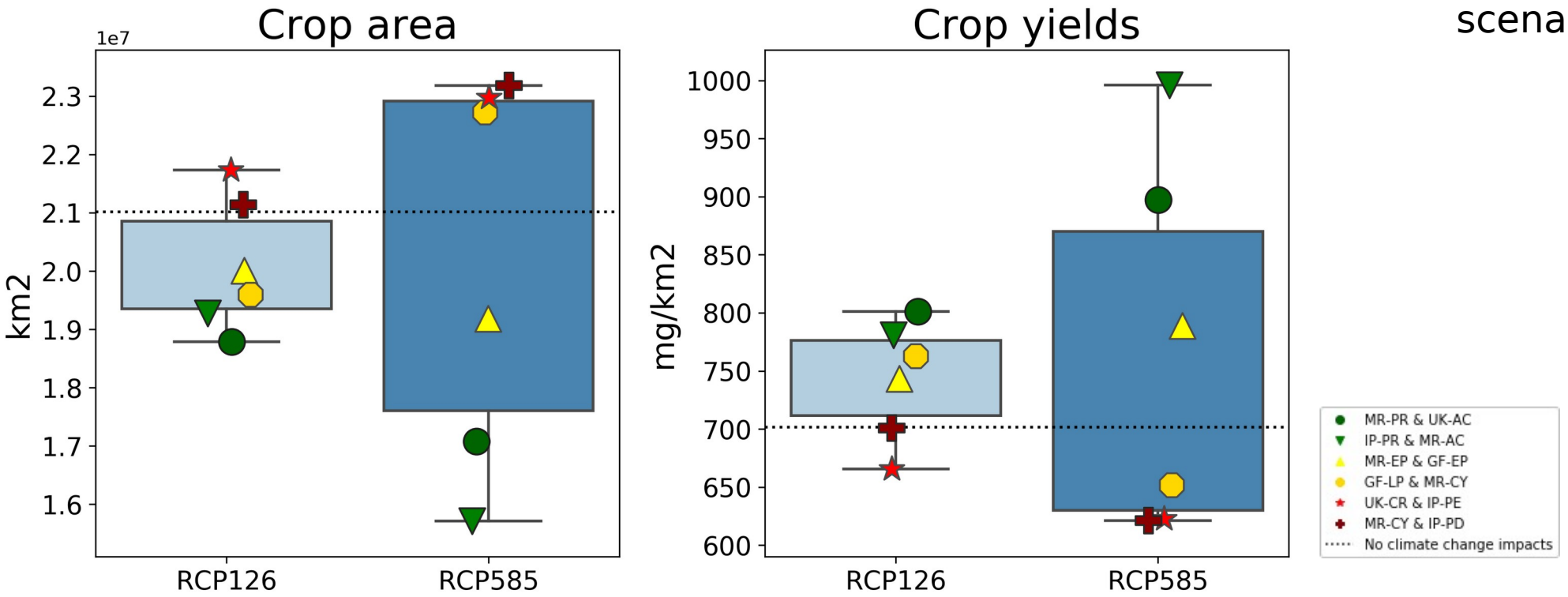
Impacts on agricultural production

Crop area and yields in 2085*



- Increase in global cropland area by almost 10% in the pessimistic scenarios (RCP 8.5)

*average of 2070-2100

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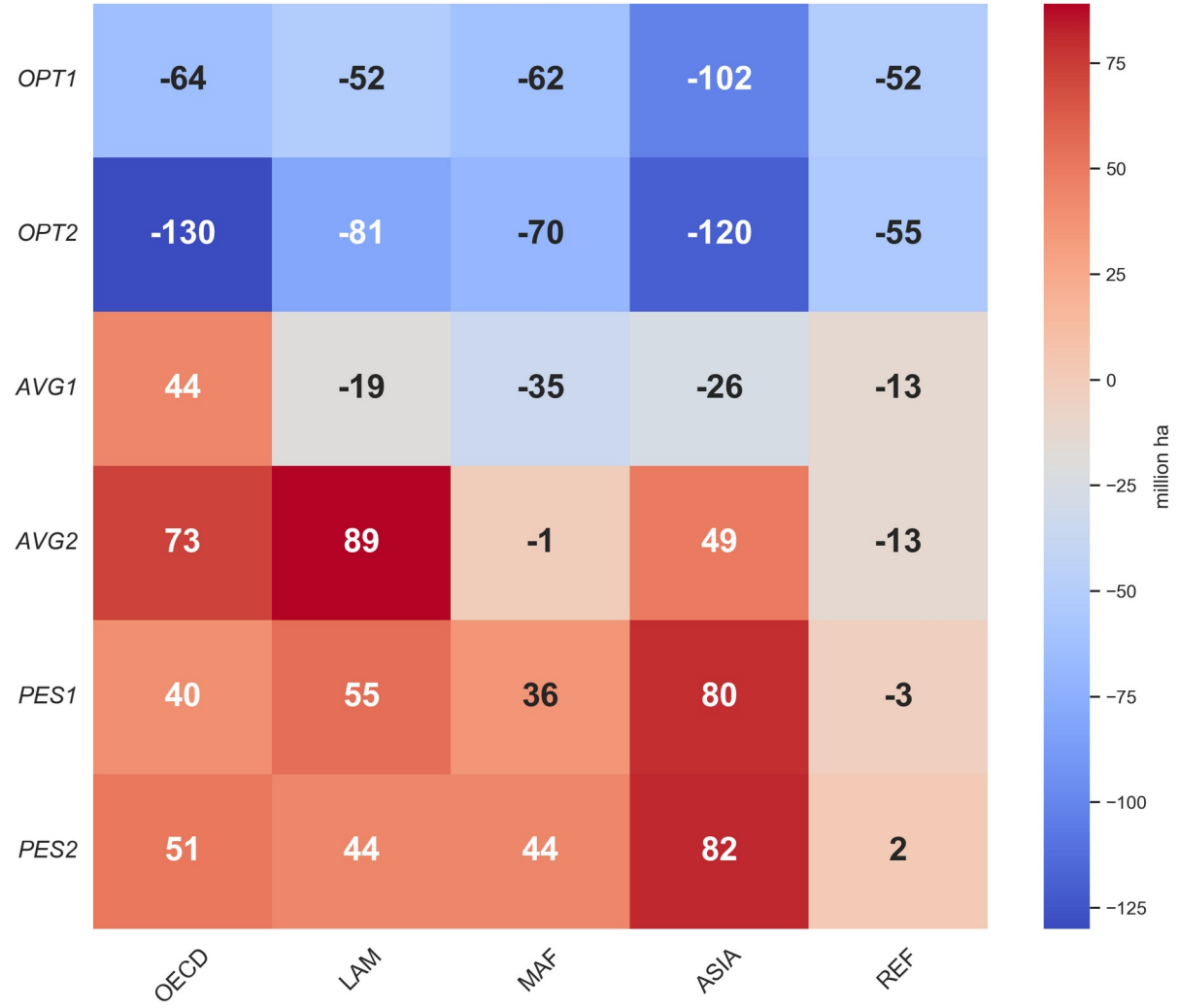
Impacts on agricultural production

