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**System for Environmental and Agricultural Modelling;
Linking European Science and Society**

Methodological concepts for integrated assessment of agricultural and environmental policies in SEAMLESS-IF

Ewert F., van Ittersum M., Bezlepkina I., Oude Lansink A., Andersen E., Bäcklund A.-K., Brouwer F., Flichman G., Heckelei T., Olsson J., Olsson L., Rizzoli A., Theesfeld I., Wery J., Wien J. E., Elbersen B., Donatelli M., Martinson L., Perez I., Svensson M., van Diepen K., van der Wal T., Wolf J.

Partners involved: ALTERRA, CRA, FLD, IAMM, IDSIA, INRA, LEI, LU, UBER, UBONN, WU

WAGENINGEN UNIVERSITEIT
WAGENINGEN UR

SEAMLESS integrated project aims at developing an integrated framework that allows ex-ante assessment of agricultural and environmental policies and technological innovations. The framework will have multi-scale capabilities ranging from field and farm to the EU25 and globe; it will be generic, modular and open and using state-of-the art software. The project is carried out by a consortium of 30 partners, led by Wageningen University (NL).

Name: Ewert, F.; van Ittersum, M.; Wolf, J.　　Acronym: WU
Address: Wageningen University, PO Box 430, Wageningen, 6700 AK, The Netherlands

Name: Bezlepkina, I.; Oude Lansink, A.　　Acronym: WU
Address: Wageningen University, PO Box 8130, Wageningen, 6700 EW, The Netherlands

Name: Brouwer, F.　　Acronym: LEI
Address: LEI, PO Box 29703, The Hague, 2502 LS, The Netherlands

Name: Andersen, A.　　Acronym: FLD
Address: The Royal Veterinary and Agricultural University, Hørsholm Kongevej 11, Hørsholm, DK-2970, Denmark

Name: Flichman, G.　　Acronym: IAMM
Address: IAMM, 3191 route de Mende, Montpellier, 34093 Cedex 5, France

Name: Donatelli, M.　　Acronym: CRA
Address: CRA-ISCI, via di Corticella, 133, 40128 Bologna, Italy

Name: Heckelei, T.; Perez, I.　　Acronym: UBONN
Address: University of Bonn, Nussallee 21, Bonn, D-53115, Germany

Name: Olsson, J.; Olsson, L.; Svensson, M.;　　Acronym: LU
Martinson, L.; Bäcklund, A.-K.
Address: Lund University, PO Box 170, Lund, S-22100, Sweden

Name: Rizzoli, A.　　Acronym: IDSIA
Address: IDSIA, Via Cantonale, Galleria 2, Manno, 6928, Switzerland

Name: Theesfeld, I.　　Acronym: UBER
Address: Humboldt University of Berlin, Resource Economics, Luisenstrasse 56, 10099 Berlin, Germany

Name: van der Wal, T.; Wien, J-E;　　Acronym: Alterra
van Diepen, K.
Address: Alterra, PO Box 47, Wageningen, 6700 AA, The Netherlands

Name: Wery, J.　　Acronym: INRA
Address: Place Viala, Montpellier, 34060 Cedex 2, France

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General information

Task(s) and Activity code(s):
Input from (Task and Activity codes):
Output to (Task and Activity codes):
Related milestones:

Executive summary

Agriculture has to adapt continuously to changes in economic, environmental and social conditions. The present perception of European agriculture within the society is rather critical with respect to its economic costs and impacts on rural development and the environment. Accordingly, the EC has entered a process of revising its agricultural policy to find a more sustainable balance between the economic, environmental and social functions of European agriculture. Integrated assessment and modelling can provide insight into the potential impacts of policy changes on agriculture and sustainable development.

The SEAMLESS project (System for Environmental and Agricultural Modelling; Linking European Science and Society) has been launched in 2005 to develop a computerized and integrated framework (SEAMLESS-IF) that allows the ex-ante impact assessment of new policies in the domain of agriculture, environment and rural development. The project runs for 4 years and follows a prototyping approach.

This report presents the methodological concepts for integrated assessment of agricultural and environmental policies as proposed to be used in SEAMLESS-IF and integrated in its first Prototype. The report builds upon an earlier report on the conceptual basis of SEAMLESS-IF (PD1.2.1) and integrates methods described in the reports PD1.3.1-1.3.7. It serves as a basis to understand the conceptual and methodological ideas underlying Prototype 1. As more insights about integrated assessment and modelling become available the methods described in this report will be further refined.

The report is structured into two main sections, one summarising the basic concepts underlying integrated assessment in SEAMLESS-IF and the other describing the different methods and their integration into the framework.

Specific part

1   Introduction

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. 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). The most recent reform of the CAP (IP/03/898, Luxembourg, 26 June 2003) aims simultaneously at improving competition in the world market, improving compatibility with multilateral negotiations to liberalise trade, maintaining viable rural communities, and achieving better targeting of measures designed to address social, environmental and consumer concerns (non-trade issues). Sustainability in farming must be achieved alongside new targets, in related but different policy fields. The EU's environmental policies have gradually changed from a procedural approach ('proscribed actions') to an ambient approach ('achievement of environmental quality targets'). 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).

The Common Agricultural Policy of the EU utilises more than 40 % of the EU budget, and there are increasing demands for this investment to support the multiple functions of agriculture and to strengthen EU economic and social cohesion. More than ever before, adequate and coordinated agricultural and environmental policies at EU, national and regional scale are needed that can facilitate agriculture's contribution to sustainable development. These policies must be cost-effective and efficient.

The design of agricultural, environmental and rural development policies would benefit from *ex-ante* assessments to estimate their (relative) contributions to sustainability and sustainable development. 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. The European Commission has introduced Impact Assessment of its policies as an essential step in the development and introduction of new policies since 2003 (EC, 2005). It explicitly calls for assessment of the economic, environmental and social impacts of policies *and* consultation with stakeholders. This implies in many cases establishment of a so-called Inter-service steering group (across various Directorates Generals, e.g., Agriculture, Environment, Economics and Finances) that is responsible for the Impact Assessment, as well as interaction with stakeholder groups. Impact Assessment is anticipated to contribute to a more coherent implementation of the European strategy for Sustainable Development (EC, 2005).

The SEAMLESS project (System for Environmental and Agricultural Modelling; Linking European Science and Society) has been launched in 2005 to develop a computerized and integrated framework (SEAMLESS-IF) that allows the ex-ante impact assessment of new policies and agro-ecological innovations in the domain of agriculture, environment and rural development. The project runs for 4 years and follows a prototyping approach.

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2 Conceptual basis of SEAMLESS-IF

2.1 General concept

The integrated project SEAMLESS-IP aims to develop a computerized framework (SEAMLESS-IF) for ex-ante impact assessment of agricultural and environmental policies. This framework must be generic and flexible to ensure that today's but also tomorrow's policies questions can be addressed. The project aims to achieve this through a modular set-up with stand-alone knowledge components that can be linked through intelligent software architecture. These software infrastructure and knowledge components have high value in themselves and are important products of the project. Hence, the project has three main outputs, the so-called triple *I* of SEAMLESS (Fig. 1):

1. Integrated framework for impact assessment. The framework allows to quantitatively (and qualitatively) assess economic, environmental, social and institutional indicators of the relationship between agricultural systems and sustainable development.
2. Infrastructure of software enabling model linkage. Intelligent use of latest software developments and technologies allows the linkage of stand-alone models and data, such that they can be (re-)used in integrated assessment and for other research purposes.
3. Individual, stand-alone, knowledge components (models, data and indicators). This includes i) existing and newly developed models which enable simulation of for instance crop and soil characteristics, farm behaviour and agricultural markets, ii) data bases to run these models together with a data framework of rules for data manipulation including (dis-)aggregation methods including associated typologies, and iii) sets of indicators representing the different dimensions of sustainability and indicator framework(s) that structure and link indicators to specified definitions of sustainability.

Integrated framework for IA

Infrastructure software   Individual components
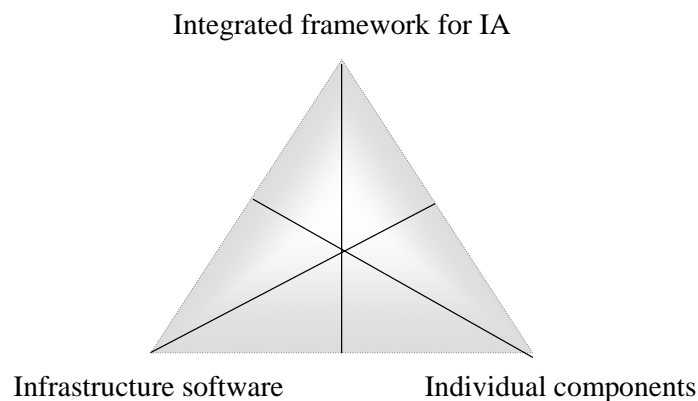
Figure 1. Triple I concept of SEAMLESS with three main outputs: 1. Integrated framework for Impact Assessment; 2. Infrastructure of software enabling model linkage; 3. Individual components of knowledge, such as models, data sets and indicators. These outputs are (more or less) connected to each other as indicated by the lines in the triangle.

Development of SEAMLESS-IF via individual components linked through software infrastructure has clear advantages in terms of maintenance, extensibility, transparency and documentation. The three *Is* each have value for different types of users, from the European Commission, international and national policy making agencies and the scientific community.

2.2 Integrated framework for impact assessment (IA)

2.2.1 Concept for assessing sustainability and sustainable development

Improving the sustainability of development is of central interest to agricultural and environmental policy. However, since the publication of the United Nations report on SD (Brundtland, 1987) numerous definitions of sustainable development (SD) have become available (Robinson, 2002) and the concept of SD remains vague. It is generally recognised that the complexity of sustainability problems demand a holistic perspective that unifies across sectors, problems, methods, disciplines, spatial and temporal scales (Swart et al., 2004) but no single operational concept is available yet that captures this complexity.

The approach for SEAMLESS-IF distinguishes between different dimensions of sustainability, i.e. natural or biophysical, social, economic and institutional, as derived from the aspects of integrated systems (Fig. 2, see also PD1.2.1). A detailed definition of sustainability of agricultural systems (S) and their contribution to SD will depend on the specific problem to be analysed. Users and stakeholders will be included in the definition of S/SD. Thus, a concept of S/SD that is operational will be obtained by combining present systems understanding with perceptions of users and stakeholders on S/SD involved in a specific assessment study.
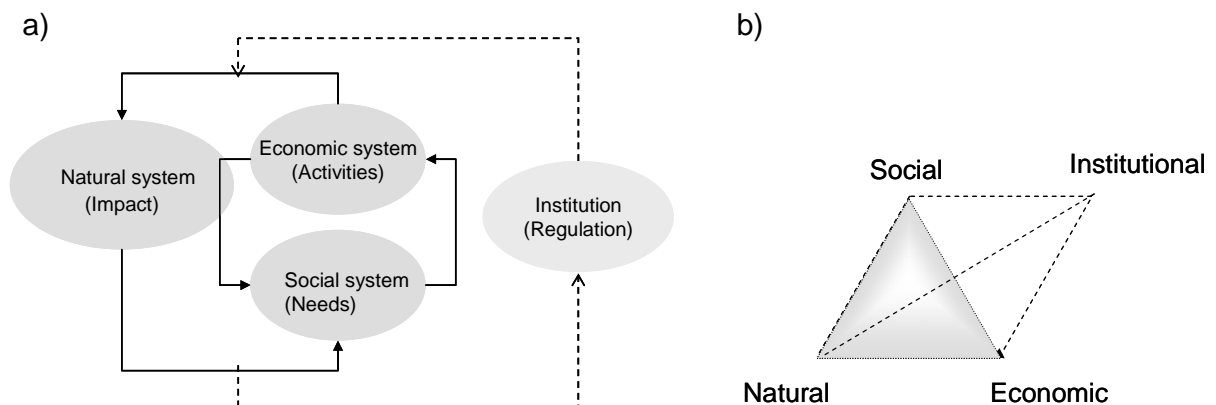
Figure 2. a) Relationships between aspects of integrated systems and b) simplified representation following the triple P concept: Planet, Profit and People (Serageldin et al., 1994).

In SEAMLESS-IF a distinction is made between sustainability and sustainable development (Fig. 3). Sustainability refers to the viability and performance of the system that is subject to investigation, whereas sustainable development refers to the viability of relationships to other systems, i.e. effects of changes in the studied system on the sustainability of other systems. Policy changes are evaluated with respect to their impacts on a specific system, e.g. sustainability of agricultural systems and related effects on other systems, e.g. rural development. This approach should allow distinguishing between impacts of policy changes as they may for example, be beneficial for the agricultural sector but negative for rural development and/or the environment.
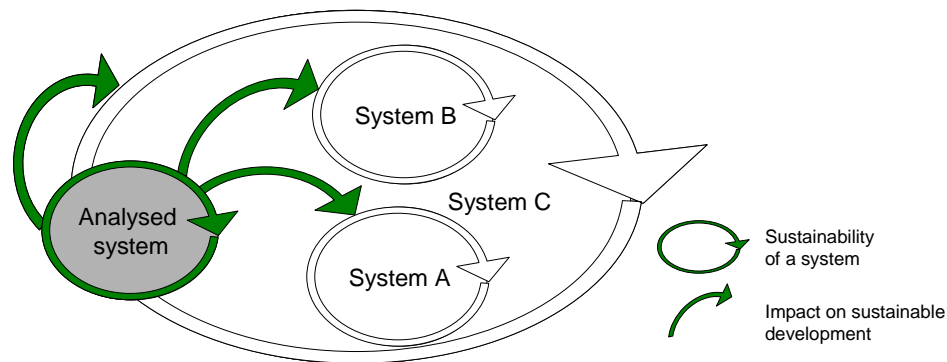
Figure 3. Schematic representation of sustainability and sustainable development as used in SEAMLESS-IF.

In SEAMLESS-IF S/SD assessment will be performed on the basis of indicators that reflect key properties of the system(s) and effects on other systems. Specification and selection of indicators will be guided by an indicator framework representing the basic understanding of S/SD of SEAMLESS-IF users (see section indicators).

