Global impact analysis of crop yield considering adaptation measures

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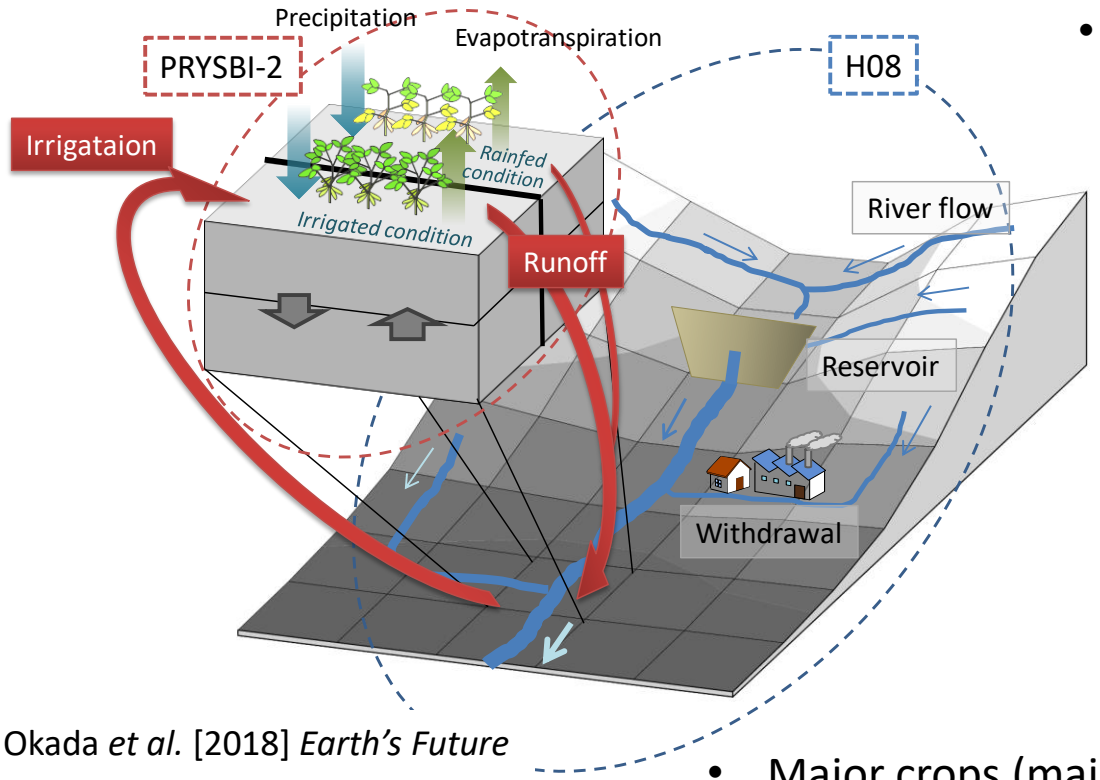
Irrigation as an adaptation measure for climate change

In many studies including IPCC AR5 WGII,

- Use of irrigation is expected to increase yields of major crops in a warmer climate.
- But, dynamic changes in water availability associated with climate change are rarely considered.

- Given the large amount of investments to irrigation equipment that have already occurred and would occur in the future, it is therefore important to address the question:
- Can we expect the benefits of irrigation for global food production in a warmer climate to be similar to the current ones?

Crop model CROVER



Okada *et al.* [2018] *Earth's Future*

- CROVER can simulate five processes simultaneously within a single model:
  - Crop growth,
  - Land surface,
  - River flow,
  - Reservoir operation,
  - Water withdrawal,

  and consequently is powerful in assessing crop yields under varying water availability conditions.

- Major crops (maize, rice, soybean, spring wheat, and winter wheat) grown in currently irrigated and rainfed areas were studied.

➢ We assessed the irrigation effect that leads to higher crop yields in irrigated condition than in rainfed condition by using the CROVER model and 20 climate projections (4 RCPs × 5 GCMs)

Evaluation of model's performance

This figure cannot be shared at this time because this study is still under review. Thank you for your kind understanding.

- The model's reproducibility is satisfactory high in capturing the mean and variance of the regional crop yields.

Fig. Comparison of crop yield between reference data and model estimation in the top three major producing regions for four major global crops.

Future change of global crop yield

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Fig. Response of global yield to global temperature changes from the preindustrial level (1850–1900).

- The change will be
  -1.4 t/ha (-28.5%) in maize,
  -0.9 t/ha (-23.4%) in rice,
  -0.3 t/ha (-15.6%) in soybean,
  +0.1 t/ha (+3.1%) in wheat
  by the end of this century under the high emission scenario.