Change in cropland area by region
2085 – RCP85

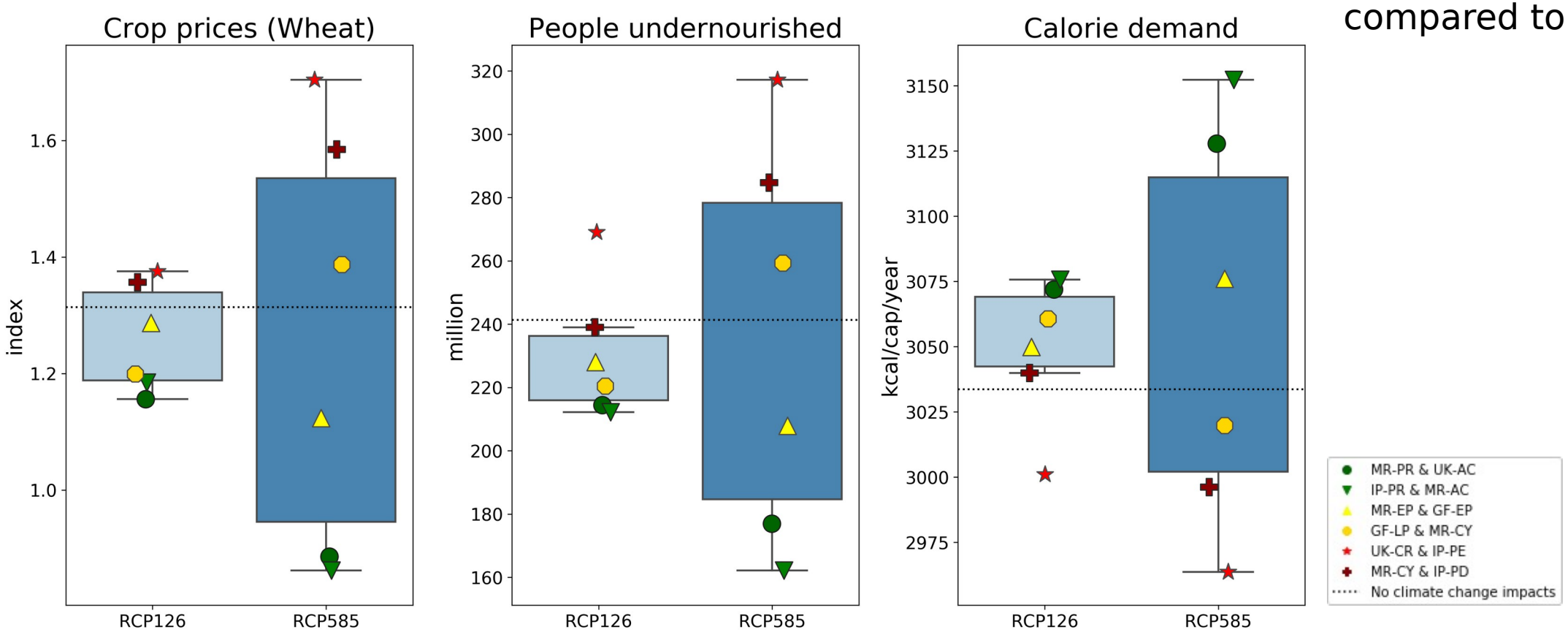


- Increase in global cropland area by almost 10% in the pessimistic scenarios (RCP 8.5)
- Regional impacts:
  - Asia highest impacts on total cropland area: difference up to 200 million

Food security

- Higher level of food insecurity only in pessimistic models
- On average decreasing undernourishment compared to no CC