A particular ambition of the project is to derive indicators from processes explaining behaviour of systems at different levels of organisation (Fig. 4). Thus, rather than scaling indicators, processes and relationships are scaled (where possible) to derive scale or level specific indicators. In this way indicators are more directly derived from system-specific process understanding.
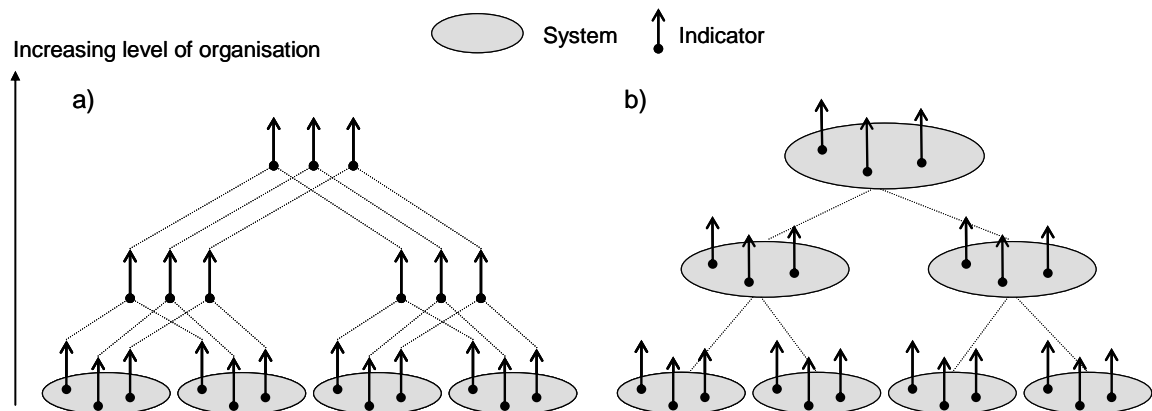
Figure 4. Different ways of estimating indicators across levels of organisation based on a) scaling of indicators and b) scaling of processes and relationships. Option b) is the aimed approach for SEAMLESS-IF.

2.2.2 Concept for integrated assessment and modelling

Integrated assessment is an analytical approach to balance the different aspects (biophysical, institutional, social and economic) of integrated systems (Harris, 2002). Although modelling 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. In fact, integrated assessment and modelling represents a problem-focused area of research, i.e. mainly project based and undertaken depending on stakeholder needs or demands (Parker et al., 2002). Thus, both modelling and stakeholder involvement are seen as important elements of the assessment procedure proposed by SEAMLESS-IF.

In awareness of the importance of integrated assessment for policy decisions on sustainable development the European Commission has introduced Impact Assessment (IA) of its policies as an essential step in the development and introduction of new policies since 2003 (EC, 2005). IA should contribute to an effective and efficient Regulatory Environment and, with regard to the economic, social and environmental dimension of Sustainable Development, to a more coherent preparation of EU decision-making. It explicitly calls for assessment of the economic, environmental and social impacts of policies and consultation with stakeholders.

As described in the above section (section 2.2.1) in SEAMLESS-IF involvement of stakeholders will be essential for the (project-specific) definitions of sustainability and sustainable development and ultimately for the selection of associated indicators including their target values and weights. But also for other steps in the assessment process with SEAMLESS-IF involvement of stakeholder is possible and required.

While integration is a key goal for integrated assessment (and for SEAMLESS-IF) it is still difficult to be truly achieved in practice. Particularly difficult is the development of a generic approach for integration that can be automated and made applicable to wide range of integrated assessment studies. A common approach is to distinguish between actors (or human activities) and environment (or disciplines or scope of assessment), (Fig. 5). More refined approaches further distinguish between stages of human impact on environment such as pressure, state, impact, response (Rothman and Robinson, 1997). In SEAMLESS-IF we follow the concept of actor and environment (Fig. 6a).
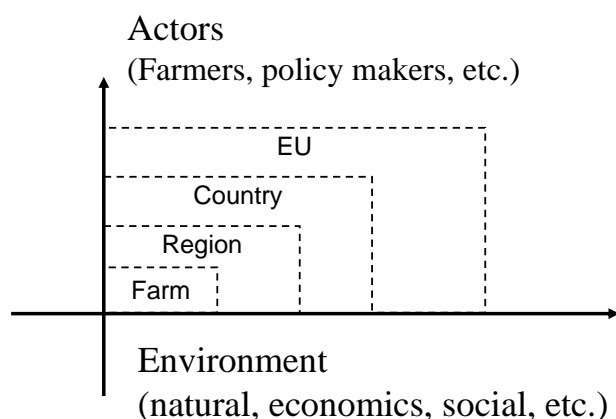
Figure 5. Schematic representation of relationship between actors and environment as used for vertical and horizontal integration in SEAMLESS-IF.

It is assumed that actors act on environment. Environment includes all aspects of integrated systems, i.e. biophysical, social and economic. Impacts on institutional environment are not considered but the constraints that institutions may pose on actors and decisions are included in the assessment. The precise description of environment depends on the specific problem and related system(s).

Actors can influence the environment via a set of activities. Importantly, actors can also be part of a system, i.e. they are also influenced by environment. In fact, changes in the environment to which actors are responsive form the conditions within which actors act. These assumptions are crucial to allow scaling across levels of organisation (Fig. 6b).

a)

b)
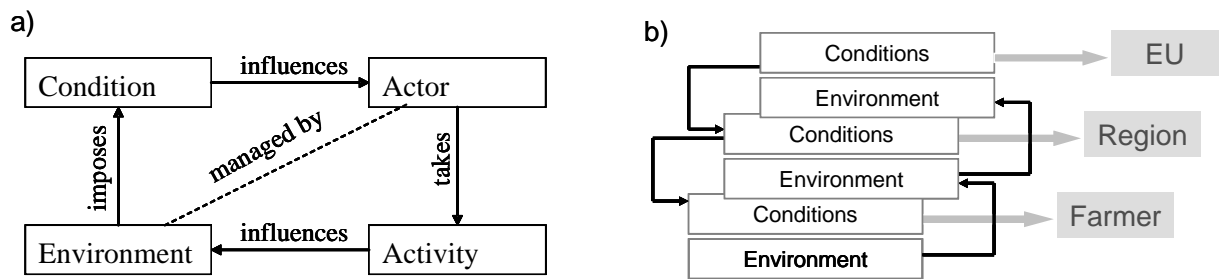
Figure 6. Schematic representation of a) the Actor – Activity – Environment - Condition concept used in SEAMLESS-IF and b) application of the concept for actors across levels of organisation.

2.2.3   Concept for assessment procedure

Integrated assessment (or impact assessment as defined by the EC) requires several steps to arrive at a proposal for policy or decision support. In an earlier report, PD1.2.1, we have made a first attempt to identify a number of steps important for integrated assessment. This has been revised considering more recent experiences. Main components of the assessment procedure and possible relationships among these are illustrated in Figure 7. It should be noted that the number and sequence of steps may differ depending on the specific project. SEAMLESS-IF will provide the possibility to implement project-specific assessment steps and sequences to describe specific project workflows.
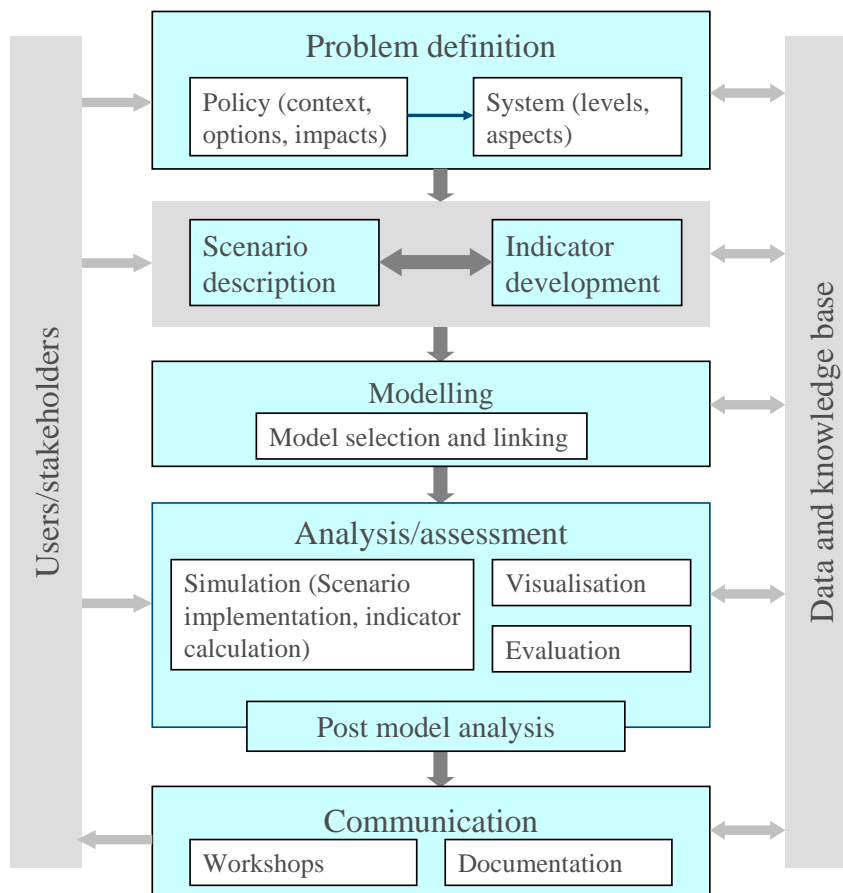
Figure 7. Main components for integrated assessment in SEAMLESS-IF. The indicated components and relationships characterise the basic assessment procedure proposed. Flexibility in designing the assessment process depending on specific project requirement is envisaged.

2.3   Infrastructure software

2.3.1   Management of knowledge and information in SEAMLESS-IF

Effective management of knowledge and information flows is a key requirement for a complex knowledge-based modelling framework as SEAMLESS-IF. Specific emphasis needs therefore to be dedicated to the use (and development) of an appropriate and innovative software architecture.

In SEAMLESS-IF data and models are decoupled. Ontology provides a medium for semantically defining generic data structures that are used by model applications for exchanging data. In SEAMLESS-IF, the use of ontology is introduced for the Knowledge Base. The aim is to provide a structure to re-use knowledge and combine components like databases, models, rules and methods. PD5.4.2 describes how the knowledge and data components are structured. Next to the use of the ontology to select, describe and organise terms that are used it is also attempted to develop an ontology that helps to exploit the knowledge base.

The advantages in using ontology are increasingly recognised. A summary on the definition, benefits and challenge of using ontology is provided in PD1.3.4.

A complete knowledge-based framework usually encompasses many ontologies with different roles that can be classified as generic, domain-oriented and task-oriented (see PD1.3.4). In SEAMLESS-IF first emphasis is on the development of ontologies for:
- Data representation
- Model representation and
- Representation of workflows.

These ontologies will ensure correct data flows and model linkages.

2.3.2   Conceptual basis for modelling within SEAMLESS-IF

The modelling concept defines the scope of our view of the agri-environmental-economic domain to be modelled and analysed. The conceptualisation is based on three domains:

1. The SEAMLESS agro-environment domain (SeamAg);

2. The Modelling domain;

3. The Application domain;

This subdivision is also referred to as the **SeAM** concept. Each sub-domain is in fact a separate dimension, orthogonally positioned to the others. It is important to have a shared understanding about all three 'worlds' in order to deliver a comprehensive product of use to all user roles. The three domains will build on the core ontology, which provides fundamental concepts to reason about space and time (see PD1.3.4).

Agro-environment domain

The SEAMLESS agro-environment domain (SeamAg) includes ecological, social, economical and institutional aspects. Central theme is the systems (-theory) paradigm (see PD1.2.1). To understand a system one must study the individual parts of the system as well as the relationships between them. As emphasis of SEAMLESS-IF is also on issues of sustainable development relationships between systems will also be consiederd. SeamAg is organised according to the concepts of Environment, Actors, Actions, Conditions (see section 2.2.2).

Modelling Domain

The modelling domain is where models are developed and implemented. The modelling domain is composed of components which consist of concepts: they are 'packages' of models

and tools (e.g. numerical integration routines), which have been aggregated because of their logical proximity and their functions. In the same component all models that are related to the same domain in SeamAg can be found. For instance, the each CLIMA component contains all models related to a specific domain within weather, such as rainfall, evapotranspiration, solar radiation, etc.. Models are made of equations and their context in time and space (e.g. their parameters). The class which includes models and tools is called modules. They are expressed by Concepts, which are used to structure and store all information in the Knowledge Base.

Models are basic modelling units. The variables of a model are defined in the core ontology. Models are packaged in components and they refer to domains. We can therefore query the ontology to discover all models related to a given domain which are packaged in a specific component.

Application domain

The Application domain reflects the way applications are composed/assembled from individual/composite software components. SEAMLESS-IF will adopt and extent the application domain from the EU5FP project HarmonIT. The application domain is captured in the Open Modelling Interface: OpenMI (Gijsbers et al., 2002). This framework consists of two prime components: Linkables and Links. In this way, OpenMI provides a conceptual model of coupling components, which are linkables, exchanging data between components and directing the order of calculations.

An application implements a number of generic workflows, which is a chain of linkables and links, where each link connects two linkables. Based on the different user roles, several workflows can be determined within SEAMLESS-IF: analyse, simulate, evaluate, visualise, communicate.

2.3.3   Conceptual design of SeamFrame

Based on the structure of the conceptual basis for modelling in SEAMLESS-IF (see above) the design describes the structure and organization of the software architecture that enables to deliver end-user applications that will support modelling according to the concept described above.

The SeamFrame software system is a result of analysis of requirement and review of modelling frameworks which are aimed at supporting a component-oriented approach to software development (Szyperski et al., 2002).

The presentation of the system is instrumental to the matching of the requirements to the main architectural elements (see Fig. 8): the Knowledge Base, the SOFA (SEAMLESS OpenMI+ Framework Architecture), that is the SeamFrame core (Knowledge Manager, Model Manager, Tool Manager), the SeamFrame Development Environment (Modelling Environment, Processing Environment), a set of framework applications: Seam:REF, Seam:LINK, Seam:KM, Seam:GAMS, Seam:MOD. Using this framework it will be possible to deliver a number of SEAMLESS end-user applications (e.g. APES, FSSIM-AM, FSSIM-MP, SEAMCAP).

