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

A typical application of SEAMLESS-IF at meso level: The Nitrate Directive and the conservation agriculture scenarios in Midi-Pyrenees.

D6.3.5.2

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Submission date: *March 22, 2009*

INTEGRATED PROJECT EU FP 6 (contract no. 010036)
Global Change and Ecosystems
Project duration: January 2005 - December 2008

Version 5

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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Belhouchette H. 2009. A typical application of SEAMLESS-IF at meso level: The nitrate Directive and Conservation Agriculture scenarios in Midi-Pyrenees. liberalization scenario applied to the EU, D6.5.3.2, SEAMLESS integrated project, EU 6th Framework Programme, contract no. 010036-2, www.SEAMLESS-IP.org, 30 pp.

Disclaimer:

“This publication has been funded under the SEAMLESS integrated project, EU 6th Framework Programme for Research, Technological Development and Demonstration, Priority 1.1.6.3. Global Change and Ecosystems (European Commission, DG Research, contract no. 010036-2. Its content does not represent the official position of the European Commission and is entirely under the responsibility of the authors.”

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General information

Task(s) and Activity code(s):	T6.3 – A6.3.4, A6.3.5
Input from (Task and Activity codes):	T6.1 - A6.1.1; T6.2 – A 6.2.3
Output to (Task and Activity codes):	all WPs
Related milestones:	M6.2.3, M6.3.4.1

Executive summary

This deliverable describes a typical meso-level application of SEAMLESS-IF. This application serves two main purposes within the SEAMLESS project. First of all it served as Test Case 2 (TC2) to test the various prototypes delivered by the SEAMLESS project and guide the development of the framework by identifying the requirements for a real-world application of the framework for ex-ante policy and technological innovations analysis. The second purpose of this application and main focus of this deliverable is to illustrate the potential use of SEAMLESS-IF to address meso-level environmental questions across domains and scales.

This deliverable builds on deliverables prepared throughout the SEAMLESS project, compiling and updating the essence of each of these individual deliverables to a final application with SEAMLESS-IF.

The deliverable highlights the potential of SEAMLESS-IF to analyze meso-level incitation for better water and nitrogen managements. For this purpose three scenarios have been defined, combing different water and nitrogen managements such as suggested in the Nitrate Directive and the Water Framework Directive. The first scenario suggest to improve nitrogen management for cereal crops based on simplify N balance. The second scenario is reserved for irrigated maize grain and irrigated peas. The objective of this scenario is to calculate new amounts of irrigation based on plant available water (PAW) which will be daily estimated by using the APES model. The last scenario is a combination of the previous two scenarios. The CAP2003 applied with 2013 conditions, by including exogenous driving forces, is taken as a reference.

After a brief description of the Nitrate Directive and Water Framework Directive and their main measures in order to reduce nitrogen leaching and water consumption, a detailed description of the three modelling phases of SEAMLESS-IF is given. For each part, the main elements and data needed for each scenarios is described.

Specific part

1 Introduction

This deliverable describes a meso-level application of SEAMLESS-IF to analyse the impact of nitrate directive application on the Midi-Pyrenees region. The application illustrates the potential of SEAMLESS-IF by analysing effects at farm scale (only arable farm type) and across different domains (social, economic and environmental).

The application focusing on the Nitrate Directive illustrates a typical question of EU policymakers dealing with environmental measures. This directive has ramifications that may differ for EU member states and regions within member states which affect the political feasibility of the agreement. Furthermore this directive may have economic and social impacts which could conflict or support other policies (at EU, national or regional level). These multi-scale and cross-domain concerns warrant the use of SEAMLESS-IF.

Apart from representing a realistic environmental question, the application also provides an elaborate test of SEAMLESS-IF. This application requires use of all backbone-chain models thus providing an elaborate test of the full system (Data base, PAES, FSSIM and indicators). Furthermore, although the directive being assessed have mainly an environmental purpose, the assessment of economic and social indicators will provide a test of the capacity of SEAMLESS-IF for integrated assessments across different domains.

1.1 Background on the Nitrate Directive policy

Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrate from agricultural sources complements the Urban Waste Water Directive by reducing and preventing pollution of water by nitrate from agricultural sources, i.e. chemical fertiliser and livestock manure, both to safeguard drinking water supplies and to protect fresh water and marine waters from eutrophication.

The Directive requires each Member State to draw up at least one code of good agricultural practices (EEC, 1991). This code (adpated to each region if required) has the objective of reducing pollution by nitrate, taking into account regional specificities across EU. It should contain provisions covering the following items, if relevant :

1. the land application of fertilizer to steeply sloping ground;
2. the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground;
3. the periods of the year when fertilizer application is not allowed
4. the conditions for land application of fertilizer near water courses;
5. the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage;
6. procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.

7. land use management, including the use of crop rotation systems and the proportion of the land area devoted to permanent crops relative to annual tillage crops;
8. the maintenance of a minimum quantity of vegetation cover during (rainy) periods that will take up the nitrogen from the soil that could otherwise cause nitrate pollution of water;
9. the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use;
10. the prevention of water pollution from run-off and the downward water movement beyond the reach of crop roots in irrigation systems.

On the basis of the results from monitoring networks specified in the Directive, zones vulnerable to nitrate pollution from agricultural sources have to be identified. In these zones action programmes have to be implemented consisting of mandatory measures, one of it being the requirement of application of the code of good agricultural practices by all farmers. Member States can decide to apply the measures in the action programmes across their whole territory, in that case they do not have to identify vulnerable zones. As shown in table 10, the strategy with regards to this classification is very different from one member state to the other.

How to reduce pollution of water by nitrate?

Several solutions are proposed by the EU to control and reduce surface and ground water nitrate pollution. Mainly, two kind of agronomic solution are distinguished: improved fertiliser management and crop rotation management.

The quantity and the nature of the nitrogen fertiliser can play an important role to determine yield and nitrogen leaching. Farmers often use high levels of nitrogen to achieve high and stable yields. However, relationships between nitrogen and yield are not linear and nitrogen use by plants is governed by the law of diminishing returns (Tremblay et al, 2001). Other factors unrelated to nitrogen fertiliser availability, such as heat units or growing degree-days, soil moisture (Martin et al., 1994; Ferguson et al., 1991), the genetic characteristics of the cultivar (Derici et al 2001; Guarda et al, 2004) and insufficient availability of other nutrients (Aulakh et al, 2005) can limit crop yield . N fertizers requirements for a crop are therefore often overestimated, thereby leading to frequent N leaching and water pollution.

The period to apply nitrogen depends closely on the characteristics of the fertiliser. For example manure and compost, in which the mineral nitrogen fraction is directly exposed to leaching, must be incorporated very late in the season so that freezing occurs soon after, or in the spring and early summer, when the mineral nitrogen can be used immediately for crop growth, and temperatures favour mineralization.

In southern Europe, after a dry year, nitrogen fertilization should take into account the amount of nitrogen left in the soil by the crop during the previous season. In the french Mediterranean region, applying 200 kg of nitrate to a wheat crop after a dry year can double the amount of N leached compared to a rainy year (Legrusse et al, 2005). The major part of nitrogen leaching occurs in fall, when crop is not yet established and the amount of rainfall is important. Two ways are possible to reduce this risk of pollution: reduce fertiliser or grow a nitrate catch crop during the rainy season, between harvest of the previous crop and sowing of the next crop. Green manures can help to reduce nitrate leaching in two ways: they absorb nitrate and reduce the amount of drainage by taking up water during the rainy season (Tremblay et al, 2001). Some crops, such as oilseed radishes, mustard, and barley, have long root systems that are capable of removing nitrate from deep in the soil profile. But when the nitrate catch crop is suppressed to sow the next crop it becomes a green manure through the rapid mineralization of its organic matter. The timing of the green manure incorporation is the key to efficient nitrogen use. It should be incorporated as late as possible in the season, so that organic matter will freeze before mineralisation can occur. When the ground thaws in spring, mineralisation will occur as temperature increases and oxygen becomes available. This coincides with the beginning of the cropping season (Tremblay et al, 2001).

