Assessing economic, social and environmental processes in agriculture with a computerized framework for the EU (SEAMLESS-IF)

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Abstract

Agricultural and environmental policies are increasingly important for the development of agricultural systems that are sustainable and can contribute to a sustainable development at large. The effectiveness and efficiency of policy development in realizing desired contributions can be significantly improved through sophisticated ex-ante assessments. The SEAMLESS integrated project (System for Environmental and Agricultural Modelling; Linking European Science and Society) develops a computerized and integrated framework (SEAMLESS-IF). SEAMLESS-IF aims to facilitate translation of policy options and their interaction with technological innovation into alternative scenarios that can be assessed through a set of indicators that capture the key economic, environmental, social and institutional issues and are derived at specific levels of agricultural systems, i.e., point or field scale, farmtype, region, EU and world. The project aims at facilitating a breakthrough in integrated use of models by creating an open source software architecture that allows use and re-uses models, databases and scenarios in the domain of agricultural systems.

Keywords: Agricultural systems, impact assessment, indicators, models, ontology

1. Introduction

The drivers that affect agricultural and other natural resource management systems and rural areas in Europe are diverse and challenging. Many factors lead to changes in European agriculture, including enlargement of the European Union, agro-technological development, societal demands for new functions, climate change and liberalisation of global markets (VAN ITTERSUM ET AL. 2006). Agricultural and environmental policies in the European Union must co-evolve to ensure their effective contribution to sustainability in agriculture and contributions of agriculture to sustainable development of society at large. Assessing the strengths and weaknesses of new policies and innovations prior to their introduction, i.e., 'ex-ante integrated assessment', is vital to target policy development for sustainable development.

The SEAMLESS integrated project (System for Environmental and Agricultural Modelling; Linking European Science and Society) develops a computerized and integrated framework (SEAMLESS-IF) to compare alternative agricultural and environmental policy options, allowing:

1. Analysis at the full range of scales (farm type to EU and global), whilst focusing on the most important issues emerging at each scale;

2. Analysis of the environmental, economic and social contributions of a multifunctional agriculture towards sustainable rural development and rural viability;

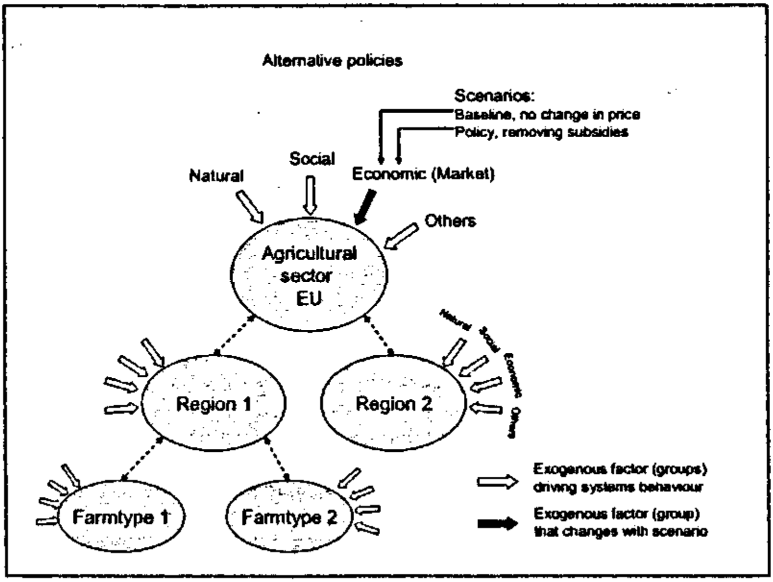
3. Analysis of a broad range of issues and agents of change, such as climate change, environmental policies, technological innovations, rural development options, an enlarging EU, international competition and effects on developing countries.

SEAMLESS brings together 29 partners from 13 countries, with a rich knowledge and expertise from economic, environmental, agronomic, social science and information technology disciplines. This paper is based on the work in the SEAMLESS project. It presents the design of a computerized integrated framework SEAMLESS-IF and starts with a brief overview of economic, social and biological transformations that can be studied within this framework. It proceeds with the key integration aspects in the project: integrated procedure of policy impact assessment; integration of scientists and prime users; integration of disciplines and models. The paper concludes with summarising comments on the role of modern software engineering in integrating the knowledge.