The core classes and components of SeamFrame are structured in a package named SOFA, or SEAMLESS OpenMI+ Framework Architecture. The SOFA contains the basic components needed for the Knowledge Base and to manage the OpenMI+ compliant executable modules constructed from models and tools.

On top of the SOFA sit the packages that contain the modelling and processing environments. The modelling environment package sets the structure that a modelling application (such as Modcom) must conform to so that it can integrate into SEAMLESS-IF. For example, it must retrieve its data (knowledge objects) through the SOFA and implement an integration interface.

The processing environment contains the implementation of the workflow environment for SEAMLESS. It enables the creation of workflows of modules, which are "executable" models and tools that implement OpenMI+ (an adapted version of OpenMI 1.0) interfaces. Further information is given in PD1.3.4.
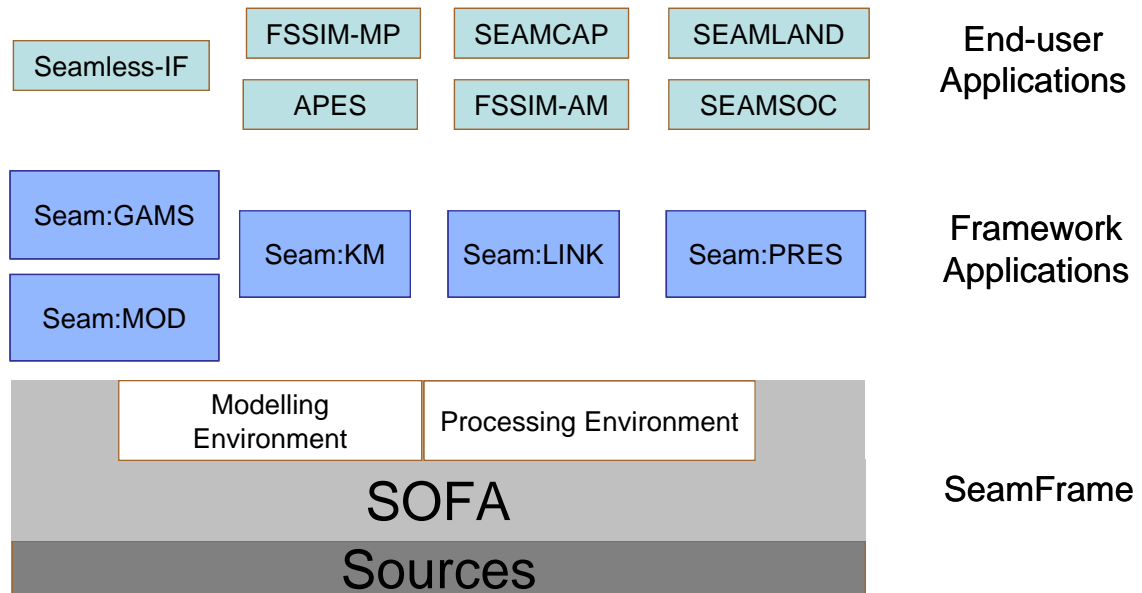
Figure 8. The SeamFrame architecture, with its development environment, composed by the modelling and processing environment, the Knowledge Base, and the end-user applications.

2.4   Individual components

SEAMLESS-IF will consist of several individual components such as models and data bases including features for indicator development and selections. These components require adequate development and integration into SEAMLESS-IF and are essential building blocks to perform integrated assessment and modelling. However, these components also have stand alone value. For instance, the development of indicator frameworks including procedures for selection and calculation of indicators will be a value beyond the present project. The same is true for models and databases which can be used and developed independent of other SEAMLESS components if required (for example APES as a crop model and FSSIM as a farm model). The software infrastructure underlying SEAMLESS-IF will ensure flexible integration of framework components depending on the project requirements. Methods of how to use and integrate these individual components into SEAMLESS-IF are described in the next section.

3 Specification and integration of methods

3.1 Development of scenarios

Policy impact assessments are commonly based on scenario analysis. A scenario is a consistent frame of assumptions about exogenous factor(s) describing the possible future of a system's environment. In SEAMLESS-IF several steps of scenario analysis will be distinguished (Fig. 9):

I.   Formulation of scenarios;
II. Implementation of scenarios;
III. Scenario assessment including simulation, evaluation and communication of results.
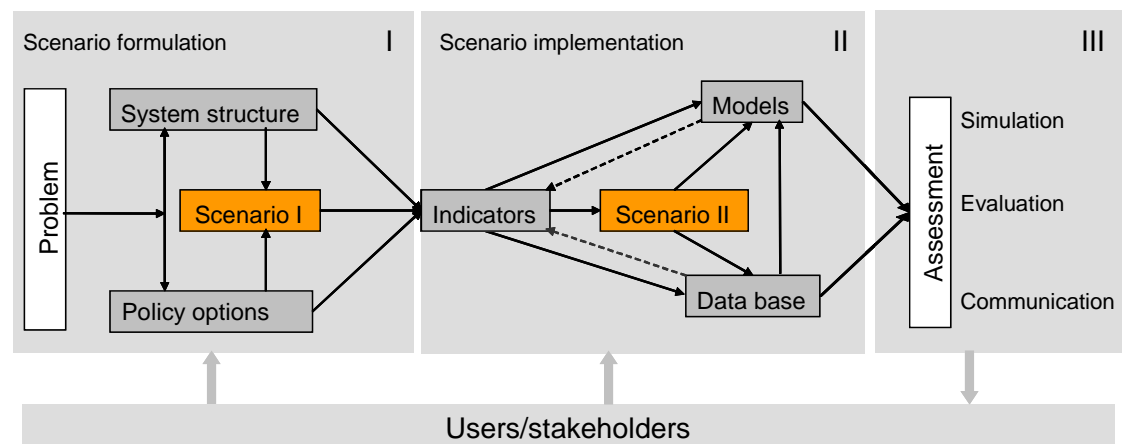
Figure 9. Steps of scenario analysis as used in SEAMLESS-IF.

The two steps of scenario formulation and implementation and their relationships to other activities such as indicator selection and modelling are explained in more detail in the following sections.

Formulation of scenarios

This is part of the problem structuring and clarifies *what* we want to analyse. Starting from a policy question, the purpose of the user question and the storylines will be identified which is the basis for the formulation or description of scenarios. This activity will clarify which differences in policy options or technological change will be considered in the assessment study. It should also clarify which parts of the system are affected by alternative scenario assumptions. Clearly, alternative scenarios will be represented by assumptions about changes in factors exogenous to the system that characterize best the anticipated policy change. For instance if we talk about a complex agricultural system we can identify many drivers but not all will change with policy, e.g. if export subsidies are reduced according to WTO agreements we need to implement these changes at the market level (main pathway) and not directly at the farm or regional level nor for the biophysical factors (e.g. climate) of our system (see Fig. 10a). This will be different for the implementation of e.g. the water framework directive or introduction of new technologies such as GMO crops. Drivers will probably have to change at the farm level (see Fig. 10b). Once the scenarios have been described in general terms, we can identify the indicators to enable comparison among policies with respect to sustainability impacts. The selection of indicators and expert knowledge on the interactions within the system leads to the specification of the relevant model chain. Then, factors (exogenous

variables) of the chosen modules have to be specified for the different scenarios. This procedure may be further automated which is still under discussion and development.

Implementation of scenarios

This refers to *how* we want to analyse it. Once we have structured our problem and clarified what our scenarios should address we implement these scenarios. This requires that we first need to specify the indicators we want to use. Indicators selection also depends (interaction) on available models and data bases. When indicators, models and data are identified scenarios can be implemented. Implementation of scenarios means that the exogenous variables of our system are identified and their values for the alternative scenarios are clarified for the models selected. For instance, changes in market prices or reduction in subsidies will be exogenous to our system. Variables that represent these changes in the model(s) considered need to be changed to the new subject to assessment
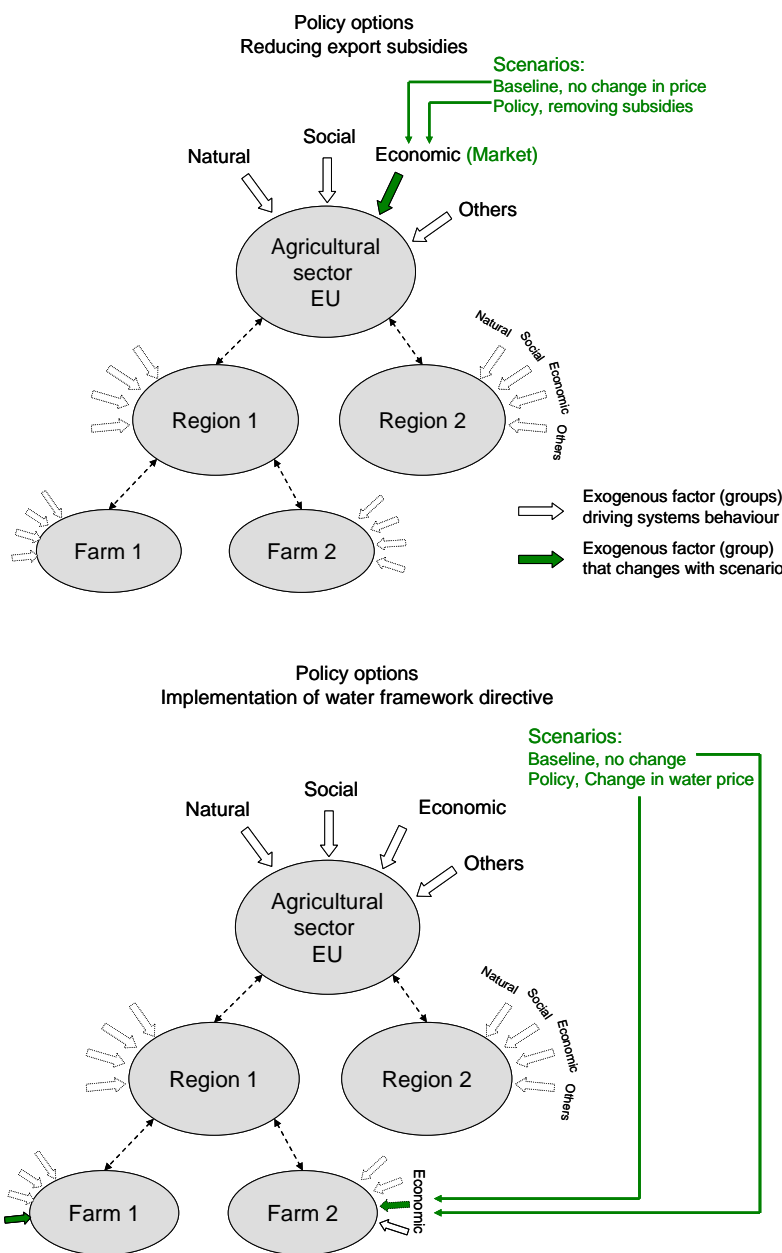
Figure 10. Selected examples demonstrating alternative policy options for different policy fields.

Several scenario frameworks exist. As SEAMLESS-IF will be developed to primarily support the assessment of impacts in policy changes and technological innovations the basic framework will consider a with/without comparison of the policy impacts:

- Baseline scenario (without the policy change based on current policy)
- Policy scenario (with policy change) and if required
- Contrasting scenario (alternative policy scenario or repetition of baseline and policy scenario for different framework conditions independent of policy change) and
- Scenario without any changes, i.e. Ceteris Paribus (scenario without any change in exogenous factors).

However, other frameworks such as the widely used IPCC SRES (Nakicenovic et al., 2000) scenarios may also be considered in the future.

Ideally, SEAMLESS-IF would support scenario development in all its steps, i.e. provide guidance for scenario formulation and implementation and link these to other activities such as simulation, evaluation and communication of results (which is not yet achieved). Issues of scenario development will receive more attention in the second period of SEAMLESS. The present vision is to provide model-specific templates for scenario development following the steps described earlier. For the future a template may also be developed for scenario formulation to allow project related specification of:

- Scenario framework to be used including the;
- Types of scenarios (e.g. baseline, policy scenario);
- Parts of the domain/system for which exogenous assumptions will be made (information come from system description);
- Exogenous factors that are likely to change with scenario assumptions.

A second template may support scenario implementation in a more automated way avoiding programming of model specific templates as presently done. This template will guide specifications of:

- Models (in fact this information may be provided from model selection, structured according to domain and hierarchical level);
- Scenario specific assumptions about model inputs;
- Scenario specific assumptions about other data not related to the models.

3.2 Specification of indicators

3.2.1 Development of indicator frameworks

Role of indicator framework

This section provides a brief overview about important issues with respect to the specification of indicators, particularly on the development of indicator frameworks and types of indicators and ways to qualify them. A detailed description about the specification of indicators is provided in the reports PD1.3.1/1.3.5 and D2.1.1.

Indicators are an aggregation of information that indicates the change or defines the status of something. Indicators are most frequently based on quantifiable data but may also be based on qualitative information. An extensive set of indicators for sustainability and environmental impact assessments in agriculture is to be incorporated in SEAMLESS-IF. These quantitative and/or qualitative indicators are to be combined in various ways for the whole range of sustainability assessments.

As clarified above (see section 2.2.1) each assessment will largely depend on how sustainability (and sustainable development) is viewed by the users and stakeholders of a specific project. Accordingly, the definition of sustainability should be reflected in the development and selection of indicators. In order to support indicator development and base their selection on arguments that are consistent with the perception and assumptions of

sustainability, indicator frameworks will be developed. Consequently, the roles of an indicator framework are:

- To create a basis for the "translation" of users' policy questions into something that the SEAMLESS-IF tool can handle, i.e. the indicator framework serves as the link between user questions and the SEAMLESS-IF;
- To ensure that a balanced approach (i.e. balanced set of indicators) is applied to each of the sustainability dimensions (i.e. environmental, economic and/or social). The development of an indicator framework requires expertise and knowledge of the system and can only be assisted by SEAMLESS-IF;
- To assist in the structured combination of indicators for deriving meaningful sustainability estimates;
- To create a systematic and flexible approach for weighing and aggregating indicators into specific sustainability estimates.
- To ensure some minimum consistency among indicators and available models and data bases

A first proposal has been made for an indicator framework that reflects the ambition of SEAMLESS-IF to assess sustainability in its different dimensions and levels of organisation ranging from farm to regional, national and the EU. The framework is partly implemented in Prototype 1.