Irrigation management can also be a crucial element to minimise nitrate leaching. Irrigation rates and frequencies that induce drainage beyond the active rooting zone have therefore an impact on nitrate leaching (Brown et al, 1977; Snyder et al, 1984). The volume of water released during irrigation periods must be carefully managed. A soil saturated with water from irrigation or from a storm will inevitably lead to leaching. Excessive irrigation over a short period of time should also be avoided.

1.2 A short outline of policy and environmental directive-analysis with SEAMLESS-IF

SEAMLESS-IF provide a computerised tool for ex-ante quantitative policy and environmental directives analysis. In order to be able to use the quantitative tool the policy question of interest needs to be defined in parameters such that an implementation in the computer system is possible. This is done by defining a scenario, defined within SEAMLESS as "a consistent framework of exogenous assumption and endogenous-related variables describing the possible future of systems". Within SEAMLESS considerable effort has been spend on arriving at a common and unambiguous definition of scenarios that can be used to analyze policy issues with SEAMLESS-IF. This has resulted in a guideline for describing a project in SEAMLESS-IF that is consistent with the SEAMLESS framework of analysis. For more information of the project definition see Janssen et al. (2007). For an elaborate discussion of the definition of scenario in SEAMLESS and several illustrations with different types of applications see Belhouchette (2007).

Conceptually, the approach to policy or technological innovation analysis in SEAMLESS-IF is summarized in figure 1. There are three phases in the analysis, which will also be used in this deliverable to facilitate the link with the modelling system. These steps are build in straight collaboration with policymakers or other stakeholders.

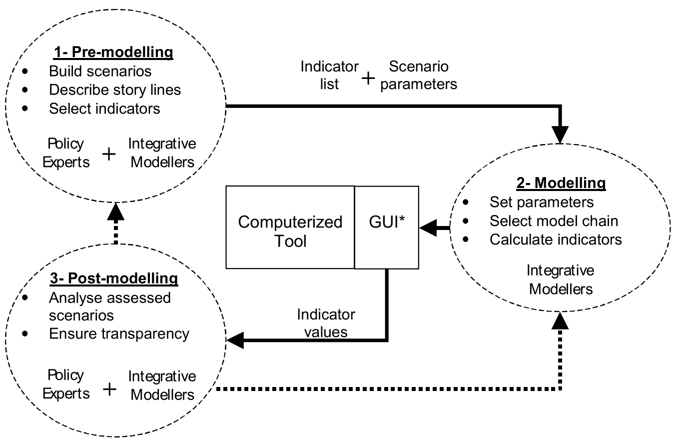


Figure 1- An overview of the three phases of the SEAMLESS methodology for scenario development, assessment and analysis (Therond et al., 2008).

Concretely (figure 2), in the first step, *pre-modelling*, the problem identified in consultation with policymakers or other stakeholders is translated into a scenario which can be analysed with SEAMLESS-IF and indicators are selected to measure the relevant impact of the policy under consideration. This pre-modelling phase is essential since in most policy questions do not translate one-on-one to a scenario in SEAMLESS-IF. Often only part of the policy can be addressed with the available tools and this limitation needs to be communicated well. Especially in the case of ex-ante policy analysis all necessary details on the implementation may not need yet be available and assumptions made can affect the conclusion of the analysis.

The *modelling* phase involves the definition of experiments aimed at providing the necessary detail and variation to address the policy question at hand. The definition of experiments leads to a selection of models that can perform the necessary simulations. The last step is to parameterize (i.e. define the experiments in terms of the appropriate parameters for each model) and run the models. The definition of experiments also includes the specification of experiments for sensitivity testing, i.e. variations in some parameters to test the robustness of the results.

The third step is *post-modelling* and consists of the analysis of the model results, creating visual displays of key findings and communicating the results to policymakers and other stakeholders through presentations and documentation in reports. The full model results can be made available through a user interface that allows viewing of the project but does not allow running new experiments.

In this deliverable we describe the application of SEAMLESS-IF in line with these three steps to analyse the impact of a environmental measures based on Nitrate Directive at farm level in the Midi-Pyrenees region.

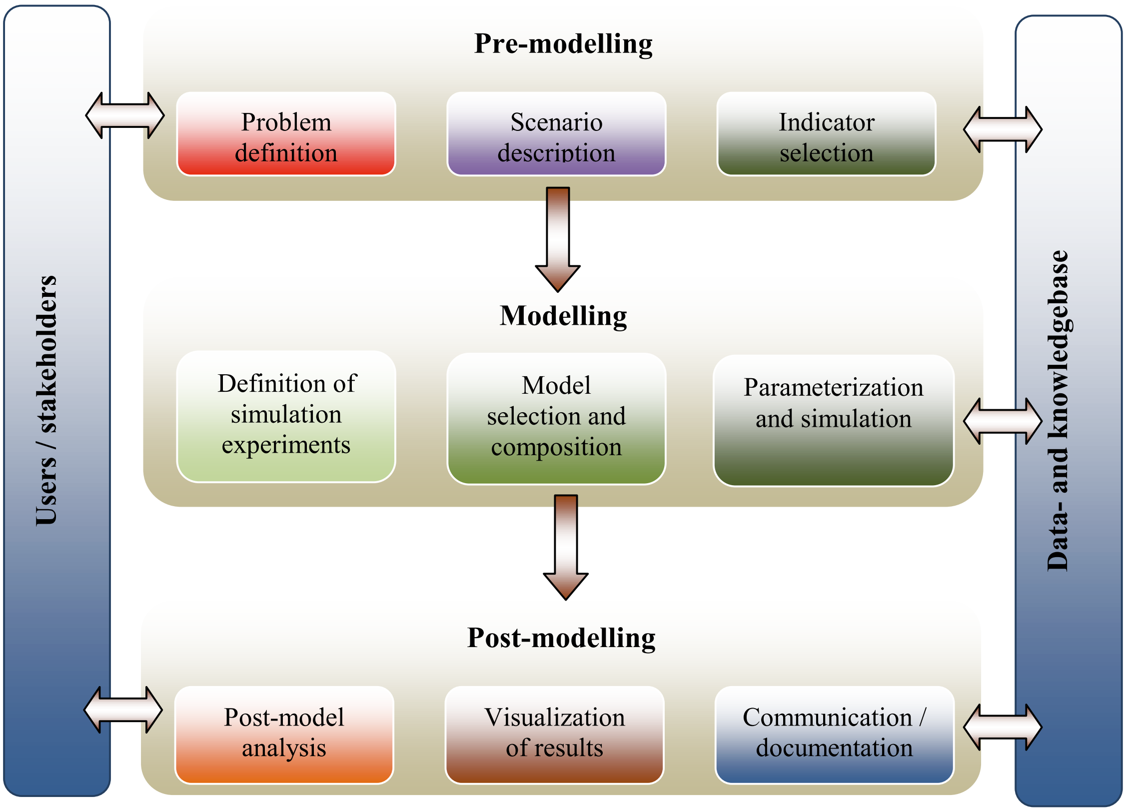


Figure 2- Integrated assessment procedure with SEAMLESS-IF

2 Pre-modelling – defining the scenario

The pre-modelling phase consists of defining the problem or research question to be analyzed, translate this problem in a scenario that can be analyzed with SEAMLESS-IF and define the indicators that will be used to measure the impact. The pre-modelling phase sets the context of the scenario analysis, providing the justification for the choice of parameters. Since there is no need to access the models during this phase the data recorded in SEAMLES-IF may also be entered after one or several meetings with stakeholders to record the agreements made.

