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

Indicator framework, indicators, and up-scaling methods implemented in the final version of SEAMLESS-IF

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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).

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Objective within the project

The objectives of this deliverable are fourfold. The first objective is to present the developed Indicator Framework, the so called Goal Oriented Framework aiming to assist users of the SEAMLESS-Integrated Framework in the selection of indicators. This objective also includes describing how the indicator framework has been implemented in the Graphical User Interface (GUI) of the SEAMLESS-IF. The second objective is to present the developed indicator package included in SEAMLESS-IF and the rationale behind it. This section also include the description of the methodology for implementation of indicators by the use of ontologies. The third objective is to give an overview the up-scaling procedures developed to ensure the availability of indicators at all scales. The fourth objective is to make a brief outline of the major scientific achievements in relation to indicator development and outlining some future developments that could be envisaged concerning the indicator framework, its implementation and the included indicators.

General Information

Task(s) and Activity code(s):	2.1
Input from (Task and Activity codes):	2.2, 2.7
Output to (Task and Activity codes):	All tasks
Related milestones:	

Executive summary

First, this deliverable presents the developed Indicator Framework, the Goal Oriented Framework, aiming to assist users of the SEAMLESS-IF in the selection of indicators. Thereafter it describes the indicator package included in SEAMLESS-IF and the rationale behind it, including which indicators that are implemented and the methodology for implementation using ontology. It thereafter describes how the indicator framework has been implemented in the Graphical User Interface (GUI) of the SEAMLESS-IF. The deliverable also describes the up-scaling procedures developed to ensure the availability of indicators at all scales. Finally some future possible developments of the indicator framework and its indicators are described.

The Goal Oriented Framework (GOF) for indicators has been developed for the computerized tool SEAMLESS-IF developed to make integrated assessment of the effects of new policies or technologies on agricultural systems. The ambition has therefore been to create an indicator framework where the environmental, economic and social dimensions of sustainable development (SD) can be related to each other in a consistent way to capture and visualize tradeoffs among indicators between and within the three SD dimensions. The GOF has several advantages. Its major rewards are its relative simplicity and the possibility to link indicators to policy goals of each dimension of sustainability and thereby facilitate the comparison of the impacts of the new policy on the different dimensions. Another important feature of the GOF is its multi-scale perspective, which will enable the comparison of effects of a new policy between scales. Yet, as typical for all indicator frameworks, also the GOF is not free from biases either determined by the models used or the stakeholders' selection of indicators. However, due to the way the GOF and its indicators are technically implemented

in the SEAMLESS-IF, it can easily be extended and include new indicators to increase and update its policy relevance.

The indicator framework has been integrated into the graphical user interface of the software tool SEAMLESS-IF. The development took place through a series of prototypes where the theoretical knowledge was by means of designs communicated to the software developers and consequently improved through the provided feedback. The direct work with indicators in the Integrated Framework (IF) takes place in the pre-modelling and post-modelling stages. In the pre-modelling stage users are flexible in either selecting indicators per theme of the GOF or by filtering the available indicators through the models which calculate them. In the post-modelling stage the indicators selected for a particular impact assessment can be displayed in flexible ways: various types of visualizations such as table or graphs and through selection of single or multiple indicators.

The SEAMLESS indicator package consists of more than 200 different indicators covering all three dimensions of sustainable development and all geographical levels targeted by the SEAMLESS project. Across scales, farm, Nuts 2, member state, a total of 80 environmental, 140 economic and only 11 social indicators are or are about to be integrated into SEAMLESS-IF Some of these indicators are extracted from OECD, EU indicators list or developed in other European projects (e.g. IRENA, SENSOR and the EU Agri-environmental indicator list currently under development).

The information needed to implement the indicators in the SEAMLESS-IF has been structured by the development of an ontology. The development of the ontology has facilitated the communication and transfer of information between the different scientific groups that have cooperated in the development of the available set of indicators. The ontology was developed through an interactive process and has resulted in the stepwise methodology for how new indicators can be created and implemented in the SEAMLESS-IF described in this deliverable.

In spite of its complex and important model chain included in the SEAMLESS-IF covering a large range of spatial scales, the integrated framework does not provide all the model outputs needed to calculate all indicators at the full range of spatial scales. Consequently, in SEAMLESS-IF the calculation of an indicator at a spatial scale higher than the scale of the model (which provides outputs used to calculate it) requires an up-scaling procedure (e.g., an indicator at regional scale calculated with for example FSSIM outputs). The up-scaling of model outputs is an important application in the area of indicator calculation that needs more attention in the further development of the SEAMLESS-IF.

As to the development of the implemented indicator framework GOF and the implemented indicators there are several issues that need more attention. Except for more testing of the issues that have been developed so far through more sets of test cases the implementation of reference levels, further development and testing of up-scaling methodologies aggregation of indicators are areas that need more attention in the future. More over there are several issues that could be developed in relation to the GUI such as an indicator editor that would allow for the creation of new indicators and the improvement of the use of the Goal Oriented Framework in the Post- Modelling face of the SEAMLESS-IF GUI.

Scientific and societal relevance

The development of an indicator framework and a set of indicators implemented in an integrated assessment framework, developed to be used in *ex ante* assessment is an achievement that is relevant form both a scientific and societal perspective. From a scientific perspective the implementation of such a framework will facilitate the evaluation and comparison *of* this framework with other existing indicator frameworks. It will also serve as a bases to assess trade- offs (adverse effects) between the three dimensions of SD induced by the implementation of a new policy. From a policy perspective the indicator framework will assist in providing a balanced set of indicators between the dimensions. It will also serve as a way to compare the effect between.

Another achievement is the development of the comprehensive set of indicators covering the environmental, economic and social dimensions of SD. Moreover it is relevant that the set of indicators have multi-scale capabilities ranging from field and farm to the EU25, which enables to assess the impacts of a policy between scales which is crucial form a societal perspective and in the long run may assist to improve the included models.

Moreover the methodology developed for how the model output can be transformed into policy relevant indicators is a scientific achievement that creates a basis for trans-disciplinary communication which has become increasingly important when aiming at integrated assessment of the impacts of a new policy.

1 Introduction

In the Sustainable Development Strategy of the European Union (EU) it is proposed that all EU policies should actively support Sustainable Development (SD) (EC, 2001). For that purpose it is stressed that a so called Impact Assessment has to be carried out to assess the impacts of each new policy. To support this work, the European Commission (EC) has introduced a guideline for Impact Assessment (EC, 2002).

There is general consensus about the importance of the simultaneous consideration of the social, economic and environmental dimensions of SD when assessing the possible future effect of a policy (Roberts and Colwell, 2001; Burchell and Lightfoot, 2004). However, due to the ambiguity of the SD concept and the complex interaction between natural and human systems, a direct measurement of sustainability is not possible, instead "alternative measurements" using sets of indicators covering the three dimensions of SD are required (Mitchell *et al*., 1995, Bockstaller *et al*., 2008). Assessing progress towards SD of a policy based on indicators covering the three dimensions will facilitate the identification of areas in one or several of the dimensions that need attention. This will in turn help to create a sound basis for the formulation of a more sustainable new policy (Bell and Morse, 1999).

In the context of SD, indicators are generally not only a tool for measurement. They can also serve as a guide for how to comprehend the concept of SD. As a consequence the assessment of the impact of a new policy using a set of indicators could even be considered a prerequisite for the implementation of SD (Ledoux *et al*., 2005). However, selecting indicators using unstructured lists of indicators may result in an un-reflected and even biased assessment of SD. It is therefore important that indicators are carefully selected. It is also important that indicators are developed with care and awareness, this includes for example, to clearly declare how indicators are assessed and which trade-offs (antagonisms or synergies) that exist between them. This is also the reason why so called indicator frameworks have been developed to create a systematic basis for SD assessment and to assist policy-makers avoiding biased indicator selection (Gudmundsson, 2003).

The SEAMLESS (**S**ystem for **E**nvironmental and **A**gricultural **M**odelling; **L**inking **E**uropean **S**cience and **S**ociety) project developed a computerised and integrated impact assessment tool providing information to be used in ex-ante impact assessment procedures of new agricultural and environmental policies using indicators covering the scales from field-farm to region, the EU, as well as some global interactions (Van Ittersum *et al*., 2008). To create a systematic basis for SD assessment another important task in the SEAMLESS project has therefore been to develop an indicator framework that could assist the users of the SEAMLESS Integrated Framework (SEAMLESS-IF) to select indicators that could be used in the assessment of a new policy. A so called goal-oriented framework (GOF) has, for this purpose, been developed within the project.

1.1 Objectives

The objectives of this Deliverable are fourfold. The first objective is to present the developed Indicator Framework, the Goal Oriented Framework aiming to assist users of the SEAMLESS-IF in the selection of indicators. This objective also includes describing how the indicator framework has been implemented in the Graphical User Interface of the SEAMLESS-IF. The second objective is to present indicator package included in SEAMLESS-IF and the rationale behind it, including which indicators that are implemented and the methodology for implementation. The third objective is to describe the up-scaling procedures developed to ensure the availability of indicators at all scales. The fourth objective is to make a brief outline of future developments that should be envisaged concerning the indicator framework its implementation and its indicators.

1.2 Outline

After a presentation of the context of the Deliverable, its general aim and outline in Chapter 1, chapter 2 present the goals oriented indicator framework (GOF) developed within the project. The chapter describes its purpose, the methodology of development, its domain of application and finally what is new, its weak points and potential improvements are discussed.

Chapter 3 presents the package of indicators included in the framework, it also describe its purpose, the methodology of development including the use of an ontology, the domain of application and finally discusses what is new, weak points, gaps, etc., potential of improvement.

Chapter 4 illustrates how the indicator framework is integrated into the graphical user interface of the SEAMLESS-IF. The direct work with indicators in the Integrated Framework (IF) takes place in the pre-modelling and post-modelling stages. In the pre-modelling stage users are flexible in either selecting indicators per theme of the GOF or by filtering the available indicators through the models which calculate them. In the post-modelling stage the indicators selected for a particular impact assessment can be displayed in flexible ways: various types of visualizations such as table or graphs and through selection of single or multiple indicators.

Chapter 5 summarise the different up-scaling approaches developed in the project.

Chapter 6 concludes the major scientific achievements made and challenges remaining both in relation to; the implemented indicator framework, the implemented indicators and the developed methodology for indicator implementation including the use of ontologies to facilitate the implementation and the up-scaling of indicators. More over the chapter summarise some of the major points in relation to the future developments and use of reference levels, aggregation of indicators and indicators of multi functionalities.

2 The SEAMLESS indicator framework (GOF)

2.1 Purpose

The general aim of the GOF is to assist the user when selecting indicators by helping them to: i) facilitate the identification of the objectives of a specific policy and link the policy goals with the process and the means to achieve these goals, ii) identify which indicators are relevant to assess the given problem and iii) ensure that the selection of indicators is balanced in relation to the three dimensions of SD, i.e. no critical issues regarding sustainability are overseen or underrepresented, which implies that trade-offs (antagonisms or synergies) between goals are identified and iv) support achieving the main goal of the end-user, i.e. to create a more sustainable new policy (Alkan Olsson *et al*., 2007, Alkan Olsson, J, *et al*., 2009, in press).

2.2 Development and domain of application

As a first step in the development of the Goal Oriented Framework (GOF) a literature review was performed, assessing the usability of different types of indicator frameworks (Geniaux *et al*., 2005). With respect to our aims to develop an indicator framework for integrated ex-ante assessment, this review identified shortcomings of the commonly used pressure-state-response framework PSR (OECD, 1993) the driving-force-state-response framework DSR (OECD, 1999) and its extension developed by the Environmental European Agency, the Driver-Pressure-State-Impact-Response framework (DPSIR) (Smeets and Weterings, 1999). The logic of the DPSIR framework is based on a causal chain considering driving forces (D) which cause pressure (P) exerted on the state (S) of the environment. As a result impact on human health and ecosystems (I) will occur which induce societal response to mitigate those impacts (R). This indicator framework and its precursors were initially developed for environmental issues, without a global or systemic vision of SD and no consideration of how economic, social and environmental factors influence each other. As argued by (Geniaux *et al*., 2005) the effects of changes in the agricultural systems caused by a policy do not follow a simple cause-effect chain, especially when considering the effects on the social domain. It was concluded that applying the DPSIR framework could result in a biased vision of SD over-representing the environmental dimension and providing a linear vision of the cause-effect relationships between the environmental, economic and social dimensions of SD (Geniaux *et al*., 2005). Recent enhancements of the DPSIR introduced the concept of causal network to address the complexity of causal-effect chains (Niemeijer and de Groot, 2008). However, the framework is still most frequently applied to specific environmental issue like nitrogen and water quality. Alternatively, Geniaux *et al*. (2005) argued that the development of an indicator framework should be based on systemic properties (Bossel, 1999; Bossel, 2000). A systemic property oriented framework appeared interesting from a theoretical point of view, as it aims to avoid long list of indicators. Bossel's generic structure is based on seven systemic properties, i.e. existence, effectiveness, freedom of action, security, adaptability, coexistence, psychological needs. However, in this approach expert knowledge plays an important role in selecting indicators linked to these properties, as the definition of these properties is rather theoretical and difficult to understand for users not familiar with this concept. As a consequence, due to lack of methodology and explicit guidelines to link specific indicators to systemic properties, this framework was not found suitable for application in SEAMLESS-IF (Alkan Olsson *et al*., 2007).

The development of the GOF has largely been driven by the ideas and views of potential users of the SEAMLESS-IF at the EU and regional level. These views have been collected at meetings arranged by the SEAMLESS project discussing the list of indicators, the structure of the GOF and possible ways to select indicators. This stakeholder information has been combined with scientific information obtained from literature reviews on indicator frameworks (Geniaux *et al*., 2005) and indicator lists (Garrod *et al*., 2006).

The GOF is developed as integrated part of the SEAMLESS-IF and its integration and use is supported by an ontology (Rizzoli *et al*., 2008; Janssen *et al*., 2009 (in press)) like other components of the system (e.g. models and database). An ontology is a finite list of concepts and relationships between these concepts. The ontology ensures that the links between indicators and model outputs and the categories developed for the GOF are conceptually sound. This structured conceptualisation, i.e. the ontology, also ensures easy alterations or extensions to the GOF. Moreover, the ontology facilitates the addition of new indicators in the SEAMLESS-IF.

2.3 Design

The GOF attempts to go further than just dividing indicators into simple lists of indicators for each dimension of SD. It considers categories such as scales, domain, dimension, generic themes, themes and sub-themes to facilitate the selection of indicators to reflect the users' perception of sustainability of the problem to be assessed. In the following section the different categories of the GOF is explained and illustrated.

2.3.1 Scales

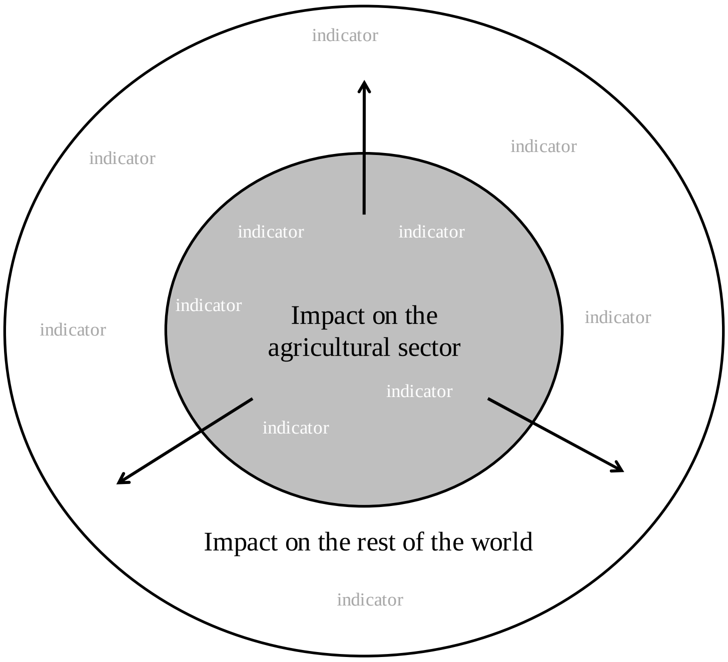
SEAMLESS-IF has been developed to allow impact assessment at different scales. Accordingly, the GOF required some way of structuring indicators with respect to the scale of assessment. The scales considered are the typical scales of SEAMLESS-IF (i.e. field/farm, region and market), which can be extended depending on demand (Ewert *et al*., this issue). Thus, the first step of the selection of indicators is to define the spatial scale at which the assessment will be carried out. As the analysis can refer to different scales, indicators can also be selected for several scales. In this way, changes at higher scale (e.g. market) can be considered while focusing on impacts at lower scales (e.g. farm type and region).

2.3.2 Domains

The SEAMLESS project aims to assess the impacts of new agricultural and environmental policies on the agricultural sector itself but it also aims to assess the effects of the agricultural sector on the society as a whole. Accordingly, in the GOF indicators are divided into two so-called domains. The first domain hosts indicators that assess impacts on the agricultural sector itself. The second domain hosts indicators that assess impacts of the agricultural sector on the society as a whole i.e., external effects of agriculture on other domains of society such as, employment in rural areas, environmental pollution and landscape amenities (Figure 2.1). This distinction has already been made by (Smith and McDonald, 1998) who for the environmental dimension separated between "on-site biophysical indicators" (impact of agriculture on itself) and "off-site biophysical indicators" (the impact of agriculture on the outside environment).

It is important to discriminate between these two domains as it is important to understand whether new policies which support the agricultural sector may be harmful to sectors outside agriculture. Considering indicators in both domains will also allow the assessment of trade-offs between these domains.

Figure 2.1: The two domains of the goal-oriented indicator framework (GOF)



2.3.3 Dimensions of Sustainable Development

Each of the two domains is further divided into the three dimensions of SD, the environmental, the economic, and the social dimension (Figure 2.1). As mentioned earlier the key objective of any sustainability assessment is to consider the effects of a new policy on all three of these dimensions. Only then it will be possible to define policies that are more sustainable.

2.3.4 Generic themes and themes

As evident from its name, the goal oriented indicator framework (GOF) is based on a goal-oriented logic for the structuring of indicators. This approach rests on an interpretation of sustainability described by (Hansen, 1996). He defines "sustainability as an ability to satisfy goals" as different to the definition of sustainability in terms of systemic properties (Bossel, 1999). To create a policy that is more sustainable, based on the interpretation of sustainability to satisfy goals, the new policy consequently has to satisfy these goals of the policy better than previous policies. In the sustainable development discourse goals are multi-dimensional and can be related to the social, economic and environmental dimensions of SD. Accordingly, the GOF follows the idea that the development of a policy is motivated by several *ultimate goals* in each of the three dimensions of SD. To achieve these ultimate goals both *processes for achievement* as well as *means* are needed. Each dimension is hence divided into three so called generic themes, *ultimate goals*, *processes for achievement* and *means.* This should facilitate the comparison of impacts on each of the dimensions of SD and increase the link to the goals of the policies and consequently to policy development in general (Table 2.1). There is no strict relation between the three generic themes as there is in the causal chain between Driver-Pressure-State-Impact and Response indicators in the DPSIR framework. The link between the GOF themes is the logic of the action chain (ultimate goal- process for achievement- means), which however may be different from dimension to dimension and question to question. This action chain is “socially constructed” and can of course be altered and amended, based on changes in the policy goals or the preferences of users. However, the literature review and the interactions with stakeholders have supported the use of the three generic categories that we proposed and included in the framework.

Interactions with potential future users of SEAMLESS-IF further showed that the names of the generic themes were too abstract. As a consequence the generic themes were given specific names to explain more specifically what the generic categories contain, based on more commonly used language (Table 2.1).

The wording “*ultimate*” does not imply that this generic theme is more important than the other two but it refers to its position in the causal chain of action. The following examples can illustrate this point. In the environmental dimension, the *ultimate goal* has been defined as to protect the health of the citizens (Table 2.1), e.g. in relation to water quality such goal includes for example to keep the nitrate levels in groundwater under the limits identified as dangerous for human health. To achieve this goal the nitrogen balance in the soil has to be maintained (*processes for achievement*). The proper use of mineral fertilizer may be a solution in terms of facilitating the control of nitrogen in the soil and avoid leaching (*means*). Different types of economic support may exist to help the farmer keeping the nitrogen levels below the limits identified as dangerous and such an indicator would also be categorised as a means but related to the economic domain.

For the economic dimension, the *ultimate goal* of a policy has been defined as to protect the economic viability of the agricultural sector. This implies that the revenues should cover the costs of operating the economic system in question (Table 2.1). Depending on the question at stake which may differ with respect to the scale, an indicator representing this theme could either be a measurement of the economic viability of farms or a measurement of the economic viability of a region derived from the aggregated economic performance of all farms in the region. To achieve the ultimate goal of economic viability the economic performance of the sector or farm has to be maintained (*processes for achievement*). Economic performance can either be measured at a micro or a macro level. From a microeconomic perspective, economic performance can be defined as the ability to attain profitability through sales volume and return on investments. Macroeconomic performance, relates more to inflation, unemployment, international competitiveness, and trade. Finally, the means of achievement *(means)* would be capital which can be defined in terms of wealth, income, material possessions and financial assets.

For the social dimension, the *ultimate goal* of a policy has been defined as the best possible quality of life of the individuals (Table 2.1). The *process for achievement* is the improvement in human and social capital, i.e., higher education, higher social participation and stronger relations and networks, which only can be developed through measures and developments that concern the totality of a population. Finally, *the means* in the social domain refer to the human capital itself considered as the number of people living in a country or region.

Table 2.1: Generic and specific themes of the Goal Oriented indicator Framework (GOF)

Dimensions/Themes	**Environmental**	**Economic**	**Social**
Ultimate goal	Protection of human health and welfare, living beings and habitats	Viability	Quality of life individual, in society
Process for achievement	Maintenance of environmental balances or functions	Performance	Social and human capital
Means	Environmental compartments and non-renewable resources	Financial and productive capital	Population

2.3.5 Sub-themes

For each dimension of SD the three generic themes are specified and divided into so called sub-themes (Table 2.2). We have aimed to develop a broad list of sub-themes covering a vast array of currently relevant policy problems in the agricultural sector ensuring that specific issues or problems linked to each dimension of SD are taken into consideration. The list of sub-themes is not fixed; new themes could be added if a user would like so. Moreover, all sub-themes may not be relevant for all assessments depending on the policy measure or the context (e.g. erosion may not be relevant in regions with little relief).

The broad range of sub-themes across the three dimensions is straightforward for decision makers at EU level. When developing the sub-theme we tried to achieve convergence with the sub-domains of the IRENA initiative (EEA, 2005) as these sub-themes and their indicators are well known by policymakers at all scales. However, not all sub-domains of IRENA are covered by sub-themes of the GOF. This is not surprising because models covering all sub-themes have not been included in the SEAMLESS-IF. The list of sub-themes was also compared to list of impacts in the EU guidelines for Impact Assessment as it was used in a recently developed assessment framework in the SENSOR project (Kristensen *et al*., 2005). The sub-themes not covered by the GOF are animal and plant health, food and feed safety and issues covering not only agriculture but other sectors like waste management, the role of agriculture in prevention of risk (e.g. fire), and to non-agricultural activities, urban land use and transport.

The development of the list of sub-themes has intentionally been made to cover sub-themes where it is known that indicators in this sub-theme display trade-offs, potential antagonisms or synergies, with indicators in other sub-themes.

For each sub-theme information on possible trade-offs with other sub-themes is therefore given in the indicator fact sheet provided through SEAMLESS-IF (see the next section). So far, only trade-offs between indicators within each dimension have been explored. The information on trade-offs is theoretical and based on literature studies and has been included to serve as a warning that excluding a specific sub-theme within a theme should be done with caution and should be the result of interactions between policy developers and if needed experts. The rationale behind displaying trade-offs is that from the perspective of one sector or stakeholder group, trade-offs between the dimensions of SD or sub-themes may not be detected as the sector's interest may create a biased view. A few examples should illustrate this point.

If the aim is to assess a new policy aiming to reduce nitrogen leaching, stakeholders from the water management sector may wish to focus on reduction of nitrate leaching and may propose a management option to reduce nitrogen surplus in the soil. In areas with high density of livestock, one option to reduce the input of organic nitrogen through manure or slurry is to compost them in order to reduce the nitrogen content and to stabilize the organic matter (Gutser *et al*., 2005). But composting may lead to an increased volatilisation of ammonia, responsible for soil acidification and natural ecosystem eutrophication, and, emissions of greenhouse gases to the air (Peigné and Girardin, 2004). From a SD perspective it would consequently be unwise not to select indicators from the sub-theme emissions of greenhouse gases and soil acidification. To increase the quality of groundwater and surface water (NO_3) a policy may try to encourage the introduction of a catch crop which may also be used for their weed-suppressing or allelopathic effect (Williams *et al*., 1998). However, a catch crop may increase the weed pressure through its volunteers in subsequent crop and consequently force the farmer to increase the use of pesticides (Bockstaller *et al*., 2006).

From the economic dimension trade-offs can be identified between the sub-theme distribution of capital and the sub-theme efficiency. Distribution of capital can be viewed in terms of the equity objective which could be antagonistic to the efficiency sub-theme, because efficiency (i.e. pareto-efficiency) does not imply equity. Another example of trade-off between sub-themes in the economic dimension is that high rates of growth can be antagonistic to stability, especially where such growth is preceded by recession.

