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

**Integration of all FSSIM components within  
SEAMLESS-IF and a stand alone Graphical User  
Interface for FSSIM**

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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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# Table of contents

<b>Table of contents</b>	<b>5</b>
<b>General part</b>	<b>7</b>
<b>Objective within the project</b>	<b>7</b>
<b>General Information</b>	<b>7</b>
<b>Executive summary</b>	<b>7</b>
<b>Scientific and societal relevance</b>	<b>9</b>
<b>Specific part</b>	<b>11</b>
<b>1 Introduction</b>	<b>11</b>
<b>2 Criteria for a generic BEFM</b>	<b>15</b>
<b>3 Design of FSSIM</b>	<b>17</b>
3.1 Conceptual design	17
3.2 Technical design	21
<b>4 The components of FSSIM</b>	<b>25</b>
4.1 Template of FSSIM-MP (Louhichi et al., 2009a -PD3.3.11)	25
4.1.1 Introduction	25
4.1.2 Modular System	26
4.1.3 Calibration and evaluation	26
4.2 Current activities according to expert knowledge (Zander et al. 2009 - PD3.3.9)	27
4.3 Livestock Activities (Thorne et al., 2009 - PD3.3.4)	31
4.4 Perennial activities (Blanco et al., 2009 - PD3.3.5)	32
4.5 Alternative activities and technical coefficient generators (Janssen et al., 2009 - PD3.3.3)	32
4.6 FSSIM Graphical User Interface	34
4.6.1 User requirements	35
4.6.2 Conceptual Design	36
4.6.3 Architecture of the FSSIM-GUI	40
<b>5 Applications</b>	<b>43</b>
5.1 Application for micro-macro analysis	43
5.2 Applications for regional integrated assessment	43
<b>6 Discussion</b>	<b>45</b>
6.1 Is FSSIM generic?	45

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6.2	<i>Can FSSIM be extended?</i>	48
6.2.1	Integration procedure	48
6.2.2	Components and tiers	49
7	<b>Conclusion and future developments</b>	<b>51</b>
	<b>References</b>	<b>53</b>
	<b>Glossary</b>	<b>59</b>

## General part

### Objective within the project

This deliverable describes the work in T3.3 to develop a bio-economic farm model called FSSIM that can adequately represent different farm types in a European situation,. Within the project, FSSIM will be linked to APES, the dynamic crop simulation model at field scale, and CAPRI, the partial equilibrium model at market scale. FSSIM is thus the vital link between the field scale and the market scale, while providing estimates of economic and environmental indicators at the farm type scale. FSSIM can consequently be used for two purposes within the project: upscaling exercises to market scale with CAPRI and EXPAMOD, and regional assessments at farm type scale of impacts of policy changes and technological innovations

### General Information

Task(s) and Activity code(s):	T.3.3, Activity 3.3.8
Input from (Task and Activity codes):	T3.3, Activity 3.3.7, 3.3.5, 3.3.2, 3.3.1, WP4 WP5
Output to (Task and Activity codes):	WP3 (T3.6, T3.2), WP4, WP5 and WP6
Related milestones:	M3.3.6

### Executive summary

Policy makers and farmers have an interest in making *ex-ante* assessments of the outcomes of their choices in terms of policy and farm plan. This interest mainly concerns the assessment of socio-economic and environmental performance of farms as a result of innovations and policies. Mathematical models based on systems analysis are suited to explore and assess uncertain future states of systems. A Bio-Economic Farm Model (BEFM) is defined as a model that links formulations describing farmers' resource management decisions to formulations that describe current and alternative production possibilities in terms of required inputs to achieve certain outputs and associated externalities.

Currently many descriptions and applications of BEFMs are being published. A BEFM that is easy to transfer between locations or farm types is called generic, which we define as 'being able to deal with different scales, locations, functionalities, and levels of detail. Although some model studies claim that their model is easily transferable to other regions and farm types, there is little evidence from literature supporting these claims.

A generic bio-economic farm model should be able to adequately represent arable, livestock and perennial activities, current agricultural activities and future alternative activities, different objective functions, different resource and policy constraints, future policies and technological innovations as scenarios and should include good calibration procedures. In SEAMLESS the Farming Systems SIMulator (FSSIM) has been developed as a generic and



transferable model that can easily be extended with new features and re-used across data-sets, farm types and locations. In this deliverable we (i) describe FSSIM and its design as an integrated generic bio-economic farm model, (ii) briefly describe each of the components of FSSIM and provide references to relevant deliverables and publications for more detail and (iii) evaluating FSSIM on criteria for generic models by describing applications of FSSIM.

Conceptually FSSIM targets two main purposes in SEAMLESS:

1. providing supply-response functions for NUTS-regions that can be upscaled to EU25 level
2. allowing detailed regional impact assessment of agricultural and environmental policies and technological innovations on farming practices and sustainability of different farming systems.

The dual purpose of FSSIM has resulted in so-called simple and detailed applications of FSSIM, corresponding with simple sample regions and detailed sample regions, respectively. Simple sample regions cover the diversity in current farming systems across the EU, while detailed sample regions can be any region for which an impact assessment is required.

This farm model includes a module for agricultural management (FSSIM-AM) and a mathematical programming model (FSSIM-MP), which forms the core of the bio-economic farm model (FSSIM). Based on mathematical programming approaches, FSSIM-MP captures resources, socio-economic and policy constraints and the farmer's major objectives. The aim of FSSIM-AM is to describe, generate and quantify production techniques of current and alternative production enterprises for which yields and environmental effects can be simulated by APES (or other cropping/livestock system models). FSSIM-AM and MP have been further sub-divided into components or sub-modules that have a more specific role and have a stand-alone value. Every component of FSSIM has been designed to be reusable and can be used in other applications and modelling exercises, independent of FSSIM. The technical design of FSSIM is based on the theory of software components, semantically aware components and tiered application.

FSSIM has been coupled to two distinct graphical user interfaces, i.e. SEAMLESS-IF and FSSIM-GUI. The FSSIM-GUI allows modellers and integrative modellers to make model runs with one or more components of FSSIM. The FSSIM Graphical User Interface is targeted at modellers both within and outside SEAMLESS who use components of FSSIM and who do not have in-depth knowledge of the three programming languages of FSSIM: GAMS, SQL and Java. The FSSIM-GUI can be found on <http://fssim.seamless-ip.org> and questions or comments can be sent to [fssim@seamless-ip.org](mailto:fssim@seamless-ip.org).

The technical integration of the different FSSIM components proved to be a challenging and time consuming task due to the complex data-types (or data-structures) being exchanged between components and to the large amounts of data that have to be exchanged between components. Based on experiences with component integration during the SEAMLESS project, an 11-step procedure for integration has been formulated, which can be used to integrate other components into SeamFrame and to keep track of their 'integration-status.'

FSSIM has been developed as a generic BEFM that targets wide applicability and models "generic" processes instead of specific processes to one research question, location or data source. Although a truly generic model might not be possible, FSSIM represents a first step in the development of a BEFM as a library of components and functionality that can be adapted to the purpose, scale, location and linked to other models.

FSSIM is a product from a joint development of agronomists and economists. This lead to a balanced definition between different types activities, policy instruments and technological

innovations, without emphasizing any in particular, to enable use of FSSIM for different study objectives. The FSSIM source code can be obtained from <http://svn.seamless-ip.org/>.

A condensed version of the deliverable has been submitted as a journal paper to a special issue of Environmental Management.

## Scientific and societal relevance

Several scientific challenges exist in the development of FSSIM, one of which is the topic of this deliverable. This challenge concerns the integration of different components based on a variety of programming languages and of knowledge into one model that can be applied to other locations and circumstances. Other scientific challenges are the development of a modular mathematical programming model at the farm scale (Louhichi et al., 2009a - PD3.3.11), collection of data to adequately represent current activities across Europe (Zander et al., 2009 - D3.3.9), development of suitable model calibration and evaluation procedures for farm models (Kanellopoulos et al., 2007-PD3.3.8), a comprehensive description of methods to define perennial, livestock and arable activities for farm models (Blanco et al., 2009-PD3.3.5; Thorne et al., 2009 -PD3.3.4) and finally generation of feasible alternative perennial, livestock and arable activities (Janssen et al., 2009 -PD3.3.3).

Once these challenges are overcome, SEAMLESS will provide a range of farm models for the EU that are capable of adequately simulating the impact of policy changes and technological innovations in terms of a range of environmental and economic indicators. These farm models can consequently be used by policy makers and other stakeholders jointly with researchers to assess the impacts of proposed policy changes and technological innovations on sustainable development of the agricultural sector.



## Specific part

### 1 Introduction

Policy makers and farmers have an interest in making *ex-ante* assessments of the outcomes of their choices in terms of policy and farm plan (cf. Rossing et al., (1997); Zander and Kächele (1999); Leeuwis (1999); EC (2005)). This interest mainly concerns the assessment of socio-economic and environmental performance of farms as a result of innovations, and the assessment of socio-economic and environmental effects of policies on the major categories of farms. Mathematical models based on systems analysis are suited to explore and assess uncertain future states of systems. As expressed by Edwards-Jones and McGregor (1994) “the utility of a series of whole farm models for the European situation would be substantial, particularly in the *ex-ante* policy assessment and marketing of on-farm technology.” Certainly, not only the European situation would benefit from assessments of agricultural innovations or agricultural and environmental policies. A Bio-Economic Farm Model (BEFM) is defined as a model that links formulations describing farmers’ resource management decisions to formulations that describe current and alternative production possibilities in terms of required inputs to achieve certain outputs and associated externalities. Janssen and Van Ittersum (2007) recently reviewed the usefulness of BEFMs for predicting the impact of policy changes.

Advantages of bio-economic farm models are that (i) they are based on a constrained optimization procedure and thereby seem to match the reality of small farmers, striving, with limited resources, to improve their lot (Anderson et al., 1985); (ii) many activities, restrictions and new production techniques with sound technical specifications can be considered simultaneously (Wossink et al., 1992; Flichman, 1996; Ten Berge et al., 2000; Weersink et al., 2004), including linkages between crop and livestock production (Antle and Capalbo, 2001); (iii) the effects of changing parameters, for example prices, can easily be assessed through sensitivity analysis (Wossink et al., 1992), and (iv) they can be used both for short term predictions and long term explorations (Van Ittersum et al., 1998).

Currently many descriptions and applications of BEFMs are being published (e.g. Bartolini et al. (2007), Acs et al. (2007), Onate et al. (2007) and Semaan et al. (2007)). BEFMs in principle provide the ability to replicate assessments for a vast range of spatial conditions and farming practices. A BEFM that is easy to transfer between locations or farm types is called generic. Although some of the model studies claim that their model is easily transferable, there appears to be no evidence from the literature of successful transfers of a model to new locations and farm types (Janssen and Van Ittersum, 2007). Existing BEFMs are rarely re-used and the newly developed models and their applications do not add many new features or approaches to the current body of literature. This lack of re-usability could be due to on the one hand these models being very specific for a location or farm type or on the other hand modellers preferring to build their own model rather than re-using existing models. Data needs, size and structure of a BEFM can limit its transferability.

In SEAMLESS we choose to develop the Farming Systems SIMulator (FSSIM) as a bio-economic farm model. Within SEAMLESS many demands are made on FSSIM to provide information to other (model) components in the project:

1. EXPAMOD requests outputs of FSSIM for 25 sample regions to derive supply-demand responses for agricultural commodities.

2. Partners in T3.3 request a farm model for their specific region, for example Brandenburg or Andalucia, so that it can be used for regional policy analysis.
3. WP6 requests an user-friendly FSSIM tool that local experts can use by easily adding policies like agri-environmental subsidies (equations, data, etc) without touching any code.
4. WP5 requires components, with clear inputs and outputs that can be integrated in SEAMLESS-IF, so that users of SEAMLESS-IF can use them. Primary concern for WP5 is the exchange of information among components, while the functionality of the components is of secondary importance.
5. WP6 collected data for Mali and adapted FSSIM to (data scarce) environments in developing countries. To apply FSSIM in such countries will require adjustments in its generic structure.
6. Partners in SEAMLESS might want to use FSSIM for educational purposes to demonstrate to their students the type of tools that can be used in Integrated Assessments. This requires a transparent and user-friendly computer program.

For each of these demands on FSSIM a specific solution could be made and has been made in previous research (e.g. see Donaldson et al. (1995) for regional application; see Kruseman and Bade (1998) for an application to a Least Developed Country; see Paris and Arfini (1999) for EU-wide policy analysis). This is time demanding and can potentially lead to diverging models with different content, conceptualization and level of detail. A better alternative is to develop a generic and easily transferable FSSIM model that can be adapted to the different demands. To determine whether a BEFM is generic, it should have a generic design and it should have been applied over a range of different locations and scales. A generic BEFM could enable a group of researchers to work jointly on one model, extending it with new features and allowing re-use across data-sets, farm types and locations (Janssen and Van Ittersum, 2007). Here we define generic as ‘being able to deal with /model/allow different scales, locations, functionalities, and levels of detail.’ The lack of generic BEFMs could limit the uptake of BEFM as a tool for assessments of policies and technological innovations on a larger scale outside the research domain, as the development and use of BEFMs remains a time and resources consuming exercise requiring specialist knowledge of researchers.

