FACCE-MACSUR

MACSUR — Summary of research results, phase 1: 2012-2015

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Summary

MACSUR — Modelling European Agriculture with Climate Change for Food Security — is a knowledge hub that was formally created in June 2012 as a European scientific network. The strategic aim of the knowledge hub is to create a coordinated and globally visible network of European researchers and research groups, with intra- and interdisciplinary interaction and shared expertise creating synergies for the development of scientific resources (data, models, methods) to model the impacts of climate change on agriculture and related issues. This objective encompasses a wide range of political and sociological aspects, as well as the technical development of modelling capacity through impact assessments at different scales and assessing uncertainties in model outcomes. We achieve this through model intercomparisons and model improvements, harmonization and exchange of data sets, training in the selection and use of models, assessment of benefits of ensemble modelling, and cross-disciplinary linkages of models and tools. The project engages with a diverse range of stakeholder groups and to support the development of resources for capacity building of individuals and countries. Commensurate with this broad challenge, a network of currently 300 scientists (measured by the number of individuals on the central e-mail list) from 18 countries evolved from the original set of research groups selected by FACCE.

In the spirit of creating and maintaining a network for intra- and interdisciplinary knowledge exchange, network activities focused on meetings of researchers for sharing expertise and, depending on group resources (both financial and personnel), development of collaborative research activities. The outcome of these activities is the enhanced knowledge of the individual researchers within the network, contributions to conference presentations and scholarly papers, input to stakeholders and the general public, organised courses for students, junior and senior scientists. The most visible outcome are the scientific results of the network activities, represented in the contributions of MACSUR members to the impressive number of more than 200 collaborative papers in peer-reviewed publications.

Here, we present a selection of overview and cross-disciplinary papers which include contributions from MACSUR members. It highlights the major scientific challenges addressed, and the methodological solutions and insights obtained. Over and above these highlights, major achievements have been reached regarding data collection, data processing, evaluation, model testing, modelling assessments of the effects of agriculture on ecosystem services, policy, and development of scenarios. Details on these achievements in the context of MACSUR can be found in our online publication FACCE MACSUR Reports at http://ojs.macsur.eu.

Introduction

Feeding an increasing global population will be an overarching challenge for humankind in the coming decades. Projected human population sizes until 2100 will surpass the carrying capacity (the human population that can be supported) of the world, or, in other words, food supplies will be insufficient to support future population with the existing farming systems. This would even be the case even under a wide range of assumptions for climate change and strength of the CO2-fertilization effect, population growth, food production and food consumption patterns (Sakschewski et al., 2014).

One of the declared targets of humankind as represented by UN decisions, is to provide sufficient food to all humans. Few countries are or will be self-sufficient in terms of food provision to their population so that adaptations to agriculture are necessary. Nowadays, the EU is a net exporter of food and food products. Projections about the future, however, are of course uncertain and so the needed agricultural adaptation are uncertain as well. One can deal with the uncertainty in a pessimistic way and adapt to the worst case. Assuming that this adaptation requires the greatest steps it may also be the most costly. Alternatively, one might hope for the best, save on adaptation measures and risk malnutrition, which, sadly to say, is already the case today. The middle, cost-efficient way requires better information on the projections, the associated uncertainties, and the importance of these uncertainties.

Credible projections about the future are conducted by simplified models of the world. A global concern like food and nutrition security requires a global assessment in the first place. Since food security is not only about food production but also about human and animal consumption, as well as the trade of produced food and feed between places of production, storage, and consumption, modelling food security must take into account physical (climate, soil), biological (soil, plants, animals, humans), and sociological (trade, commerce, politics) aspects. Common to all aspects is that the actual processes occur at small scales (small in the sense of small extents) of space and time with corresponding variability, and that the processes may be correlated at larger scales (teleconnections in climate, international trade, landscapes). The correlations may intensify or dampen effects, depending on whether the correlations are positive or negative. Therefore, it is necessary to determine both at small scales what effects might occur in the future and how strong this effect is at greater scales.

Overview of activities

More than 50 crop models (Bindi, 2013), thirteen farm-scale models (Hutchings and Kipling, 2014), ten grassland models (Bellocchi et al., 2013) and 26 regional socio-economic models (Bojar, 2013) were in use by MACSUR members at the onset of the network. The activities in MACSUR did not proceed in isolation but generally had their individual focus within collaborations with international networks or projects, e.g. AgMIP, SOLID, AgroScenari, AnimalChange, CCAFS, Global Research Alliance on Greenhouse Gases, the Animal Health Network). Theme-level meetings as well as work-package specific workshops provided opportunities for researchers to meet, share knowledge, undertake collaborative exercises and plan future initiatives. Links formed with international networks like AgMIP and GRA have been extended beyond the original narrow links between selected disciplines to the all three Themes. An extensive list of outputs is contained in the phase-1 report to FACCE (Köchy et al., 2015).

