Improved crop modelling for supporting policy design on climate change impacts, adaptation and mitigation — CropM in MACSUR

Executive Summary

- Climate change conditions the resource base upon which agricultural production is based, and, as such, it also severely impacts the ecosystem services delivered by agricultural production systems. Therefore, **climate change considerations are relevant for most of the agriculture-related policies**, including the Common Agricultural Policy, the Climate Change Policy, and environmental protection policies such as the Water Framework, Groundwater, and Habitat directives. These policies will require relevant changes in the near future because of how climate change will interact with agricultural production systems, and the FACCE-JPI knowledge hub **MACSUR provides some of the knowledge base on which to build such policy changes.**
- Assessing climate change impacts and adaptation and mitigation options in European agriculture requires the use of a range of models (crop, livestock, economic) and the integration of their results. By joining the work of many (> 40) European research groups in MACSUR, substantial progress in improving and applying models for assessing climate change impacts and adaptations in crop production has been made that can effectively assist policy design and recommendations. The results from such MACSUR research formed part of the scientific bedrock of the COP21 agreement in Paris in 2015. **Without MACSUR, the significant European agricultural contribution to the IPCC and UNFCCC would not have been evident.**
- Areas of progress include the use of crop model ensembles, improved scaling methods, better uncertainty assessment, data generation and model improvements for better capturing effects of extreme and adverse weather, development of context-sensitive adaptive strategies. **These efforts have led to robust assessments of climate change impact on crop production and associated effects** on ecosystems.
- The crop modelling community is now **ready for conducting a comprehensive assessment of climate change impacts, and to identify adaptation and mitigation options for Europe at multiple scales**, in order to play an active role for shaping future European agricultural, environmental and climate policies.

Modelling for supporting climate change research

High complexities of climate change impacts and adaptation for managing climate risks in European agriculture call for a careful policy design relying on robust research-based findings. Such assessments should not only focus on impacts on productivity, but should also assess impacts on product quality, economic values as well as environmental and climate (GHG) impacts of the agricultural systems. Assessments are required at local, regional, national and European scale, because of the different needs and contexts of different stakeholders. Crop models form an essential and integral part of the integrated assessments to tackle these complicated matters[1]. In this context, important advancements and milestones in crop modelling have been achieved during the past five years via the crop modelling theme (CropM) of the pilot FACCE-JPI knowledge hub MACSUR.

An example of how MACSUR has supported policy design was the process of the COP21 meeting in Paris in December 2015, where MACSUR research contributed to the IPCC 5th Assessment Report and played an important role in the scientific underpinning of the climate change breakthrough agreement at COP21. Further integrated assessments of agricultural systems linking results from crop, livestock and economic models will be required in the future for Europe to play an evidence-based and leading role in future climate change reports and policies.

Examples of advancements to improve European agriculture

Improvements of models:

- limitations identified[1]
- crop management and crop rotations[2] added
- environmental impacts such as nitrate leaching and N_2O emissions[3] included
- uncertainties assessed and reduced[4]
- climate sensitivities of yields assessed with a large model ensemble[5]
- scaling methods improved[6]

Dialogue with stakeholders:

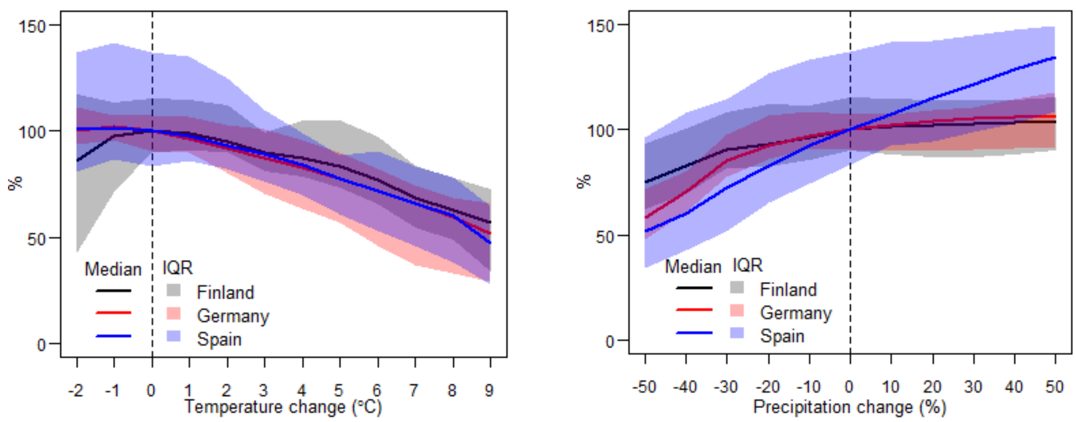
- fruitful engagement of local stakeholders of regional case studies
- stakeholder perceptions analyzed
- stakeholders identifying needs for analyses, risks and needs for adaptations
- active engagement with national and European policy makers (e.g. two EU stakeholder meetings at Brussels)