2. What transformations?

Since the Rio Earth Summit in 1992 the integration of sustainability with agriculture has been a major item on the EU policy agenda, and there has been an overall shift from policies supporting agriculture towards policies supporting sustainable rural development in a broader sense (see also EWERT ET AL. 2006). The ongoing EU enlargement to the Central and Eastern European countries, the pressure for trade liberalisation and the integration of environmental and other multifunctionality considerations into EU policy have stimulated a review of the Common Agricultural Policy (CAP). In particular, one of the examples studied in SEAMLESS is assessment of WTO trade liberalization. The policy context of this example combines the forecasted evolution of the CAP reform in the EU until 2013 (in the baseline scenario) and further trade liberalization as currently discussed in WTO negotiations (in the policy scenario). More precisely, the latest proposal of EU on the elimination of the trade-distorting instruments released in 2004 is used: (a) reductions in import tariffs with an average cut of bound tariffs by 60 %, with different percentage reductions depending on the tariff level, (b) elimination of export subsidies, (c) expansion of tariff rate quotas to 10% of domestic consumption, (d) bilateral trade agreements giving duty-free access to all agricultural products. Figure 1 illustrates a so-called top-down approach of subsidy elimination policy that leads to product price changes at the sector level.

Figure 1: Top-down assessment of policy options (from EWERT ET AL. 2006)



The policy impacts that can be assessed within this example at the EU level are the effects of new prices on: budgetary expenses, total welfare, income of consumers, employment in agriculture and in rural areas, competitiveness of cereal and meat production, water pollution by nitrate and pesticides in water tables and rivers, energy consumption by agriculture, etc. At the level of a typical agricultural region of EU the same impacts can be studied both at regional level and for each farmtype.

Implementation of the Water Framework Directive, Natura 2000, the Birds and Habitats Directives, the Nitrates Directive, and the integration of animal health and welfare into agri-environmental standards require an integrated action and evaluation at different spatial scales (ranging from detailed local scales up to EU and global scales). While the first example illustrates a top-down analysis, i.e. from EU to farmtype level, the SEAMLESS-IF platform can be also used to assess the interaction between the EU environmental policies and technological innovations, i.e. a bottom-up analysis. Technological innovations, such as integrated water, nutrient and pest management, genetic improvements, changed crop rotations, organic production methods, improvement of irrigation systems and other will have a role to play in the improvement of farming systems competitiveness and in the reduction of environment pollution (BELHOUCHETTE ET AL. 2006). Technological innovations adopted at field-farm level influence the sustainability of farming systems at higher levels: farmtype, region, and EU.

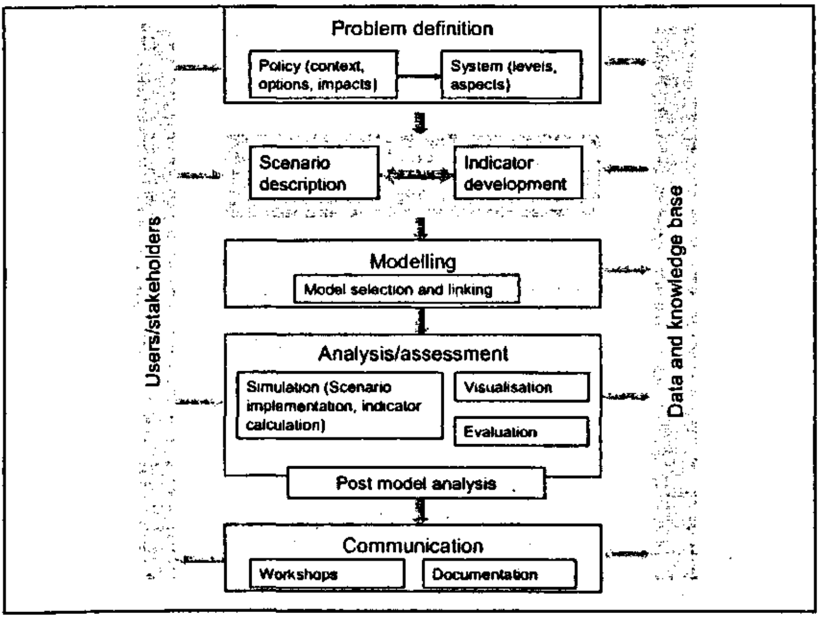
For example, if farmers react to EU environmental policies for water by the implementation of agro-ecological techniques on a wide basis it will certainly have a significant impact on water quantity and quality. However, this may also lead to reduced competitiveness of European agriculture, reduced crop production, and increasing costs and yield uncertainties. It will also have significant impacts on farmers (increased workload and yield uncertainties), on biodiversity, on rural and tourist populations (landscape changes) and on consumers (food quality and security). It may also have positive or negative effects on greenhouse gas emissions (especially methane and nitrous oxide) and on carbon sequestration, with implications for the Kyoto protocol objectives. Assessing the strengths and weaknesses of new technologies, systems or policies prior to their introduction would greatly facilitate transparency in decision making at the various scales.