Impacts on food security indicators in 2085



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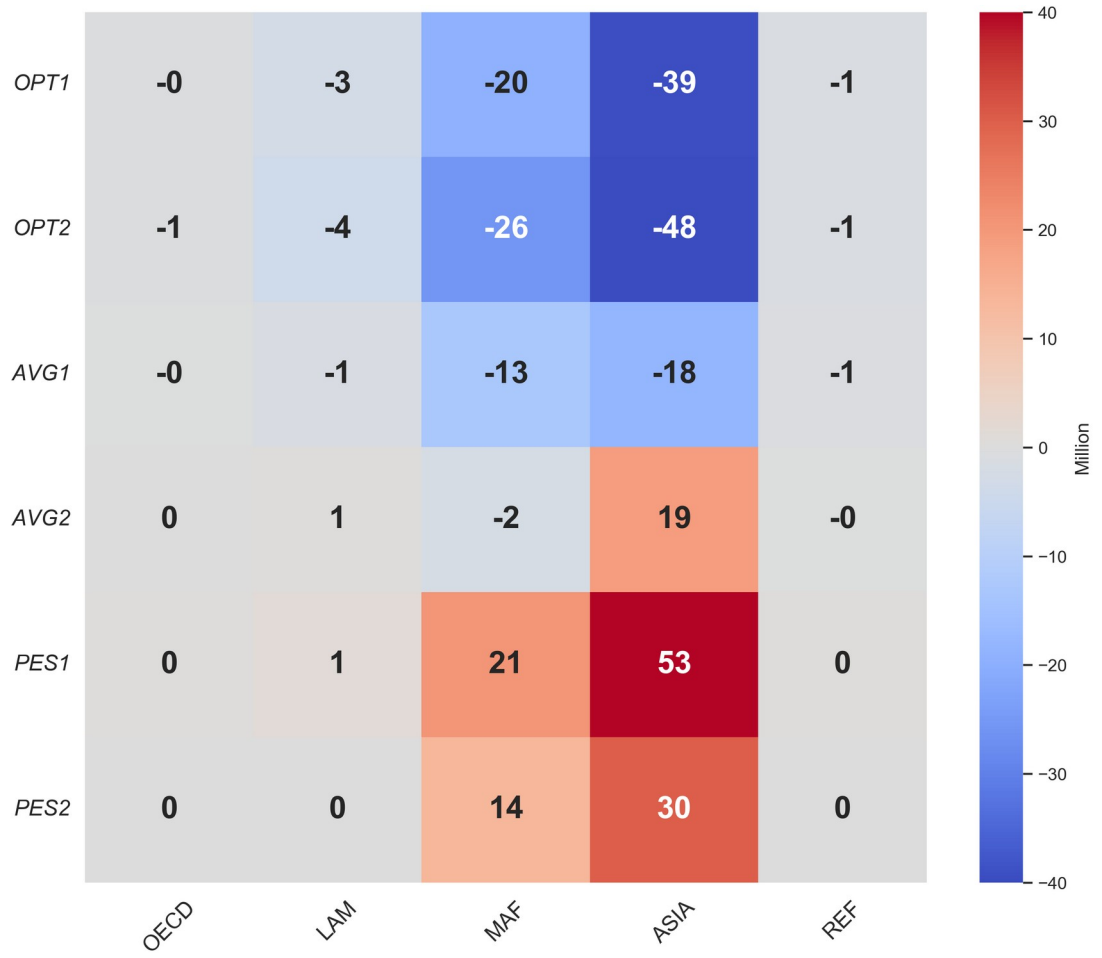
Food security

Change in undernourishment (2085) – RCP85



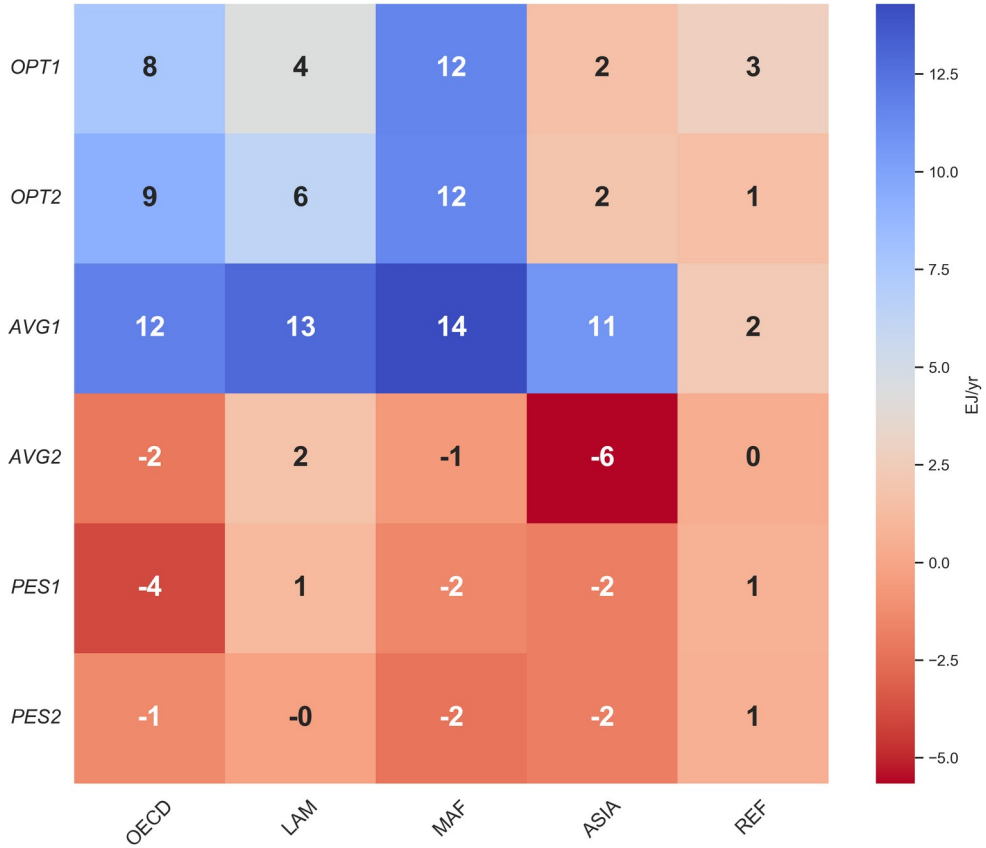
- Higher level of food insecurity only in pessimistic models
- On average decreasing undernourishment compared to no CC