The types of crops simulated by the fifty crop models presented in MACSUR range from grasslands and cereals to fruit trees. Output of crop models is often used as input for farm or socioeconomic models at scales differing from the crop model. It is therefore important to select appropriate crop models and to consider their quality and the methods used for upscaling of outputs in space (from plot to region), in time (from minutes of weather impact to yields of years), in environment (across soils, landscapes, microclimate, management, farm types). Therefore, the models have been used to compare their performance (Asseng et al., 2015), in ensemble simulations of climate effects (Asseng et al., 2015), for studying the propagation of uncertainties in the modelling chain, i.e. from input variables and assumptions to output (Cammarano et al., 2015), for simulating crop rotations (Kollas et al., 2015), and for assessing the loss of information and precision in scaling up from point to regional level (Ewert and al, 2015; Hoffmann and Ewert, 2015). Individual studies provided information on changed crop phenology (Olesen et al., 2012) and a crop's relative advantage over other crops that may be used in more aggregated models (Elsgaard et al., 2012). Methods to reduce the modelling effort for specific purposes have been developed by establishing temperature-precipitation response surfaces for crop cultivars (Rötter et al., 2014; Pirttioja et al., 2015). These response surfaces can be used in probabilistic assessments of climate change impacts and might be directly integrated in stochastic economic models as developed during phase 1 (Hoveid, 2015). In contrast to more general crop models, very detailed models may be sued to guide the breeding of cultivars for specific regions or climates (Rötter et al., 2015). Even though the studies produced additional knowledge of possible effects of climate change, they also increased our knowledge about the range of uncertainty (Rötter, 2014) and it will be necessary to match possible effects at a fine scale with their importance in aggregated models at a coarse scale.

Crop models implemented in model clusters for integrated impact assessments face additional challenges compared to stand-alone models (Ewert et al., 2015). These include the incorporation of feedbacks at farm level between different kinds of farm operations (where the farmer's goal is economic profit), assumptions on availability and profitability of farm technology and resources that might reduce theoretical optimal yields and, furthermore, regulations (greening, fertilizer, land-use) that limit a farmer's options to achieve optimal yields. As the model clusters become more complex it becomes increasingly difficult to calibrate the models and validate their output with independent data (Ewert et al., 2015) so that the credibility of the models rests on the plausibility of integrated models and their links.

Grassland yield models are similar to crop models with respect to projecting yields in relation to environmental conditions. Ten grassland production models are used within the MACSUR network and have been compared against test data. The comparison provided similar insights as the comparison of cereal models: the median of model ensembles is a better predictor than any of the individual models (Sándor et al., 2015). To be useful in integrated impact assessment, however, model outputs must also include information about feed quality. This information is often not produced by crop models adapted for grasslands but requires dedicated models. Here, the link between different farm operations is most obvious.

The effect of climate on livestock has been studied in the MACSUR network by determining thresholds of the temperature-humidity index above which the productivity and health of swine and dairy cows decline (Lacetera et al., 2015). Whether these thresholds are passed in the future depends of course on the housing of the animals, be it outdoors, indoors or in open shelters and available technology and associated cost for climatization of the housing (Schönhart and Nadeem, 2015). Work on the impacts of THI on dairy cow production and mortality has been part of the Oristano regional case study, assessing climate change impacts on farming systems in the region (Roggero, 2015). The latter issues can be addressed in farm-scale models.

Farm models within the MACSUR network fall into two broad categories: those addressing economic issues (profitability, management) and those addressing environmental issues (e.g. GHG emissions or fertilizer application). Within the MACSUR network, the first category comprises ten models, the second three models (Hutchings and Kipling, 2014). Farms are usually the focus of regulations and the smallest unit where climate change, crop production, feed production, husbandry, and constraints by economy, environment, and regulations act together. One example is the management of N and GHGs (Dalgaard et al., 2015) which has implications at the global scale (Bodirsky et al., 2014). Therefore, farms may be the nucleus at which joint impacts of climate change on agriculture may be studied for impact assessment models and may provide solutions for mitigation of GHG and adaptation (Del Prado et al., 2015). Livestock production systems at the farm-scale represent a highly complex modelling challenge. Model comparisons such as that undertaken by Hutchings et al (in prep) are pathways to developing the increased understanding and collaboration that is required to develop more integrated modelling tools within what has previously been a highly disparate and diverse collection of modelling disciplines. The farm scale is the one that stakeholders in the food-supply chain are most interested in (Schiermeier, 2015) and gaining an overview of how stakeholders can be best engaged by modellers to produce relevant solutions to real life problems is a developing focus of studies within MACSUR (for example König et al. [in prep.], Seddaiu et al. [2015]). Policymakers, however, are often more interested in larger units which requires scaling between farm and regional or country level for communicating results to stakeholders.

