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Why do crop models diverge substantially in climate impact projections?

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Introduction

Robust projections of climate impact on crop growth and productivity by crop models are key to designing effective adaptations to cope with future climate risk. However, current crop models diverge strongly in climate impact projections (Asseng et al., 2013, 2015). Previous studies tried to compare or improve crop models regarding the impact of one single climate variable (Asseng et al., 2013, 2015; Wang et al., 2017; Durand et al., 2018). However, this approach is insufficient, considering that crop growth and yield are affected by the interactive impacts of multiple climate change factors and multiple interrelated biophysical processes.

Materials and Methods

Here, a new comprehensive analysis was conducted to look holistically at the reasons why crop models diverge substantially in climate impact projections and to investigate which biophysical processes and knowledge gaps are key factors affecting this uncertainty and should be given the highest priorities for improvement. First, eight barley models and eight climate projections for the 2050s were applied to investigate the uncertainty from crop model structure in climate impact projections for barley growth and yield at two sites: Jokioinen, Finland (Boreal) and Lleida, Spain (Mediterranean). Sensitivity analyses were then conducted on the responses of major crop processes to major climatic variables including temperature, precipitation, irradiation, and CO_2, as well as their interactions, for each of the eight crop models.

Results and Discussion

The results showed that the temperature and CO_2 relationships in the models were the major sources of the large discrepancies among the models in climate impact projections (Figure 1). In particular, the impacts of increases in temperature and CO_2 on leaf area development were identified as the major causes for the large uncertainty in simulating changes in evapotranspiration, above-ground biomass, and grain yield (Figure 1). Our findings highlight that advancements in understanding the basic processes and thresholds by which climate warming and CO_2 increases will affect leaf area development, crop evapotranspiration, photosynthesis, and grain formation in contrasting environments are needed for modelling their impacts.

Conclusions

We indicated that the temperature and CO_2 relationships in the models were the major sources of the large discrepancies among the models in climate impact projections. In particular, the impacts of increases in temperature and CO_2 on leaf area development were identified as the major causes for the large uncertainty in simulating changes in evapotranspiration, above-ground biomass, and grain yield.

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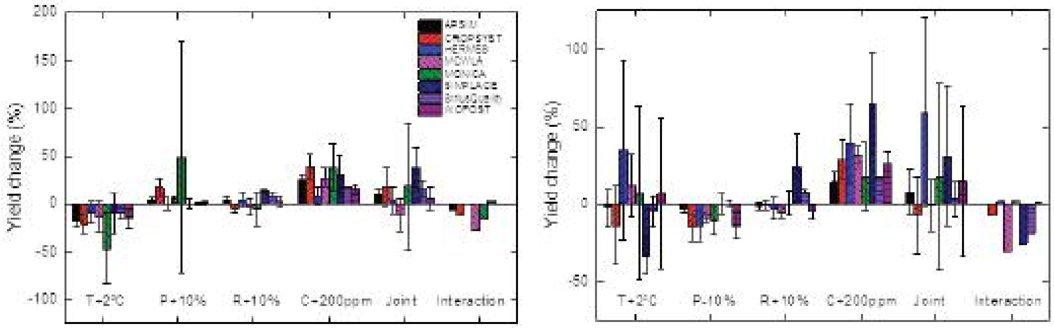

Figure 1. Simulated yield responses to changes in temperature, precipitation, solar radiation, and CO_2, singly or in combination, as well as their interactions, by eight crop models at Jokioinen (a) and Lleida (b). The error bars represent the standard deviations of estimates based on the 30 years simulation results.

Keywords: Agriculture, climate change, crop growth simulation, model improvement, uncertainty.

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