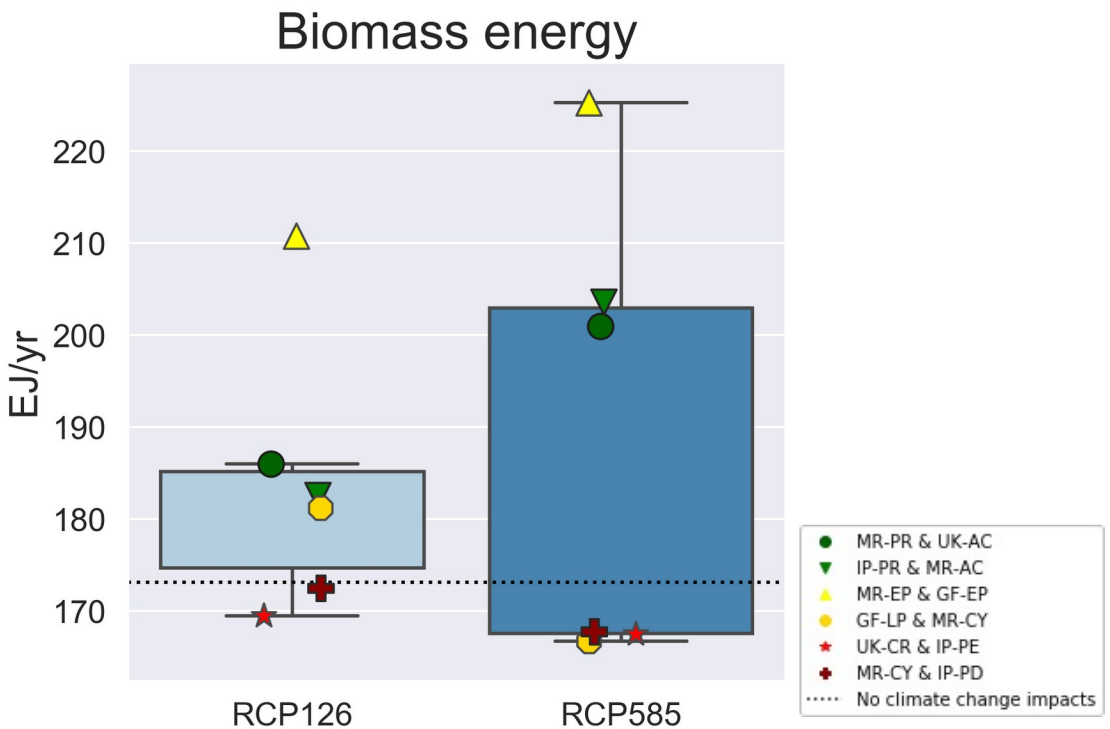
- Middle east and northern Africa impacted most, also difference between models greatest.
  - Food security targets affected by crop yield impacts

Mitigation targets

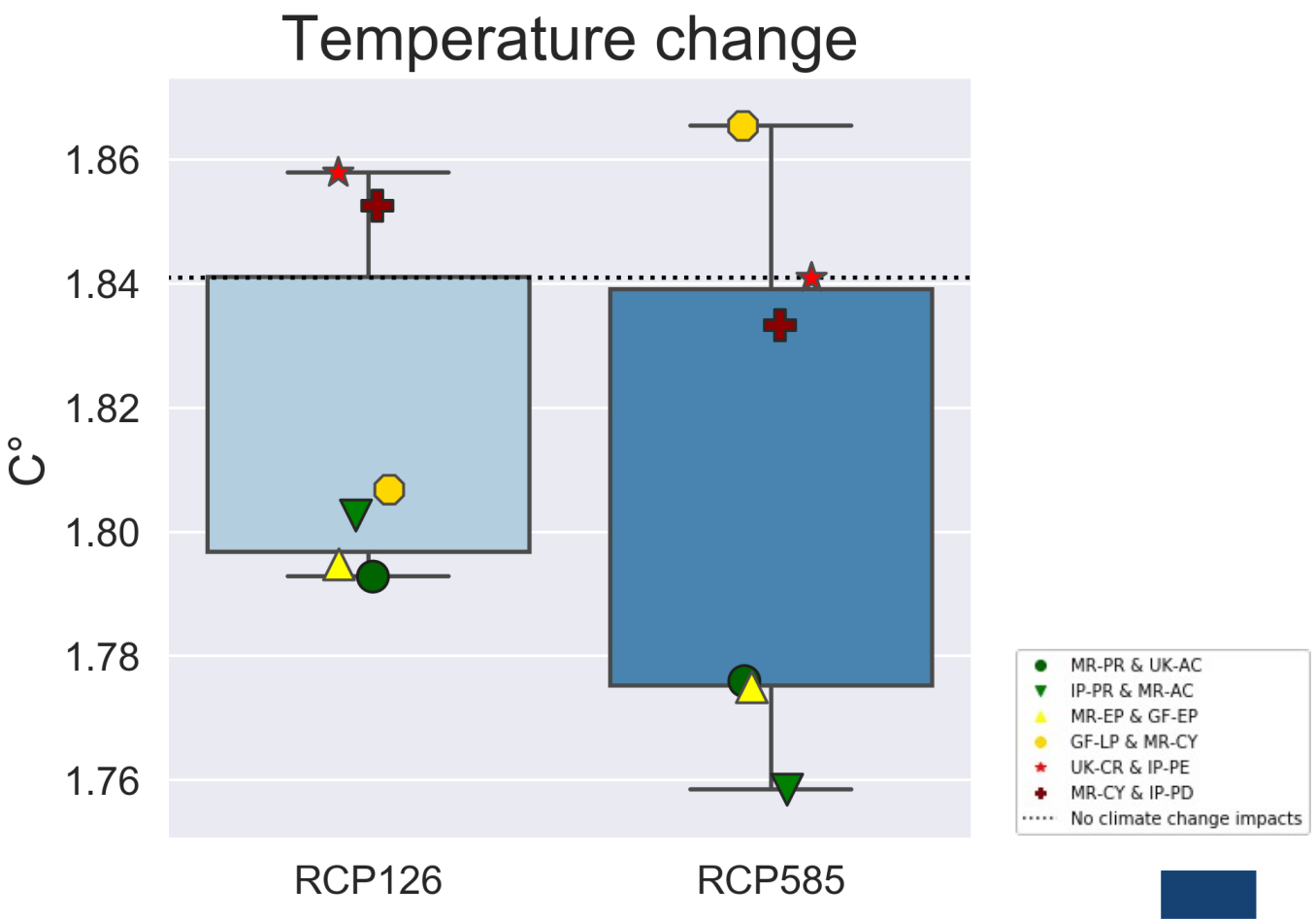
- Set of ‘optimistic’ and some ‘average’ models show an increase in energy from biomass and renewable energy shares