2.1 Problem definition and choice of model chain

The project we chose for this example aims to assess how environmental agro-technologies promoted by the EU Nitrate Directive and the Water Framework Directive can improve farming systems sustainability and their impact on the environment.
The study is conducted on one main farm type of the Midi Pyrenees region, using the model chain APES-FSSIM-Indicators (Figure 3).

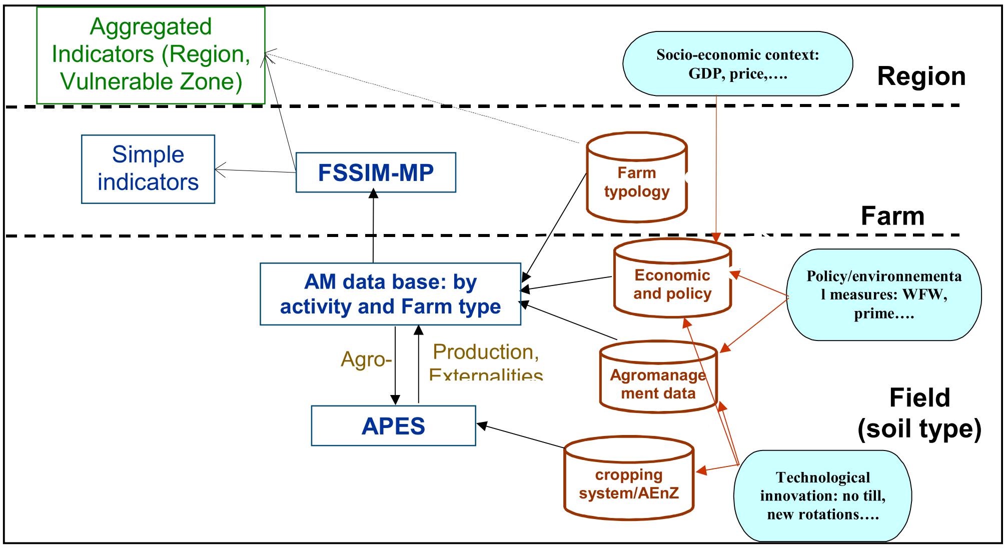


Figure 3- Model chain used in the Sustainable water and nitrogen management scenario.

Scenarios are derived from the Nitrate Directive application of SEAMLESS-IP (PD 6.3.3.2). These scenarios are (figure 4):

1- The baseline 2013 scenario refers to:
- Modelling the implementation of the CAP reform as decided in 2003 with national and regional adjustments:
  - set aside: minimum of 10% of the farm Usable Agriculture Area with fallow
  - modulation: 3% reduction of premiums between 2003 and 2013
  - decoupling: decoupling of premiums as currently implemented in each country
- Business as usual trends between 2003 and 2013
  - inflation: 1.9 % a year

- yield trend: no yield trend, between 2003 and 2013, due to technology innovation is implemented in this application
- price trend: no trend price is directly implemented in this application

- Modelling current activities:
  - existing crops as provided by the SEAMLESS survey on current activities (available in SEAMLESS database)
  - existing irrigation and nitrogen management techniques provided by the SEAMLESS survey on current activities (available in the SEAMLESS database).

2- Three alternative scenarios:
- Better Water Management – here alternative irrigation management for each irrigated cereal crop are computed by a daily time step simulation model APES which triggers irrigation when plant available water decrease under a given threshold (see experiment designer section).
- Better Nitrogen management – here alternative nitrogen management differentiated by soils are computed by the Production-Enterprise-Generator which calculates a simplified nitrogen balance as recommended in the Nitrate Directive for the Nitrate vulnerable zones of the region Midi-Pyrenees.
- Better Nitrogen (Nitrate Directive) and Water management (Water Framework Directive) – here the two options are combined.

Our interest is to compare a set of impact indicator values (assessed by the modelling chain APES-FSSIM) between scenarios allowing assessing sustainability of investigated cropping and farming systems.

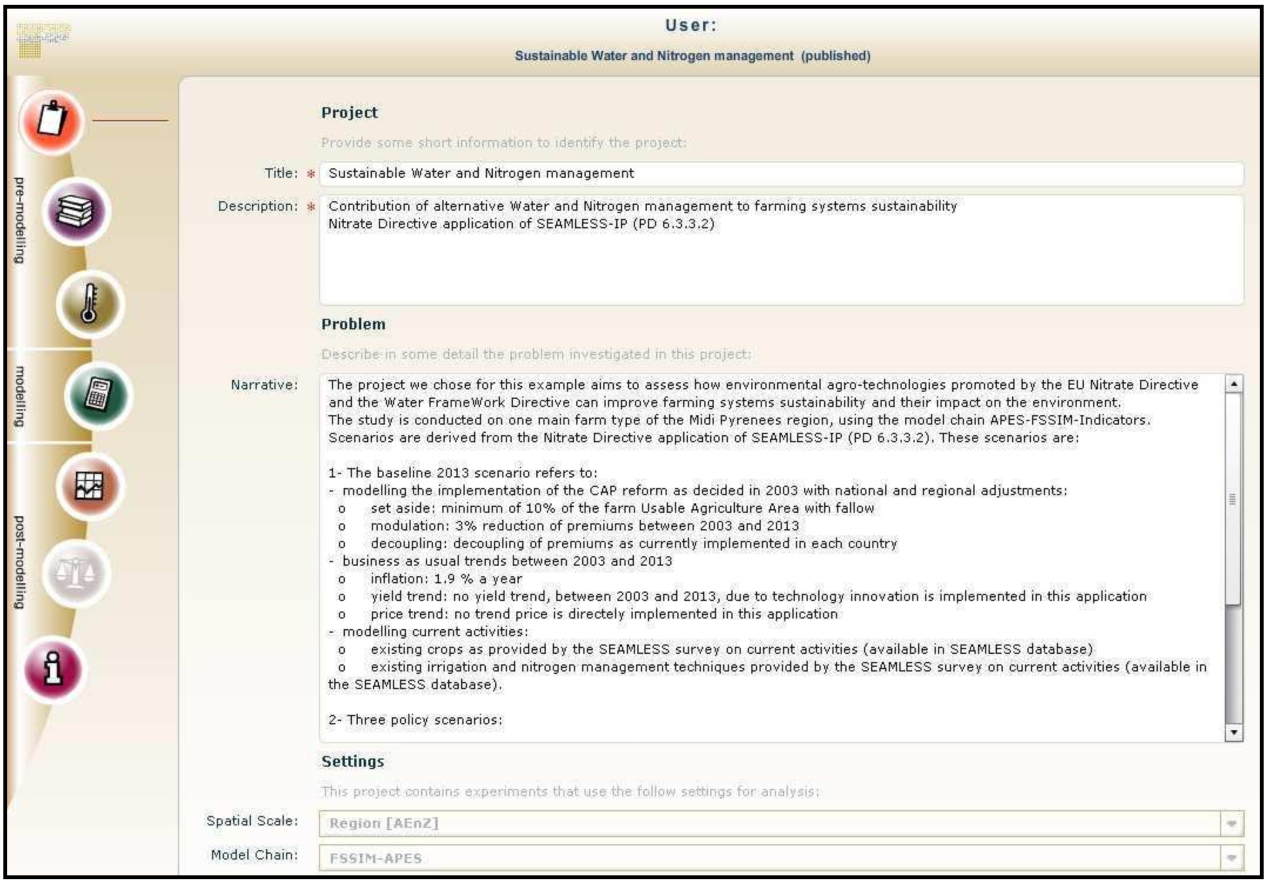


Figure 4- Screenshot of the problem definition in SEAMLESS-IF

2.2 Scenario definition

There are four main scenarios[1] that we want to contrast, the baseline 2013 scenario and three alternative scenarios combining better water and nitrogen managements. In order to be able to analyze these two scenarios quantitatively we need to be more specific in terms of what aspects of the environmental measures we are going to analyze as well as the context in which we assess the scenarios.