3. Integrated procedure of policy impact assessment for decision support

Integrated policy impact assessment in SEAMLESS has the following main ambitions:

- Interdisciplinary, i.e. linking information across disciplines
- Cross-scale, i.e. linking information across scales and levels of organization
- Multidisciplinary and multiple scale, i.e. information is not only required about responses of one system/discipline and at one scale of multiple systems and scales at the same time.

Figure 2: Main components of SEAMLESS-IF assessment procedure (from EWERT ET AL. 2006)



Main components of SEAMLESS-IF assessment procedure and possible relationships among these are illustrated in Figure 2. SEAMLESS-IF will provide the possibility to implement project-specific assessment steps and sequences to describe specific project workflows. At the problem definition stage the conceptual understanding of the policy questions is derived. User questions and storylines are converted to scenarios which represent different policy options to be compared. Indicators are chosen to represent the problem. Depending on the assessment, one or more models are triggered by the system to perform simulations. Necessary input data that originate in external and internal databases through the knowledge base are passed to the models. Relevant output can be stored in the knowledge base for further use. At the end of the assessment procedure results are produced, presented and visualized using different tools.

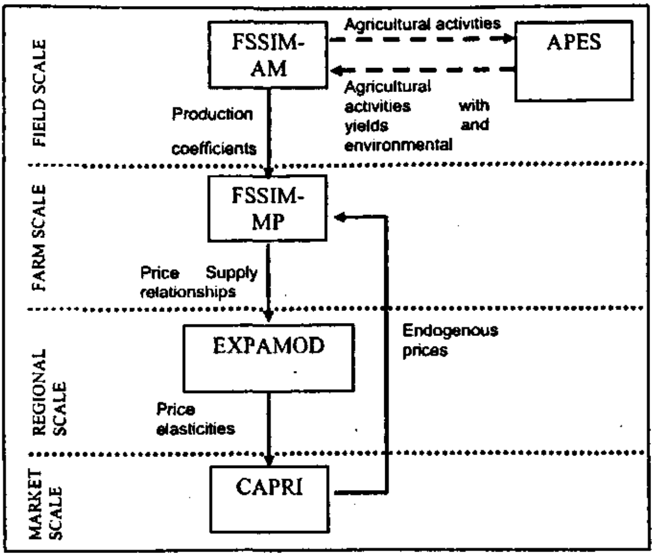
Integrated impact assessment or assessments of sustainable development imply a multidimensional approach where all dimensions of sustainability (Economic, Environmental, Social and Institutional) are taken into consideration. Moreover, a new policy does not affect the assessed system in a balanced way and it is therefore crucial to assess the trade offs between the dimensions. In SEAMLESS an extensive set of indicators (single and composite) for sustainability and environmental impact assessments in agriculture is being developed. The single indicators are used to evaluate the degree of sustainability for each dimension of sustainability: economic, environmental, social. These indicators are mainly the model outcomes (see Section 4). The composite sustainability indicators combine information from single indicators that may be from the same sustainability dimension and have the same measurement unit, or may be from different sustainability dimensions. Different methodologies can be applied for aggregation of single indicators, such as multiplication of indicators, summation of the weights (similar between different indicator types or not) of indicators, power averaging of the indicators, normalization (based on unique unit of measurement), applying the law of the minimum, multi-criteria analysis, etc. (ALKAN OLSSON ET AL. 2006). The literature study on indicators of multifunctionality (based on the work performed within the Multagri project, see e.g. ZANDER ET AL. 2007), which analysed the existing literature on multifunctionality) has shown that there is a lack of indicators to describe some domains, which is a challenge in SEAMLESS.

4. Integration of models

SEAMLESS-IF can have a large number of different models and processing tools. These models are different concerning the methods that are used and the scales. Specific models and processing tools are required just for permitting the linkage between some of the basic models. In many cases, direct "aggregation" is not possible for moving from one scale to another one, because the models that are used at the first level and those used at the second one apply different methods, have different specifications of variables. This is the reason for creating intermediate models that allow those linkages (FLICHMAN ET AL. 2006).