Indicator framework(s) for SEAMLESS-IF

Briefly, any indicator framework in SEAMLESS-IF should structure and categorize indicators to facilitate the evaluation of output from models and data bases reflecting the perception of sustainability and sustainable development as defined by the users and stakeholders. In the development phase of SEAMLESS-IF users and stakeholders are not involved in the application of SEAMLESS for specific projects. Thus, activities about the development of indicator framework(s) for SEAMLESS-IF were largely independent of users and stakeholders. However, several classifying factors for an indicator framework could be identified:

1. The framework should allow distinctions to be made between indicators relevant to assess impacts of agri-environmental policies on the sustainability of the agricultural sector and on sustainable development, i.e. the society as a whole. These are the two domains of the framework (Fig. 11);
2. The framework should distinguish indicators according to the different levels of organisation (i.e. from farm to EU);
3. Also, it should account for the three sustainability dimensions (i.e. environmental, economic and social);
4. In addition to the three factors above, a further separation is made according to themes with reference to the goal based approach (Fig. 12). This assumes that indicators can represent goals, process of achievement and means to achieve these goals;
5. Eventually, the introduction of sub-themes should classify indicators with reference to issues such as viability, performance and maintenance etc. (Fig. 12).
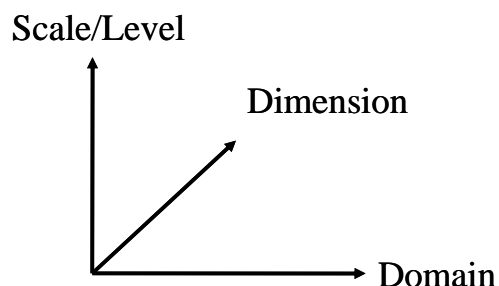
Scale/Level

Dimension

Domain

Figure 11. Main classifying factors of the Indicator framework

The framework includes:
- Ecological indicators such as for example N leaching, pesticide leaching, global warming potential, water surface runoff, P balance, soil erosion, water use, energy use due to mineral fertilizer and crop diversity;
- Economic indicators such as production of main agricultural products, net value of capital, land factor price, gross margin, export/import ratios of main agricultural products, terms of trade, profits of the processing industry, budgetary expenditure, tariff revenues, and total welfare;
- Social indicators such as food availability, poverty, labour use, income per capita, fraction of total population employed in agriculture, education level of farmers, age of farmers, population density, gender distribution in agriculture, types and specialization of farms, and off-farm income.

Alternatively, a second framework has been proposed (but has not been considered in Prototype 1) which attempts to be more based in systems thinking (Fig. 12). In this framework classifying factors for main and co-existing systems and system properties will be introduced and will substitute the factors domain, themes and sub-themes from the first framework.

Eventually, SEAMLESS-IF will support the development of new indicator frameworks.

Indicator Framework I	Indicator Framework II
Dimensions	**Dimensions**
Biophysical, economic, social, institutional	Biophysical, economic, social, institutional
Level of organisation *(spatial scales)*	**Level of organisation** *(spatial scales)*
Field, farm, region, country, EU, globe	Field, farm, region, country, EU, globe
Domains	**System/co-existing systems**
Sustainability, Sustainable development	EU agricultural system, others (developing countries)
Themes *(goal based approach)*	**Properties**
Ultimate goal, processes of achievement, means	Existence, effectiveness, freedom, security, adaptability, co-existence
Sub-themes/issues	
Viability, performance, capital, maintenance, …	

Figure 12. Two proposed indicator frameworks for SEAMLESS-IF. Only dimensions and level of organisation are considered as classifying factors for structuring indicators in Prototype 1.

3.2.2   Selection and calculation of indicators

The development of an indicator framework for SEAMLESS-IF (or its selection for a specific project) and its application to select indicators (for a specific project) is a complex process. It is determined by the availability of data, the ability of models to produce the required output (variables), the demands of users (stakeholders, experts, etc.), the policy questions, etc. Most importantly, this process will require interaction with SEAMLESS-IF users and experts of the system (Fig. 13).

The selection of indicators requires clarification about the problem at stake and the associated policy questions and scenarios to be investigated. These need to be translated into the (main) related indicators (single or composite). The underlying indicator framework will support this selection and ensure that selected indicators are sound and sufficient for the evaluation of impacts on sustainability and sustainable development.

An indicator calculator will be developed to provide support to the user for:

- Translation of policy questions and scenarios into related indicators;
- Aggregation of a new composite indicator, if needed;
- Information supply about which indicators are feasible to be assessed based on the output from models and data bases in SEAMLESS-IF;
- Selection of indicators relevant to the policy question(s);
- Application of an indicator at a higher or lower level of organisation.
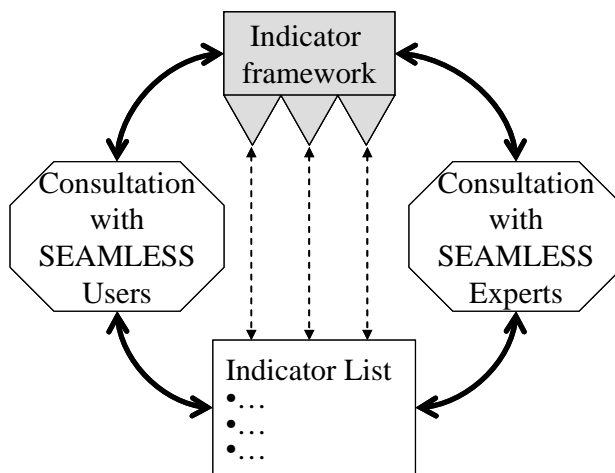
Figure 13. Schematic representation of the procedure for indicator selection in SEAMLESS-IF.

3.2.3   Types of indicators

A main distinction in indicator types is that between composite indicators that are an aggregated result from different single indicators (as discussed in the next paragraph) and single indicators. Another distinction is that between quantitative and qualitative (e.g. based on a survey involving opinions). Model outputs are the basis for quantitative indicators.

Single indicators

The single indicators are used to evaluate the degree of sustainability for the following single data:

- environmental, economic and social output variables from modelling in SEAMLESS-IF;
- environmental, economic and social data sets in SEAMLESS-IF;

- results from statistical analysis of environmental, economic and social data/model output variables from SEAMLESS-IF.

Composite indicators

Assessments of sustainability and environmental impacts cover a multidimensional space of themes. Even within one sustainability dimension (economic, environmental, or social), such an assessment will address a range of themes. It appears to be difficult to interpret a list of single indicators as a totality. For example, it will then be difficult to compare the results from two scenarios (e.g. baseline versus policy scenario) and to come to a general conclusion in a transparent and scientific way. To avoid the trap of unconscious weighing of single indicators, adding of apples to oranges, etc., a formal procedure for the aggregation of single indicators appeared to be essential.

The composite sustainability indicator combines 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. An indicator calculator is to be developed, with which the user of SEAMLESS-IF can define a formal procedure for deriving a composite indicator and subsequently, can calculate that indicator.

The aggregation of single indicators has the advantage that this combines the effect of a number of driving factors, but has the disadvantage that some information is lost. Different methodologies can be applied for aggregation of single indicators, such as multiplication of indicators, summing 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.

3.2.4   Qualification of indicators: targets, thresholds and reference levels

An indicator without pre-specified value or without context has little meaning. Hence, thresholds, targets, benchmarks or reference levels are needed to assess the contribution to sustainable development of a change in indicator from one scenario to the other. The establishment of targets, thresholds etc. can be scientifically based. However, if the scientific basis is missing or weak, targets etc. can also be defined by the stakeholders based on their risk estimates, risk handling behaviour and social acceptance.

Qualification of indicators is the method for measuring the output from models or data bases with an indicator for sustainability (i.e. the yardstick). This indicator may be applied for qualitative or quantitative judgment of the output of SEAMLESS-IF, such as the nitrogen balance given as kg nitrogen or as six classes from very low to very high. The output may also be judged as being above or below a reference level.

3.2.5   Pre- and post-model analysis

Qualitative analysis of pre- and post-model calculations are an essential part of integrated assessment in SEAMLESS-IF. Thus, tools/models for both pre-model analysis (i.e. which are the most interesting indicators for relevant policy questions, and to some extent which model runs and data retrieval are needed to answer these policy questions) and post-model analysis (i.e. which results from SEAMLESS-IF are relevant to answer policy questions and what do they mean, and which results from SEAMLESS-IF are not in the plausible range) will be developed to analyze the significance of SEAMLESS-IF results.

An example of such latter type of pre- and post-model analysis is the Procedure for Institutional Compatibility Assessment (PICA). The SEAMLESS-IF approach initially assumes that the appropriate and required institutions are in place for resource management and policy effectiveness towards sustainability. PICA questions these assumptions and will

develop a procedure to test them and to assess the institutional (in)-compatibility of policy options.

Institutions - defined as the formal and informal rules of a society or of organisations - form mechanisms that facilitate or hamper the decision making about steps towards sustainable development, the subsequent, implementation of these steps and, thus, influence the resulting behaviour of targeted actors (e.g. compliance with regulations, intended behavioural changes). Crucial institutional aspects include the roles and positions of the main political actors, the available options (or, action alternatives) for the main stakeholders (e.g. water board, farmers, etc.), the type of government intervention (incentive-based instruments, command-and-control, etc.), the way of policy implementation (e.g. via administrative authorities at various levels), and the farmer's competencies and capabilities (e.g. income level, communication capacity, social capital).

As a *pre-model tool*, PICA will test if (and which) institutional constraints might hinder a specific policy option to reach its objective. This will contribute to the selection of relevant and sensible models and indicators. Used as part of a *post-model analysis*, PICA relates the output of the quantitative SEAMLESS-IF models to the institutional context and facilitates interpretation of those model results. A proposal for a procedure of how to perform institutional compatibility assessment in SEAMLESS-IF is presented in Figure 14.
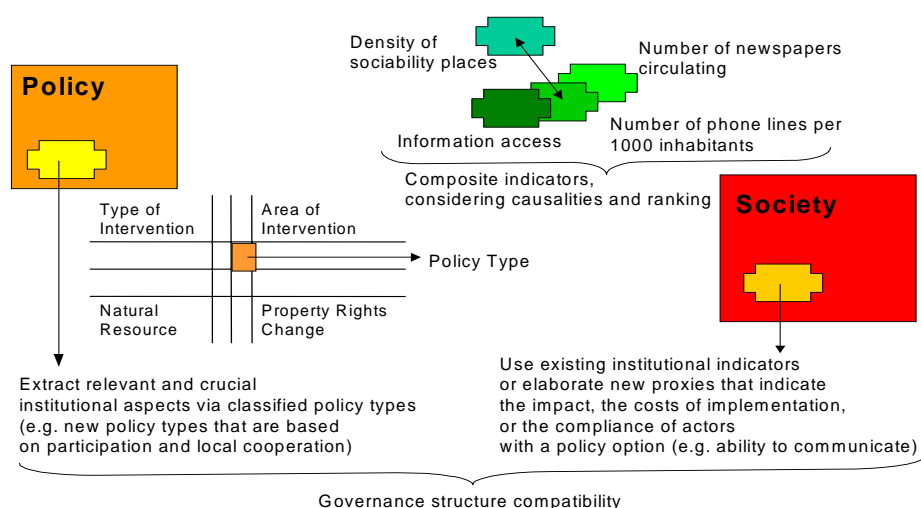
Figure 14. Procedure for institutional compatibility assessment.

3.3 Specification of models and procedures for up- and downscaling

3.3.1 Approaches for up-and downscaling

Level and scale

It is first required to clarify the meaning of up- (and down-) scaling as it will be used in SEAMLESS-IF. There is considerable confusion about terms such as scale and level. While scale refers to physical dimensions (most commonly space and time) of observed entities and phenomena (meaning that dimensions and units of measurement can be assigned), the term

level refers to *level* of organization in a hierarchically organised system (O'Neill and King, 1998). An example is the biological organisation with levels such as organ, organism, population, community, ecosystem, landscape etc. Changes in scale are usually continuous, e.g. changes in space or time. In contrast, changes in level are discrete, e.g. from ecosystem to landscape. However, moving up the organizational hierarchy from one level to the next usually implies that spatial and temporal scales also change. Scale has typically three characteristics, i.e. the extent or duration, the resolution and the grain (Blöschl and Sivapalan, 1995; O'Neill and King, 1998). The extent or duration defines the boundaries, the area or the magnitudes. Resolution refers to the finest detail that is distinguishable and the grain is the finest detail that is internally homogenous. A change in scale or *scaling* means a change in these characteristics.

Methods of scaling

Introductory information about scaling, aggregation and integration and associated methods can be obtained from elsewhere (Ewert, 2005). Briefly, several methods are available and are commonly used:
1. Extrapolation of input or output data;
2. Aggregation of input or output data;
3. Integration of models from different levels of organisation, i.e. nested simulation;
4. Generation of empirical response functions (or technical coefficients) to represent lower level relationships in higher level models;
5. Development of integrated (meta-) models.

While some methods (method 1 and 2) assume that processes and relationships do not change with scale or level of organisation other methods consider that dominant processes may change depending on level of organisation. However, knowledge about important processes or relationships is not always available which limits the applicability of methods 3 to 5.

A particular problem is to model simultaneously responses at different scales or levels of organisation (Ewert et al., 2006). Such multi-level modelling also implies that information or data from different disciplines are combined. However, direct linking of models which have been developed based on discipline-specific paradigms remains complicated as methods for calculation and specification including the definition of variables may differ. An associated problem is that the number of models and required tools for model linking will extend the complexity of the composite model significantly so that understanding and interpretation of results become difficult or even impossible.