The structure of a bio-economic farm model in its most basic form can be represented as (Hazell and Norton, 1986):

$$\text{Max (or Min) } [w = c'x] \quad (1)$$

$$\text{Subject to } Ax \leq b \quad (2)$$

$$x \geq 0 \quad (3)$$

where  $w$  is the objective value, which is a linear function of the  $n$  production activities ( $x$ ) and their respective contributions ( $c$  – coefficients) to the objective.  $Ax \leq b$  represents the  $m$  linear constraints with their upper bounds  $b$  which represent resource endowments or policy targets and thresholds.  $A$  is an  $m \times n$  matrix with Technical Coefficients, describing the agricultural activities. An activity is a coherent set of operations with corresponding inputs and outputs, resulting in e.g. the delivery of a marketable product, the restoration of soil fertility, or the production of feedstuffs for on-farm use (Ten Berge et al., 2000). The variables  $x$  are the decision variables in the optimization procedure of the Linear Programme (Van Niejenhuis and Renkema, 1989). This simple formulation assumes economic rationality of profit maximization. A generic bio-economic farm model should adequately represent arable, livestock and perennial activities (Thornton and Herrero, 2001; Pacini, 2003), current agricultural activities and future alternative activities (Van Ittersum and Rabbinge, 1997; Hengsdijk and Van Ittersum, 2002), different objective functions (Freund, 1956; Hardaker et al., 1997), different resource and policy constraints, and future policies and technological

innovations as scenarios (Louhichi et al., 1999). This was identified by Janssen and Van Ittersum (2007) as a major challenge. Also the generic bio-economic farm model should contain appropriate calibration procedures (e.g. Howitt (1995), while maintaining its predictive power, as a method to remedy any deficiency of the assumptions of economic rationality or simple profit maximization. Integration is the process of conceptually and technically linking parts of knowledge into a whole by a group of researchers. The integration of these different elements of a generic bio-economic farm model is a conceptually and technically challenging task, as the bio-economic farm model should be transparent, robust and easy to configure. For example, the configuration for an application to a dairy farm in Scotland studying the effects of agri-environmental policies on regional farm income would be completely different from the configuration for an application of the effect of reduced farm quotas at the scale of the whole European Union.

In SEAMLESS we choose to develop the Farming Systems SIMulator (FSSIM) as a generic and easily transferable model that can easily be extended with new features and re-used across data-sets, farm types and locations. In this deliverable we want to (i) describe FSSIM and its design as an integrated bio-economic farm model, (ii) briefly describe each of the components of FSSIM and provide references to relevant deliverables or publications and (iii) evaluate FSSIM on criteria for a generic BEFM by describing applications.

It is clear that required resources for development and maintenance as well as the level of abstraction will increase with more general applicability. Therefore, the question in reality will not be "generic or not", but rather relate to an optimal degree of being generic with some remaining restrictions on applicability. Still we believe that for scientific progress the challenge is to understand and model the "generic" processes, i.e. to identify and model those processes relevant to many purposes, research questions, locations and scales. Trying to shift the balance from the current emphasis on specific BEFMs to more generic BEFMs seems correct from a scientific and efficient from an application point of view

In Chapter 2 criteria for a generic BEFM be introduced, while Chapter 3 describes the conceptual and technical integration of FSSIM. Chapter 4 describes each of the components of FSSIM in some detail, including the FSSIM-Graphical User Interface (GUI). In Chapter 5 relevant applications of FSSIM are shortly described, both for micro-macro analysis and for regional integrated assessments. Finally, FSSIM is evaluated as a generic model in Chapter 6 and features of FSSIM will be discussed in relation to its purpose and re-use.



## 2 Criteria for a generic BEFM

Several criteria have to be met in our view to by a BEFM to be classified as generic. The **first criterion is that it should be relevant for a range of agri-environmental zones**. An agri-environmental zone is a homogenous combination of soil and climate types, that covers parts or whole administrative regions. An example of such a definition of agri-environmental for the European Union can be found in Hazeu et al. (2009). These biophysical conditions strongly affect the current farm structure, the farming possibilities and potential in a location and thus the specification of a BEFM. For example, for a highland area with only grazing a different configuration of the BEFM is required than for a lowland fertile area.

The **second criterion is that the BEFM should be applicable to a range of farm types**, for example, arable, livestock and mixed farming systems, and low and high intensity systems as defined by a farm typology. Different farm types can be identified on the basis of a farm typology (Andersen et al., 2007). The BEFM should have the capability to handle these different farm types consistently and without bias.

The **third criterion is the capability to address different purposes**, e.g. assessments of technological innovations or policy issues (Janssen and Van Ittersum, 2007). Assessments of policy issues have usually a short-term horizon and require realistic and validated modelling of farm responses, while assessments of technological innovations are explorative and often based on postulated optimizing farm responses (Flichman and Jacquet, 2003).

The **fourth criterion is the capability to handle applications at different levels of detail in input or output data**. Data availability will differ with the application, scale and location. For example, for regional studies often other type of data compared to an application at national or continental level. Moreover, accurate assessment of some indicators (e.g. landscape, biodiversity and greenhouse gas emissions) requires more detailed data on agricultural activities and their effects than that of other indicators (e.g. farmer income, total costs, revenues). The data requirements depend also on the purpose of the application and perspective of the researcher.

Finally, the **fifth criterion is that the model should be capable to link to different types of models simulating processes at different scales**. Linking could be required to assess the impact of simulated land use changes on markets, bio-physical, structural or esthetical parameters of landscapes, and on emissions to water and air. For example, the up-scaling of farm responses to market level models is relevant for assessments of high level policies, while for assessments of biodiversity and landscape impacts of farming linking to landscape models is relevant. The BEFM should not be constrained in its linking to one specific type of model, but instead be capable to exchange input and output data with each of these model types in a flexible way.





## 3 Design of FSSIM

### 3.1 Conceptual design

This Section presents an overview of the bio-economic farm model, FSSIM (Farm System Simulator) with a modular set-up, which can be used as a standalone model and as a model within the framework for integrated assessment, i.e. SEAMLESS-IF (Van Ittersum et al., 2007). The structure of FSSIM allows it to be applied to farm types that differ in soils and climate, resource endowments, agricultural activities and their management options and utility functions, and that may be subject to a broad range of agricultural and agri-environmental policies. Conceptually, FSSIM fulfils two main purposes:

1. providing supply-response functions for NUTS-regions that can be upscaled to EU25 level, e.g. micro-macro analysis,
2. allowing detailed regional integrated assessment of agricultural and environmental policies and technological innovations on farming practices and sustainability of the different farming systems.

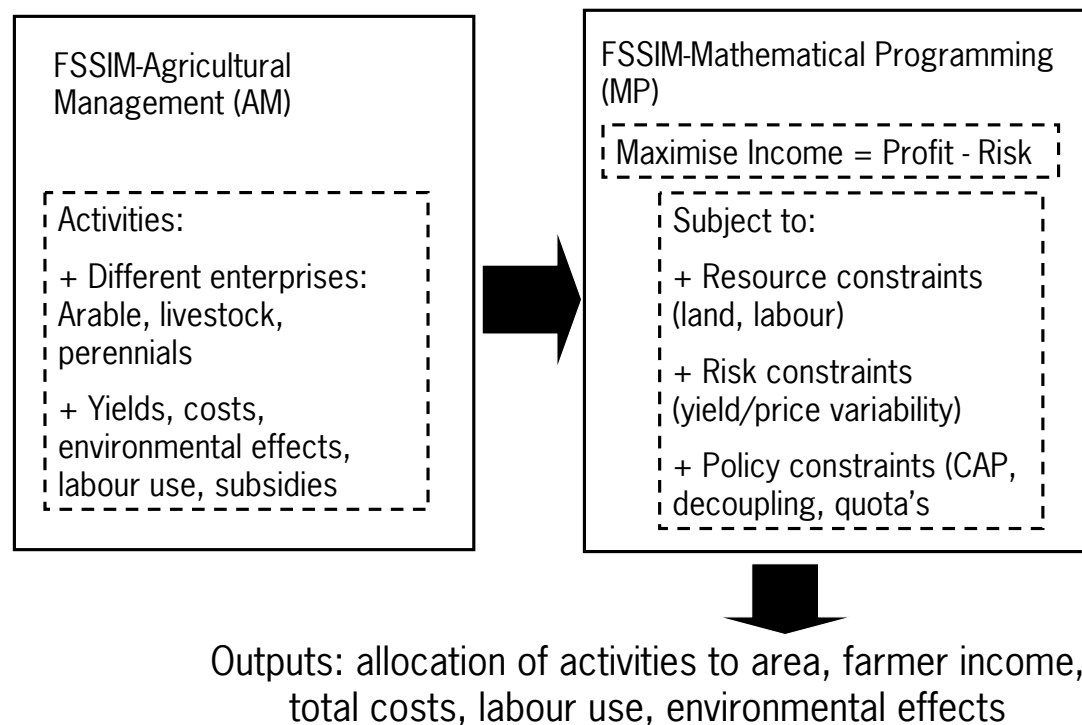
For the first purpose, FSSIM can be much coarser, while for the second purpose FSSIM needs more detailed specifications of policies, agricultural practices and technological innovations. It was found that the data-requirements for the second purpose of FSSIM could not be met in a large number of regions, due to the large efforts required for data collection. Therefore, the dual purpose of FSSIM resulted in a simple and detailed application type of FSSIM, corresponding with the simple sample regions and detailed sample regions, respectively. Simple sample regions cover the diversity in farming systems in the European Union, while detailed sample regions can be any region for which an impact assessment is required. Within SEAMLESS, 21 simple sample regions (Table 1) have been selected across the EU-25 and 6 detailed sample regions, i.e. Flevoland, Brandenburg, Midi-Pyrénées, Andalusia, Zachodniopomorskie, and Koutiala in Mali. The applications to the detailed sample regions should demonstrate the powerful analysis that can be carried out throughout the EU, if data collection could be centrally organised.

For both the detailed and the simple sample regions a farm typology has been developed covering the heterogeneity in farming systems and biophysical endowments. Based on the Farm Accountancy Data Network (FADN) and Farm Structural Survey (FSS), this farm typology has provided for each sample region (NUTS2 level) a set of typical well-defined farms in terms of size (i.e. total available agricultural land), intensity (i.e. output per ha), land use and specialisation. The developed typology has been linked to bio-physical characteristics by spatially allocating the farm types to sub-regional areas with homogenous bio-physical endowments, creating so-called agri-environmental zones (Elbersen et al., 2006; Andersen et al., 2007).

**Table 1. The 21 simple sample regions in SEAMLESS**

Nuts-region	Environmental zone	Partner
ALENTEJO	Mediterranean South	IAMM
ANDALUCÍA	Mediterranean South	IAMM
AUVERGNE	Alpine South	INRA/CEMAGREF
BRANDENBURG	Continental	ZALF
CASTILLA Y LEÓN	Mediterranean north	IAMM
CHAMPAGNE-ARDENNE	Atlantic Central	INRA
DANMARK	Atlantic North	FLD
EMILIA-ROMAGNA	Mediterranean north	INRA
FLEVOLAND	Atlantic central	WU
GALICIA	Lusitanian	IAMM
MIDI-PYRÉNÉES	Mediterranean north	INRA
NORTHUMBERLAND and TYNE and WEAR	Atlantic north	UEDIN
ÖSTRA MELLANSVERIGE	Nemoral	UMB
PODLASKIE	Continental	SGGW
POITOU-CHARENTES	Lusitanian	INRA
SARDEGNA	Mediterranean south	INRA
SCHWABEN	Continental	ZALF
SOUTHERN AND EASTERN (IRELAND)	Atlantic central	UEDIN
THESSALIA	Mediterranean south	WU
UUSIMAA	Boreal	UMB
ZACHODNIOPOMORSKIE	Continental	SGGW

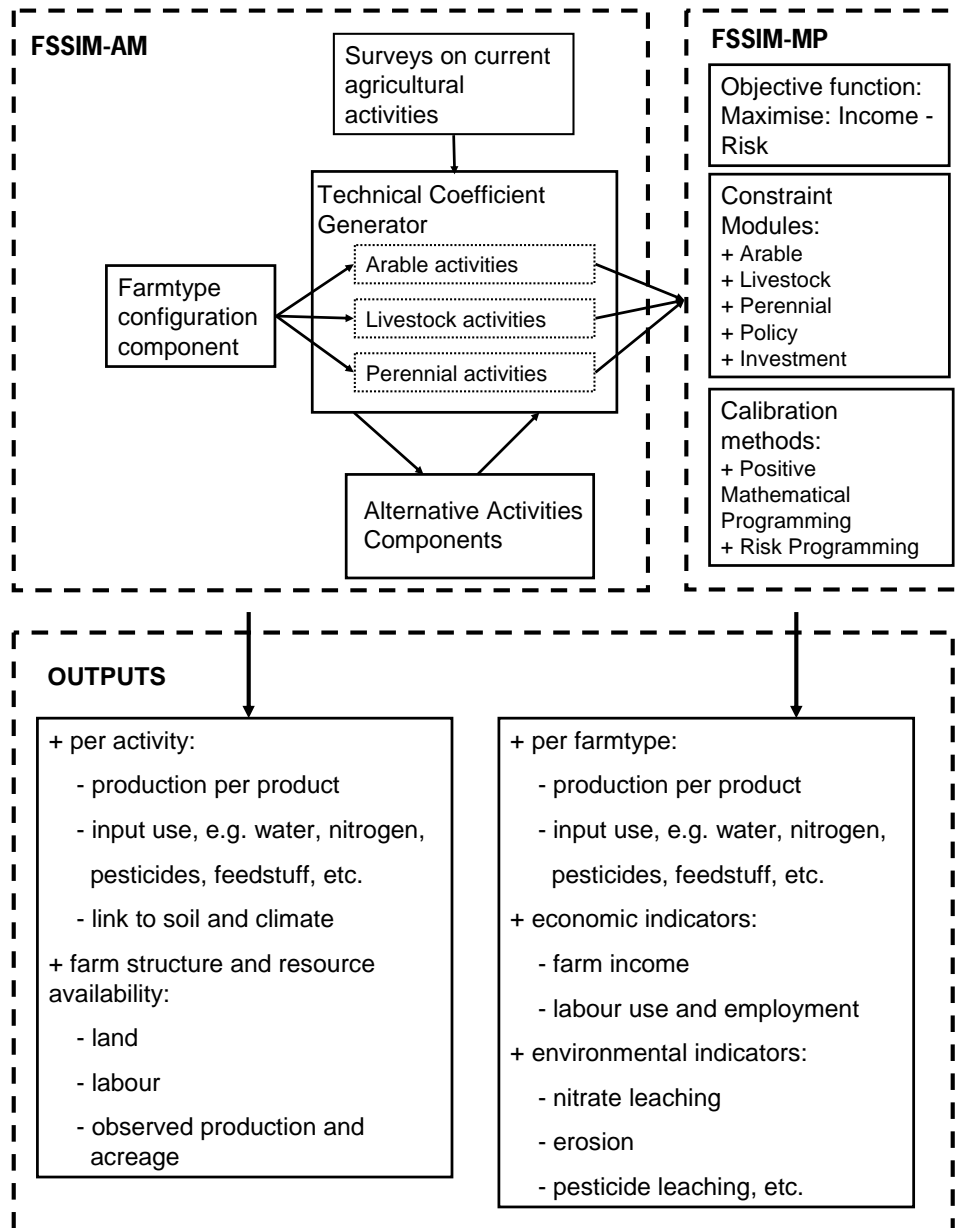
The FSSIM model includes a module for agricultural management (FSSIM-AM) and a mathematical programming model (FSSIM-MP) (Fig. 1). The latter constitutes the core of the FSSIM. Based on the mathematical programming approach, FSSIM-MP captures resources, socio-economic and policy constraints and the farmer's major objectives. The use of a mathematical programming approach has the advantage of directly embedding relevant EU policies on compensation payments, set-aside obligations, sales quotas and cross-compliance restrictions as well as capturing important relationships between agricultural production activities. The aim of FSSIM-AM is to describe, generate and quantify production techniques of current and alternative production enterprises which can be simulated by APES (or other cropping/livestock system models) in terms of production and environmental effects. The fully quantified activities, i.e. the complete sets of agricultural inputs and outputs are assessed in FSSIM-MP on their contribution to the farmer's and policy goals considered. Alternative activities are new activities or ones currently not widely practiced in the study area, and include technological innovations and newly developed cropping or husbandry practices (Van Ittersum and Rabbinge, 1997; Hengsdijk and Van Ittersum, 2002). As current activities are widely practiced in a sample region, their management operations and some of the associated outputs can be based on observed data and expert knowledge.