Energy from biomass compared to no CC (2085) – RCP85





Mitigation targets



- Set of ‘optimistic’ and some ‘average’ models show an increase in energy from biomass and renewable energy shares
- Temperature difference can be up to 0.1 degrees for RCP85 productivity impacts, and 0.07 degrees for RCP26
  - Mitigation efforts may not align with policy target!

Conclusion

- Large uncertainty in crop productivity responses affect IAM model simulation results
- Mitigation and food security policies may fall short:
  - SDG 2: Pessimistic model combinations show that global hunger might increase in some regions, as crop prices increase
  - SDG 13: There is a difference of 0.1 degrees
    - Which can be quite significant in reaching mitigation targets

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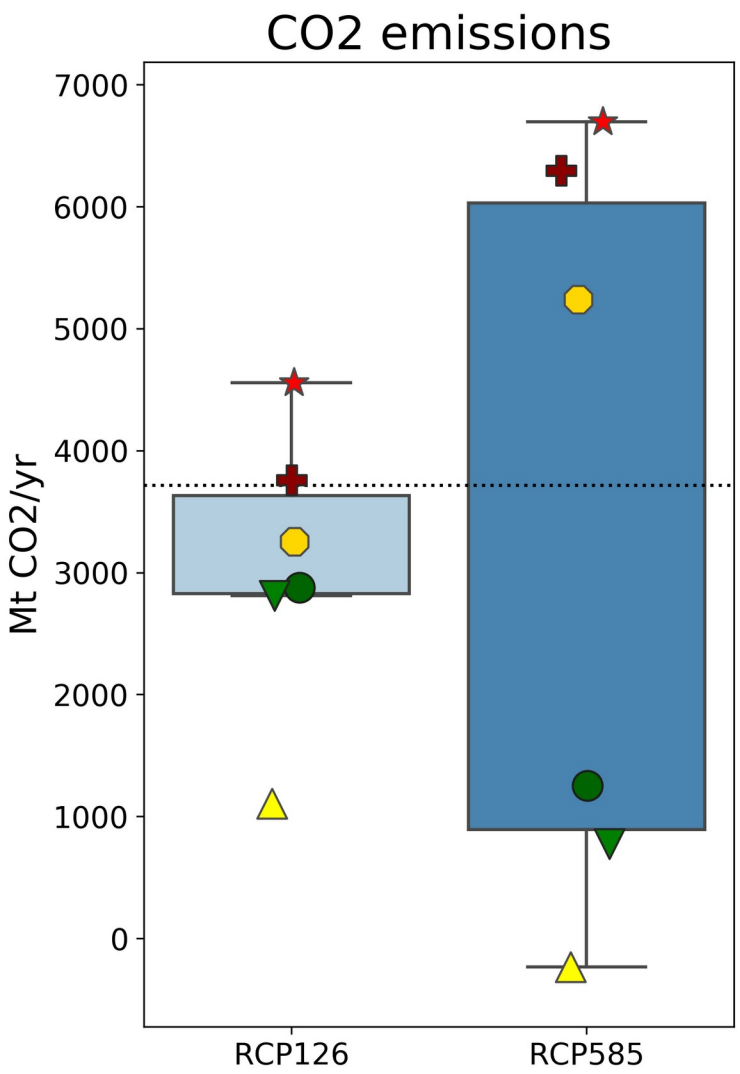
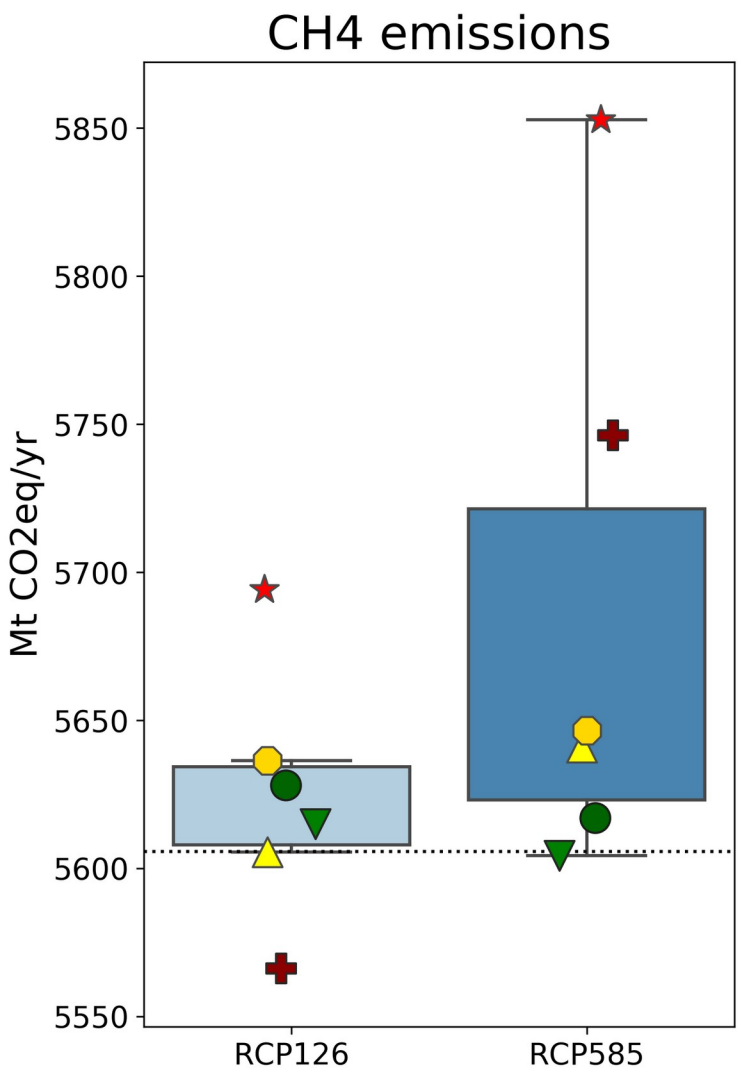
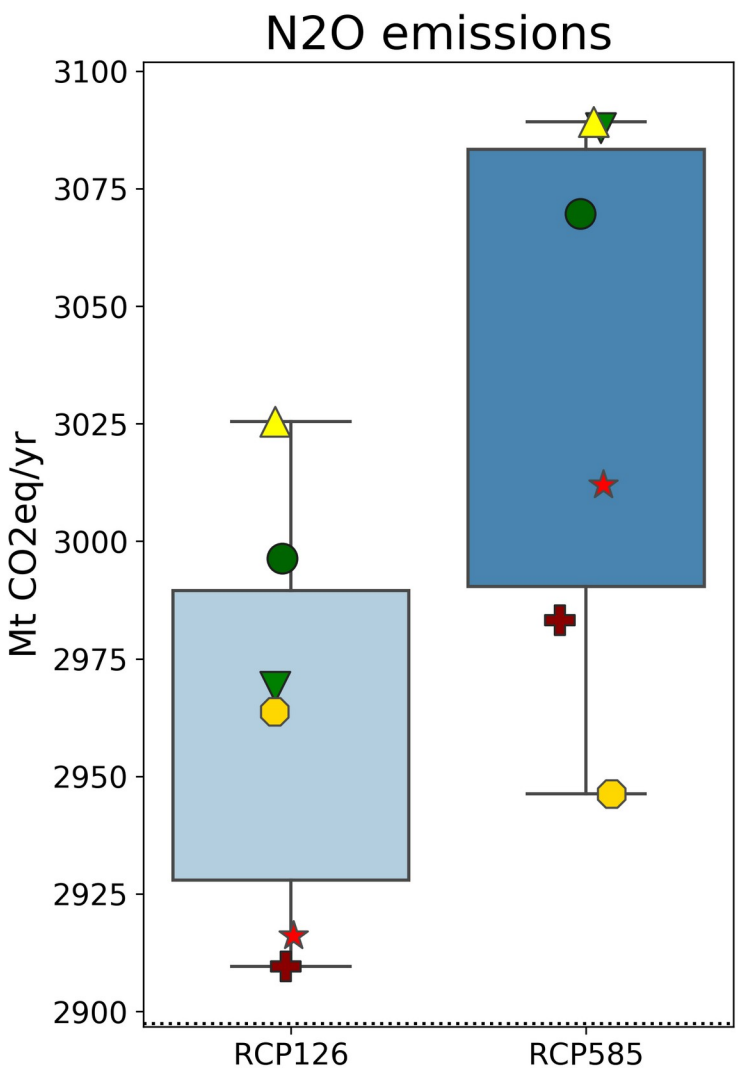