3.3.2   Multi-level modelling in SEAMLESS-IF

General overview

A first set of models has been identified and integrated into Prototype 1 of SEAMLESS-IF (Fig. 15). The approach used is a combination of methods 1-4 mentioned above (section 3.3.1). Key models of the resulting composite model are APES, FSSIM, EXPAMOD and CAPRI. The models simulate different aspects of the system at different levels of organisation. In this report only a summary description of models and linkages is provided. Detailed information can be obtained from report PD1.3.2.
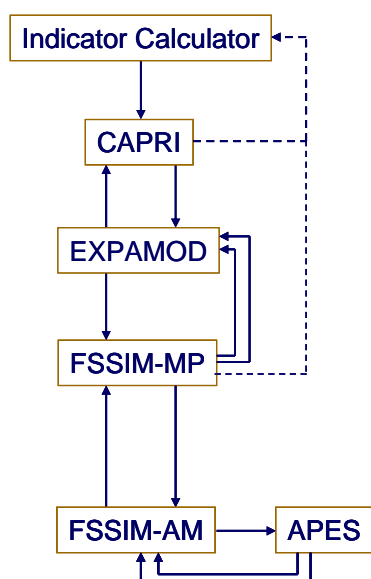
Figure 15. Simplified representation of relationships among models in Prototype I.

Selection of individual models

Briefly, **APES** (Agricultural Production and Externalities Simulator) is a modular simulation model targeted at estimating the biophysical behavior of agricultural production systems in response to weather and agro-technical management options. APES itself consists of several components representing crops, soil water, carbon and nitrogen, management activities and a component used to generate/estimate synthetic weather (Fig. 16). Advanced prototypes will also consider components for grassland, orchards, vineyards and agroforestry. APES has been designed to allow further extension of this list of components if required. The current APES structure and functionalities are described in the PD 3.2.19, whereas a more detailed description of model components is provided in the PD 3.2.18

The considered components represent deterministic models developed to perform point (field-level) simulations. They usually comprise a fair amount of process knowledge about biophysical relationships.

Agro-ecological simulations typically present numerous requirements which are common across systems (see PD1.3.2) Modcom is a realization of a framework that meets these requirements. The objective of the Modcom project is to develop a framework that facilitates the assembly of simulation models from previously and independently developed and tested component models. Modcom provides a set of interface specifications that describe components in a simulation and it provides implementations of the core simulation services. Main core services are integration capabilities using different methods, events handling, and data communication. Modcom allows running simulations, setting initial and final time, time step, type of integrator. Once components are registered with Modcom, simulation configurations (components and link among components, parameters values, type of outputs) can be controlled via an XML file. Modcom is a software library implemented for the .NET framework and written in C#.
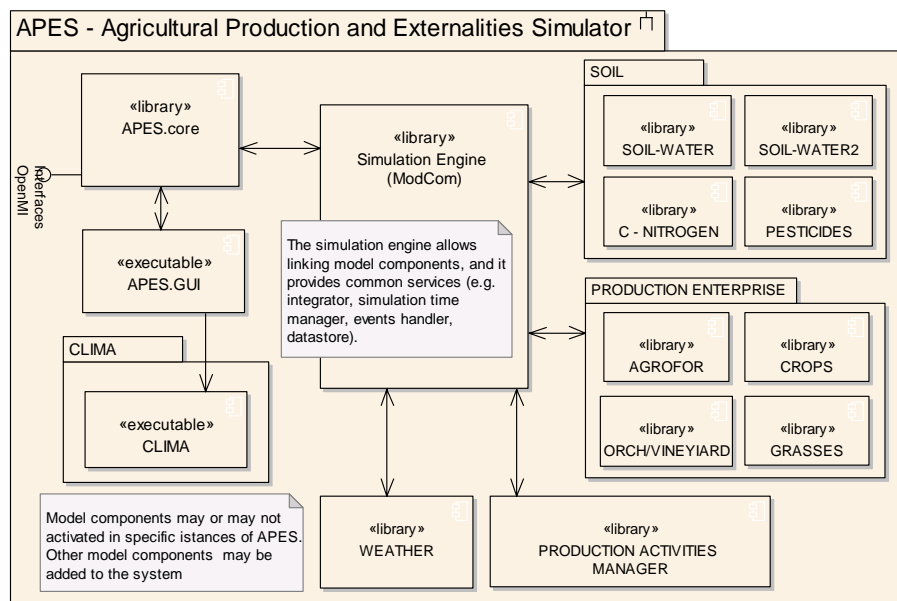
Figure 16. APES component diagram. APES is composed of three main groups of software units: the graphical user interface and the core services component to run Modcom; the simulation engine Modcom, and the model components. Model components can be grouped as soil components, production enterprise components, weather and agricultural management. See text for details.

FSSIM (Farm System SIMulator) is an integrated modelling system developed to assess the economic and ecological impacts of agricultural and environmental policies and technological innovations. Based on the link of biophysical and micro-economic models, FSSIM seeks to describe the technical aspects at the farm level given specific biophysical conditions, using different sets of constraints to derive a set of feasible technological alternatives for each farm type. The principal characteristic of this type of models is the application of engineering production and environmental functions derived from biophysical models (APES) and other sources (experiments, expert knowledge, surveys, etc.). Built on the philosophy of a *generic* model, FSSIM has to be valid for every type of farming system and every geographic location in the EU25 and in Least Developed Countries but also for multiple research issues applicable to the micro level. FSSIM consists of an agricultural management module (FSSIM-AM) and a mathematical programming model (FSSIM-MP). FSSIM-AM aims to identify current and alternative activities and to quantify their input output coefficients (both yields and environmental effects). Current activities refer to the base period used as benchmark for calibrating the models. The base period will be an average of several recent years before the scenario period. Alternative activities refer to future estimations due to changes in the policy environment and/or technological changes. FSSIM-AM includes: 1. a procedure to derive current activities using a survey and a complementary procedure using FADN data, 2. Production Enterprise Generator (PEG), 3. Production Technique Generator (PTG) and 4. Technical Coefficient Generator (TCG) (Fig. 17). Both current and alternative activities can be simulated through the use of the biophysical modelling system APES. FSSIM-MP seeks to represent the actual farmers' behaviour using the knowledge of technical and socio-economic constraints, the relation between production factors, the amount of output obtained and the costs of each production activity and future market prices. FSSIM-MP includes: 1. the objective function describing the farmers' behaviour as a maximization of expected income minus some measure of its variability (together "expected utility"), depending on states of nature and market; 2. the set of explicit constraints related to technical (land, water, equipment) and socio-economic resources (labour, finances, cash flow) as well as those related to policy and environmental measures

(price and market support, quota and set-aside obligations, cross-compliance policies, agri-environmental measures, etc).
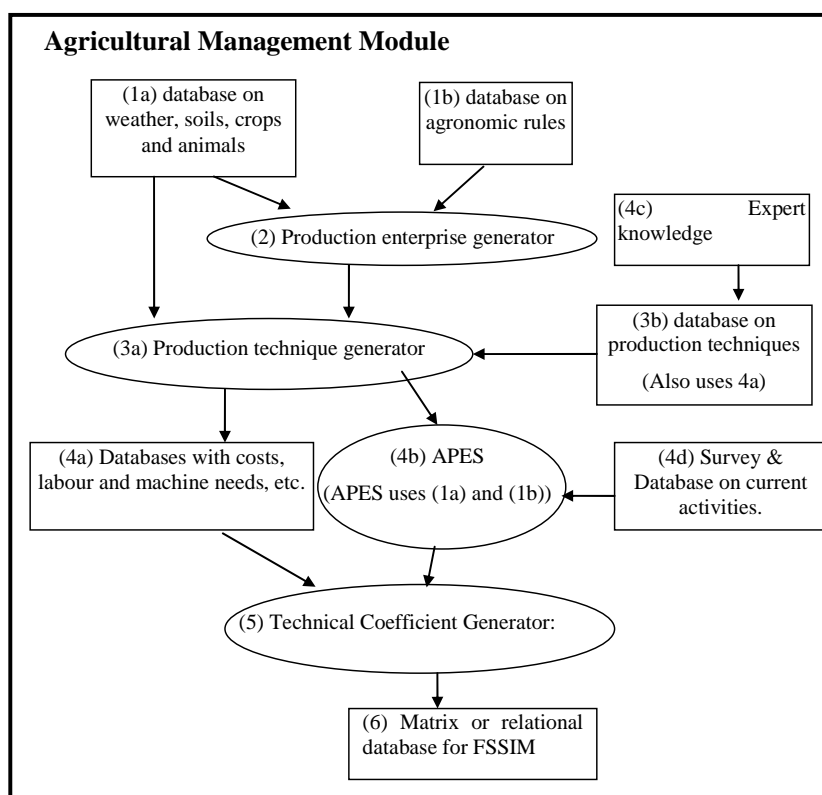

Figure 17: Agricultural Management Module and its components: algorithms, databases and connections

CAPRI is a modelling system developed to assess the effect of CAP policy instruments at EU, Member State and sub-national level. It consists of specific data bases, a methodology, its software implementation and the researchers involved in their development, maintenance and applications.

The data bases exploit wherever possible well-documented, official and harmonised data sources, especially data from EUROSTAT, FAOSTAT, OECD and extractions from the Farm Accounting Data Network (FADN). Specific modules ensure that the data used in CAPRI are mutually compatible and complete in time and space. They cover about 50 agricultural primary and processed products from farm type to global scale including input and output coefficients.

The economic model builds on a philosophy of model templates which are structurally identical so that instances for products and regions are generated by populating the template with specific parameter sets. This approach ensures comparability of results across products, activities and regions, allows for low cost system maintenance and enables its integration within a large modelling network such as SEAMLESS-IF. At the same time, the approach opens up the chance for complementary approaches at different levels, which may shed light on different aspects not covered by CAPRI or help to learn about the extent of aggregation errors in CAPRI.

The economic model is split into two major modules (Fig. 18). The supply module consists of independent aggregate non-linear programming models representing activities of farmers at regional or farm type level captured by the Economic Accounts for Agriculture (EAA). The programming models are a kind of hybrid approach, as they combine a Leontief-technology for variable costs covering a low and high yield variant for the different

production activities with a non-linear cost function which captures the effects of limited labour and capital mobility among activities on farmers' decisions. The non-linear cost function allows for perfect calibration of the models and a smooth simulation response rooted in observed behaviour. The models capture in high detail the CAP premium payments. Constraints include NPK balances and a module with feeding activities covering nutrient requirements of animals. Main constraints outside the feed block are available arable and grassland, set-aside obligations and milk quotas. The complex sugar quota regime is captured by a component maximising expected utility from stochastic revenues. Prices are exogenous in the supply module and provided by the market module. Grass, silage and manure are assumed to be non-tradable and receive internal prices based on their substitution value and opportunity costs.

The market module consists of two sub-modules. The sub-module for marketable agricultural outputs is a spatial, non-stochastic global multi-commodity model for about 40 primary and processed agricultural products, covering the whole world aggregated to 18 trading blocks. Bi-lateral trade flows and attached prices are modelled based on the Armington assumptions(Armington, 1969). The behavioural functions for supply, feed, processing and human consumption apply flexible functional forms where calibration algorithms ensure full compliance with micro-economic theory including curvature. The parameters are synthetic, i.e. to a large extent taken from the literature and other modelling systems. Policy instruments for other trading blocks than the EU are represented by price wedges based on Producer and Consumer Support Estimates (PSE/CSE) from the OECD (bi-lateral) tariffs, the Tariff Rate Quota (TRQ) mechanism and, for the EU, intervention stocks and subsidized exports. This sub-module delivers prices used in the supply module and allows for market analysis at global, EU and national scale, including a welfare analysis. A second sub-module ensures balancing of young animals including the required price adjustments within the EU.

As the supply models are solved independently at fixed prices, the link between the supply and market modules is based on an iterative procedure to finally obtain equilibrium prices. After each iteration, during which the supply module works with fixed prices, the constant terms of the behavioural functions for supply and feed demand are calibrated to the results of the regional aggregate programming models aggregated to Member State level. Solving the market modules then delivers new prices. A weighted average of the prices from past iterations then defines the prices used in the next iteration of the supply module. Equally, in between iterations, CAP premiums are re-calculated to ensure compliance with national ceilings.
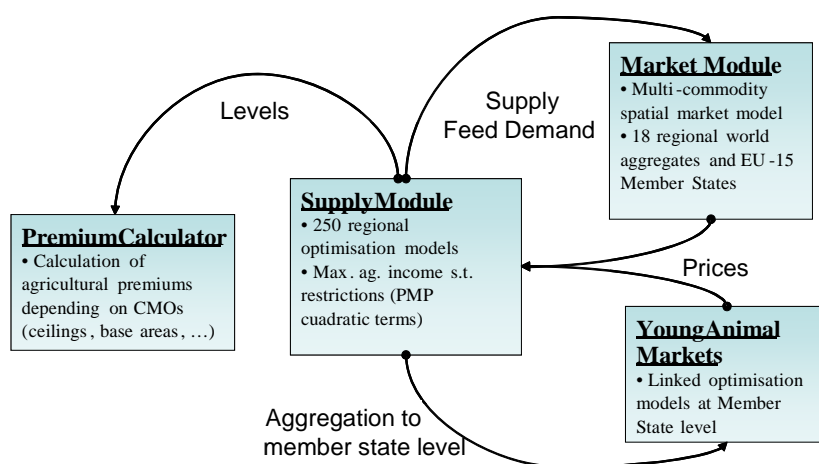

Figure 18: The CAPRI Modelling System

EXPAMOD (data expansion model) allows for interpolation and aggregation of results obtained by FSSIM (and territorial) models from a sample of regions to all EU regions. Results from a stratified sample of regions used for FSSIM simulations will be scaled to all other regions considered in the analysis by higher level models such as CAPRI. Thus, the sampled regions should represent the heterogeneity of biophysical and farm variables of the entire area studied (EU25).

The methodology to map the supply behaviour of farm models (FSSIM) to the market model (CAPRI) comprises the following sequence of steps (see also Fig. 19):

1) Simulation of FSSIM supply response to price variations through a set of price experiments to obtain price-quantity data set. The price variation in the experiments shall be realistic with respect to the expected price variations in the application of the system. Possibly a simplified pre-test application of the market model is necessary to obtain the range of price variation in future versions of the system.

2) Estimation of an econometric Meta-model explaining supply response based on prices and other explanatory variables, which determine FSSIM supply response, but are also available for the rest of the EU regions.

3) Use of this Meta-model to extrapolate supply response to farm types in other regions.

4) Aggregation of supply response to the level of CAPRI regions (NUTS2 administrative units) using representativity weights of FSSIM farm types. A mapping from FADN regions to CAPRI regions needs to be included as well as a mapping from FSSIM to CAPRI products at this point.

