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# ARE OUR MODELLING TOOLS READY TO COPE WITH AGRICULTURAL SYSTEMS EVOLUTION?

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## 1 Introduction

Agricultural systems are continuously changing to better cope with demands by society, environmental concerns, and changing climate. As a result, new concepts have been developed such as agroecology, ecosystem services, multifunctional agriculture, and climate smart agriculture. These new agricultural concepts require tools to help with the analysis, design and evaluation of new systems. However, modeling the evolution of farming systems is challenging both for computer scientists and agricultural modellers. This paper discusses how these evolutions require new modelling concepts, tools and approaches to help improving the analysis, design and evaluation of farming systems. The key question is how the modeling community can evolve our models from cropping system models to an integrated platform capable of handling a continuously changing farming system.

## 2 Scientific challenges

### *New biophysical knowledge*

The first challenge is the new biophysical knowledge that has to be acquired in order to cope with change. This concerns different evolutions:

- Climate change: how to integrate new processes regarding the effects of extreme temperatures and responses to tropospheric ozone?
- Smart agriculture: how to better represent mitigation processes and related greenhouse gases emissions?
- Integrated pest management: how to integrate biotic regulation functioning? How to represent pest and pest natural enemies typically represented by different modelling approaches? How to predict potential spreading of alien pests and diseases facilitated by changing climatic conditions?

### *New practices*

The second challenge concerns the development of new types of agricultural systems. Representing the decision process of these new agricultural systems and the impact of the agricultural operations on the biophysical system is therefore an important issue:

- How to represent new crop management as conservation agriculture, intercrops, agroforestry systems, mixed crops?
- How to represent interactions with the field environment that provides natural enemies such as hedges?

### *Integrating diverse production on the same farm*

There is a general movement towards more diversified farming systems. More research focuses on integrating livestock and cropping systems together.

- How to represent an increasing diversity of production systems and related interactions?
- How to integrate flows of resources within the farm?
- How to share resources among competing activities?

### *Changes of scales*

A big challenge in implementing new farming practices is to integrate the surrounding area of the farm either as a biological reservoir or in order to link it with the agri-food chain or to analyse complementarity within a territory.

- How can models deal with scales and change of scales for crop production, processing and management?

*Working with farmers, resources managers and policy-makers*

Agroecological farming systems target specific environmental and social conditions. There is a real need to work with farmers and to integrate specific local conditions:

- Do we have the tools to interact with stakeholders while developing and applying simulation models; how to create ad hoc models (library of modules, repositories of parameters)? Do we need web interfaces?
- How to integrate partial knowledge and stakeholder knowledge?
- How to represent simulation results in a meaningful way?
- How to run models in digitally-isolated rural areas?

*Issues regarding data*

Not only farming systems are changing, but also data acquisition. Data flow has increased dramatically during the last ten years due to the availability and use of remote data among others, and new options are made available even by smartphones.

- How to deal with large increases in the amount of data?
- How to integrate data from satellite images (from initialization to real-time process) in running processes?

**3 Evolutions required in our modelling platforms**

When checking the different scientific challenges, some general challenges for the modelling platforms emerge:

- Integrating new formalisms
- Integrating complex management options
- Integrating different production systems
- Integrating cross spatial and temporal scales
- Allowing on-site development or parametrisation
- Using real-time data

Some of these challenges will not require considerable modification of actual modeling platforms. For example, integrating new formalisms to take into account extreme temperature or CO<sub>2</sub> impacts on crop production is not something that requires modifying the architecture of modeling platforms.

Some other challenges are more complicated such as representing complex management options and their impacts on the biophysical systems. Diversifying production systems or integrating pests is also complex as some modeling platforms are more or less dedicated to a specific type of agricultural production (e.g. cereals).

Other challenges may need much more substantial changes such as integrating hedges or landscape structures because this will require representing the system in a 2-D (or 3-D) dimension. The other important example is the use of the platform in a participatory manner and allowing for the integration of farmer's knowledge while developing the appropriate model.

We conclude that the main problem is not lack of scientific understanding in most cases, or lack of software architecture and approaches amenable to deploy the platforms and capabilities that are needed. What is lacking is more a concerted effort that brings together many disciplines, including software engineering, to create the conditions to make progress in this area.

We point to a common misunderstanding about the ease to develop and use of simulation tools. Resources are made available to produce specific analyses, but very rarely to develop new tools, infrastructure, and even for targeted data collection. In the same way as the demand for integrated simulation has grown, the complexity of tools required has increased as has the need for verifying quality and reproducibility of results. All of this cannot be performed without an articulated approach in which there are dedicated resources available to reconsider tools and modelling frameworks development.