**Figure 1. An overview of FSSIM as a combination of Agricultural Management module and Mathematical Programming module.**

As FSSIM-AM and MP are quite large entities, these have been further sub-divided into components that have a more specific role and a stand-alone value (Fig. 2). It was decided that every component of FSSIM should be reusable on its own, independent of FSSIM for other applications and modelling exercises. Components exist for collecting data on simple and detailed current activities, for specifying livestock activities or livestock related constraints, for specifying policies and for calibration (Fig. 2). In the next Chapter all these different components will be discussed one by one with some applications in Chapter 4.

When applying FSSIM, the base year, baseline and policy experiments must be defined. The base year experiment is used to calibrate FSSIM to the observed situation and therefore only current activities will be included in FSSIM and calibration parameters ('costs') will be determined that capture the part of farmer behaviour that FSSIM is not able to model explicitly due to deficiencies in the assumptions of economic rationality and maximization of expected utility based on income and risk. The baseline experiment is a future year and includes policies that have already been agreed upon and FSSIM uses this baseline experiment as a reference experiment for the policy experiments that should occur in the same year as the baseline experiment. For the applications within SEAMLESS, the base year is 2003, and the year of the baseline is 2013 for applications in simple sample regions and 2020 for applications in detailed sample regions.



**Figure 2. FSSIM-MP and AM with their individual components or modules**

FSSIM is build on the following assumptions:

1. A farmer is rational decision maker that tries to optimise annual profit, while minimizing the risk to income loss due to yield and price variability.
2. An average farm as found in the farm typology (Andersen et al., 2007) as modelled in FSSIM can adequately capture the behaviour of a group of farms in a region. Different types of average farms can be upscaled to the region and after upscaling still adequately represent the behaviour of the farms in the region.
3. Technological progress can be adequately captured by defining different types of alternative activities.
4. In a calibration process, calibration parameters like non-linear cost terms capture those parts of farmer behaviour that can not be adequately represent by FSSIM (e.g. economies of scale) and can help to improve the model behaviour.

These assumptions present some limitations to FSSIM:

1. FSSIM has not been developed to model individual farms and to provide advice to farmers, although it could easily be adapted to such a purpose.
2. FSSIM does not model or consider in its results issues that refer to structural change of one farmtype into another farmtype.
3. FSSIM does not model transformation processes that occur over time within an average farm explicitly. The transformation path to arrive from the baseyear situation to the baseline situation is unknown.
4. Although FSSIM can be adapted to deal with questions of work allocation to activities during the year, the present version of FSSIM does not model this explicitly.

## 3.2 Technical design

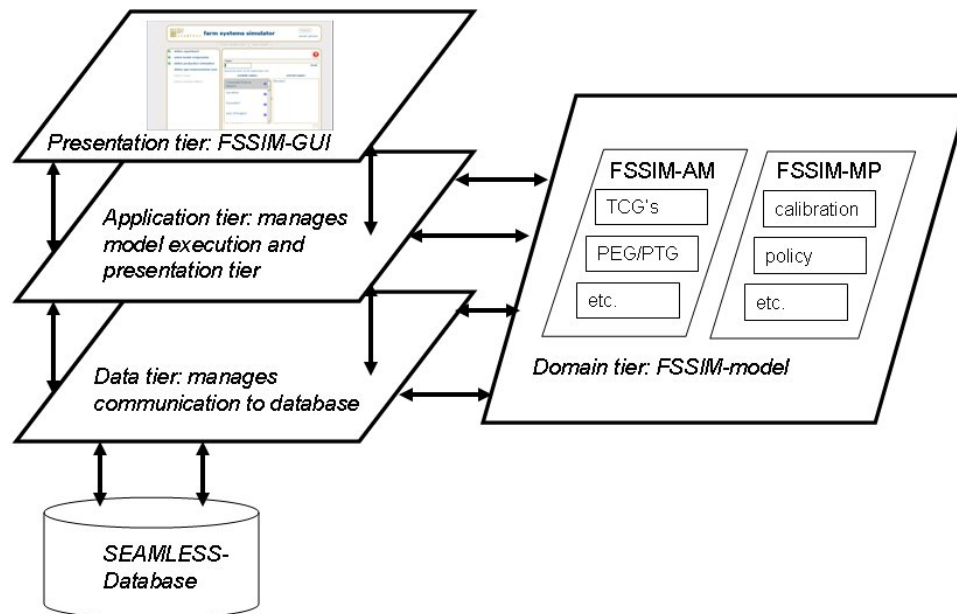
An adequate technical design is required to achieve a conceptually generic model, that is relatively easy to use, maintain and extend. The technical design of FSSIM is based on the theory of software components, semantically aware components and multi-tiered application. The division of a model in software components supports the modularity of FSSIM in the conceptual components presented in Section 3.1 and 4 (Fig. 2). The components are made semantically aware. Semantically aware components use a common “dictionary” of shared data types to ensure meaningful, consistent and explicit exchange of information between FSSIM components. Finally, multi-tiered applications help to separate common operations such as data storage and access, visualization and execution of the model from the implementation of the model in source code, thereby allowing modelers to focus on model implementation (Evans, 2003; Knapen et al., 2007) (Fig. 3). The implementation based on these three theories, i.e. software components, semantically aware components and tiered applications, ensure that the FSSIM model can be divided into parts that can be developed, maintained and extended simultaneously with an adequate data-exchange between these parts.

Software components (Szyperski et al., 2002) means that a model (or program) can be dissected in distinct autonomous parts (e.g. a component) that communicates with other components in the model and provides services to other components or a model. For something to be called a software component, it must have a clearly defined interface, be able to communicate with other components, encapsulate its inner workings, be non-context specific and independently re-usable in other situations (Szyperski et al., 2002). FSSIM is divided into two main components, i.e. FSSIM-MP and FSSIM-AM which each are divided into smaller components, for example, the livestock component of FSSIM-AM generating livestock activities and the policy component of FSSIM-MP that models agricultural EU policies. This design allows to use, replace and improve FSSIM components independently facilitating model development and maintenance of the model by different modelers.

The interfaces of FSSIM components, i.e. the inputs and outputs of a component are annotated and described explicitly in an ontology (Athanasidis and Janssen, 2008). In computer science, an ontology is considered the specification of a conceptualization (Gruber, 1993). Such a conceptualization is expressed in a machine readable format, for example the Web Ontology Language (McGuinness and Van Harmelen, 2004). The use of an ontology facilitates clear definitions for loosely integrated models in an open software environment (Li et al., 2007; Rizzoli et al., 2008). The ontology with the component interfaces functions as a common dictionary and ensures consistent definitions of concepts and data types across

components. The ontology helps to link internal FSSIM components and to link FSSIM to models from other domains. Component modelers have to interact to clarify the interfaces of each of the components.

The tiers in FSSIM consist of presentation tiers, a data tier, an application tier and domain tier. The presentation tier is the graphical user interface (GUI), which obtains user-input and presents the model results. Two different presentation tiers are linked to FSSIM, the SEAMLESS-Integrated Framework GUI and the FSSIM-GUI. The FSSIM-GUI (Section 4.6) is used to operate FSSIM as standalone model independent of other SEAMLESS models. In SEAMLESS-IF, FSSIM is integrated with other models and is run as part of a model chain managed by the SEAMLESS-IF GUI. The FSSIM application tier manages the interaction between different tiers, especially the model execution from the presentation tier. FSSIM forms its own domain tier. The data tier handles data requests by the application tier or domain tier and communicates with the SEAMLESS database to retrieve this data. Finally, the domain tier consists of the components of FSSIM and offers to functionality of FSSIM to the other tiers. Advantage of a tiered application is the separation of roles and modularity, as changes in one tier do not directly have to affect other tiers.



**Figure 3. Technical design of FSSIM**

FSSIM-MP is built in GAMS, while FSSIM-AM is built in Java™. All the input and output data are stored in relational database in PostgreSQL. Wrappers developed in Java™ ensure the meaningful data-exchanges between FSSIM-AM and MP. The models developed under different modelling environments (e.g. Java™, GAMS) need to be wrapped up as OpenMI compliant linkable model components, in order to be linked into a workflow and communicate with other linkable model components. Model wrappers have been designed to interface between these linkable model components and these provide the following functionalities:

1. wrapping the model to a compliant interface and defining the exchange items (model inputs and outputs);
2. initializing the model component right after the start of the execution of the workflow;
3. preparing the meta-model formulation that describes the model for each run;
4. preparing dynamically the model inputs data in the exact format the model needs for each run of the model;

5. retrieving model outputs of each run and scaling them to the required level (e.g. aggregation) to be stored or communicated with other linkable model components via domain manager.





## 4 The components of FSSIM

### 4.1 Template of FSSIM-MP (Louhichi et al., 2009a -PD3.3.11)

#### 4.1.1 Introduction

FSSIM-MP seeks to represent the actual farmers' behaviour using the knowledge of technical and socio-economic constraints, the relation between production factors, the amount of output obtained and the costs of each production activity and future market prices. FSSIM-MP includes two parts: the objective function describing the farmers' behaviour and goal, based on the maximization of expected income minus some measure of its variability, according to different states of nature and market; and the set of explicit constraints related to technical (land, water, equipment) and socio-economic resources (labour, finances, cash flow) as well as those related to policy and environmental measures (price and market support, quota and set-aside obligations, cross-compliance policies, agri-environmental measures, etc).

The principal FSSIM-MP specifications are: (i) a static model with a limited number of variants depending on the farm types and conditions to be simulated. For incorporating some temporal effects, agricultural activities are defined as "crop rotations" and "dressed animal" instead of individual crops and animals; (ii) a risk programming model based on the Mean-Standard deviation method in which expected utility is defined under two arguments: expected income and risk. The attractiveness of the Mean-Standard deviation method is that it leads to relatively convenient solutions using quadratic programming; (iii) a positive model in the sense that its empirical applications simulate the observed behaviour of economic agents and where the main objective is to reproduce the observed production situation as precisely as possible; (iv) a generic model designed with the aim to be easily applied to different regions and conditions.

The mathematical structure of FSSIM-MP in the baseyear is formulated as follows:

$$\text{Maximise: } U = p'x + s'x - d'x - x'Qx / 2 - k - \phi\sigma \quad (4)$$

(or in words: Maximise Utility = Gross margin + Subsidies – cost terms – calibration term – fixed costs – risk term)

$$\text{Subject to: } Ax \leq B \quad (5)$$

Where:  $U$  is the variable to be maximised,  $p$  ( $n \times 1$ ) vector of gross margin of each agricultural activity,  $s$  ( $n \times 1$ ) vector of subsidies per unit for each agricultural activity (depending on the Common Market Organisations (CMOs)),  $d$  ( $n \times 1$ ) vector of parameters of the cost function,  $Q$  ( $n \times n$ ) symmetric, positive (semi-) definite matrix of the cost function (the estimation of the vector  $d$  and the matrix  $Q$  depends on the calibration approaches),  $x$  ( $n \times 1$ ) vector of agricultural activities' level,  $k$  represents fixed costs (including annuity for investment),  $A$  ( $m \times n$ ) matrix of technical coefficients,  $B$  ( $m \times 1$ ) vector of available resource levels,  $\phi$  scalar of the risk aversion coefficient,  $\sigma$  variable representing the standard deviation of income according to states of nature defined under two different sources of variation: yield -due to climatic conditions- and prices. Agricultural activities ( $i$ ) are defined in FSSIM-MP as a combination of crop rotation or dressed-animal ( $r$ ), agri-environmental zone ( $s$ ), production technique ( $t$ ) and production system ( $s$ ) (i.e.  $i \cong r,s,t,sys$ ).

