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

Application of FSSIM in two Test Case regions to assess agro-environmental policies at farm and regional level

PD 6.3.2.2

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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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General information

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Executive summary

This deliverable presents the results of the first application of the bioeconomic farm model FSSIM for a set of farm types representing the arable farming systems in two Test Case regions of the SEAMLESS-IP project: Midi-Pyrénées (France) and Sikasso (Mali). This application is performed through the FSSIM standalone version (i.e. outside the SEAMLESS-IF system) and it has two aims: (i) to test the capacity of FSSIM to capture the diversity of conditions from the North to the South, regarding biophysical and socio-economic aspects; and (ii) to provide a first example of assessment at the field and farm levels of the economic and ecological impacts of specific agricultural and environmental policies and technological innovations. The impact assessment at the field level was done through the biophysical model CropSyst, used as a substitute for APES, which is not yet operational for an application.

FSSIM is a comparative static mathematical programming model which seeks to capture resource, socio-economic and policy constraints and the major farmer's objectives. It was designed to be sufficiently generic and flexible to be applied for all relevant farming systems, easily transferable between different geographic locations, reusable and with a rich usage comfort.

The simulated scenario in the French region (Midi-Pyrénées) is focused on the adoption of the Nitrate Directive (91/676/EC). The Nitrate Directive is an environmental measure designed to reduce water pollution by nitrate from agricultural sources and to prevent such pollution occurring in the future. The CropSyst-FSSIM-Indicators modelling chain was used to compare a baseline scenario driven by the CAP reform, and a policy scenario combining the CAP reform with the application of the Nitrate Directive and the adoption of alternative crop management. This modelling chain was operated "manually", i.e. using specific databases filed by one component for the next one, but in a manner consistent with the future applications done inside SEAMLESS-IF when the modelling chains will be operational.

The tested scenario in the Malian region (Sikasso) is based on the adoption of new cropping techniques, more efficient and suited to a wide range of socioeconomic and biophysical conditions. These techniques are usually designed at the plot level within research stations and sometimes in farmers' plots. FSSIM was used in this scenario as a tool to assist and establish a dialogue between agronomic research and farmers, in order to help the adoption or design processes of these new cropping techniques.

After a brief description of the FSSIM framework, particularly model design, specification and components (farm activities, resource constraints, policies specification and objective function etc.), sections 3 and 4 present the results of the application for the two Test Case regions respectively. Each section exposes the context, the tested scenarios, the required input data, the procedure followed for running the model (i.e. specification of components, modules and calibration procedure used) and the results of the application. The conclusions,

in relation to the comparison of the scenarios and the implications for future FSSIM development and integration into SEAMLESS-IF, are given in section 5.

1 Introduction

The Farm System Simulator (FSSIM) is a generic bio-economic model, developed within the SEAMLESS-IP project (Van Ittersum et al. 2007), to assess at the farm level the impact of agricultural and environmental policies on farm's performance and agricultural sustainability. FSSIM follows a primal-based approach, where technology is explicitly represented. It uses engineering production functions derived from biophysical models. These functions constitute the essential linkage between the biophysical and economic models.

FSSIM consists of a data module for agricultural management (FSSIM-AM) and a mathematical programming model (FSSIM-MP). FSSIM-AM aims to identify current and alternative activities and to quantify their input output coefficients (both yields and environmental effects) using the biophysical model APES (for now we use CropSyst as alternative to APES in Midi-Pyrénées awaiting the availability of APES) and other data sources (expert knowledge and surveys). FSSIM-MP seeks to describe farmer's behaviour given a set of biophysical, socio-economic and policy constraints, and to predict his reactions under new technologies, policy and market changes. The communication between the different tools and models is based on explicit definitions of spatial scales and software for model integration.

Conceptually FSSIM targets two main purposes within SEAMLESS-IF: (i) providing supply-response at EU25 level and (ii) allowing detailed regional assessment of the effect of agricultural and environmental policies and technological innovations on farming practices and sustainability. The dual purpose of FSSIM led to the conception of a structure sufficiently generic and flexible applicable to all relevant farming systems, easily transferable between different geographic locations, reusable and with a rich usage comfort. In addition, as FSSIM-AM and MP are quite large entities, they have been further sub-divided into components or sub-modules that have a more specific role and a stand-alone value. It is foreseen that it will be possible to reuse every component of FSSIM, independently of the rest of FSSIM, for other applications and modelling exercises.

This deliverable presents the results of the first application of FSSIM for a set of farm types representing arable farming systems, in two Test Case regions (Midi-Pyrénées and Sikasso). This application was performed through the FSSIM standalone version (i.e. outside the SEAMLESS-IF system). It used FSSIM-MP and input data stored in Excel sheets, without using the FSSIM-AM and the SEAMLESS database which are not yet operational for these applications. The input data come from different sources such as FADN data for the farm typology, local experts for the technical and economic coefficients, the CropSyst model for the environmental effects at field level, and local databases for the Malian region.

The application of FSSIM is based on the following steps: (i) selection of the relevant farming systems using FADN or other data sources; (ii) identification of representative farm types using the "*average*" farm (i.e. a virtual farm derived by averaging historical data from farms that are grouped in the same type) (iii) modelling of the different farm type behaviours in order to reproduce the observed situation; (iv) implementation of the selected scenarios and analysis of their impacts on the socio-economic and environmental performance of the farm; (v) calculation of the relevant outputs and indicators. In Mali we used the local farm typology associated with an ad hoc database based on surveys and expert knowledge providing all information required by FSSIM-MP in the absence of a crop model.

After a brief description of the design and components of FSSIM-MP, we present the other components used in these regional applications, such as the CropSyst model, the farm typology, the input output matrix and objective function.

2 FSSIM model: design and components

FSSIM-MP is a comparative static mathematical programming model with a non-linear objective function representing farmer's behaviour. It is an individual farm model calibrated at the farm level and working with exogenous prices coming from different sources. The principal FSSIM-MP specifications are: (i) a static model with a limited number of variants depending on the farm types and the conditions to be simulated. Nevertheless, to incorporate some temporal effects, agricultural activities are defined as "crop rotations" and "dressed animal[1]" 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 expected income and risk (Hazell and Norton 1986); (iii) a positive model, where the main objective is to reproduce the observed production situation as precisely as possible by making use of the observed behaviour of economic agents and; (vi) a generic model designed with the aim to be easily applied to different regions and conditions.

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

Maximise: $U = p'x + s'x - d'x - x'Qx/2 - k - \phi\sigma$

Subject to: $Ax \leq B$; $x \geq 0$

Where: **U** is the variable to be maximised (i.e. utility), **P** is a (n x 1) vector of gross margin of each agricultural activity, **S** is a (n x 1) vector of subsidies per unit for each agricultural activity (depending on the Common Market Organisations (CMOs)), **d is** a (n x 1) vector of parameters of the cost function, **Q is** a (n x 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 is a** (n x 1) vector of the level of agricultural activities, **K** represents single fixed costs (including annuity for investment) at farm level, **A** is a (m x n) matrix of technical coefficients, **B is** a (m x 1) vector of available resource levels, **Φ** is a scalar for the risk aversion coefficient, **σ** is the standard deviation of income according to states of nature defined under two different sources of variation: yield (due to climatic conditions) and prices.

The agricultural activities (*i*) are defined in FSSIM-MP as a combination of crop rotation (*r*), soil type (or agri-environmental zone) (*s*), production technique (*t*) and production orientation (*sys*) (i.e. $i \cong r,s,t,sys$). That is, an agricultural activity is a way of growing a rotation taking into account the management type. However, if data on crop rotations are missing the agricultural activities can be defined using individual crops (i.e. mono-crop rotations).

The principal technical and socio-economic constraints that are implemented in FSSIM-MP are: arable land per soil type (or agri-environmental zone), irrigable land per soil type, labour and water constraints. The same rule was applied for all of these constraints: the sum of the requirements for each resource cannot exceed resource availability.

A set of policy instruments linked to crops and livestock activities are implemented in FSSIM-MP. These involve the CAP support regime (price and market support, set-aside schema, quota system, etc.) including the Common Market Organisation (CMOs) regulations and certain cross-compliance and agro-environmental measures included in Horizontal and Rural Development Regulations, respectively. In case of a non-EU application (like the Mali application) these policy instruments can be deactivated.

FSSIM is a risk programming model. To estimate the risk aversion coefficient, three options are proposed in the risk module to be selected by users:

[1] The concept of 'dressed animal' represents an adult animal and young stock taking into account the replacement rate.

- **Risk neutral:** implies that the risk aversion coefficient is equal to zero ($\phi = 0$), farmers are risk neutral and the problem is simplified to an income maximization problem.
- **Risk averse: set risk aversion coefficient:** implies that the user has to choose the value to attribute to the risk aversion coefficient. The chosen value should range from 0 to 1.65 ($0 < \phi \leq 1.65$). The range value comes from literature.
- **Risk averse: automatic choose of risk aversion coefficient:** implies that the model will attribute automatically a value to the risk coefficient which gives the best fit between the model's predicted crop pattern and the observed values in the base year. This value ranges between 0 and 1.65 ($0 < \phi \leq 1.65$).

FSSIM-MP can be calibrated using any or all of the following approaches, depending on the application type: (i) the risk approach, (ii) Monte Carlo, (iii) the standard Positive Mathematical Programming (PMP) procedure (Howitt, 1995a), (iv) the Rhöm and Dabbert's PMP approach (Röhm and Dabbert, 2003).

FSSIM-MP has a modular set-up, including modules on crops, livestock, perennial, investment, premium, risk, policy and Positive Mathematical Programming (PMP). These modules are linked indirectly by an integrative module named the "common module" involving the objective function and the common constraints (Figure 2.1). Each module includes two GAMS[2] files. The first one links the data-definition and the module's equations and the second one contains the module's equations. Each module generates at least one variable which is used to define the common module's equations, thus providing a link between the different modules.

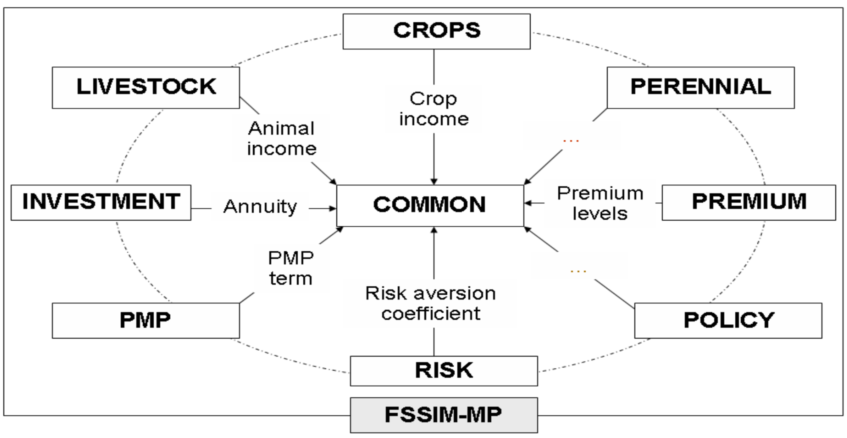

Fig. 2.1. FSSIM-MP structure

Thanks to its modularity, FSSIM-MP provides the ability to add and remove modules (and their corresponding constraints) following the needs of the simulation, to select one or several calibration approaches between different options (risk, Monte Carlo, standard PMP, Rhöm and Dabbert PMP approach) and to control the flow of data between the database and software tools. FSSIM-MP can be run with simple or detailed survey data (i.e. according to the level of detail of the available data). Additionally, it can read input data stored in any

[2] General Algebraic Modelling System which is used to program the model.

relational database (e.g. Access DB), Excel or GAMS include files, provided that they are structured in the required format.

A simulation for a specific farm type using FSSIM provides a set of outputs summarizing land use and selected production techniques, input use, farm income and externalities (e.g. nitrogen surplus, nitrate leaching, pesticide use, etc.) of the farm type. These outputs can be used directly or translated into indicators (simple or composite) to provide measures of the impact of policies.

3 Application of the CropSyst-FSSIM model chain to asses the impact of Nitrate Directive in Midi-Pyrénées

3.1 Context and tested scenario

As stated in the DOW the role of test case 2 is to test "how SEAMLESS-IF platform can be used to analyse the interactions between EU environmental policies and the various agro-ecological technologies, entering the system at farm level, and their overall impact on economic, social and environmental dimensions on the sustainability of farming systems and on their contribution to sustainable development". To answer this question the bio-economic modelling chain (farm typology-CropSyst-FSSIM-Indicators) is designed to reproduce the major drivers of selection by the farmers of alternative production system in response to CAP implementation (in the baseline scenario) and its interactions with the implementation of EU environmental directives. To achieve this objective, several scenarios are defined to be tested at farm, regional and EU scales: nitrate directive, conservation agriculture (no soil tillage), incentive measures to promote ecological farming (organic farming)… (Belhouchette et al., 2007). On the basis of data and models availability at the time of Prototype 2 delivery we will present here only the nitrate directive in the Midi-Pyrénées region.

3.2 The nitrate directive in the Midi-Pyrénées region

3.2.1 Introduction

The first directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrate from agricultural sources complements the Urban Waste Water Directive in order to reduce and prevent pollution of water by nitrate from agricultural sources, i.e. chemical fertiliser and livestock manure. It has been promulgated in 1991 by the Environmental EU commission (EEC, 1991). This Directive stipules that each Member State should draw up at least one code of good agricultural practices. This code, adapted to each region if needed, has the objective of reducing pollution by nitrate, taking into account regional specificities across EU (Belhouchette et al., 2005).

Each member state has defined different zones vulnerable to nitrate pollution from agricultural sources. In these vulnerable zones, action programmes including the production of the code of good agricultural practices are defined. Member States can also decide to apply the measures in the action programmes across their whole territory (e.g. as in Denmark and Germany) and not only in specific vulnerable zones (as in France) (EEC, 2000).

In the Midi-Pyrénées region, the current delineation of the nitrate vulnerable zone (NVZ) is based on a first delineation defined in 2002 and updated in 2004 (Prefecture Midi-Pyrénées, 2002) (Figure 3.1). It covers more than 37 % of the area (DIREN, 2004).

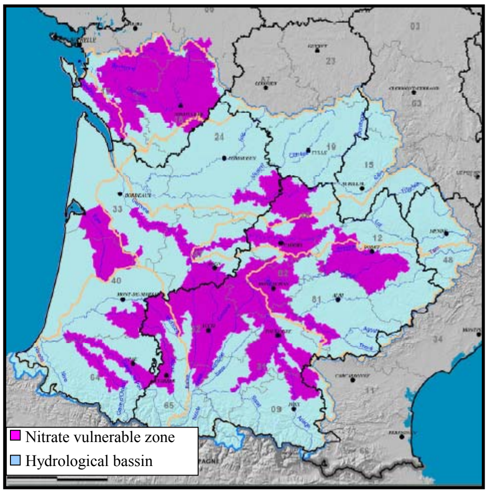

Fig. 3.1- NVZ in the Midi-Pyrénées region (source: DIREN- Midi-Pyrénées region)

In the application presented in this deliverable, the nitrate directive was implemented for the whole Midi-Pyrénées region, and not only for the nitrate vulnerable zone. The reason is that the share of nitrate vulnerable zone by farm type is not yet identified in the database provided by WP4. The implementation of the nitrate directive for the whole region can be a source of over-estimation of its economic and environmental impacts at regional scale but also at farm level because a farm type may have only a part of its land resource in a NVZ.

