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Methodological and empirical progress and challenges in integrated assessment of agricultural systems and policies

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Abstract

In this contribution we first present a methodology for integrated assessment of agricultural systems (SEAMLESS Integrated Framework), illustrate its application in an integrated assessment of high commodity prices and then discuss its flexibility and limitations. From there we take a broader view and reflect on key scientific and empirical questions with respect to the development of research tools for the integrated assessment of agricultural systems.

Keywords: agricultural systems, integrated assessment, modelling

1. SEAMLESS INTEGRATED FRAMEWORK FOR INTEGRATED ASSESSMENT OF AGRICULTURAL SYSTEMS

SEAMLESS Integrated Framework (SEAMLESS-IF) was designed to facilitate translation of policy questions into alternative scenarios that can be assessed through a set of indicators that capture the key economic, environmental, social and institutional aspects of the underlying questions (Van Ittersum et al., 2008). The framework integrates relationships and processes across disciplines and scales which are conceptualized following the paradigm of hierarchy theory (Ewert et al., 2009). The relationships and processes at different levels of organization are modelled in so-called model components. These components include a modular, bio-physical simulation model calculating agricultural production and externalities at field level (APES); a bio-economic farm model quantifying the integrated agricultural, environmental and socio-economic aspects of farming systems (FSSIM); and an agricultural sector model (CAPRI) providing information on supply-demand relationships and corresponding product prices. Various scaling methods have been used to link information from one level to another or to simulate the feedbacks between levels of organisation and processes. This includes a method to quantify and assess alternative management options for farms and a method to enhance consistency of micro-macro linkages (EXPAMOD – Perez Dominguez et al., 2009). The framework uses a European data base with data on soils, weather, farming systems, agro-management, prices and sectoral accounts as well as a library containing indicators for economic, environmental, social aspects organised in an indicator framework. The model components can be used stand-alone or linked through a software infrastructure making use of the Open Modelling Interface (OpenMI). The conceptual linkage of model components and data is facilitated through the use of ontologies ensuring consistent exchanges of inputs and outputs across components.

The framework was tested and improved using two test applications, one on trade liberalisation (Bezlepkina et al., 2010) and one assessing measures in the context of the Nitrates framework directive (Belhouchette et al., 2011). To co-ordinate and stimulate the challenging task of maintenance and further development of a broad range of models, their data requirements and their linkage, a SEAMLESS Association (www.seamlessassociation.org) was established with the core partners of the FP6 research project. One of the activities of the Association was an integrated assessment of high commodity prices on European agricultural systems which will be presented in the next section.

2. INTEGRATED ASSESSMENT OF HIGH COMMODITY PRICES

For the second time in just 3 years agricultural commodity prices are high. Some of the relevant questions related to sustained high prices in the near future are: (a) what effects do high prices have on agriculture in the European Union as a whole and how do regions that differ with respect to agricultural productivity and production orientation, respond to this new economic environment?; (b) will a sustained price increase for key agricultural commodities lead to further intensification of agricultural production and which environmental consequences may arise from this for the EU as a whole, in specific "problem regions" or for different farm types?

The agricultural market model CAPRI (Britz and Witzke, 2008), the bio-economic farm model FSSIM (Louhichi et al., 2010) and the integrated database for European agriculture (Janssen et al., 2009) have been used to assess a number of scenarios. The model chain is applied for a Base year (i.e. year 2003), mainly for calibrating FSSIM on the observed cropping patterns, and is next applied to a Baseline and 4 high price scenarios for the year 2013. These scenarios consist of shocks given to the CAPRI market model that lead to increasing commodity prices (Adenäuer et al., 2010). In Scenario E1, a shortfall of supply in Australia due to water scarcity is simulated. Scenario E2 addresses an increase in the international raw oil price. Increasing demand from evolving countries like China and India as well as stronger demand for biofuels are tackled in scenario E3. The last scenario (E4) combines a global shortfall in the production of agricultural commodities with a global increase of food demand. The resulting price increases from scenario E4 are then taken over to the FSSIM model in order to assess the impact of increased prices on different farm types in 15 regions across the EU. The FSSIM farm typology is based on the existing EU farm typology (Decision 85/377/EEC, 1985) which classifies farms according to their income and specialization. This farm typology has been extended with the farm's land use and intensity of farming to better account for environmental aspects of farming (Andersen et al., 2007). Impacts of the scenarios on commodity prices will be presented, as well as their implications on the different arable and livestock farm types in the 15 regions.