Table 2.2: List of themes and sub-themes of the GOF

Environmental dimension		**Economic dimension**		**Social dimension**	
Theme	Sub-theme	Theme	Sub-theme	Theme	Sub-theme
Protection of human health and welfare, living beings and habitats	Air: pollution (pesticides)	**Viability**	Stability/dynamics	**Quality of Life**	Service infrastructure
	Water: Quality (NO3, pesticide)		Government Intervention		Poverty/Wealth
	Landscape: Heterogeneity		Distribution of capital		Accessibility connected to service infrastructure
	Biodiversity: Species and habitat diversity		Public preferences for environmental capital		Landscape Amenities
Maintenance of environmental balances or functions	Climate: Greenhouse gases emissions (CO_2, CH4, N_2O)	**Performance**	Productivity	**Social Human Capital**	Education
	Soil acidification: NH_3 emissions		Profitability		Employment
	Soil fertility (Organic matter, N, P, K)		Efficiency		Social capital as a consequence of education
	Surface water eutrophication: P runoff		Growth		Innovation
	Ecological regulation of agrosystems		Trade		
			Government intervention		
			Non-farm activities		
Environmental compartments and non-renewable resources	Soil erosion	**Financial and productive capital**	Capital stocks	**Population**	Age
	Soil compaction		Capital services		Gender
	Soil pollution (heavy metals, salinisation, etc.)		Savings and investment		Migration
	Water quantity (depletion of resource)		Borrowing and debt		Share of agricultural population in total population
	Minerals (P, K)		Capacity		Population growth
	Energy (oil)				
	Use of renewable resources (e.g. biofuel)				

2.3.6 Indicators

Each sub-theme can host one or several indicators that in different ways explain the sub-theme. The GOF allows the implementation of new indicators through the flexibility in the number of sub-themes as well as indicators.

Each indicator is produced from the output of the models included in the SEAMLESS-IF, at a specific scale and with a specific unit. These models are designed to assess future impacts of a change in the studied agricultural system. In this way indicators included in the SEAMLESS-IF are explicitly made to be used for ex-ante assessment. (For more information on the SEAMLESS-IF indicator package see chapter 3.)

2.4 Advantages and limitations

2.4.1 Advantages

One of the major advantages of the GOF is that it uses the same generic categorisation of each of the three dimensions of SD. Other indicator frameworks such as the DPSIR have different categories for each dimension. This approach is unique according to recent reviews of assessment methods (Rosnoblet *et al.*, 2006). Using the same categorisation between dimensions has several advantages. First, it facilitates the communication between policy experts working in the different dimensions of SD. Second, and closely linked to the above mentioned advantage, it increases the comprehension and awareness of the inherent logic of achieving the goals of a policy (goals –processes of achievement- means) within each dimension, which in turn may assist policy makers to compare as well as explain how a policy may have beneficial effects on one dimension and detrimental on another. Third, through its focus on policy goals the GOF puts the policy process in the centre which may facilitate the communication between researchers and policy makers in executing an impact assessment. Fourth, based on this categorisation, the framework can also be used to steer the policy development towards achieving one or several specific goals or to assess how changes in the different dimensions affect specific goals. Fifth, the generic structure across dimensions helps to select balanced sets of indicators between the three SD dimensions. There is of course no direct link between the generic categorisation of each dimension and a balanced selection of indicators between dimensions. However, the underlying idea is, as discussed earlier, that if the dimensions are clearly visible and appear on “equal terms” it is more difficult to bias selections of indicators. Moreover, in the guidelines for how to use the framework it is clearly recommended to select indicators from each dimension. The DPSIR framework for example does not provide guidance to select a balanced set of indicators, also not between different themes within one dimension of SD.

Another important advantage with the GOF is that it is created to serve as a basis for ex ante assessments. The DPSIR is for example built for ex post assessment and is therefore, less straightforward to use in an ex-ante assessment as state and impact indicators are generally based on measured data (Bockstaller *et al.*, 2008). Response indicators are not needed in the *ex ante* assessments made by the SEAMLESS-IF, since potential responses to a given problem are explored on the basis of (policy) scenarios.

The GOF includes information on trade-offs (so far only between sub-themes within one dimension) to help the users to select indicators from sub-themes showing trade-offs between each other. This is particularly important as both research and administration are highly specialised and often only work with issues covering one dimension at the time and they are therefore prone to outweigh the sub-theme they defend or work within. As discussed earlier, the DPSIR framework has a less straightforward approach towards how to handle trade-offs. In addition the categorisation in DPSIR, of a given indicator often raises discussion between experts, particularly at lower level, than country level (Girardin *et al*., 2005).

Moreover, the GOF can help its user to discriminate between indicators that assess how the agricultural sector influences itself and how the agricultural sector influences other parts of the society. This is essential when developing sector policies that should not be harmful to other sectors.

The chosen categorisation comparing *ultimate goals, means for achievements and processes* does not create an absolute system for comparison but opens up for an assessment of the dynamics of the effects of a new policy on each dimension. These categories are generic but the sub-themes and the included indicators can be altered and changed over time. The reason for including this flexibility is that the policy agenda is continuously evolving, new policy issues appear and the goals that are deemed important to achieve may alter. The practical implementation of this flexibility is facilitated in SEAMLESS-IF through its component-based design and the use of the ontology supporting linkages between different framework components and their output and the indicators. In this way it is relatively easy to include a new indicator if the model producing it is included.

Finally as implemented in SEAMLESS-IF and the Graphical User Interface the GOF becomes simple, straight forward and easy to understand and use for non-experts.

2.4.2 Limitations

Due to the flexibility provided for selecting indicators, the framework is rather open to the users' interpretation of SD and how it is best measured. The user's vision of SD is expressed by the selected indicators and their associated goals. Thus, the vision of SD can change depending on the user's perspective on which indicators are found important. In this way our proposed approach is consistent with the approach developed by several scholars (Hansen, 1996; Robinson, 2004), stating that there is no single operational definition of SD but many. However, this open ended approach can make it difficult to compare the result from different impacts. The approach taken with the GOF is that the final selection of indicators determines the weight given to the different goals in the different dimensions and is largely influenced by its users' perception of SD.

The GOF can also easily lead to very long lists of indicators as the framework implicitly aims at completeness without a clear definition of essential and universal properties of SD as discussed above. The list of indicators included in the SEAMLESS-IF is already rather long. Two approaches can be proposed to address this limitation. If users want a "complete picture of the impacts of a new policy" with the strong and weak points of the system, he/she may want to use a long list. The other approach could be to identify the "weakest point" for each theme, based on already collected information of behaviour of the system under a specific policy regime, i.e. which sub-theme or indicator is most probably adversely affected by the new suggested policy. For example, in a region with intensive livestock, issues linked to nutrient management may be the "weakest point". However the definition of which is the "weakest point" may be difficult and even controversial. The approach suggesting to focus on the "weakest point" has been proposed in the systemic approach developed by (Bossel, 1999; Bossel, 2000) and is also forwarded in the EU Impact Assessment guidelines (EC, 2002) where it is argued that impacts of the policy options and major future problems should be identified.

Another solution to avoid long lists of indicators would be to create a framework with fixed sub-themes. Such a framework would limit the possibility of the stakeholders to influence the selection of indicators and it would be an approach that is less open to incorporate policy changes. However, even when using such a less flexible framework it would be difficult to produce a fixed list of indicators, as the indicators selected will depend on the issue and scope of the assessment. The approach using fixed lists could even be in contradiction with the EU guidelines for Impact Assessment where it is stated that "*Gathering options and information from interested parties is an essential part of the policy-development process, enhancing transparency and ensuring that proposed policies are practically workable and legitimate form the point of view of stakeholders*" (EC, 2002, p 9). The rationale behind this statement is that fixed lists, at least so far, mainly have been an expert product which of course limits the possibility of other "interested parties" to influence which issues are important. From this perspective, the flexibility given by the GOF can rather be seen as something positive giving stakeholders the chance to influence the policy development process. The choices in the GOF are however not totally free. As mentioned earlier, the list of indicators included in SEAMLESS-IF can be seen as a pre-selection of indicators. Moreover, it is suggested to select at least one indicator per generic theme and dimension. It is also strongly suggested that a certain sub-theme is only removed when it is clearly not needed and if no trade-offs have been detected with that sub-theme (e.g. water depletion issue can be taken away in an assessment in a region where water is not a limited resource for agriculture).

As mentioned earlier, the indicators included in the SEAMLESS-IF are explicitly made to be used for ex-ante assessment. This makes it to a certain extent difficult to compare these indicators to indicators included in other packages. For example the Indicators included in the (IRENA) (EEA 2005) and the United Nations (UN) (United Nations Commission on Sustainable Development 2006) indicator packages are made to be used in so called ex-post assessment, where indicators are based on empirical data and used to evaluate the effect of an already implemented policy. However, when developing the SEAMLESS indicator packages the project has strived towards developing indicators that are as similar as other well known indicator initiatives as possible.

3 SEAMLESS indicator package and how it can improve the IA of future agricultural and environmental policies

The aim of this chapter is to present the package of sustainability indicators developed for the final version of SEAMLESS-IF following the proposals for prototype 2 and prototype 3 D2.1.2 (Alkan Olsson, *et al.*, 2007).\

3.1 Methodology

3.1.1 Organisation of the indicator package within an indicator framework

The indicator list was developed within the SEAMLESS project which is structured and presented through an indicator framework, i.e. the goal-oriented indicator framework (GOF). This framework covers a broad range of themes linked to the three main dimensions (environmental, economic, social) of sustainability, and generic themes across the three dimensions (see Chapter 2) (Alkan Olsson *et al.*, 2007, 2009).

Three objectives underpinned the development of the SEAMLESS-IF indicator list across scales:

- to provide policy-makers and stakeholders with indicators which they are used to use and/or which they would like to use;
- to ensure scientific soundness of SEAMLESS-IF indicators, i.e. their relevance to represent impacts at stake;
- to cover the various themes and sub-themes of each dimension of the GOF, i.e. to create a balanced set of indicator able to assess the sustainability of a new policy (see Table 3.1).

The SEAMLESS- IF is developed to support ex- ante assessment of new policies. To assess future impacts, scenarios created in models are essential. Within SEAMLESS-IF indicators are therefore primarily model (or model chain) output. The development of the indicators included in the SEAMLESS-IF has therefore been constrained by the nature of the available model outputs.

Outputs from three main models integrated in SEAMLESS-IF are used for the indicator calculation: the agricultural sector model SEAMCAP; the farming system model FSSIM; and the cropping system model APES. Despite the range of scales covered by the models included in SEAMLESS-IF some key indicators can currently not be calculated directly from model outputs. To address this problem generic up-scaling procedures have been developed and associated to each indicator that needs to be up-scaled (See further Chapter 5).

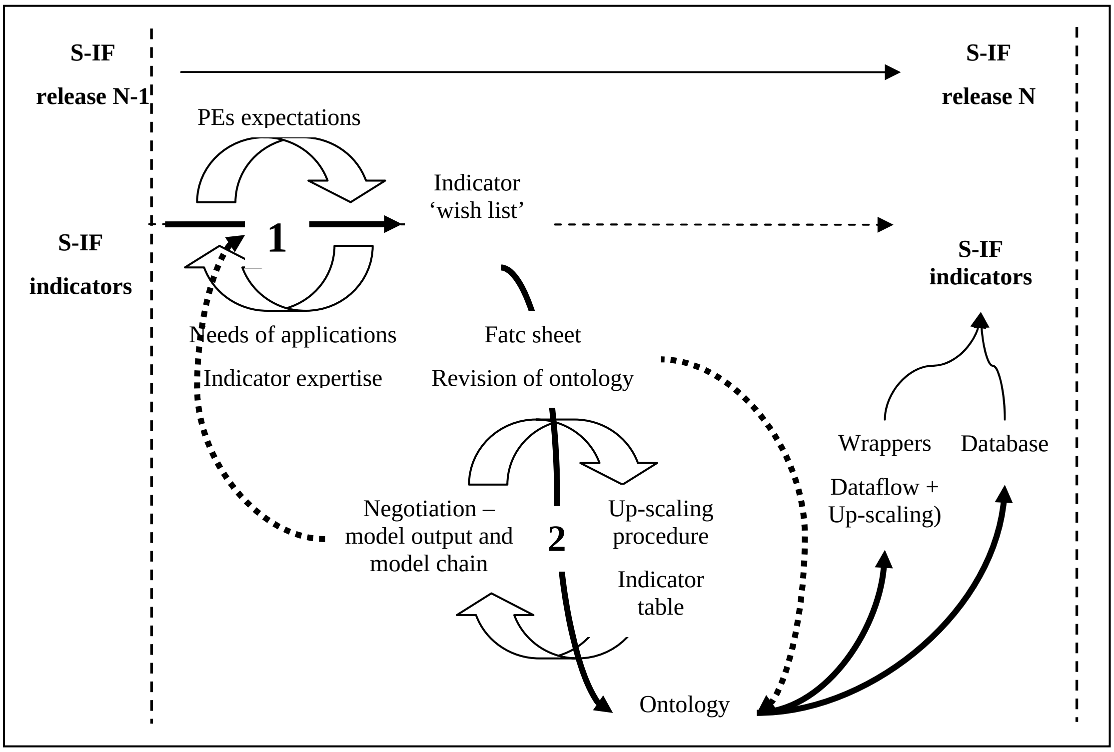
3.1.2 Implementation in SEAMLESS-IF

The development and implementation of indicators within the SEAMLESS-IF has necessitated an iterative and structured interaction between indicator, database, model and software developers as well as tool evaluators.

The indicator development and implementation work started from a literature study on sustainability indicators and frameworks, evolved through the development of the indicator ontology, the identification of indicators that can be computed by the models included in SEAMLESS-IF and the needed scaling procedures and other post-modelling processing.

The indicator implementation in SEAMLESS-IF can be described as a procedure comprising 16 successive steps. Although at first glance this procedure can be considered as linear, several steps are cyclical. The developed steps were also accompanied by a cyclical evaluation-improvement procedure involving different type of developers. The procedure is depicted in Figure 3.1.

Figure 3.1: Schematic representation of the procedure for indicator implementation SEAMLESS-IF from one release to another with its two interactive dialogues indicated with 1 and 2



The procedure is characterised by two interactive dialogues, where participants to the development discus and negotiate the relevant indicators and. At the beginning of the procedure, a first interactive dialogue aims at defining what the expected list of SEAMLESS indicators is. This first dialogue consist of indicator experts (WP2 in the SEAMLESS project)), integrative modellers (WP6 in the project) and potential Policy Experts who are interacting with project-participants of WP7. In the further development of the tool after the ending of the project it is anticipated that policy experts requiring a specific assessment in this dialogue may identify new indicators that are relevant for that specific assessment but not yet implemented in the SEAMLESS-IF. The second interactive dialogue concerns different groups of experts of the developed integrated framework i.e.; model experts (WP3 in the project) and integrated framework experts (WP5 in the project) to assess the possibilities of implementation of a given indicator. This dialogue is needed to influence the further model development and consequently the output of SEAMLESS models. As such, the second interactive dialogue includes (i) the negotiations with the model developers regarding the transformation of model output; (ii) the revision of the ontology; (iii) the description of the indicator in the indicator fact sheet and in the indicator table; and (iv) the development of up-scaling procedures.

In the two interactive dialogues, the indicator experts of WP2 played a key role as a facilitator, coordinator and conductor of this procedure. The procedure can be formalized in 16 steps (box 1). Steps 1 and 2 address the indicator selection, steps 3 to 7 concern the preliminary work with the modellers before implementation of an indicator into SEAMLESS-

IF, whereas steps 8 to 16 focus on the implementation. When a new indicator is introduced, most those of 16 steps need to be repeated. Step 8 and 10 for example do not need to be repeated in every case.

Box 1: Implementation procedure of indicators into SEAMLESS-IF

Step 1: *Identification of potential indicators* to implement. This step concerns indicator experts (WP2), policy expert (PEs) and WP7 or integrative modellers (IMs) (WP6).

The selection of indicators implemented in the SEAMLESS-IF was guided by three requirements, namely:

- requirements expressed by policy experts, who are the users of the tool (in the project collected by WP7 and WP6).
- requirements expressed and discovered within the development of applications in WP6 (IMs).
- scientific requirements for reliable indicators as determined by the indicator expert (WP2).

Step 2: *Creation of an 'indicator wish list'* consists of the required indicators by the indicator expert, Policy Expert PE and model developer. This list also includes those indicators that needs to be p-scaled, but for which there are no up-scaling methods available yet. At this stage, the feasibility of the implementation regarding availability of model outputs, data, etc; is not considered.

Step 3 *Assessment of the feasibility* of implementation by indicators experts (WP2) with model developers (WP3). The check whether required model outputs are available and whether they need to be transformed or up-scaled. The outcome from this step is twofold:

- If model output needs to be up-scaled, then the work will continue in steps 4, 5 and 6.
- If model output needs a transformation, then the work will go through step 7.

Step 4: *Description of the up-scaling procedure* according to the structure developed in the indicator fact-sheet. Step 5: *Sending of the developed algorithms* to WP5. Step 6: *Implementation of the up-scaling algorithms* in SEAMLESS-IF in Java code (a wrapper) by WP5.	Step 7: *Negotiation* of a potential model transformation with model developers (WP3) This requires that: i) An indicator expert from WP2 suggests which model output is desired and gives a suggestion of how the current model output can be transformed. ii) Model expert (WP3) implement the model transformation and confirms it to the indicator expert (WP2)

Step 8: *Revision* of the the form and content of *indicator fact-sheet template* by indicator experts (WP2) before each new release of SEAMLESS-IF (WP2).

Step 9: *Filling in of indicator fact sheets* for new indicators, or revise existing sheets (according to new template) of already implemented indicators by indicator experts (WP2).

Step 10: *Development (or revision) of the indicator ontology* (design the structure of the concepts, which have to be linked into the system, see next chapter).

Step 11: *Building of the 'indicator table'* in the form of a Microsoft Excel spreadsheet based on the structure of the most current ontology. In other words, the ontology is presented as a Microsoft Excel spreadsheet, which is called the 'indicator table' (see Annex 1).

Step 12: Population of the 'indicator table' by indicator experts (WP2). This includes the indicators that are (i) up-scaled; and (ii) have undergone transformation in WP3.

Population of 'indicator table' means to fill in all the information relevant to each specific indicator in the indicator table. This information should include:

a) The name of latest existing model output that is needed to calculate this indicator. The existence and naming of this model output can either come from (i) browsing the database; and (ii) direct communication with the model experts from WP3.

b) If the model output is a transformed model output the model expert (WP3) has to confirm that the model transformation has been implemented in the model.

Without this information, or with incorrect information, the indicator cannot be implemented or the wrong thing will be calculated.

Step 13: *Sending of the populated 'indicator table'* by the indicator experts (WP2) to the database expert (WP4).

Step 14: *Implementation the content of the 'indicator table'* into the SEAMLESS-IF. In technical terms this means that (s)he "populates the database-schema generated from the ontology".

Step 15: *Development of the model wrappers* allowing to store indicator values in the database and displaying them by the software experts (WP5). Wrappers are pieces of programming code that make sure a model is compatible with SEAMLESS-IF, can read required input data from the database and writes calculation results (outputs) into the proper places.

Step 16: *Development of the Seam:PRES functionalities* according to outcomes of previous steps by the software experts (WP5). Based on the performed experiment and selection of indicators to display Seam:PRES knows what information to request from SeamFrame (the server), which retrieves it from the database and returns it. Seam:PRES then puts the values into a table or a figure, e.g. a chart.

3.1.3 Indicator concepts and Ontology

Among the various Integrated Assessment and Modelling tools currently developed, SEAMLESS-IF has been built as a joint effort of thirty partners and their researchers (ca 150), each of them providing specific knowledge in his own discipline (Van Ittersum *et al.*, 2008). In the course of such tool development crossbreeding between different scientific knowledge is necessary as each discipline uses with its own way notions and concepts that sound similar, like resource efficiency, profitability, productivity, environmental soundness or social viability. To solve the problem of multitude of meanings for indicators and the related concepts and to facilitate the integration of indicators into SEAMLESS-IF and their linkage with model outputs and other components the SEAMLESS project developed an indicator ontology i.e. a finite list of concepts and the relationships between these concepts. This indicator ontology shared by all scientists from various disciplines and backgrounds working on an integration task, serves as a knowledge-level specification of the joint conceptualization (Gruber, 1993; Rizzoli *et al*, 2008) and enabled implementing indicators in the IAM platform. The ontology supports and facilitates the communication of complex concepts needed to define, present, compute and displays social, economical and environmental indicators at the wide range of scales investigated by SEAMLESS-IF.

The development of the SEAMLESS indicator framework led to define three specific indicator-related concepts.

Firstly the "endorsed indicators" correspond to the impact indicators of SEAMLESS-IF. They are issued from the first interactive dialogue of the procedure presented above and accordingly meet the main Policy Experts expectations and applications and scientific requirements. Even if all the impact indicators of this so called "wish list" cannot be assessed within SEAMLESS-IF yet it has been decided to implement all of them within the SEAMLESS indicator framework. The objective of this choice (to also implement the endorsed indicators not assessable with SEAMLESS-IF) is to keep track of and to highlight the ideal list of indicators that should be available to handle all the main sustainability issues of agricultural systems. Given this choice within SEAMLESS-IF the endorsed indicators can have four different statuses: implemented (assessable), implementation in progress (should be assessable), not implemented yet (but implementation seems technically possible), implementation not possible. Accordingly only the "implemented" endorsed indicators can be assessed with the modelling chains of SEAMLESS-IF. These "implemented" endorsed indicators are linked to a specific SEAMLESS model or model chain used to compute them and to the corresponding model output. Finally, the implemented endorsed indicators requiring an up-scaling procedure are linked to the required up-scaling procedure (i.e. algorithm).

Secondly the "Indicator Group" corresponds to an indicator impact-oriented family grouping together a set of endorsed indicators providing information on the same impact but at different scales. This indicator group allows highlighting links between endorsed indicators providing information on the same process but at different spatial and/or temporal scales (e.g.: the nitrate leaching group brings together the Nitrate leaching in kg N-NO3/ha/y at field level, at farm level and the share of the area with nitrate leaching over a given threshold computed at landscape or regional level). The indicator groups are linked to the GOF components and to a factsheet describing characteristics of endorsed indicators (belonging to the given indicator group). The link to the GOF allows allocating endorsed indicators within the GOF i.e. all endorsed indicators belonging to an indicator group have the same positioning within the GOF. Each indicator group is linked to a fact sheet describing all the characteristics of the endorsed indicators belonging the indicator group (purpose, impact, described processes, scales, detailed description of calculation, information needed for interpretation, possibilities of up-scaling/aggregation and evaluation of the indicator). In this way, the indicator group factsheet is process oriented i.e. provide characteristics on all endorsed indicators providing information on a given process.

Thirdly the "model variables" correspond to the intermediate variables necessary to interpret and understand the causality chain lying behind the indicator values. These intermediate variables correspond to inputs or outputs of models belonging the model chain used to handle the investigate assessment problem. The list of key model variables has been jointly identified by the WP2, WP3 and WP6. Each model variable is linked to the SEAMLESS model providing them and to the corresponding model input or output.

Given these concepts the final indicator ontology allowing to implement indicator concepts into SEAMLESS-IF is presented in box 2 (See also Appendix 5):

Box 2: Ontology of the indicator concepts for the implementation into SEAMLESS-IF

- **IndicatorGroup:**
    - name or label (single String)
    - description (single string)
    - has FactSheet (single String, a link to the factsheet in pdf format)
    - has EndorsedIndicators(multiple).
    - has TradeOff (multiple)
    - has Domain: agriculture or rest of the world (multiple)
    - has Dimension (multiple)
    - has Theme (multiple)
    - has Sub theme (multiple)

- **EndorsedIndicator:**
  - name or label (single String)
  - description (single string)
  - has Model (single Model) (model that produces this indicator at this scale)
  - has ModelOutputName (single String)
  - Is Part Of IndicatorGroup (single)
  - Unit (single: string)
  - One Spatial Resolution (the finest scale of the model which provides model outputs necessary to calculate the indicator)
  - One Spatial Extent (i.e. the scale at which the indicator is displayed)
  - One Temporal Resolution
  - One Temporal Extent
  - one thresholdmin (single: float)
  - one thresholdmax (single: float)
  - a status property single string gets four values: implemented, implementation in progress, not implemented yet, implementation not possible
  - a thresholdOfVariation property single string: gets three values, calculable, not relevant, not available
  - has Model variables (i.e. variables necessary to explain and to investigate indicator values) (multiple)
  - has upscaling procedure (who can be set to "no upscaling procedure")

ModelVariable:
  - name (single String)
  - description (single string)
  - has Model (single Model) (model that produces this model variables)
  - has ModelVariableName (single String)
  - One Spatial Resolution
  - One Spatial Extent
  - One Temporal Resolution
  - One Temporal Extent
  - unit (single: string)

As model outputs transformation and aggregation are calculations (small models) necessary to transform and upscale model output(s) and/or database parameter(s) into an indicator they cannot be part of the SEAMLESS ontology.

3.2 Presentation of the indicator list

Across scales, farm, Nuts 2, member state, a total of 80 environmental, 140 economic and only 11 social indicators are integrated into SEAMLESS-IF. Examples of indicators are shown in Table 3.1.

Indicators are implemented in SEAMLESS-IF by means of so called "indicator table". The whole list of indicators is presented in Appendix 1. Not all indicator information (according to the ontology) is included in this table but is available in two other tables (see Appendix 2 and 3). To facilitate the integration of the indicator information in the database and to avoid redundancy of information all indicators were grouped in so called "indicator groups" (see previous section describing the ontology). A so called indicator fact sheet was also developed. This fact sheet is related to the indicator group. The indicator fact sheets supply more detailed information on the indicator to assist users in the selection and interpretation of the indicator. The fact sheet contains information about the model(s) used to calculate the indicator, the scale for which it is produced and the up-scaling procedures used if applicable, how and indicator could be interpreted, information about trade-offs or other background information such as references to scientific literature (Appendix 4). All indicator fact sheets are available through the SEAMLESS-ID graphical user interface.

Table 3.1: Example of indicators implemented in the SEAMLESS IF displayed in the goal-oriented indicator framework (GOF) at different scales (farm, normal font; Nuts 2, italic; member state or EU level, bold).