CO2 emissions
Mt CO2/yr
7000
6000
5000
4000
3000
2000
1000
0
RCP126
RCP585


CH4 emissions
Mt CO2eq/yr
5850
5800
5750
5700
5650
5600
5550
RCP126
RCP585


N2O emissions
Mt CO2eq/yr
3100
3075
3050
3025
3000
2975
2950
2925
2900
RCP126
RCP585

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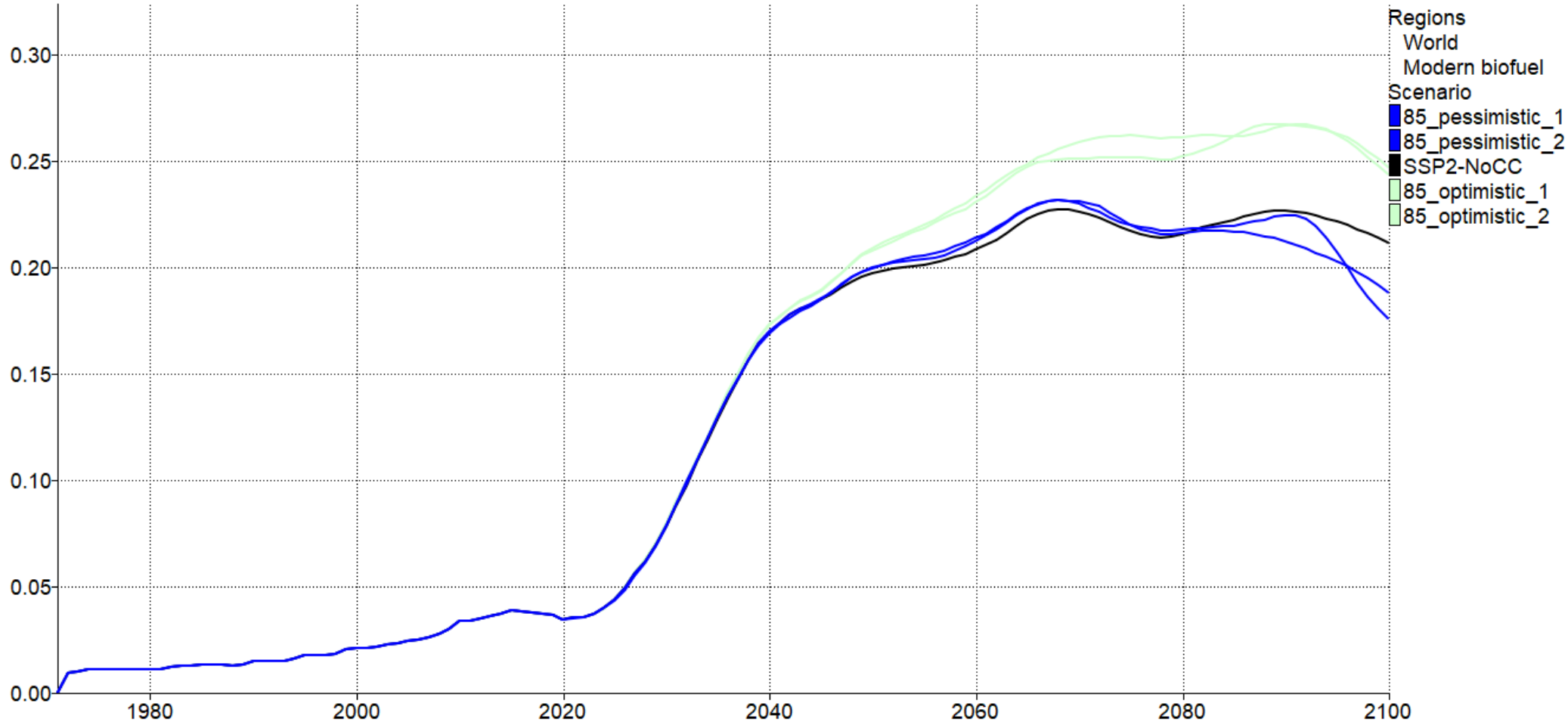
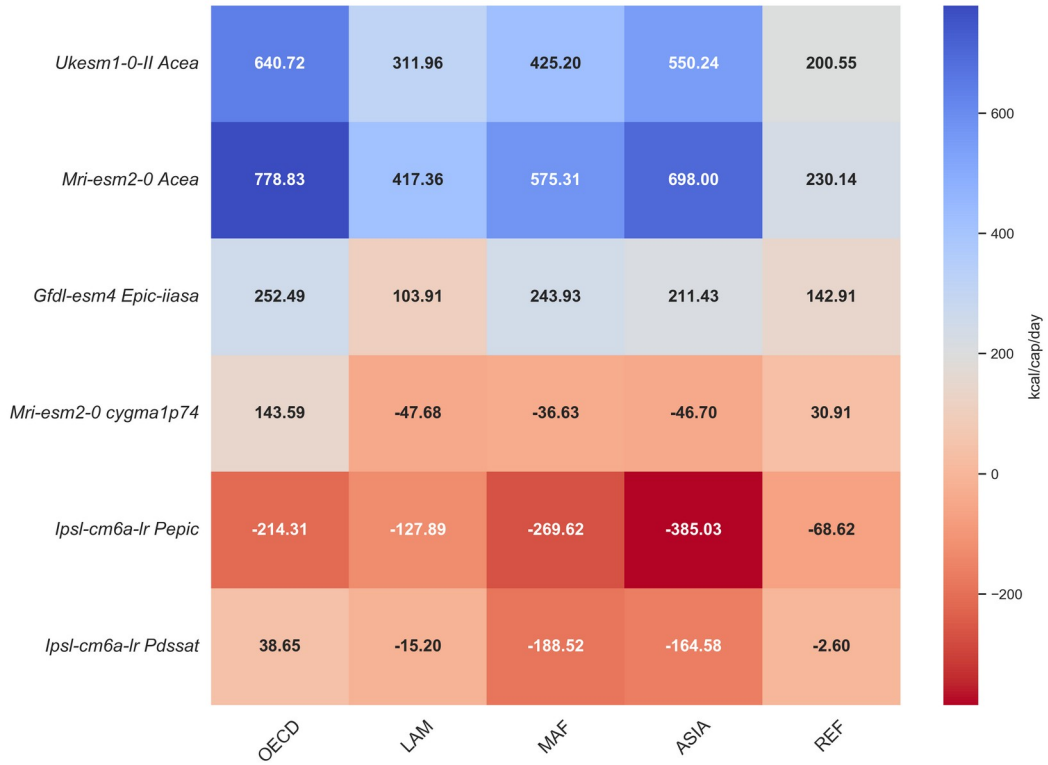
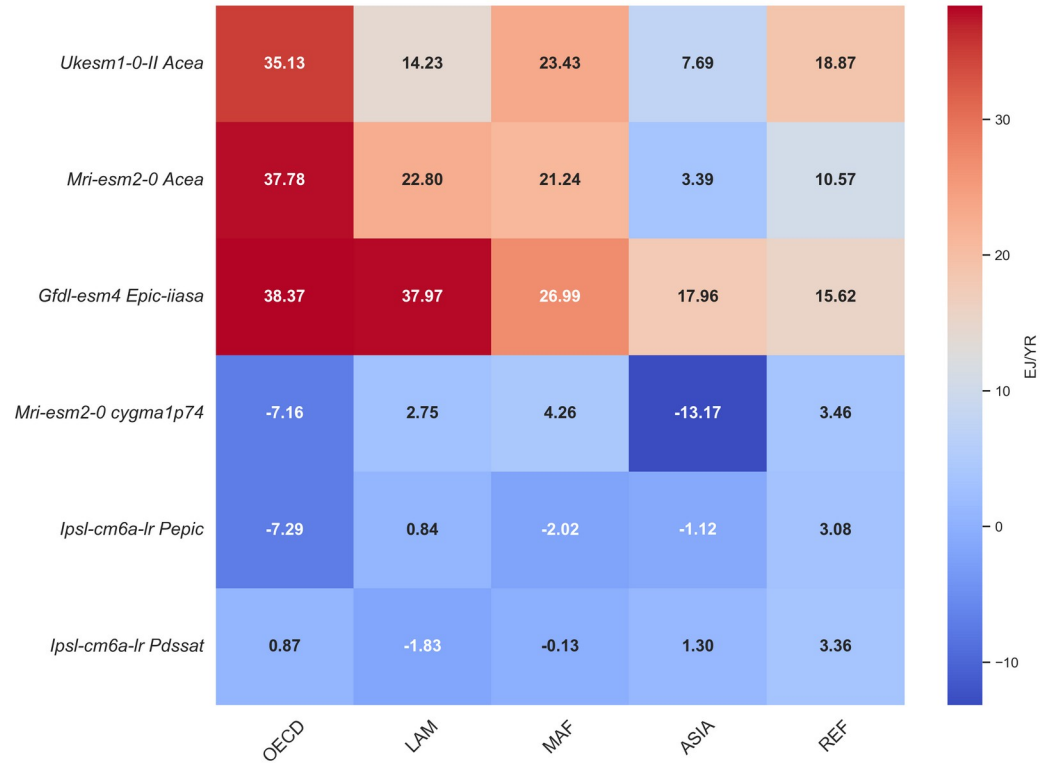
Primary energy share - 1971