2.2.1 Using a baseline as a reference point

The baseline scenario of SEAMLESS-IF examines the consequence of continuing to implement the current European Common Agricultural Policy until 2013.
This scenario includes the current situation in terms of implementation of EU environmental policies and the cross compliance conditions, as well as other future changes already foreseen in the current legislation (e.g. sugar market reform) (Louhichi et al., 2006).
In practise, the baseline scenario which is adopted in 2003 will be implemented until 2013, taking into account several exogenous assumptions mainly on prices and technological progress (figure 5).

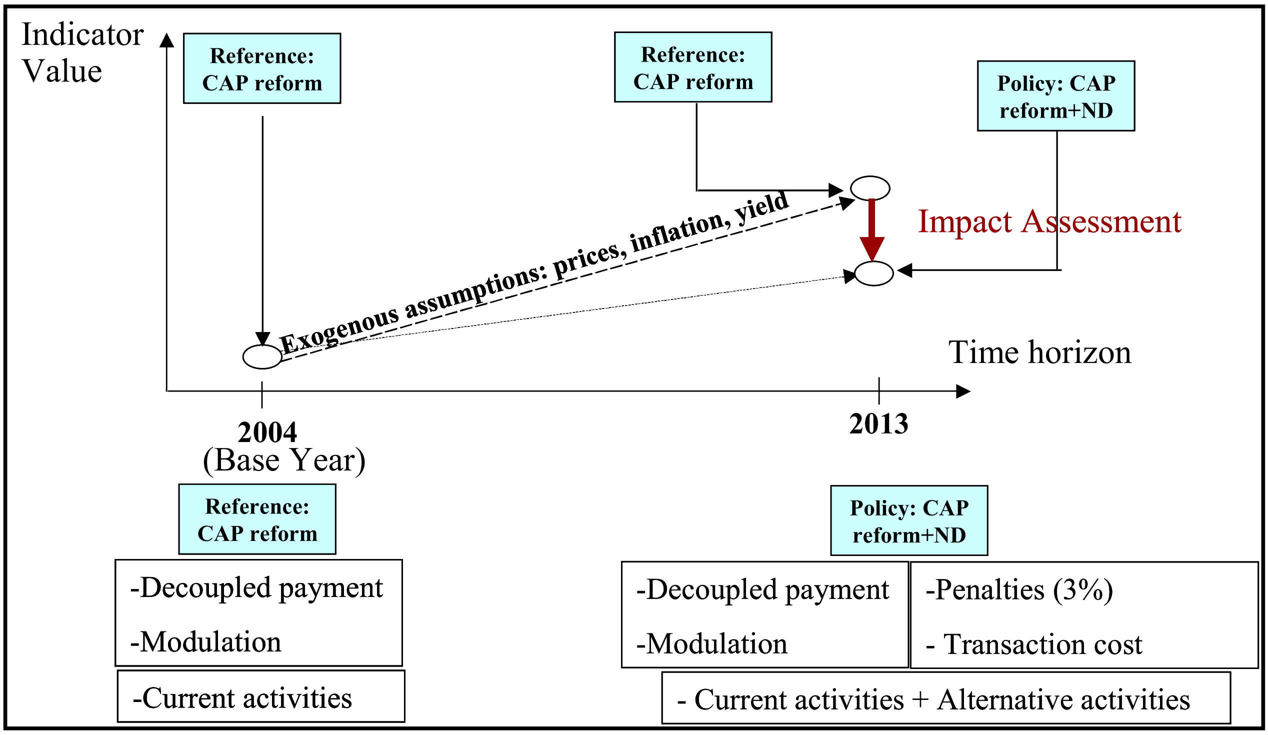


Figure 5- Ex-ante policy analysis based on a baseline scenario.

The other developments that are deemed of relevance are described in the baseline. In intuitive terms the baseline can be thought of as describing the situation in 2013 based on the

[1] The expression "experiment" is used synonymous with the expression "scenario" inside SEAMLESS-IF

situation in 2003 (the year for which we have all necessary data for running the models) given the developments known or expected to occur between 2003 and 2013. The known or expected developments consist of really autonomous developments like population growth, but may also include policies that are being implemented between 2003 and 2013. As illustrated by figure !!! comparing the situation in 2013 with the situation in 2003 gives the compound effect of the policy to be assessed as well as autonomous developments. Comparing the situation in 2013 with and without the alternative scenarios in place provides the actual impact of the alternative scenarios isolated from other developments affecting the situation in 2013.

2.2.2 Choice of context and outlook

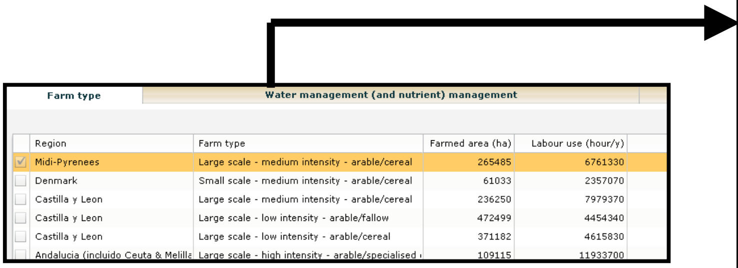
In SEAMLESS-IF scenarios are defined in terms of context, outlook and policy options.

- *Context* describes the biophysical and agro-management system used in the analysis. This context is defined in terms of:

- Farm types: For this application FSSIM is intended to be applied to a set of farm types representing the arable farming system in Midi-Pyrénées. The farm typology developed in SEAMLESS-IP take into account the heterogeneity in farming and biophysical endowment. Based on Farm Accountancy Data Network (FADN) and Farm Structural Survey (FSS), this farm typology provides, for each sample region (NUTS2 level), a set of typical farms defined by 4 criteria : size, intensity, land use and specialisation.

In the Midi-Pyrénées region three of these farm types have been selected as representative of the main arable farming system. The main characteristics of the selected farm type (large scale-medium intensity-arable/cereal) that is retained for this application is described in Table 1. From this Table it could be possible to extract the data on resource endowment of the selected farm type, such as the available land per soil type, the irrigation possibilities, family labour availability… These data are used to define constraint', RHS value as well as the observed crop pattern used for the calibration.

Table 1: arable farm type selected for the Midi-Pyrenees environmental analysis. *Source: SEAMLESS database (Average: 2002-2003-2004)*



Farm type | Water management (and nutrient) management

	Region	Farm type	Farmed area (ha)	Labour use (hour/y)
✓	Midi-Pyrenees	Large scale - medium intensity - arable/cereal	265485	6761330
	Denmark	Small scale - medium intensity - arable/cereal	61033	2357070
	Castilla y Leon	Large scale - medium intensity - arable/cereal	236250	7979370
	Castilla y Leon	Large scale - low intensity - arable/fallow	472499	4454340
	Castilla y Leon	Large scale - low intensity - arable/cereal	371182	4615830
	Andalucia (incluido Ceuta & Melilla	Large scale - high intensity - arable/specialised	109115	11933700

Speclanduse_name	Cereal
Farm represented	2600
Total area/Farm	115
Irrigable area/Farm	37%
Soil Types	40% clay; 60% clay-loam
Crop pattern (%) Cereals Oilseeds Protein Fallow Other crops	 65 18 3 8 7

- Crop management: For each scenario, the main crop water and nitrogen managements are described as follow:

* *Baseline scenario:* A survey has been lead in order to collect data on the current crop activities in the Midi-Pyrénées region. Some local experts, part of the regional agriculture advisory services, have been interviewed. We also used field experiments and statistical database. These data have been collected for the most frequent cropping systems in the region. They take into account climatic variation and other factors as pests and weeds.