### 4.1.2 Modular System

FSSIM-MP consists of components (i.e. blocks of equations) that capture the agricultural activities (e.g. arable, livestock, perennials) and components for inclusion of alternative policies, calibration procedures (Positive Mathematical Programming (PMP)), risk and trend analysis (Figure 4). The principal policy instruments implemented in FSSIM-MP are price and market policies, set-aside schemes, quota schemes, production and income support policies, taxes and levies, cross-compliance and agri-environmental measures Figure 4. Policy instruments in FSSIM-MP are modelled either as part of the objective function (e.g. premiums as monetary incentives), or by including them as constraints (e.g. set-aside and quota schemes).

These components are solved simultaneously and they are managed by an integrative component (Fig. 4), containing the objective function and the common constraints. Thanks to its modularity, FSSIM-MP provides the capability to add and remove components (and their corresponding constraints) in accordance with the needs of the simulation experiment and to control the flow of data between the database and the software tools. FSSIM-MP has been programmed in the General Algebraic Modelling System (GAMS, 2008).

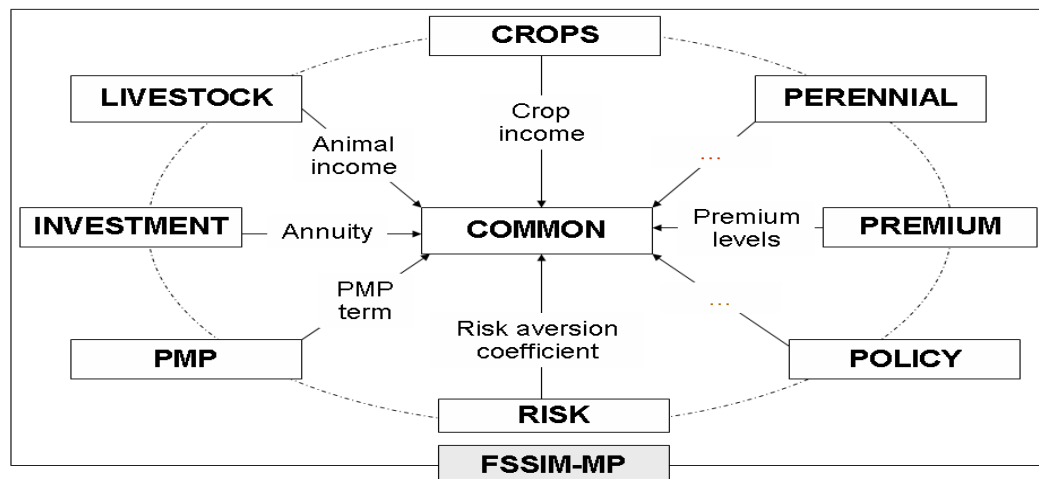


Figure 4. The components of FSSIM-MP

### 4.1.3 Calibration and evaluation

In order to increase confidence to the result of the analysis and assure the quality of the model, an evaluation procedure follows the model building phase. This contributes to identifying possible problems and gives insight for model improvements. Model building and evaluation should be involved in an iterative procedure. Calibration is part of such an iterative procedure and is defined as a process of using a hypothesized function and data on input and output levels in the base year to derive specific model parameter values that 'close' the model (Howitt, 2005). In other words, adjusting model parameters in order to reproduce the observed values of a base year. This implies that the purpose of the calibration procedure is to 'fit' the simulated results of the model to an observed reference output. Many different approaches to calibration exist. FSSIM-MP can be calibrated using risk, Monte Carlo, standard Positive Mathematical Programming (PMP), Röhm and Dabbert's PMP approach, other variants of PMP (Kanellopoulos et al., 2009) or combinations of risk and PMP depending on the application type (Howitt, 1995; Röhm and Dabbert, 2003). The Percentage Absolute Deviation (PAD) is used to quantify the deviation between simulated and observed cropping pattern, and thus provides information on the need for further model calibration.

The PAD measure is defined as the average (over crops) absolute deviation between the model results and the data, divided by the average actual value (Norton and Schiefer, 1980).

## **4.2 Current activities according to expert knowledge (Zander et al. 2009 - PD3.3.9)**

Agricultural activities are sets of crops (or animals) plus management operations (“production techniques”) with corresponding inputs and outputs. Current activities (CA) can be derived from observed data or from experts with knowledge of the average current situation. The distinction between alternative and current activities is that current activities represent what farmers do at present (averaged over the range of normal weather conditions in the region) and alternative activities represent what farmers might do in future. Farmers carry out many different activities and the mix of current activities will differ from farm to farm. An important term in this context is “typical”. The collected current activities describe what a typical farmer might do in a specified region for each of the various farm types that are based on level of intensification. A conceptual approach has been developed to identify: (i) the current production enterprises (i.e. crop rotations or dressed animals), (ii) their respective production techniques, and (iii) the assessment procedures for the various inputs and outputs.

The methodology is meant to be general enough to provide sufficient details to get information from potentially all European regions. To define current activities for APES and FSSIM, we intend to use two main data sources, FADN data and a survey answered by local experts. Although APES and FSSIM basically use different variables, there are interconnections that allow to process inputs for FSSIM from APES variables and vice versa. For example, the timing of a field operation is an exact date for the execution of that field operation (= APES requirement). This same timing counts towards the required labour in FSSIM-MP, which is constrained by the labour available to the farmer.

In order to collect data for the current activities two computer-based surveys were developed. The Detailed Survey was planned to be applied to all 21 sample regions, which represent the variation in soils and weather across the EU. However, as this was revealed to be far too time consuming, there are now 6 detailed sample regions left. Data concerning the remaining 18 regions are collected by means of the Simple Survey. The tools differ in their demands concerning agronomic data and the scope they cover. While the Detailed Survey asks for very sophisticated agronomic information about crop farming, the Simple Survey concentrates on economic data for crop and livestock farming as well as policy variables. The main difference between the Simple and Detailed Survey, is the information on precise timing of management operations, which is collected in the Detailed Survey. The Simple Survey will also be completed for the detailed sample regions, in order to get some livestock and policy data here, too and to permit the comparison of model runs for the simple and detailed sample regions.

The detailed survey’s Graphical User Interface contains eight pages that guide experts through a structured survey with mainly closed questions. The pages of the closed survey forms are structured in a hierarchical way, first defining the rotations and then adding management procedures, where every following page adds more information to these management procedures. In most cases the expert is asked to combine different items from existing lists e.g. combine crops to a rotation. The survey is designed to obtain the most complete information set on agricultural activities with a minimum of effort for typical farms of the regions (Table 2) by an expert, who has good knowledge and who has access to good data sources on the current activities in the region.

**Table 2. Structure of the Detailed Survey**

Page	Task	Collected information
1	Determine metadata about survey and expert!	General information on users (name, contact etc.). and chosen NUTS region
2	Create current combinations of intensity levels! Page is deleted	Combinations of production orientation and farm types (i.e. with or without livestock) defined by the expert - the intensity is now defined per rotation
Generation of cropping procedures		
3	Create crop rotations and some specifications to each element!	Farm type and production-orientation-specific crop rotations composed of plant species or groups of plant species Crop-specific harvesting products and their usage (for most plants there are several options of usage e.g. seed production, forage etc.) Cropping type: intercropping type (if yes, the type of intercropping practised); irrigation type (if yes, the type of irrigation applied); tillage type: (no, minimum tillage etc.)
4	Add management procedures for every crop!	Management procedures/technology profiles: Crops and rotations are grouped by crop and previous crop group (which are leaf, cereals and fodder legumes) in order to reduce the workload. For each of these combinations (cropping types, rotation, plant/usage/specification) the expert compiles a technology profile consisting of a sequence of management procedures. Management procedures are e.g. crop protection/herbicide/couch grass control.
5	Add outputs and inputs to every management procedure!	Required input/output in relation to pedo-climatic zones or cropping zones
6	Add timing to every management procedures!	The timing of management events is either on- or off-season. Each management procedure between sowing and harvesting is specified by a phenological description..
Adding site-type-specific quantities of input and output to cropping procedures		
7	Add amount for every input and output!	Amounts of inputs/outputs (e.g. application rates, amount of fertilizer etc.) adapted to the site types

The Simple Survey is being carried out for all 21 investigated NUTS regions. Wherever possible, local partners have taken the needed data out of national or regional publications. NO interviews with local experts were planned. However, such publications often give recommendations instead of averages for agronomic data and some partners found it helpful to consult local experts. If the data are available, the completion process should not take more than two days.

The simple survey structure differs considerably from the organisation of the detailed one. It includes one part for each topic: livestock, crop farming and policies. Livestock is subdivided into separate sheets for beef cattle, dairy cattle, small ruminants for dairy, small ruminants for meat and grassland (Fig. 5a). The requested variables slightly differ per sheet and an example for dairy activities is given in Table 3. Three production intensity levels can be entered. The first variable is either milk production or daily weight gain. By inserting figures here, the respondent defines automatically the intensity levels in his region. In the crop part there is only one list of variables that must be filled out for all crops grown a region (Fig. 5b). The crops grown in a region can be deduced from the list of crops appearing in the FADN data for

the region. On a separate sheet rotations need to be entered to enable APES to be used also for Simple Regions. The policy part consists of four sub-parts, e.g. CAP compensation payments, cross compliance, agri-environmental measures and national subsidies respectively.

Table 3. Variables of the simple survey for dairy cattle.

Name	Unit	Description
MilkProduction	[kg/head*year]	Milk production of an average cow per year
SizeOfHerd	[]	Number of animals in an average herd
SoldMilk	[kg/head*year]	Sold milk per cow and year
PriceForMilk	[EUR/kg]	Milk price (gross)
RevenuesFromMilk	[EUR/head*year]	= Sold milk x milk price
WeightOfCalveAtBirth	[kg/head]	Weight of the calve at birth
WeightOfCalveAtSelling	[kg/head]	Weight of the calve at selling
PriceForMaleCalves AtSelling	[EUR/head]	Average market price for male calves
PriceForFemaleCalves AtSelling	[EUR/head]	Average market price for female calves
LossRate	[%]	Calves died
WeightOfHeiferAtSelling	[kg/head]	Weight of the heifer at selling (heifer: 1-2 years old)
PriceOfHeiferAtSelling	[EUR/head]	Average selling price of heifers (heifer: 1-2 years old)
ReplacementRate	[%]	Replacement rate (Example: If this is 27.9%, the useful life of a cow will be 3.6 years.)
CostsOfReplacement	[EUR/head]	= Price of the young female at selling * replacement rate
WeightAtMaturity	[kg/head]	Weight of the cow at maturity
AgeAtFirstCalving	[months]	Average age of cow first calving
NumberOfCalvesPerCow	[]	Number of calves per cow
AgeOfCowAtSelling	[years]	Average age of the old cow at selling
PriceOfCowAtSelling	[EUR/head]	Average price of the old cow at selling
RevenuesFromCow	[EUR/head]	= Price of cow at selling * replacement rate
CostsOfConcentrates	[EUR/head*year]	Average costs of concentrates fed (per head and year)
AmountOfConcentrates	[kg/head*year]	Average amount of concentrates fed (per head and year)
CostsOfInsemination	[EUR/head*year]	Costs of insemination (per head and year)
CostsOfVeterinary	[EUR/head*year]	Costs of veterinary (per head and year)
OtherVariableCosts	[EUR/head*year]	Cost of hygienic and medicine (beyond veterinary), mineral fodder, epizootic fund (or regional pendant), check of milk production
SumOfVariableCosts	[EUR/head*year]	= Cost of concentrates + cost of insemination + cost of veterinary + other variable costs
TotalRevenues	[EUR/head*year]	= Revenues from milk + revenues from calves * number of calves per cow/age of cow at selling + revenues from cow/age of cow selling
GrossMargin	[EUR/head*year]	= Total revenues – sum of variable costs



SEAMLESS: Simple Survey

Database Edit View Help

FLEVOLAND

livestoc: dairy cattle

current item: dairy cattle [100002]

list of items in region: FLEVOLAND [686]

id	inher	regio	est	name	unit	low intensity	medium intensity	high intensity
1	1...	686	1...	MilkProduction	[kg/head*year]	7000	7500	8000
2	1...	686	1...	SizeOfHerd	[]	83.6	84	71.3
3	1...	686	1...	SoldMilk	[kg/head*year]	7000	7500	8000
4	1...	686	1...	PriceForMilk	[EUR/kg]	0.32	0.32	0.32
5	3...	686	1...	RevenuesFromMilk	[EUR/head*year]	2240	2400	2560
6	1...	686	1...	WeightOfCalveAtBirth	[kg/head]	40	40	40
7	1...	686	1...	WeightOfCalveAtSelling	[kg/head]	40	40	40
8	1...	686	1...	PriceForMaleCalvesAtSelling	[EUR/head]	135	135	135
9	1...	686	1...	PriceForFemaleCalvesAtSelling	[EUR/head]	80	80	80
10	1...	686	1...	LossRate	[%]	7	7	7
11	3...	686	1...	RevenuesFromCalve	[EUR/head]	99.98	99.98	99.98
12	1...	686	1...	WeightOfHeiferAtSelling	[kg/head]	550	550	550
13	1...	686	1...	PriceOfHeiferAtSelling	[EUR/head]	700	700	700
14	1...	686	1...	ReplacementRate	[%]	30	30	30
15	3...	686	1...	CostsOfReplacement	[EUR/head]	453.3	526.4	682.5
16	1...	686	1...	WeightAtMaturity	[kg/head]	650	650	650
17	1...	686	1...	AgeAtFirstCalving	[months]	24	24	24
18	1...	686	1...	NumberOfCalvesPerCow	[]	5	4	4
19	1...	686	1...	AgeOfCowAtSelling	[years]	6	5	5
20	1...	686	1...	PriceOfCowAtSelling	[EUR/head]	650	650	650
21	3...	686	1...	RevenuesFromCow	[EUR/head]	210	210	210
22	1...	686	1...	CostsOfConcentrates	[EUR/head*year]	258	302	356