Mutual learning:

- common methodologies and interfaces between crop modelling, livestock modelling and economic modelling[7]
- common climate change scenarios[5]
- regional case studies[8]

Recommendations:

- adaptive crop management under climate change in Europe[9]
- adapting wheat cultivars to climate change across Europe[10]
- defining crop management and fertilization for sustainable agriculture[11]



A MACSUR study shows that winter wheat yields are projected to decrease with increasing temperatures (a) and increase with increasing precipitation (b) in different parts of Europe (sites in Finland, Germany and Spain). Changes are shown as relative (%) to yields during the baseline climate 1981-2010 with ensemble median responses of period-mean and interquartile ranges (IQR) across 26 crop models (source: Pirttioja et al 2015, Fig 8).

Conclusions:

➔ Crop modelling for climate change and food security made substantial progress through fruitful and increasing collaboration within and beyond the MACSUR crop modelling community. This collaboration has led to an increased international visibility of European research. The improved modelling is now mature to be effectively used for providing guidance for strategic and visionary policy design, such as on investments in research and technologies that reduce effects of extreme events on crop yield, acknowledge and promote different adaptation strategies in the various European contexts and direct and support efforts that reduce risks and enhance opportunities through crop and soil management and plant breeding.

➔ MACSUR is now in a position to conduct comprehensive impact, adaptation and mitigation assessments: two European wide integrated impact assessments focusing on wheat and maize initiated by CropM are underway. The CropM partners use models that are capable of analysing a wide range of aspects of climate change and agricultural crop production, including impacts on crop productivity and quality, nitrogen flows and losses (e.g. leaching), GHG emissions (e.g. nitrous oxide emissions) and changes in soil carbon. The integrated and flexible use of this range of models allows assessments of climate change impacts as well as adaptation and mitigation strategies to be assessed at multiple scales, which will provide policy makers and stakeholder with critical information on the sustainable development of European agricultural systems.

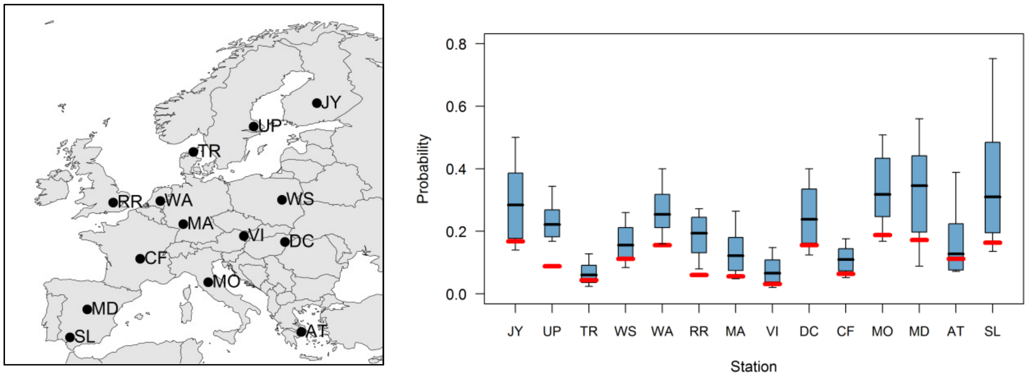
➔ MACSUR closely cooperates with international Programs like AgMIP and the Global Research Alliance to integrate regional and European assessments into global studies and contributed to updates of IPCC findings[5,12,13].

Outlook

Future studies should address critical policy-relevant questions such as:

- How can needs for adaptation and mitigation be reconciled under climate change?
- How can detailed information on impacts and adaptation be upscaled from local to regional and European scales?
- What is the potential for storing soil carbon in European agricultural soils given increasing demands for biomass for food, fibre and bioenergy?
- What is the need for innovations in crops and crop production systems to meet future sustainability requirements?
- How should future farming systems be designed in various European regions to anticipate climate-driven changes and meet sustainability targets such as those complying with a low carbon world?

For these important questions that underpin European and national agricultural and resource policies, we recommend further establishing and using the models, scientific frameworks and protocols developed in MACSUR. These can provide a standard and basis, even beyond the immediate MACSUR community, to ensure alignment of assessments across countries, regions and applications and to compare integrated assessment results and derived recommendations for policy use. We aim to further engage with stakeholders to ensure that assessments are designed and applied to meet the different needs of policy makers and the various actors in the agricultural and food sector.



A MACSUR study shows that probabilities of occurrence of adverse events from sowing to maturity causing major threats for wheat production are projected to increase all over Europe under climate change (source: Trnka et al 2014, Fig 4). Red lines indicate the 1981–2010 baseline and box plots indicate the 2060 (RCP8.5) climate scenarios. The calculations consider a medium-ripening cultivar. The locations are ordered from north to south along the x axis.

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