The example in Figure 3 demonstrates the links between four models integrated in SEAMLESS-IF tool so far. These models have been developed by different teams (having dissimilar educational backgrounds and research intentions) and are based on methodologies from different disciplines. One of the models is the agricultural sector model (CAPRI) that simulates supply-demand relationships in the EU25 for agricultural commodities. CAPRI derives information on price-supply relationships from two other models, e.g. bio-economic farm models (with FSSIM-AM being an agricultural management module and FSSIM-MP a mathematical programming model) and a regional up-scaling model (EXPAMOD). The bio-economic farm models in turn simulate farm behaviour and use agricultural activities (i.e. crop rotations, management options with respect to fertilization, cultivitation and irrigation) assessed through a simulation model for agricultural production and externalities (APES). In Figure 3 the links indicate linkages between economic models, for example from a partial equilibrium model at the regional scale (CAPRI) to a bio-economic model at the farmtype scale (FSSIM). The dashed link indicates the linking to models from other disciplines, such as for example biophysical models at the field scale.

Figure 3: Links between models developed at different scales: field, farmtype, region, market (EU)



5. Integration of scientists and users

Although modeling is central to integrated assessment it is not seen anymore as a purely scientific activity that provides systems descriptions and prescriptions for decision makers but as a participatory approach with strong emphasis on communication. Thus, both modeling and stakeholder involvement are seen as important elements of the assessment procedure proposed by SEAMLESS-IF (Figure 2).

SEAMLESS-IF is built for prime users (EU DG) but we envisaged that it can be used without any change in the tools and the software by other (groups of) users for the same type of application (policy assessment by regional decision makers for example) or for other type of applications (for example researchers for design of innovative agricultural systems). Unlike users, stakeholders are not using SEAMLESS-IF but their expert knowledge is used in the procedure for problem structuring and analysis of scenarios and indicators.

Interaction with users and stakeholders is required (a) during the development of SEAMLESS-IF (basically at every stage presented in Figure 2) and (b) for the application of SEAMLESS-IF after 2008, the end of the project. SEAMLESS strongly targets at the scientific community beyond the project, through development of its stand-alone knowledge sources, such as models, databases and indicators, and through the development of the software architecture.

6. Integration of knowledge: Technical solutions

One of the obstacles to the integration of research and to the cross-fertilisation of ideas from different disciplines is the variety of formalisms, which is also reflected in the software tools implementing the research results. The sheer amount of knowledge that is made available within the SEAMLESS project can easily overwhelm also the best scientists, even those who have the best outlook on all the disciplines and models that are to be linked in the SEAMLESS integrated framework. In order to keep this knowledge manageable and useful an infrastructure to organize the various sources of knowledge into a knowledge base (KB) is developed. With the KB the integration of science domains, methods and their implementations in software components is facilitated by generating data (-bases), code for models, KB search and management tools and KB-aware construction of workflows (ordered sequences of applications of tools on models and data). The KB is an integral part of the software backbone, SeamFrame, and serves as a kind of knowledge broker between components and between components and users. In SeamFrame all components need to implement a standard interface. For this, SeamFrame complies to the Open Modelling Interface (OpenMI; www.openmi.org; GIJSBERS AND GREGERSEN 2005). We have opted for the OpenMI 1.2 standard and its Java implementation.

The knowledge in the SEAMLESS Knowledge Base is formally represented by means of ontologies. An ontology is an explicit and formal specification of a shared conceptualization (GRUBER 1993). Ontologies are quickly becoming a standard for knowledge representation, and their use in the project will facilitate and foster the dissemination of the knowledge we have elaborated in SEAMLESS. Although the use of ontology as knowledge representing and structuring entities is growing rapidly in the software industry, the application is still far from trivial. It requires agreements among scientists from different scientific domains on the shared concepts they use. Within SEAMLESS we are developing the ontology to allow the KB to play indeed an important role in organizing and locating relevant knowledge to be used in impact assessments.

7. Concluding remarks

This paper only briefly presents conceptual and technical aspects of an integrated assessment approach: models, databases, software design, scenarios, and indicators. Its main purpose is to introduce SEAMLESS-IF as a tool for impact assessment – a tool that is being designed to integrate the knowledge on farming with other aspects of sustainable development across various scales – and to illustrate its applicability for assessing changes at the farmtype level. SEAMLESS targets at a working version of the integrated assessment framework by 2008 for its prime users in the European Commission. At the same time the software backbone of the project, SeamFrame, is anticipated to provide an open source means to facilitate integration of models and other knowledge sources from different domains and programmed in different environments and languages. Finally, the different components of SEAMLESS-IF are designed to have stand alone value. These components can be used for targeted applications or serve as a starting point for further scientific development. As such, we aim that the integrated framework facilitates condensation and synthesis of scientific knowledge in the domain of agriculture and its environment.

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