In 2002, in the Midi-Pyrénées more than 45% of the water quality in term of nitrate concentration is judged as average or very bad (Table 3.1). Only 3% of the water body is considered of very good quality (IFEN, 2002).

Table 3.1 Percentage of superficial water with different quality in the Midi-Pyrénées region and in France. Only the nitrate concentration is considered for this classification.

Water quality qualification	Midi-Pyrénées (%)	France (%)
Excellent	2.9	3.1
Good	48.5	37.1
Average	30.9	33.3
Very bad	17.7	26.5

Sources: SIEau (Réseau Système d'Information sur l'Eau), Estimations IFEN (NOPOLU), 2002

Figure 3.2 shows the evolution of the “average” and “very bad” water quality, expressed in nitrate concentration, in the Midi-Pyrénées region from 1990 to 2002. Those curves prove that despite the nitrate directive measures the quality of the occurrence of water bodies with insufficient water quality is still high and has not significantly changed since 1990.

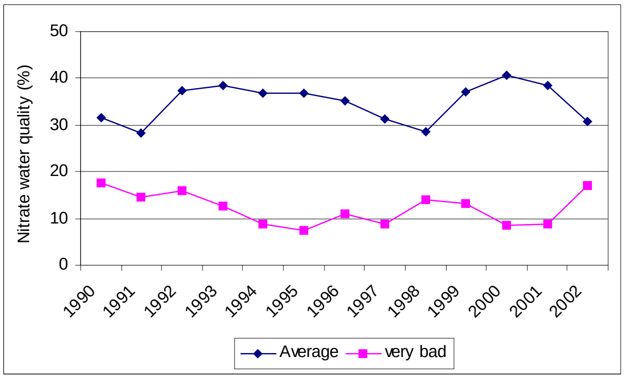

Fig. 3.2 Percentage of superficial water with “average” and “very bad” quality, expressed in nitrate concentration, in the Midi-Pyrénées region and in France. *(Sources: SIEau (Réseau Système d'Information sur l'Eau), Estimations IFEN (NOPOLU), 2002).*

3.2.2 Steps for the implementation of the Nitrate Directive

Only the first measure from the nitrate directive was selected to be implemented using the model chain: CropSyst-FSSIM. This measure stipulated that farmers should fertilize according to the crop requirement and the soil provision of nitrogen (Appendix). They should also keep records on the amounts of mineral and organic nitrate fertilization.

Figure 3.3 shows the model chain and the steps needed for the implementation of such measure.

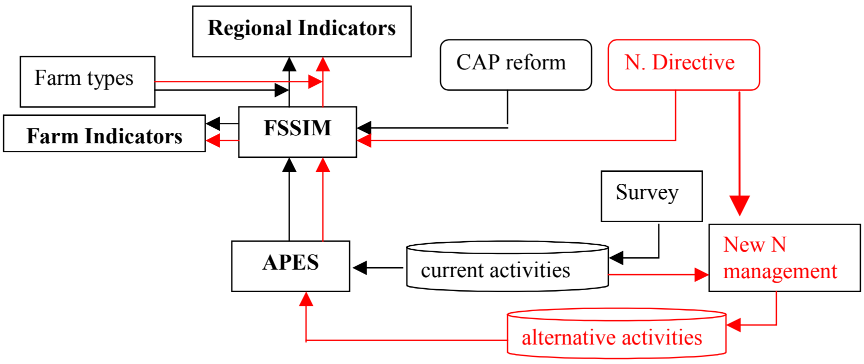

Fig. 3.3. Model chain for current and alternative activities. For this application CropSyst is used instead of APES model. First, the model chain for the CAP reform is run (black arrows) to assess the baseline scenario and then the Nitrate directive (red arrows) is run to assess the policy scenario.

3.3 Data requirement

To apply the CropSyst-FSSIM model chain three types of data are required: (i) the bio-physical characteristics of the agri-environmental zones used as input for the bio-physical model CropSyst, (ii) the farm types characteristics used in FSSIM to define constraints’ RHS (Right-Hand Side) value and to calibrate the model, and (iii) the input output data/coefficients of the current and alternative activities which include technical, social and economic information such as yield, input use (e.g. fertiliser, water, labour…), prices, costs, premiums, etc.

3.3.1 Biophysical data

Midi-Pyrénées is the largest region in France with a surface of 4 5348 km2. It is as big as Denmark and bigger than Belgium, Switzerland or The Netherlands. Agriculture in Midi-Pyrénées is very important, with production equally divided between livestock and crops. It represents the first French region by its number of holdings (around 60.000) and the fifth by its agricultural production.

The main crops cultivated in the region are cereals, proteagenous and oleaginous plants. They represent approximately 40% of the cultivated areas of the region (Agreste- annual farm statistics, 2006). 5% of the total cultivated area of the region was lying fallow in 2006. 9% of the total cultivated area is irrigated. Rainfed annual grain crops are therefore predominant in the Midi-Pyrénées region. In this application the crops are the main ones cultivated in the region without distinction of cultivars within a species.

The soil types in the region can be limited to the two main soil types locally known as terrefort (calcareous clay) and boulbène (clay-loam).

3.3.2 Input-output coefficient

Through a survey data has been collected on the current crop activities in the Midi-Pyrénées region. For this survey local experts, part of the regional agriculture advisory services, have been interviewed. We also used field experiments and statistical database. These data have been collected for the most frequent cropping systems in the region. They take into account climatic variation and other factors as pests and weeds.

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

Additionally, for each crop a set of economic data has been specified including product prices payed to farmer (the average value and the variability), variable costs and premiums. The expected producer prices are collected from a regional database and based on the 1999–2003 average. Variable costs are calculated by adding input costs for fertilizers, seeds, irrigation, biocides and the application costs associated with each event. The premiums are a three year average around 2001 according to Agenda 2000 regulation (which is taken as the base year policy).

An example of a set of input-output data used in this application is given in Table 3.2.

Table 3.2. An example of a set of input-output coefficients

Crops	Production techniques	Yield (T/ha)		Variable costs (Euro/ha)		Prices (Euros/Ton)	Premiums (Euro/ha)
		Soil Clay-loam	Soil Calcareous Clay	Soil Clay-loam	Soil Calcareous Clay		
Soft wheat grain	Tr: rainfed	5.5	7	362	430	116.23	309
	Ti: irrigated	-	-	-	-		
Durum wheat	Tr: rainfed	-	5.5	-	496	135.3	613
	Ti: irrigated	-	-	-	-		
Barley	Tr: rainfed	7	5	492	357	93.75	309
	Ti: irrigated	-	-	-	-		
Maize	Tr: rainfed	6.5	-	517	-	119.66	309
	Ti: irrigated	9.5	9.5	859	859		469
Sunflower	Tr: rainfed	-	2.2	-	293	213.27	363
	Ti: irrigated	-	-	-	-		
Soya	Tr: rainfed	2	2	297	386	196.30	363
	Ti: irrigated	3.3	2.5	512	297		523
Rapeseed	Tr: rainfed	1.9	2.5	277	416	203.78	363
	Ti: irrigated	-	-	-	-		
Peas	Tr: rainfed	4	4	365	365	132.68	364
	Ti: irrigated	4.5	4.5	423	383		549
Oats	Tr: rainfed	3.6	3.6	492	492	116.23	309
	Ti: irrigated	-	-	-	-		
Fallow	Tr: rainfed	-	-	61	61	-	309
	Ti: irrigated	-	-	-	-		

Source: Chambre d'Agriculture Midi-Pyrénées (http://www.midipyrenees.chambagri.fr/)

In the SEAMLESS context a set of alternative activities can also be generated using PEG, PTG and TCG generators. These activities can be defined as new rotation using current and alternative crops, new rotation including a nitrate catch crop within the current rotation (e.g. Wheat-Radish-wheat), a new activity which is grown in the study area but not identified as a current activity (marginal activity, e.g. sorghum-sorghum in the Midi-Pyrénées region), or combination of all those options. However, these generators were not yet available when this application started, so the set of alternative activities and their input output coefficients were manually generated. As described in §3.2.2 these activities are based on current crops, but with new nitrate management which differ only in the applied dose of nitrogen fertilizer but not in the dates of application. The amounts of N from mineral fertilizer needed by crop are calculated based on the "local advisory services" recommendations. Once the new amount of

N from mineral fertilizer is calculated for each activity, the CropSyst model is launched to simulate yields and externalities. Accordingly, a specific Excel sheet has been developed to calculate the crop N requirements (Appendix).

3.3.3 Farm data

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

In the Midi-Pyrénées region three of these farm types have been selected as representative of the main arable farming system. The main characteristics of these farm types are described in Table 3.3. From this we extract the data on resource endowment of each farm type, such as the available land per soil type, the irrigation possibilities, and family labour availability. These resource endowments are used to define constraints' RHS value in FFSIM-MP as well as the observed crop pattern used for the calibration.

Table 3.3 Main characteristics of the three arable farm types in the Midi-Pyrénées region extracted from the FADN data.

	Farm type 1	**Farm type 2**	**Farm type 3**
Specialisation_land use	Arable/Cereal	Arable/Fallow	Arable/others
Size_name **Intensity_name**	Large Medium	Large Medium	Large Medium
Farm represented (number)	2330	990	1736
Area by Farm (ha)	113.9	101.5	123.3
Irrigable area by Farm (%)	37	30	13
Soil Types (% of texture)	Clay (40%) Clay-loam (60%)	Clay (36%) Clay-loam (64%)	Clay (41%) Clay-loam (59%)
Available labour (hours)	2901.6	3260.3	3179.0
Observed Crop pattern (ha) Cereals Oilseeds Protein Fallow	 72.8 19.5 2.9 11.4	 52.4 17.7 4.3 18.9	 53.3 43.3 5.9 11.5

Source: FADN database (average of the three years around 2001)

Some observations with table 3.3:

1- the farm types are similar. This result seems due to the fact that the two criteria specialisation and land use are correlated.

2- only the large arable farms are represented (more than 100ha). The small farms (< 8UDE) in the Midi-Pyrénées region are not represented by the farm typology procedure retained in SEAMLESS.

3- For each soil type, different organic matter content is associated as is mentioned in the PD4.3.1 and PD4.6.1. There are 65 combinations of farm types and agri-environmental zones. Simulating yield and externalities for all agri-environmental zones with our manual procedure is a very time consuming task. Thus, for each activity, the yield and the externalities are simulated considering only the two simplified soil types (see section on investigated soil types).

4- no information is available in the current SEAMLESS database concerning the share of the irrigable area by soil type. The share of the irrigable area by soil type therefore had to be attributed based on a first estimate. For the next version, the share of irrigable area by soil type will be attributed based on expert knowledge.

5- only the total available labour by farm type is available in the FADN database, without distinguishing the share of temporary and permanent labour. This appears to affect the performance of the model (see 3.5.2.1 on model calibration).

3.4 Biophysical model "CropSyst" (as a temporary surrogate to APES)

3.4.1 Model calibration and validation

There are advantages in adopting field scale crop simulation models to analyze regional and watershed level agricultural production, because agricultural recommendations and policies are generally implemented at this scale (Moen et al., 1994; Chipanshi et al., 1999). Integrating geographic information systems (GIS) and crop models is attractive because it allows simultaneous evaluation of spatial and temporal phenomena (Hartkamps et al., 2004). A handful of studies have been carried out (Kunkel and Hollinger, 1991; Van Lanen et al., 1992; Moen et al., 1994; Haskett et al., 1995) using crop simulation models linked to a GIS for regional or watershed yield simulations using region-specific representative soils types, crop varieties, and planting times. In these studies, weather inputs are generally obtained from local stations representative for the region, and soil characteristics required for the simulation are generally estimated from texture data using pedotransfer functions. Thus, the crop model is first calibrated and evaluated by using experimental data at field scale, and then used, for assessing production and externalities at regional scale (Moriondo et al., 2007; Lui et al., 2007). This type of work has been done with the CropSyst model at the level of a watershed (Belhouchette et al., 2008). Using this approach implies to have a large set of experimental data for model calibration and evaluation. For this reason, this procedure is usually implemented to assess the production of only one or two crops under different management scenarios (Basso et al., 2007; Wesseling and Feddes, 2006). Thus, such a procedure cannot be used in the SEAMLESS project, where the objective is to asses the production and the externalities for different activities in several EU regions.

In this deliverable, a new approach based on expert knowledge and modelling is developed in order to simulate, for different activities, production and externalities.

3.4.2 Model parameters

The CropSyst input parameters can be either, ii) available in the literature (L), or ii) calibrated (Cal) to match model output against experimental or expert data. CropSyst inputs were set based on:

<u>Parameters input</u>

- <u>Soil</u>: The bulk density and water contents at field capacity and wilting point were determined using data of the INRA experimental site at Auzeville (Haute-Garonne).

The hydraulic conductivity was estimated from texture using the Pedotransfer functions proposed by the SoilPar software (Acutis and Donatelli, 2003).

- Weather: Climatic data come from a 53 years daily measurements database (from January 1949 to December 1997) collected at the Blagnac meteorological station (INRA, Toulouse). From this database daily temperature, rainfall and radiation were compiled into a climatic file
- Management: Those data concern mainly: sowing and harvesting dates and the amounts and the dates of irrigation and nitrogen fertilization.
- Crop: The phenological stages, growth and morphologic characteristics such as maximum rooting depth, and specific leaf area were compiled for use in the simulation. The crop parameters are fixed such as are described by Donatelli (2001).

Parameters calibration

The model calibration aims at optimising the crop phenology and the production (potential yield) obtained by simulation for each crop per rotation to the observed data. Thus, for model calibration usually two steps are identified:

i-" crop phenology"

The crop phenology is the thermal time required to reach specific development stages; it is calculated as growing degree-days accumulated throughout the growing season, starting from planting until harvest (Moriondo and al., 2007). For cereal crops, the main phenological stages are emergence, peak LAI, flowering, grain filling and maturity. They have to be adjusted, using 3-4 years of experimental data or field observations, depending on the result of the simulated date. The main objective of such adjustment is to prove first, the model capability to simulate correctly the crop cycle and second, to check the model sensitivity to climatic variations.

The methodology proposed in this report was targeted to these two objectives. First, reproducing the crop cycle by matching the simulated "harvest date" to the observed one established from local expert, and second, by comparing the simulated harvest dates (expressed en degree days) for different climatic conditions, which should varied within the maximum and the minimum range of harvest dates established by the local experts. The simulated "harvest date" represent the average of 53 years of simulation (from 1949 to 1997).

Parameter adjustment is done by increasing or decreasing all the dates, from sowing to harvest, by the same number of degree-days. The adjustment stop when observed date of harvest is the same as the simulated one (the average of 53 years of simulation).

ii- Calibration of other crop parameters.