	Domain 1 **Impacts on the agricultural sector**			**Domain 2** **Impacts on the rest of the world**		
	Dimension of sustainable development			Dimension of sustainable development		
Themes	**Environmental**	**Economic**	**Social**	**Environmental**	**Economic**	**Social**
Ultimate goals	Pesticide use	Net farm income Percent of subsidies in farm income *Percent of subsidies in farm income* **Agricultural income**	*Equity* **Equity** **Monetary poverty rate**	Nitrate leaching Pesticide leaching Crop diversity *Percent of area with high leaching* **Nitrate surplus**		*Equity* **Equity**
Processes for achievement	Soil Org.Mat. change *P balance* **N2O emissions**	Direct payments **Direct payments** Productivity of farm inputs Value of farm production	Labour use *Total labour use* *Potential employment*	Volatization *NH3 emissions* *P balance* **N2O emissions**	**First pillar CAP expenditure** **export subsidy outlays** **profit of the agr. processing industry** **Terms of trade**	*Fairness*
Means	Soil erosion Water use by irrigation **Energy use by min. fertilizer** **Use of mineral P**	Share of animal production *Share of animal production* **Share of animal production** Total costs	Labour use *Labour use* **Labour use**	Soil erosion Water use by irrigation **Energy use by min. fertilizer** **Use of mineral P**	*Land shadow prices* **Land value**	Labour use *Labour use* **Labour use**

3.3 Application domain

The set of indicators offered through SEAMLESS-IF enables a multi-scale integrated assessment of SD from the farming systems to the agri-environmental zones and the EU level. In comparison with many former initiatives the broad spectrum covered and the type of the proposed indicators allows for a deeper analysis of environmental pressures and impacts, economic costs and benefits and socio-demographic dynamics. For example, through the integration of the APES model, indicators assessing emissions like nitrate leaching can be calculated considering key processes in the soil. This is not the case for simple indicators describing farmers' practices like nitrogen use or indicator based on the calculation of a nitrogen balances (Bockstaller *et al.*, 2008). However, the implementation of such process-based indicators requires a detailed description of fertilization and pesticides management for the farm types of a given region or member state. Another example is the assessment of economic indicators at NUTS2 level. SEAMLESS contain two different possibilities to assess these indicators which gives the possibility to capture complementary impacts of a policy option.

The social indicators included in this list were derived from economic data, on labour and income distribution since no social model have until now, been integrated in SEAMLESS-IF. It is well known from literature and from other projects aiming at sustainability that a main attention is frequently given to economy and environment. Many reasons can be identified to explain why less weight is put on the social dimension of sustainable development. These reasons are connected with the difficulties related to methodologies to collect relevant data and quantifying or assessing aspects that are fundamental for social issues. They are also related to the subjectivity of the interpretation of what should be considered as social in the sustainability evaluation. Moreover, the models that are considered within Seamless have not been built up with the concern of fully covering social issues. And as Seamless aims to provide evaluation of scenarios across various scales, an extra difficulty is added, as the diversity of relevant social issues across Europe, and even more across the world, is very high.

To solve this problem, and in face of the clear need and demand to include also social issues in the Seamless framework, an extra effort was therefore required. One of the social dimensions considered for the development of new indicators has been the Quality of Life, still only partly represented in existing indicators, at least in relation to agriculture. The quality of the landscape and the way this landscape can support of multiple functions can be considered as one of the components of the quality of life of a population (Council of Europe, 2000). As the rural landscape is directly created and transformed by agricultural practices, changes in agriculture lead to changes in the landscape, and thus to changes in the functions they can support and the social demand related to it.

As a response to the lack of social indicators a landscape amenities model has been conceived as a way to calculate the impact of changes in agriculture, on the landscape pattern, and thus on its capacity to support diverse functions (see further PD2.2.5, Pinto-Correira T, *et al.*, 2009). The landscape amenities model is built up so that it can be based on indicators that can be directly calculated from the SEAMLESS model outputs, and thus related to the SEAMLESS model chain but it is still not integrated but can be used as a separate methodology based on indicators produced by the SEAMLESS-IF. These indicators come from the environmental dimension (crop diversity, intensity and specialisation). The methodology on how to interpret these indicators is however developed in the social domain, since the value of landscape amenities is mainly related to the social demand for the same, and it is the capacity to satisfy this demand which should be assessed. The Agriculture Impact on Landscape Amenities indicator can consequently be considered as a composite indicator referring to the set of functions valued by society, provided by a given landscape, and the changes in these functions motivated by changes in the rural and farm systems and structure.

3.4 Discussion

The SEAMLESS-IF multi-scale approach with its explicit up-scaling procedures, as well as the integration of the indicators into a generic flexible software system linked to a large database mark an important progress with respect to the creation of an efficient set of indicators to assess the sustainability of future agri-environmental policies. This flexibility is supported by the ontology and a clear implementation procedure. However, some methodological issues remain unclear, such as the determination of reference values and the aggregation of indicators into composite indices. For the former, a reflection on determination of reference value, thresholds and target value was launched by WP2. Proposals were made in PD2.5.1 (Van Der Heijde M, *et al*., 2007).

Furthermore, there are still indicators related to certain themes of the GOF that are not covered. Regarding the environmental dimension, a weak point is certainly the impacts on biodiversity due to the lack of a specific model. Surrogates (or indicator based on farming practices, like the crop diversity indicator (Table 3.1) have been proposed (Braband *et al* 2003, Bockstaller *et al*.; 2008). In terms of economic indicators there are two issues which remain uncovered: public preferences for environmental capital and non-farm activities. Moreover, only few indicators representing the social dimension are proposed. This reflects the lack of integration of a specific model addressing social processes. The current available indicators are based on economic outputs. For the landscape issue which address simultaneous a social and environmental issue, a specific work has been undertaken in developing the Landscape Amenities Model (Pinto-Correira T, *et al*., 2009).

However, in spite of those gaps, as SEAMLESS-IF is a flexible system, further extension of the indicator list is possible through the integration of new models, databases, following the implementation procedure described at the beginning of this chapter.

4 Implementation of the GOF in the SEAMLESS Graphical User Interface

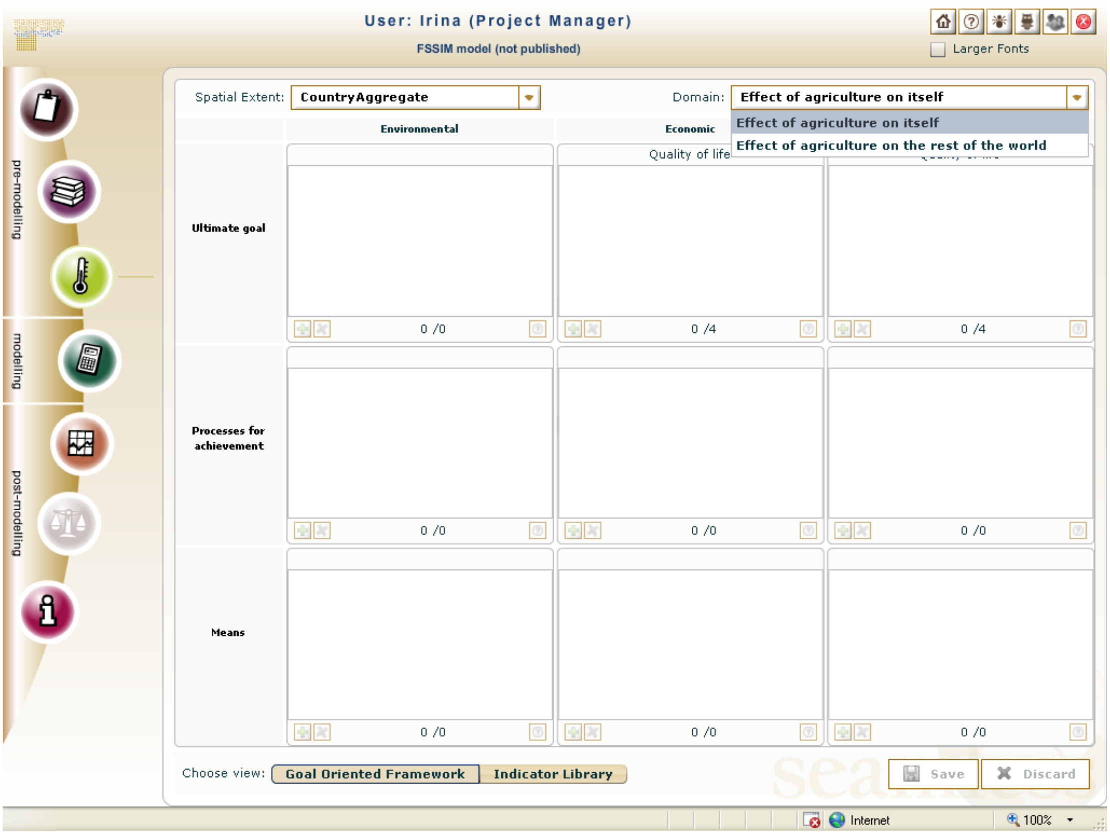
4.1 Indicators in the pre-modelling stage of the SEAMLESS-IF

To make an impact assessment using SEAMLESS-IF the first operation to do will be to generally define the problem and its scope scale wise. The second step will be to select indicators relevant for the particular problem. This section will describe how the GOF can be used to select indicators using pre-modelling stage of the SEAMLESS-IF GUI.

Figure 4.1: Indicator Selection Menu button in the Pre-modelling stage

There-modelling stage of the SEAMLESS-IF is covered by the first three menu-buttons on the left hand side of the GUI: Problem, Experiment, Indicators (Figure 4.2).

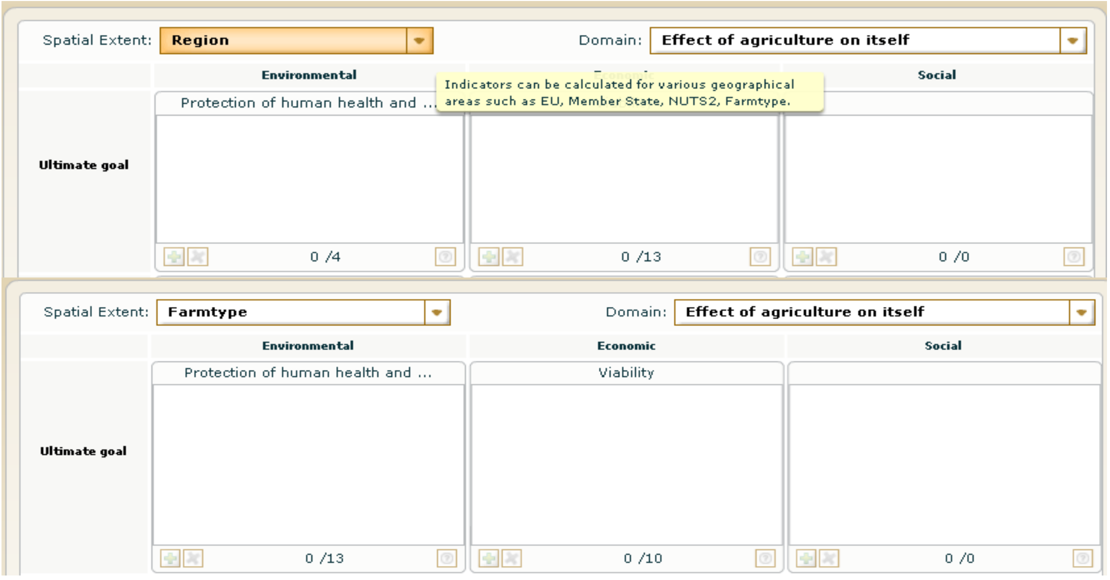
Figure 4.2: Screen shot of the first page of the SEAMLESS-IF indicator manager showing the main features of the GOF



The first screen of the so called indicator manager (the part of the SEAMLESS-IF where indicators are selected) provides an overview picture of the general themes of the GOF (Figure 4.3). The first step to do is to select one domain and thereafter select indicators included in this domain. It is possible to select between the domains *effects of agriculture on it self* and *effects of agriculture on the rest of the world* by using a scroll down tab at the right top of the screen (Figure 4.2). As a general principle indicators should be selected for both these domains.

Indicators are calculated for different scales and these differences in scales can be used to; i) make general assessment of what effect a specific change in a policy will have at the EU level as well as in depth studies of the effects on one or a few regions using the same tool and the same indicators ii) compare effects on an indicator between scales (farm, regional and EU) which is crucial for policy-makers to understand at which level and by which means the policy should be constructed to affect the targeted problem in the most efficient way and iii) compare the effects on sustainability between different scales and regions.

Figure 4.3: Availability of indicators per theme depends on the selected Spatial Extent: Region (top) and Farmtype (below)



The issue of scale is addressed as follows. First one defines at which spatial extent that is relevant for the specific assessment. This is done by scrolling the list called Spatial Extent at the right of figure. The ToolTip for Spatial Extent (Figure 4.4) clarifies its definition and tells that indicators can be calculated for various spatial extent: EU, Member State, NUTS2, Farm type. However, the scale of an indicator refers to both Spatial Extent and Resolution.

The spatial “extent” is in the SEAMLESS project defined as the spatial area and temporal period or horizon concerned by the study or the scales at which users expect indicator values (e.g.: watershed, farm for spatial extents and a decade or to 2020 for temporal extents).

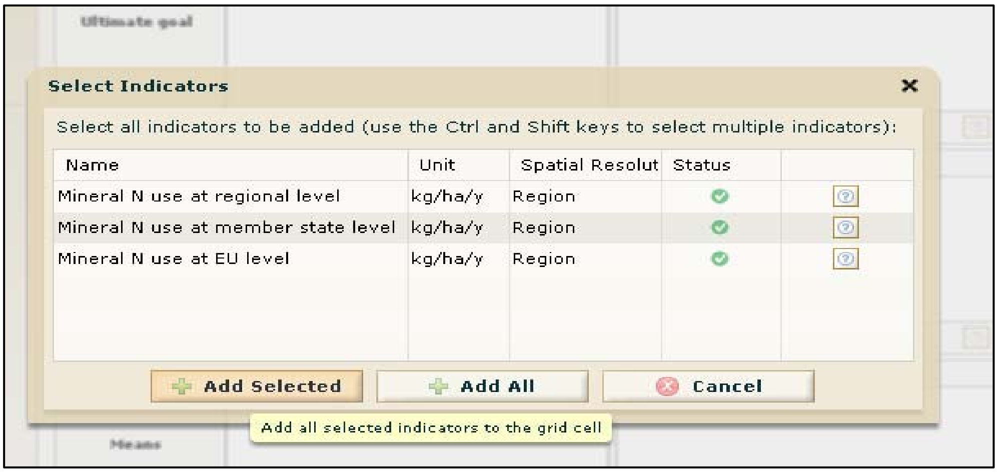
Spatial resolution is displayed per indicator as illustrated below (Figure 4.9). Spatial Resolution of and indicator refers to the finest unit used in calculation of this indicator. The “resolution” or “support unit” is the finest unit on which information is calculated or observed or displayed. When using models the spatial resolution corresponds to the simulation units which i.e. the spatial unit considered as homogenous to which the model is applied to get simulated values (e.g.: for a crop model like APES the plot or AEnZ and for a farm type model like FSSIM-MP the farm type.

When a Spatial Extent has been selected it is possible to see how many indicators that are endorsed in the tool at that specific scale. This information is displayed below each box. The first number is related to how many indicators that are selected and the second number is related to how many indicators that endorsed at that specific scale.

Figure 4.4: Selection of indicators by pushing the green cross

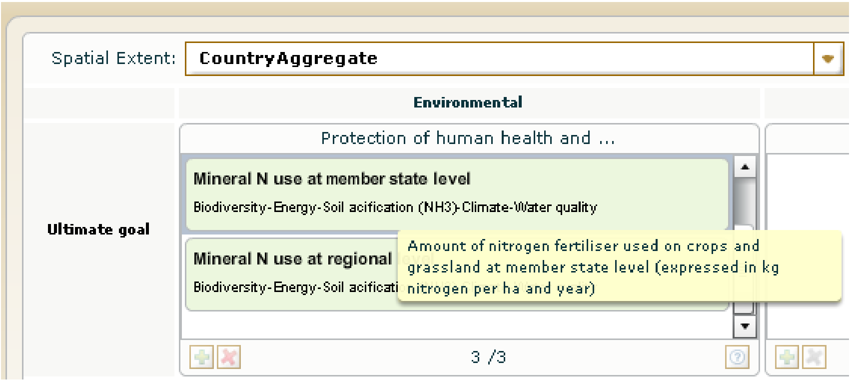
The next step is to select the indicators. This is done by clicking the green cross at the bottom left of each box (Figure 4.5).

Figure 4.5: List of indicators available for the selected generic theme and scale



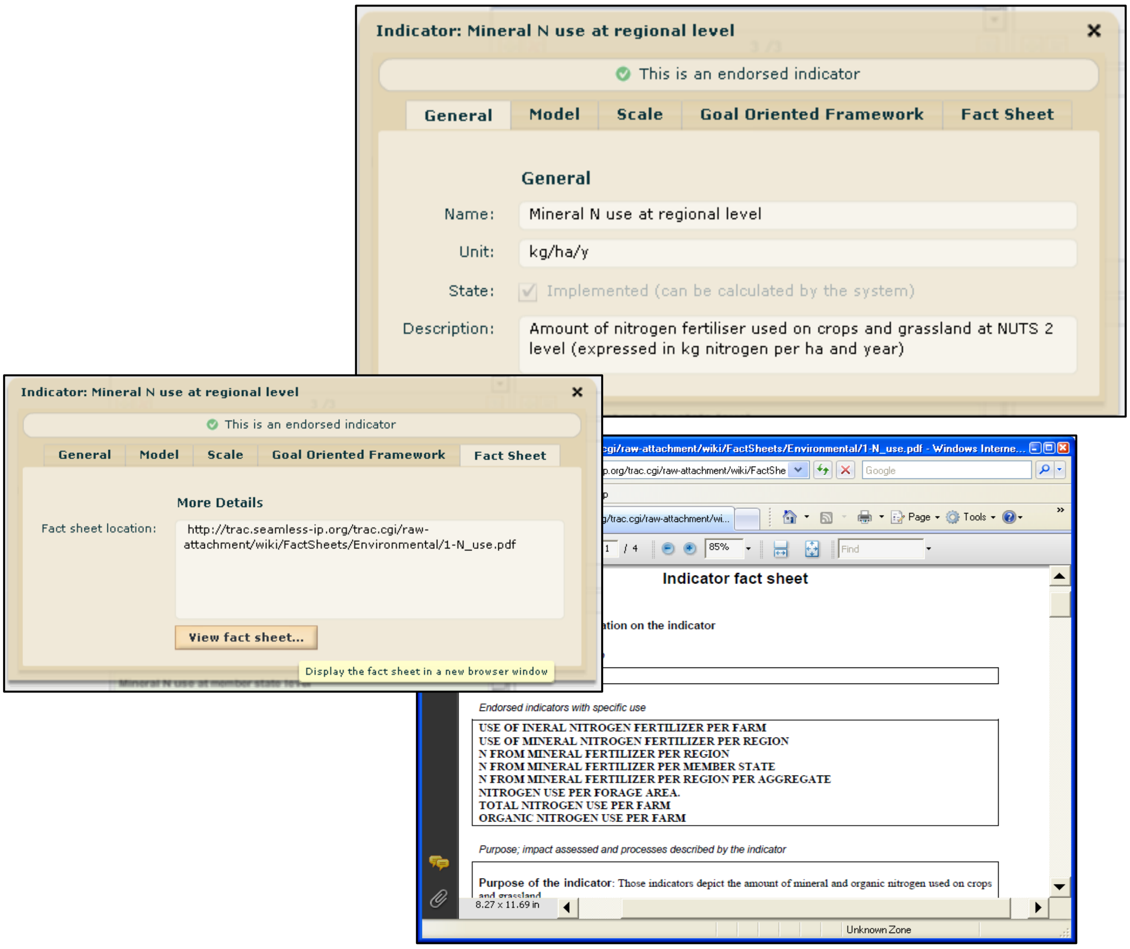
When clicking the green cross a list displaying the endorsed indicators is shown (Figure 4.6). Also non endorsed indicators that could easily be implemented at a later stage are shown in lighter grey. The information that is given about the indicators in this list is which sub theme it belongs to, its name, its unit, and the scale. To select an indicator it should be selected and thereafter the Add selected button should be clicked. If all indicators are wanted, the Add all indicator button, should be clicked. When the add button has been clicked the selected indicator is displayed in the box of the first screen (Figure 4.7). This procedure is then repeated for each box of the indicator framework till the user is satisfied with the selected package of indicators. To delete any selected indicator the indicator should be marked and the button with a red cross at the bottom of each box should be clicked.

Figure 4.6 Display of selected indicators per general theme



To acquire more infor-mation on the selected indicators it is possible to mark the indicator and click on the question mark at the right below each box and a box with general information on the indicator will appear (Figure 4.8).

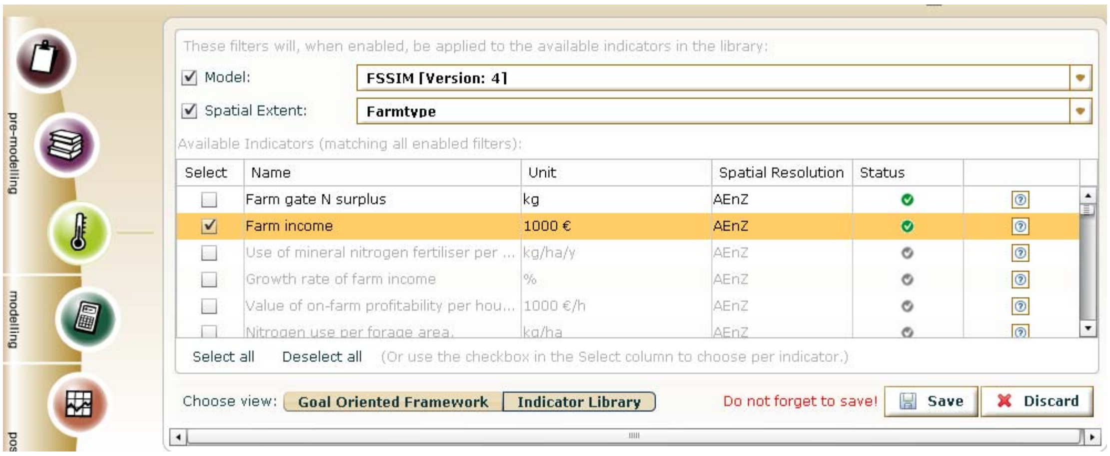
Figure 4.7 Boxes with general information on the selected indicator (a), Indicator Factsheet (b) and the loaded Indicator Factsheet (c)



In the end of this box there is a PDF link to the so called fact sheet of the indicator that include all detailed information on each indicator. On the top of the box it is showed whether the indicator is endorsed or not, green cross it is endorsed and grey cross it is not endorsed i.e. it is not implemented in the tool. This was a wish from the users that wanted to see the progress of the implementation. In the box there are four more tabs with information on which model that produce the indicator, the scale for which it is produced or if any up scaling procedures have been used. All information about where the indicator is positioned in the GOF is given under another tab and in the last tab there is a link to the indicator fact sheet giving more detailed information on the indicator and how it could be interpreted as well as information about tradeoffs.

Based on comments from users it is expected that they on several occasions would prefer to select indicators directly and not pass the intermediary step of selecting domains, and general themes. Some users even have ready lists of indicators that they would like to use such as the agri- environmental list (CEC, 2005). A general request has therefore that it should be possible to select indicators directly from a list. It has therefore also been made possible to select indicators direct from the so called indicator library where the indicators can be sorted either by which model that have produced them or by model spatial extent (Figure 4.9). Additional flexibility is enabled through the possibility to sort indicators (by name, unit, spatial resolution and also in the post-modelling stage by values).

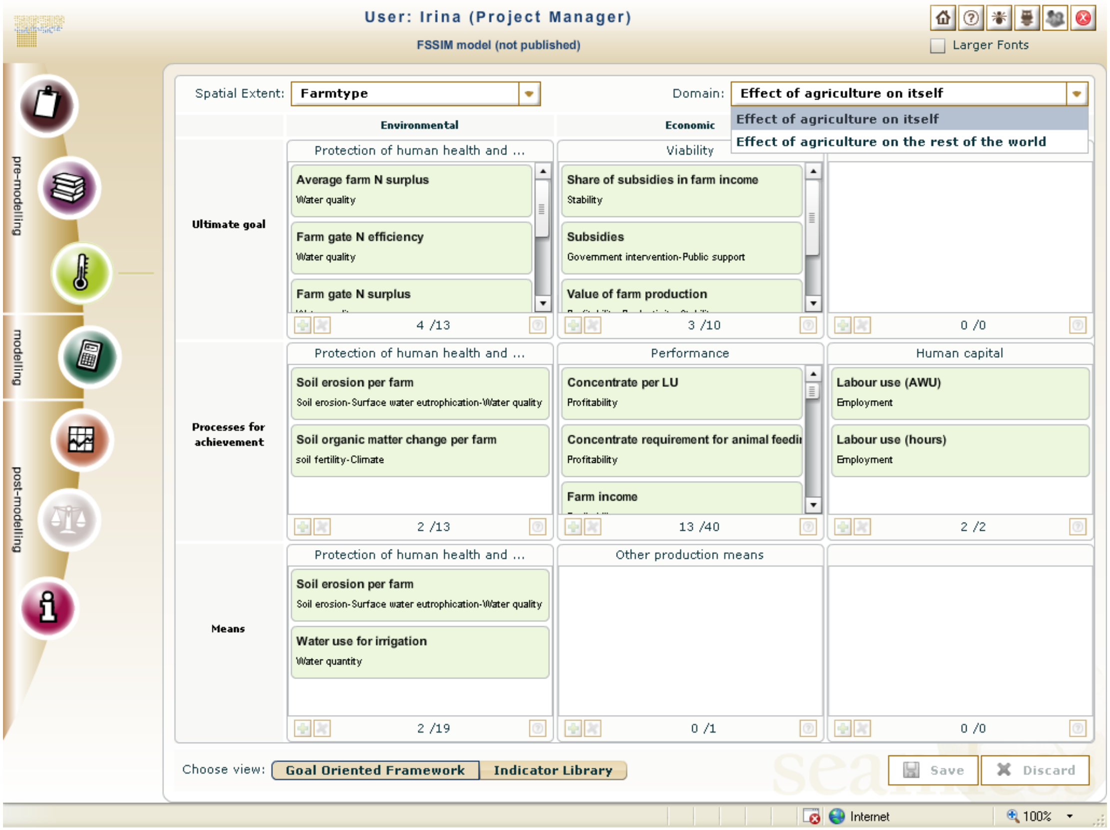
Figure 4.8: Display of the indicator library sorting indicators either by which model that produces them or by Spatial Extent or both



The indicators that are selected in the Indicator Library View can also be displayed in the Goal Oriented Framework by switching to this view in the lower part of the screen. This dual way of selecting indicators allows for flexibility in the indicator selection performed by for example modellers (via library) and by policy experts (via GOF). Discussions which are necessary to select the indicators through the GOF also are assumed to create demand for indicators which are currently not implemented in the system.

