



FACCE-MACSUR

Task C4.4: Development of methods for the probabilistic assessment of climate change impacts on crop production

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Abstract/Executive summary

Various attempts have been made to determine the relative importance of uncertainties in climate change impact assessments stemming from climate projections and crop models, respectively, and to analyse yield outputs probabilistically. For example, in teh ENSEMBLES project, probabilistic climate projections (Harris et al. 2010) have been applied in conjunction with impact response surfaces (IRS), constructed by using impact models, to estimate the future likelihood (risk) of exceeding critical thresholds of crop yield impact (see, Fronzek et al., 2011, for an explanation of the method). In this task, we aimed to further develop and operationalize these methods and testing them in different case study regions in Europe. The method combines results of a sensitivity analysis of (one or more) impact model(s) with probabilistic projections of future temperature and precipitation (Fronzek et al., 2011). Such an overlay is one way of portraying probabilistic estimates of future impacts. By further accounting for the uncertainties in crop and biophysical parameters (using perturbed parameter approaches), the outcome represents an ensemble of impact risk estimates, encapsulating both climate and crop model uncertainties.

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Introduction

IRS analysis provides impact estimates across a wide range of climatic conditions. It facilitates estimation of the likelihood of future impacts, by making direct use of probabilistic climate change projections. Impacts can then be assessed within a quantified risk framework. This approach has been developed in the ENSEMBLES project with case studies from various sectors. The principle approach has been described by Fronzek et al. (2010); two case studies with crop models have been presented by Børgesen and Olesen (2011) and Ferrise et al. (2011). One aspect that we have the opportunity in MACSUR to expand is to incorporate aspects of impact model uncertainty by using ensemble modelling approaches. These comprise multi-model ensembles as well as parameter perturbations of individual crop models. The sensitivity of an impact model to changes in key climate variables is tested by systematically modifying temperature and precipitation values of baseline weather data so that the changes cover the range of changes projected for the future at three chosen locations representing contrasting wheat cultivation environments in Europe: Finland (northern, low yielding location), Spain (southern, low yielding) and Germany (central, high yielding). The period 1981 to 2010 is used as the baseline. In the first stage of the study the model simulations are performed only for the baseline CO₂ level (360 ppm). The simulations are performed on a daily time step for water-limited yields assuming optimal nutrients. This first basic exercise will yield at least two papers - the first one to be submitted to Climate Research as part of the Special Issue from the CropM Oslo International Symposium. In a second phase (IRS2), various adaptation options will be evaluated and IRS is being overlaid with probabilistic projections of temperature and precipitation (see, e.g. Rötter et al., 2012).

Results

One application of the Impact Response Surface (IRS) method for Europe was presented by N Pirttioja at the CropM International Symposium and workshop at Oslo, 10-12 February, 2014; Title: "Examining wheat yield sensitivity to temperature and precipitation changes for a large ensemble of crop models using impact response surfaces".

Impact response surfaces (IRSs) depict the response of an impact variable to changes in two explanatory variables as a plotted surface. Here, IRSs of spring and winter wheat yields were constructed from a 25-member ensemble of process-based crop simulation models. Twenty-one models were calibrated by different groups using a common set of calibration data, with calibrations applied independently to the same models in three cases. The sensitivity of modelled yield to changes in temperature and precipitation was tested by systematically modifying values of 1981-2010 baseline weather data to span the range of changes projected for the late 21st century at three locations in Europe: Finland (northern, mainly temperature-limited), Spain (southern, mainly precipitation-limited) and Germany (central, high current suitability). Only a baseline CO₂ level was considered and simplified assumptions made about soils and management with an aim to distinguish differences in model response attributable to climate.

The patterns of responses depicted in the IRS plots can be used to compare model behaviour under a range of climates, evaluate model robustness, locate thresholds, and identify possible model deficiencies while searching for their causes. Preliminary results indicate that while simulated absolute yield levels vary considerably between models, inter-annual relative yield variability for baseline conditions is remarkably consistent across models, especially for spring wheat. Results are sensitive to calibration method, as the same models calibrated by different groups exhibited contrasting behaviour. Further work will examine other responses (e.g. CO₂ and adaptation options) and combine IRSs with probabilistic climate to evaluate risks of yield shortfall.

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