Trading of agricultural products may link close and remote places of production and has the potential to dampen geographic variation in production at the level of the consumer. Therefore, economy has an integrating role in the assessment of climate effects on the various operations of agriculture. Global economic models require input of crop yields at country level which usually requires upscaling from plot or field level (Müller and Robertson, 2014). Global economic models differ in principle from biophysical models. Biophysical models are usually process-based whereas most economic models used in climate impact assessments are based on observed correlations between quantities and prices of traded goods resulting from a posited equilibrium of supply and demand. Economic models have been compared for crop production, land area used for crops, prices of cereals, and consumption under different climate scenarios (Nelson et al., 2014). Models differed most strongly with respect to the first three variables and least with respect to consumption due to model structure and specifications of future trends.

There is good evidence that mitigation and adaptation options for European agriculture to cope with climate change are largely impacted by farm management in the pursuit of financial profit (Brouwer and Sinabell, 2015). Providing a consistent economic framework for the future across many agriculturally relevant commodities turned out to be one of the greatest challenges of modelling agriculture with climate change for food security. The regional case studies (Köchy et al., 2015) provided excellent opportunities for studying policy effects on farm income at regional scales under various scenarios of the future. Most current economic and trade models tended to be (comparatively) static and there are few approaches for long-term economic modelling, taking into account technological progress (e.g. advances in plant breeding) with focus on 2050 and beyond. Agronomic crop models that are consistent across scales are essential for sound economic analysis. Economic models require further development on availability and use of resources (labour, capital and natural resources), which is largely context dependent. Updates of the IPCC scenarios presented in 2013 will be taken into consideration for the period 2015-2017, and related narratives will be implemented in further modelling efforts (Köchy and Zimmermann, 2013). In the context of studying potential policy-driven mitigation options, socio-economic models should be able to reflect changes in diets (e.g. reduced meat consumption) and related major implications for livestock production in Europe and/or import of meat and feed, and subsequently change of global emissions and trade patterns as well (Scollan et al., 2015). This is not a trivial issue since consumer behaviour is significantly influenced by real income development, lifestyle changes and local food traditions. Hence the diet changes are not likely to be uniform in Europe, which leaves some scope for price differences as well, as can be observed even today in livestock commodity markets in the EU. The integration of such livestock dimensions is not elaborated on a wide scale and require the integration of models at farm, regional, European and global scales.

Even though the three Themes in MACSUR had different agendas due to differing starting points, membership composition and research needs, there were common interests and achievements across disciplines and countries. These are exemplified by establishing common resources (data, modes of presentation), conducting international comparisons of methodologies and performance of models, developing scenarios in international teams and identifying common foci of research topics, creating joint university courses, working on joint papers across different nationalities, in particular on publications with case studies from various countries, and finally, developing joint research proposals with partners from other countries that otherwise might not have met.

Integration and stakeholders

The farm and regional scale can be considered the nucleus for integrated assessments and dialogues with stakeholders. The MACSUR network also comprises regional case studies (Köchy et al., 2015) where climate impacts are studied at this level and communication with stakeholders is most intense. Three case studies had been initially selected as most advanced in their integrated involvement of different scientific disciplines, and to represent the range of European climate and farming systems: Northern Savo (Finland), Mostviertel (Austria) and Oristano (Italy) (Dono et al., 2013; Mitter et al., 2015; Virkajärvi et al., 2015). Although very different in climate and agricultural systems, they share one marked, common feature: a projected change in water availability. Excess water in spring or fall may cause problems for accessibility of fields with heavy machinery, while a lack of water requires irrigation or change in crops or operation. Projected needs of adaptation at farm level can highlight required changes in regulations, compensations, subsidies or expectations for the delivery of social and ecosystem services beyond land cultivation and food.

The previous paragraphs showed clearly that model results must be interpreted in the light of the models' limitations. These limitations must be clearly communicated to decision makers whose choices are informed directly or indirectly by the models (Rivington and Wallach, 2015) and who are likely to require information on the reliability of integrated modelling tools. A framework for classification for testing using differential split-sample tests using best available proxy-data are recommended (Refsgaard et al., 2014). Importantly, model evaluation needs to take into account not only the technical capabilities of modelling solutions, but also the extent to which their outputs are ‘fit for purpose’ in relation to stakeholder requirements. In work that drew on expertise from MACSUR and involved a number of other related projects, Bellocchi et al. (2015) reviewed deliberative approaches to model evaluation which incorporate this principle.