Projected irrigation effects on global and regional yields

- The metric of irrigation effect here is expressed in yield gain in the irrigated condition over yield in the rainfed condition normalized to irrigated yield.
- **Most regions**: the irrigation effect would rapidly decrease with future warming.

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Fig. Response of irrigation effect to global temperature changes from the preindustrial level (1850-1900).

Projected irrigation effects on global and regional yields

- Lower emission scenario: the irrigation effect would be maintained at the current level.
- **High emission scenario**: the irrigation effect at the end of this century would decrease to 61% of the current level

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Fig. Time series of the irrigation effect in nine regions.

Future changes in irrigation-induced production gain

- Lower emission scenario: the global production gains would unchanged from the current level.
- **High emission scenario**: the gains would decrease to 34.0 Mt or 52.9% of the current level (72.2 Mt) by the end of this century.

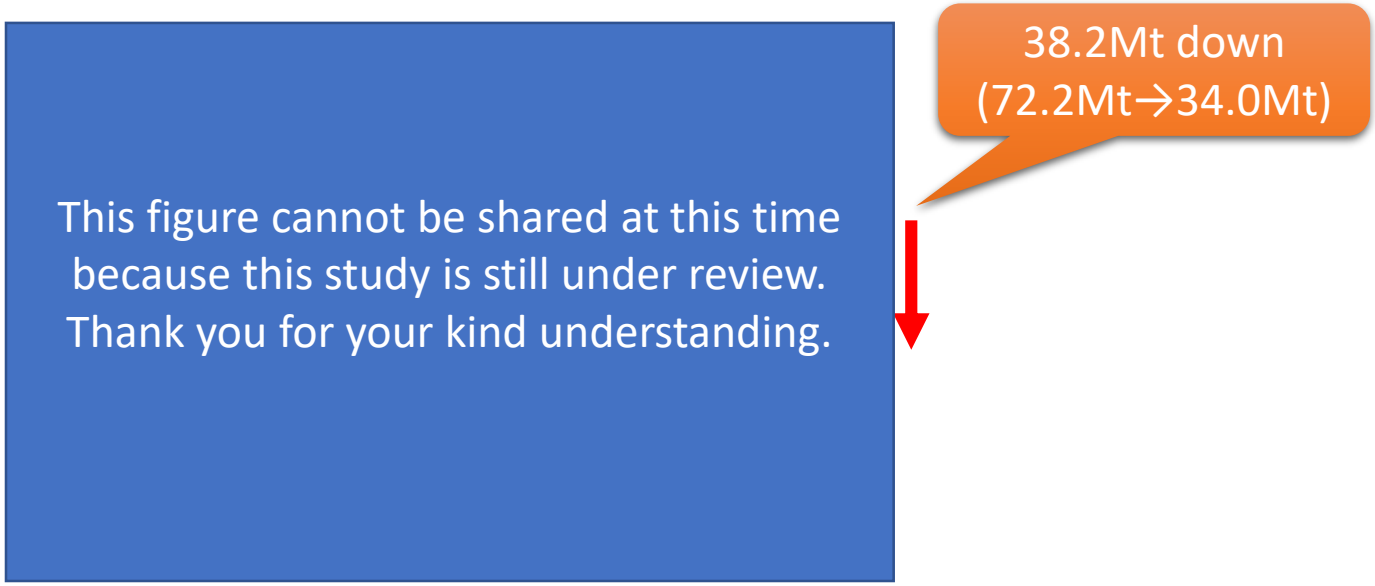

Fig. Projected global total production gains achieved by irrigation.

Future changes in irrigation-induced production gain

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- **High emission scenario**: the gains would decrease to 34.0 Mt or 52.9% of the current level (72.2 Mt) by the end of this century.

38.2Mt down
(72.2Mt→34.0Mt)

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Fig. Projected global total production gains achieved by irrigation.

Yield also decreases by 19.0%

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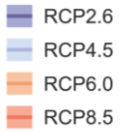


Fig. Response of global yield to global temperature changes from the preindustrial level.