In total 65 rotations were identified, with 11 different crops. The principal types of rotations are soft wheat-sunflower, durum wheat sunflower and maize-maize for grain. Combined to management types, soil types and production systems, these rotations define the so-called current agricultural activities. For each crop within agricultural activities a set of data were collected. It includes the data on amount and temporality of management events: sowing, harvesting and tillage events, weed, pest and disease management (pesticide events and tillage events), water management, nutrient management, labour use, average yield, yield variability…

Additionally, for each crop a set of economic data has been specified including product prices, variable costs and premiums. The expected producer prices are collected from regional database and based on the 2000–2003 average. Variable costs are calculated by adding input costs for fertilizers, seeds, irrigation, biocides and the application costs associated with each event. The premiums are the three years average around 2002 according to Agenda 2000 regulation taken as base year policy.
* *Better water management scenario:* In the SEAMLESS context a set of alternative activities can also be generated using PEG, PTG generators. These activities can be defined as new crop nitrogen and water practices or a new activity which is grown in the study area but not identified as a current activity (marginal activity, e.g. sorghum), or combination of all those options. The activities defined in this experiment are defined based on current crops, but with new water management which depend only on the applied dose of water and not on the dates of application. The amounts of irrigation needed by crop are calculated using the APES model.

* *Better nitrogen management scenario:* In this experiment the N fertilization is calculated for each crop with simplified N balance at field level, using target yield, soil nitrate pool, type of fertilizer and type of rotation.

* *Batter water and nitrogen management scenario:* here the two options are combined.

- *Outlook* describes key trends (or deviations from trends) that may affect the outcome of the tested scenarios. In SEAMLESS-IF a variety of trends may be altered relative to the trends used in the baseline: relative exchange rates, shifts in consumer demand for agricultural products (for example related to expected population growth), demand for agricultural products from the biofuel industry, yearly inflation rate, energy prices (energy is an important input cost in agriculture), growth of agricultural yields between base and simulation year and modulation (percentage of first pillar payments moved to the second pillar in the CAP reform). In the current test case only the economic inflation is considered as described in figure 6.

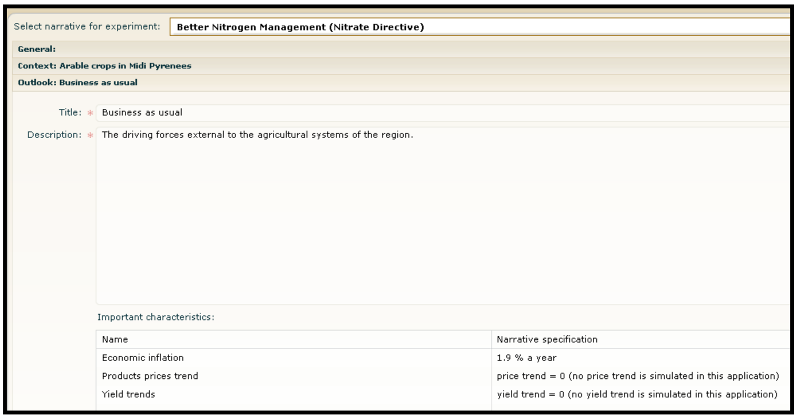


Figure 6- screenshot of outlook in SEAMLESS-IF.

2.2.3 Policy options

This section presents briefly the major policy elements for the CAP 2003 reform, which are the same used for the alternative scenarios (figure 7). The CAP2003 reform implies the decoupling of most direct aid payments from production. This new agricultural policy is expected to reduce many of the incentives to intensive production that have increased environmental risks. Cross-compliance and modulation have become compulsory; with the latter increasing further the budget available to finance social and environmental measures under the second pillar. Compulsory cross-compliance refers to statutory EU standards in the field of environment, food safety, animal health and welfare at farm level. Beneficiaries of direct payments will also be obliged to maintain all agricultural and in good agricultural and environmental conditions (OECD, 2004).

- *Single farm payment scheme*

The single farm payment (SFP) will replace most of the existing premium under different common market organizations. For some countries, such as France, farmers will be allotted payment entitlements based on historical reference amounts received during the period 2000-2002 (Louhichi et al., 2006).

For the baseline scenario , but also for the policy scenarios, the SFP is calculated at farm level based on the average of previous payments from 2000-2003, referred to as the “historical payment”. The direct payments included in the single payment for all EU regions are: (i) Premiums for cereals, oilseeds, protein crops and energy crops, (ii) traditional and established durum wheat premiums, (iii) direct income support for dairy cows, (iv) direct payments to sheep and goat, (v) national envelopes for dairy cows, sheep & goat and bovine meat cattle, (vi) slaughter premiums for adult cattle and claves, and (vii) national premiums to dairy cows in northern Sweden and Finland.

- *Introduction of dynamic modulation*

In order to finance the Rural Development Regulation (RDR) measures, direct payments for farms with more than 5 000€ direct payment per year is reduced by 3% from 2007 onward. This 5% reduction will result in additional RDR funds of EUR 1.2 billion per year.

- *Compulsory cross-compliances*

This conditionality implies regulatory requirements, which farmers have to comply with to fully receive the European income support that is applied for. The set of conditions that apply are based on 18 EU directives and regulations with standards on public health, animal and plant health, the environment and animal welfare. Additionally farmers have to comply with national fixed regulations and conditions on maintaining their farmland in good agricultural and environmental conditions. National governments are also obliged to preserve the area with permanent grassland (EC, 2004). In the Midi-Pyrenees region farmer has to fulfil to receive the European income support: (i) diversification of crop pattern: the crop pattern should contains (i) at least two different crop families (cereals, oilseeds ...), each having more than 5% of total available land, or (ii) at least three different crops (wheat, barley, canola…), each having more than 5% of total available land, (ii) environmental set-aside: farmer has to keep, at least 10% of its COP (area grown with cereal, oil and protein crops) + fallow, hemp and flax area as environmental set-aside.

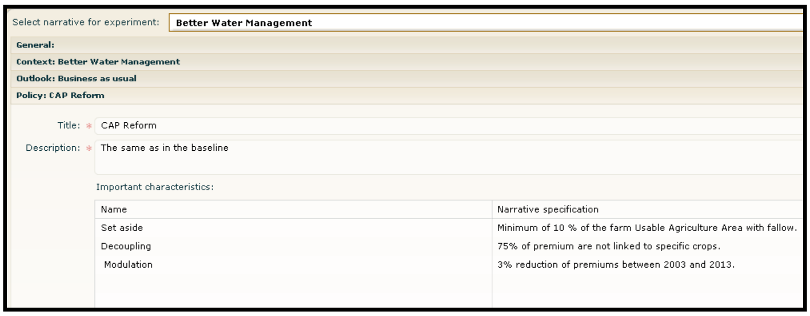


Figure 7- Screenshot of policy options in SEAMLESS-IF.

2.3 Indicator selection

So far we have defined the policy that needs to be assessed, the experiments needed to address this question as well as the limitations of our experiments in terms of the complexities of the actual policy. The last step in the pre-modelling phase is to select the indicators that will be used to measure the impact of the tested scenarios (figure 8).