Change in Calorie demand (2070-2100)



Change in Biomass Energy (2070-2100)



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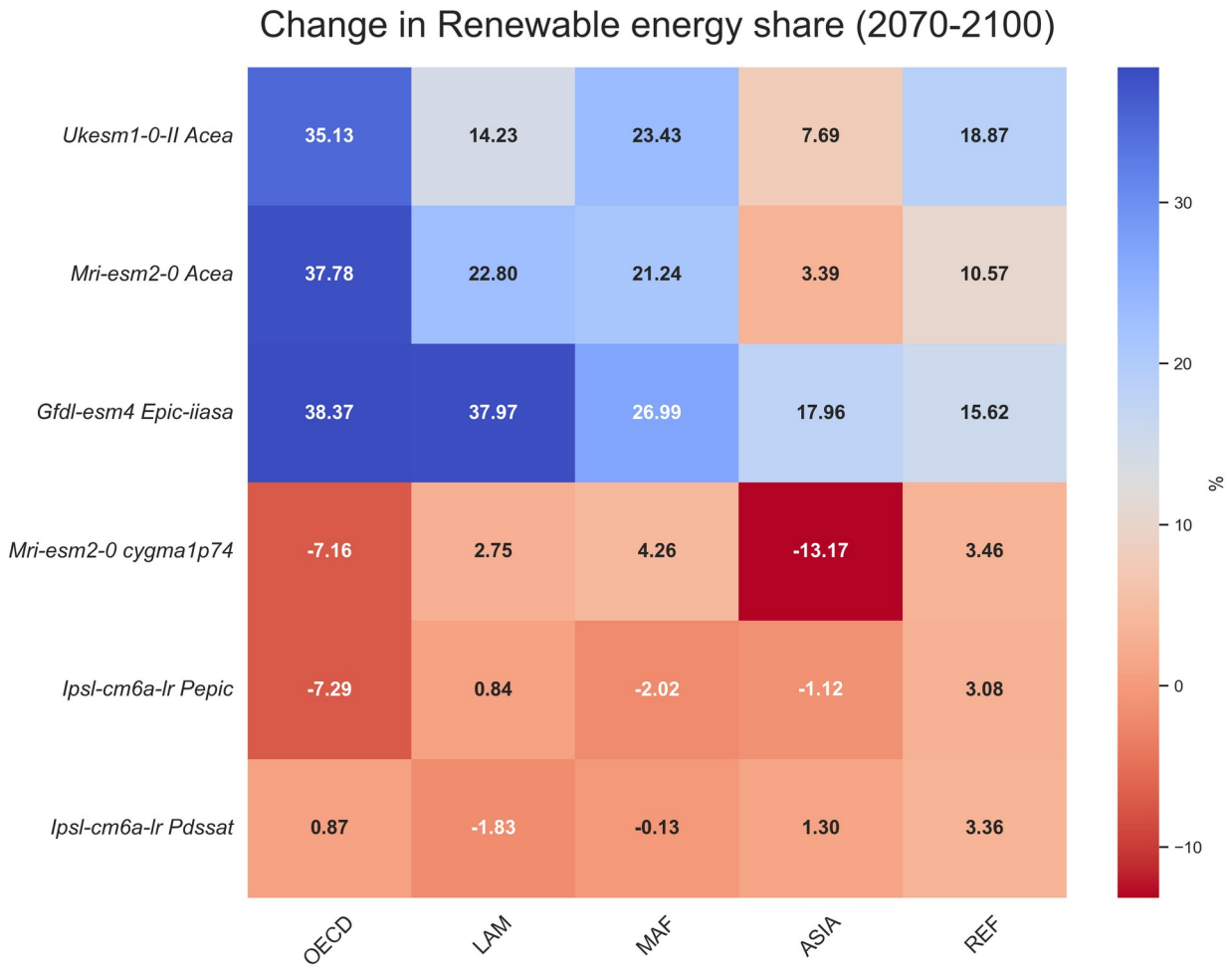
Mitigation targets



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Regional impacts