Future changes in irrigation-induced production gain

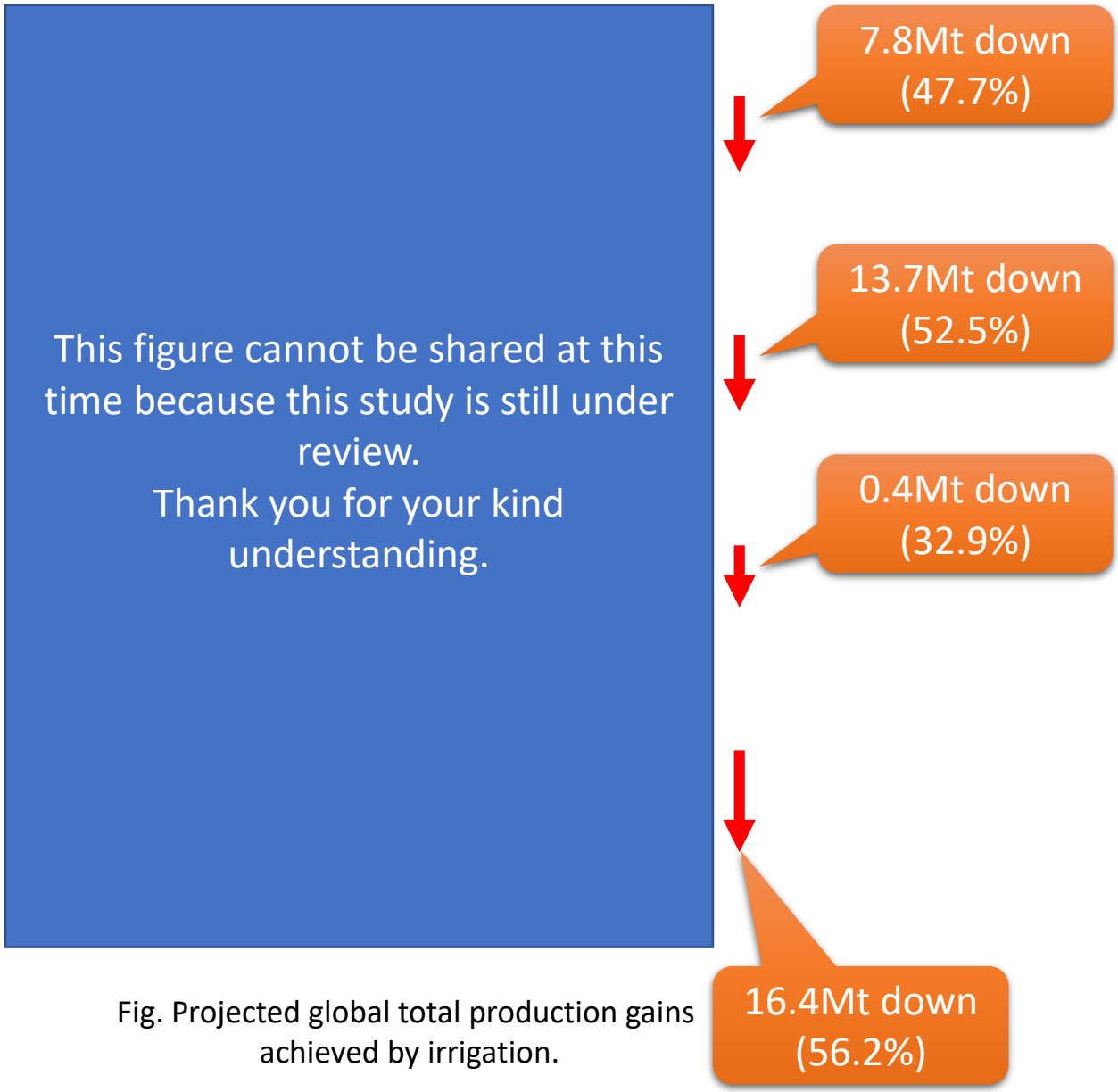
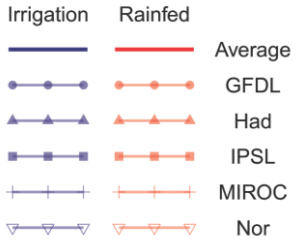


Fig. Projected global total production gains achieved by irrigation.

Future changes in irrigated & rainfed yields

- Crop yield under rainfed condition would gradually increase to the yield level in irrigated condition.
  - Future increased precipitation leads to an increase of water availability for irrigation as well as increase of rainfalls for rainfed condition, but which conducts more benefits on yield of rainfed crops than irrigated ones.
  - Increased CO_2 also contributes to improve the water use efficiency of the crops, which benefit but is partly offset by increased biomass with CO_2 rise.



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Temperature increase [degree C]

Fig. Response of irrigated and rainfed yields in major global crops to global temperature changes from the preindustrial level.

Discussion

- Annual investments to irrigation facilities approximately cost US$1.1 thousand/ha for the past 20 years in developing countries.
- FAO states that additional investments of US$ 960 billion is required to meet food demands in 2050.

➢ The projected declines in the irrigation effect might deteriorate cost-benefit ratios in the new development of irrigation infrastructures.

➢ Moreover, this might affect yield growth rates, which are required to keep pace with increasing demand for food.

- Replacing rainfed cropland with irrigated one is deemed as an adaptation measure to climate change and would be promising for some regions where agricultural drought risk would increase.
- But irrigation might be a less effective means in adaptation for the remaining regions than initially thought.

Thank you for your attention