FLEVOLAND:

a. The livestock sheet of the Simple Survey

SEAMLESS: Simple Survey

Database Edit View Help

BRANDENBURG

crop: Barley, spring - Grain [non-irrigated]

current crop: Barley, spring - Grain [non-irrigated] [1007]

set of crops in region: BRANDENBURG [291]

id	name	unit	AZ 23-28	AZ 29-35	AZ 36-45	AZ > 45	AZ < 23	Moor
4	Yield	[t/ha]	2.8	3.4	4.5	5.3	0.0	0.0
5	PestHerbicideApplicationNumber	[]	0.75	0.75	1	1	0.0	0.0
6	PestHerbicideApplicationIngredient	[kg/ha]	0.0	0.0	0.0	0.0	0.0	0.0
7	PestInsecticideApplicationNumber	[]	0.0	0.0	0.0	0.0	0.0	0.0
8	PestInsecticideApplicationIngredient	[kg/ha]	0.0	0.0	0.0	0.0	0.0	0.0
9	PestFungicideApplicationNumber	[]	0.6	0.7	1	1	0.0	0.0
10	PestFungicideApplicationIngredient	[kg/ha]	0.0	0.0	0.0	0.0	0.0	0.0
11	PestGrowthRegulationApplicationNumber	[]	0.0	0.0	0.0	0.0	0.0	0.0
12	PestGrowthRegulationApplicationIngredient	[kg/ha]	0.0	0.0	0.0	0.0	0.0	0.0
13	FertilizerNitrogen	[kg/ha]	58	70	93	109	0.0	0.0
14	FertilizerPhosphorus	[kg/ha]	13	15	20	24	0.0	0.0
15	FertilizerPotassium	[kg/ha]	41	50	67	79	0.0	0.0
16	IrrigationMeanApplicationNumber	[days]	0.0	0.0	0.0	0.0	0.0	0.0
17	IrrigationMeanApplicationWater	[m³/ha]	0.0	0.0	0.0	0.0	0.0	0.0
18	Price	[EUR/t]	117.6	117.6	117.6	117.6	0.0	0.0
19	TotalRevenue	[EUR/ha]	329	400	529	623	0.0	0.0
20	CostsOfFertilizer	[EUR/ha]	60	73	96	113	0.0	0.0
21	CostsOfCropProtection	[EUR/ha]	42	39	58	69	0.0	0.0
22	OtherVariableCosts	[EUR/ha]	49	51	55	57	0.0	0.0
23	SumOfVariableCosts	[EUR/ha]	151	163	209	239	0.0	0.0
24	GrossMargin	[EUR/ha]	178	237	320	384	0.0	0.0
25	LaborDemand	[h/ha]	2.8	2.9	3.1	3.2	0.0	0.0

b. The crop-sheet from the Simple Survey

Figure 5. Examples sheet from the Simple Survey for crops and for livestock

### 4.3 Livestock Activities (Thorne et al., 2009 - PD3.3.4)

The objectives of the livestock component in SEAMLESS are the quantification of the relations between available feed quantity and quality, feed intake by the various selected animal species, animal production, and waste production.

We use the “French” feed evaluation and rationing system for protein and energy (Jarrige, 1988; Jarrige, 1989 ) to quantify the relationships between feed intake and animal production. The application of the French evaluation system within the livestock module of SEAMLESS is described in detail in Thorne et al. (2009).

In APES, forage production will be simulated for different agro-environmental zones, i.e. the production and quality of different forage crops (e.g. maize and alfalfa) and of grassland management types including harvesting regime, and nutrient management, etc. Feed availability and feed requirements will be matched endogenously in the FSSIM-MP farm model.

Based on the EU production structure of livestock farms (in the FADN) the following ruminant animal types have been identified: dairy cattle, suckler cows, growing and finishing cattle beef cattle, sheep and goats. The energy and protein requirement calculations are described in detail in Thorne et al.(2009).

Initialization parameters for the SEAMLESS livestock module have been collected through the Simple Survey (Section 4.2). Within this survey, basic information has been collected concerning the production (structure) of different animal types. An example of the type of livestock parameters collected is given in Table 3 for dairy systems. The livestock component generates inputs (feed requirements in terms of quantity and quality) and outputs (e.g. milk production) for different age cohorts which can be used to scale up to a herd. For this purpose we introduce the concept of ‘dressed animal’, which represents an adult animal and young stock taking into account the replacement rate.

In the French feed system, the feed requirements of animals and the characteristics of feed are expressed in terms of net energy, crude protein and fill units. Each of these elements is here introduced shortly. The French energy system is a net energy (NE) system (i.e. energy values represent ingested energy that is actually useable for maintenance and productive purposes). Feedstuffs are assigned two net energy values: UFL (Net energy for maintenance and production in lactating animals) and UFV (Net energy for maintenance and body weight gain in meat producing animals). Both net energy values are expressed in feed units which are defined relative to the NE content of 1 kg of standard barley for milk (1700 k cal) and meat (1820 k cal) production. Feed units are additive.

The protein component of the French system represents, in common with most of the other more modern European systems, an attempt to treat protein transactions in a (slightly) more mechanistic way than the older DCP (digestible crude protein) based systems. The principal aim is to characterise feeds according to their content of Protein Digestible in Intestine (PDI). PDI refers to the fraction of the ingested protein that may be regarded as truly available for metabolism by the animal. PDI is the sum of two “biologically” distinct fractions: the dietary protein that remains undegraded after transit through the rumen but **is** digestible in the small intestine (sometimes referred to as “by-pass” protein in other systems) and protein of microbial origin that is also truly digestible in the small intestine.

Estimation of voluntary feed intake under the French system is based on the interaction of feed and animal characteristics that will determine the quantity of a particular forage that can be consumed. The “fill unit” (Jarrige et al., 1986) is defined with respect to a reference forage



(an average pasture grass cut at the grazing stage of the first growth) that contains one fill unit per kg of dry matter.

In Thorne et al. (2009) for each animal type mathematical formulas are provided to calculate the energy, protein and intake capacity of the animals, together with sample calculations for one region. These formulations have been implemented in the Java™ programming language and tested with datasets for different animal types in different regions as found in the Simple Survey.

#### **4.4 Perennial activities (Blanco et al., 2009 - PD3.3.5)**

In Blanco et al. (2009), we present the module for perennial activities in FSSIM, which provides a medium-term modelling framework to model the mix of annual and perennial activities. Basically the idea is to make a distinction between the existing stock of perennial crops and new plantations in terms of input-output coefficients. Given the difficulty of obtaining detailed economic data through the lifetime of the plantation, a decision has been made to simplify data collection by distinguishing three age-classes for each perennial crop: plantation period, growth period and productive period. This modelling framework enables to take into consideration sunk cost and adjustment cost effects of investment decisions and will provide the medium-term response of perennial producers to changes in incentives.

#### **4.5 Alternative activities and technical coefficient generators (Janssen et al., 2009 - PD3.3.3)**

The main objective of Janssen et al. (2009) was to describe the structure of the Agricultural Management module of FSSIM (Fig. 6) with respect to alternative activities for cropping activities and technical coefficient generators for current and alternative activities. The components of FSSIM-AM are the Production Enterprise Generator (PEG), Production Technique Generator (PTG), the Agricultural Production and Environment Simulator (APES), the Simple Management Translator (SMT), the surveys for agricultural management data (Section 4.2) and Technical Coefficient Generator (TCG). The different components together enable the quantification of agricultural activities in terms of technical coefficients (inputs and outputs) that are offered to the FSSIM-MP models. PEG and PTG are only used for alternative activities, while SMT and TCG are both used for alternative and current activities. The procedures for constructing production enterprises and production techniques are quite different for current and alternative activities, the addition of costs and labour requirements and the processing of APES outputs are largely the same for current and alternative activities. Current activities are based on observed data and expert knowledge of current farming systems (Section 4.2), while alternative activities are based on agronomic limitations of the farming systems considered.

PEG is a tool to generate a feasible set of production enterprises (crop rotations or livestock systems) of farms based on crop suitability filters, such as soil and climate characteristics. The PEG contains a number of 'crop suitability and rotation filters' that limit in an early stage the number of crop rotations for which production techniques need to be defined and that limit the number of simulations to be carried out by APES. The 'crop suitability and rotation filters' are a set of rules and parameters that filter out any options that are not possible or desirable from an agronomic point of view.

PTG is a tool to describe production techniques of agricultural activities for the feasible set of production enterprises. A production technique is a complete set of agronomic inputs characterized by type, level, timing and application technique. Production Techniques consist

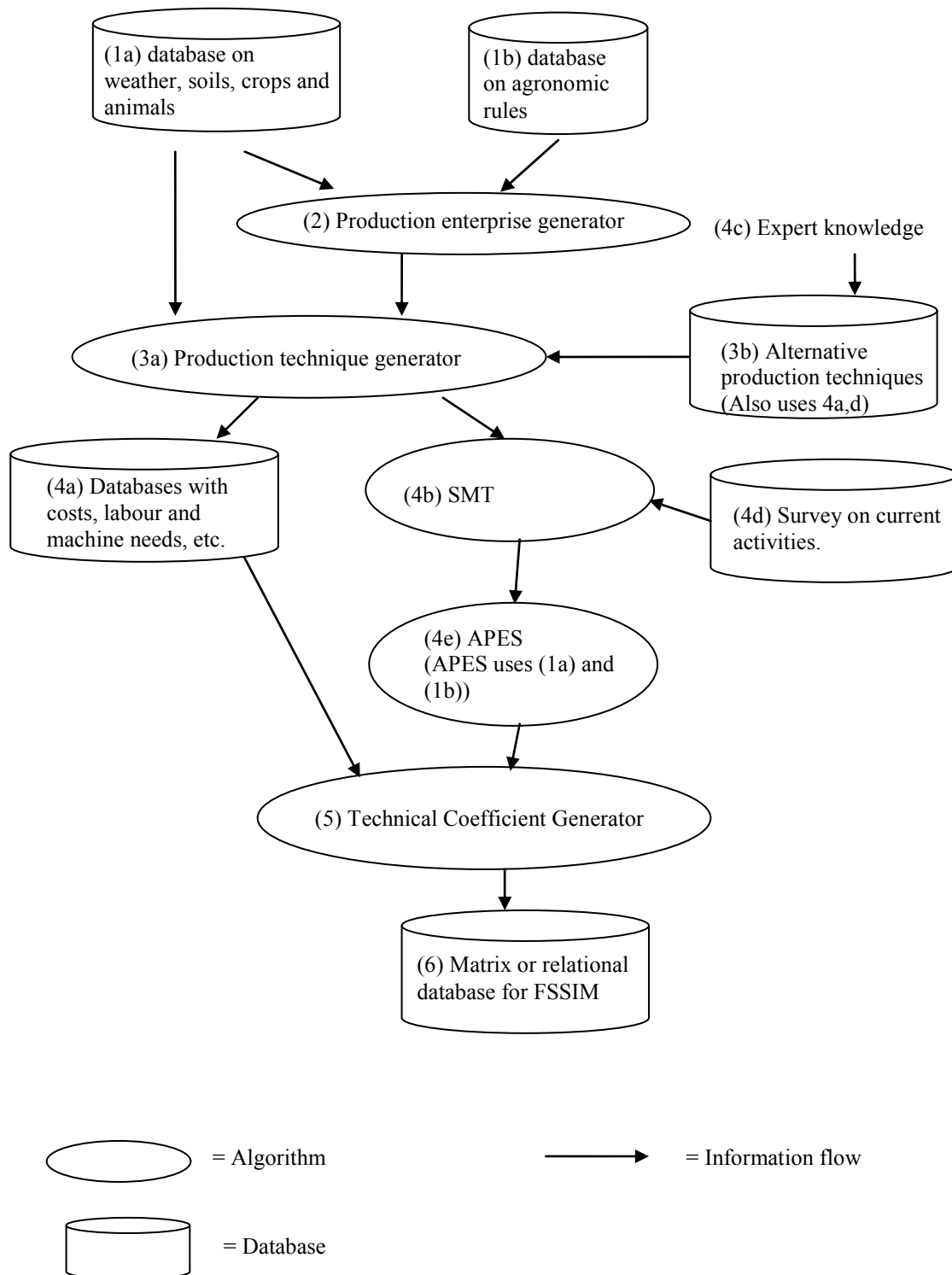
of 5 management practices: general management, water management, nutrient management, weed, pest and disease management, and conservation management. Each of these management practices consists of several aspects, for example, the method and level of application (full replacement of water, e.g. 100% or allowing some water shortage), the timing of the application (both time window and timing rule used, e.g. irrigate every 14 days starting from the 1<sup>st</sup> of July) and input type (for example, manure or fertilizers). The PTG produces a set of agricultural activities (i.e. rotation plus production technique for the crops in the rotation), which can consequently be assessed by the Agricultural Production and Externalities Simulator for yields and environmental effects.

The Simple Management Translator (SMT) processes simple survey data (Section 4.2) into sets of inputs required for running APES based on expert-based management rules (Oomen et al., 2009). In the SMT, the aggregated physical input use from the simple survey is converted into a number of crop management events characterized by amounts, timing rules, machinery usage and working depths. Expert crop-specific management rules have been developed for sowing, harvesting, tillage, nutrient and water management. For example, if the simple survey data indicates that 150 kg N/ha is applied in a wheat crop, the management rule determines that this amount is applied in three splits, i.e. 30% in the first split at beginning of tillering, 40% in the second at ear initiation and 30% of the total in the last split at development of the last leaf. When detailed crop management data is available, for example through the detailed survey (Section 4.2), the conversion of the simple management data through expert rules in the SMT is not needed.