It is important to note that the selected indicators will become available for further visualisations in the Post-modelling stage of the SEAMLESS-IF. Switching between these stages and modifying the selection of indicators is enabled.

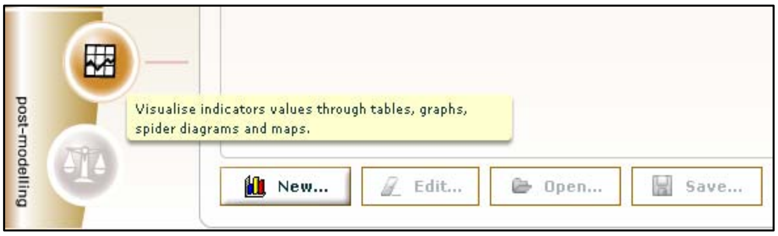
Figure 4.9: Display of the indicators that have been selected through the indicator library



4.2 Indicators in the post-modelling stage of the SEAMLESS-IF

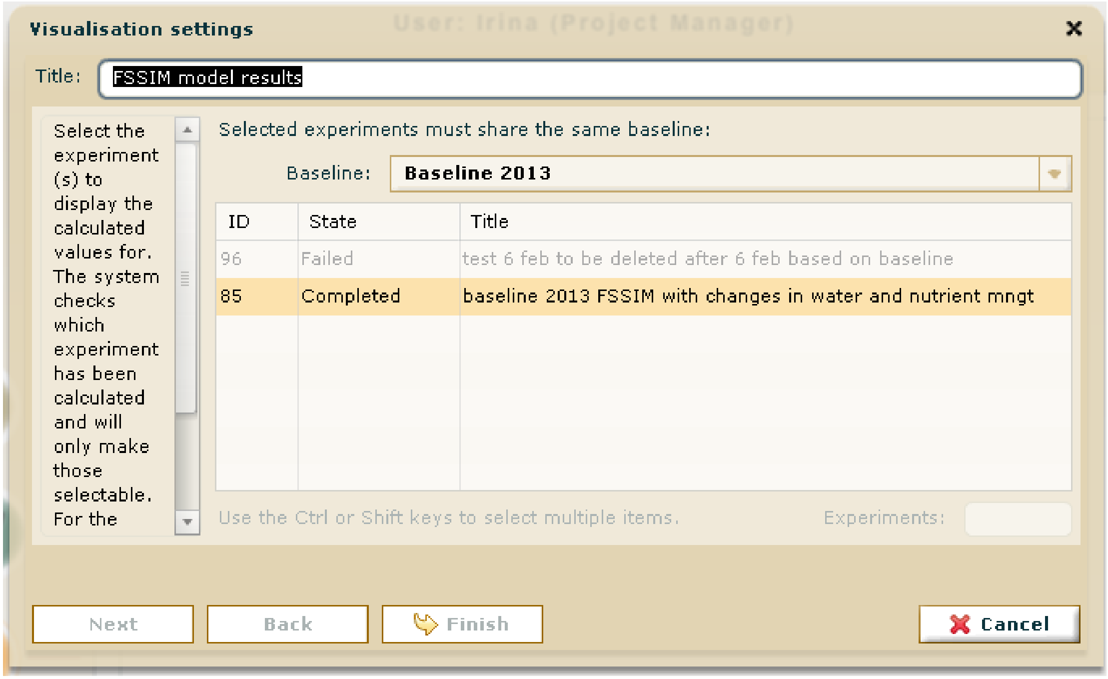
Indicators that have been calculated are available for further visualisations in the post-modelling stage which can be activated through the left-menu options (Figure 4.11).

Figure 4.10: Post-modelling stage of the SEAMLESS-IF: Creating New Visualisation screen



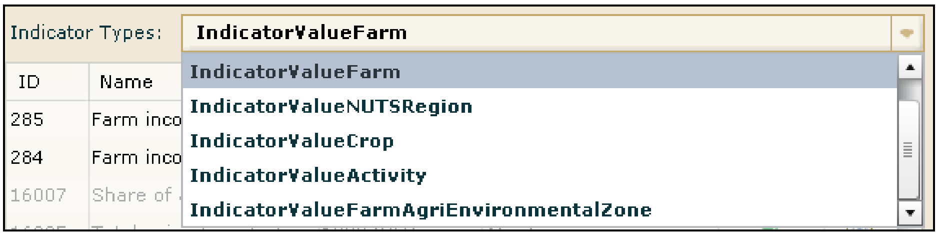
To create a new visualisation, first the system allows choosing for which experiment the indicator values will be presented. Only those experiments are available for selection for which the calculated values have been stored in the database (Figure 4.12).

Figure 4.11: Selecting the experiment for which new visualisation will be created



After the NEXT button is pressed, the following screen (Figure 4.14) appears allowing to select indicators of the same type from the list (Figure 4.13).

Figure 4.12: Scroll-down list of indicator types to make selection

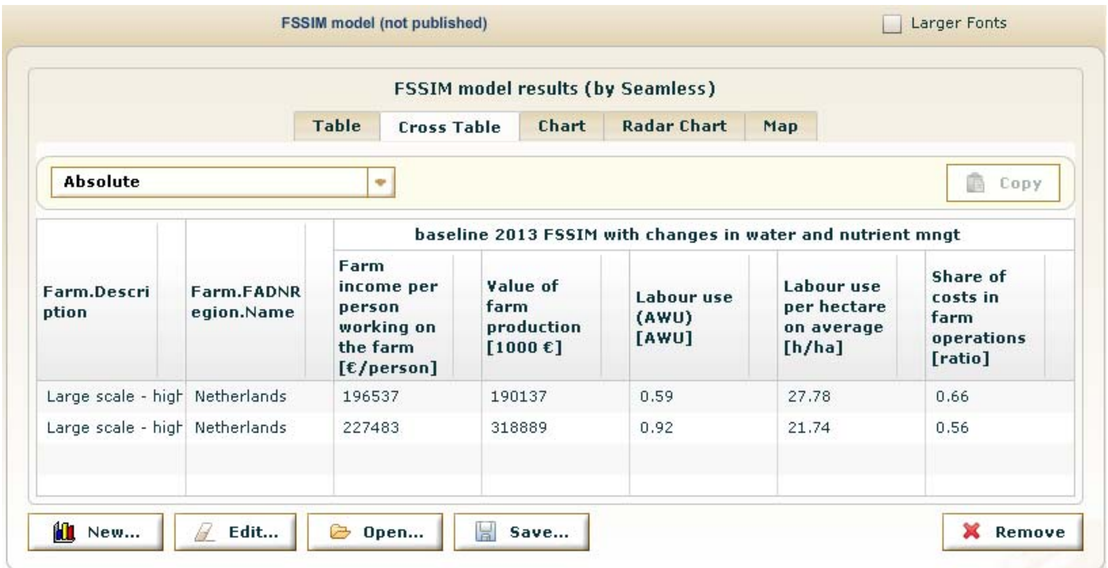


Through such filtering, the indicators that belong to the same spatial extent are made available for selection. Multiple indicators can be selected by using the Ctrl or Shift keys (Figure 4.14). Overall, the system offers to display only those indicators which have been selected in the pre-modelling stage. Since all values after each experiment run are stored, the system allows for flexibility in moving between pre- and post-modelling stages thereby enabling for flexible selection of indicators.

Figure 4.13: Selecting indicators from the pre-filtered list of indicators (here filtering is done for the farm-type indicators)

After the indicators have been selected, to complete the visualisation, the Finish button is activated. Further screen-shots demonstrate that the selected indicators can be viewed in the form of a Table, Cross Table, Chart, radar Chart and Map(Figure 4.15).

Figure 4.14: Selected view in the Cross Table format for 5 indicators presented as absolute values and calculated for 2 Dutch farmtypes within one experiment



The indicator values can be displayed as absolute values but also as differences to the baseline values, in absolute values and in percentage (Figure 4.16).

Figure 4.15: Displaying indicator values as absolute values and differences to the baseline

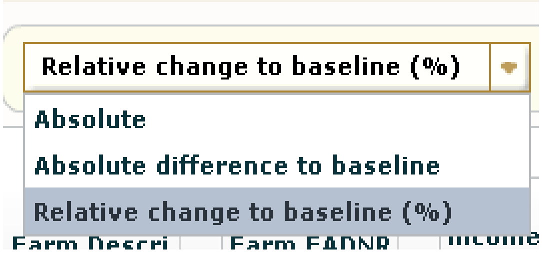


Figure 4.16: Button allowing to copy-paste the data

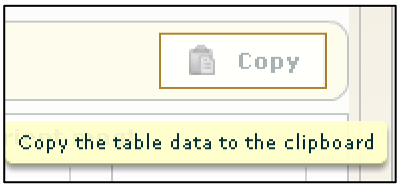
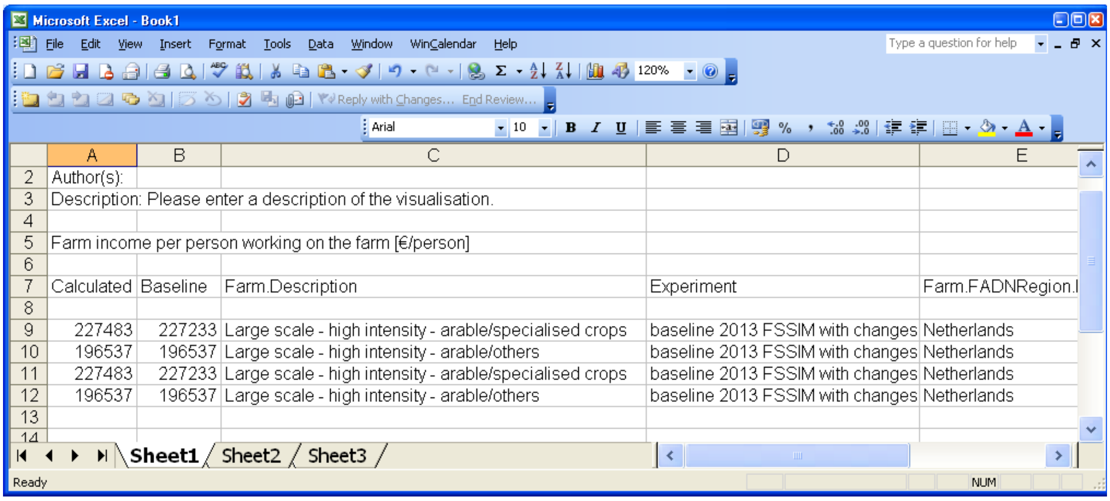


Figure 4.17: The data from the Table view are copied into Excel spreadsheet

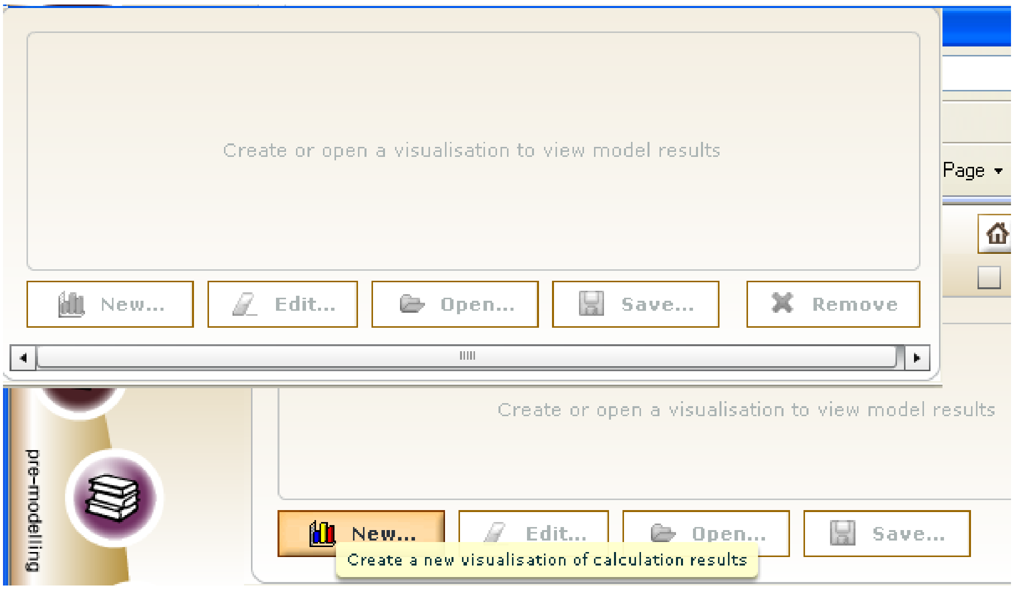


	A	B	C	D	E
2	Author(s):				
3	Description: Please enter a description of the visualisation.				
4					
5	Farm income per person working on the farm [€/person]				
6					
7	Calculated	Baseline	Farm.Description	Experiment	Farm.FADNRegion.l
8					
9	227483	227233	Large scale - high intensity - arable/specialised crops	baseline 2013 FSSIM with changes	Netherlands
10	196537	196537	Large scale - high intensity - arable/others	baseline 2013 FSSIM with changes	Netherlands
11	227483	227233	Large scale - high intensity - arable/specialised crops	baseline 2013 FSSIM with changes	Netherlands
12	196537	196537	Large scale - high intensity - arable/others	baseline 2013 FSSIM with changes	Netherlands

4.3 Indicators in the integrated framework: User rights, Ontology Browser, links to the database and to additional information materials

The Graphical User Interface of the SEAMLESS-IF supports various user roles, in other words enables for customised access to the system to users with various degree of access. For example, relevant to indicators, the users when having rights of the Project Manager may flexibly choose the indicators suitable to specific assessment projects. The Viewers are only allowed to browse through the Indicator Table, perform filtering of indicators in the Table view but are not entitled to save changes. In the post-modelling part such users are able to browse through the existing visualisations but are not allowed to modify them or to create new ones (Figure 4.19).

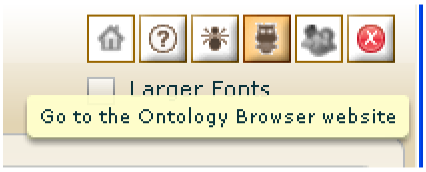
Figure 4.18: Access to creating a NEW visualisation is available (lower part of the picture) and not (upper part)



Indirectly to the main user interface of the SEAMLESS-IF but nevertheless linked to the system of servers that support the functioning of the tool, there are two other parts where indicators are linked to: the Ontology Browser and the integrated database.

Access to the Ontology Browser – a web link which enables viewing the existing concepts of the SEAMLESS-IF – is provided through the top menu of the SEAMLESS-IF (Figure 4.20).

Figure 4.19: Access to the Ontology Browser v1.0 through the top part of the SEAMLESS-IF menu



When the Ontology Browser is open, two views are of relevance for the Indicator concepts (Figure 4.21 and Figure 4.22). These views allow browsing through the concepts to find out the relationships with other concepts, definitions of the existing concepts.

Figure 4.20: Ontology Browser view for the object 'Indicator (left side) and its attributes and relationships with other objects in the system (on the right)

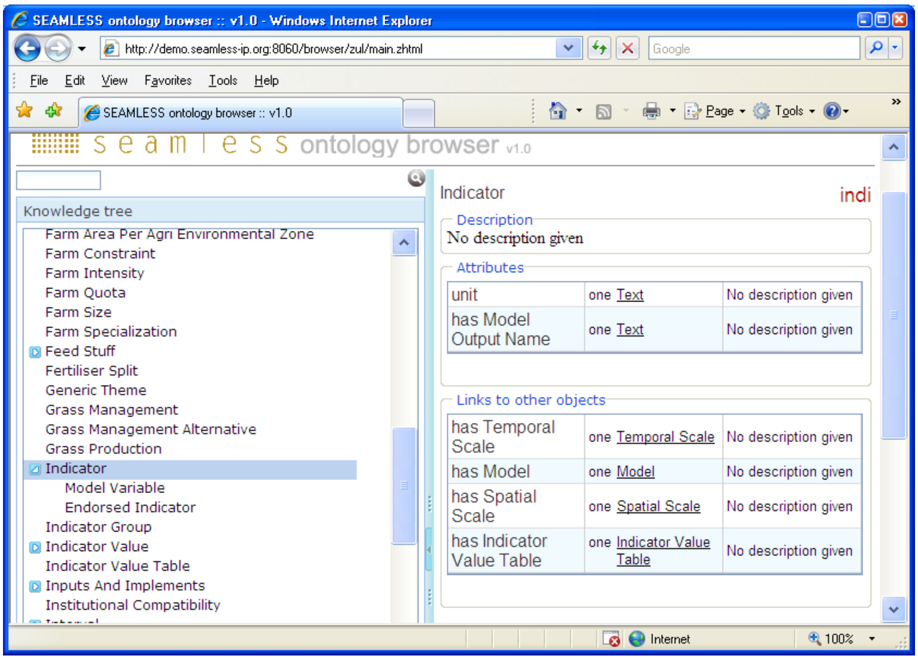
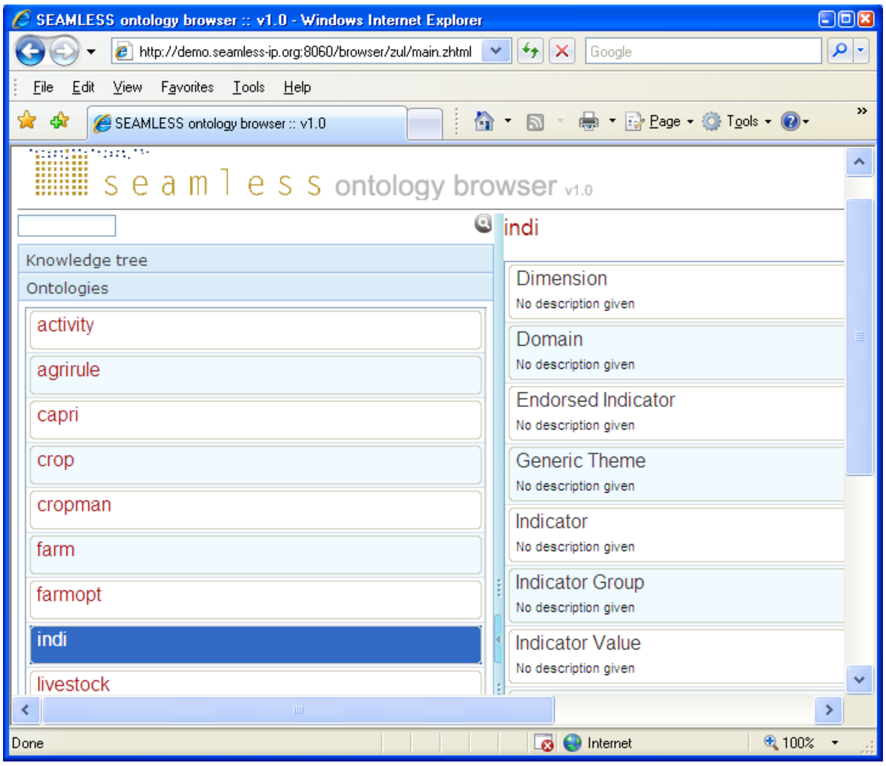


Figure 4.21: View of the relevant concepts and objects (right) for the Indicator Ontology (left)



The indicator ontology as presented in section 4 has been used in creating the schema for several indicator Tables in the SEAMLESS-IF database. Data in these Tables are assessed through the software platform and are dynamically updated by the values from the newly created experiments (model calculation runs).

There is additional information that the SEAMLESS-IF user interface allows to obtain by clicking on the left menu.

Figure 4.22: The i-info menu button on the left menu of the SEAMLESS-IF

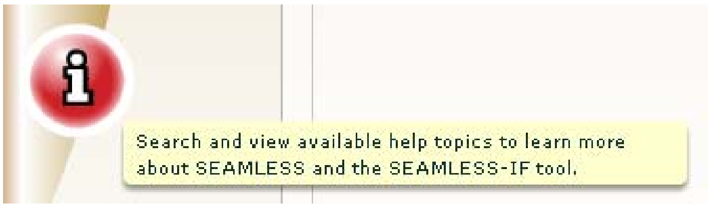


Figure 4.23: Search function allows browsing through the information that is relevant to indicators (in the form of PowerPoint presentation or other types of documents)

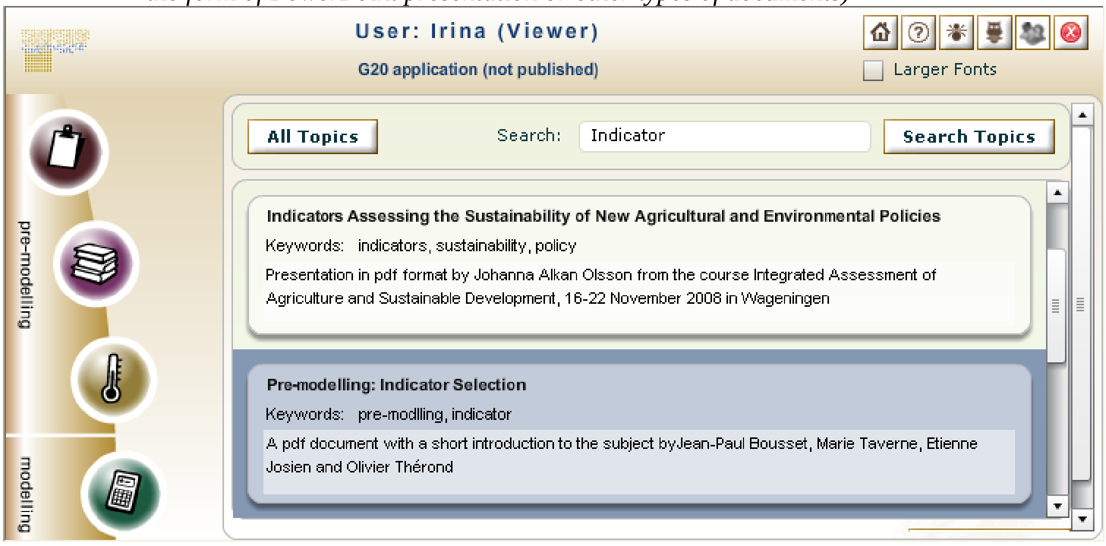
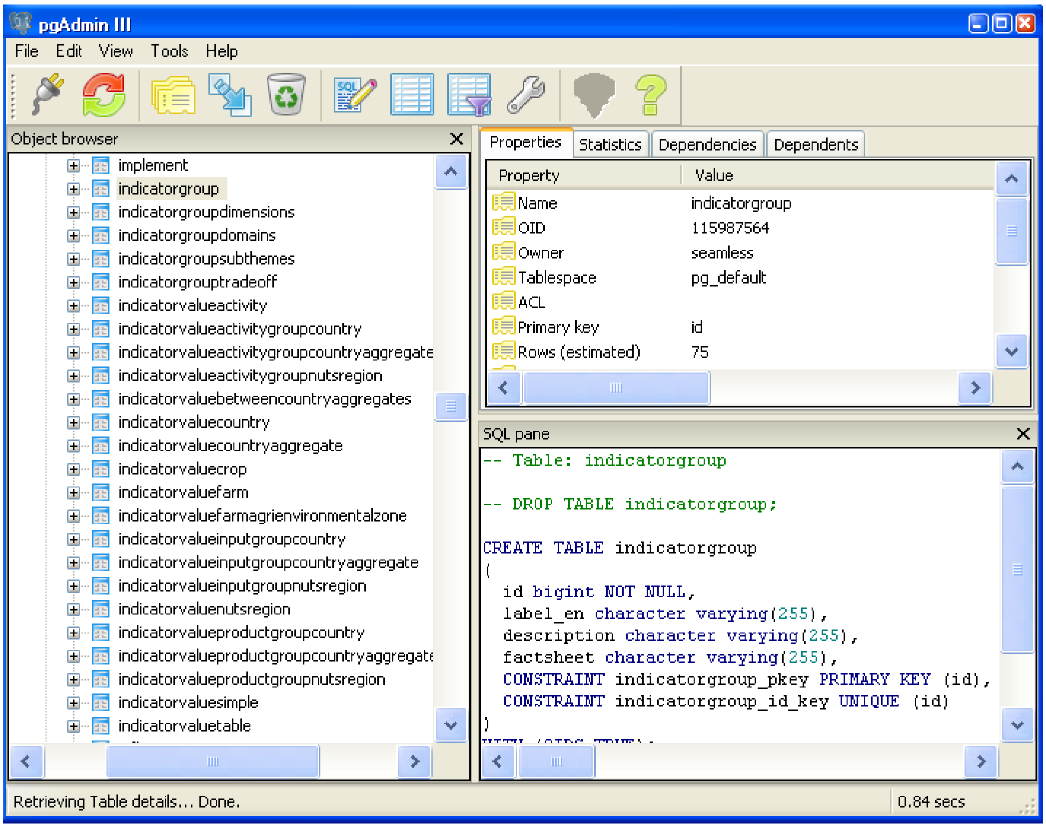


Figure 4.24 View of the SEAMLESS-IF database as accessed through the PgAdmin interface with the list of Tables on the left



These Tables as presented in Figure 4.24 for example, contain the indicator names, indicator values per experiment, indicator type, etc. An example of the Table with Indicator Groups and the link to the location of indicator factsheets on the server is presented in Figure 4.25

Figure 4.25: Content of the Table "IndicatorGroup" in the SEAMLESS-IF database

Edit Data - modellers (trac.seamless-ip.org:5432) - seamdb_final_06012009 - indicatorgroup

File Edit View Help

No limit

	oid	id [PK] bigint	label_en character varying(255)	description character varying(255)	factsheet character varying(255)
1	116247686	1	Nitrogen use	Amount of nitrogen fertilizer used on crops and grassland (expressed in kg N per ha)	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/1-N_use.pdf
2	116247687	2	Nitrate leaching	Amount of nitrate leached under the root zone of crops and grassland due to fertilization and nitrc	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/2-NO3_leaching.pdf
3	116247688	3	Pesticide use	Amount of pesticides used (expressed in g of active ingredients per ha) in a farm to evaluate the p	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/3-Pesticide_Use.pdf
4	116247689	4	Soil organic matter	Evolution of the soil organic matter content in soil in percentage (soil fertility issue) or absolute val	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/4-Organic_matter.pdf
5	116247690	5	Soil erosion	Soil losses by water erosion along the slope	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/5-Erosion.pdf
6	116247691	6	Runoff	Surface runoff due to low water infiltration	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/6-Runoff.pdf
7	116247692	7	Water use (quantity)	Amount of water used by irrigation on crops	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/7-Water_use.pdf
8	116247693	8	Volatilization	Volatilization of ammoniac due to nitrogen fertilization or/and livestock (stable, grazing, manure sto	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/8-Volatilization.pdf
9	116247694	9	Crop diversity	Land use diversity (and, conversely, dominance) – relevant for biodiversity and for environmental	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/9-Crop_diversity.pdf
10	116247695	10	% low fertilised grassland	% low fertilised grassland per farm type	http://trac.seamless-ip.org/trac.cgi/raw-attachment/wiki/FactSheets/Environmental/10-Percent_low_input_

5 Methodologies for up-scaling of indicators and presentation of up-scaled indicators in the SEAMLESS-IF

5.1 Motivation

The SEAMLESS-IF models have been designed to simulate behaviour of the key hierarchical agricultural systems (field, farm, region, EU and world).