Most of simulation models have a large number of parameters, many of which are not directly measurable (Ruget et al., 2002). Estimating their values requires development of specific methods depending on the number of parameters to adjust and on the data available. Some parameters describing physical laws are generic; others require an adaptation to the plant genotype. This adaptation relies on specific experiments which can be tedious and costly. Consequently, it is worthwhile to concentrate on the most influential parameters, e.g. those to which model outputs are the most sensitive. This procedure may involve providing a standard set of parameters for adapting the model to a new plant or to new specific pedo-climatic situations (Wallach et al., 2006).

To realize correctly a sensitivity analysis, a large experimental dataset is required. For a regional analysis, this kind of information is usually not available. In this case, the results of previous studies realized at field scale in the same region with the same objective, can be used to select the parameters to which the model is sensitive.

In this deliverable, and based on the analysis done in the Midi-Pyrénées region by Donatelli, (2002) only the coefficients of biomass-transpiration (KBT) and of light conversion to above ground biomass (KLB), were determined by calibration since the model is very sensitive to these two parameters (Stöckle and Nelson, 1993; Stöckle et al, 2003).

Accordingly in our application, the CropSyst model was calibrated, for each crop, against observed yield during the simulated years. Values of KBT and KLB were adjusted within a reasonable range of variation based on previous research and expert knowledge in order to have the best model estimation of the biomass accumulation observed for each crop in the calibration experiments (Donatelli et al., 1997). Adjustment stopped when further modification of crop parameters would generate little or no improvement on the basis of the relative error, a statistical index used to quantify the degree of fitness in the relationship between measured and simulated aboveground biomass (Cabelguenne et al., 1990).

3.4.3 Model evaluation

Usually the agreement between simulations and measurements is evaluated using regression analyses and statistical indices, e.g., the mean square error (MSE).
The mean squared error is defined as:

$$MSE = \sum_{i=1}^{N} (Y_i - \hat{Y}_i)^2$$

Where N is the number of measurements, Y_i is the ith measured value and $\hat{Y}_i$ is the corresponding simulated value.

For regional analysis, the above model evaluation criteria cannot be used as only the average observed yield is available and not the yearly observed measurement (Y_i). To deal with the lack of yearly information we propose the following procedure based on a decomposition of the MSE.

It has been shown that *MSE* can be decomposed as the sum of 3 terms, namely

$$MSE = (Bias)^2 + SDSD + LCS$$

$$(Bias)^2 = \left[(1/N)\sum Y_i - (1/N)\sum \hat{Y}_i\right]^2$$

$$SDSD = (\sigma_Y - \sigma_{\hat{Y}})^2$$

$$LCS = 2\sigma_Y \sigma_{\hat{Y}}(1 - r)$$

(Kobayashi and Salam, 2000).

- The first term, the squared bias, is the difference between average observed yield and average predicted yield, squared. In our case, average observed yield is provided by the expert and average predicted yield is obtained from the model simulations, so this term is easily calculated.
- The second term is the difference between the standard error of the observed yield and the standard error of predicted yield, squared. The standard error of observed yield is related to the max and min values provided by experts. It will be necessary to define exactly what this relation is. The standard error of the predicted values is easily calculated from the series of model simulations. So this term is also easily calculated, once one has defined the relation between the expert max and min values and the standard deviation of observed yields.
- The final term involves the standard deviations of observed and calculated yield and also the correlation coefficient *r* between observed and calculated values. This term

cannot be calculated for the survey data; it requires having the individual yields each year.

Lacking data for the final term we could use as criteria of model fit *(Bias)²* and *SDSD* either separately or their sum. To calculate these criteria we need to establish a relation between the min/max from the experts and the standard deviation associated to it. There are two possible approaches to establish this relation

- First approach

The hypothesis underlying the first approach is that the min/max values from experts represent inter-annual variability (outliers removed)

Example: let state that the expert have 10 field in mind, that the average production over theses field for 8 years are: 102, 95, 83, 53, 92, 84, 89, 79. Considering the value of 53 as an outlier the expert provides the information min=79; max=102 ; mean= 84.625.

We want to compare the variability of the experts' data to the ones simulated (more precisely the inter-annual variability of the simulated yield). We then need to eliminate the outlier from the simulations, similar as done for the data provided by the expert. An outlier criterion needs to be defined (there is no absolute definition for this, it depends on the context). For simplicity we assume that the expert considers as outlier the values that are >±k standard deviation (SD) from the mean value (the value of k still needs to be determined, see below). With such an assumption we can calculate the mean and SD after removing the outliers from the model simulations.

We then need a criterion to measure the difference between the variability of the simulation to the min/max from experts. One option would be to compare the min/max distance from the experts with the min/amx distance from the simulation. Using the min/max distance seems to suggest that we don't need to convert the min/max SD. However we need the SD to define the outliers, since these comparisons are commonly based on data with outliers removed.

- Second approach

We would like to combine the comparison of inter-annual variability (min/amx distance) with the comparison of means. We have shown above that it is logical to combine bias² and SDSD. For the simulations we can compute the SD without need for an additional hypothesis. But for min/max from the we need one. For simplicity we can consider that min/max from the expert corresponds to ±k SD

In order to implement these two approaches to evaluate the model we need to determine the value of k. Chebyshev shows that at least $\left[1-(1/k^2)\right](100)$ % of the observations are at a distance k from the mean *for any distribution.* For example, taking k=2 gives that at least 75% of the observations are at a distance <±2 SD from the mean (k=3 -> 88.89% ; k=4 -> 93.75%).

Note that each interval contains at least the mentioned fraction, but depending on the distribution a greater fraction is possible. For example the normal distribution has 95% of its observations between ±2 SD, and the uniform distribution 100% (when the above formula gives 75%).

To get back to the two above approaches suggested. For approach 1, if the expert removes 10% of the values (outliers) this corresponds to ±2 SD and provides a clue to characterize outliers. Similarly for approach 2, we can consider a 10% threshold as a ±4 SD.

Initial soil conditions

The initial conditions describe the soil water, nitrate, ammonium, organic matter, phosphorus etc. contents at the beginning of the simulation. Those parameters are usually measured.

At regional scale, such information is usually missing. To avoid this problem an alternative strategy was employed. First, long-term CropSyst simulations were run, and second, an average value is calculated but without considering the results of the first 5 years. Doing that, we assume that after 5 years of simulation the impact of the initial conditions on the crop yield will be very low.

3.4.2 Results

Model evaluation

As an example, figure 3.4 shows the density of the distribution of the simulated yield of wheat from wheat-sunflower activity (on a terrefort soil). To evaluate the quality of the simulation according to the survey database (Min / Average / Max), we followed the steps described in 3.4.1.

1. The Shapiro test gave a p-value > 0.05 which mean that the distribution can be considered as normal.
2. The mean value from simulations is close to the observed one (a difference of 194 kg/ha compared with a mean value of 5500 kg/ha). The simulation thus gives good average simulations results but there is still a small bias.
3.
    a. Under the normal distribution hypothesis, 6.7% of the simulations outputs are out of the Min/Max range (mostly less than the Min which can come from the bias observed in 2.).
    b. Only one simulation is out of the Min/Max range (nbr of points out 1/22 inf; (1))
    c. For the simulation data which are out of the Min/Max range, the sum of their distance to the Min/Max values has a value of 117 kg/ha which can be neglected regarding the mean value of 5500kg/ha.

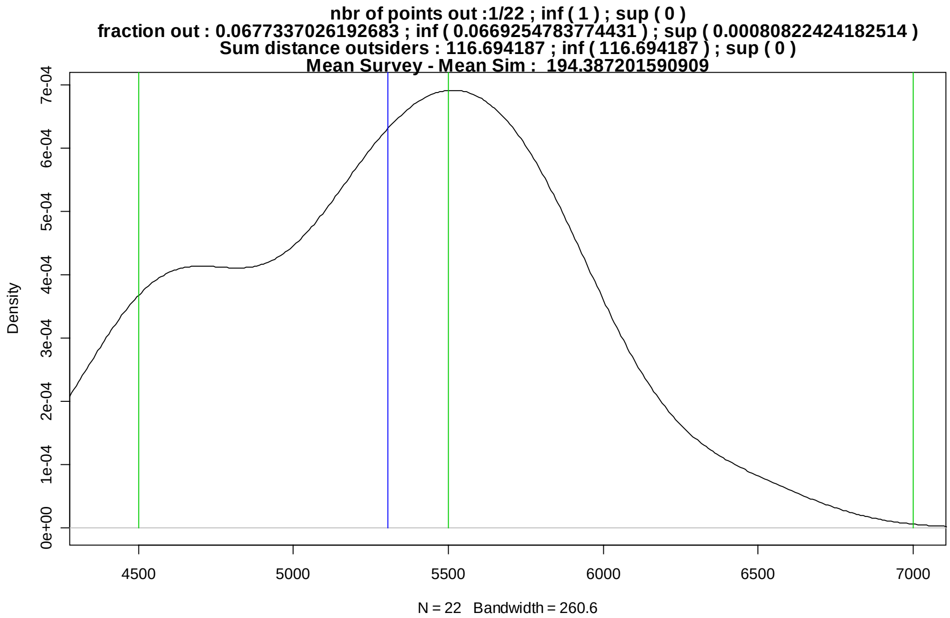

Fig. 3.4 Shapiro test for model evaluation for a wheat crop on a Terrefort soil in the Midi-Pyrénées region.

Current activities vs. alternative activities

As an example, figure 3.5 presents a comparison of nitrate leaching for the main current and alternative activities in the Midi-Pyrénées region in the Nitrate Directive application[3]. For both soil types, the nitrate leached is less for alternative activities than for the current one, except for some activities in the terrefort soil such as irrigated grain maize. For both activities and soil types, yield is the same for alternative activities as for current ones.

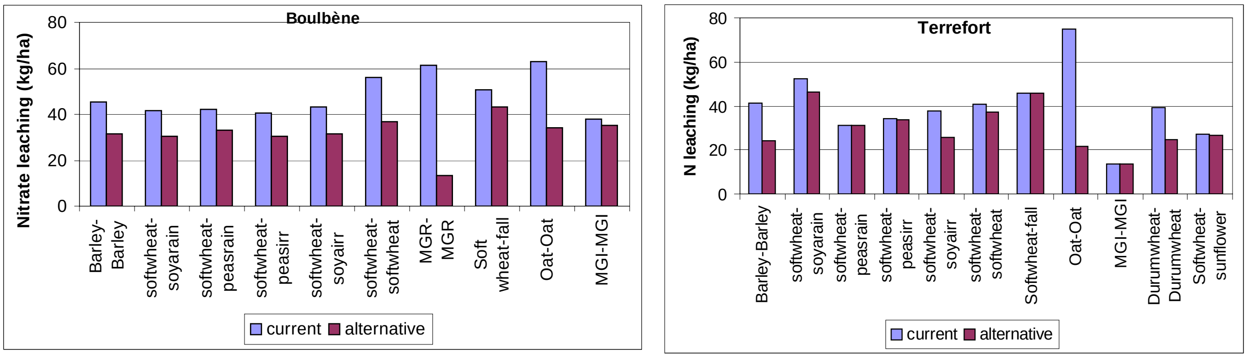

Fig. 3.5. Comparison of the nitrogen leached by soil type for the main current and alternative activities in the Midi-Pyrénées. Simulation is done using the CropSyst model.

3.5 Bio-economic farm model "FSSIM"

3.5.1 FSSIM specification: selected modules and calibration procedure

The set of components, modules, constraints and calibration procedure used in the FSSIM application to the Midi-Pyrénées region, are the following (Figure 3.6):

- **Components:** the selected components are: (i) *the farm typology* developed in SEAMLESS project by WP4 to provide for each sample region (NUTS2 level) a set of typical, well defined, farms in terms of size, intensity, land use and specialisation; (ii) the *detailed computer-based survey* developed by the ZALF team to collect detailed information on current activities using local expert knowledge (Borkowski et al., 2007); (iii) the biophysical model *CropSyst* (used instead of APES) to estimate the environmental impacts of current and alternative activities at the field level and (vi) the mathematical programming model *FSSIM-MP* to simulate farmer's choice in term of activities and assess the economic and ecological impacts of the selected scenarios at the farm level (Louhichi et al, 2007).
- **Modules:** the selected modules are the crops, premiums, risk, positive mathematical programming (PMP), perennial, policy and the common modules. The livestock and the investment modules are switched off since the present application focused on arable farming systems. The perennial module was used to fix the area of perennial crops at their observed levels in the base year situation (i.e. no investment and no removal possibility was introduced).
- **Constraints:** all the constraints of the selected modules are activated in this application. These constraints are: arable land per soil type (i.e. agri-environmental zone), irrigable land per soil type, labour requirement, institutional restrictions (set-aside and production quota) and risk constraint. The rotation constraint is taken into account while defining the set of agricultural activities. The water constraint was not activated because the amount

[3] Alternative activities are activities with a better nitrogen management practices (table 3.5)

of available water in each farm type was missing. The labour constraint was activated but not binding as the labour availability is much greater than the labour requirements. This is due to the fact that the labour availability which is taken from FADN database comprises both temporary and permanent labour.

- **Calibration procedure:** the calibration procedure is based on two steps: in the first step, we apply the risk approach in order to calibrate the model, as precisely as possible. That consists of selecting in the risk module the option "automatic choice of risk aversion coefficient". The model assigns automatically a value to the risk aversion coefficient which gives the best fit between the model's predicted crop pattern and the observed values. The difference between both values is assessed statistically by using the Percent Absolute Deviation[4] (PAD). The aim of this step is to ensure that the model produces acceptable results before going to the second step. To do this test, the following assumptions was taken: if the PAD is less then 15% the model is acceptable and we can start the second step, if PAD is more than 15%, the model should be improved before applying the second step. In the second step, we apply the Positive Mathematical Programming according to Röhm and Dabbert approach in order to calibrate the model exactly to the observed situation (Louhichi et al. 2007). The base year information for which the model is calibrated stems from a three-year average around 2001[5].

- **Exogenous assumption for building the baseline scenario**: the adopted exogenous assumptions between the base year and the baseline scenarios are the following: (i) an assumed inflation rate of 1.19 % per year; (ii) a projection in producer prices obtained from the market model SEAMCAP and (iii) a yield trend to reflect technical progress. These exogenous assumptions will affect the average prices and yields as well as the prices and yields according to the states of nature. Table 3.5 gives the percent changes of crop product price and yield between the baseyear and the baseline scenarios. The baseyear price and yield are presented in the Table 3.2.

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[4] Percent Absolute Deviation (%):

$$PAD \quad (\%) = \frac{\sum_{i=1}^{n} \left| \hat{X}_i - X_i \right|}{\sum_{i=1}^{n} \hat{X}_i} . 100$$

Where $\hat{X}_i$ is the observed value of the variable i and X_i is the simulated value (the model prediction). The best calibration is reached when PAD is close to 0.

[5] For the final year of the project, the base year is changed to 2003.