SEAMLESS-IF contains a library of indicators organized in the Goal Oriented Framework (GOF) which groups indicators to their *spatial scale* (country, region, farm type, agro-ecological zone), *general domain* (effect of agriculture on itself or effect of agriculture on the rest of the world), *domain* (environmental, economic and social) and *type of measure* (an ultimate goal, process for achieving goals, or means spend to achieve goals) (Alkan Olsson et al., 2007). The availability of indicators is obviously related to the choice of model-chain. Since we employ models from the farm to global level we can also select indicators at all these levels.

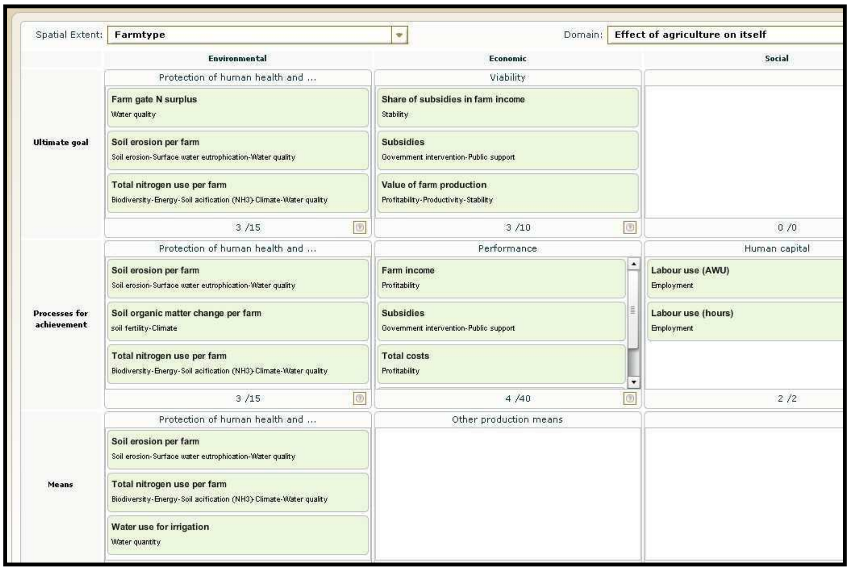


Figure 8- Screenshot of indicators in the Goal Oriented Framework of SEAMLESS-IF.

The main challenge is to select from the rather extensive list the indicators that are most relevant for the question at hand. Key concerns with environmental measures is the impact of on *agriculture itself*. Changes in farmer production and environmental externalities result from changes in *agricultural production* due to changes in *crop practices*.

The change in crop practices does not only affect income earned from agriculture but also affects the environmental sustainability of the cropping system. While alternative crop managements are expected to decline environmental nitrogen and water consumption and then water and soil pollutions, yields and farm income are expected to remain stable or slightly decrease. A such effect of alternative practices are measured by selecting different socio-economic and environmental indicators (figure!!!).

In the current version of SEAMLESS-IF two environmental indicators are available: crop diversity and nitrate leaching. *Crop diversity* measures the effect of agriculture on its environment and is computed from the surface area occupied by each crop. The indicator is based on a reciprocal Simpson's index which assures that the indicators is equal to the number of crops when each crop has the same share of the total farm area. Higher values of the indicator signal higher crop diversity which would contribute to soil and water conservation, reduce pesticide and insecticide utilisation through reducing presence of pests, diseases and weeds and may relate to landscape features (plot size and ecological infrastructure) (C. Bockstaller, 2009a).

Nitrate leaching is also a measure of the impact of agriculture on its environment. It is defined as the ′amount of nitrate leached by farm type under the root zone of crops and grassland due to fertilisation and nitrogen management after harvest (crop residues, catch crops, etc.), (expressed in kg nitrogen in nitrate form per ha and year)'. Nitrate leaching is of concern due to its detrimental effects on water quality and is considered as a threat to public health. Nitrate leaching is part of the FSSIM model output at farm level. The underlying calculations are based on a simulation of the nitrogen cycle in at a daily basis from which yearly totals are computed (C. Bockstaller, 2009b).

Finally we include *labour use* as a social indicator of the availability of agricultural employment. A decrease in agricultural employment is a matter of concern since this may contribute to an already declining viability of rural communities. As with the environmental indicators labour use measures the impact of agriculture on its environment.

3 Modelling – specifying and running experiments

The main activity of the modelling phase is translating the description of the experiments from the pre-modelling phase into specific model runs to be executed in SEAMLESS-IF. The selection of the model chain has already occurred in the definition of the project at the start of the application. This also determined the indicators that are available for assessing the results of the models. These two topics therefore do not require further attention in the modelling phase.

3.1 Parameterisation of experiments

As is immediately obvious from the experiment plan in paragraph!!! all experiments in this application use the 2013 baseline outlook and policy options. These are already pre-defined in SEAMLESS-IF and do not require further attention. With the baseline results already residing in the system, we can focus on defining the parameters of the three experiments: better water management, better nitrogen management and better water and nitrogen managements. For these three experiments we can leave most context elements as they are in the baseline for 2013 (farm type, current list of activities…) and we only need to change the amounts of irrigation and nitrogen fertilization:

* *Better nitrogen fertilisation*: in this scenario, only the cereal crops (winter soft wheat, winter durum wheat, winter barley, oats and maize grain) are selected for a better nitrogen fertilisation. The new amount of N fertilisation for each crop is calculated by a simplified N balance based on target yield, soil nitrate pool, type of fertilizer and type of rotation (figure 9).

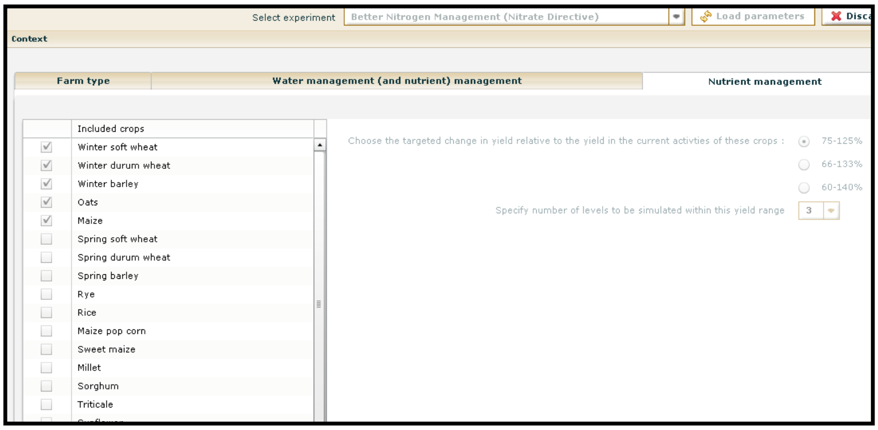


Figure 9- Screenshot of the list of cereal crops selected for the better nitrogen management scenario

* *Better water management:* for this scenario only irrigated maize grain and peas are selected for a better irrigated management based on plant available water (PAW). That means irrigation is triggered when the half of PAW is reached (figure 10).

