Climate risk assessment using multiple conceptual system models: A framework and application to water demand

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Abstract: Climate risk assessments that seek to capture the effect of future change on key agricultural processes are often informed by quantitative models, and the outcomes of these assessments are therefore strongly dependent on how key processes are represented in these models. Sensitivity assessments and 'stress tests' are increasingly used in risk assessments to understand system vulnerability by evaluating the amount of stress that the risk-absorbing system can tolerate, as well as identifying critical performance thresholds and characterising the degree of system robustness to small changes in climate assumptions.

To some extent these methods have been applied to support the assessment of agricultural systems through the use of impact response surfaces (IRSs) (Fronzek et al., 2019; Pirttioja et al., 2019), although there exist alternative methods such as bottom-up (or 'scenario-neutral') climate risk approaches that are more holistic and can better elucidate the role of process conceptualisation. We develop a multi-model framework for exploring the implications of model process conceptualisation on climate risk assessment, which combines bottom-up and multi-model approaches to allow scrutiny of selected models through exploration of process representation and key system performance under historical and future climate. We apply the framework to a viticulture water demand case study, considering three alternative process conceptualisations, each based on different theoretical foundations: (1) an empirical model; (2) a dual crop coefficient model; and (3) a crop model that simulates grapevine growth and development including water demand and use.

While the different system models display consistency in the direction of irrigation sensitivity with respect to annual rainfall and potential evapotranspiration (PET) (i.e., increasing irrigation as a result of decreasing rainfall and increasing PET), we found up to an order of magnitude difference in sensitivity to these forcing climate attributes between models. These differences ultimately lead to distinct interpretations related to likely system performance changes, including potential system failure thresholds (e.g., demand shortfall). Diagnosis of these differences, and critical analysis of whether these responses were reflective of the system in the context of the performance metrics of interest allowed for confidence in model results, as well as exclusion of models that were deemed unsuitable. This study and framework highlight several challenges associated with single-conceptual model analyses in the context of assessing agricultural systems under a changing climate and demonstrates the need for future risk assessments to explicitly consider the role of uncertainty in model process representation.

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REFERENCES

Fronzek, S. et al. (2019) Determining sectoral and regional sensitivity to climate and socio-economic change in Europe using impact response surfaces. Regional Environmental Change 19(3), 679-693. Doi: 10.1007/s10113-018-1421-8

Pirttioja, N. et al. (2019) Using impact response surfaces to analyse the likelihood of impacts on crop yield under probabilistic climate change. Agricultural and Forest Meteorology 264, 213-224. Doi: 10.1016/j.agrformet.2018.10.006

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