Table 3.5. Price and yield changes between base year and baseline scenarios

Crops	Price change (%)	Yield change (%)
Durum wheat	10%	22%
Soft wheat	4%	-7%
Barley	-3%	15%
Maize	-13%	5%
Sunflower	0%	1%
Soya	-19%	-1%
Rapeseed	11%	21%
Peas	9%	-4%
Oats	-8%	20%
Maize fodder	29.9	13.2

- **Base year and baseline policy representation:** the Agenda 2000 (since 2000) Regulation constitutes the base year policy. The recent CAP reform of June 2003 in Luxembourg, as it would be implemented in 2013 in the EU25, is considered as the principal policy assumption operating in the baseline scenario. Performed in 2013 instead of 2020 as was expected, the baseline scenario will be the reference for the interpretation and analysis of the selected policy scenarios. The reason for selecting 2013 (instead of 2020) is the uncertainty about the new CAP after 2013, but the methodology presented here would remain valid for a longer time horizon.
- **Simulation policy scenarios and their implementation in the model chain CropSyst-FSSIM:** the policy test case is the integrated assessment of the Nitrate Directive (91/676/EC) (Belhouchette et al., 2007). In arable farming systems, the implementation of the Directive is based especially on (i) better management of mineral and organic nitrogen fertilization; (ii) respect of the restricted period for applying manure or nitrogen fertilizer taking into account the type of fertilization and the land use and (iii) maintenance of a minimum quantity of vegetation cover during (rainy) periods for the uptake of soil nitrogen that might otherwise cause water pollution. The implementation of these measures in the model chain CropSyst-FSSIM was achieved through the steps described in Table 3.6.

Table 3.6. The implementation of the Nitrate directive in CropSyst and FSSIM-MP

Measures	Implementation
M1: Better management of nitrogen mineral and organic fertilization	- Generate a set of alternative activities (AA) based on current crops, but with the aim to reach potential yields with a better N use efficiency - Identify N use and potential yield associated to each AA using local handbook. In this application the average yield reported for the current activities (from 1998 to 2002) is considered as the potential yield. It means that all the effort will be concentrated on minimising N use and thus the associated fertilisation costs. - Assess the environmental externalities associated to each AA using CropSyst. - Quantify the other inputs-outputs of each AA (costs, premiums, etc.) using the local handbook and database. The cost of each AA is calculated as the average cost of the corresponding current activity minus the reduction in fertiliser costs due to better N use efficiency. The difference is increased by 5% so as to take into account the private transaction costs relating to the collection of information on the policy, the participation in training sessions… An increase of AA yield variability by 10% is also assumed in this application as the decrease of N application generally increases the yield variability. - Provide (in complement to current activities) the set of AA and their input output coefficients to FSSIM-MP. From the first test we have observed that the model select very few numbers of AA. It means that most of them are inefficient under the retained assumptions in term of costs and yield variability. Thus, two solutions are possible to improve AA competition: penalising current activities (i.e. cross-compliance instrument) or subsidising alternative activates (i.e. agri- environmental measure). In this application we have chosen the first solution. It consists to include in FSSIM-MP, through the constraint system, a compulsory cross-compliance under which the receipt of EU support payment would be conditional to the selection of alternative activities. If one or more of the current activities are selected by the model, the premium will be cut by 3%. The implementation of this cross-compliance measure inside GAMS is done through the following constraint: $$\sum_{r,s,t} X_{r,s,t,\text{"CURR"}} - BigN * Bv \le 0$$ BigN: a big number such as 10^6 Bv: a binary variable; Bv = 0 the condition is fulfilled; Bv =1 the condition is not fulfilled and the premium included in the objective function is cut by 3%.
***M2:** Respect of the restricted period to apply manure or nitrogen fertilizer*	*The same implementation as for the M1 measure but the identification of N use and potential yield for each alternative activity was done through CropSyst simulations as opposed to using the handbook.*
***M3:** Maintain a minimum quantity of vegetation cover during rainy periods*	*The only difference, regarding implementation, to the previous measure is that the generated rotations include nitrate catch crops in order to maintain minimum vegetation cover and ensure nitrate absorption during rainy periods.*

In the application reported here we implemented only the first measure as the other two measures (i.e. M2 and M3) require more time in data collection and in CropSyst simulations.

Table 3.7 gives a brief definition of the baseline in comparison to the simulated scenario which combines the 2003 CAP reform with the application of the M1 measure of the Nitrate Directive.

Table 3.7. Definition of baseline and policy scenarios

	Baseline scenario [2013]	**Nitrate Directive [2013]**
2003 CAP reform	- Decoupled payment (taking into account the known implementation of Member States) - Modulation implementation	
Measures		Cross-compliance restriction (a 3% cut of EU premiums if the alterative activities based on better management of nitrogen mineral fertilization are not applied)

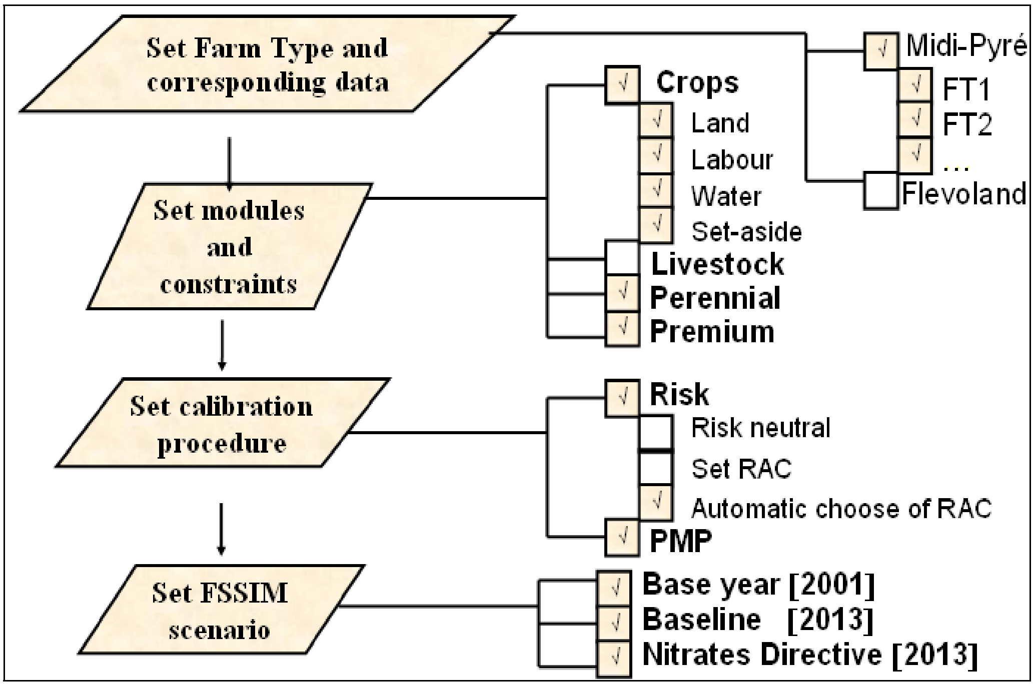

Fig. 3.6. Modules, calibration procedure and policy scenarios selected in the French Test Case region

3.5.2 Results and discussion

The results of the Nitrate Directive scenario are shown, after a brief presentation of model calibration results as well as a short comparison of the impacts of the 2003 EU CAP reform as it would be implemented in 2013 and the continuation of Agenda 2000 Regulations, ceteris paribus (i.e. except inflation, all the exogenous assumptions adopted in the baseline scenario are deactivated in this test in order to asses the separate impact of 2003 CAP reform).

First, the results for each farm type are shown. Subsequently, the aggregated results across all the simulated arable farm types are computed as the weighted sum of the results for each farm type. The weights for each farm type correspond to the share of farms belonging to that farm group.

The impacts of the different scenarios are illustrated through a set of technical (crop pattern), economic (farm income, production and premiums) and environmental indicators (only nitrate leaching in this example). In order to make the results comparable across scenarios and farm types, the economic indicators are expressed in constant 2001 prices and the environmental indicators are defined per hectare of usable farmland.

3.5.2.1 *Model calibration*

As we explained above, model calibration was based on risk (first step) and Positive Mathematical Programming according to Röhm and Dabbert approaches (second step). The calibration results for the three farm types are summarised in Table 3.8.

As shown in this table, the PAD obtained in the first step for the three farm types are bigger than the fixed threshold which is 15%, showing that the model is unfairly calibrated. This is explained by the limited number of binding constraints (i.e. only three constraints are binding: total land, irrigable land, and obligatory set-aside), the lack of specification of technologies (i.e. the only technology distinction is between rainfed and irrigated techniques) and the low price and yield variability (i.e. the risk constraint plays a very small role in this case). Given the much better PAD results in the Mali application (see below), in which FSSIM-MP has been augmented with labour and equipment constraints for four periods within a year, it seems plausible that the lack of binding constraints causes the high PAD values.

According to the PAD results the model needs to be improved before applying the second step. However, since some data are missing in term of technology and constraint specifications we decided to accept these results because the purpose of this application is only methodological. We will start the second step which allows the exact calibration of the model (i.e. PAD equal to zero).

Table 3.8. Results of model calibration

Crops	Farm type 1			Farm type 2			Farm type 3		
	ϕ = 1.65			ϕ = 1.5			ϕ = 0.5		
	Obs. Level (ha)	Sim. Level (ha)	WAD (%)	Obs. Level (ha)	Sim. Level (ha)	WAD (%)	Obs. Level (ha)	Sim. Level (ha)	WAD (%)
Soft wheat	13.12	0.00	12	12.30	0.00	12	13.15	2.47	9
Durum wheat	17.3	66.44	43	11.43	59.28	47	31.56	83.65	42
Barley	4.10	0.00	4	1.57	0.00	2	2.39	0.00	2
Oats	3.15	0.00	3	-	-	-	-	-	-
Maize	35.09	19.05	14	27.10	14.42	13	6.21	8.25	2
Rape	2.19	0.00	2	1.40	0.00	1	1.62	0.00	1
Sunflower	14.28	0.00	13	12.63	0.00	12	33.95	0.00	28
Soya	2.98	7.7	4	3.65	0.00	4	7.8	8.25	0
Peas	2.91	1.93	1	4.39	0.77	4	5.95	0.00	5
Fallow	11.35	11.35	0	18.92	18.92	0	11.5	11.50	0
Tobacco	0.32	0.32	0	0.87	0.87	0	-	-	-
Grass	3.81	3.81	0	1.86	1.86	0	7.01	7.01	0
Apple	0.24	0.24	0	0.47	0.47	0	0.07	0.07	0
Vines	3.10	3.10	0	4.92	4.92	0	2.06	2.06	0%
PAD Without PMP (%)	94.5			94.3			88.6		
PAD With PMP (%)	0.00			0.00			0.00		

WAD: weighted absolute deviation[6]

ϕ: Risk aversion coefficient

Source: model results

3.5.2.2 Impact analysis of 2003 CAP reform at farm and aggregated levels

Compared to the Agenda 2000 Regulations (base year), the adoption of the 2003 CAP reform leads (Table 3.9), as expected, to (1) a decrease of the oilseeds area due to the alignment of premiums for cereals and oilseeds (i.e. abolishment of additional direct payment for oilseeds); (2) a decline of the durum wheat area in detriment to protein crops and other cereals (cf. Tables A.11, A.12 and A13 in appendices), as the supplement for durum wheat in traditional

6

$$WAD_i(\%) = \frac{\left|\hat{X}_i - X_i\right|}{\sum_{i=1}^{n} \hat{X}_i}.100$$

$$PAD\ (\%) = \sum_{i=1}^{n} WAD_i$$

production zones was reduced and integrated in the single payment scheme; (3) a reduction of the irrigated area since the additional compensation payment for irrigated crops is included within the single payment; and (4) a drop of farm income, reaching 20% for one farm type, provoked mainly by modulation and decoupling. These tendencies are observed in all three farm types of the Midi-Pyrénées region, with different degrees according to farm's resource endowments (Table 3.9). Minor differences are observed in the cropping plan of farm type 3, which shows an increase in oilseeds in detriment to cereals. This is explained by the substitution of durum wheat with oilseeds instead of maize, due to lower availability of irrigable land.

Regarding the environmental results, the implementation of the 2003 CAP reform induces an increase of nitrate leaching in farm type 1 explained by the substitution of durum wheat and oilseeds by other cereals (particularly oats) that lead to higher pollution levels, probably because of lower biomass production, and a minor decrease in the others farm types due to extensification (decline of irrigated compared to non-irrigated maize).

Table 3.9. Comparison at the farm level of economic and environmental results for the Agenda 2000 and the 2003 CAP reform in the farm types of the Midi-Pyrénées region[7]

		Agenda 2000 [2001]	**2003 CAP reform [2013]**	
	Indicators / Unit [a]	Value	Value	% change compared to Agenda
Farm type 1	Farm income (K€)	81	65	-20%
	Premiums (K€)	39	29	-26%
	Nitrate leaching (kg N-NO_3^- /ha)	33.5	40.3	20%
	Crop pattern (ha)			
	Cereals	72.8	75.3	3%
	Oilseeds	19.5	17.0	-13%
	Protein crops	2.9	2.8	-3%
	Fallow	11.4	11.4	0%
Farm type 2	Farm income (K€)	79	67	-15%
	Premiums (K€)	34	25	-26%
	Nitrate leaching (kg N-NO_3^- /ha)	31.4	29.8	-4.5%
	Crop pattern (ha)			
	Cereals	52.4	54.2	3%
	Oilseeds	17.7	15.0	-15%
	Protein crops	4.3	5.2	21%
	Fallow	18.9	18.9	0%
Farm type 3	Farm income (K€)	77	63	-18%
	Premiums (K€)	48	35	-27%
	Nitrate leaching (kg N-NO_3^- /ha)	34.5	33.7	-2.5%
	Crop pattern (ha)			
	Cereals	53.3	45.4	-15%
	Oilseeds	43.3	49.6	15%
	Protein crops	5.9	7.6	29%
	Fallow	11.5	11.5	0%

(a) Monetary values for 2013 are deflated to be expressed in constant 2001 prices.
Source: model results

The economic results obtained at the farm level remain consistent when aggregated at the regional level (Table 3.10). However, some differences appear, regarding the cropping plan and nitrate leaching. As shown in Table 3.10, the same trends are observed in terms of farm income and premium at both farm and aggregated levels. But in terms of crop pattern and nitrate leaching, the impact of 2003 CAP reform seems marginal in absolute term at the regional level, compared to that at the farm level. This could be attributed to the weighted aggregation approach, which could mask the impact of policies at farm level.

[7] More results are given in Annexe

Table 3.10. Comparison at the aggregated level (Midi-Pyrennes region) of technical, economic and environmental results for the Agenda 2000 and the 2003 CAP reform in the Midi-Pyrénées region

		Agenda 2000 [2001]	**2003 CAP reform [2013]**	
	Indicators / Unit [a]	Value	Value	% change to Agenda
Aggregated level (NUTS 2 region)	Farm income (K€)	79	67	-15%
	Premiums (K€)	41	32	-21%
	Nitrate leaching (kg N-NO_3^-/ha)	34	37	10%
	Crop pattern (ha)			
	Cereals	63	62	-1%
	Oilseeds	26	26	0%
	Protein crops	4	5	16%
	Fallow	13	13	0%

(a) Monetary values for 2013 are deflated to be expressed in constant 2001 prices.
Source: model results

3.5.2.3 *Impact analysis of the Nitrate Directive at farm level*

Table 3.11 compares the results of the baseline scenario (including all the exogenous assumption as well as the baseline policy representation) to the base year 2001 and to the simulated policy scenarios, performed for year 2013. The comparison between the base year and the baseline scenarios will be briefly exposed, as it was partly analysed in the previous section. The aim here is just to estimate the impact of the exogenous assumptions (on prices and yield) in the baseline outcomes. The principal result of this comparison is that the integration of the projected yields and prices absorb the shock induced by the implementation of the 2003 CAP reform. Indeed, the decline of farm income varies between 15 and 20%, when the 2003 CAP reform is implemented, and between 3 and 11%, when the trend for yield and prices is combined with the CAP reform. This positive effect can be partially explained by the increase in cereal yields and in prices for durum wheat, protein crops (grain legumes) and oilseeds. Regarding the technical, economic and environmental indicators, the variations obtained from the simulation of the 2003 CAP reform alone remain valid when combining the assumptions on prices, yields and policy.

