FACCE-MACSUR

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

Task leader: Reimund P. Rötter[1*] (P92)
Co-leader: Mikhail A. Semenov[2] (P25)

Partners involved:

[3] Finnish Environment Institute (SYKE); Mechelininkatu 34a, Helsinki FINLAND (sub-P92)
[4] University of Florence, Piazazale delle Cascine 18, IT50144 Florence, ITALY (P62),
[5] Leibniz Centre for Agricultural landscape research, Muencheberg, GERMANY (P147)
[6] Potsdam Institute of Climate Impact Research (PIK), Telegrafenberg, Potsdam, GERMANY (P83)
[7] University of Bonn, Katzenburgweg 5, 53115 Bonn, GERMANY (P115)
[8] Aarhus University, BlichersAlle 20, DK-8830 Tjele, DENMARK (P189)
[9] Mendel University in Brno, Brno 603 00, CZECH REPUBLIC (P17)
[10] CEIGRAM-AgSystems, Technical University of Madrid, 28040, SPAIN (P24),
[11] University of Leeds, Leeds, UK (P22),
[12] National Institute for Agricultural Research (INRA), research groups at Avignon (P196), Clermont - Ferrand (P201), and Toulouse (P206),

[1] MTT Agrifood Research Finland, Plant Production Research, Lönnrotinkatu 5, 50100 Mikkeli, Finland

*reimund.rotter@mtt.fi

[2] Rothamsted Research, Computational and Systems Biology Department, Harpenden Herts, AL5 2JQ, UK

Revision	Changes	Date
1.0		2014-07-03

Instrument:	Joint Programming Initiative
Topic:	Agriculture, Food Security, and Climate Change
Project:	Modelling European Agriculture with Climate Change for Food Security (FACCE-MACSUR)
Due date of deliverable:	month 24
Submission date:	2014-07-03
Start date of project:	1 June 2012
Duration:	36 months
Deliverable lead partner:	MTT Finland
Revision:	0.0
Work Package:	CropM 4.4
Document ref number:	C4.4 v1.0

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.

Table of Contents

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 CO_2 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.

Acknowledgements
We thank especially Nina Pirttioja and Stefan Fronzek of the Finnish Environment Institute (SYKE) for coordinating the crop simulation exercise, processing of outputs and presentation of results; Many thanks to Holger Hoffmann, Thomas Gaiser and Frank Ewert (University of Bonn), Ines Minguez-Tudela, Roxana Savin and Margarita Ruiz-Ramos (Technical University of Madrid) and Tapio Salo, Taru Palosuo and Reimund Rötter (MTT Agrifood Research Finland) for sharing data.
This paper is a contribution to the FACCE MACSUR knowledge hub.
The work was funded by various national grants /financiers supporting FACCE JPI knowledge hub MACSUR.

References

Børgesen CD, Olesen JE (2011) A probabilistic assessment of climate change impacts on yield and nitrogen leaching from winter wheat in Denmark. Natural Hazards and Earth System Science 11:2541–2553

Ferrise R, Moriondo M, Bindi M (2011) Probabilistic assessments of climate change impacts on durum wheat in the Mediterranean region. Natural Hazards and Earth System Science 11:1293–1302

Fronzek S, Carter TR, Luoto M (2011) Evaluating sources of uncertainty in modelling the impact of probabilistic climate change on sub-arctic palsa mires. Natural Hazards and Earth System Science 11:2981–2995

Fronzek S, Carter TR, Räisänen J, Ruokolainen L, Luoto M (2010) Applying probabilistic projections of climate change with impact models: a case study for sub-arctic palsa mires in Fennoscandia. Climatic Change 99:515–534

Harris GR, Collins M, Sexton DMH, Murphy JM, Booth BBB (2010) Probabilistic projections for 21st century European climate. Natural Hazards Earth System Sciences 10:2009–2020

Rötter RP, Höhn J, Fronzek S (2012). Projections of climate change impacts on crop production – a global and a Nordic perspective. Acta Agriculturae Scandinavica, Section A (Special Issue), 62(4), p. 166-180, doi:10.1080/09064702.2013.793735.