5) Calibration of regional supply modules in CAPRI to aggregated supply response. In prototype 1 calibration to elasticities (percentage changes) around base year values is realized. In subsequent versions of the system, a fit to price-quantity data is envisaged.

These steps apply to the extrapolation and aggregation of the supply response from FSSIM models to the market model. For subsequent prototypes, similar approaches are explored for the extrapolation of other indicators from the farm type models to other regions.
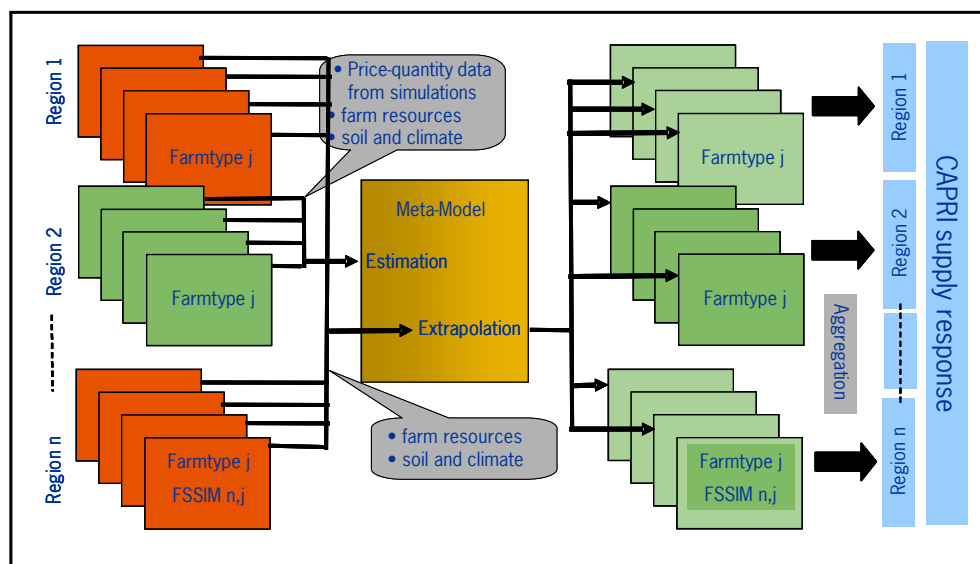

Figure 19: Extrapolation of data from FSSIM to CAPRI with EXPAMOD

3.3.3 Linkages among models

The individual models described above can be used independently if required input data, including parameters, are available. However, in SEAMLESS an attempt is made to combine quantitative information from different disciplines and levels of organisation through linking of models. These linkages pose some challenges as modelling approaches and underlying paradigms may differ considerably among models. For Prototype 1 much emphasis was on linking APES with FSSIM and FSSIM with CAPRI which are described in some more detail in the next sections

Linking APES and FSSIM

The combined FSSIM-APES model is primarily developed for application at the farm and regional level. Both models can be used independently from each other but in SEAMLESS-IF APES will be used as generator of specific relationships/coefficients to perform FSSIM simulations, i.e. the assessment of current activities in terms of their externalities and the assessment of alternative activities in terms of their yields and externalities.

Figure 20 shows the flow of information between FSSIM-AM, APES and FSSIM-MP. The flow starts with FSSIM-AM and its three components PEG, PTG and TCG. These three components are processing tools that prepare and adapt data inputs for APES and FSSIM-MP. The PEG is a processing tool that defines the set of alternative agricultural enterprises that will be proposed to the system. Combined with the PTG, that generates different types of management, it is possible to define the Agricultural Activities. One example can be crop production, a wheat-soybean rotation (production enterprise) which uses irrigation and fertilisation (management technique, specified with the PTG). These two generators work with rules that allow to define a large number of (primarily alternative) activities.

The number of these alternative activities could be very high if all possible combinations of crops and techniques in the rotations are allowed. However, not all combinations are feasible from a technical point of view. The role of the two generators, PEG and TCG, is to generate activities that are realistic using "filters". Still, the number of alternative activities will be high and further thinking is required of how to further reduce this number.

Clearly, the linkage between APES and FSSIM-AM is through the specification of production enterprise and production technique (management). Data flows in the sub-system APES-FSSIM are the following (Fig. 20):

- Arrows 1 - 2: The PEG and the TCG define activities to be simulated both in APES and in FSSIM. These activities are defined by their inputs and outputs. The input requirements for defining each agricultural activity need as well exogenous data (from databases, surveys, expert knowledge) or endogenous data (results of other tools or models).
- Arrow 3: Indicates the results obtained with APES in terms of yields and externalities.
- Arrow 4: Results obtained in APES as well as exogenous information from the databases (prices, costs, level of constraints) flow into the TCG.
- Arrow 5: The TCG, after receiving and processing this information prepares the input data in the format needed by FSSIM-MP and send these coefficients to FSSIM-MP.
- Arrow 6: Finally, the results of FSSIM-MP are obtained, as well for economic, social and environmental variables, for a certain type of policy scenario.
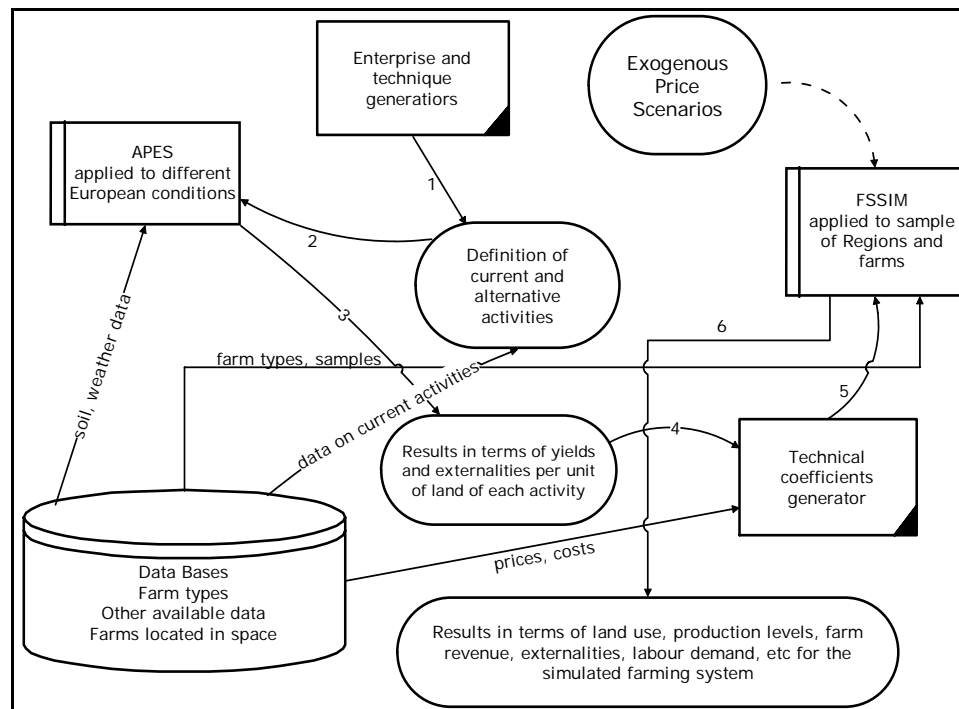
Figure 20: Data flow between APES and FSSIM

Types of assessments that can be performed with the combined APES-FSSIM models including potential outputs and data requirements are described in more detail in PD1.3.2.

Linking FSSIM and CAPRI

The integration of CAPRI into SEAMLESS-IF is essentially done using the supply responses obtained through the use of FSSIM for calibrating the supply behaviour of CAPRI (Fig. 21). This integration implies very important methodological changes concerning the CAPRI supply module. Once this supply response is introduced in CAPRI, it will be confronted -in the CAPRI market module- with the demand to generate endogenous prices. These endogenous prices are a feedback to FSSIM-MP models. One iteration is necessary to perform this procedure. The model EXPAMOD, has been developed to expand the supply results of FSSIM to the entire EU for input into CAPRI. For Prototype 1 no other information will be transferred between FSSIM and CAPRI.

Data flows for the FSSIM-CAPRI integration (Fig. 21) are the following:

- Arrows 1 - 2: The supply results obtained by the APES-FSSIM sub-system applied to the Sample of regions and farms are used as inputs for the EXPAMOD, that expands these results to the whole EU.
- Arrow 3: These results, expanded to the whole EU, are used by a model that calibrates CAPRI supply behaviour to FSSIM behaviour.
- Arrow 4: Supply results at the EU level, are used in CAPRI Market Model for obtaining new endogenous prices.
- Arrow 5: The endogenous prices will be used for new simulations in FSSIM.
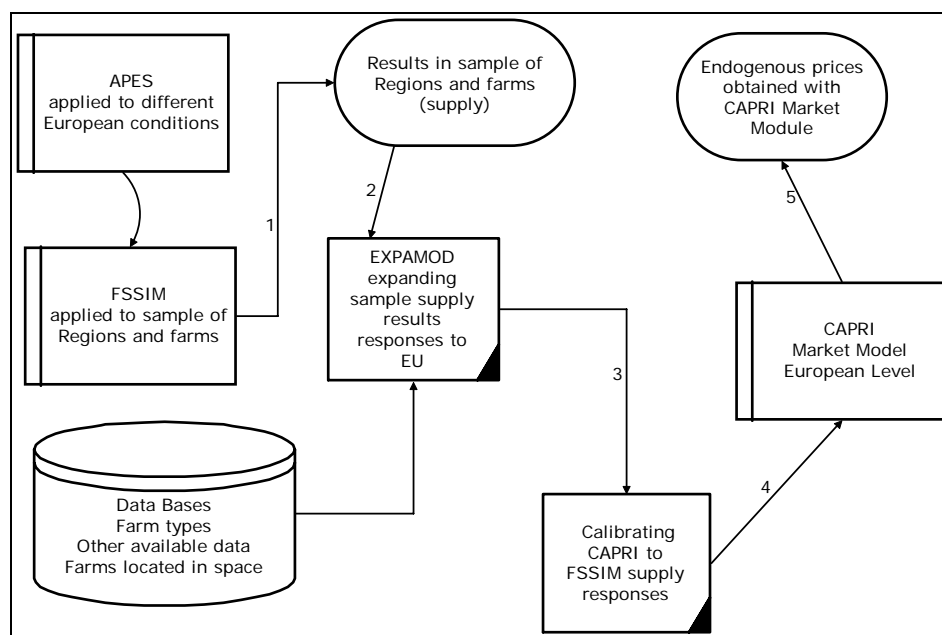
Figure 21: Data flow between FSSIM and CAPRI

3.3.4 Moving towards advanced Prototypes

The described links between APES-FSSIM-CAPRI have been introduced into Prototype 1. SEAMLESS-IF will gradually evolve and consider more models to eventually enable assessment of the environmental, economic and social impacts of policy changes on agricultural sustainability and sustainable development (Fig. 22). Models that will be included in Prototype 2 are Territorial, Rural Employment and Developing Countries models as well as the global market model GTAP. Specific emphasis will also be dedicated to the spatial allocation of farm types and the development of appropriate algorithms (see also section 3.4.3 Typologies). Integration of these models into SEAMLESS-IF is described in PD1.3.2
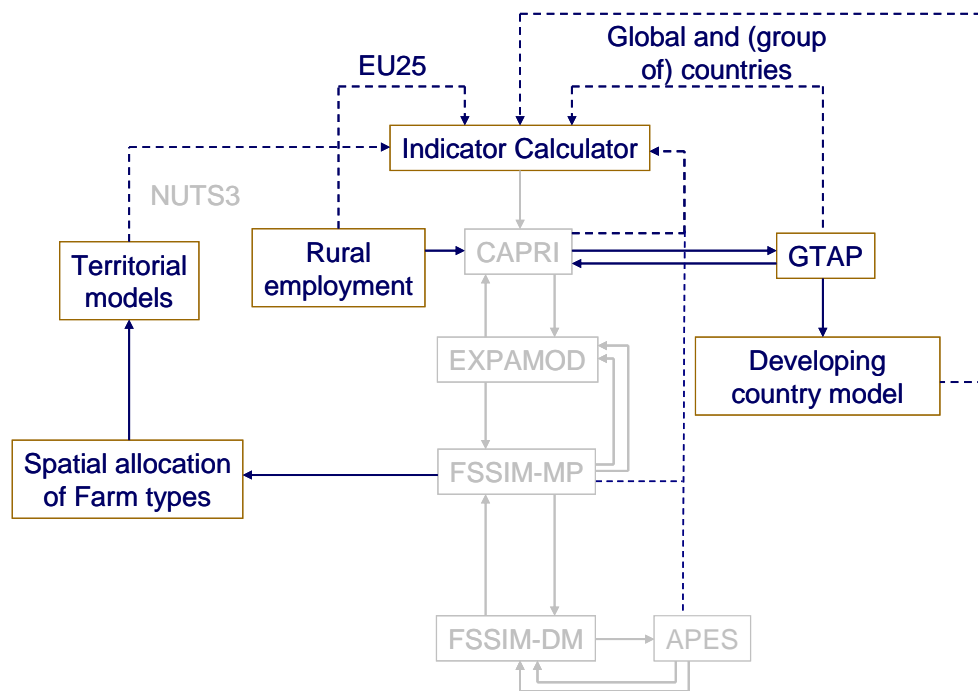
Figure 22: Data flow between models as planned for the final version of SEAMLESS-IF

3.4 Specification of data bases

3.4.1 Data needs and integration (the data framework)

The diversity of models used in SEAMLESS-IF, the inclusion of both quantitative and qualitative indicators and the hierarchical system approach result in a very complex demand for data. The data have to provide information on the biophysical, social, economic and institutional aspects of a system. Furthermore, the data need to be organised to support modelling and assessments at different spatial scales.

Providing necessary data for SEAMLESS-IF requires synthesis of existing datasets that have been generated for very different purposes and with very different methods. For example data on agriculture have been generated with the purpose of monitoring the agricultural sector mainly from an economic point of view. On the other hand data have been gathered on environmental issues mainly to provide information on the state of the environment and linked to assessment of environmental issues. Also, data refer to very different spatial (and temporal) scales. Typically, economic and social data are linked to administrative regions whereas environmental data are linked to landscape units or grids.