The results of the baseline scenario are now compared to the results of the simulated policy scenario. The only difference between these two scenarios is the implementation of the Nitrate Directive (M1 in Table 3.6). The main result, shown in Table 3.11, is that the cross compliance restriction was not respected by farm type 2, as the corresponding binary variable (Bv) is equal to 1 and the given premiums decrease by ca. 3%. This implies that the penalty of 3% is not enough to force this farm type to respect the cross-compliance by substituting the current activities with the alternative ones. The impact on farm income and cropping plan for this farm type is marginal, meaning that the baseline crop pattern remains optimal even with the 3% cut of premiums. Minor changes were observed in terms of management, involving the inclusion of some alternative activities for cereals in the crop pattern. This implies that some crops are more efficient with the alternative management under the simulated condition. However, this substitution is still marginal in absolute terms, since the share of alternative activities in the total farm area is less than 20%.

The threshold from which this farm type starts adopting cross-compliance is estimated to be a premiums cut of 6%. Obtained through a sensitivity analysis, this threshold shows that farmers are able to respect the cross-compliance but with a significant loss of income.

In contrast, the response of farm types 1 and 3 to the Nitrate Directive scenario is completely different. The cross-compliance restriction was fulfilled and the whole agricultural area was devoted to alternative activities. This implies that the loss of income induced by the adoption of the alternative activities is less than 3% of the premium received in the baseline scenario.

Regarding the environmental results, the impacts of the Nitrate Directive scenario seem very positive, especially in farm types 1 and 3 which chose to adopt the alternative management activities. In these farms, nitrate leaching decreased respectively by ca. 40% and ca. 26%, showing the major role played by the simulated instrument (M1 in Table 3.6) in controlling nitrate pollution. Even if this reduction appears too optimistic and may be difficult to accomplish in reality, the global tendency remains very realistic. Indeed, similar results were obtained in other studies (Flichman and Jacquet, 2003). This shows the beneficial effects of policies based on the efficient combination of inputs, as opposed to classical policies acting on the outputs, such as taxes or permit systems acting on the outputs.

Table 3.11. Impact of the Nitrate Directive (policy scenario) on some technical, economic and environmental indicators of the farm types of the Midi-Pyrenées region, simulated with the CropSyst-FSSIM chain.

		Base year [2001]	Baseline scenario [2013]		Nitrate Directive [2013]	
	Indicators / Unit [a]	Value	Value	% change to baseyear	Value	% change to baseline
Farm type 1	Farm income (K€)	81	72	-11%	71	-1%
	Premiums (K€)	39	29	-26%	29	0%
	Nitrate leaching (kg N-NO_3^- /ha)	33.5	41.1	23%	24.6	-40%
	Crop pattern (ha)					
	Cereals	72.8	75.8	4%	76.5	1%
	Current	*72.8*	75.8	4%	0.0	-100%
	Alternative	-	-	-	76.5	100%
	Oilseeds	19.5	16.5	-15%	16.0	-3%
	Current	*19.5*	16.5	-15%	0.0	-100%
	Alternative	-	-	-	16.0	100%
	Protein *crops*	2.9	2.9	0%	2.7	-7%
	Current	*2.9*	2.9	0%	-	-100%
	Alternative	-	-	-	2.7	100%
	Fallow *(current)*	11.4	11.4	0%	11.4	0%
Farm type 2	Farm income (K€)	79	77	-3%	76	-1%
	Premiums (K€)	34	25	-26%	24	-4%
	Nitrate leaching (kg N-NO_3^- /ha)	31.4	36.4	16%	36	-1%
	Crop pattern (ha)					
	Cereals	52.4	44.9	-14%	45.3	1%
	Current	*52.4*	44.9	-14%	40.4	-10%
	Alternative	-	-	-	4.9	100%
	Oilseeds *(current)*	17.7	23.7	34%	23.3	-2%
	Protein crops*(current)*	4.3	5.8	35%	5.8	0%
	Fallow *(current)*	18.9	18.9	0%	18.9	0%
Farm type 3	Farm income (K€)	77	74	-4%	73	-1%
	Premiums (K€)	48	35	-27%	35	0%
	Nitrate leaching (kg N-NO_3^- /ha)	34.5	34.8	1%	25.8	-26%
	Crop pattern (ha)					
	Cereals	53.3	53.2	0%	54.6	3%
	Current	*53.3*	53.2	0%	0.0	-100%
	Alternative	-	-	-	54.6	100%
	Oilseeds	43.4	41.9	-3%	41.1	-2%
	Current	*43.4*	41.9	-3%	0.0	-100%
	Alternative	-	-	-	41.1	100%
	Protein crops	6.0	7.6	27%	7.0	-8%
	Current	*6.0*	7.6	27%	0.0	-100%
	Alternative	-	-	-	7.0	100%
	Fallow	11.5	11.5	0%	11.5	0%

(a) Monetary values for 2013 are deflated to be expressed in constant 2001 prices.
Source: model results

3.5.2.4 Impact analysis of the Nitrate Directive at the aggregated level

Table 3.12 shows the aggregated response of all three farm types to the Nitrate Directive scenario. As expected, the trend obtained at the farm level remains the same at the aggregated level such as (i) a partial substitution of current activities by alternative; (ii) a marginal decrease of farm income and premium due to penalty and the adoption of alternative activities; (iii) a decline of nitrate leaching attributed to alternative activities which are more efficient in environmental terms.

Table 3.12. Impact of the nitrate Directive (policy scenario) on arable farming systems (weighted average across farm types) in Midi-Pyrénées

		Base year [2001]	**Baseline scenario [2013]**		**Nitrate Directive [2013]**	
	Indicators / Unit [a]	Value	Value	% change to baseyear	Value	% change to baseline
Aggregated level (NUTS 2 region)	Farm income (K€)	79	74	-7%	73	-1%
	Premiums (K€)	41	30	-26%	30	-1%
	Nitrate leaching (kg $N\text{-}NO_3^-$/ha)	34	38	13%	27	-29%
	Crop pattern (ha)					
	Cereals	62.8	62.7	0%	63.5	1%
	Current	*62.8*	*62.7*	*0%*	*8.5*	*-85%*
	Alternative	-	-	-	*55.0*	*100%*
	Oilseeds	26.1	25.5	-3%	24.9	-2%
	Current	*26.1*	*25.5*	*-3%*	*4.9*	*-81%*
	Alternative	-	-	-	*20.0*	*100%*
	Protein crops	4.1	4.9	19%	4.6	-6%
	Current	*4.1*	*4.9*	*19%*	*1.2*	*-75%*
	Alternatives	-	-	-	*3.4*	*100%*
	Fallow *(current)*	13.0	13.0	0%	13.0	0%

(a) Monetary values for 2013 are deflated to be expressed in constant 2001 prices.
Source: model results

3.5.3 Conclusion and main lessons from the case study in Midi-Pyrénées

The application of the CropSyst-FSSIM model chain in the Midi-Pyrénées region has produced significant results reflecting the plausible responses of arable farming systems to the tested policies. However, even if these results reflect the plausible tendencies, they must be interpreted with caution according to model assumptions and results.

This application has also shown the great interest of this kind of models to represent complex agricultural systems and to predict the impact of policy change. However, since it was the first application diverse lessons could be taken into account for future development such as:

- Model calibration before applying PMP should be improved: this can be completed through the introduction for example of water availability (inactive for the moment) and improved labour constraints (not binding in the current simulations).
- Definition of yields, costs, externalities etc. per crop within crop rotation: input output coefficients of crops are defined for the moment independent of crop rotation. This means that the yield of barley, for example, is the same if the barley is included

in monocrop or in multicrop rotations. Thus, it would be appropriate to take into account this variability in the future. It is possible to generate these values with the CroSyst model but as it is done outside of the system the large number of simulations is time consuming.

- The distinction between vulnerable (VNZ) and other zones has to be considered. In the current version the Nitrate Directive was implemented for the whole region presuming that the entire region is a vulnerable zone, while VNZ represent only 40% of the total area.
- Additional data is needed for the evaluation of the CropSyst model. These data are yield variability, possible dates of harvest, dates and amounts of each management application... The problem is that these data are not available from the detailed survey, so we have to define a procedure to collect or estimate this information.
- Only 2 soil types are considered in this application. This means that the simulation of all soil types will be very time consuming when done outside of the SeamFrame architecture.

4 Application of FSSIM to a Malian region (Sikasso)

In this application it was not possible to use a crop model, as a temporary replacement of APES, because of the lack of previous work in the region to calibrate a crop model for the main crops. An ongoing effort with APSIM (Sissoko, unpublished) on cotton and sorghum crops will produce a calibrated version for a new application. In the application described below we only used the FSSIM model with yields provided to FSSIM-AM from expert knowledge and experimental data both for current and alternative activities. It was therefore not possible in this first application to calculate indicators of environmental impacts.

4.1 Context and tested scenario

Policies of rural development in the Southern regions of Mali were targeted towards cotton production and implemented principally through a para-state company: the Malian Company for the Development of Textile Industry (CMDT). The company manages almost the whole cotton sector and implements extensive programs of rural development in the area. Since 2001, the Malian State entered in a process of progressive decentralization to be completed by 2008 with the privatization of the cotton company.

This reorganization was decided after the crisis of 2001 when the production fell abruptly, due to a strike by most producers through their trade-union, creating a huge deficit along the value chain. This crisis was linked to a fall of the price paid to producers. It originated from bad management of the cotton company, with very high costs of operation and no reserve funds (whereas the system envisaged the constitution of guarantee funds). In the future cotton organization, the principle of uniformity in the whole country of the prices for the purchase of cotton and for inputs and seeds will be kept..

International prices of cotton are variable, but their long term trend is downward. The price in Mali doubled after the 1994 devaluation of the FCFA and has been falling ever since. As the FCFA is pegged to the Euro, the recent rise of the Euro versus US$ increases the production costs in Mali.

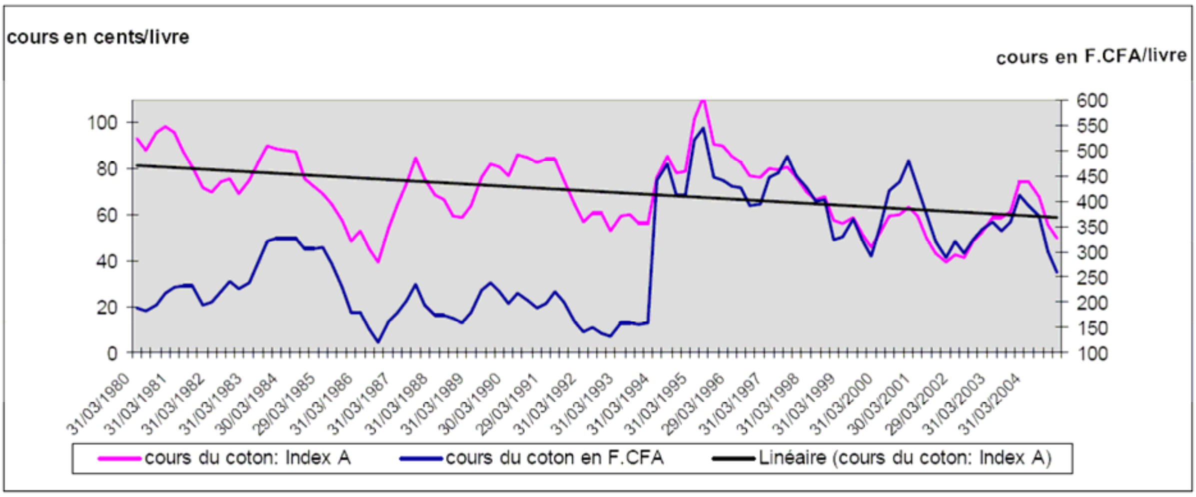

Fig. 4.1. Evolution of world prices of cotton (Indice Cotlook A, trimestriel).

Source: (Perrin 2005).

Based on this context, three kinds of scenarios based on cotton prices trend were developed. The current document only presents the results of the last scenario (introduction of technical innovations). The first scenario (modification of the price of cotton) one was tested in 2006, showing a relative resilience of cotton producers to the modifications of cotton prices (Simien, 2006). The second scenario (modification of the cotton sector) has not been tested so far.

4.1.1 Modification of the price of cotton

The evolution of the international price of cotton is difficult to predict. The estimate of the levels of production and therefore supplies, net import from China and, to a lesser extend, consumption seems delicate in the long term, which induces a strong uncertainty in the forecasts of price beyond six months (Perrin, 2005). The removal of state subsidies by the United States as required by the WTO ruling on cotton should help increase the cotton price. In Europe, cotton remains marginal and subsidies granted to the producers have little weight on the world market. «The fact that the European Union is a marginal cotton producer implies that the impact of the cotton production of the European Union on the evolution of prices on the world market is negligible. In addition, for this sector, the European Union does not grant subsidies for exportation and allows a postpaid access right[8]». Since SEAMCAP does not include cotton as a crop we were not able to test the impact of prices with a scenario of reform neither of the European subsidies (which would not significantly affect world prices) nor for a removal of US subsidies of cotton which would affect world market prices. The GTAP model does include cotton (as part of fibre crops) but is not yet available for simulations in SEAMLESS-IF.

Base year for FSSIM and CAPRI calibration in SEAMLESS-IF were 2001 and 2002 (and have shifted to 2003 in the last version of the database). However at this period the prices to the producer were high: 200 Fcfa / kg in 2001 and 180 Fcfa / kg in 2002. The current situation with prices of about 160 Fcfa / kg in 2005 and 165 Fcfa / kg in 2006, already corresponds to a fall of 14 %.

The scenarios to be tested are therefore be based on a fall of the prices to the producer compared to 2001/02 (average of 190 Fcfa/kg) of 15%, which corresponds to the current situation. This situation of a relatively low price will be continued over the period of simulation.

Two other levels of prices have been tested: one amplifying the price reduction to 30 % from the average price of 2001/02 (that is a fall to 133 Fcfa per kilogram) and the other one testing an increase of 15 % above average price 2000/02 which is 218,5 Fcfa / kg, above the best levels of the previous years.

These scenarios assume that the principle of uniformity of the purchase prices of seed cotton and of that of inputs is maintained on the whole of Mali and that prices are guaranteed (mechanism of fixing of price and fund of support) avoiding therefore price fluctuations (very low volatility), while a stronger volatility has been simulated with the scenario of privatization (see next section).