Technical coefficient generators (TCGs) (Hengsdijk and van Ittersum, 2003) are algorithms to process data and information into technical coefficients directly usable by a mathematical programming model (e.g. FSSIM-MP) and cropping systems models (e.g. APES). The Current Activities component (CAC) of the TCG processes survey data into compatible inputs for FSSIM and links them to regional farm types, while calculating an average over several years for the observed cropping pattern, product price and yield variability for these farm types using data from the FADN-based farm typology (Andersen et al., 2007).

The PEG, PTG, SMT and TCG have been implemented and designed in Java<sup>TM</sup> programming language to facilitate the integration with SeamFrame and develop components that are reusable and extensible and that can be decoupled. The objectives during development were to completely separate algorithm from data and user interface to facilitate easy linkage to other databases and user interfaces and to make the algorithms easily extensible and comprehensible. These objectives were achieved by (i) linking the algorithms to databases through the SEAMLESS ontology, (ii) developing a user interface at the very end, (iii) using strategies for software design that allow flexible use of algorithms in components.

For alternative perennial and livestock activities, similar methods can be developed as for arable activities. Parts of the PTG and PEG can be reused to generate feasible alternative livestock and perennial activities on the basis of current activities and expert rules or filters. It will be investigated, which of the technical coefficients of perennial and livestock activities can reasonably be varied to create alternative activities.



**Figure 6. Relationships between algorithms and database components in FSSIM-AM**

## 4.6 FSSIM Graphical User Interface

FSSIM has been coupled to two distinct graphical user interfaces, e.g. SEAMLESS-IF and FSSIM-GUI. Here we will only describe the FSSIM GUI, as that is the graphical user interface (GUI) to interact with FSSIM as a standalone application. The FSSIM-GUI allows

modellers and integrative modellers to make model runs with one or more components of FSSIM. The FSSIM-GUI should thus help modellers and integrative modellers to evaluate components one by one and work with FSSIM across data-sets. The FSSIM-GUI is targeted at modellers internally in or beyond SEAMLESS who would like to use components of FSSIM, without having a deep knowledge of all three programming languages of FSSIM: GAMS, SQL or Java. Most of the modellers and integrative modellers as users of the FSSIM-GUI are foreseen to reside in WP3-T3.3 and WP6 for the different test-case regions. The FSSIM-GUI should provide the modeller the flexibility to run components for data provided for a region by WP4 or by ZALF through the simple or detailed survey and visualize outputs of the components. The FSSIM-GUI is not a database browser, and thus has no features that support such usage. The FSSIM-GUI can be found on <http://fssim.seamless-ip.org> and questions or comments can be sent to [fssim@seamless-ip.org](mailto:fssim@seamless-ip.org).

#### 4.6.1 User requirements

Two rounds of discussions were held with potential users. The first discussion round occurred through e-mail, while the second discussion round was during a T3.3 meeting at ZALF. Both these discussion rounds took place during autumn 2006 and the following list of user requirements was obtained:

1. Running each of the components independently and together
  - a. Include or exclude policy constraints in a simple way: 1st prototype;
  - b. Create new policy constraints;
  - c. Create new equations without using a GAMS-editor or knowing GAMS;
  - d. To export inputs and outputs to whatever format: txt, CSV, ascii, xml, gdx;
  - e. Select all crops for running in a region;
  - f. Storing results from one component (FSSIM-AM) and being able to run the next component (FSSIM-MP) in an independent way (without having to run the previous model again);
  - g. In FSSIM-AM the possibility of selecting both current and alternative activities at the same time in order to generate all agriculture activities that will be used by FSSIM-MP in the baseline and policy scenarios.
  - h. Running all scenarios in the same time;
  - i. Running the model for different scenarios and perform sensitivity analysis;
  - j. Running with different datasets from different regions.
2. Documentation
  - a. Viewing how costs are calculated within components/ Exploring the model and see how it is build up / View the equations/data in the model / add a "help";
  - b. Manual;
  - c. Describe in the help a description of how the different components are linked together;
  - d. Provide a procedure to include new datasets as part of the manual.
3. The inputs and outputs of each of the models
  - a. Viewing is required;
  - b. The calculation of the gross margin before running FSSIM-MP. ;
  - c. To be able to see the Gams output (log or lst-file) to identify binding and nonbinding constraints and slack;
  - d. Relevant output:
    - i. Activities chosen and their level;
    - ii. Distribution of area, number of animals etc;

- iii. Production;
  - iv. Gross margin.
4. Editing:
- a. To give to the user the capacity to define his own rotations;
  - b. Manipulate data (temporarily) before they are read into FSSIM-MP.
5. Technical Implementation:
- a. Provide the possibility to store previous runs and projects per user of the FSSIM-GUI. In this way, old model runs can be retrieved and be improved. Also model runs of others can be made visible to a larger community of users;
  - b. Several perspectives of the FSSIM GUI based on the type of user, for example the WP 6 type of integrative modeler could get a perspective more based on the application of FSSIM to the regions, which is organized according to the scenarios, while the T3.3 modeler could get a perspective targeted at developing FSSIM;
  - c. Web based distributed application of the FSSIM-GUI;
  - d. GAMS plug-in for Eclipse.

#### 4.6.2 Conceptual Design

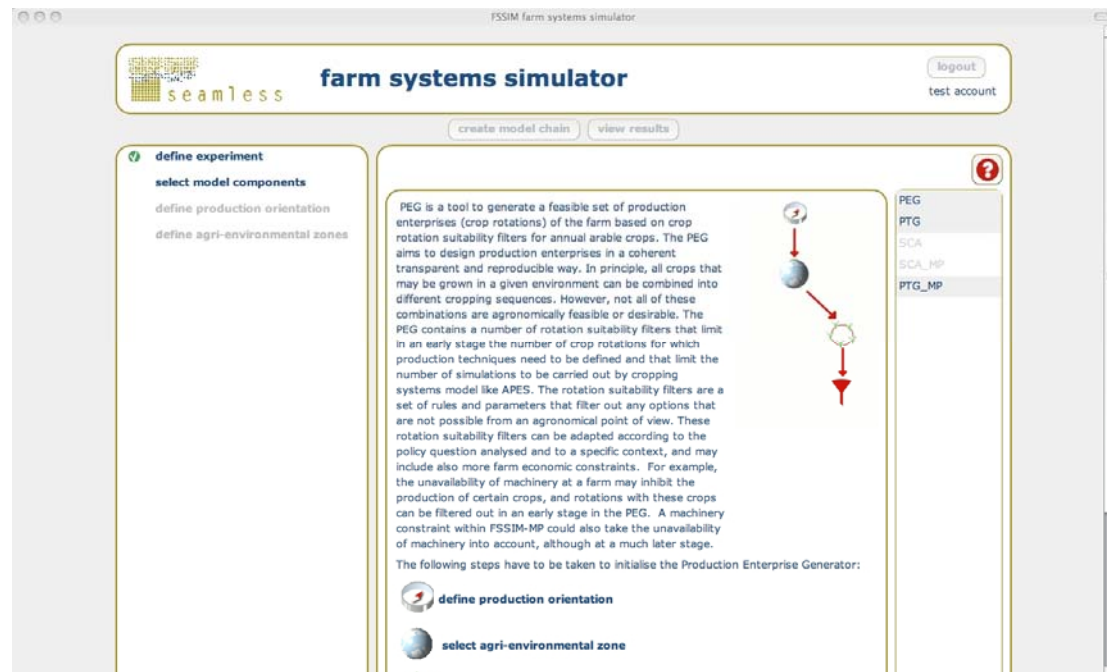
FSSIM is a component-based model, whereby each model component has a distinct purpose in the overall model chain. Besides this farm systems model, there is a need for a user event model, e.g. a method to initialize, run and analyse the different model components. A graphical user interface (GUI) encapsulates such a user event model. The definition of the users determines the user event model. As the definition for the FSSIM user is quite broad, ranging from people with no experience to advanced modellers in bio-economic modelling, we propose a similar component-based set-up for the GUI. The present GUI is targeted at MSc students and researchers with little experience in bio-economic modelling. For the advanced modellers, we offer the source code of the different model components, because such users require a model development environment, which are available. It is not our intention to build another model development environment.

The FSSIM model components use data that is described in the SEAMLESS ontology. The user of SEAMLESS-IF is not allowed to change these data, while the user of the FSSIM-GUI is allowed to change some of the variables for some of the model components. This meant that we needed to design a separate data model that tracks the possible changes for the different model components. Moreover, each model component is accessed via an adaptor class that maps this new data model back to seamless data model before the model component can be invoked.

The application is web-based, which makes the application easy accessible for the research and agricultural community. The user interface has a public and restricted part. Within the public part of the website, we inform the user about FSSIM and its components. The user must register in order to gain access to the restricted part. By registering users, the simulations executed by each user can be stored, retrieved and repeated at a later stage by that user. Also, modifications of input data or outputs created through a simulation are stored on a central database and accessible for the user that created the simulation.

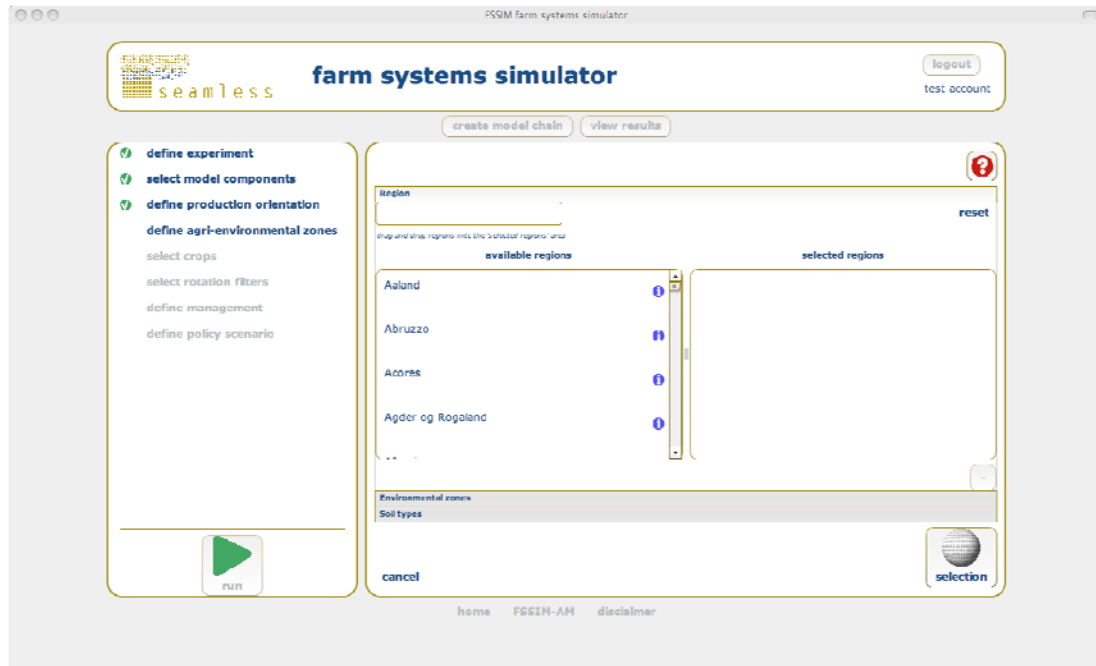
The emphasis of the user model is on the initialisation of the different model components. In order to run a simulation a user must create a new model experiment. Each experiment has a distinct name and description and contains meta-data about the purpose and assumptions of the simulation. Then, the user selects and parameterises the FSSIM components with default

or user-defined variables, such as components to generate and quantify alternative cropping or livestock activities, to assess current activities or to simulate farm behaviour in response to defined policies (i.e. the mathematical programming model). In the screen to select component, there is an introduction text to the component (Fig. 7). Some of the components depend upon each other or cannot be combined. The application is only offers the possible combinations or automatically selects the dependent components.



**Figure 7. Screen displaying textual description of components and option to select components on right hand side.**

The left side of the screen shows a navigation menu indicating the initialisation steps to be taken based upon previous entries (Fig. 7). This example shows the initialisation steps for the components Production Enterprise Generator, Production Technique Generator, and Mathematical Programming component. The following step is to select or define a production orientation. Apart from the default seamless production orientations, the user can add a production orientation suited to his model experiment or choose a previously defined production orientation.



**Figure 8. Screen of the GUI displaying the selection of regions, environmental zones and soil types.**

Figure 8 shows the initialisation screen for the selection of a set of regions, environmental zones and soil types. An agri-environmental zone is a location that is defined as a region with a distinct environment and soil type. The user has the option to select a set of agri-environmental zone based upon a combination of these characteristics. All lists are adaptive, meaning that only viable combinations of regions, environmental zones and soil types are offered to user to ensure proper initialisation of the different model components.

If the user selected the model components Production Enterprise Generator or Production Technique Generator, then the following steps are to select the crops and rotation filters. The nutrient and water management options can only be initialised when the user selected the Production Technique Generator. Figure 9 shows the GUI screen to edit the nutrient management by providing a relative yield range and the number of levels to be simulated in this yield range.