However, despite the wide range of scales covered by these models there can be gaps between the scale at which model outputs are available (i.e. the model scale) and the scale at which policy makers' demand indicators for decision making (i.e. the decision scale). Accordingly, to meet expectations of policymakers, there is a need for procedures changing the scale of this information from the model to the decision scale.

As defined in PD6.2.2.3 (Turpin *et al*., 2007), there are several reasons to upscale indicators:

- The SEAMLESS-IF user cannot rely only on indicators calculated at the farm level.
- There are too many farm types that are represented differently in each region, which makes homogeneity at a regional level very essential.
- Many policy options require analysis on politically defined zones, such as the vulnerable zone defined in the Nitrate Directive.

The characteristics scales of agro-ecological processes investigated within SEAMLESS-IF (S-IF) are triple: spatial, temporal and complexity (Dalgaard *et al.*, 2003; Ewert *et al.*, 2006). In this report we are interesting and define only those relative to spatial and temporal aspects. We present hereafter definitions based essentially on Faivre *et al*. (2004), Bierkens *et al*. (2000) and Blöschl and Sivapalan (1995).

Blöschl and Sivapalan (1995) distinguish three main types of scales:

- the Process scale is the scale that natural phenomena exhibit and is beyond our control,
- the Observation scale is the scale at which the process is observed (measured). It is chosen according to the technical and logistical constraints.
- the Model or modelling scale: the scale at which the process is represented (modelled).

Dalgaard *et al.* (2003) and Bierkens *et al.* (2000) add the Decision or Decision-Maker or policy scale: the scale at which policy maker decision are made considering that "What is an appropriate scale depends in part on the question one asks" (Wiens, 1989).

As Faivre *et al* (2004), Bierkens *et al.* (2000) and Dalgaard *et al.* (2003), in this report we use the term scale in its colloquial sense (vs. cartographic sense) i.e. large scale refers to large area (in the cartographic sense large scale refers to small area). The temporal and spatial scales are defined through three main attributes (Faivre *et al*. 2004; Bierkens *et al*., 2000, Jansen *et al*., 2007):

The "extent" which corresponds to the spatial area and temporal period or horizon concerned by the study as a watershed, a farm for spatial extents and a decade period or the 2020 horizon for temporal extents. It corresponds to the area and period over which model outcomes are calculated (or observations are made or policy measures are to be made).

The "resolution" (or support unit, simulation unit, grain) corresponds to the largest area or period on which the property of interest is considered homogenous. It corresponds also to the finest spatial unit on which information is calculated (or observed or displayed). When using models the spatial resolution corresponds to the simulation units which is for a crop model (e.g.: APES) the AEnZ plot (i.e. the spatial unit considered as homogenous to which the model is applied to get simulated values) and for a farm type model (e.g.: FSSIM-MP) the farm type. Within this area we only know the average value of the investigated property and not the within area variation. It is not always possible to have the average value for all the support units. For example for a SEAMLESS-IF project at European level which uses a model chain with FSSIM, farm behaviour are only computed for farm types of the 23 simple regions and not for all the European Farm types.

The "coverage rate" which corresponds to the ratio between the resolution and the extent.

As there is often a gap between the scale at which most agro-ecological informations are commonly available (i.e. observation scales and model scales) and the scale at which policy makers' decisions concerning agriculture and environment are made (i.e. decision scale) there is a great need for scale change procedures (Dalgaard *et al*., 2003; Bierkens *et al*., 2000). Scale change refers to transferring information across scales. Upscaling (or scaling-up) refers to transferring information[1] from a given scale to a larger scale while downscaling (or scaling-down) is associated to the opposite procedure. Authors distinguish three main procedures of scale change (Bierkens *et al*., 2000 and Faivre *et al*., 2004, see Figure 5.1):

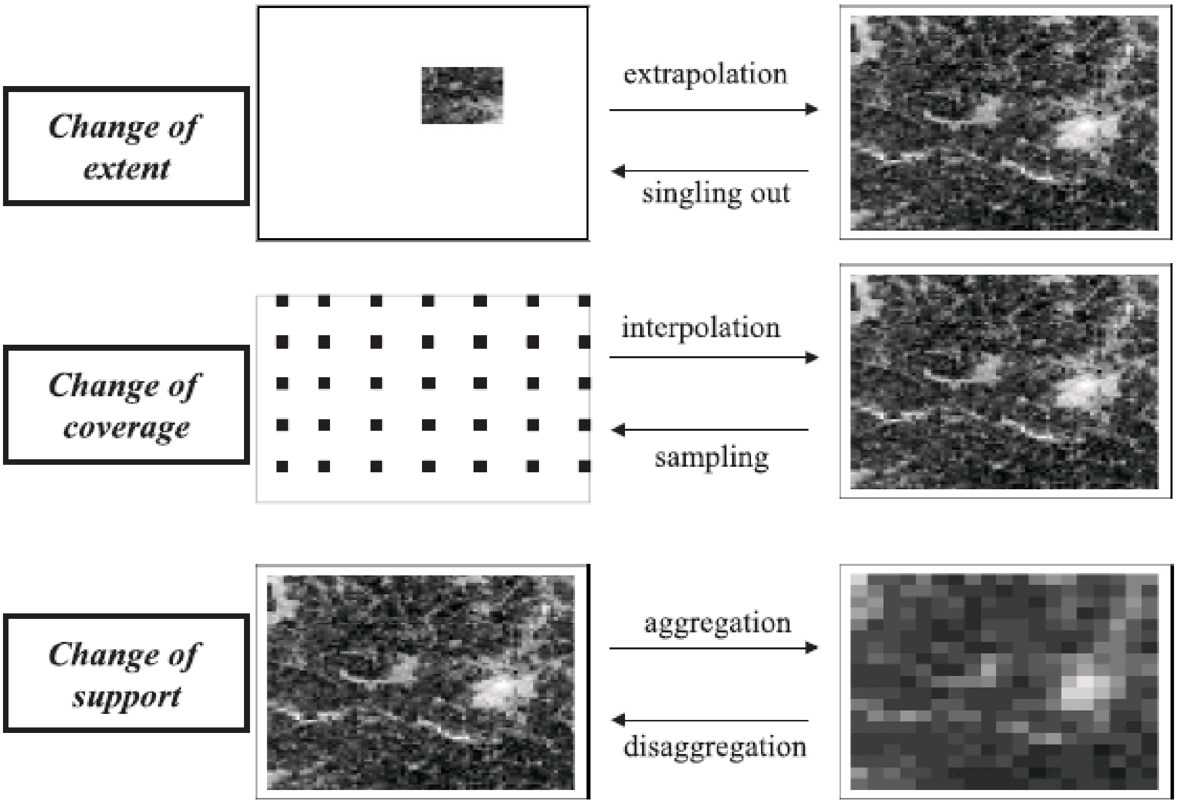
1. Increasing or decreasing the resolution called respectively "aggregation" and dissagreggation. For example, within SEAMLESS-IF the transfer of information from Homogenous Spatial Mapping Units (HSMU) to Agro-Environmental Zones (AEnZ) correspond to a procedure of aggregation.

2. Increasing or decreasing the extent, which is called "extrapolation" respectively "singling out". Generalisation of observed or calculated information beyond the extent leads to accept the assumption of scale-independent uniformitarianism of pattern and processes (Wiens, 1989).

3. Increasing or decreasing coverage rate called respectively "interpolation" and "sampling" (i.e. taking a sub-set of support units). For example the use of price-quantity responses of FSSIM farms to determine through regression equations the price-quantity responses of non-FSSIM farms (for more details see Bezlepkina *et al*., 2006) is a procedure of interpolation since the whole set of FSSIM farm types (i.e. farm types of simple sample regions) have been selected to cover the whole space of possible farm types characteristics used as parameters in the regression equations.

[1] In this report we do not discuss upscaling of processes which concerns the existence of different processes that act at different scales and is linked with the complexity scales.

Figure 5.1: Procedure of scale change involving extent, resolution and coverage rate (after Bierkens et al., 2000)



In many studies these three procedures are linked as increasing the extent usually also entails enlarging the support and sometime in coverage (Ewert *et al*., 2006, Dalgaard *et al*. 2003, Bierkens *et al*., 2000, Wiens, 1989).

5.2 Up-scaling concepts used in SEAMLESS

Within SEAMLESS-IF the concepts of resolution and extent[2] are used to describe the spatial and temporal scales of the policy assessment problem. The finest scale of the model(s) providing data to calculate indicators is the resolution of the indicator (i.e. "the finest unit on which the information is calculated") and the scale at which Policy Experts expect to have the information is the extent of the indicator.

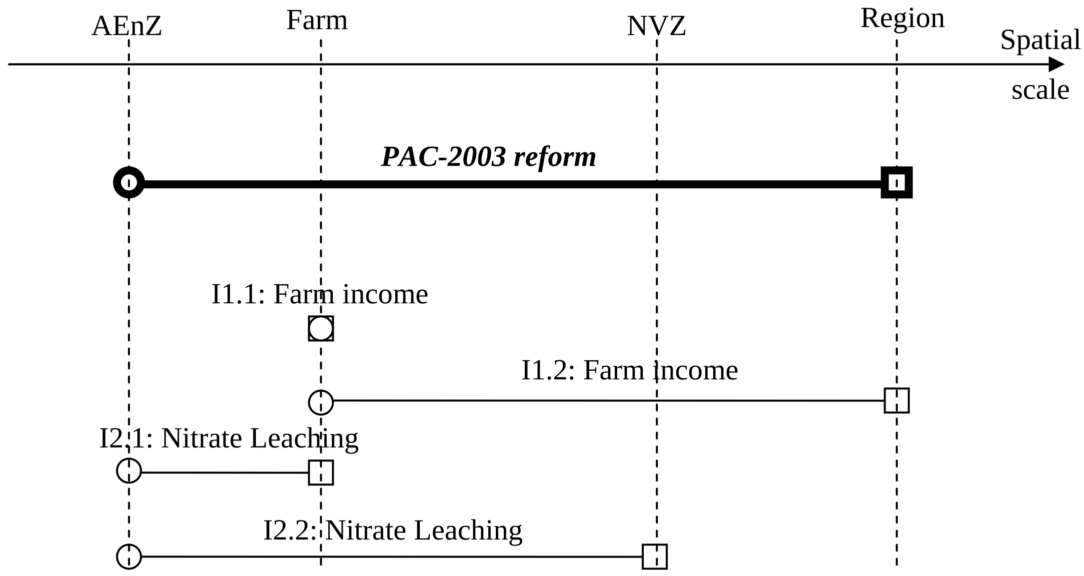
Indicator resolution and indicator extent (spatial and temporal) are endorsed indicator dependent and so within a SEAMLESS-IF project these combinations of scales can differ from a selected endorsed indicator to another. For a given project (i.e. policy assessment problem) resolutions of each selected indicator must be equal or higher to the problem resolution and extents of each selected indicator must be equal or smaller to problem extent

[2] **The "extent" is the spatial area and temporal period or horizon concerned by the study or the scales at which users expect indicator values** (e.g.: a watershed, a farm for spatial extents and a decade period or the 2020 horizon for temporal extents).

The "resolution" or "support unit" is the finest unit on which information is calculated or observed or displayed. When using models the spatial resolution corresponds to the simulation units which i.e. the spatial unit considered as homogenous to which the model is applied to get simulated values (e.g.: for a crop model like APES the plot or AEnZ and for a farm type model like FSSIM-MP the farm type.

(i.e. indicator resolutions and extents are restricted (limited) by the problem assessment resolution and extent, see Figure 5.2).

Figure 5.2: Example of link between spatial resolution and extent of the problem assessment and spatial resolutions and extents of some indicators (the same logic is applied to manage temporal scales within SEAMLESS-IF). In this figure circles indicate resolutions and squares indicate extents. The information corresponding to the problem assessment are in bold while the information related to indicators are in non bold. Scales of the project and of indicators are also described in the table



Main elements on scale change concepts and procedures are presented in PD6.2.2.3 (Turpin *et al*., 2007). Considering spatial scales of indicators two cases can be distinguished:

- the indicator resolution is equal to the extent and consequently no aggregation procedure is needed;
- the indicator resolution is smaller than the extent and consequently an aggregation procedure is needed.

The choice of the indicator resolution and the extent can be examined from either a scientific or a stakeholder point of view:

(i) a **scientific** point of view:

- the indicator resolution should be chosen for a given impact (indicator) at the level where the processes is modelled (e.g. field for nitrate leaching, field and farm for nitrogen emission to air).
- the extents should be the levels where it is scientifically relevant to observe an impact. For the water quality issue, it is at the hydrological watershed or an area concerned by a groundwater table.

(ii) a **stakeholder** point of view:

- the indicator resolution depend on the finest level where information can be provided, i.e., within SEAMLESS-IF the level of model which provide outputs used to assess the investigated indicator, e.g. AEnZ (field), farm type, region.
- the indicator extent should correspond with the level at which Policy experts expect information to take a decision, i.e. the decision scale: e.g. NUTS2 level.

A compromise should be reached between both expectations while avoiding some errors like:

- to aggregate model outputs at a scale where it is not relevant to observe the given impact (e.g.: a national or European nitrate leaching indicator);
- to provide the stakeholders with too detailed results at a scale which is not relevant for them (e.g. nitrate leaching at field level: this level is not relevant for policy making).

Given these considerations new indicators should be defined if the indicator extent is higher, than the scientifically relevant level of observation of the investigated process. Those indicators should be based on the distribution of results, calculated at the scientific level, within the extent: e.g. for nitrate leaching that currently cannot be calculated at hydrological level, within SEAMLESS-IF the highest scientific level is the farm. This level could not be relevant for policy decision making. In this case, new indicators can be defined: % of regions with nitrate leaching exceeding thresholds, % agricultural area with nitrate leaching exceeding thresholds and complementary statistics information can be provided quartile, median value of nitrate leaching in regions, etc. About 20 up-scaling procedures have been developed in SEAMLESS and their detailed description can be found in (Turpin *et al*, 2009).

5.3 Up-scaling methods in SEAMLESS

In SEAMLESS-IF the calculation of an indicator at a spatial scale higher than the scale of the model (which provides outputs used to calculate it) requires an up-scaling procedure (e.g., an indicator at regional scale calculated with FSSIM outputs). This type of up-scaling for indicator calculation corresponds to the spatial aggregation of models outputs and is mainly based on the use of:

- Typologies of fields (AEnZ), activities, farms and/or regions. These typologies simplify the diversity to allow handling it with the complex model structure developed in SEAMLESS-IF. These typologies create groups of items that should have homogenous characteristics and behaviour according to investigated policy and/or technological changes.
- Sets of weights for the typology groups (for weighting calculation) which translate the representativeness of the group within the whole population (e.g. number of farms in each farm type, area of an AEnZ in a region, total area of the farms for each farm type). In many case weights used to up-scale model outputs to the higher level may be inferred from the indicators characteristics. Indeed the combination of the assessment criteria unit, the indicators spatial scale and the model that provide outputs allow generally determining the weight to use in the up-scaling procedure. Table 5.1 presents some examples of relationships between the indicator characteristics and the weight used in the up-scaling procedure. The conceptual relation and the final list of the possible and relevant relations between indicator characteristics and weight used to upscale model outputs in SEAMLESS-IF have to be defined jointly by the researchers developing the integrated framework, the indicators and the applications (while testing SEAMLESS-IF).
- An algorithm of aggregation.

A series of algorithms have been developed and some of them are implemented in the final version of SEAMLESS-IF. These are two indicators (total farm income in a region and nitrate leaching in a region) which appear on the list of indicators available for the selection in the User Interface. Examples of indicator up-scaling algorithms are found in Table 5.1.

Table 5.1: Examples of relations between indicator characteristics and weight used for the up-scaling procedure required to calculate indicators

Indicators characteristics			Weight for up-scaling procedure
Unit of assessment criteria	Scales of assessment problem	Model providing the output that are up-scaled	
Ha	region	FSSIM	Number of represented farms x farm type area
Ha	NVZ	FSSIM	Number of represented farms x area inside the NVZ by farm type
Ha	AEnZ/Water basin	APES	Area inside the water basin by AEnZ by activity
Animal	region	FSSIM	Number of represented farms x number of animal by farm type
AWU	region	FSSIM	Number of represented farms x number of AWU by farm type
Farm	region	FSSIM	Number of represented farms

For all the economic indicators that can be calculated at NUTS2 level either by using an aggregation of FSSIM outputs or as a direct output from SEAMCAP, a systematic comparison will be held, to improve the complementarities between the two sets of indicators.

Within SEAMLESS-IF the user has to define the assessment problem scales (Jansen *et al.*, 2007) specified throughout the definition of its spatial and temporal extents ("the boundaries, the area or the magnitudes of the problem" i.e. the territory and the time horizon associated with the problem) and its spatial and temporal resolutions ("the finest detail that is distinguishable" i.e. on which indicator values can be displayed). Extent generally corresponds to decision scale. Resolution corresponds to model scales as these simulation units are used to represent (model) the diversity and the variability of the European conditions investigated. For instance across EU:

- AEnZ (i.e. Field scale), the simulation units of APES, represent the variability of soil-climate-slope conditions,
- Current activities, the simulation units of FSSIM-AM, represent the diversity of current agricultural activities within sample regions,
- Farm types, the simulation units of FSSIM-MP, represent the diversity of farms
- NUT2 markets, the simulation units of regional modules of SEAMCAP, represent the diversity of market conditions.

The models scales associated with a given problem are linked to the problem assessment scales. Indeed problem assessment scales allow to automatically infer the SEAMLESS model chain adapted to address the problem and consequently the associated models and model scales (Jansen *et al.*, 2007).

Within SEAMLESS-IF the user has also to select indicators and by this way determine the spatial and temporal scales associated with each selected indicator. By definition these scales are all potential "decision scales".

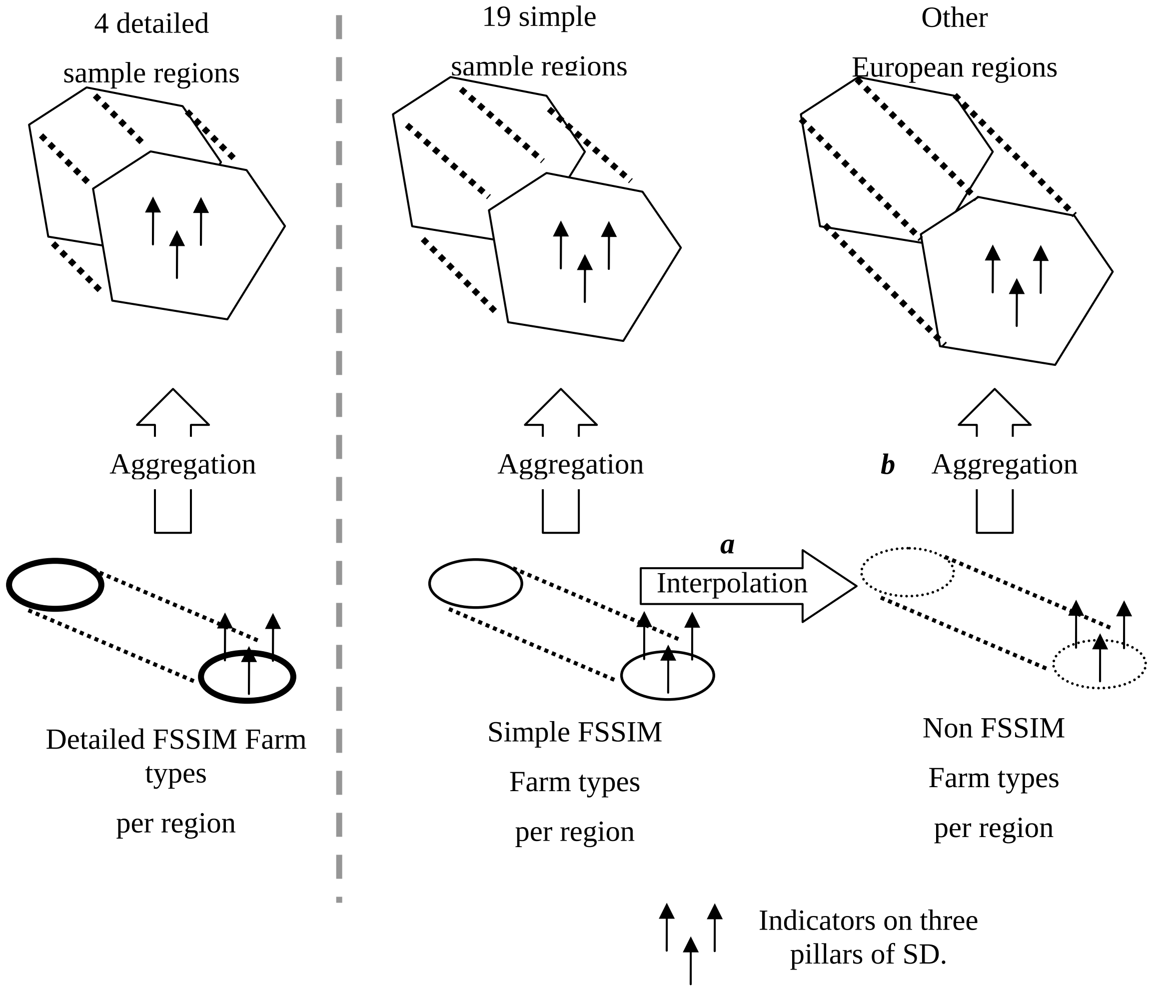
Ideally within SEAMLESS-IF quantitative indicators should be directly based on model outputs. However in many cases policy experts' requirements for impact assessment in terms of decision spatial scales exceed the application domain of available models and associated model outputs. Indeed in spite of its complex and important model chain covering a large range of spatial scales, SEAMLESS-IF does not allow to provide all the model outputs needed to calculate all indicators at the full range of spatial scales (for example nitrate leaching is provided by APES at AEnZ level but not at a higher level). Consequently within the simple and detailed sample regions indicators have to be calculated through two main ways according to the link between the scales at which the indicator have to be displayed and the scale of the model which provides outputs used for indicator calculation:

- if the indicators scale correspond to the model scale, indicators are calculated without scale change procedure. This type of indicators is called hereafter simple indicators.
- if the indicators scale is higher than the model scale indicators are calculated with upscaling procedure(s). This type of indicators is called hereafter complex indicators (see Figure 5.3).

In the second case, scale change can implies consideration of new processes and properties emerging on the scale investigated. Such emerging processes or properties influence the studied system state and consequently should be taken into account in the upscaling procedures. These processes can concern physical transfer between neighbouring AEnZs (e.g.: water, pollution and pathogen transfer between AEnZs) and can result from new function and organisation of the system at the higher scale (e.g.: AEnZ management depending on labour and equipment constraints at farm level, farm water allocation depending on water constraints at catchments basin level) (Faivre at al., 2004).

Considering the available models within SEAMLESS-IF some of these processes cannot be represented. For instance all processes related to physical transfer between AEnZ (i.e. AEnZ type) are not handled within SEAMLESS-IF. If this spatial interactions are important for the processes studied or for handling the user question it is necessary to interface the SEAMLESS model chain with another type of model (e.g.: an hydrological model) taking into account lateral water and element fluxes between AEnZs or to use outcomes of SEAMLESS model chain as inputs of an ad-hoc model (chain) dealing with this specific issue.

Figure 5.3: Overview of the main upscaling (of FSSIM outputs) procedures presented in this report and their link with the types of regions (detailed, simple, other) and farm types (detailed FSSIM, simple FSSIM and non FSSIM farm type). The letters in the right sight a (interpolation) and b (aggregation) describe the kind of upscaling procedures used to calculate indicators within other European regions.



Furthermore in SEAMLESS-IF, FSSIM-MP will only be run for the farm types of a sample (*i.e.* subset) of European regions (i.e. the simple sample regions), in order to limit time and resource required for i) data collection at regional level, especially for agro-management in FSSIM-AM ii) manual parameterization of FSSIM and iii) computer runs. Due to this situation the objective to demonstrate the potential use of SEAMLESS-IF to perform impact assessments at European level led to the development of a specific procedure to upscale outputs of the FSSIM-farm types (of the simple sample regions) to all the non FSSIM-farm types (of the non-sample European regions). As the “simple sample regions” (*i.e.* region type) have been selected to represent i) the variation in farm types within the Environmental Zones (EnZ) and ii) the biophysical variation (i.e. of AEnZ across EU25) this typology covers the whole space defined by the combination of farm types and EnZ. This situation allows to interpolate (vs. extrapolate) results from FSSIM-Farm type to non-FSSIM farm types. Once this interpolation is performed, and consequently the non-FSSIM farm outputs calculated (i.e. interpolated), the procedure of aggregation of information to provide indicators at a higher spatial scales is the same as the one used in simple and detailed region to upscale information from farm level to higher levels shortly presented above (see Figure 5.3).