4.1.2 Modification of the cotton sector

Two scenarios are linked to the measures of economic policy taken with the privatization of CMDT and the reorganization of the sub sector as indicated in §4.1: one favourable to the cotton production where the privatization conveys a better functioning of the sector (less

[8] Communication of the Commission to the Council and the European Parliament entitled «To reach a sustainable agricultural model for Europe by the reformed CAP - sectors of the tobacco, the olive oil, cotton and sugar. Brussels, 23.9.2003 N° COM (2003) 554 final.

taxes on inputs, lower interests on campaign credits, cotton price remains stable) and one unfavourable, with higher taxes on inputs (cost increase of 23%), higher interests on credit (due to worse guaranty) and unstable cotton price (variability of 30%). Scenarios are contrasted to better evaluate the effect of privatization on the price of the inputs and the system of credit of the cotton sub sector as well as on the volatility of the cotton price.

4.1.3 Scenarios with technical innovations

Two alternative technologies will be tested or combined in different scenarios:

- Productivity increase with improved cropping systems
- Organic cotton

In both scenarios we use average prices over the period 2001 and 2002 (see § 4.2.3 on more detail of economic data).

The simulation of the effect of innovations on the farming system has been considered in SEAMLESS-IF within the framework of Test case 2. This Test case had not been considered for Mali in the initial DOW. However, we decided to test these innovations, because the FSSIM and APES versions developed for LDC countries should be able to test these changes. Moreover, these innovations are part of the current policy debate in Mali, and therefore provide a good opportunity to demonstrate the capabilities of SEAMLESS-IF.

Prototypes of cotton cropping systems under water deficit have been tested in experimental station and in farmer's fields (Lançon and al, 2007; Rapidel and al, 2005; Turini, 2005). Combining denser sowings of more compact varieties and use of growth regulators, can lead to a significant reduction of the period of fructification of the cotton plant. Its cycle is then better adapted to the short rainy season in Mali.

The introduction of a legume in the rotation is not a recent innovation. It aims to solve the problems of soil fertility, while also improving food and feed production during the long dry season (Enyong and Al., 1999). This innovation was never adopted widely despite many studies on the factor of adoption (Pannell and Al., 2006). The low opportunity cost of land is one of the major explanations (Buckles and Triomphe, 1999).

Organic cotton was introduced in Mali by the Swiss ONG, Helvetas. It is cultivated on some hundred of hectares. Few dependable technical data were are available, due to the lack of capitalization of the technical monitoring accomplished by this ONG.

To benefit from the label, a farm should be converted completely to organic farming. To get the label farmer has to leave a plot fallow and then grow 3 years of organic cotton. The organic cropping pattern is strict: no artificial pesticides, no inorganic fertilisers, no herbicides. The costs are limited, but yields are also lower than under conventional agriculture. The price is now 238 FCFA /kg organic seed cotton that is 44 % above the price paid for the rest of the sub sector. In 2001/2002, it was 220 FCFA/kg, 20% above the normal price (190 FCFA/kg). The organic grain sector is not developed yet and is not further considered in the analysis.

4.2 Data requirement

4.2.1 Database

The database gathered by the cotton company CMDT covers year 1997 to 2002. It includes farm structural data about farms and their respective cropping patterns. Covering 52 villages and 3000 farms (CMDT, 2007) the survey includes farm characteristics such as demography, equipment, animals, cropped areas. A smaller sample is used to survey in more details the cropping pattern of all crops within the farms. We used this database to feed FSSIM. We also used the PCP GESED[9] database which regroups the results of in-depth interviews with farmers about their field practices.

4.2.2 Farm types

Farms are differentiated by their capacity to intensify the use of productive factors (Djouara et al., 2006). These are defined based upon productive orientations and techno-economical features. Farms are studied based on a classification proposed by research but simplified by CMDT (Giraudy, 1994). Four classes are distinguished by their equipment and animal herd size; *type A*: two pairs of oxen, a plough, a weeder, a seeder, a cart, a donkey and a herd of at least 10 animals ; *type B*: pair of oxen, one plough and one weeder; *type C* : farm incomplete set of mechanical tools; *type D* : no equipment at all, they work by hand hoes).

According to Traoré et al. (2005), farm type A and B represent respectively 28 and 57 % of the farms while farm type C and D regroups only 10 and 5% , or 15 % together. Given this small number, we regrouped them in one new group C. In practice type A tends to represent large farms, B medium and C and D small farms. The study is realized according to this classification.

4.2.3 Current activities

Choice of current techniques

All cropping techniques were taken from the survey database. Some variations were introduced between cropping techniques on the same crop, described below.

We distinguished 2 or 3 planting dates for each crop with a significant impact on yields and two levels of fertilization: organic fertilization (OM) and without organic fertilization (no OM). In the region 61% of the cotton plots receive manure against 10% for millet and sorghum, and 20% for maize.

The multiple ways organic fertilizers are produced were not accounted for in the analysis. Cost was estimated at 3 FCFA per kg of manure and we considered that farmers apply an average of 5Tons per hectare (Kanté, 2001). With planting dates and the use of organic fertilization we constructed three types of crop management systems for cotton (Traore, 2007). For grains only planting time was taken into account and for peanuts only one technique was selected. The variations of current techniques introduced in the model are presented in Table 4.1.

[9] Pôle de Compétence en Partenariat pour la Gestion des écosystèmes de Savane, Environnement et Développement

Table 4.1. Variations of production techniques introduced into FSSIM-MP

Crops	**Production techniques**		
	T1	**T2**	**T3**
Cotton	Early planting around June 1st + OM	Early planting around June 1st + no OM	Late planting around July 1st with or without OM
Millet	Early planting around May 18 without OM nor mineral	Normal planting around June 15 without OM nor mineral	Late planting around July 15. without OM nor mineral
	T1	**T2**	
Maize	Normal planting around June 15th plus mineral fertilization	Late planting around July 10 + mineral fertilization	
Sorghum	Medium planting around June 15 and without OM nor mineral	Medium planting around July 15 and without OM nor mineral	

Soil types introduced in the model

In the former version of the model (Simien, 2006), soils were allocated according to three types: lowland soil (S1) especially for rice and tuber crops, good soil ("bas glacis") (S2) and marginal land (S3) for grain, cotton and peanut. In the studied villages, the lowland plots were not common. We decided to overlook S1 and take into account only the most common soil types, S2 and S3. Yields and input requirements vary with soil types. According to Kanté et al. (1993), 80% of the grain crops and cotton are planted in the good soils. Yields were extracted from the database for the good soils (S2) and for marginal soils (S3) we applied the reduction coefficients proposed in Table 4.2.

Table 4.2. Coefficient applied to determine yield of crops on marginal soil (S3)

	Crops			
	Cotton	**Sorghum**	**Maize**	**Millet**
Coef. K	0.79	0.61	0.39	0.95

Source: (Kanté et al., 1993)

Crop yield into marginal soil (S3) = Yield (S2) x Coef. K

Crop choice and rotations

We selected only the major crops, the ones whose median acreage in the sample exceeds 0.5 hectares. It includes cotton, millet and sorghum. We added the association maize/bean (MANI) (Table 4.3). Peanut is cultivated in farms B and C but not in large farms (A). We then classified the rotations. Some rotations last 2 years others 3 years and others do not show clear pattern. Only the most frequent rotations were considered.

Table 4.3. Area of the main crops by farm types

Farm type		Crops: Maize	Sorghum	Millet	Cotton	Mani	Ground Nut	Total area
A	Area (ha)	0.86	2.04	3.9	3.44	1.13	0.5	11.88
	%*	52.5	57.5	92.5	90	80	83	
B	Area (ha)	0.84	1.55	3.4	2.5	0.9	0.4	9.65
	%	64	72	98	91	78	86	
C	Area (ha)	0.4	1.18	2.58	1.44	0.67	0.36	6.63
	%	43	53	91	88	67	88	

*: % of farms where the crop is actually present

Yield determination of each crop compared to rotation

For each crop of each rotation, yields depend on rainfall, planting date, fertilization. Yields are calculated in average over the last six years. For each rotation, yields of each crop are determined and introduced in the model. Table 4.4 is an example of cotton in the rotation Cotton_Sorghum_Millet which is a function of planting time and fertilisation. For each crop, yield is determined by the rotation and the defined techniques.

Table 4.4. Cotton yield in the Cotton_Sorghum_millet rotation by planting date (D1 or D2) and use of organic fertilizers (OM or no OM).

	D1_OM	D1_no OM	D2
Yield (kg/ha)	1233	1005	824
CV %	37	33	24
Student Test	0.00		
		0.00	

Economic data, such as farm gate crop prices were taken from the 2001 and 2002 OMA (Observatoire du Marché Agricole) database. Prices were averaged over the last two years. Input prices were calculated based on the production quantity. These prices allowed to determine the cost of each decision variable.

Table 4.5. Input-output prices

Input	Price (€)	Output (crop-products)	Price (€)
Cotton Weed killer	7.01	Fonio (*Digitaria exilis*)	0.38
Maze Weed killer	5.14	Maize	0.15
Insecticide	5.69	Millet	0.19
Urea	0.26	Sorghum	0.20
Complex of cotton	0.31	Mixture maize/bean	0.17
Complex of cereal	0.28	Cotton	0.29
Mepiquat chloride	9.15	Organic Cotton	0.35
Seed protection	4.57	Ground Nut	0.27
Traditional protection (neem oil)	3.05		
Organic Matter (100 kg)	0.46		

4.2.4 Alternatives activities: prototype, legume and organic cotton

The three technical alternatives which were tested are: 1) a *prototype* (cotton cycle shortened to better handle a situation of water stress); 2) introduction of groundnuts in the rotation and 3) organic cotton. The prototype is well documented as it is based on field tests in experimental stations and farmers' fields (Lançon et al., 2007; Rapidel, 2005; Turini, 2005). Denser plantations of more compact varieties and the use of plant growth regulators, allows to reduce the fructification period of the cotton plant, giving to the crop a better adaptation to a short rainy season. But higher crop densities require more labour time, in particular for planting, and weeding. Experiments of the cotton prototype in farmers fields allowed to construct three types of crop management systems according to the technical and financial operations, to the similarities of the practices and the producers' objectives (Traore, 2005). The test concerns these three technical options according to the type of farmers.

Introduction of a legume in the crop rotation is an old practice in Mali (IRCT, 1969). It is supposed to improve soil fertility and to produce forage for animals during the long dry season (Enyong et al., 1999). Since 1974 (year when CMDT was created), this practice was progressively lost as cotton expanded in the countryside. Because of the soil fertility constraints we introduced peanut in the rotations and created two new rotations: Cotton_Maize _peanut and Cotton_Sorghum _peanut.

In Mali, organic cotton is promoted by Helvetas, a Swiss NGO (Merceron et al., 2005). The organic cropping pattern is strict: no pesticides, no herbicides and no chemical fertilizers. Production costs are limited as well as yields but selling prices are higher. We decided to test this new production method introducing it within the model.

4.3 Bio-economic farm model "FSSIM"

4.3.1 FSSIM specification: selected modules and calibration procedure

The set of the components, the modules, the constraints and the calibration procedure used in the FSSIM application to the Malian region (Sikasso), are the following (cf. Figure 4.2):

- **Components:** the selected components are: (i) the *detailed computer-based survey* developed by the ZALF team to collect detailed information on current activities using local expert knowledge (Borkowski et al., 2007); and (ii) the mathematical programming model *FSSIM-MP* to assess the economic and ecological impacts of the selected scenarios at the farm level.
- **Modules:** the selected modules are the crops, the risk, the livestock and the common modules.
- **Constraints:** the retained constraints are the arable land per soil type (or agri-environmental zone), the irrigable land per soil type, the labour requirement per period, the equipment requirement per period and the risk constraint.

  In order to take into account the periodicity of labour and equipment, which is a key driver of farmer's behaviour in this Malian region, without changing the structure of FSSIM-MP, we have divided the year into four sub-periods (sp) and then we have disaggregated the requirement and the resource availability according to the following equation:

  Labour constraint per sub-period: For each sub-period (sp), the sum of labour required for each selected activity (Lr*Lr_dis), expressed in hours, should be less than the amount of family labour (Flabour*Fl-dis) available in the farm in this sub-period, plus the amount of temporary labour (Tlabour) if needed.

$$\sum_{i,p} X_i * Lr_{i,p} * Lr\_dis_{i,p,sp} / N_r \leq Flabour * Fl\_dis_{sp} + Tlabour_{sp}$$

X_i: level of the selected activity i (i.e. $i = r,s,t,sys$) (in ha)
$Lr_{i,p}$: labour type required per year (P) for each activity i (hour/year)
N_r: number of years within each crop rotation
Flabour: family labour available (expressed in hour/year)
$Tlabour_{sp}$: temporary labour (in hour/subperiod)
$Lr\_dis_{i,p,sp}$: dis-aggregation per sub-periods of labour requirement per crop within each activity (%)
Fl_dis_{sp}: dis-aggregation per sub-periods of available family labour (%)

Equipment constraint per sub-period: as well as for the labour constraint, for each sub-period and each kind of equipment (K'), the sum of equipment required for each selected activity (Er*Er_dis), expressed in hours per year, should not exceed the available equipment (Ea*Ea_dis) plus rented equipment (Eb) if needed. The possibility of renting equipment, which is an endogenous variable, will depend on the supply and demand of equipment.

$$\sum_{i,p} X_i * Er_{i,k',p} * Er\_dis_{i,k',p,sp} / N_r \leq Ea_{k'} * Ea\_dis_{k',sp} + Eb_{k',sp}$$

X_i: level of the selected activity i (i.e. $i = r,s,t,sys$) (in ha)
$Ea_{k'}$: available equipment per kind (in hour/year)
$Eb_{k',sp}$: rented equipment per kind and sub-period (in hour/subperiod)
$Er_{i,k',p}$: equipment type required per year for each activity i and kind (hour/year)
N_r: number of years within each crop rotation
$Er\_dis_{,i,k',p,sp}$: dis-aggregation per sub-periods of equipment requirement per crop within each activity (%)
$Ea\_dis_{,k',sp}$: dis-aggregation per sub-periods of hours of available equipment (%)

Land constraint: the FSSIM land constraint was modified in order to take into account the possibility of land enlargement through the clearing of land. This practice seems very frequent in Mali. The cost of clearing land is included in the objective function.

$$\sum_{r,t,sys} X_{r,s,t,sys} \leq Totland_s + Tcl_s$$

$X_{r,s,t,sys}$: level of the selected activity i (i.e. i = r,s,t,sys) (in ha)
$Totland_s$: initial land endowment per soil type (in ha)
Tcl_s: cleared land per soil type (in ha)

Subsistence constraint: to account for the use of production for subsistence needs of the family a minimum production requirement is included for cereals as a constraint. The requirements are based on FAO data on family consumption needs (215/kg/person/year), although the observed production is less than these minimum requirements from the FAO. Production in excess of the subsistence needs is sold on the market.