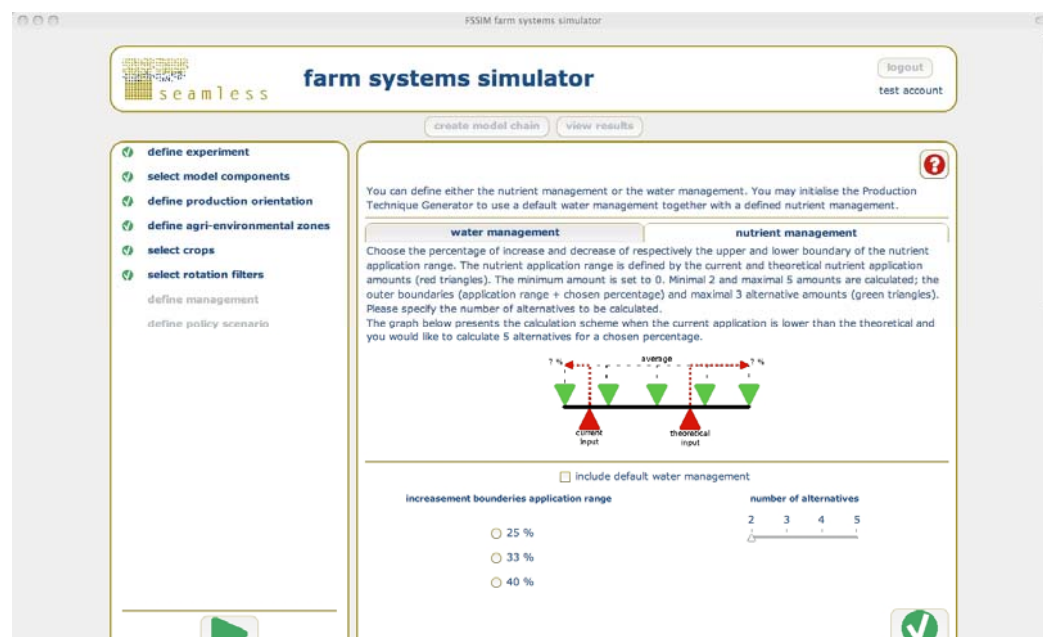


Figure 9. The screen in the GUI to define nutrient management.

If the user selected the Simple Current Activities model component, the steps in the left navigation pane (Fig. 9.) are different. The user has to select the representative farms. Representative farms have a typology that is characterised by farm size, specialisation and intensity. The user is presented with a list of viable combinations of these characteristics, which is based upon the previously selected agri-environmental zones. Not all representative farms exist in a particular agri-environmental zone.

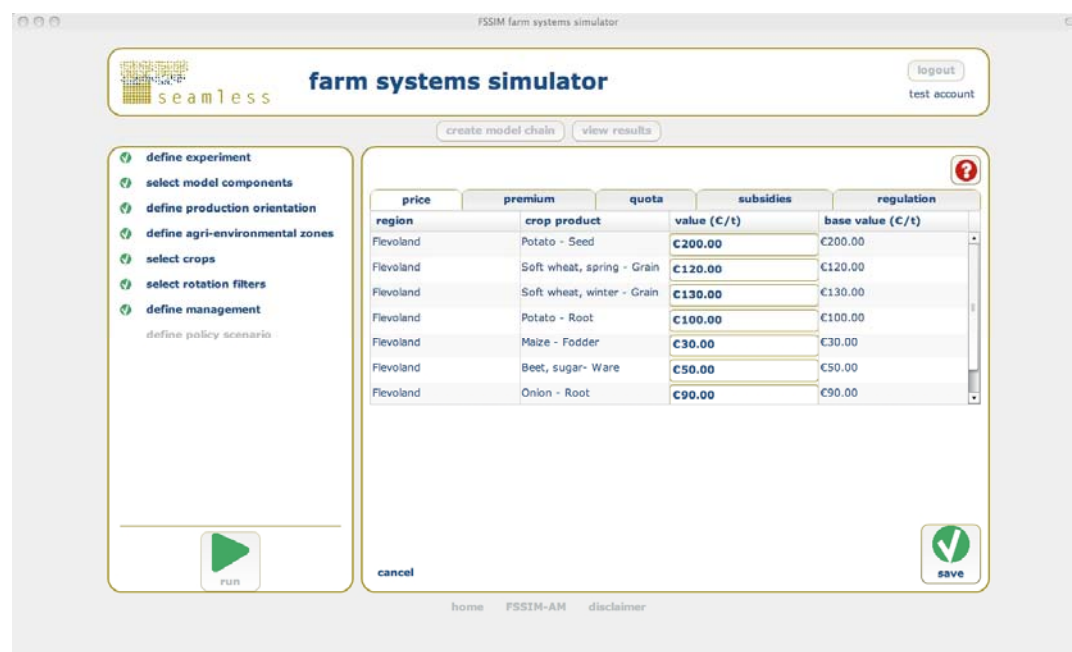


Figure 10. Screen to edit producer prices for a region as input parameters to the FSSIM-MP component

The FSSIM-MP component can also be initialised. The initialisation is identical to SEAMLESS-IF, which means that the user is allowed to change the main properties on



output price, subsidies, quotas and regulation. Figure 10 shows an example of an FSSIM-MP parameter screen to edit producer prices for regions.

If the components are properly initialised, the user is presented with a summary of the initialisation and the model components are ready to run. The actual model run is performed on the application server. The outputs of the run are stored in the FSSIM database and indexed for future reference. The user is automatically redirected to the ‘view results’ area of the application. The ‘view results’ area allows the user to view and download the main results for each model component. The downloadable data is presented in an XML format, which is easy to import in a spreadsheet program like MS Excel. The MP output data is presented as a GDX file, the native format of GAMS, which can be read in a GAMS editor.

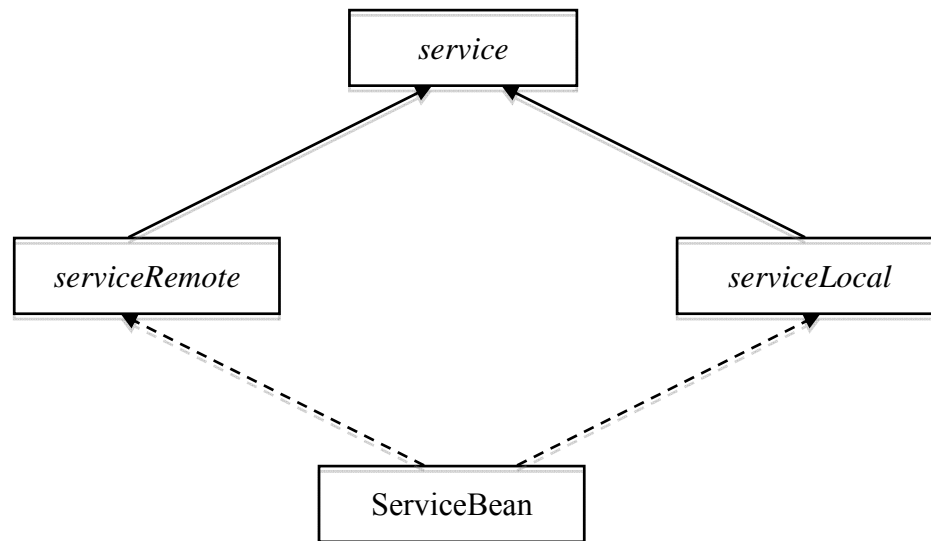
#### 4.6.3 Architecture of the FSSIM-GUI

The architecture of the FSSIM-GUI is a service-oriented architecture, which is a software design that consists of two parts; a set of services and the service infrastructure. A service is a declaration that clearly defines a specific functionality of the application. This functionality can be used by other services within the application or any other client. A service infrastructure is a framework that deals with the information flows between services and tiers. The actual implementation of the service declaration registers the service at the infrastructure and can use the infrastructure to perform its task in a simple and efficient manner.

The application has three tiers; a data tier, a service tier and a user interface tier. The first tier, the data tier, is an object-oriented data model representing the variables for the different model components and user management. In order to persist the data, the data model is mapped to a relational database using an object relational mapping tool that is part of the service infrastructure. The second tier is the service tier, which contains the service declarations and its implementation. These service declarations are the gateway to the functionality of the application and hides all technicalities, e.g. the implementation and linkages between tiers, for a client (which can be a user interface, another service or another application). It clearly specifies what the application can do. The third tier, the user interface, is actually a client of the application. It only uses the registered service declarations and the service infrastructure to manage the simulation runs. The user interface implements an event model that handles the different actions from a user in order to successfully use FSSIM.

We chose Java Enterprise version 1.6 as the framework for our application. Java Enterprise is a proven framework for complex applications that use different software technologies and for applications that have to be scalable. There are two popular open source application servers, JBoss and Glassfish, which implement the service infrastructure. We chose JBoss, as it is the most widely used and has native support of Hibernate, a tool to facilitate the connections, mapping and interaction between a database tier and a java tier. Hibernate is also used within SEAMLESS-IF.

Each service has three java interfaces, that depend on the service client (Fig. 11). There is a ordinary java interface if you would like to use the application outside a framework, a java interface with the postfix ‘local’ if you would like to run the application within the framework on one java virtual machine (JVM) and a java interface with the postfix ‘remote’ if you would like to run the application to run in a distributed environment (multiple JVMs). Each service is implemented by one ‘stateless bean’, an ordinary java class annotated as ‘stateless’. The annotation ‘stateless’ means that the framework will invoke only use an instance of thebean for specific functions and the instance is not retained for use of other functions. The instance, which is created by the framework, will not retain any state that may be altered by the invoked function. The bean may depend on other (abstract) services to fulfil its function.



**Figure 11. UML diagram of a typical service implementation.**

The graphical user interface is built in Adobe Flex 3, a leading technology for building rich internet applications; internet sites that have a look and feel of a desktop application. As Flex is based on a different technology, called Actionscript, than Java, we choose Granite Data Services as an infrastructure to connect the service tier to the GUI. Granite is an open source tool that uses the same protocol and a similar implementation to connect Flex to Java as the popular Adobe Flex Data Services or BlazeDS. Also, Granite is not limited to one CPU. The Java data model is automatically mapped to an Actionscript data model by Granite. The Actionscript data model allows the developer of the GUI to have access to the same data types as defined in the data tier of the application.



## 5 Applications

FSSIM has been applied in a number of cases over the last years by different research groups for two purposes, i.e. micro-macro analysis (Section 5.1) and regional integrated assessment (Section 5.2).

### 5.1 Application for micro-macro analysis

FSSIM was used to provide input to supply-response functions at NUTS2 level that were upscaled to EU level. In this context, FSSIM was applied to 13 regions and 55 arable farm types throughout the EU to obtain values for price elasticities of different crop products. A price elasticity is the percentage change in supply as a results of one percent change in price. Table 4 provides an example of FSSIM results in the form of price elasticities for soft wheat in five regions. In Kanellopoulos, et al. (2009), a description of the application to two of these 13 regions can be found, i.e. Flevoland in the Netherlands and Midi-Pyrénées in France. FSSIM is used according to a standardized and automated procedure in each region. First, data are retrieved from FADN (EC, 2008) and from the simple survey on agricultural management (Section 4.2) for each farm type in a region. Second, these data are processed in an automated way through FSSIM-AM to prepare the technical coefficients, e.g. specifications of relevant activities and farm and policy parameters. Subsequently FSSIM-MP optimizes the objective using the region-specific and farm-specific sets of activities and constraints with an automated calibration procedure (Kanellopoulos et al., 2009). By using a standardized and automated procedure, the application is repeatable and consistent over different farm types. Case-specific characteristics of farm types and regions beyond those implied by the standard data sources, technology generation differentiated by biophysical conditions and FADN based farm type resources could not be taken into account.

**Table 4. Price elasticities for soft wheat for five different regions as derived from simulations by FSSIM (Kanellopoulos et al., 2009; Pérez Domínguez et al., 2009).**

Region (land)	Price Elasticity for Soft wheat
Andalucía (Spain)	0.22
Midi-Pyrénées (France)	4.37
Poitou-Charentes (France)	2.36
Brandenburg (Germany)	0
Flevoland (Netherlands)	2.26

### 5.2 Applications for regional integrated assessment

Six detailed regional assessments have been done using FSSIM involving different farm types (e.g. arable and livestock), different scales (e.g. individual farm types, catchments and regions), different geographical locations (e.g. North, East, Western and Southern Europe, Africa) and using different components to estimate yields and environmental effects of activities (e.g. models and expert knowledge). In some of these applications, adjustments to FSSIM-AM or alternative procedures to estimate technical coefficients have been made dependent on the availability calibrated cropping systems models and detailed data for regions or farm types.

In one application, FSSIM and CropSyst (Stöckle et al., 2003) were jointly applied to assess the impacts of the Nitrates Directive (EC, 1991) on three arable farm types in the French Midi-Pyrénées region (Louhichi et al., 2008). Table 5 provides values for the indicators farm

income and nitrate leaching for the baseline and counterfactual “Nitrates Directive” experiment as an example of results of a regional integrated assessment. Louhichi et al. (2008) also applied FSSIM-MP in four farm types in the Sikasso region (Mali) evaluating the impacts of improved cropping practices and introduction of organic cotton. Majewski et al. (2009) applied FSSIM to several arable farm types in the Zachodniopomorskie region in Poland to investigate the impacts on economic indicators and cropping pattern due to changes in farm quotas and the introduction of biofuels. In a catchment in Scotland, Mouratiadou, et al. (2009) used outputs of the process-based nitrogen simulation model NDICEA (Van der Burgt et al., 2006) in FSSIM-MP to assess impacts of EU’s 2003 reform of the Common Agricultural Policy (EC, 2003) on economic and water quality indicators of two farm types. The application to livestock farming is an assessment of the consequences of an increase in milk quota and concentrate prices on dairy farms in Auvergne, France and in Flevoland, Netherlands (Louhichi et al., 2009b).

The impacts of alternative irrigation and nutrient management on crop allocation, farm income and environmental indicators is investigated using FSSIM-MP, FSSIM-AM and APES for Flevoland in the Netherlands (Janssen et al., 2009). In this application, a standardized and automated procedure processes data of arable activities from the simple survey and FADN to create inputs for the cropping systems model APES of which the results are subsequently provided to FSSIM-MP. This procedure can be used for other regions and thus allowing to combine applications on regional integrated assessments and micro-macro analysis.

