Comprehensive global climate impact assessment for crop yields

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Climate change impact assessments are often incomplete

- Sparse sampling of scenarios, models and crops
- Very high computational requirements
- Large uncertainties in drivers (climate scenarios, management) and modeled responses make interpretations of results from sparse sampling difficult
- We here employ potent, light-weight crop model emulators for
  - 9 different global gridded crop models
- to simulate crop yield impacts across the full CMIP5 and CMIP6 climate projections for
  - RCP2.6,
  - RCP4.5, and
  - RCP8.5
Step 1, the basis: the CTWN-A Experiment

The CTWN-A data cube: Regular disturbances of 31-year AgMERRA weather data

- **Carbon dioxide**: 360, 510, 660, 810 ppm ($n_C=4$)
- **Temperatures**: -1°C to +6°C, skipping 5°C ($n_T=7$)
- **Water supply**: -50 to +30, skipping -40 + fully irrigated ($n_W=9$)
- **Nitrogen supply**: 10, 60, 200 kgN/ha ($n_N=3$)
- **Adaptation**: regain lost growing season under warming (yes/no)

The full CTWN-A experiment is described by [Franke et al. (2019)](https://doi.org/10.1029/2019ER005799).
Step 2: The CTWN-A crop yield emulators

The CTWN-A emulators are trained on the CTWN-A data cube, fitting a 3rd-order polynomial regression model

- for each 0.5° grid cell, crop and crop model with
- C, T, W, and N as regressors and
- fitting individual models for irrigated and rainfed as well as adapted (A1) and non-adapted (A0) systems.

They can well reproduce simulated climate change impact scenarios, including simulations based on GCM projections with inter-annual variability.

The full CTWN-A emulator suite is described by Franke et al. (2020).
Step 3: the CMIP5 and 6 archives

- All models that provided monthly daily mean near surface air temperature (tas) and monthly precipitation (pr) values
- CMIP5: 45 models, CMIP6: 29 models
Step 6a: growing season changes (1980-2010 vs. 2069-2099) in T

- CMIP6 cooler in RCP2.6 and warmer in RCP8.5
- ensemble and ensemble range smaller in CMIP6
Step 6b: growing season changes (1980-2010 vs. 2069-2099) in P

- wetter future, but CMIP6 dryer than CMIP5
- ensemble and ensemble range smaller in CMIP6
Step 7: emulated yield impacts

CMIP6, RCP8.5, all crop combined

change in global productivity [-]

year (AD)

2020 2040 2060 2080

min/max +/- 1SD

CARAIB EPIC-TAMU LPJmL

GEPIc PEPIC PROMET

JULES pDSSAT

LPJ-GUESS median

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Results: more uncertainty in impact models than in climate projections

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Results: ... and even stronger so in CMIP5
Response to CO$_2$ strongly affects crop model uncertainty share

Seasonal cycle of crop model contribution to overall variance in SSP1, RCP 2.6; SSP2, RCP 4.5; SSP5, RCP 8.5.

CMIP6, static [CO$_2$]
Conclusions

• The GGCMI CTWN-A experiment-based emulators (Franke et al. 2020) allow for an unprecedentedly large ensemble of crop yield projections, which can be employed to assess the full breadth of future climate scenarios

• Broad range of possible climate impacts projected for productivity of major crops

• There are substantial differences in
  • regional responses
  • crop model responses, especially with respect to the effects of elevated [CO₂]

• Next steps
  • better analysis of crop model specifics that lead to strong deviation in projected impacts
  • improve global management data to better represent diverse crop management systems in crop model simulations
References

• The GGCMI project

• Phase 1:

• Phase 2:
Thanks and invite

• Thanks to all GGCMI participants and data suppliers
• Come and join, Phase 3 (improved remake of the ISIMIP fast track in 2012) just starting
  • [https://agmip.org/ag-grid-2/](https://agmip.org/ag-grid-2/)
  • [https://www.isimip.org/](https://www.isimip.org/)
• We provide access to a very large data set on crop yields, input data and secondary outputs to help with your own analysis