These data needs require a set of activities to arrive at a common data framework for SEAMLESS-IF (Fig. 23):
- Collection and standardization of model input data;
- Collection and integration of model output data;
- Design of specific routines, protocols and knowledge rules for facilitating access and inclusion of input and output data in SeamFrame, including the specifications for the development of metadata;
- Adaptation of input (and output) data for inclusion in the knowledge base. The adaptation of data involves the production of typologies but also procedures for aggregation and disaggregation of input and output data.

More detailed information on the spatial units and how data will be made spatially explicit is described in PD1.3.3.
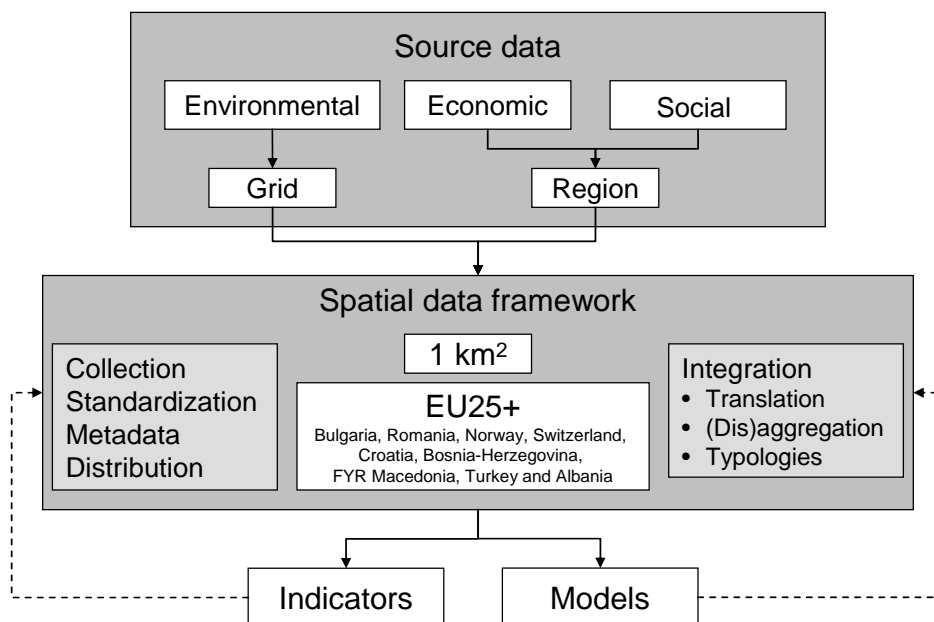
Figure 23: Data framework and integration in SEAMLESS-IF

For the knowledge base of SEAMLESS-IF the different data sets will be pre-processed and linked to a common spatial framework enabling linkages between the different data sources. The finest scale in the spatial framework will be 1km^2 grid cells. The spatial extend of the area for which consistent data will be provided is EU25. However, as several data sets provide information for a larger area these will also be considered. This applies to Bulgaria, Romania, Norway, Switzerland, Croatia, Bosnia-Herzegovina, FYR Macedonia, Turkey and Albania.

Development of a SEAMLESS-IF data base

The integrated use of the diversity of data types and the large amount of data needed and produced by SEAMLESS pose considerable requirements on the development of a data base. The conceptual structure of this data base is still under development but will need to satisfy demands from different user types (i.e. from coders to viewers) of SEAMLESS-IF.

3.4.2 Data selection

Based on a first consultation of data needs a first selection of data has been made (Table 1, see also PD1.3.3). Some of these data have already been made available for use in Prototype 1 (Table 2).

Table 1. First selection of databases for SEAMLESS-IF

Issue	Data sets
Farming data	FADN, COCO, CAPREG, Eurostat: Eurofarm, Eurostat: AGRICULTURE, FAOSTAT, AMAD
Environmental data	MARS soil and climate data, Digital elevation model Pan Europe, European rivers and catchments ERICA, Water catchments Pan-Europe, European Environmental classification, Corine Land Cover 2000.
Socio-economic data	Eurostat: Region, Eurostat: Eurofarm, Eurostat: Agriculture, Eurostat: Environmental statistics, Eurostat: Sirene
Global data	GTAP

Table 2. Databases and content provided for Prototype 1

Database	Content
SEAM:DB Biophys	Biophysical typology (no variables but information on spatial framework)
SEAM:DB Soil	Soil characteristics
SEAM:DB Weather	Weather data
SEAM:DB FADN	Farm types and characteristics (for 100 agricultural regions in EU15, based on 2003)
SEAM:DB Farmtypes	Farm typology, distribution of farm types in a biophysical region (SEAM:DB Biophys), (in Prototype 1 only data for Flevoland, Brandenburg, Andalucia and Midi-Pyrenees)
SEAM:DB Crops	Crop distribution, share of crop types in a biophysical region (SEAM:DB Biophys)
SEAM:DB AgriculturalManagement	Agricultural management, actual activities (in Prototype 1 only data for Flevoland, Brandenburg, Andalucia and Midi-Pyrenee)
SEAM:DB Region	Regional (administrative) typology
SEAM:DB GTAP	Global trade data

3.4.3   Typologies

Scaling of information is a key concern in SEAMLESS-IF. Detailed information about processes and relationships cannot be obtained consistently at fine scales across the European space as it is neither available nor could it be handled technically and understandably. Thus, simplifications are required to transfer information to larger scales. A common approach is to group information according to important characteristics. Grouping algorithms or typologies (i.e. a systematic classification of types that have characteristics or traits in common) need to be developed for farms (farm typology) and environmental conditions (hereafter referred to as agri-environmental typology). Several examples for farm and environmental typologies are available. Any typology largely depends on the aims for its application.

Farm typology

In SEAMLESS the main reason for developing a farm typology is to reduce the simulation effort for farms across Europe to a smaller representative number of farms. Also, individual

farm data can not be made available for reasons of confidentiality. A farm typology is specifically required to:

- Bridging economic, environmental and social assessments,
- Linking farming data to environmental data;
- Linking market level modelling to farm/field level modelling;
- Creating "Open source" data bases and
- Communicating results.

Previous work (Andersen et al., 2004; EEA, 2005) and results from a statistical analysis of farm data from the FADN database (Reidsma et al., In review) suggest that characteristics such as farm intensity, specialisation, economic size and utilised agricultural area may be good classifiers for a farm typology that can satisfy these requirements. In SEAMLESS-IF the following factors were used for the classification of farms into farm types:

- Size: Measured as the economic size of farms;
- Intensity: Measured as the total output in Euro per ha;
- Specialisation: Measured as the standard gross margins from different types of crops and livestock;
- Land use: Measured as the proportion of the agricultural area covered by specific types of crops.

To reduce the number of farm types the two last dimensions are combined in one dimension. This is possible because not all combinations of these two dimensions are relevant. In total of 189 farm types are identified. This is the aggregate of 3 size types, 3 intensity types and 21 combined specialisation/land use types. An example of a SEAMLESS farm type is then: Small scale, low intensity, arable/cereal.

The typology is described in more detail in report PD4.4.2 where also thresholds for the separation into individual groups are given.

Agri-environmental typology

For the SEAMLESS project an agri-environmental typology of the EU25 territory has been developed. It will be used as a basis for:

- upscaling of APES point information,
- determining FSSIM runs (farm type bio-physical endowment combinations),
- selection of sample regions,
- collection of data (on agricultural management) in sample regions,
- presentation of farm type information and modelling results.

The agri-environmental typology (AEnZ) is based on a combination of three classifications that are integrated into one land typology. The resulting classification is hierarchical:

- First level: 13 environmental zones (EnZ),
- Second level: 6 topsoil organic carbon classes (OCTOP), and
- Third level: 3 agri-mask classes (AGRI-MASK) regarding constraints to agriculture.

Thus, each agri-environmental land type is defined by its Environmental Zone, topsoil carbon class and agrimask class. The dataset is based on the 1 x 1 km^2 SEAMLESS-IF standard grid. The geographical coverage of the typology is EU25+ plus Russian enclave Kaliningrad and Serbia/Montenegro. The topsoil organic carbon dataset is adapted to the SEAMLESS spatial framework. This implies that the SEAMLESS-IF grid cells for which organic carbon data are missing are marked as 'no data'.

It can be used to characterise the NUTS2 regions and as a basis to select representative NUTS2 regions. The typology is described in detail in PD4.3.3. In SEAM:DB_Biophys the

resulting 2775 land types are presented by NUTS-region, environmental zone and soil type including also the area of the land types. The regions included in SEAM:DB_Biophys are a very important part of the spatial framework of SEAMLESS as it is to these regions the different level of modelling are connected: APES at the level of homogenous soil and climate conditions within administrative regions, FSSIM at the level of homogenous climate conditions within administrative regions and CAPRI at the level of the administrative NUTS2 regions. However, as regions from different typologies do not necessarily coincide in their spatial distribution and size (e.g. NUTS2, HMSU and AEnZ) procedure(s) will be developed to address such mis-matches.

Farm Type allocation

A particular challenge is the development of an algorithm for the spatial allocation of farm types. This is required as farm information need to be provided in their biophysical (e.g. soil, climate) context. A first proposal of an approach builds on new developed land use maps (DYNASPAT) with homogenous mapping units (HSMU). The workflow for the development of a spatially explicit farm typology is represented in Figure 24 and is further explained in the reports PD4.7.1. The aim is to provide information on farm types at the level of agri-environmental land types within NUTS2 regions.
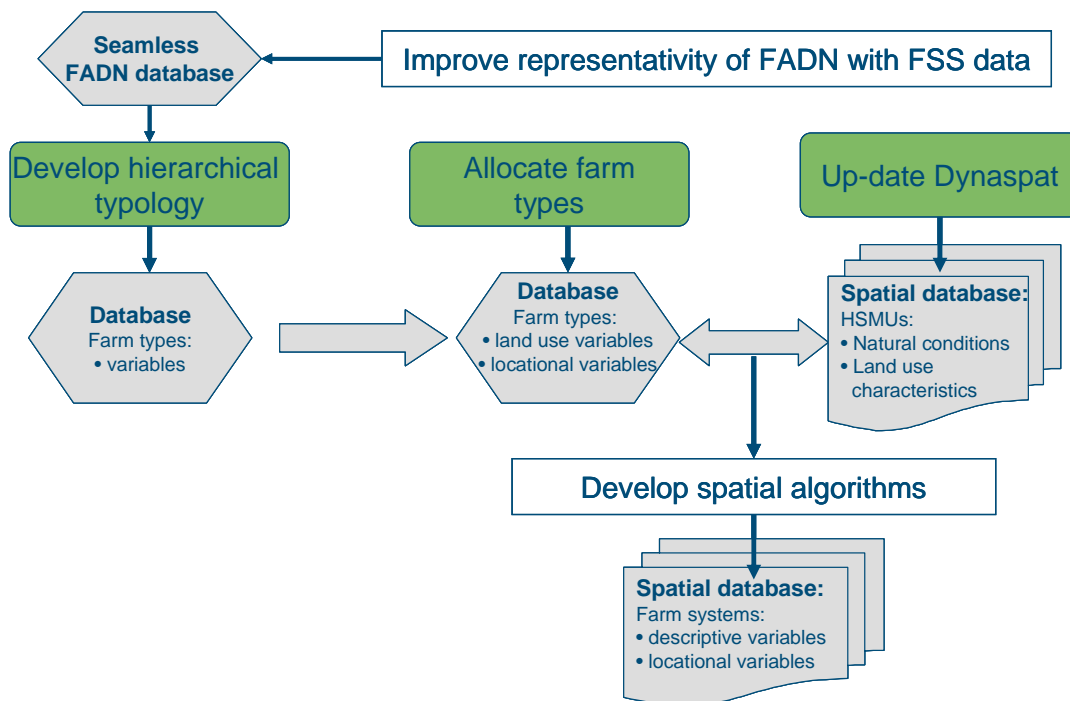

Figure 24. Workflow for development of spatially explicit farm typology.

3.4.4 Software issues

The databases for the first prototype has been developed using the open-source software PostgreSQL. Other software to be developed in the next steps are a generic data loader that can be used for all data in the bases and a viewing tool for viewing and browsing the data.

3.5   Application of SEAMLESS-IF

3.5.1   Need for an application procedure

SEAMLESS-IF is a framework meant to perform and support integrated assessment of policy impacts on agricultural sustainability and sustainable development. As the integrated assessment process is rather complex a general procedure has to be developed to guide the user through the individual steps of the assessment process such as conceptualization of the problem (i.e. identifying the question, the systems and their expected behaviour), definition of scenarios, the selection of tools and methods from SEAMLESS-IF, implementation and model building, simulation and analysis of results. This will also ensure consistency for assessment projects performed with SEAMLESS-IF. In a first effort a procedure was developed for the application of SEAMLESS-IF by prime users at the EC. The procedure has been described in detail in the report PD1.3.6.

3.5.2   Assumptions underlying a general application procedure

As one result of the work on PD1.3.6 it became evident that the development of a generic procedure suitable for different types of users is apparently not possible. In fact, even for the application of SEAMLESS-IF by prime users as set of assumptions had to be formulated to specify the applicability range of this procedure. Later efforts will have to try to develop a more generic concept or user-type specific procedure for the application of SEAMLESS-IF. For the first version the following assumptions were made:

Assumption 1: SEAMLESS-IF is built primarily for prime users as defined in PD7.2.1.1 (EU DG) but it can be used without any change in the tools and the software by other 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). Nevertheless the procedure described here is only for policy assessment by a prime user and specific procedures will have to be used for other types of applications and other types of users.

Assumption 2: unlike users, stakeholders are not using SEAMLESS-IF but their expert knowledge could be used in the procedure for definition of story lines and analysis of scenarios and indicators. In addition some stakeholders will also be involved in WP6 to evaluate some of the simulation models (FSSIM and APES) on the basis of expert knowledge, but this has nothing to do with the routine procedure of using SEAMLESS-IF which is described here.

Assumption 3: when using SEAMLESS-IF the objective of a prime user is to assess the impact of a specific policy. This policy can eventually be combined with technological or organizational changes at farm or regional levels. SEAMLESS-IF is not designed for policy definition/optimization but for policy assessment. It may be easily adapted to these objectives but this would imply the definition of specific procedure, which are not described here.