**Table 5. Farm income and nitrate leaching of three farm types in the Midi-Pyrénées region in France<sup>a</sup>.**

Farm type	Farm income (k€/year)	Nitrate leaching (kg N-NO <sub>3</sub> -/ha)		
	Baseline	Nitrates directive <sup>b</sup>	Baseline	Nitrates directive <sup>b</sup>
Large scale-medium intensity-arable cereal	72	71	41	25
Large scale-medium intensity-arable fallow	77	76	36	36
Large scale-medium intensity-arable (others)	74	73	34	26

<sup>a</sup> A regional integrated assessment of the nitrate directive (adapted from Louhichi, et al. (2008))

<sup>b</sup> Experiment based on Nitrates directive (EC, 1991)

## 6 Discussion

### 6.1 Is FSSIM generic?

The applications of FSSIM (Section 5) are evaluated using the criteria defined for generic BEFM introduced in Section 2 (Table 6). For criterion 1, FSSIM has been applied for different climate zones, e.g. Atlantic, Continental, Mediterranean, Lusitanian and Alpine and soil types e.g. sandy and clay soils. FSSIM has been applied to a range of different farm types (criterion 2) with different specializations (e.g. specialised crops based arable, cereal-based arable, livestock and mixed farms), different intensities (e.g. extensive and intensive farms) and sizes (e.g. small sized farms in Mali and Zachodniopomorskie to large sized farms in Midi-Pyrénées). FSSIM needs to be extended to be able to simulate farm types with perennial, intensive horticulture and intensive livestock systems. Intensive livestock (e.g. pigs, poultry) and horticulture (e.g. greenhouse production) systems are characterized by capital intensive, often soil-less and high external input use activities and these systems are often not bound to land and labour resource constraints. FSSIM needs to be extended with constraints related to capital availability and an adapted definition of capital intensive activities for these farming systems. Extending FSSIM for perennial farming systems requires incorporating the temporal changes in perennial crops from a growing and establish crop to a productive crop.

With respect to criterion 3, in most applications FSSIM has been used to assess the effects of policy changes and in two applications to assess the impact of technological innovations (Louhichi et al., 2008; Janssen et al., 2009). FSSIM may be applied in the future to assess the impacts of societal or physical trends, for example the effects of climate change and increases in energy prices on farm performance.

In the various applications, different data sources, level of detail (e.g. criterion 4) and model configurations have been used. In the application for micro-macro analysis the level of detail in data was lowest, as only regional data sources could be used that were standard available (Kanellopoulos et al., 2009). In the regional integrated assessment studies, more detailed data and specifications could be used, often by incorporating ad-hoc procedures (Louhichi et al., 2008; Louhichi et al., 2009b; Majewski et al., 2009; Mouratiadou et al., 2009).

Criterion 5 required that a generic BEFM can be linked to different types of models. FSSIM has been linked to economic models (EXPAMOD/CAPRI) (Pérez Domínguez et al., 2009) for up-scaling of its supply responses, but also to an environmental externality simulation model (NDICEA) and different cropping systems models (CropSyst and APES). A useful extension of the model linking is to link FSSIM to a landscape model, that allows to visualize or analyse the results of FSSIM at the landscape level.

Not all components of FSSIM have been used in each application (Table 6). In some applications, both FSSIM-AM and MP were used. In other applications only FSSIM-MP was used in combination with other models and methods than FSSIM-AM to quantify farm activities. Individual components of FSSIM may also be used as stand alone tool, for example, the integrative component, crop component and risk component of FSSIM MP (Fig. 4) to assess the response to changing risk on an arable farm or the livestock component of FSSIM-AM to calculate yearly feed requirements in terms of energy, protein and intake capacity of different farm animals. FSSIM needs to be configured depending on the data availability, research question and location. For example, to identify improved nitrogen fertilization techniques, FSSIM-AM components for both current and alternative activities

need to be configured in order to allow for a realistic farm response by including all potentially relevant production activities. FSSIM-MP can be configured without the PMP-based calibration procedures and instead risk calibration procedures can be used, because the aim is to identify more optimal nitrogen fertilization techniques as the current practices and not to simulate in a realistic and validated farm responses. Alternatively, if the research question is to assess the short term effects of the abolishment of the EU set-aside policy, then the PMP calibration procedure of FSSIM-MP is required, but components for alternative activities in FSSIM-AM may not be needed as in the short term agricultural management is less likely to change significantly.

FSSIM is available for use and extension, for new purposes, locations and scales, either through its GUI or by working directly with the source code of the model. FSSIM will be maintained and extended during the next four years as part of the SEAMLESS association ([www.seamlessassociation.org](http://www.seamlessassociation.org)). FSSIM would benefit from extensions to model biodiversity, landscape and conservation indicators, from procedures for sensitivity and uncertainty analysis, from a more detailed modeling of the relationships between livestock density, grassland and manure production and from further calibration and validation of the model to new locations and research questions.

**Table 6. Applications of FSSIM used to evaluate the generic nature of FSSIM according the criteria defined in Section 2.**

Reference for application	Region	Components used	Purpose <sup>a</sup>	Climate	Soil type  Classified carbon content	Farm types	Type of assessment <sup>b</sup>	Level of detail + = low, ++ = medium, +++ = high	Link to other models
(Kanellopoulos et al., 2009)	13 in Europe	FSSIM-AM and MP	1	13 across in Europe	Very low to very high	Arable	2	+	EXPAMODC APRI
(Louhichi et al., 2008)	Midi-Pyrénées, France	FSSIM-MP	2	Mediterranean Lusitanian Alpine	Very low to very high	Arable	1 and 2	++	CropSyst
(Louhichi et al., 2008) Mali	Sikasso, Mali	FSSIM-MP	2	Tropical	Very low*	Arable	1 and 2	++	Expert
(Louhichi et al., 2009b)	Flevoland, Netherlands / Auvergne, France	FSSIM-AM and MP	2	Atlantic	Low to very high	Livestock	2	+	--
(Majewski et al., 2009)	Zachodniopomorskie< Poland	FSSIM-MP	2	Continental	Very low to very high	Arable/ Livestock	2	++	--
(Mouratiadou et al., 2009)	Catchment in Scotland, UK	FSSIM-MP	2	Atlantic	Moderate to very high	Arable	2	++	NDICEA
(Janssen et al., 2009)	Flevoland, Netherlands	FSSIM-AM and MP	2	Atlantic	High to very high	Arable	1	+++	APES

**a: 1 = up-scaling of supply responses, 2 = regional integrated assessment**

**b: 1= technological innovation; 2 = policy changes**



## 6.2 Can FSSIM be extended?

### 6.2.1 Integration procedure

The conceptual and technical integration of the different FSSIM components has proved to be a challenging and time-consuming task due to the complex data-types (or data-structures) being exchanged between components, the large data amounts and diverse data sources required to run FSSIM. The required investment in conceptual and technical integration might be a barrier to the initial development and maintenance of a generic BEFM. As a result of the experiences with integrating components in to FSSIM, a procedure for integration has been formulated, which can consequently be used to integrate the other components into the SeamFrame and keep track of their ‘integration-status.’

This integration procedure follows the following steps:

1. Conceptual development and implementation of stand-alone component;
2. Stand-alone component tested with ‘test data’ in local storage, subsequently tested with ‘real data’ in local storage;
3. Enter component interfaces (e.g. inputs and outputs of the model) in an ontology and link to other ontologies and generate database (DB) schema and java-beans;
4. Carefully check DB-schema and java beans: do these fit the requirements?
  - a. If the schema does not fit the requirements, then go back to step 3;
5. Prepare data for component, precisely following structure of the DB and submit to WP4, who can enter it in the integrated SEAMLESS database:
  - a. Are any adaptations of the DB schema necessary based on the data preparation? If so, then make them, starting again from Step 3, so adapting the model interface in the ontology. When no more adaptations are required, freeze/finalize DB-schema and the Java-beans;
6. Deliver a version of the component that is running with a test-dataset that should be precisely reproduced by the wrapper;
7. Develop the wrapper: once the db-schema/java-beans have been frozen, the wrapper for the model can be developed as an untested prototype;
8. Testing the wrapper with the data for one region or location or experiment in terms of providing the correct inputs to the model and reading the correct outputs from the component:
  - a. If errors in schema, go back to step 3 to make adaptations to the schema;
9. Testing the component with the data generated by the wrapper of the model for one region or location or experiment;
10. Making the tested and approved component available in the SEAMLESS-IF, by entering the correct dataset on the production copy of the DB that is linked to the SEAMLESS-IF. Test in SEAMLESS-IF for one region or location or experiment and test whether the new model-chain and the old model chain works in the SEAMLESS-IF;
11. Test for more regions, locations, experiments with the data from the DB.

Going through the integration procedure might require three to four months for one component. The data-schema as captured by the ontology might work when reaching step 11, but could probably be simplified, so another step is then to optimize the data-schema. Then the procedure could be followed again, only this time much faster.

This integration procedure can now be used to extend FSSIM with new components, e.g. for perennial activities, multi-functionality or intensive livestock or horticultural systems. A

technical barrier to the use of the FSSIM is the different programming paradigms used in components. Researchers are usually specialised in one programming paradigm. Training, easy user interfaces and documentation may help to overcome this barrier and generalists, who technically overlook FSSIM and its components, are required to maintain an overview.

### **6.2.2 Components and tiers**

The choice for semantically aware software components for FSSIM proved to be a good choice as components could be integrated into the SeamFrame one by one independently from one another and because modellers could change the inner working of their components provided this did not affect the interface of the component to other components. Thus modellers could work relatively independently from each other on their components. In programming languages, the implementation of the components differs. For example, in the Java<sup>TM</sup> programming language, components can easily be created and managed due to the proximity in paradigms of object-oriented programming and component. In GAMS, a mathematical programming language, it is more challenging to set up completely independent components in the vision of Szyperski et al. (2002), as there is a requirement for a common part that all the components can refer to and thus there exists dependency between them. We solved this tension by not having completely separate components, but creating a hybrid form (Fig. 4; Section 4.1). These hybrid components are as independent as they can be from other components of FSSIM-MP, but they still refer to a common component that steers them through their execution.

All the models have thus been configured as components and are part of the domain tier (or model tier) in the tiered SeamFrame application. Through the use of a tiered application, the technologies used in each tier are the most appropriate for that tier. The data are stored in a relational database that ensures the integrity and consistency of the data, while the modelers can focus on algorithms that manipulate this data in a modeling language, for example GAMS. Software engineers could focus their attention on designing powerful presentation tiers (e.g. SEAMLESS-IF and FSSIM-GUI described in Section 4.6) and application tiers, that, for example, load the appropriate data from the database and process requests for concurrent model runs. The use of a tiered application was instrumental in allowing researchers to contribute according to their knowledge. An important disadvantage is that, for each tier specialist, knowledge is only required to understand the tier and its functioning. To have an overview of the whole tiered application thus requires a range of specialist knowledge on each of the different tiers, which places a quite heavy demand on researchers that have a specialization in one of the tiers.



## 7 Conclusion and future developments

- This deliverable describes the current version of FSSIM and each of its components and presents the approach to conceptually and technically integrate FSSIM.
- FSSIM has been developed as a generic BEFM that targets wide applicability and models “generic” processes instead of specific processes to one research question, location or data source. Although a truly generic model might not be possible, FSSIM represents a first step in the development of a BEFM as a library of components and functionality that can be adapted to the purpose, scale, location and linked to other models.
- FSSIM is a product from a joint development of agronomists and economists. This lead to a balanced definition between different types activities, policy instruments and technological innovations, without emphasizing any in particular, to enable use of FSSIM for different study objectives.
- FSSIM can be easily maintained and extended, as it comprises individual components that can be extended and maintained independent from other components.
- The FSSIM GUI is the graphical user interface (GUI) to interact with FSSIM as a standalone application. The FSSIM-GUI allows modellers and integrative modellers to make model runs with one or more components of FSSIM. The FSSIM-GUI should thus help modellers and integrative modellers to evaluate components one by one and work with FSSIM across data-sets.



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## Glossary

<i>Activity</i>	A coherent set of operations with corresponding inputs and outputs, resulting in e.g. the delivery of a marketable product, the restoration of soil fertility, or the production of feedstuffs for on-farm use
<i>Bio Economic Farm Model</i>	a model that links formulations describing farmers' resource management decisions to formulations that describe current and alternative production possibilities in terms of required inputs to achieve certain outputs and associated externalities.
<i>Components</i>	A component has to have a clearly defined interface, be able to communicate with other components, encapsulate its inner workings, be non-context specific and be able to be independently re-used in other situations
<i>FSSIM</i>	Farming Systems SIMulator (FSSIM) as a generic and easily transferable model that can easily be extended with new features and re-used across data-sets, farm types and locations.
<i>FSSIM-AM</i>	FSSIM Agricultural Management is to describe, generate and quantify production techniques of current and alternative production enterprises which can be evaluated by APES (or other cropping/livestock system models) in terms of production and environmental effects.
<i>FSSIM-MP</i>	The Mathematical Programming Model (FSSIM-MP) constitutes the core of the bio-economic farm model (FSSIM). Based on mathematical programming approach, FSSIM-MP seeks to capture resource, socio-economic and policy constraints and the farmer's major objectives.
<i>Generic</i>	being able to deal with /model/allow different scales, locations, functionalities, and levels of detail.
<i>Integration</i>	Integration is the process of conceptually and technically linking parts of knowledge into a whole by a group of researchers.
<i>Ontology</i>	considered as a specification of a conceptualization, where a conceptualization is 'an abstract, simplified view of the world e.g. systems under study that we wish to represent for some purpose'