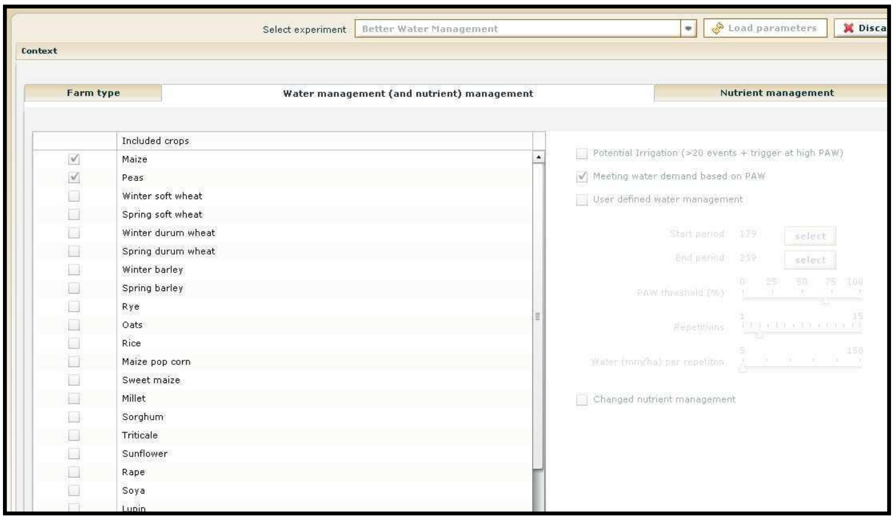


Figure 10- Screenshot of the list of crops selected for the better water management scenario

3.2 Visualization of the model chain

It is possible to check whether the appropriate indicators have been selected before running the actual experiments. This may be essential since indicators that have not been selected in the pre-modelling phase will not be available for analysis after the model runs have been completed. To this end there is a visual representation of which part of the model chain will provide the indicators that are selected. For this application, the model chain APES-SCA[2]-FSSIM is implemented as showed in figure 11.

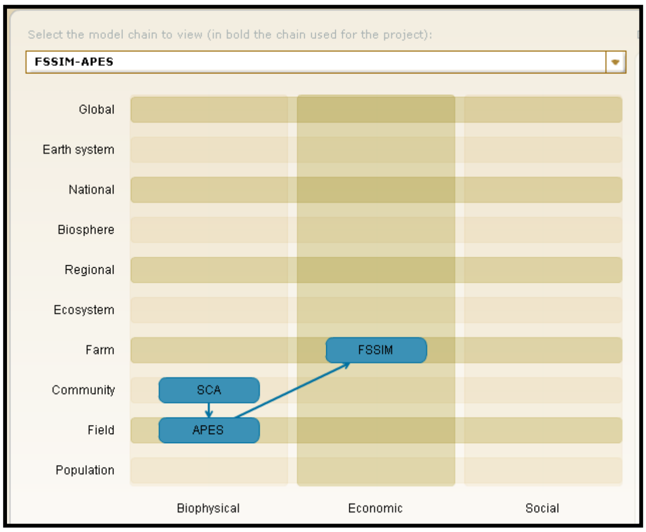


Figure 11- Screenshot of the visualisation of the model chain in SEAMLESS-IF.

[2] SCN: simple current activity

3.3 Running the model chain

The experiments are run by adding them to the queue in the processing centre of the SEAMLESS server (see figure **Erreur ! Source du renvoi introuvable.**). Depending on the complexity of the model-chain and the presence of experiments from other users on the server the model runs can take 5 to 10 hours. Hereby each instance of FSSIM takes about 2 hours. APES generally solves within 3 to 4 hours. These numbers are only estimates, because currently there is only limited experience with executing the whole model chain on the server. Total run time depends on the complexity of the analysed scenario as well as on the computing power of the server.

4 Post-modelling – analyzing and presenting results

In the post-modelling phase the model results are analyzed and presented to stakeholders though reports, presentations etc. In order to arrive at an integrated assessment across domains and scales the results for indicators first need to be understood in isolation, i.e. for each indicator at a time, and then the results for various indicators can be contrasted and their implication for sustainable development assessed.

In the remainder of this chapter we first analyse the results at farm level in economic, social and environmental terms.

The next part then looks in more detail at the intermediate variables impact. This part is reserved to analyse how crop yield changes under each scenario. The yield variables is a key point to understand how farm income and nitrogen leaching vary from a scenario to an other one.

Before using the model chain APES-FSSIM, both model APES and FSSIM are evaluated by developing specific methodologies by using regional data (Casellas et al., 2009; Louhichi et al., 2008).

For the FSSIM model, the calibration was based on risk (first step) and Positive Mathematical Programming according to Röhm and Dabbert approaches (second step). The PAD (percent absolute deviation) obtained in the first step for the selected farm type types is bigger than the fixed threshold which is 15%, showing that the model is unfairly calibrated. This is explained by the limited number of binding constraints (i.e. only three constraints are binding: total land, irrigable land, and obligatory set-aside), the lack of specification of technologies (i.e. the only technology distinction are done between rainfed and irrigated techniques) and the lower price and yield variability (i.e. the risk constraint plays a very small role in this case). According to these results we decided to implement the second step, which consist to use the PMP method (i.e. PAD equal to zero).

4.1 Socio-Economic results

Table 2 gives an overview of different socio-economic indicators for the selected farm type.

Table 2- socio-economic indicators for alternative scenarios

Scenarios	Farm income (Eu/ha)	Share of subsidies (%)	Labour (h)
Better water management	1003	0.27	1113
Better nitrogen management	1122	0.24	1368
Better water and nitrogen management	1003	0.27	1113

The alternative scenarios show almost same values of farm income, share of subsidies and total labour. These scenarios are compared to the baseline one. Figures !!! present a comparison of the socio-economic indicators to the baseline scenario:

- **Farm income (figure 12)**: The farm income highly increases when the alternative scenarios are compared to the baseline one. The main reason is that less nitrogen fertilisation and water for irrigation are used. The highest value of farm income is observed for the better nitrogen fertilisation. The better water management scenario and the better water and nitrogen managements showed the same farm income values.

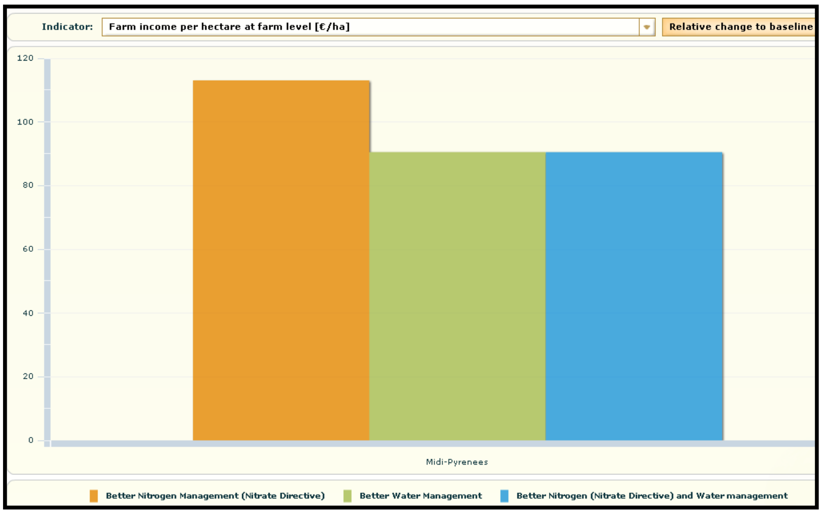


Figure 12- screenshot of farm income for the alternative scenarios

To understand such results a deep analysis on term of crop pattern by soil, rotation and management is required. The current version of SEAMLESS-IF, which is continuously under development, doesn't allow to access such results. However, a part of those results can be explained by the fact that, even if the yield of most cereal crops decreases under the better nitrogen management scenario compared to the baseline one (figure 13), these crops are more profitable in the case of better nitrogen management scenario. This result is probably du to the fact the total cost in the better management scenario is lower then in the baseline one (CAP2003 reform).