Assumption 4: for this prime user each policy analysis must have a EU coverage but they may be interested to zoom in on specific regions for a more detailed impact assessment. This will require more data, generally not available in databases with EU coverage, but may allow to use more detailed models and a larger set of indicators. This part of the project should be conducted with the same procedure but with additional partnerships with decision makers and stakeholders of this region and the corresponding country.

Assumption 5: the role of models and databases in SEAMLESS-IF is to provide information to an 'indicator calculator' in order to produce a set of indicators for policy assessment. The use of models for more detailed behavioral analysis of the agricultural systems in response to policy is useful but models has been primarily built for calculation of indicators.

Assumption 6: each problem/question asked by the user is translated into scenarios (policy versus baseline scenarios) which capture external constraints applied to the agricultural systems. Using SEAMLESS-IF for ex ante assessment requires simulation of the expected behaviour of the systems and not analysis of their actual behaviour by survey or measurements.

Assumption 7: because of the complexity of agricultural systems and of the policy imposed on them we assume that each problem/question will require its own description of the system, its own dashboard of indicators and therefore its own modelling project.

Assumption 8: due to the complexity of the system simulated and to the risk of error propagation (due to the multiscale approach, the model and/or data quality) the prime user will be able to factor an experiment but may not necessarily be able to set-up and perform the analysis and assessment. A project implemented in SEAMLESS-IF requires interdisciplinary scientific expertise on the agricultural systems and technical expertise on SEAMLESS-IF itself. Assessment of a policy will frequently require all types of users: i.e. linker, provider, runner, viewer and, in some cases, coder. Most of the users from an EC-DG will likely act as a viewer but under the contract with an organisation which may be (partly) internalized in a DG and has the expertise of coder, linker, provider and runner.

Assumption 9: one or several "negotiation" steps will be required to adjust the problem definition and the list of assessment indicators to the capability and precision of the models, to the quality and geographical coverage of the databases and to the time and resources allocated by the user to each project.

3.5.3   Phases of application procedure

For the application of SEAMLESS-IF separation is made between users and managers. User refers to the prime user (the EC) while manager is the organisation which can manage the whole process of using SEAMLESS-IF for each policy assessment problem proposed by users. Four main phases for the application of SEAMLESS-IF by prime users have been identified:
  1.   Defining the problem
  2.   Specifying the project
  3.   Running the project
  4.   Analysing the problem

These phases have been further refined and a number of steps have been identified. These steps are described in the report PD1.3.6. A summary is provided in Table 3.

Table 3. Phases and steps for the application of SEAMLESS-IF

Phase	Step

1. Defining the problem

    1.1 What is the problem and can it be addressed with SEAMLESS-IF?

2. Specifying the project

    2.1 Building a story line in interaction with users and stakeholders

    2.2 The manager prepares a preliminary project which can be run with SEAMLESS-IF to address the problem, using information from the story line and its knowledge on the capabilities of SEAMLESS-IF

    2.3 Presentation of the preliminary project to the user and "negotiation" to reach a compromise between user's requirements and SEAMLESS-IF capabilities

3. Running the project

    3.1 Check if a similar project has been run previously with SEAMLESS-IF

    3.2 Scenario description

    3.3 Indicator selection

    3.4 Specification of the models and databases, typologies and model links required to calculate these indicators

    3.5 Identification of the aspects of the system and sustainability issues which cannot be captured by the modeling approach

    3.6 Run the models and calculate the indicators

    3.7 Apply procedures defined in step 3.5 to address aspects which cannot be handled with the modelling approach

4. Analysing the problem

    4.1 The manager prepares the presentation formats (dashboards, maps, tables etc.) of indicators adapted to the scales and time step defined with the user in step 2.3

    4.2 Presentation and discussion with the users of the obtained results in order to reach a common conclusion on the assessment of the policy

    4.3 (optional) Identification of a new problem to be analysed on the basis of the results of step 4.2

3.6   Participatory methods

3.6.1   User and stakeholder involvement in SEAMLESS-IF

A significant part of the integrated assessment is the involvement of users and stakeholders. Specific interactive work methods are needed to foster user and stakeholder involvement for integrated assessment as in SEAMLESS-IF. Clarification is required of how to interact with users and stakeholders a) during the development of SEAMLESS-IF and b) for the application of SEAMLESS-IF after 2008, the end of the project. First, the development of SEAMLESS-IF should occur in interaction with the Prime users. For this, a User Forum has

been initiated. Second, after completion of SEAMLESS-IF, its application requires also interaction with the actual users (i.e. organizations that order assessments with SEAMLESS-IF). Participatory methods are expected to play an important role in involving the main users. A description of main users (DGs, EEA, JRC, OECD, COPA/COGECA and European Parliament) and their work and objectives has been provided in report PD7.2.1/1.2.2.

3.6.2 Participation during the development of SEAMLESS-IF

Participation by prime users

The development of SEAMLESS-IF is to be done in interaction with the Prime users at the EU level and the individual parts of SEAMLESS-IF are to be refined and tested at the regional level in interaction with regional authorities and interest organizations. During this development period (2005-2008) user involvement is needed for issues such as developing and improving the capabilities and functioning of SEAMLESS-IF, the user interface of SEAMLESS-IF, evaluation of the results from the regional test cases, etc.

A main part of this participation at the EU level occurs in the User Forum, as described in the following section. SEAMLESS scientists have in this way a chance to receive inputs and ideas from users on the different aspects of SEAMLESS-IF during its development. At the same time, prime users (e.g. DG officers) will gradually realize how SEAMLESS-IF may support their policy work.

User forum

A Prime User Forum core group representing three DGs (Agri, Environment and EcFin) has been identified and contacted. User Forums are held twice a year at the EC in Brussels. The participants of the last meeting in April 2006 were updated about the main progress in Demo Version/Prototype 1. The Impact Assessment practices in the DGs was another main point on the agenda. The interaction continued in groups around themes such as work flow, indicator selection and modelling chain aspects.

Main conclusions were: (a) there is a genuine interest in SEAMLESS-IP from the forum participants; (b) impact assessment is obviously on the agenda of the DGs; (c) it was stressed that the SEAMLESS-IF framework needs to be kept as open and flexible as possible to tackle all sort of future questions; (d) to increase trust in SEAMLESS-IF a discussion about SEAMLESS beyond 2008 has been requested by the forum participants.

In the next phase of the project the interaction with Prime users will be complemented with targeted focus group meetings around specific issues. It is to be expected that the themes of the user forums will change related to the future changes in the project work. The composition of the user forum might be changed accordingly. For example, participation of JRC and EEA has been suggested by the DGs, since these might be among the organizations that will carry out assessments eventually using SEAMLESS-IF.

Stakeholder participation

The validity of the policy scenarios will be of better quality if they are furnished with input from stakeholders. These inputs are needed on the following:
(a) Defining critical sustainability issues: a policy change (e.g. trade liberalization) results in changes in the farming structure and the farmer's behaviour in a region. The associated changes in the environmental and socio-economic conditions are assessed with SEAMLESS-IF. Representatives are asked to give suggestions on the likely economic, ecological and social effects in that test case. At the same time they also point to region-specific institutional constraints that might hinder the implementation (or, reduce the

effectiveness) of the policy. This information is used to evaluate the SEAMLESS-IF results, and may form the basis for the compilation of new scenarios;

(b) Selection of indicators: Indicators that represent the main changes in the three sustainability dimensions in the regional study, should be selected and targets for each indicator should be established in interaction with the regional representatives;

(c) Evaluation of the SEAMLESS-IF approach in general: the appropriateness and effectiveness of the SEAMLESS-IF application in the test cases and the plausibility of its results are to be evaluated by the representatives and scientists.

Protocols for user and stakeholder interaction

Participatory protocols are guidelines that serve as a step-by-step help to organize user participation. Several participatory protocols have been suggested to be used in the testing/improvement process of developing SEAMLESS-IF. Form of participation (and protocols) will differ depending on the purpose and motive for interaction with the individual participant. Detailed description of these protocols can be obtained from report PD1.3.7.

3.6.3   Participation when applying SEAMLESS-IF after 2008

Prime users

Application of SEAMLESS-IF requires interaction with the actual users which are the organizations that order assessments with SEAMLESS-IF. For example, an assessment is ordered by a unit within a DG: in fact, SEAMLESS-IF will be developed to be primarily used by the EC. Such an assessment can be an ex-ante analysis of forthcoming or expected policy changes, but could also be to facilitate implementation or to make an ex-post analysis of policy decisions.

When it is decided that such an assessment is to be carried out and that SEAMLESS-IF is the preferred tool, an institute or consultant (or manager see section 3.5.3) that has got the assessment contract, should produce first a translation of the policy questions. This translation consists of a specification of the SEAMLESS-IF application with respect to: (a) general problem definition; (b) scenarios; (c) indicators; (d) models and data bases required for the selected indicators; (e) time and spatial scale; etc.

Potentially, three types of contracts/uses of SEAMLESS-IF are possible. These are through (i) the EC, (ii) the Joint Research Centre and (iii) a SEAMLESS consortium which will need to be established. In any case, the involved institutes will need sufficient expertise and knowledge of the conceptual basis and the modelling/data/software structure of SEAMLESS-IF in order to apply it appropriately.

Participation of other users

We foresee that there can be uses of SEAMLESS-IF, in which it is of importance that stakeholders on several levels can participate in the problem definition and scenario building. This could be the case if SEAMLESS-IF is used for solving problems on a regional and local level, with which a democratic process is essential and representatives of the research community, policy makers, local stakeholders, interest groups and citizen need to act together. It is important that there is a consensus behind the scenarios and that the views of all parties are built in. For such assessment projects, democratic participatory methods are applied.

3.6.4   Specific participatory methods for SEAMLESS-IF

Five methodological key issues that should be taken into account in the design of participatory methods for problem definition, co-learning, synthesis and dissemination, have been discussed for the use of SEAMLESS-IF (see report D7.3.1). They are: definition of the subject matter for discussions, identification and mobilization of stakeholders, definition of issues of the discussions, selection and adaptation of a relevant participatory method, and definition of the roles of scientists. A large set of pre-defined participatory methods has been provided in this report, with a detailed description of the discussion issue (mapping diversity of view versus participants reaching consensus; advising policy makers versus empowerment of participants), and the subject matter for the discussion (field and scope definition, procedure and realization – how to use, resource considerations, best practices and potential pitfalls). Finally, the report provides guidance for defining what we are consulting about for the use of SEAMLESS-IF, who to consult, when to consult, how to carry out the consultation, how to analyze the results of consultation, and how to provide feedback, and how to evaluate the exercise. Examples of guidance for the construction and application of participatory protocols for the pre and post modeling stages in SEAMLESS-IF are provided.

The methods proposed to be used in SEAMLESS (D 7.3.1) can be illustrated in a graph according to the structure defined by van Asslet et al. (2001), (Fig. 25). In this structure the participatory methods are placed according to the aim and usage of the method along two axes: the motivation axis which runs from democratization to advising and the targeted output axis, between mapping out diversity and reaching consensus.
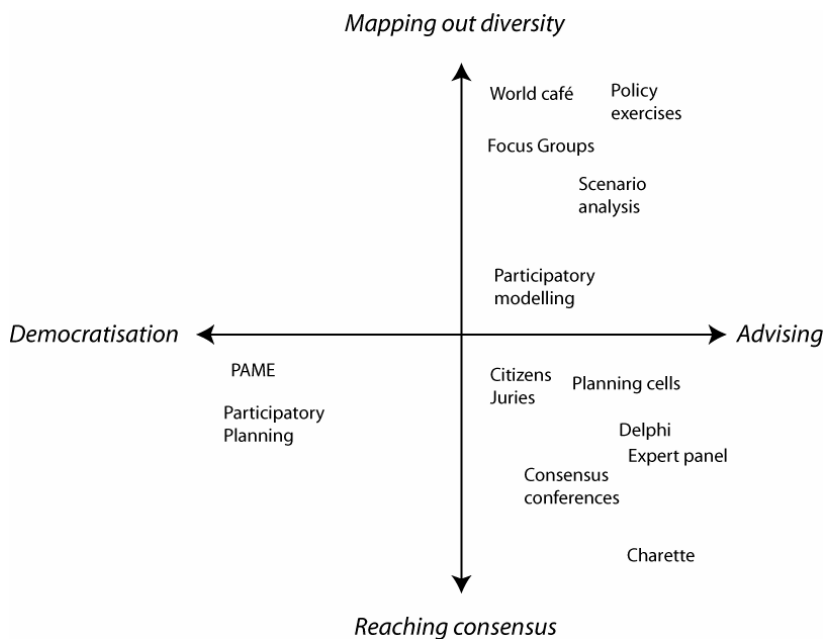

Figure 25. An overview of participatory methods displaying their suitability for different goals

Methods placed high on the vertical axis, *mapping out diversity*, are methods that seek to reveal a spectrum of options and information. They enable a group to disclose information or test alternative strategies in a permissive environment. Methods placed low on the vertical axis can be used for *reaching consensus* and are thus methods that seek to define one single option or decision. They enable a group to reach an informed decision on an issue. When using SEAMLESS-IF, *mapping out diversity* is likely to be preferred for selection of

indicators to reflect the diversity of sustainability perception, while *reaching consensus* will be more adapted for scenario definition to ensure consistency in scenario assumption.

On the horizontal axis methods placed to the left enable *democratisation* and enable the participants to use their own knowledge to tackle policy issues that directly concern them.

Methods to the right on the horizontal axis are for *advising* and can be used to reveal stakeholders' knowledge, values and ideas that are relevant for decision-making.

Participatory methods can be used for a wide range of reasons and for a wide scope of participants, from democratizing science and empowering the citizens to informing decision makers and using their knowledge to e.g. define plausible scenarios.

When the ordering units of a SEAMLESS-IF assisted study are organisations within the Commission as envisaged, the participatory methods that should be a part of SEAMLESS-IF will be found along the *advising axis* (Figure 25), horizontally between *mapping out diversity* and *reaching consensus*. Out of these methods, the ones which are relevant for decision-makers or experts are mainly: Participatory Modelling, Scenario analysis, Focus Groups, Delphi Methods, Expert Panels as they are *"Consultation"* methods. They are designed for obtaining information from stakeholders and to provide this information to the policy-makers (advising issue). They are useful for providing decision-makers with public values, assumptions, and preferences and substantive information to improve decisions. But they do not imply anything about what will be done with the advice received.

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