3. LESSONS LEARNED AND REMAINING CHALLENGES

The SEAMLESS project has advanced the harmonisation of data and model components for integrated assessment of agricultural systems. As such it is a step towards overcoming fragmentation in modelling agricultural systems and contributing to a better information basis for impact assessment of new policies. Naturally, important scientific questions remain or have emerged during the project.

The integrated framework described in this paper follows one of the possible methodological pathways for integrated assessment. The method focuses on integration of stand-alone components that are effective in simulating specific processes and relationships, including crop and livestock production and externalities, farm responses and supply-demand relationships. A benefit of this approach is that it allows the integrated assessment tools to be structured into relatively independent components and to benefit from advances of science focusing on specific parts of the system. It offers flexibility regarding the choice of methodology, software and data in each of the components and allows maintaining and further developing them independently from each other as long as interfaces required for component linkage do not change. The approach might also be beneficial from an institutional point of view as clear property rights and responsibilities can be attached to each component. Not all of the outputs from each of the components may be needed for a specific application but their inclusion provides a degree of flexibility needed for a broad range of applications (Ewert et al., 2009). At the same time a key question is whether this approach allows an adequate system representation for specific problems, i.e. related to climate change or a biobased economy, and captures the most relevant feedback mechanisms and interactions which may occur at the interface of subsystems, e.g. between crops and livestock, between different fields and landscapes, or between farms and markets and between different sectors. The components themselves provide a specific conceptual view of the system analysed as each component presents one or several sub-systems. But certain processes of interest might over-arch these sub-systems, while not being properly presented by the interfaces of the components. Further on, most components do not allow for a continuous representation of e.g. spatial and temporal scales, but apply to specific scales, e.g. breaking down space into administrative regions. Consequently, scaling methods need further attention, both from a conceptual and a testing point of view. The development of EXPAMOD (Perez Dominguez et al., 2009) theoretically improves consistency between the micro and macro level, but in practice data and computational requirements are very substantial (see also below) and so far an obstacle for full EU scale application.

In SEAMLESS we have aimed at a high degree of methodological, semantic and also technical integration. In terms of re-using a particular model chain this has clear advantages. However, there may be trade off between the degree of integration and flexibility when a model chain has to be amended in new applications.

A particular challenge of the research method is the high data demand, specifically regarding agricultural management. Modelling production processes and their externalities explicitly requires precise information on the quantity of inputs (e.g. how much nitrogen is applied to a particular crop) but also the timing of the inputs (e.g. in how many splits is the nitrogen applied and when, as this largely determines vulnerability to losses). Many attributes of current activities, often even basic ones such as the amount of fertilizer used on specific crops, are not available from official statistics such as the Farm Structure Survey and Farm Accountancy Data Network. High spatial variability of key location-specific factors such as soil, slope and climate - each of which impact on the choice of agricultural activities but as well on their interaction with the environment - provides a specific challenge, both from a data and from a modelling perspective. The FSSIM template was therefore defined per agri-environmental zone capturing differences in soils, slope and climate. But there are obvious numerical limits to that approach.

Another challenge relates to the identification and definition of alternative or future agricultural activities. Agronomists have worked extensively and published on this issue (e.g. Hengsdijk and Van Ittersum, 2003) and have proposed hierarchical methods to systematically derive and assess alternative activities. Yet, because of the discontinuity of the production functions, the theoretically infinite number of options (crops x general x water x nutrient x pest and disease x conservation management options) and the difficulty of assessing the alternatives, their (partial) inclusion in future studies keeps an arbitrary element.

Models such as FSSIM and CAPRI are (comparatively) static, calculating a new state or equilibrium resulting from a policy change or other factors. They do not reveal the dynamic and multiple changes that may occur as a result of local or international developments. FSSIM, for instance, can simulate the changes in crop and technology choice based on average prices and yields and a measure of their variation. Farmers may, however, respond in different ways to external changes, including collaboration with colleagues in terms of land use, labour and machines and structural change. Farm structural change is highly relevant for single and aggregate farm behaviour, but its dependency on policy and markets is difficult to incorporate into a model chain in a robust and computationally feasible way. A partial equilibrium model such as CAPRI will not reveal the short term price fluctuations that we are experiencing presently and which may yet be very important for the long-term viability of farming sectors and stability of societies.

A final challenge is the continuity needed in research, development and maintenance of integrated assessment framework and the underlying components. Each of them require substantial resources, testing, further development and maintenance before they can be used with sufficient confidence and before they have obtained some degree of credibility amongst the user community. Projects of four years are not sufficient and the specific expertise required to develop and maintain these tools requires a longer term perspective in terms of funding, human capacity and science-policy interface.

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