- **Calibration procedure:** the calibration procedure is based on the risk approach using the option "automatic choose of risk aversion coefficient". The model assigns automatically a value to the risk aversion coefficient, which gives the best fit between the model's predicted crop pattern and the observed values. The base year information for which the model is calibrated stems from a three-year average around 2004.

- **Reference scenario:** the base year scenario is used as the reference scenario for the interpretation and analysis of the selected policy scenarios. There is no necessity to build a specific baseline scenario such as in EU application since there is no change in term of policies between the retained base year (i.e. 2004) and the current situation but also because the currently available data cannot be used to estimate the trend for price and yield. If GTAP becomes available projections of cotton prices, possibly with the abolishment of US subsidies, could be used as a reference scenario.
- **Simulation policy scenarios and their implementation in FSSIM:** the simulated scenarios consist in the adoption of technological innovation which are based on three technical alternatives: 1) a *prototype* (cotton cycle shortened to better handle a situation of water stress); 2) introduction of groundnuts in the rotation and 3) organic cotton.

Table 4.6. Implementation of the selected scenario

Measures	Implementation
M1: cotton cycle shortened to better handle a situation of water stress	- Generate a set of alternative activities (AA) based on cotton crops with alternative production technique. - Quantify the inputs-outputs of each AA (costs, yield …) using the local handbook and database. - Provide (in complement to current activities) the set of AA and theirs input output coefficients to FSSIM-MP.
M2: introduction of groundnuts in the rotation	- Generate a set of alternative activities (AA) based on new rotations with groundnuts. - Quantify the inputs-outputs of each AA (costs, yield …) using the local handbook and database. - Provide (in complement to current activities) the set of AA and theirs input output coefficients to FSSIM-MP.
M3: organic cotton	- Generate a set of alternative activities (AA) based on cotton crops with alternative production orientation (organic system). - Quantify the inputs-outputs of each AA (costs, yield …) using the local handbook and database. - Provide (in complement to current activities) the set of AA and theirs input output coefficients to FSSIM-MP.

Table 4.7. Definition of reference and policy scenarios

	Reference scenario [2004]	Policy scenario [2004]
Activities	Current activities	
Measures		M1: cotton cycle shortened to better handle a situation of water stress M2: introduction of groundnuts in the rotation M3: organic cotton

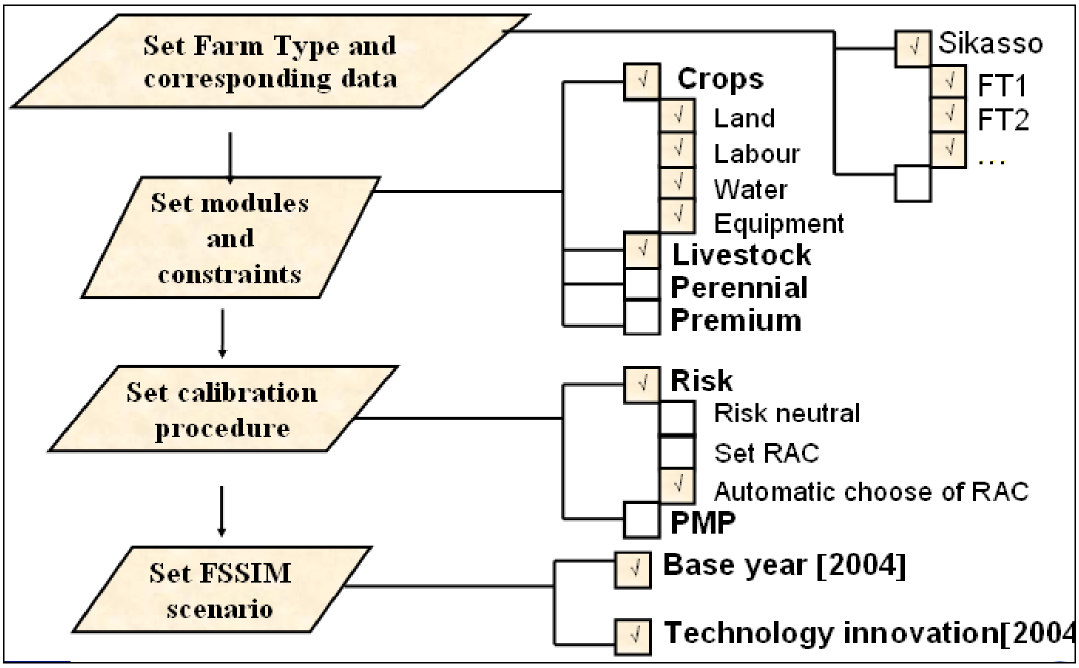

Fig. 4.2. Modules, calibration procedure and policy scenarios selected in the Malian Test Case region

4.3.2 Results and discussion

4.3.2.1 Model calibration

Model calibration was tested by comparing the results of the crop allocation selected by the model (simulated value) and the crop allocation actually observed (reference value). The difference between both values is assessed statistically by using the percent absolute deviation (PAD). The results of the comparison of the crop allocations for the three farm types (=the three model types) are presented in Table 4.8.

For all three models, the allocation of pearl millet, sorghum and maize are very close to the observed values in the three farm types. Nevertheless, in the A farm type, Maize area is overestimated. In the B and C types, the area devoted to maize plus bean is underestimated. Groundnut is never selected by the model. Cotton is overestimated in types B and C.

The obtained PAD in the three farm types seems very acceptable even only one farm type the fixed threshold which is 15%. That's why we have decided in this stage to consider that the model is fairly well calibrated, and can be used to test the introduction of alternative cropping techniques in the farms. Note that we do not apply a PMP calibration used in the application to the Midi-Pyrénées.

Table 4.8. Results of the model calibration for the three farm types

Crops	Farm type A			Farm type B			Farm type C		
	Obs. level (ha)	Sim. Level (ha)	WAD (%)	Obs. Level (ha)	Sim. Level (ha)	WAD (%)	Obs. level (ha)	Sim. level (ha)	WAD (%)
MANI	1.13	1.08	0.42	0.9	0.3	6.25	0.67	0.29	5.73
COTT	3.44	3.43	0.08	2.5	3.6	11.46	1.44	2.53	16.44
MAZE	0.86	1.47	5.14	0.8	0.8	0.00	0.4	0.4	0.00
MILE	3.9	3.82	0.67	3.4	3.3	1.04	2.58	2.23	5.28
SORG	2.04	2.06	0.17	1.6	1.7	1.04	1.18	1.18	0.00
GROU	0.5	0	4.21	0.4	0	4.17	0.36	0	5.43
Total area	11.87			9.6			6.63		
PAD without PMP (%)	10.7			23.9			32.8		
Student test	0.63			0.69			0.7		

WAD: weighted absolute deviation[10]
Source: model results

4.3.2.2 Impact of alternative cropping techniques on crop pattern

Selection of techniques and rotations by the models

The simulation results after introduction of alternatives cropping techniques are presented in Table 4.9. Organic cotton and groundnut rotations were never selected by the models. These results are therefore not presented. In the farm type A, the prototype 1 was selected for 66 % of the cotton area, whereas the prototype 2 was selected on 71% of the cotton area in farm type B. The model for farm type C (the farm type with limited equipment) did not select alternative cropping techniques.

10
$$WAD_i\,(\%) = \frac{\left|\hat{X}_i - X_i\right|}{\sum_{i=1}^{n}\hat{X}_i}.100$$

$$PAD\,(\%) = \sum_{i=1}^{n} WAD_i$$

Table 4.9. Impact of alternative cropping activities (policy scenario) on the crop allocation of the three farm types

	Farm type A			Farm type B			Farm type C		
Crops	Ref. area (ha)	CT (% area)	AT (% area)	Ref. area (ha)	CT (% area)	AT (% area)	Ref. area (ha)	CT (% area)	AT (% area)
MANI	1.15	100	-	0.29	0	0	0.32	100	0
COTT	3.48	34	66	3.27	29.0	71.0	2.54	100	0
MAZE	1.32	100	-	0.71	51.1	48.9	0.40	100	0
MILE	3.64	37	63	3.27	29.0	71.0	2.20	100	0
SORG	2.29	-	100	2.34	15.5	84.5	1.17	100	0

CT: Current techniques
AT: Alternative techniques
Source: model results
The values represent the % area for each crop after introduction of new cropping techniques. The value for cereals corresponds to the proportion of these crops in rotation with the new cotton cropping technique.

In the models A an B, the new techniques are all applied on the best soils (S2) (Table 4.10). Cotton-pearl millet rotation is grown on S3 soils (Traore, 2007).

The introduction of alternative cropping techniques does not change the fact that the models select the Cotton- millet rotation. The rotations actually used in all three farm types are similar: for triennial rotation, Cotton-maize-millet, and Cotton-maize-sorghum and Cotton-sorghum-millet to a lesser extent; for biennial rotation, Cotton-Maize and Cotton-Sorghum. Cotton-sorghum-maize, Cotton-millet-maize or Cotton-millet are not currently used by farmers. Millet does not precede Maize. Farmers consider that Sorghum and Maize do benefit better than millet from the after effects of cotton fertilization (Table 4.11).

Table 4.10. Crop allocation per soil type and production technique (current, CURR or alternative, ALT) under the simulated scenario

	CROP	Sol	Tech.	Cropping technique	Area (ha)
Farm type A	MANI	S3	T110	CURR	1.15
	COTT	S2	T411	ALT	2.29
	COTT	S3	T110	CURR	1.19
	MAZE	S2	T110	CURR	1.32
	MILE	S2	T110	CURR	1.32
	MILE	S2	T411	ALT	2.29
	MILE	S3	T110	CURR	0.04
	SORG	S2	T411	ALT	2.29
Farm typee B	COTT	S2	T411	ALT	2.32
	COTT	S3	T220	CURR	0.95
	MAZE	S2	T110	CURR	0.36
	MAZE	S2	T411	ALT	0.35
	MILE	S2	T411	ALT	2.32
	MILE	S3	T220	CURR	0.95
	SORG	S2	T110	CURR	0.36
	SORG	S2	T411	ALT	1.98
Farm typee C	MANI	S2	T110	CURR	0.32
	COTT	S2	T111	CURR	1.56
	COTT	S2	T110	CURR	0.32
	COTT	S3	T110	CURR	0.67
	MAZE	S2	T111	CURR	0.40
	MILE	S2	T111	CURR	1.54
	MILE	S3	T110	CURR	0.67
	SORG	S2	T111	CURR	1.17

Source: model results

Table 4.11. Comparison of the selected rotations after introduction of alternative techniques

Farm type	Rotation	% area	Used by farmers
Farm type A	COTT_SORG_MILE	61.78	Yes
	COTT_MILE_MAZE	10.85	No
	COTT_MILE	19.79	No
	SORG_MAZE	7.57	Yes
Farm type B	COTT_SORG_MILE	52.14	Yes
	COTT_SORG_MAZE	0.89	No
	COTT_MILE_MAZE	17.31	No
	COTT_MILE	20.03	No
	COTT_MANI	9.64	Yes
Farm type C	COTT_SORG_MILE	52.14	Yes
	COTT_SORG_MAZE	0.89	No
	COTT_MILE_MAZE	17.31	No
	COTT_MILE	20.03	No
	COTT_MANI	9.64	Yes

Source: model results

4.3.2.3 Impact of alternative cropping techniques on production and family consumption

The adoption of alternative techniques in farms A and B increases cotton production (+11 and 7%, resp.), whereas cereal production decreases by 1%. To compensate for this loss, less cereal is sold. The share of the production that is devoted to subsistence needs of the family is raised by 23%. In all three models, all cotton production is sold. In actual farm, the share devoted to self consumption is less than family needs according to FAO (215 kg/person/year), and these needs have been introduced in the model as a constraint. Moreover, when introducing an alternative technique, the models simulate automatically increased selling, whereas in actual farms, cereals are sold only when money is scarce, to pay for other food needed by the family, or to attend social duties, like marriage, baptises or deceases.

Table 4.12. Impact of alternative activities (policy scenario) on production and family consumption of the farm type A, in comparison to reference scenario

Crops	Produced quantity		Sold quantity		Family consumption	
	Reference scenario (Kg)	Policy scenario (% change to reference)	Reference scenario (Kg)	Policy scenario (% change to reference)	Reference scenario (Kg)	Policy scenario (% change to reference)
MANI	1788.71	6.56 %	1643	4.79 %	145.85	26.40 %
MAZE	2523.76	-10.12 %	2386	-11.36 %	137.31	11.72 %
MILE	3753.17	-5.22 %	3571	-6.85 %	182.47	26.40 %
SORG	2090.42	10.64 %	1896	9.04 %	194.09	26.41 %
COTT	3883	10.61 %	3883	10.61 %	0.00	0.00 %
Cereal total	10156	-1.10 %	9496	-2.79 %	660.00	23.33 %

4.3.2.4 Impact of alternative cropping techniques on farm income

Table 4.13 shows the farm income after introduction of alternative cropping techniques, compared to the income simulated before this introduction. In farm types A and B, incomes are increased due to more cotton produced and charges that do not increase proportionally. Incomes increase by 56 254 FCFA (86 €) in farm A and 44 654 FCFA (68€) in farm B. More labour is also needed, as shown in Table 4.13.

When discussing with farmers about these results, they do approve the alternative techniques, but the value of the simulated increase of the global income does not mean anything to them: they do not have any notion on their global income, and are not able to judge if the increase in income is correct or not.

Table 4.13. Impact of alternative activities (policy scenario) on economic and social indicators of the farm types of the Malian region, in comparison to reference scenario.

	Farm income			Additional working time
	Reference scenario [2004]	Policy scenario [2004]		Policy scenario (% change to reference)
Farm types	Value (€)	Value (€)	% change to reference	
Farm type A	2313.04	2398.85	3.71 %	2.93 %
Farm type B	1763.88	1831.97	3.86 %	4.24 %
Farm type C	1063.26	-	-	-

Source: model results

4.3.3 Conclusion and main lessons from the case study in Mali

The use of FSSIM to test the suitability of new cropping techniques has produced interesting results, and it was possible, to a certain extent, to foster producer participation in this exercise.

However, the capabilities of FSSIM to generate meaningful insights and profound discussions around the functioning of a Malian farm is limited, and will probably remain so, as long as some important features will not be considered properly:

- The fate of the crop residues. Soil organic matter conservation is a key issue in Malian farms, and the crop residues are used to feed the livestock during the dry season, and to produce manure. The current association between livestock and crops in FSSIM does not allow to simulate such intricate relations, and prevents us to initiate a dialogue about, for example, introduction of cover crops.
- The evolution of equipment of the farm is not considered. In poor countries, access to credit has to be taken into account, to allow for such evolutions. The solution of hiring services at a fixed cost is not realistic. Simulation on the long term and discussions on the possible evolution of the farms have to consider such possibilities (acquiring/losing draught oxen, etc)

5 Conclusion and suggestions for the SEAMLESS project

The results presented here for a French and a Malian region should be considered as preliminary results of the first application of the FSSIM model in real application conducted in interaction with users and stakeholders for the definition of the scenarios. The lack of a functional version of APES to cover the range of crops and techniques for this type of application did not allow to analyse the full potential of the "meso backbone modelling chain" (i.e. SEAMDB/APES/FSSIM-AM/FSSIM-MP/Indicators) to assess scenarios at regional level. Nevertheless its temporary replacement by an another crop model (CropSyst) in Midi Pyrenees shows that this modelling chain can be functional for complex scenarios combining economic and environmental drivers and provides sound results when discussed with local experts. This first application of FSSIM in different farm types of a EU (France) and a LDC (Mali) region indicates that this model should be sufficiently generic to cover the range of grain crops-based farming systems that SEAMLESS-IF aims to address. Further tests will be conducted in other regions and for other types of farming systems (perennial, grasslands and animals).

