Complex scaling issues in integrated assessment modelling: Approaches used and their integration into SEAMLESS-IF

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Introduction

Agricultural systems and associated problems of sustainability and sustainable development are typically complex. Several methods have been developed to effectively describe and analyse complexity. It is argued that hierarchy theory can provide a much needed conceptual framework for developing successful scaling theories and approaches to reach this objective. Hierarchy theory partitions complex systems into nested levels that share similar temporal and spatial scales.

In the recently developed integrated assessment (IA) modelling platform SEAMLESS-IF (Van Ittersum *et al*., 2008) the concept of hierarchical system has been adopted. SEAMLESS-IF integrates relationships and processes across disciplines and scales which are conceptualized and modelled following the paradigm of hierarchy theory. Several scaling approaches are used in SEAMLESS-IF which are presented in this paper. Specific emphasis is on the integration of these different approaches. The progress achieved and the challenges experienced in modelling complexity within the paradigm of hierarchy theory are discussed.

Scaling methods in SEAMLESS-IF

Different methods have been employed in natural sciences to estimate systems responses across scales or levels of organization (see Ewert *et al*., 2006). These include data extrapolation, data aggregation, model linking, development of summary models, scaling or aggregation of model parameters. The method chosen depends on the specific objective.
SEAMLESS attempts to capture the biophysical, economic and social, and to some extent the institutional dimensions of agricultural systems. Modelling efforts consider different levels of organization from the local field to the globe. Central to the SEAMLESS-IF approach is the linking of different models across scales and disciplines (Figure 1) to address (parts of) the complexity of the agricultural system. The core set of processes for which models were selected refers to the market level (CAPRI), the farming system level (FSSIM) and to the biophysical processes at the field level (APES) (Figure 1). Additional models can be considered if required.
The linking of models required a set of other approaches to scale information. These include:

- Generation of coefficients for (static) model linking;
- Development of typologies to define simulation units and to support data sampling;
- Scaling of model parameters;
- Extrapolation and aggregation to transfer data across scales (e.g., from farm to EU)

Due to the complexity of the developed model chain computational extensive dynamic model links were not considered, only one feedback loop (with a single iteration) is implemented from FSSIM to CAPRI and back to FSSIM. The link between APES and FSSIM is static in the form that APES generates coefficients for the FSSIM models.

The complex model structure(s) required simplification of data to consistently apply models across space. Different types of data are grouped into homogenous classes determined by the factors that explain most of the variability in the data with respect to specific variables of interest. The resulting typologies are the basis for up- and down-scaling procedures in

SEAMLESS-IF. The following three main typologies have been developed and used so far; the Agri-environmental Zonation (AEnZ), the farm typology and the administrative (NUTS2) regions (the latter has not been developed but is used in the project). These typologies are used to define simulation units to which data are scaled (e.g., aggregation of biophysical input data per AenZ for APES), to support data sampling (e.g., collection of management activity data per sample region for FSSIM), to transfer data between models that represent different scales (e.g., extrapolation of FSSIM outputs to feed CAPRI) and to scale up indicators (e.g., aggregation of FSSIM outputs to compute indicators at regional level). As there are spatial mismatches between typologies, approaches have also been developed to link simulation units of different typology (e.g., spatial allocation of farm types across AenZs).

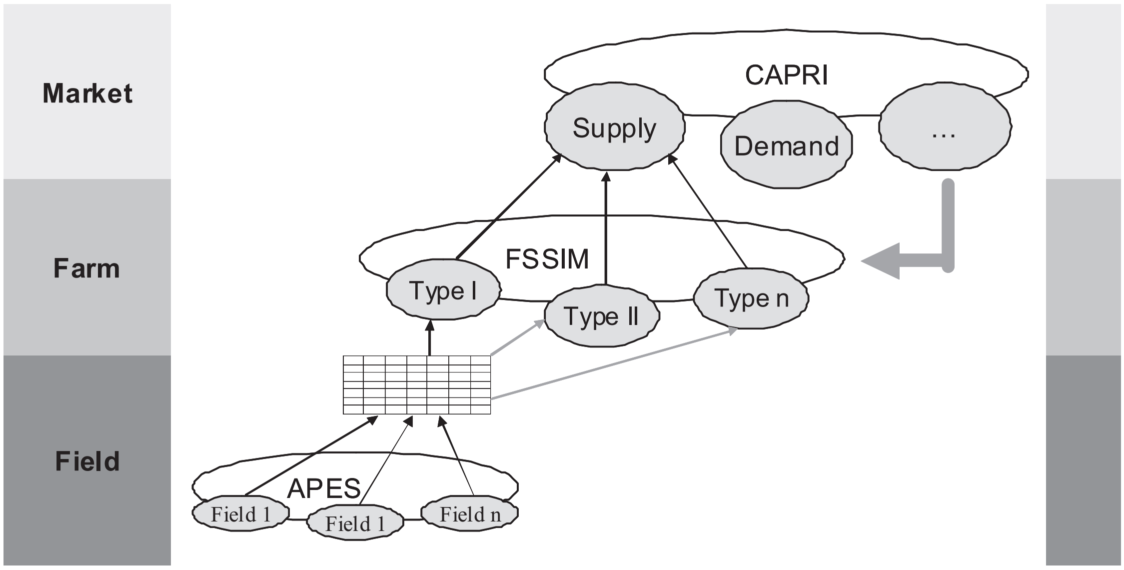

Figure 1. Schematic representation of nested linking of CAPRI-FSSIM and APES within a hierarchical system.

Discussion and conclusions

We have combined several scaling methods into a coherent modelling framework for IA of complex problems in agriculture. First experiences in working with SEAMLESS-IF show that the developed framework provides useful results and advances IA capabilities of earlier frameworks. Yet, the developed model chain is relatively complex and further simplifications may improve its usability and transparency. Further modelling work should therefore focus on developing simplified models for the different parts of the overall system. This can only be achieved if the most important drivers and processes are identified and understood for well specified problems. The developed chain (Figure 1) can be of assistance in the process.

References

Ewert, F., *et al*., 2006. Proceedings of the iEMSs. Burlington, USA, July 2006. http://www.iemss.org/iemss2006/sessions/all.html.
Van Ittersum, M.K., *et al*., 2008. Agricultural Systems 96: 150-165.