6 Major scientific achievements and future developments of the content and use of the SEAMLESS-IF indicators

This chapter conclude on some of the major scientific achievements made in relation to the development of the indicator framework and the indicators. It also discusses some of the future possible developments that could be made in relation to; the implemented indicator framework GOF and its endorsed set of indicators. The chapter is divided into 6 sub section related to seven main areas of future development.

6.1 Indicator Framework and its implementation in the Graphical User Interface

The GOF is an attempt to create an indicator framework where the three dimensions of sustainability (SD) can be related to each other despite their inherent differences. This is a crucial requirement for integrated assessment tools which aim to consider trade-offs between as well as within the different dimensions of SD. In this role the GOF can support policy makers to create a comprehensive and transparent "picture" of the changes which the implementation of a specific policy option may bring to each of the sustainability dimensions so that no critical issues are overseen.

By linking the three dimensions of sustainability to three themes, *ultimate goals, means and processes of achievement*, the GOF helps non-specialists to better understand the positive and negative effects of the assessed policy. The GOF assists to structure the indicators into meaningful information related to the SD agenda and helps to balance between the different goals in each of the three dimensions. As implemented in SEAMLESS-IF the GOF is simple, straight forward and easy to understand and use for non-experts. The proposed approach also meets the recommendations in the EU guidelines for Impact Assessment (EC, 2005)

As there is no single operational definition of sustainability available, an indicator framework has to provide flexibility to comply to the interpretation of sustainability by the user. We conclude that the proposed GOF provides this feature. It is sufficiently flexible and open to engage stakeholders in a discussion around the goals, means and processes that are most important for a specific assessment problem including the indicators that are most relevant. Thus, the GOF does not impose a view of SD on the potential users but suggests subjects for discussion.

Five points of further development can be identified:

- An important challenge for future work is the population of the GOF with indicators representing all themes and scales and filling all gaps presently identified and to further enhance the assessment capabilities of included indicators (see section 6.2 and 6.3).
- The link between the selection of indicators in the pre-modelling phase of the SEAMLESS-IF and the post modelling phase should be improved.
- Work on aggregation of result within each theme and/or generic theme of the GOF should be made (see section 6.5). In relation to this work, ideas on how these aggregated indicators could be presented in the GOF and the GUI should be developed.
- The GOF as implemented in the final version of the SEAMLESS-IF should be tested with policy experts from different levels, (regional, national and EU) to enable

improvements of its implementation and better assessment of whether the GOF is able to create a more balanced selection of indicators.

- Implement other indicator frameworks in the SEAMLESS-IF to enable to test the GOF in relation to them, for example the DPSIR.

6.2 The SEAMLESS-IF set of indicators and their Methodology of Implementation

There is a substantial number of indicators implemented in the SEAMLESS-IF (see appendix 1). This set of indicators is covering many of the themes identified as important in the GOF. As a result of the up-scaling work undertaken in the project these indicators are also now covering several policy relevant scales. As a result of developing the methodology for implementing indicators in the Integrated Framework a good structure for communication between indicator developers and model developers have been developed using the creation of ontologies as its basis. This work ensures and facilitates that policy relevant indicators are being developed which over all increases the usefulness of the tool in the policy context.

However, due to the models initially included in the project there are still themes not covered by the GOF. Regarding the environmental dimension, a weak point is certainly the impacts on biodiversity. Indicators based on agricultural practices are included, like the crop diversity indicator (Table 3.1) but this is not enough to grasp all aspects of biodiversity. Moreover only few indicators representing the social dimension have been implemented in the SEAMLESS-IF and the extension of the list depends on the integration of social models. The social indicators that are available are to a large extent based on economic outputs, i.e. they are more socio-economic indicators than social and several themes in the social dimension of the GOF are still to be filled with indicators. There is however one exception and that is related to the quality of life where the so-called landscape amenity model (LAM) have been developed using environmental indicators as a basis(Pinto, Correira, T., *et al*. 2009).

Five points of further development can be identified:

- Initiate projects to develop models/indicators to cover the uncovered themes in the social dimension.
- Develop a model predicting the impact on biodiversity in a regional context taking into consideration land use, cropping systems and input use. To our knowledge few initiative are available. One recent initiative was the development of qualitative model (with output expressed on a qualitative scale between 1 and 5) on farm level from a group working with Life Cycle Analysis (Jeanneret *et al*., 2006). This model is adapted to Swiss conditions and would require an adaptation to rest of the EU. In terms of economic indicators there are two issues which remain uncovered by indicators: public preferences for environmental capital and non-farm activities.
- Continue to test and develop the landscape amenity model (LAM) initiating new test cases.
- Develop a Graphical User Interface to the LAM and integrate the LAM into SEAMLESS-IF.
- Develop the way uncertainties will be handled in the SEAMLESS-IF and include an assessment of the quality of each indicator in the GUI.

6.3 Up-scaling of indicators

The work on up-scaling procedures for indicators has progressed well methodologically. Various algorithms of up-scaling methods are listed in Table 5.1. There are however a few remaining challenges which are common to other up-scaling initiatives in the project (for example EXPAMOD, see D3.6.12, Adenäuer *et al*, 2009).

One of them is the issue of areas coverage. The problem is, as mentioned in Andresen *et al* (2007) that the agricultural area represented at the regional level in the SEAMLESS farm typology is at the moment too low, because the regulation on the use of FADN data which only allow the use of aggregates that are based on at least 15 sample farms.

*Table 6.1 The share of the agricultural area covered when applying the SEAMLESS farm typology at the regional level respecting the disclosure rules of FADN (sample regions in **BOLD**)*

Area coverage	FADN region
0-24%	Baleares, **Alentejo-Algarve**, Madrid, Kozep-Magyarorszag, Cantabria, Lisboa e Vale do Tejo (Ribatejo e Oeste), Pohjanmaa (Vali-Suomi), Corse
25-49%	Sodra och Mellersta Sveriges skogs- och mellanbygdslan, Saarland, Cyprus, Eszak-Magyarorszag, Provence-Alpes-Cote-d'Azur, Murcia, Sisa-Suomi (Ita-Suomi), Molise, Extremadura, Lazio, Liguria, Kozep-Dunantul, Rhone-Alpes, Pohjois-Suomi, Acores-Madeira, Estonia, Abruzzo, Languedoc-Roussillon, Toscana, Eszak-Alfold, Basilicata, Alsace, Navarra, Campania, Lan i Norra Sverige
50-74%	Haute-Normandie, **Andalucia** (incluido Ceuta & Melilla), **Midi-Pyrenees**, Pais Vasco, Northern Ireland, Marche, Del-Alfold, Umbria, Slovenia, Friuli-Venezia Giulia, Aquitaine, Etela-Suomi, Veneto, Limousin, Basse-Normandie, Rheinland-PfalzDel-Dunantul, Lombardia, Calabria, Sodra och Mellersta Sveriges slattbygdslan, **Brandenburg**, Valle d'Aosta, Mecklenburg-Vorpommern, Sicilia, Sardegna, Comunidad Valenciana, Asturias, **Poitou-Charentes**, Aragon, Piemonte, Nyugat-Dunantul, **Auvergne**, Pays-de-la-Loire, Bourgogne, England-West, Franche-Comte, Galicia, Sachsen, Slovakia, Sterea Ellas-Nissi Egaeou-Kriti, La Rioja, Thessalia, Hessen, Picardie, Trentino-Alto Adige, Lorraine, Lithuania, Baden-Wurttemberg, Norte-Centro (PT)
75-100%	Nord-Pas-de-Calais, Puglia, Latvia, Centre (FR), Bretagne, Thuringen, **Netherlands**, Nordrhein-Westfalen, Luxembourg, England-East, Schleswig-Holstein, Sachsen-Anhalt, Castilla-La Mancha, England-North, **Castilla y Leon, Bayern**, Belgium, Malopolska-Pogorze, Makedonia-Thraki, Ipiros-Peloponnisos-Nissi Ioniou, Austria, Ile-de-France, Hamburg, Bremen, Berlin, Niedersachsen, **Emilia-Romagna**, Czech republic, Scotland, Pomorze-Mazury, **Denmark**, Canarias, Champagne-Ardenne, Wales, Ireland, **Mazowsze-Podlasie**, Wielkpolska-Slask

Initially it was estimated that 80% of the agricultural area should be represented at the regional level when applying the typology, but this is not the case in the present dataset where all dimensions of the farm types (Size, intensity and specialisation/land use) is included and taken into account the threshold level of 15 sample farms. Only in 37 of the 117 FADN regions we have more than 75% of the area represented (see Table 6.1). In 33 of the regions less than 50% of the area is represented.

There are 4 types of solutions to the area coverage problem, as identified in Andersen *et al* (2007):

- Option 1 is to merge all farm types with less than 15 sample farms into one or more aggregated farm types. This will keep the information on farm types that are already represented, but it will also create some new aggregated farm types that will be very heterogeneous.
- Option 2 is to skip one or more dimensions of the farm types in the critical regions. This mean that we will loose details in some of the farm types already represented, but that we will increase the area represented.
- Option 3 is to keep the farm types that already have more than 15 sample farms and add the farm types that have less than 15 sample farms by letting these be represented by farms of the same type in neighbouring regions.
- Option 4 would be to try to elaborate a method to add and describe the farm types based on the method for spatial allocation of farm types. This has already been used on the agricultural area, so that the data in the database will include all farm types present at the regional level and information on the area they manage.

At the moment the most viable solution to this problem seems to be a variant of option 3. The farm type information will be aggregated for 'agro-management zones' i.e. for each of the 13 environmental zones used in the biophysical typology. This approach is also used in relation to alternative activities, where rotation constraints are gathered for these regions. It will thus fit in the overall spatial framework. This should get an area coverage very close to 100% in all regions – if not we will handle the specific problems individually to reach a 100% coverage.

When this issue is addressed, the up-scaling of indicators will become more precise.

The second methodological issue, as has been mentioned in Turpin *et al* (2007), is the use of the transformation of one farm type to another which in the project is addressed in the structural change model (only partially integrated into the framework) and documented in Zimmermann, *et al* (2008). This issue is also directly linked to the up-scaling procedure in EXPAMOD.

One reminder to make here is that indicators are calculated for the baseline and for the ex-ante policy scenario. The matter here is that weights derived from the observed data are only suitable for the calibration of the model in the base year, since they refer to FSSIM results. For ex-ante scenario analysis, farm type weights should be adjusted to consider structural changes in agriculture (see Zimmermann *et al.*, 2008). Within this aggregation structural change can be reflected by adjusting the Farmtype weights according to the results of the structural change analysis as described in Zimmermann *et al* (2008). Their estimates for stationary transition probabilities are made available in the SEAMLESS database and connected to the SEAMLESS typology so that they could directly be used for any up-scaling procedure. However this is technically not yet integrated into SEAMLESS-IF due to technical problems.

The implementation of up-scaling algorithms in the SEAMLESS-IF has been done to a limited extend partly due to the availability of resources. With respect to the Graphical Interface of SEAMLESS-IF, further flexibility can be allowed by developing a so-called Indicator Editor where a user could select the level of up-scaling and define which weights (s)he is willing to use.

The main explanation for the limited implementation of up-scaled indicators (two up-scaled indicators) into the software is that the synthesis of data required for calculation of an aggregated/upscaled indicator is rather demanding. For example, the data comes from various sources, FSSIM model runs (each model run for one farm type) and the database (weights). Therefore specific wrapping programming procedures need to be developed for each up-scaled indicator. This is similar to the input data preparation process for EXPAMOD (see D3.6.12, Adenäuer *et al*, 2009). In other words, separate models that ensure the calculation of indicators are currently written in Java code whereas when compared to the nature of other backbone models integrated into SEAMLESS-IF, these calculation routines could have been programmed in GAMS for example and consequently integrated into the software framework. This is here presented as an alternative and not as criticism to the approach followed.

In any case, the demanding process of implementing the up scaled indicators is technically comparable to the integration of model components, when each type of calculation algorithm needs to be programmed and software procedures need to be written to connect the input and output flows of such algorithms. Thus this requires a combination of modelling, programming and software developing skills which has always been a challenge due to a limited amount of available persons with these skills.

6.4 Use of reference levels

In order to interpret indicators and assess the impact of policy and behavioral changes and innovations in agriculture and agroforestry, adequate reference levels are crucial. A literature review have contributed to an extended glossary of terminology for further use in the SEAMLESS project, and has also clarified the interpretations given in different disciplines on the various components related to reference levels (see PD2.5.1). Five types of reference levels, thresholds, critical values and critical ranges, target values and quality norms retained our attention. Several options can be envisaged to identify these reference values.

None of these types of reference levels have been implemented in the SEAMLESS-IF yet but several of the integrative steps have been taken, for example how to integrate reference levels in to the ontology.

One future possibility could be to just implement quality norms into the SEAMLESS –IF and compare the performance of the relevant indicators in the policy scenarios to these norms.

Further work is necessary both on the definition of reference levels including temporal dimensions when the time span for comparisons is a couple of years.

6.5 Aggregation of indicators

As have been discussed in this report the SEAMLESS project has developed a rather large set of indicators covering several scales. It is clear from the interaction with potential users of the integrated framework that different types of indicators are needed. To analyse specific issues the specific indicators are needed. However when it is more important to get a general view of the impact of a new policy, on one or a combination of the dimensions of sustainable development an aggregation of a set of indicators is needed.

As a consequence there is a need to develop aggregation methods in order to synthesise the information provided by a set of many indicators, so that comparisons of scenarios and conclusions concerning sustainability is possible to simplify. However as concluded in the SEAMLESS project in interaction with its potential users in the policy sphere such a procedure should never replace a first analysis using non aggregated indicators. Instead, the two steps should be seen as complementary.

The aggregation of indicators faces several methodological difficulties, including how to deal with weighting, thresholds, and the consecutive loss of information. A wide range of methods have been proposed to avoid some basic pitfalls such as aggregating values with different units. But we are in the project well aware of the subjectivity of weighting as inherent to this kind of approach, especially when it addresses the assessment of sustainable development. As a consequence two complementary approaches to combining indicators were studied during the project:

- A multi criteria assessment based on a survey approach. The output is a set of weights for one or more themes shown in the indicator framework developed by WP2.
- Those weights could be used to build a “dashboard” based on a hierarchical decision tree using qualitative rules.

A Multi Criteria Analysis allows a transparent weighting procedure and can serve as a basis to a more qualitative approach using a dashboard presentation. Such an approach provides a presentation of aggregation results in an easily intelligible form.

The implementation of this method in SEAMLESS-IF remains to be implemented and tested, since it was not possible to carry out during the current project as the priority was laid on the implementation of “simple” indicators.

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Appendix 1 Indicator table

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
			(id from sheet model)		(id from sheet upscaling procedure)	(id from sheet spatialscale)	(id from sheet temporalscale)			(id from sheet indicatorgroup)
1011	Use of mineral nitrogen fertilizer per farm	Amount of nitrogen fertilizer used on crops and grassland per farm (expressed in kg nitrogen per ha and year)	6	NITR	1	1	1	kg N/ha/y	implemented	1
1012	Use of mineral nitrogen fertilizer per region	Amount of nitrogen fertilizer used on crops and grassland per farm (expressed in kg nitrogen per ha and year)	1	?	6	3	1	kg N/ha/y	not implemented yet	1
1013	Regional mineral N use	Amount of nitrogen fertilizer used on crops and grassland per farm for a region (expressed in kg nitrogen per ha and year)	3	NMIN.NUTS.REG	1	5	1	kg N/ha/y	implemented	1
1014	Regional mineral N use for a member state	Amount of nitrogen fertilizer used on crops and grassland per region of a member state (expressed in kg nitrogen per ha and year)	3	NMIN.COUNTRY.REG	1	6	1	kg N/ha/y	implemented	1
1015	Regional mineral N use per aggregate	Amount of nitrogen fertilizer used on crops and grassland for the regions of an aggregate of member states	3	NMIN.AGGREGATE.REG	1	7	1	kg N/ha/y	implemented	1
1016	Nitrogen use per forage area.	Amount of total nitrogen (mineral and organicà used on forage area C6per farm (expressed in kg nitrogen per ha and year)	1		1	1	1	kg N/ha	not implemented yet	1
1017	Total nitrogen use per farm	Amount of total nitrogen (mineral and organicà used on crops and grassland per farm (expressed in kg nitrogen per ha and year)	1		1	1	1	kg N/ha	not implemented yet	2
1018	Organic nitrogen use per farm	Amount of organic nitrogen used on crops and grassland per farm (expressed in kg nitrogen per ha and year)	1		1	1	1	kg N/ha	not implemented yet	2

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1021	Nitrate leaching per farm	Amount of nitrate leached by farm type under the root zone of crops and grassland due to fertilization and nitrogen management after harvest (crop residues, catch crops, etc.), (expressed in kg nitrogen in nitrate form per ha and year)	6	POLLUT	1	1	1	kg NO3-N/ha/y	implemented	2
1022	Percent of area with high leaching	Percent of area of a region with activities responsible for high nitrate leaching over a threshold based on the water quality guideline	1	?	12	3	1	%/y	implemented	2
1031	Pesticide use	amount of pesticides used (expressed in kg of active ingredients per ha and year) in a farm to evaluate the pressure on all environmental compartments	6	PHY	1	1	1	g active ingredient/ ha/y	implemented	3
1032	Percent of area with high pesticide use	Percent of area of a region with activities presenting a high pesticide use over a threshold	1	?	18	3	1	%/y	not implemented yet	3
1041	Soil organic matter change per farm	Average change of the soil organic matter content in soil per farm (expressed in percent soil organic matter in soil per year)	6	ORGMAT	1	1	1	%/y	implemented	4
1042	Carbon sequestration per farm	Average carbon sequestration by rotations per farm (expressed in ton of carbon per ha and year)	6	?	1	1	1	t/ha/y	implementation in progress	4
1043	Carbon sequestration per region	Average carbon sequestration by rotations per region (expressed in ton of carbon per ha and year)	1	?	6	3	1	t/ha/y	not implemented yet	4
1051	Soil erosion per farm	Soil losses by water erosion along the slope (expressed in ton of soil per ha)	6	EROSION	1	1	1	t/ha/y	implemented	5
1052	Erosion peak per farm	Daily maximumlosses by water erosion along the slope (expressed in ton of soil per ha and day)	6	?	1	1	1	t/ha/d	implementation in progress	5
1053	Percent of area with high erosion	Percent of area of a region with activities responsible for high erosion, over a threshold	1	?	19	3	1	%/y	not implemented yet	5

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1061	Surface runoff per farm	Surface runoff due to low water infiltration per farm type (expressed in mm water per ha and year)	6	?	1	1	1	mm/y	implementation in progress	6
1062	Surface runoff peak per farm	Daily maximum surface runoff due to low water infiltration per farm type (expressed in mm water per ha and day)	6	?	1	1	1	mm/d	implementation in progress	6
1063	Percent of area with high runoff	Percent of area of a region with activities responsible for high runoff, over a threshold	1	?	20	3	1	%/y	not implemented yet	6
1071	Water use (quantity)	Amount of water used by irrigation on crops per farm (expressed in mm water per ha and year)	6	WATER	1	1	1	mm/y	implemented	7
1072	Percent of area with high water use	Percent of area of a region with activities responsible for high water use by irrigation, over a threshold	1	?	21	3	1	%/y	not implemented yet	7
1081	Ammoniac volatilization (fertilization) per farm	Volatilization of ammoniac due to nitrogen fertilization per farm (expressed in nitrogen in form of ammoniac per ha and year)	6	?	1	1	1	kg NH3-N/ha/y	implementation in progress	8
1082	Ammoniac volatilization (fertilization) per region	Volatilization of ammoniac due to nitrogen fertilization per region after aggregation of farm value (expressed in nitrogen in form of ammoniac per ha and year)	1	?	6	3	1	kg NH3-N/ha/y	not implemented yet	8
1091	Crop diversity	Land use diversity (and, conversely, dominance) – relevant for biodiversity and for environmental quality, in relation to cropping pattern and concentration/ distribution.	1	?	1	2	1	unitless	implementation in progress	9
1101	Percent low fertilised grassland per farm	% low fertilised grassland per farm type	1	?	1	2	1	%/y	not implemented yet	10
1111	Percent non sprayed area per farm	% non sprayed by pesticide area per farm tye	1	?	1	2	1	%/y	not implemented yet	11

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1121	Percent area with conservation tillage per farm+B65	% area with conservation tillage (no-till or reduced tillage) per farm type	1	?	1	2	1	%/y	not implemented yet	12
1131	Percent of area with catch crop	% of area with catch crop per farm type	1	?	1	2	1	%/y	not imple-mented yet	13
1141	Pesticide leaching	amount of pesticides (active ingredients) leached under the root to groundwater	6	?	1	1	1	g active ingredient/ ha/y	not implemented yet	14
1151	Pesticide runoff	amount of pesticides (actives ingredients) in the soluble fraction transfered by runoff to surface water	6	?	1	1	1	g active ingredient/ ha/y	not implemented yet	15
1161	Pesticide volatilization	amount of pesticides (active ingredients) volatilized	6	?	1	1	1	g active ingredient/ ha/y	not implemented yet	16
1171	Soil fertility loss per farm	% of farm area with significant increase of soil organic matter	6	?	1	1	1	%/y	not implemented yet	17
1172	Soil fertility gain per farm	% of farm area with significant decrease of soil organic matter	6	?	1	1	1	%/y	not implemented yet	17
1181	Regional nitrate surplus	Surplus of nitrate resulting from the calculation of regional balance (nitrogen input-nitrogen output-NH3 volatilization) for a region	3	NIT_SUR.NUTS.REG	1	5	1	kg N/ha/y	implemented	18
1182	Regional nitrate surplus for a member state	Surplus of nitrate resulting from the calculation of a balance (nitrogen input-nitrogen output-NH3 volatilization) for the regions of a member state	3	NIT_SUR.COUNTRY.REG	1	6	1	kg N/ha/y	implemented	18
1183	Regional nitrate surplus per aggregate	Surplus of nitrate resulting from the calculation of aggregateal balance (nitrogen input-nitrogen output-NH3 volatilization) for the regions of an aggregate of member states	3	NIT_SUR.AGGREGATE.REG	1	7	1	kg N/ha/y	implemented	18

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1191	Regional CH4 emissions	amount of CH4 that is emitted due to livestock (entheric fermentation, manure management) and rice production for a region	3	CH4_EMI.NUTS.REG	1	5	1	kg CH4/ha/y	implemented	19
1192	Regional CH4 emissions for a member state	amount of CH4 that is emitted due to livestock (entheric fermentation, manure management) and rice production per member state	3	CH4_EMI.COUNTRY.REG	1	6	1	kg CH4/ha/y	implemented	19
1193	Regional CH4 emissions per aggregate	amount of CH4 that is emitted due to livestock (entheric fermentation, manure management) and rice production per aggregate	3	CH4_EMI.AGGREGATE.REG	1	7	1	kg CH4/ha/y	implemented	19
1201	Regional N2O emissions	amount of N2O that is emitted from the land managements and breeding activities on a yearly basis for a region	3	N2O_EMI.NUTS.REG	1	5	1	kg N2O/ha/y	implemented	20
1202	Regional N2O emissions for a member state	amount of N2O that is emitted from the land managements and breeding activities on a yearly basis for the regions of a member state	3	N2O_EMI.COUNTRY.REG	1	6	1	kg N2O/ha/y	implemented	20
1203	Regional N2O emissions per aggregate	amount of N2O that is emitted from the land managements and breeding activities on a yearly basis for the regions of an aggregate of countries	3	N2O_EMI.AGGREGATE.REG	1	7	1	kg N2O/ha/y	implemented	20
1211	Regional warming potential	Aggregation of CH4 and N2O emissions weighted by a greenhouse effect impact factor for a region	3	GLWP.NUTS.REG	1	5	1	kg equivalent CO2/ha/y	implemented	21
1212	Regional warming potential for a member state	Aggregation of CH4 and N2O emissions weighted by a greenhouse effect impact factor for the regions of a member state	3	GLWP.COUNTRY.REG	1	6	1	kg equivalent CO2/ha/y	implemented	21
1213	Regional warming potential per aggregate	Aggregation of CH4 and N2O emissions weighted by a greenhouse effect impact factor for the regions of an aggregate of countries	3	GLWP.AGGREGATE.REG	1	7	1	kg equivalent CO2/ha/y	implemented	21
1221	Regional ammoniac emissions	Volatilization of ammoniac due to nitrogen fertilization or/and livestock (stable, grazing,	3	?	1	5	1	kg NH3-N/ha/y	not implemented	22

		manure storage and fertilization) for a region, (expressed in nitrogen in form of ammoniac per ha and year)							yet	
id	**label_en**	**description**	**model**	**modeloutputname**	**upscaling procedure**	**spatialscale**	**temporalscale**	**unit**	**implemented**	**ispartofindicatorgroup**
1222	Regional ammoniac emissions for a member state	Volatilization of ammoniac due to nitrogen fertilization or/and livestock (stable, grazing, manure storage and fertilization) for the regions of a member state, (expressed in nitrogen in form of ammoniac per ha and year)	3	?	1	6	1	kg NH3-N/ha/y	not implemented yet	22
1231	Regional phosphorus balance	Phosphorus balance (input-output) for a region. Inputs are phosphorus from mineral fertilizer and at tail. Outputs are phophorus exported by crops (expressed in kg P2O5/ha)	3	PHO_SUR.NUTS.REG	1	5	1	kg P2O5/ha/y	implemented	23
1232	Regional phosphorus balance for a member state	Phosphorus balance (input-output) for the regions of a member state. Inputs are phosphorus from mineral fertilizer and at tail. Outputs are phophorus exported by crops (expressed in kg P2O5/ha)	3	PHO_SUR.COUNTRY.REG	1	6	1	kg P2O5/ha/y	implemented	23
1233	Regional phosphorus balance per aggregate	Phosphorus balance (input-output) for the regions of an aggregate of countries. Inputs are phosphorus from mineral fertilizer and at tail. Outputs are phophorus exported by crops (expressed in kg P2O5/ha)	3	PHO_SUR.AGGREGATE.REG	1	7	1	kg P2O5/ha/y	implemented	23
1241	Regional use of mineral phosphorus	Use of mineral phosphorus for a region (expressed in kg P2O5/ha)	3	PMIN.NUTS.REG	1	5	1	kg/ha/y	implemented	24
1242	Regional use of mineral phosphorus for a member state	Use of mineral phosphorus for the regions of a member state (expressed in kg P2O5/ha)	3	PMIN.COUNTRY.REG	1	6	1	kg/ha/y	implemented	24
1243	Regional use of mineral phosphorus per aggregate	Use of mineral phosphorus for the regions of an aggregate of countries (expressed in kg P2O5/ha)	3	PMIN.AGGREGATE.REG	1	7	1	kg/ha/y	implemented	24
1244	Regional use of mineral postassium	Use of mineral postassium for a region (expressed in kg K2O/ha)	3	KMIN.NUTS.REG	1	5	1	kg/ha/y	implemented	24