Several methods of communicating scientific results and interaction with shareholders have been used in the MACSUR network. They have been compared (König et al., in prep) and the framework to categorize them may aid other projects in selecting appropriate methods for stakeholder engagement. The higher the political level, the more difficult, however, it becomes evidently to engage decision makers in scientific projects. Within nine years, more than 200 EU-funded scientific projects produced different tools for use by decision makers in impact assessments; most of them at EU level and with a focus on agriculture, environment and transportation (Podhora et al., 2013). The tools, however, were more researcher-driven than stakeholder-driven and may be hard to find or to use for interested decision makers. Thus, there is still a great mismatch between the interests and needs of stakeholders and the solutions provided by science. In this context, the logical role for the broad community brought together by the MACSUR knowledge hub is to collate, review and draw strategic conclusions from the outputs of individual stakeholder engagement projects, in order to spread and develop best practice and to explore at a strategic level the options for improved stakeholder engagement to increase the relevance of agricultural modelling and related research to farmers, policy-makers and other groups. The work of König et al. (in prep.) and comparisons of the experiences and outcomes of different projects (Seddaiu et al., 2015) are examples of how this approach can be applied.

The work of MACSUR has the potential to influence national and European policies through interaction with decision makers. MACSUR researchers are keen to publish their results in peer-reviewed journals, where they are eventually picked up by national administrators. Similarly, national, FACCE and EU representatives attend larger scientific meetings (in Europe and elsewhere) where MACSUR results are presented by MACSUR members, e.g. the conference on Climate-Smart Agriculture (Montpellier, 2015). Meetings, workshops and congresses organized in the context of MACSUR are also frequently attended by representatives administering national programmes. MACSUR members are part of national boards involved in national programming. Other members of MACSUR have met frequently with national representatives on bilateral basis (GB members, etc.) or multi-laterally (national sector level research and ministries) in small groups (national meetings). Such dialogues directly result in setting priorities in national programmes. Additionally, MACSUR coordinators are invited by the FACCE GB (with national representatives) to provide overviews of results and identify the contributions of MACSUR to policy support in the participating countries. A workshop directly aimed at policymakers (Brussels, 2015) resulted in greater mutual understanding of expectations and capabilities of research in the area of climate change and food security. At the global scale, MACSUR gained visibility through collaboration with the Agriculture Modelling Intercomparison and Improvement Project (AgMIP) (Rosenzweig et al., 2013).

The knowledge gained within the MACSUR network is not only passed on decision makers, but MACSUR provided opportunity through its network for institutional visits of staff, methodological workshops, and training workshops to junior researchers.

Conclusion

Overall, in its first phase the MACSUR knowledge hub achieved significant scientific advancement in modelling agriculture with climate change and development of a research agenda for improving existing models and working on new models. Beyond the science, the knowledge hub created a trans-disciplinary awareness of who is active in the area of climate change impacts on agriculture and contributed to more integrated viewing of climate change impacts on agriculture across disciplines and scales. It facilitated the exchange of ideas, concepts, and theories between researchers across disciplines and contributed to the understanding of data and model demands of specialized thematic models. As a result, researchers and stakeholders obtained a greater awareness of the broader implications of climate change and policies in agriculture by including constraints and buffer mechanisms from socio-economy. The establishment of a network in Europe that is on par with other international networks created synergies among research in the participating countries and highlighted the European capacity in contributing to global food security by policies based on science.

The work achieved in the first three years of MACSUR laid the foundation for the next two years of the knowledge hub. In the coming phase (2015–2017), we intend to emphasize cross-disciplinary scientific activities and make use of more case studies and step up engagement with stakeholders within the constraints of the available budget. This will contribute to the development of a research community in agricultural modelling that is more integrated and able to face future challenges, to the production of strategic reviews that shape the research agenda for agricultural modelling under climate change, the delivery of an assessment of CC impacts on European agriculture based on integrated models at EU level, and to a report on the outcomes of regional assessments based on case studies to be presented in 2017.

Ensemble model results are best put to use by coordinated cycles of model improvement and projection for improving overall projections (Challinor et al., 2014). This improvement and communication with stakeholders will be the task of the MACSUR knowledge hub beyond 2017. Therefore, the project leadership team is already now preparing a vision for the implementation of MACSUR after the second phase and invites the FACCE Governing Board to continue its eminent role as interpreter of research in climate-smart agriculture for national governments.

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