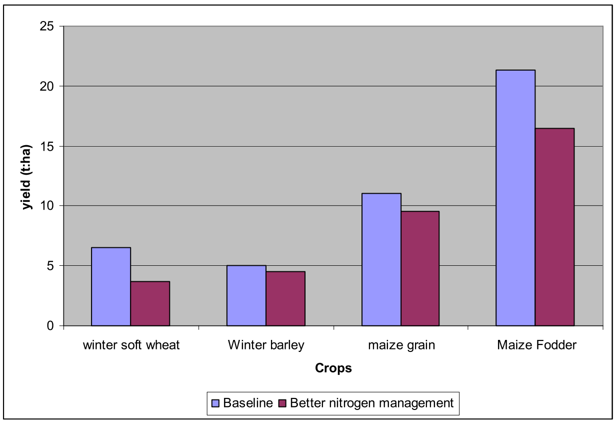


Figure 13- Crop yield for baseline scenario (CAP2013 reform) and a better nitrogen management scenario.

- **Share of subsidies in farm income (figure 14)**: The results of the alternative scenarios are compared to the 2003 EU CAP reform as it would be implemented in 2013. The share of subsidies highly decreases to reach 40% for the better nitrogen management scenario and 35% of the better water and better water and nitrogen scenarios.

Figure 14- Screenshot of share of subsidies in farm income (%) for alternative scenarios.

- **Labour use**: By reducing the amount of water and nitrogen fertilisation, the total labour for the alternative scenarios is less important then for the baseline scenario. The most important reduction is observed for better water management and better water and nitrogen management. In fact, the labour use needed for 1 hectare of irrigated maize grain is 49.7 h/ha. Reducing the amount of water based on plant available water will induce necessarily a reduction of the total labour use as is shown in figure 15.

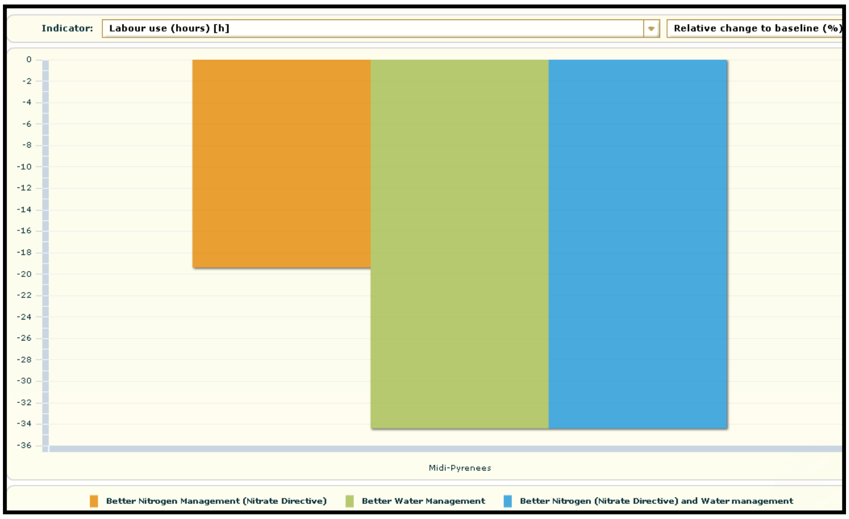


Figure 15- Screenshot of labour use (hours) for alternative scenarios.

4.2 Nitrogen leaching

For the alternative scenarios the total nitrogen leaching at farm scale decreases compared to the baseline one. The most important nitrogen leaching reduction is observed for the better nitrogen management where the nitrogen leaching drop by 67% compared to the baseline scenario (table 3).

Table 3- Nitrogen leaching for baseline and alternative scenarios.

Scenarios	Baseline scenario	Better water management	Better nitrogen management	Better water and nitrogen management
Absolute values (kg/ha)	20.2	12.5	14.5	14.5
Relative reduction to baseline		40%	28%	28%

The only difference between the baseline scenario and the alternative scenarios is the implementation of the first measure of the Nitrate Directive (better nitrogen management). The same application is implemented using the stand alone versions of the model chain APES-FSSIM-Indicators (Belhouchette et al., 2009). In this application, in addition to the first measure of the nitrate directive, a 3% of cross compliance restriction and 5% of transaction cost were added. The results obtained by adding the policy part of the Nitrate Directive showed small differences with the current application in term of nitrate leaching. This difference, is probably due to different strategies of crop production adopted by farmers to face the income loss due to the 3% of penalty.

The application outside SEAMLESS-IF showed also that 3% of penalties are not enough to enforce farmers to adopt the Nitrate Directive. The threshold from which this farm type starts adopting cross-compliance is estimated to be a premiums cut of 17% (or 65% of additional premium) premium. Obtained through a sensitivity analysis, this threshold shows that farmers are able to respect the cross-compliance but with a significant loss of income (Louhichi et al., 2008).

4.3 Intermediate variable: yield by crop (t/ha)

For the three alternative scenarios the yield of main crops are compared to baseline scenario (figure 16):

- For the rainfed crops, the yield decreases except for soya and fodder maize. The most important decrease is noted for the soft winter wheat.

- Concerning irrigated crops, the yield of maize highly decreases with the scenario better water management. Inversely, the yield of irrigated peas slightly increases.

- The combination of a better water and nitrogen managements provokes an increase in the yield of irrigated maize. This result proves that for a better irrigated crops, water and nitrogen should be managed simultaneously, otherwise, yield and externalities can be affected.

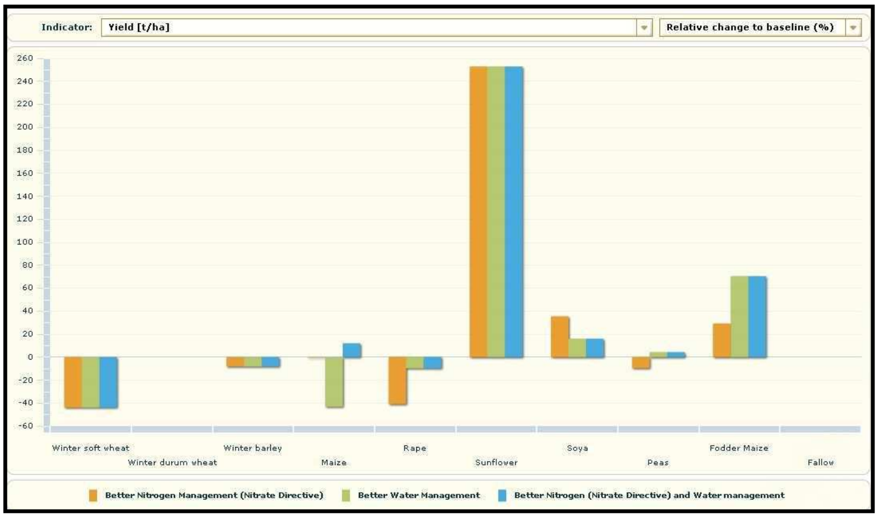


Figure 16- Screenshot of relative yield variability of alternative scenarios to the baseline scenario.

5 Conclusions

These results show that this modelling chain can be functional for complex scenarios combining economic and environmental drivers with technological changes, and provided relevant results at farm, when discussed with local experts. Results of this study indicate that the modification of environmental regulations may lead to several economic, social and environmental changes. These modifications lead to the adaptation strategies adopted by farmers in order to minimize the farm income losse due to the environmental measures. These strategies are usually traduced by the modifications in crop rotations on each soil type and by consequence in the crop management options and their spatial allocation. So, as a consequence of farm profitability change, several modifications occurred at field scale depending of the biophysical context and the economic and social constraints. In Louhichi et al (2008) and Belhouchette et al. (2008) more details and results on farmer strategies adaptation regarding the nitrate directive are presented and analyzed by using the same model chain developed in this application.

This work highlights some key methodological aspects for future improvements and further uses of the meso backbone modeling chain of SEAMLESS-IF:

i) organization of iterative and cyclical interactions with local experts in order to validate the data used in this application and the scenarios results.

ii) development of additional scenario options enabling to test more complex scenarios including policy and environmental measures.

iii) development of sound methodologies for models calibration and validation at field, farm and regional levels.

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Glossary