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1245	Regional use of mineral postassium for a member state	Use of mineral postassium for the regions of a member state (expressed in kg K2O/ha)	3	KMIN.COUNTRY.REG	1	6	1	kg/ha/y	implemented	24
1246	Regional use of mineral postassium per aggregate	Use of mineral postassium for the regions of an aggregate of countries (expressed in kg K2O/ha)	3	KMIN.AGGREGATE.REG	1	7	1	kg/ha/y	implemented	24
1251	Regional energy use by mineral fertilize	Indirect energy use due to mineral fertilizer application for a region (expressed in ton of oil equivalent (toe))	3	MIN_ENER.NUTS.REG	1	5	1	toe/ha/y	implemented	25
1253	Regional energy use by mineral fertilize per aggregate	Indirect energy use due to mineral fertilizer application for the regions of an aggregate of countries (expressed in ton of oil equivalent (toe))	3	MIN_ENER.AGGREGATE.REG	1	7	1	toe/ha/y	implemented	25
1261	Average farm N surplus	Nitrogen balance at farm gate averaged by farm area. Imports are: purchased supplement feed, fertilizer, animals, imported manure N, N deposition, biological fixation. Exports are: sold feed in crops and roughage, milk, meat, animals, exported manure N	1	NFarmsurplus	1	2	1	kg N/ha	implemented	26
1262	Farm gate N surplus	Nitrogen balance at farm gate. Imports are: purchased supplement feed, fertilizer, animals, imported manure N, N deposition, biological fixation. Exports are: sold feed in crops and roughage, milk, meat, animals, exported manure N	1	Farmgate_Nsurplus	1	2	1	kg N/farm	implemented	26
1263	Farm gate N efficiency	Ratio N exported/N imported at farm gate. Imports are: purchased supplement feed, fertilizer, animals, imported manure N, N deposition, biological fixation. Exports are: sold feed in crops and roughage, milk, meat, animals, exported manure N	1	Farmgate_Nefficiency	1	2	1	%	implemented	26
1271	Energy use of mineral nitrogen	Indirect energy use due to consumption of mineral nitrogen fertilizer on crops and grassland per farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1272	Energy use of tillage	Direct energy use due to tillage for the crops of a farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1273	Energy use of irrigation	Direct energy use due to irrigation for the crops of a farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1274	Energy use for feed	Indirect energy use by imported feed for a farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1275	Energy use of animal housing	Direct energy use in housing operation and building heating for livestock (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1276	Energy use for crop and forage per farm	Main sources of energy use (mineral nitrogen+tillage+irrigation) for crop and forage production of a farm type	1		1	2	1	toe/ha	not implemented yet	27
1277	Energy use for livestock per farm	Main sources of energy use (feed and housing) for livestock of a farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1278	Energy use per farm	Energy use for crop and forage production (mineral nitrogen+tillage+irrigation) and livestock (feed and housing) of a farm type (expressed in ton of oil equivalent (toe)/ha)	1		1	2	1	toe/ha	not implemented yet	27
1281	Average energy efficiency for crop	Ratio: Energy use for crop and forage production/crop and forage production (expressed in ton of oil equivalent (toe)/ton dry matter)	6			2	1	toe/t DM	not implemented yet	28
1282	Average energy efficiency for milk production	Ratio: Energy use for milk production/milk production (expressed in ton of oil equivalent (toe)/ton milk)	1			2	1	toe/t milk	not implemented yet	28
1283	Average energy efficiency for beef production	Ratio: Energy use for crop and forage production/crop and forage production (expressed in ton of oil equivalent (toe)/ton beef)	1			2	1	toe/t beef	not implemented yet	28

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
1291	Stocking rate on the total forage area	Stocking rate (livestock density) on the total forage area of a farm type (expressed in LU/ha of forage area)	1			2	1	LU/ha	not implemented yet	29
1292	Stocking rate on the grassland area	Stocking rate (livestock density) on the grassland (permanent and sown) area of a farm type (expressed in LU/ha of grassland area)	1			2	1	LU/ha	not implemented yet	29
1301	Share of permanent grassland in the forage area	Share of permanent grassland in the forage area of a farm type (expressed in %)	1			2	1	%	not implemented yet	30
1302	Share of grassland in the forage area	Share of grassland (permanent and sown) in the forage area of a farm type (expressed in %)	1			2	1	%	not implemented yet	30
10101	Agricultural Income at EU level	Value of agricultural output (including premia/subsidies) minus variable costs at EU level	3	TOT_AGR_INC.AGGREGATE.REG	1	7	1	Mn €	implemented	101
10102	Agricultural Income at member state level	Value of agricultural output (including premia/subsidies) minus variable costs at member state level	3	TOT_AGR_INC.COUNTRY.REG	1	6	1	Mn €	implemented	101
10103	Agricultural Income at NUTS2 level	Value of agricultural output (including premia/subsidies) minus variable costs at NUTS2 level	3	TOT_AGR_INC.NUTS.REG	1	5	1	Mn €	implemented	101
10104	Agricultural income per total labour input in a region	Agricultural income per total labor input in a region	3	INC_AWU.NUTS.REG	1	5	1	Euro/AWU	implemented	101
10105	Agricultural income per total labour input at a member state	Agricultural income per total labor input at a member state	3	INC_AWU.COUNTRY.REG	1	6	1	Euro/AWU	implemented	101
10106	Agricultural income per total labour input at EU level	Agricultural income per total labor input at EU level	3	INC_AWU.AGGREGATE.REG	1	7	1	Euro/AWU	implemented	101
10107	Agricultural income per ha in a region	"Income per hectare of agricultural production activities" in a region	3	INC_ACT.NUTS.REGACT	1	5	1	Euro/ha	implemented	101
10108	Agricultural income per ha at a member state	"Income per hectare of agricultural production activities" at a member state	3	INC_ACT.COUNTRY.REGACT	1	6	1	Euro/ha	implemented	101

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
10109	Agricultural income per ha at EU level	"Income per hectare of agricultural production activities" at EU level	3	INC_ACT.AGGREGATE.REGACT	1	7	1	Euro/ha	implemented	101
10201	Total value of animal production per hectare in a region	Total value of all primary animal agricultural products produced per hectare at NUTS2 level	3	ANIM_VAL.NUTS.REG	1	5	1	Euro/ha	implemented	102
10202	Total value of animal production per hectare at member state level	Total value of all primary animal agricultural products produced per hectare at member state level	3	ANIM_VAL.COUNTRY.REG	1	6	1	Euro/ha	implemented	102
10203	Total value of animal production per hectare at EU level	Total value of all primary animal agricultural products produced per hectare at EU level	3	ANIM_VAL.AGGREGATE.REG	1	7	1	Euro/ha	implemented	102
10301	Total value of crop production per hectare in a region	Total value of all primary crop agricultural products produced on the NUTS2 level	3	CROP_VAL.NUTS.REG	1	5	1	Euro/ha	implemented	103
10302	Total value of crop production per hectare at member state level	Total value of all primary crop agricultural products produced at member state level	3	CROP_VAL.COUNTRY.REG	1	6	1	Euro/ha	implemented	103
10303	Total value of crop production per hectare at EU level	Total value of all primary crop agricultural products produced on the NUTS2 level	3	CROP_VAL.AGGREGATE.REG	1	7	1	Euro/ha	implemented	103
10401	Total agricultural output in a region	Total agricultural output value per region in a region	3	TOT_AGR_OUT_VAL.NUTS.REG	1	5	1	Mn €	implemented	104
10402	Total agricultural output at member state level	Total agricultural output value per region at a member state	3	TOT_AGR_OUT_VAL.COUNTRY.REG	1	6	1	Mn €	implemented	104
10403	Total agricultural output at EU level	Total agricultural output value per region at EU level	3	TOT_AGR_OUT_VAL.AGGREGATE.REG	1	7	1	Mn €	implemented	104
10405	Total agricultural output per hectare in a region	Total agricultural output value in a region	3	OUT_VAL.NUTS.REG	1	5	1	Euro/ha	implemented	104
10406	Total agricultural output per hectare at member state level	Total agricultural output value per region at member state level	3	OUT_VAL.COUNTRY.REG	1	6	1	Euro/ha	implemented	104
10407	Total agricultural output per hectare at EU level	Total agricultural output value per region at EU level	3	OUT_VAL.AGGREGATE.REG	1	7	1	Euro/ha	implemented	104

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
10501	Total agricultural inputs in a region	Total value of all inputs but labour for producting agricultural primary products in a region	3	TOT_AGR_INP_VAL.NUTS.REG	1	5	1	Mn €	implemented	105
10502	Total agricultural inputs at a member state	Total value of all inputs but labour for producting agricultural primary products at a member state	3	TOT_AGR_INP_VAL.COUNTRY.REG	1	6	1	Mn €	implemented	105
10503	Total agricultural inputs at EU level	Total value of all inputs but labour for producting agricultural primary products at EU level	3	TOT_AGR_INP_VAL.AGGREGATE.REG	1	7	1	Mn €	implemented	105
10504	Total agricultural inputs per hectare in a region	Per hectare value of all inputs for producting agricultural primary products at NUTS2 level	3	IN_VAL.NUTS.REG	1	5	1	Euro/ha	implemented	105
10505	Total agricultural inputs per hectare at a member state	Per hectare value of all inputs for producting agricultural primary products at member state level	3	IN_VAL.COUNTRY.REG	1	6	1	Euro/ha	implemented	105
10506	Total agricultural inputs per hectare at EU level	Per hectare value of all inputs for producting agricultural primary products at EU level	3	IN_VAL.AGGREGATE.REG	1	7	1	Euro/ha	implemented	105
10601	Direct CAP payments at EU level	Payments made directly to farmers under the First Pillar of the CAP, at EU level	3	TOT_PREM.AGGREGATE.REG	1	7	1	Mn €	implemented	106
10602	Direct CAP payments at member state level	Payments made directly to farmers under the First Pillar of the CAP, at member state level	3	TOT_PREM.COUNTRY.REG	1	6	1	Mn €	implemented	106
10603	Direct CAP payments at NUTS2 level	Payments made directly to farmers under the First Pillar of the CAP at NUTS2 level	3	TOT_PREM.NUTS.REG	1	5	1	Mn €	implemented	106
10604	Subsidies received per ha and region at EU level	Subsidies received per ha and region at EU level	3	REG_SUBSIDY.AGGREGATE.REG	1	7	1	Euro/ha	implemented	106
10605	Subsidies received per ha and region at member state level	Subsidies received per ha and region at member state level	3	REG_SUBSIDY.COUNTRY.REG	1	6	1	Euro/ha	implemented	106
10606	Subsidies received per ha and region at NUTS2 level	Subsidies received per ha and region at NUTS2 level	3	REG_SUBSIDY.NUTS.REG	1	5	1	Euro/ha	implemented	106
10607	Subsidies received per annual work unit and region at EU level	Subsidies received per annual work unit and region at EU level	3	AWU_SUBSIDY.AGGREGATE.REG	1	7	1	Euro/AWU	implemented	106

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
10608	Subsidies received per annual work unit and region at member state level	Subsidies received per annual work unit and region at member state level	3	AWU_SUBSIDY.COUNTRY.REG	1	6	1	Euro/AWU	implemented	106
10609	Subsidies received per annual work unit and region at NUTS2 level	Subsidies received per annual work unit and region at NUTS2 level	3	AWU_SUBSIDY.NUTS.REG	1	5	1	Euro/AWU	implemented	106
10701	Share of animal production in a region	Share of value of animal production in total agricultural production in a region	3	ANIM_SHARE.NUTS.REG	1	5	1	%	implemented	107
10702	Share of animal production at a member state	Share of value of animal production in total agricultural production at a member state	3	ANIM_SHARE.COUNTRY.REG	1	6	1	%	implemented	107
10703	Share of animal production at EU level	Share of value of animal production in total agricultural production at EU level	3	ANIM_SHARE.AGGREGATE.REG	1	7	1	%	implemented	107
10801	Total Welfare at EU level	Aggregated monetary utility, at EU level, of different sections of society resulting from agricultural production and consumption.	5	TOT_WEL.AGGREGATE.REG	1	9	1	Mn €	implemented	108
10802	Total Welfare at member state level	Aggregated monetary utility, at member state level, of different sections of society resulting from agricultural production and consumption.	5	TOT_WEL.COUNTRY.REG	1	8	1	Mn €	implemented	108
10901	Money metric at EU level	Total annual consumer surplus - measurement to assess consumer welfare, at the EU level.	3	MONEY_METRIC.AGGREGATE.REG	1	9	1	Mn €	implemented	109
10902	Money metric at member state level	Total annual consumer surplus - measurement to assess consumer welfare, at the member state level.	3	MONEY_METRIC.COUNTRY.REG	1	8	1	Mn €	implemented	109
11001	Profits of the Agricultural Processing Industry at EU level	Accounting profits of the agricultural processing industry (dairy and oilseeds) at EU level	5	TOT_PROC_INC.AGGREGATE.REG	1	9	1	Mn €	implemented	110
11002	Profits of the Agricultural Processing Industry at member state level	Accounting profits of the agricultural processing industry (dairy and oilseeds) at member state level	5	TOT_PROC_INC.COUNTRY.REG	1	8	1	Mn €	implemented	110
11101	Tariff Revenues at EU level	EU budget income, at EU level, from applying Tariffs on imported goods	3	TAR_REV.AGGREGATE.REG	1	9	1	Mn €	implemented	111

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
11102	Tariff Revenues at member state level	EU budget income, at member state level, from applying Tariffs on imported goods	3	TAR_REV.COUNTRY.REG	1	8	1	Mn €	implemented	111
11201	First Pillar CAP Expenditure at EU level	Sum of direct payments to farmers, export subsidy outlays, and intervention stock costs, at EU level	3	TOT_FEOGA_BUD.AGGREGATE.REG	1	9	1	Mn €	implemented	112
11202	First Pillar CAP Expenditure at member state level	Sum of direct payments to farmers, export subsidy outlays, and intervention stock costs, at member state level	3	TOT_FEOGA_BUD.COUNTRY.REG	1	8	1	Mn €	implemented	112
11301	Terms of trade	Price indexes of export and import, terms of trade at EU level	3	TERMSOFTRADE.AGGREGATE.REG	1	10	1	None	implemented	113
11402	Export Subsidy Outlays at member state level	Compensation payments paid to EU exporters under CAP First Pillar, at member state level. Equal to quantity exported multiplied by difference between EU price and world price	3	TOT_SUBEX.COUNTRY.REG	1	8	1	Mn €	implemented	114
11501	Second Pillar CAP expenditure at the EU level	Compensation payments for farmers who invest in rural public goods; at the EU level.	3		1	9	1	Mn €	not implemented	115
11502	Second Pillar CAP expenditure at member state level	Compensation payments for farmers who invest in rural public goods; at the member state level.	3		1	8	1	Mn €	not implemented	115
11503	Second Pillar CAP expenditure per hectare at member state level	Compensation payments for farmers who invest in rural public goods; per hectare at member state level.	3		1	4	1	Mn €	not implemented	115
11601	Intervention Stock Costs at EU level	The monetary cost, at EU level, of buying, managing and selling surplus agricultural produce.	3	TOT_INT.AGGREGATE.REG	1	9	1	Mn €	implemented	116
11602	Intervention Stock Costs at member state level	The monetary cost, at member state level, of buying, managing and selling surplus agricultural produce.	3	TOT_INT.COUNTRY.REG	1	8	1	Mn €	implemented	116
11701	Shadow price for labour per farm type at member state level	Marginal welfare change resulting from a unit rise in the net demand for labour, per farm type at a national level.	5		1	4	1	1 000 €	not implemented	117

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
11801	Shadow price for capital per farm type at member state level	The present value of the social returns to capital (before income taxes), measured in units of consumption, per farm type at a national level.	5		1	4	1	1 000 €	not implemented yet	118
12001	Farm income	Net farm income per farm type	1	Z	1	2	1	1 000 €	implemented	120
12002	Average farm income at NUTS2 level	Average farm income in a region	1	Z	2	3	1	1 000 €	implemented	120
12003	total farm income in a region	Total farm income in a region	1	Z	7	3	1	Mn €	implemented	120
12004	Growth rate of farm income	Growth rate of farm income	1	zvariation	1	2	2	%	implemented	120
12005	Average growth rate of farm income in a region	Average growth rate of farm income in a region	1	zvariation	2	3	1	%	implemented	120
12006	Value of on-farm profitability per hour of work	Value of on-farm profitability per hour of work	1	Z/TLABOUR	1	2	1	1 000 €/hour	implemented	120
12007	Mean value of on-farm profitability per hour of work in a region	Mean value of on-farm profitability per hour of work in a region	1	Z/TLABOUR	2	3	1	1 000 €/hour	implemented	120
12101	Share of subsidies in farm income	Percent of subsidies in farm income	1	subsidiesshare	1	2	1	%	implemented	121
12102	Variation of subsidies share in farm income	Variation of subsidies share in farm income over a simulation period	1	Subsidiesshare-variation	1	2	2	%	implemented	121
12103	Mean subsidy share in farm income for a region	Mean subsidy share in farm income for a region	1	subsidiesshare	2	3	1	%	implemented	121
12104	Variation of subsidies share in farm income in a region	Variation of subsidies share in farm income in a region	1	subsidiessharevariation	2	3	2	%	implemented	121
12201	Subsidies	total payments made directly at farm level, from first pillar CAP, second pillar, or regional policies	1	PRME	1	2	1	1 000 €	implemented	122
12202	Mean subsidies received by farms in a region	average payments made directly at farm level, from first pillar CAP, second pillar, or regional policies at NUTS2 level	1	PRME	2	3	1	1 000 €	implemented	122

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
12203	Total public support for farms in a region	total payments made directly at farm level, from first pillar CAP, second pillar, or regional policies, at NUTS2 level	1	PRME	7	3	1	Mn €	implemented	122
12204	Total public support for farms in a region from EU	total payments made directly at farm level, from first and pillars CAP at NUTS2 level	1	PRME	7	3	1	Mn €	implemented	122
12205	Total public support for farms in a region from regional policies	total payments made directly at farm level, from regional policies, at NUTS2 level	1	PRME	7	3	1	Mn €	implemented	122
12206	Growth rate of subsidies for a farm type	variation of the subsidies received at the end of the simulation period relative to the subsidies received at the beginning	1	PRME	1	2	2	%	implemented	122
12208	Public support growth rate at NUTS2 level	variation of the total payments made by public authorities at the end of the simulation period relative to the payments at the beginning	1	PRME	2	3	2	%	implemented	122
12301	Marginal productivity of all subsidies at farm gate	amount of money a farm type would earn if the subsidies were raised by 1 euro	1	subsidy.m	1	2	1	€	implemented	123
12302	Marginal productivity of EU subsidies at farm gate	amount of money a farm type would earn if the EU subsidies were raised by 1 euro	1	subsidy.m	1	2	1	€	implemented	123
12303	Marginal productivity of regional subsidies at farm gate	amount of money a farm type would earn if the regional subsidies were raised by 1 euro	1	subsidy.m	1	2	1	€	implemented	123
12304	Average marginal productivity of subsidies at fNUTS2 level	amount of money the farms would earn if the subsidies were raised by 1 euro	1	subsidy.m	2	3	1	€	implemented	123
12401	Value of farm production	Value of production at farm gate	1	GPROD	1	2	1	1 000 €	?	124
12402	Total value of farm production at NUTS2 level	Total value of production at NUTS2 level	1	GPROD	2	3	1	1 000 €	?	124
12403	growth rate of farm production	index of farm production change per hectare in region	1	GPROD mod.	1	2	1	%	under development	124
12404	growth rate of regional production	index of farm production change per hectare in region	1	GPROD mod.	2	3	1	%	under development	124

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
12405	Value of farm production per ha	Value of production at farm gate per ha	1	GPROD mod.	1	2	1	€/ha	under development	124
12406	Total value of farm production at NUTS2 level per ha	Total value of farm production at NUTS2 level per ha	1	GPROD mod.	2	3	1	€/ha	under development	124
12501	Profit of the banking system at the member state level	Total annual accounting profit of the banking system - defined as the availability of financial services and, therefore, of credit - at the member state level.	1	**?**	1	4	1	Mn €	under development	125
12502	Profit of the banking system at the EU level	Total annual accounting profit of the banking system - defined as the availability of financial services and, therefore, of credit - at the EU level.	5	**?**	1	3	1	Mn €	under development	125
12601	Total costs	Total costs (intermediate consumptions) at farm gate	1	TCOST	1	2	1	1 000 €	implemented	126
12602	Total costs at NUTS2 level	Total costs (intermediate consumptions) at NUTS2 level	1	TCOST	2	3	1	1 000 €	implemented	126
12701	Share of debts in farm income	Percent of debts in farm income	1	annuityshare	1	2	1	%	implemented	127
12702	Variation of debts share in farm income	Variation of debts share in farm income over a simulation period	1	annuitysharevariation	1	2	2	%	implemented	127
12703	Mean debts share in farm income for a region	Mean debts share in farm income for a region	1	annuityshare	2	3	1	%	implemented	127
12704	Variation of debts share in farm income in a region	Variation of debts share in farm income in a region	1	annuitysharevariation	2	3	2	%	implemented	127
12801	Land shadow price	Land shadow price is the amount of money a fam would earn if it had the capacity of cropping one more hectare	1	E_toland.m	1	2	1	1 000 €	implemented	128
12802	Mean land shadow price in a region	The mean land shadow price is the amount of money farmers would earn if they had the capacity of cropping one more hectare	2	E_toland.m	2	3	1	1 000 €	implemented	128
12901	productivity of inputs	productivity of inputs is the amount of money earned per euro of input bought	1	inputprod	1	2	1	€/€	under development	129

id	label_en	description	model	modeloutputname	upscaling procedure	spatialscale	temporalscale	unit	implemented	ispartofindicatorgroup
13001	productivity of intermediate consumptions	productivity of intermediate consumption is the amount of money earned per euro of intermediate consumption used	1	intconsprod	1	2	1	€/€	under development	130
13101	equity	difference between the income of the richer farm type and income of the poorer one	1	Z	13	5	1	1 000 €	under development	131
13201	fairness	this indicator compares the income growth rate of the richer and poorer farm types	1	Z	14	5	2	unitless	under development	132
13301	income inequality	income inequality		?	15				under development	133
13401	Net value of capital stocks at member state level	The market value of fixed assets obtained by the gross capital stock minus accumulated consumption of fixed capital, at the member state level.	1	**?**	1	4	1	Mn €	under development	134
13402	Net value of capital stocks at NUTS2 level	The market value of fixed assets obtained by the gross capital stock minus accumulated consumption of fixed capital, at the EU level.	1	**?**	1	3	1	Mn €	under development	134
13403	Net value of capital stocks per farm type	The market value of fixed assets obtained by the gross capital stock minus accumulated consumption of fixed capital, per farm type.	1	**?**	1	2	1	Mn €	under development	134
14001	family work force	family work force	1	familylabour	1	2	1	AWU	implemented	140
14002	total family work force	total potential employment in on-farm families in a region	1	familylabour	2	3	1	1000 AWU	implemented	140
14101	accessibility to temporary labour	accessibility to temporary labour	1	rentedlabour	1	3	1	1000 AWU	implemented	141
15201	Land value changes in a region	Shadow value of the land restriction in a region	3	LANDVALUE.NUTS.REG - comp.	1	5	1	%	not implemented	152
15202	Land value changes at a member state	Shadow value of the land restriction at a member state	3	LANDVALUE.COUNTRY.REG - comp.	1	6	1	%	not implemented	152
15203	Land value changes at EU level	Shadow value of the land restriction at EU level	3	LANDVALUE.AGGREGATE.REG - comp.	1	7	1	%	not implemented	152
15301	Ratio of exports to imports at member state level	Quantity of agricultural commodities exported as a proportion of quantity imported	3	EXPTS.COUNTRY.REGPROD/IMPTS.CO	1	8	1	proportion	not implemented	153

				UNTRY.REGPROD						
id	**label_en**	**description**	**model**	**modeloutputname**	**upscaling procedure**	**spatialscale**	**temporalscale**	**unit**	**implemented**	**ispartofindicatorgroup**
15302	Ratio of exports to imports at EU level	Quantity of agricultural commodities exported as a proportion of quantity imported	3	EXPTS.AGGREGATE.REGPROD/IMPTS.AGGREGATE.REGPROD	1	9	1	proportion	not implemented	153
20101	labour use (hours)	Labour force in a farm-type expressed in worked hours	1	TLABOUR	1	2	1	hours	implemented	201
20102	labor use (AWU)	Labour force in a farm-type expressed in Average Worked Units	1	TLABOUR	1	2	1	AWU	implemented	201
20103	mean labour use per farm type in a region	Average labour used per farm in a region	1	TLABOUR	2	3	1	hours	implemented	201
20104	total labour use in a region	Total labour used in farms in a region	1	TLABOUR	6	3	1	1000 hours	implemented	201
20105	growth rate of labour use in a region	Growth rate of labour use in a region	1	TLABOUR	2	3	2	%	implemented	201
20106	share of family labour	Share of total labour use due to family work force	1	TLABOUR	2	3	1	%	implemented	201
20107	employment rate of family work force	share of the total potential family work force really employed in arming activities	1	TLABOUR	2	3	1	%	under development	201
20108	share of labour use due to livestock	Share of total labour use in a region for livestock activities	1	TLABOUR ?	2	3	1	%	should be	201
20109	number of animals per worker	This indicator depicts the work charge for breeders	1	TLABOUR ?	2	3	1	LU/AWU	should be	201
20201	monetary poverty rate	percent of population whose income is lower than 60 % of the median income in the population	1	Z	16	5	1	%	under development	202
20301	Potential employment	Potential work force in a region	1	WORK	2	3	1	AWU	implemented	203

