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# Adapting crop phenological cycles to climate change to improve global yields

Sara Minoli (1,2,3), Jonas Jägermeyr (4,5,1), and Christoph Müller (1)

(1) Climate Impacts and Vulnerabilities, Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association, 14412, Potsdam, Germany (sara.minoli@pik-potsdam.de), (2) Integrative Research Institute on Transformations of Human Environment Systems (IRI THESys), Humboldt-Universität zu Berlin, 10099, Berlin, Germany, (3) Albrecht Daniel Thaer-Institut für Agrar- und Gartenbauwissenschaften, Humboldt-Universität zu Berlin, 10099, Berlin, Germany, (4) Department of Computer Science, University of Chicago, Chicago, IL 60637, USA, (5) NASA Goddard Institute for Space Studies, New York, NY 10025, USA

Adapting crop phenology to the local climate is essential to successfully grow field crops at any location. Current growing periods that are suitable for local conditions can be parametrized in global crop modeling with observational crop calendars. However, these do not allow for adapted growing periods under climate change and many studies thus assume static sowing dates and cultivar selection for climate impact assessments. Recently there has been increasing attention towards the importance of growing periods and phenology simulation for improving global estimations of global yields, as well as for simulating farmers decision making under future climate conditions.

Here we investigate the potential of adapting sowing and harvest dates to changing climatic conditions based on Waha et al. (2012) and Minoli et al. (2019) respectively. These are rule-based approaches that use climate statistics and agronomic principles in order to identify the most suitable average growing periods of major food crops. According to these rules, farmers take into account the long-term average temperature and precipitation seasonality of the previous 20 years and crop-specific physiological limits to define the growing period that maximizes the time for yield formation, while minimizing the risk of encountering stressful environmental conditions. Phenological parameters, such as heat unit requirements, are then estimated to parametrize adapted crop cultivars in each simulated grid cell.

We use climate scenario ensemble from the ISIMIP2b database and a recently advanced version of the global gridded crop model LPJmL (Jägermeyr & Frieler, 2018) to simulate historical (1986-2005) and end-of-century (2080-2099) yields of major grain crops. Under future climate we simulate two counterfactual management settings: (i) sowing and cultivar adapted to the historical climate (unchanged management), and (ii) sowing and cultivar adapted to the 2080-2099 climate (adaptive management) respectively.

Preliminary results show that generally adaptive management has positive effects on yields of all crops. Across current cultivated areas, median yields of adapted crop growing periods and cultivars are +3% (wheat) to +24% (maize) higher than the non-adapted ones. However, we also find that the rule-based estimation of the optimal growing period, can also lead to some apparent "maladaptation" cases, where the adapted growing periods have adverse yield effects. These are mostly occurring in areas where the rule finds strong limitation to crop growth, such as too high temperatures or too dry growing seasons, and it selects the shortest maturity cultivars. We will discuss the uncertainty embedded both in the rule-based approach and in the crop model and their implications for modelling adaptation of cropping systems to climate change.