Appendix 2 Indicator group table

Id	Label_en	Description
1	Nitrogen use	Amount of nitrogen fertilizer used on crops and grassland (expressed in kg N per ha)
2	Nitrate leaching	Amount of nitrate leached under the root zone of crops and grassland due to fertilization and nitrogen management after harvest (crop residues, catch crops, etc.)
3	Pesticide consumption	Amount of pesticides used (expressed in g of active ingredients per ha) in a farm to evaluate the pressure on all environmental compartments
4	Soil organic matter change	Evolution of the soil organic matter content in soil in percentage (soil fertility issue) or absolute value (carbon sequestration)
5	Soil erosion	Soil losses by water erosion along the slope
6	Runoff	Surface runoff due to low water infiltration
7	Water use (quantity)	Amount of water used by irrigation on crops
8	Volatilization	Volatilization of ammoniac due to nitrogen fertilization or/and livestock (stable, grazing, manure storage and fertilization)
9	Crop diversity	Land use diversity (and, conversely, dominance) – relevant for biodiversity and for environmental quality, in relation to cropping pattern and concentration/distribution.
10	% Low fertilised grassland	% Low fertilised grassland per farm type
11	% Non sprayed area	% Non sprayed by pesticide area per farm tye
12	% Area with conservation tillage	% Area with conservation tillage (no-till or reduced tillage) per farm type
13	% Of area with catch crop	% Of area with catch crop per farm type
14	Pesticide leaching	Amount of pesticides (active ingredients) leached under the root to groundwater
15	Pesticide runoff	Amount of pesticides (actives ingredients) in the soluble fraction transfered by runoff to surface water
16	Pesticide volatilization	Amount of pesticides (active ingredients) volatilized
17	Soil fertility change	% Of farm area with significant increase or decrease of soil organic matter

Id	Label_en	Description
18	Nitrate surplus	Surplus of nitrate resulting from the calculation of regional balance (nitrogen input-nitrogen output-NH3 volatilization)
19	Total CH4 emissions	Amount of CH4 that is emitted due to livestock (entheric fermentation, manure) and rice production, per region, per member state
20	Total N2O emissions	Amount of N2O that is emitted from the land managements and breeding activities on a yearly basis per region, per member state
21	Global warming potential	Aggregation of CH4 and N2O emissions weighted by a greenhouse effect impact factor per region, per member state
22	NH3 emissions	Emissions of NH3
23	Phosphorus balance	Phosphorus balance per region, per member state
24	Mineral P, K use	Mineral P, K use per region, per member state
25	Indirect energy use by mineral fertilizer	Indirect energy use by mineral fertilizer per region, per member state
26	Gross nitrogen balance	Nitrogen balance (nitrogen import-nitrogen export) at farm level
27	Energy consumption	Energy consumption due to use of mineral fertilizer, tillage implement, irrigation for crop production, and imported food and animal housing for animal production
28	Energy efficiency	Energy efficiency for crop crop production, specific animal production (milk, beef, pig) expressed in energy consumption per production unit
29	Stocking rate	Livestock density expressed in number of livestock unit (LU) per unit of forage or grassland area per farm type
30	Grassland share	Percentage of grassland (total or permanent) per farm type
101	Agricultural Income	Value of agricultural output (including premia/subsidies) minus variable costs
102	Total value of animal production per hectare in a region	Value per hectare of all primary animal agricultural products produced
103	Total value of crop production per hectare in a region	Value per hectare of all primary crop agricultural products produced
104	Total agricultural output	Total agricultural output value per region net of subsidies
105	Total agricultural inputs	Total value of all inputs but labour for producting agricultural primary products
106	Direct CAP payments	Payments made directly to farmers under the First Pillar of the CAP

Id	Label_en	Description
107	Share of animal production	Share of value of animal production in total agricultural production
108	Total Welfare	Aggregated monetary utility of different sections of society resulting from agricultural production and consumption. Sum of money metric (consumer surplus), agricultural income, processing profits and tariff revenues minus 1st Pillar CAP expenditure
109	Money metric	Total annual consumer surplus that would result from the application of a given policy expressed in terms of the difference between what a person would be willing to pay and what (s)he actually has to pay to buy a certain amount of a good.
110	Profits of the Agricultural Processing Industry	Accounting profits of the agricultural processing industry (dairy and oilseeds)
111	Tariff Revenues	EU budget income from applying Tariffs on imported goods
112	First Pillar CAP Expenditure	Sum of direct payments to farmers, export subsidy outlays, and intervention stock costs
113	Terms of Trade	Price indexes of export and import
114	Export Subsidy Outlays	Compensation payments paid to EU exporters under CAP First Pillar, equal to quantity exported multiplied by difference between EU price and world price.
115	Second pillar CAP expenditure	Compensation payments for farmers who invest in rural public goods; i.e. in environmental and rural functions.
116	Intervention Stock Costs	The monetary cost of buying, managing and selling surplus agricultural produce
117	Shadow price for labour	Marginal welfare change resulting from a unit rise in the net demand for labour.
118	Shadow price for capital	The present value of the social returns to capital (before income taxes), measured in units of consumption.
120	Net Farm Income	This indicator aims to assess the total income earned by each farm type
121	Percent of Subsidies in Net Farm Income	Percent of subsidies in farm income
122	Subsidies	Total payments made directly at farm level, from first pillar CAP, second pillar, or regional policies
123	Marginal productivity of subsidies	This group of indicators deals with the relative efficiency, in terms of farm income growth, of public payments, from the policymaker's point of view
124	Value of farm production	Value of production at farm gate
125	Profit of the banking system	Total annual accounting profit of the banking system - defined as the availability of financial services and, therefore, of credit.
126	Total costs	Total costs (intermediate consumptions)
127	Percent of debts in net farm income	Percent of debts in farm income
128	Land shadow price	Land shadow price is the amount of money a farm would earn if it had the capacity of cropping one more hectare

Id	Label_en	Description
129	Productivity of inputs	Productivity of inputs is the amount of money earned per euro of input bought
130	Productivity of intermediate consumption	Productivity of intermediate consumption is the amount of money earned per euro of intermediate consumption used
131	Equity	Difference between the income of the richer farm type and income of the poorer one
132	Fairness	This indicator compares the income growth rate of the richer and poorer farm types
133	Income inequality	Income inequality
134	Net value of capital stocks	The market value of fixed assets and it is obtained by the gross capital stock minus accumulated consumption of fixed capital.
140	Family work force	Family work force
141	Accessibility to temporary labour	Accessibility to temporary labour
152	Land value changes	Shadow value of the land restriction
153	Ratio of exports to imports at EU level	Quantity of agricultural commodities exported as a proportion of quantity imported
201	Labour use	Labour force in farming sector
202	Monetary poverty rate	Percent of population whose income is lower than 60 % of the median income in the population
203	Potential employment	Potential work force for on-farm activities

Appendix 3 Domain, subthemes and themes

Indicator group	Subtheme	Theme	Generic theme	Domain	
				Effect of agriculture on itself	Effect of agriculture on the rest of the world
Nitrogen use	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Nitrogen use	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Nitrogen use	Climate	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Nitrogen use	Soil acification (NH3)	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Nitrogen use	Energy	Environmental compartments and non-renewable resources	Means	x	x
Nitrate leaching	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Pesticide consumption	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Pesticide consumption	Direct effect on farmer's health	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Pesticide consumption	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Pesticide consumption	Ecological regulation of agrosystems	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Soil organic matter change	Climate	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Soil organic matter change	Soil fertility	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Soil erosion	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Soil erosion	Surface water eutrophication	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Soil erosion	Soil erosion	Environmental compartments and non-renewable resources	Means	x	x
Runoff	Surface water eutrophication	Maintenance of environmental balances or functions	Processes for achievement	x	x
Runoff	Soil erosion	Environmental compartments and non-renewable resources	Means	x	x

Indicator group	Subtheme	Theme	Generic theme	Domain	Indicator group
				Effect of agriculture on itself	**Effect of agriculture on the rest of the world**
Water use (quantity)	Water quantity	Environmental compartments and non-renewable resources	Means	x	x
Volatilization	Eutrophication	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Volatilization	Soil acification (NH3)	Maintenance of environmental balances or funcitons	Processes for achievement		x
Crop diversity	Landscape	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
% Low fertilised grassland	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
% Low fertilised grassland	Ecological regulation of agrosystems	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
% Non sprayed area	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
% Non sprayed area	Ecological regulation of agrosystems	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
% Area with conservation tillage	Soil erosion	Environmental compartments and non-renewable resources	Means	x	x
% Of area with catch crop	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Pesticide leaching	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Pesticide runoff	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Pesticide volatilization				x	x
Pesticide volatilization	Direct effect on farmer's health	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Soil fertility change	Soil fertility	Maintenance of environmental balances or funcitons	Processes for achievement	x	
Nitrate surplus	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Total CH4 emissions	Climate	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Total N2O emissions	Climate	Maintenance of environmental balances or funcitons	Processes for achievement	x	x

Indicator group	Subtheme	Theme	Generic theme	Domain	
				Effect of agriculture on itself	Effect of agriculture on the rest of the world
Global warming potential	Climate	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
NH3 emissions	Eutrophication	Maintenance of environmental balances or funcitons	Processes for achievement		x
NH3 emissions	Soil acification (NH3)	Maintenance of environmental balances or funcitons	Processes for achievement		x
Phosphorus balance	Soil fertility	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Phosphorus balance	Surface water eutrophication	Maintenance of environmental balances or funcitons	Processes for achievement	x	x
Mineral P, K use	Minerals	Environmental compartments and non-renewable resources	Means	x	
Indirect energy use by mineral fertilizer	Energy	Environmental compartments and non-renewable resources	Means	x	x
Gross nitrogen balance	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal	x	x
Energy consumption	Energy	Environmental compartments and non-renewable resources	Means	x	x
Energy efficiency	Energy	Environmental compartments and non-renewable resources	Means	x	
Stocking rate	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Stocking rate	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Stocking rate	Surface water eutrophication	Maintenance of environmental balances or funcitons	Processes for achievement		x
Grassland share	Biodiversity	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Grassland share	Landscape	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Grassland share	Water quality	Protection of human health and welfare, live beings and habitats	Ultimate goal		x
Grassland share	Soil erosion	Environmental compartments and non-renewable resources	Means		x
Agricultural Income	Stability	Viability	Ultimate goal	x	

Indicator group	Subtheme	Theme	Generic theme	Domain	
				Effect of agriculture on itself	Effect of agriculture on the rest of the world
Agricultural Income	Profitability	Performance	Processes for achievement	x	
Total value of animal production per hectare in a region	Profitability	Performance	Processes for achievement	x	
Total value of animal production per hectare in a region	Productivity	Performance	Processes for achievement	x	
Total value of crop production per hectare in a region	Profitability	Performance	Processes for achievement	x	
Total value of crop production per hectare in a region	Productivity	Performance	Processes for achievement	x	
Total agricultural output	Stability	Viability	Ultimate goal	x	
Total agricultural output	Profitability	Performance	Processes for achievement	x	
Total agricultural output	Productivity	Performance	Processes for achievement	x	
Total agricultural inputs	Profitability	Performance	Processes for achievement	x	
Total agricultural inputs	Productivity	Performance	Processes for achievement	x	
Direct CAP payments	Stability	Viability	Ultimate goal	x	x
Direct CAP payments	Profitability	Performance	Processes for achievement	x	x
Direct CAP payments	Government intervention	Performance	Processes for achievement	x	x
Share of animal production	Productivity	Performance	Processes for achievement	x	
Total Welfare	Stability	Viability	Ultimate goal	x	x
Money metric	Profitability	Performance	Processes for achievement		x
Money metric	Productivity	Performance	Processes for achievement		x
Profits of the Agricultural Processing Industry	Profitability	Performance	Processes for achievement	x	
Tariff Revenues	Government intervention	Performance	Processes for achievement		x
111	Trade	Performance	Processes for achievement		x
Tariff Revenues	Stability	Viability	Ultimate goal	x	x

Indicator group	Subtheme	Theme	Generic theme	Domain	
				Effect of agriculture on itself	Effect of agriculture on the rest of the world
First Pillar CAP Expenditure	Profitability	Performance	Processes for achievement	x	x
First Pillar CAP Expenditure	Government intervention	Performance	Processes for achievement	x	x
First Pillar CAP Expenditure	Trade	Performance	Processes for achievement	x	x
Terms of Trade	Trade	Performance	Processes for achievement	x	x
Export Subsidy Outlays	Government intervention	Performance	Processes for achievement	x	x
Export Subsidy Outlays	Trade	Performance	Processes for achievement	x	x
Second pillar CAP expenditure	Profitability	Performance	Processes for achievement	x	
Second pillar CAP expenditure	Productivity	Performance	Processes for achievement	x	
Second pillar CAP expenditure	Government intervention	Performance	Processes for achievement	x	
Intervention Stock Costs	Profitability	Performance	Processes for achievement	x	x
Intervention Stock Costs	Government intervention	Performance	Processes for achievement	x	x
Shadow price for labour	Usual production means	Other production means	Means	x	x
Shadow price for labour	Usual production means	Other production means	Means	x	x
Shadow price for capital	Financial capital	Financial and productive capital	Means	x	x
Shadow price for capital	Financial capital	Financial and productive capital	Means	x	x
Net Farm Income	Profitability	Performance	Processes for achievement	x	
Percent of Subsidies in Net Farm Income	Stability	Viability	Ultimate goal	x	
Subsidies	Government intervention	Performance	Processes for achievement	x	x
Subsidies	Public support	Viability	Ultimate goal	x	x
Marginal productivity of subsidies	Government intervention	Performance	Processes for achievement	x	
Value of farm production	Stability	Viability	Ultimate goal	x	
Value of farm production	Profitability	Performance	Processes for achievement	x	

Indicator group	**Subtheme**	**Theme**	**Generic theme**	**Domain**	
				Effect of agriculture on itself	**Effect of agriculture on the rest of the world**
Value of farm production	Productivity	Performance	Processes for achievement	x	
Profit of the banking system	Capital stocks	Financial and productive capital	Means		x
Profit of the banking system	Financial capital	Financial and productive capital	Means		x
Total costs	Profitability	Performance	Processes for achievement	x	
Percent of debts in net farm income	Stability	Viability	Ultimate goal	x	
Land shadow price	Profitability	Performance	Processes for achievement	x	
productivity of inputs	Productivity	Performance	Processes for achievement	x	x
productivity of intermediate consumption	Productivity	Performance	Processes for achievement	x	
Equity	Stability	Viability	Ultimate goal	x	x
Equity	Poverty	Quality of life	Ultimate goal	x	x
Fairness	Stability	Viability	Ultimate goal	x	x
Fairness	Poverty	Quality of life	Ultimate goal	x	x
Income inequality	Stability	Viability	Ultimate goal	x	x
Income inequality	Poverty	Quality of life	Ultimate goal	x	x
Net value of capital stocks	Etability	Viability	Ultimate goal	x	
Family work force	Usual production means	Other production means	Means	x	x
Accessibility to temporary labour	Usual production means	Other production means	Means	x	x
Land value changes	Profitability	Performance	Processes for achievement	x	
Land value changes	Government intervention	Performance	Processes for achievement	x	
Ratio of exports to imports at EU level	Trade	Performance	Processes for achievement	x	x
Labour use	Employment	Human capital	Processes for achievement	x	x
Monetary poverty rate	Poverty	Quality of life	Ultimate goal	x	x
Potential employment	Employment	Human capital	Processes for achievement	x	x

Appendix 4 Example of indicator factsheet

Indicator fact sheet

1. General information on the indicator

Name of the indicator group

NITRATE LEACHING

Endorsed indicators with specific use

NITRATE LEACHING PER FARM

PERCENT OF AREA WITH HIGH LEACHING

Purpose; impact assessed and processes described by the indicator

Purpose of the indicator:

This indicator depicts the amount of nitrate leached under the root zone of a crop due to fertilization and to nitrogen management after harvest, for example by maintaining crop residues, catch crops, etc. (expressed in kg nitrogen in nitrate form per ha).

Impact:

This indicator depicts the impact that a given policy can have on nitrate leaching for farms types within a region and at regional level. Nitrate is a major component of water quality and is considered as a threat to public health.

Processes described by the indicator:

The leaching is calculated on a daily basis by simulating with APES the nitrogen cycle in the crop-soil-water system. The daily values are cumulated for the cropping year.

Scales

	Resolution*	Extent**	Other extents after upscaling
Spatial	AEnZ,	Farm type	NUTS2
Temporal	year	Simulation period	

* The “resolution” or “support unit” is the largest area or period on which the property of interest is considered homogenous and the finest unit on which information is calculated or observed or displayed.

** The “extent” is the spatial area and temporal period or horizon at which policy questions may be evaluated by SEAMLESS. The spatial resolution and the extent can be : activity*AEn, farm type, Nuts2 region, member state, EU, etc. The temporal resolution and extent can be the simulation period, the year, etc.

References

Goulding K., 2000. Nitrate leaching from arable and horticultural land. Soil Use and Management, 16, 145-151.

Glossary

Word	Explanation
Nitrate leaching	Amount of nitrogen (expressed in kg nitrogen in nitrate form) in drainage water. This amount may be transferred to groundwater or to surface water if the field is drained artificially or if there is a permeable layer in the soil.

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Institution:

INRA

2. Detailed description

Assumptions underlying the indicator

It is assumed that the amount of nitrate leached will reach the nearest body of water and have an impact on the water quality by increasing the nitrate content.

Model output and data used

Calculation by APES for each activity associated with the farm type for a simulation period of 50 years. Calculation of an average for the farm type for the predicted activities by FSSIM:

At farm level: output from FSSIM POLLUT: Nitrate leaching (kg NO_3-N/ha/year)

Equations

Indicator equal to the model output

3. Reference level for interpretation

General comments

A threshold for least significant difference between two scenarios will be calculated and based on the standard deviation of the model output calculated for the simulation period (50 years)

4. Information needed for interpretation

Basic questions addressed by this indicator:

Intermediate results needed for interpretation

Model ouput/indicator	Comment
Cropping pattern (surface of each crop)	
Percent of area with catch crop	
Nitrate leaching per crop	
Nitrogen fertilization per crop	
Soil type	

Comments

Trade-off between indicators: see table three

Themes	Sub-themes	Trade-off with other sub-themes		
Human health and welfare, living beings and habitats	Water: Quality of groundwater and surface water (NO_3)	Some mitigation options for NO3 leaching may be reduced by increasing NH_3 emissions.	Mineral fertilization can meet crop requirement and result in a decrease in nitrate leaching. But high energy cost remains.	Introducing catch crop thereby increasing the risk of pest and weeds and increasing the use of pesticides.

Comments

Some mitigation options for NO3 leaching may be reduced by increasing NH3 emissions. Mineral fertilization can meet crop requirement and result in a decrease in nitrate leaching. But high energy cost remains. Introducing catch crop thereby increases the risk of pest and weeds and increases the use of pesticides (not addressed by Seamless).

5. Possibilities of upscaling/aggreation

Indicator name	**Spatial indicator extent**	**Model**		**type of algorithm**
		model	**spatial scale**	
Percent of area with high leaching	**NUTS2**	**FSSIM**	**Farm type**	**Percent of area above a threshold**

Interpretation of the upscaled indicators:

The nitrate leaching indicator addresses a local impact (water quality). At a higher scale such as NUTS2 regions, it is not relevant to calculate an average value. A specific indicator based on distribution of nitrate leaching per activity is more appropriate: the "percent of area with high leaching" indicator is proposed at NUTS2 level.

6. Evaluation of the indicator

Relevance of the indicator for the theme

Medium/good: The indicator assesses the amount of nitrate leached under the crop but not the amount reaching water bodies.

Relevance of the indicator for the scale

Good

Facilities/problems in implementation

Calculation of nitrate leaching with the model APES requires detailed data on climate, soil and crop management

Appendix 5 Conference poster on indicator ontology

From models to indicators: Ontology as a knowledge representation system

O. Therond[1*], N. Turpin[2], S. Janssen[3], I. Athanasiadis[4], R. Knapen[5], C. Bockstaller[6], J. Alkan Olsson[7], F. Ewert[3,8], I. Bezlepkina[9]

Introduction

Within Integrated Assessment and Modelling (IAM) platform impact indicators have to be linked to model outputs and to user-relevant concepts, like scale and indicator framework and dimension.

IAM projects face with the multitude of meaning across indicator concepts, scales and domains. To solve this problem the SEAMLESS project (30 partners and ~ 150 researchers) developed **an indicator ontology: a finite list of indicator related concepts and the relationships between these concepts**.

This indicator ontology shared by all scientists from various disciplines serves as a **knowledge-level specification of the joint conceptualization and enabled a fully operational implementation of a wide diversity of sustainability indicators in the IAM platform.**

Methods

Impact indicators in SEAMLESS are based on modelling chain outputs (Fig. 1). **Indicator development necessitated iterative and structured interactions between indicators, database, models and software developers as well as tool evaluators**. The indicator development procedure sketched in the Figure 2 enabled SEAMLESS researchers to build a generic indicator ontology.

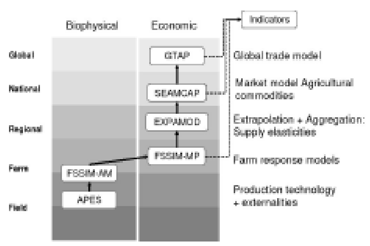

Figure 1: The SEAMLESS model chain

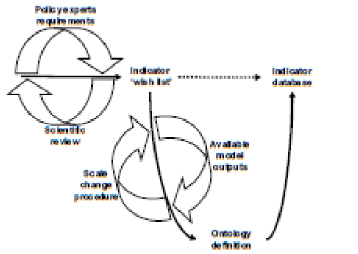

Figure 2: The indicator development procedure

Results

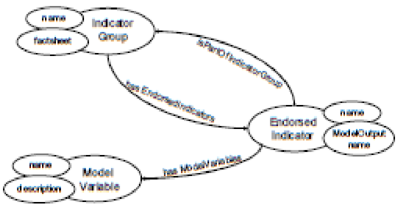

Fig 3: A simplified representation of the three key concepts of the indicator ontology

The indicator ontology introduces three key concepts (Fig. 3):

- The **endorsed indicators** are the impact indicators of SEAMLESS-IF. They are linked to a SEAMLESS model and a specific model output. They have spatial and temporal resolutions and extents and if needed an up-scaling procedure (see Turpin et al., session A2-2 and Fig. 4).
- The **Indicator Groups** cluster together a set of endorsed indicators providing information on the same impact but at different spatial and/or temporal scales (see Fig. 4). The indicator groups are positioned within the Goal Oriented Framework - GOF (Bockstaller et al., session B2-1 and Fig. 5). The GOF aims at guiding the user in the selection of indicators, preventing him from focusing on a single issue. The indicator groups are linked to a factsheet describing characteristics of their endorsed indicators (Fig. 6).
- The **model variables** correspond to the intermediate variables (model inputs or outputs) necessary to interpret and understand the causality chain underlying the indicator values.

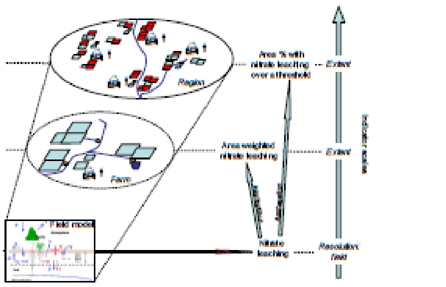

Figure 4: The three endorsed indicators of the "Nitrate leaching" indicator group

The indicator ontology in details:

Endorsed Indicator:
- Name or label
- Description
- has Model (model that produces this indicator)
- has ModelOutputName
- is part of IndicatorGroup
- Unit
- has Spatial Resolution (the scale of the model)
- has Spatial Extent (i.e. the scale of the indicator)
- has Temporal Resolution
- has Temporal Extent
- has Model variables
- has Upscaling procedure

Model variable:
- Name
- Description
- Unit
- has Model
- has Spatial Resolution
- has Spatial Extent
- has Temporal Resolution
- has Temporal Extent

Indicator Group:
- Name or label
- Description
- has FactSheet
- has EndorsedIndicators
- has TradeOff
- has GOF Domain
- has GOF Dimension
- has GOF Theme
- has GOF Sub theme

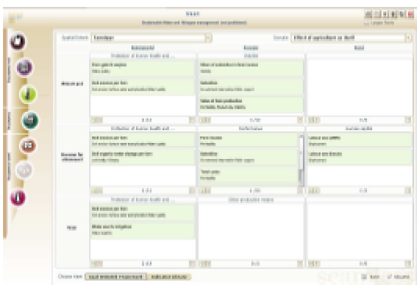

Figure 5: Example of endorsed indicator positions within the Goal Oriented Framework

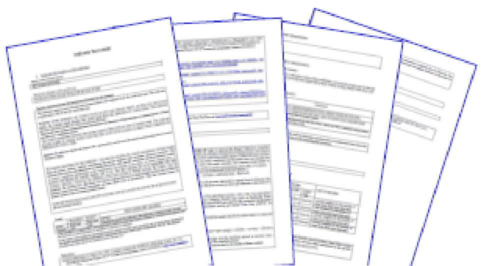

Figure 6: The indicator factsheet describing endorsed indicators of an indicator group.

Discussion

This ontology supports and facilitates the communication of complex concepts needed to define, implement, select, describe, compute and displays social, economical and environmental indicators at the wide range of scales investigated by SEAMLESS-IF. **Its generic character allows managing sustainability indicators in IAM platforms.**

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