Beyond the testing and application of the FSSIM model, and beyond the classical methodological aspects of bio-economic models, this work provides insights in some key methodological aspects for future improvements and further uses of the meso backbone modelling chain of SEAMLESS. The main aspects are:

- *The amount and quality of data on current activities required by the FSSIM model to be properly calibrated and used*. It indicates that the population and the updating of the SEAMLESS-IF database will be a crucial task for the future. On the other hand the applications done in the two regions showed that most of these data already exist in several regional databases and they can be completed with local expertise at a limited cost when it is included in a partnership around an application of interest for users and stakeholders. The possibility of populating the SEAM-DB through these regional applications should be considered for the future of SEAMLESS-IF and adapted software and procedures should be envisaged by WP4 and WP5.

- *The need for a sensitivity analysis of the Scenario-APES-FSSIM modelling chain for each application before defining the final scenario to be used for communication with the users*. The Midi Pyrenees application indicates for example that the final result on one indicator can be sensitive on the assumptions made on alternative activities such as the opportunity cost of a simple alternative activity such as a N fertilisation adapted to the objective yield.

- *The need for an APES crop model with a high credibility for users in term of yield and externalities simulation for the range of crops and alternative activities* which have to be taken by FSSIM, especially when interacting with users and experts. The trade-off between the capability of the model and the realism of the scenario for the users and stakeholders will be one important issue in the future. In addition it is likely that any single crop model will never cover properly the full range of alternative activities and for all the environmental indicators targeted in SEAMLESS-IF. There will be a need to develop a methodology to estimate these externalities by a combination of crop model and expert knowledge.

- the two examples of applications presented here give confirmation that the analysis of a policy scenario in comparison with a baseline scenario and at different levels will require a complex process to be conducted by SEAMLESS experts before providing results to the users, because of the number of intermediate variables to be analysed. The Integrative Modellers GUI of SEAMLESS-IF should help in this process but it is likely that the procedure of analysis will have to be adapted to each SEAMLESS-IF project depending on scenario, scales, data quality and type of user.

Results presented here for the Midi Pyrenees region, despite their preliminary and incomplete nature with regards to a SEAMLESS-IF application, provide a valuable dataset for the other work packages in order to guide and illustrate the development of the models and indicators (WP3 and WP2), of the GUI and of SEAM-Press (WP5, WP1) and to support the interactions with users (WP7). They can be used for these internal purposes but not disseminated before publication of the methodological aspects presented in this deliverable.

References

Acutis, M., and M. Donatelli, 2003. Soil PAR 2.00 : Software to estimate soil hydrological parameters and functions. European Journal of Agronomy. 18 : 373-377.

Agrest 2006. http://www.agreste.agriculture.gouv.fr/.

Belhouchette, H., Wery, J., Thérond, O., Duru, M., Bigot, G., Was, A., Kloczko-Gajewska, A., Leenhardr, D., Majewski, E., Josien, E., Bergez, J-E., Henning, J., Thenard, V., 2005. Report on the major characteristics of environmental policies and agro-ecological technologies to be studied in test case 2. Seamless project, report N° 11, PD 6.1.2. 87pp.

Belhouchette H., Braudeau E., Donatelli M., Mohtar R. H., Wery J. 2008. Integrating spatial soil organization data with a regional agricultural management simulation model: a case study in northern Tunisia. American Society of Agricultural and Biological Engineers. Accepted for publication 2008.

Bruno B., Matteo B., Luigi S. and Edward C. M. Analyzing the effects of climate variability on spatial pattern of yield in a maize–wheat–soybean rotation European Journal of Agronomy, Volume 26, Issue 2, February 2007, Pages 82-91

Cabelguenne, M., C.A. Jones, J. R. Marty, P. T. Dyke, and J. R. Williams. 1990. Calibration and validation of EPIC for crop rotations in southern France. *Agricultural Systems*. 33: 153-171.

Chipanshi, A. C., E. A. Ripley, and R. G. Lawford. 1999. Large-scale simulation of wheat yields in a semi-arid environment using a crop-growth model. *Agricultural Systems*. 59: 57-66.

CMDT, 2007. Note de réflexion sur le devenir du système d'information de la CMDT. Suivi Evaluation: 5 P.

Djouara, H., Bélières, J.P. and Kébé D., 2006. Les exploitations agricoles familiales de la zone cotonnière du Mali face à la baisse des prix du coton-graine. Cahiers Agricultures 2004 ; 13 : 1-8, vol. 15, n° 1, janvier-février 2006.

Donatelli M. 2002. Simulations with CropSyst of cropping systems in Southern France. Common Agricultural Policy Strategy for Regions, Agriculture and Trade (QLTR-200-00394). CIEAHEM report. 13p.

Donatelli, M., C. O. Stöckle, E. Ceotto, and M. Rinaldi.1997. Evaluation of CropSyst for cropping systems at two locations of northern and southern Italy. *European Journal of Agronomy*. 6 : 35-45.

EEC, 1991. Implementation of Nitrate Directive. European Environment Commission report, Annex 2: Code(s) of good agricultural practices. 1991.

EEC, 2000. Implementation of Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources. European Environment Commission. Synthesis from year 2000 Member States reports.

Enyong, L.A., Debrah, S.K. and Bationo, A., 1999. Farmers' perceptions and attitudes towards introduced soil-fertility enhancing technologies in western Africa. Nutrient Cycling in Agroecosystems, 53(2): 177-187.

Giraudy, F., 1994. Résultats de l'enquête agricole permanente 93/94. Annuaire statistique, Bamako. Compagnie Malienne de Développement des Textiles (CMDT); Service Suivi-Evaluation (SSE).

Hartkamp, A. D., J. W.White, W. A. H.Rossing, M. K. Van Ittersum, E. J. Bakker, and R. Rabbinge. 2004. Regional application of a cropping systems simulation model: crop residue retention in maize production systems of Jalisco, Mexico. *Agricultural Systems*. 82: 117-138.

Haskett, J. D., Y. A. Pachepsky, and B. Acock. 1995. Use of the beta distribution for parameterizing variability of soil properties at the regional level for crop yield estimation. *Agricultural Systems*. 48: 73-86.

Hazell P.B.R. & Norton R.D. 1986. Mathematical Programing for Economic Analysis in Agriculture. New York: Macmillan Publishing Co, 400p.

Howitt, R. E., 1995. A Calibration Method for Agricultural Economic Production Models. Journal of Agricultural Economics, 46(2), p. 147-159.

Ifen, 2002. "Les dépenses des Départements en matière d'environnement", Les données de l'environnement, n°79, 4 p.

IRCT, 1969. Expérimenation régionale cotonnière. Rapport d'activité, Station de n'tarla, République du Mali.

Kanté, S., 2001. Gestion de la fertilité des sols par classe d'exploitation au Mali-Sud. Documents sur la Gestion des Ressources Tropicales. Doctorat Thesis, Wageningen University and Research Centre Departement of Plant Science, 225 pp.

Kanté, S., Defoet, T. and Bengaly, A., 1993. Description et utlisation des toposéquences. Rapport d'étape, IER, Département de Recherche sur les Systèmes de Production Rurale, Sikasso -Mali.

Kunkel, K.E., and S.E. Hollinger. 1991. Operational crop yield assessments using CERES-Maize and SOYGRO. 20th AMS Conf. on Agricultural and Forest Meteorology, Salt Lake City, UT. 10–13 Sept. 1991. *Am. Meteorological Soc.*, Boston, MA.

Lançon, J., Wery, J. and Rapidel, B., Angokaye, M., Gérardeaux, E., Gaborel, C., Ballo, D. and Fadegnon, B.,, 2007. A methodology to design and assess integrated crop management systems: application to cotton in West Africa. Agronomy for Sustainable Development.

Liu J., Williams J. R., Zehnder A. J.B. and Yang H. 2007. GEPIC – modelling wheat yield and crop water productivity with high resolution on a global scale Agricultural Systems, Volume 94, Issue 2, May 2007, Pages 478-493.

Louhichi, k., Flichman, G., Blanco, M. 2007. - A generic Template for FSSIM for all farming systems-, PD3.3.11, SEAMLESS integrated project, EU 6th Framework programme, contract no. 010036-2, www.SEAMLESS-IP.org, 85p.

Merceron, F., Traoré, D. and Zgraggen, N., 2005. Programme de promotion du coton biologique au Mali. Rapport annuel d'activités, ONG Helvetas, Bamako.

Moen, T.N., H. M. Kaiser and S. J. Riha. 1994. Regional yield estimation using a crop simulation model: Concepts, methods, and validation. *Agricultural Systems*, 46, 79-92.

Moriondo M., Maselli F. and Bindi M. 2007. A simple model of regional wheat yield based on NDVI data European Journal of Agronomy, Volume 26, Issue 3, April 2007, Pages 266-274

Rapidel, B., Sissoko, F., Traoré, B.S., Lançon, J. and Wery, J.,, 2005. Diversification des itinéraires techniques recommandés pour la culture cotonnière au Mali. In: M. Adégnika, F. Okry and B. Ouédraogo (Editor), Conférence Coton de l'Afrique de l'Ouest et du Centre. CORAF-INRAB-IFDC, Cotonou, pp. 191-194.

Röhm, O., and Dabbert, S. 2003, Integrating Agri-Environmental Programs into Regional Production Models: An Extension of Positive Mathematical Programming, American Journal of Agricultural Economics, 85(1): 254-65.

Rugeta F., Brisson N., Delécolle R., and Faivre R. 2002. Sensitivity analysis of a crop simulation model, STICS, in order to choose the main parameters to be estimated. Agronomie 22 (2002) 133-158

Simien, A., 2006. Tests et évaluation du modèle FSSIM dans la région Sud-Mali. Master Thesis, Agro M, Montpellier, 79 pp.

Stöckle, C. O., and R. Nelson. 1993. ARCCS: ArcInfo-CropSyst Cooperator., Biological Systems Engineering Department. Washington State University, Pullman, WA.

Stöckle, C., O., M. Donatelli, and R. Nelson. 2003. CropSyst, a croping systems model. *Europ. J. Agronomy*, 18: 289-307.

Traore, B.S., 2005. Recherche d'alternatives techniques pour une gestion durable des systèmes de culture à base de cotonnier pour les paysans du Mali. Rapport de recherche de la campagne 2004. Institut d'Economie Rurale, 12ème session du comité de programme.

Traore, B.S., 2007. Utilisation d'un modèle de simulation du fonctionnement de l'exploitation agricole comme interface de dialogue entre la recherche agronomique et les agriculteurs concernant l'adoption de nouvelles options techniques de culture. Agronomie et Agroalimentaire, Option: Agronomie et Systèmes de Culture de Intégrés Thesis, Montpellier SupAgro, 34 pp.

Traore, B.S., Rapidel, B. and Sissoko, F., 2005. Evolution des techniques culturales en zone cotonnière entre 1997 et 2002. Les Cahiers de l'Economie Rurale, 2ème trimestre(IER).

Turini, T., 2005. Adaptation en milieu paysan d'un prototype d'itinéraire technique: Cas de la culture cotonnière en condition de forte contrainte hydrique. Mémoire de fin d'études: DIPLOME D'AGRONOMIE APPROFONDIE Spécialisation AGRO ENVIRONNEMENT, Option Production Végétale Durable.

Van Ittersum, M., Ewert, F., Heckelei, T., Wery, J., Olsson, J.A.; Andersen, E., Bezlepkina, I., Floor, B., Donatelli, M., Flichman, G., Olsson, L., Rizzoli, A., Van der Wal, T., Wien, J.E. & Wolf, J. 2007. Integrated assessment of agricultural systems - a component-based framework for the European Union (SEAMLESS). *Agricultural Systems (In press).* DOI 10.1007/s0011090000086.

Van Lanen, H. A. J., M. J. D. Hack-ten Broeke, J. Bouma, and W. J. M. de Groot. 1992. A mixed qualitative/quantitative physical land evaluation methodology. *Geoderma*, 55 (1-2): 37-54.

Wallach D., Makowski D., Jones J. 2006. Working with Dynamic Crop Models. Edition: 1st Date: 8/24/2006 Publisher(s): Elsevier Science & Technology.

Wesseling J.G. and Feddes R.A. 2006. Assessing crop water productivity from field to regional scale Agricultural Water Management, Volume 86, Issues 1-2, 16 November 2006, Pages 30-39

William D. Batchelor, Bruno Basso and Joel O. Paz. 2002. Examples of strategies to analyze spatial and temporal yield variability using crop models *European Journal of Agronomy*, *Volume 18, Issues 1-2*, *December 2002*, *Pages 141-158*

Glossary

Agricultural activity a coherent set of crops or animals plus the operations (also called 'production technique') 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 (Van Ittersum & Rabbinge, 1997; Ten Berge et al., 2000)

Alternative activities Activities that are not currently used, but might be technically feasible alternative for the future, often technological innovations or newly developed cropping or husbandry practices (PD 3.3.1).

Current activities Activities that are currently being practiced and can be derived from observed data.

Production enterprise The description of a coherent set of crops (rotation) and animals without a specified (production) technique that form production systems of farming systems.

Production Coefficient a row in the input-output matrix of FSSIM-MP, which describes for a crop in a rotation with a certain management what the technical coefficients are.

PEG: Production enterprise generator
a tool to generate a feasible set of production enterprises of the farm based on crop suitability filters, like soil-type, climate and for annual arable crops rotation constraints (or for animal husbandry systems herd composition constraints).

Production orientation Value driven aims and restrictions of the agricultural activity that direct the input and output levels (Van Ittersum & Rabbinge, 1997), for example 'integrated', 'organic', 'conventional' or 'highly innovative.'

Production technique Complete set of agronomic inputs (e.g. management practices) characterized by type, level, timing and application technique (Van Ittersum and Rabbinge, 1997).

PTG: Production technique generator
A tool to describe production techniques of agricultural activities on the basis of the feasible set of production enterprises.

Technical coefficients Coefficients describing the inputs needed to achieve one unit of output or the activity's contribution to the realisation of user defined goals (or objective in modelling terms) (Ten Berge et al., 2000)

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

COP: Cereals, Oilseeds and protein crops

GAMS: General Algebric Modeling System

CAP: Common Agricultural Policy

CROPSYST: Cropping Systems Simulation Model

APES: Agricultural Production and Externalities Simulator

FADN: Farm Accountancy Data Network

OM: optimization models

FSSIM: Farm Simulator System

FSSIM-AM: Farm Simulator System-Agricultural Management

FSSIM-MP: Farm Simulator System -Mathematical Programming model

CMOs: Common Market Organisations

Appendix

Crop nitrate supply= nitrate from mineral fertilization + nitrate from livestock manure.

i- the amount of nitrate from mineral fertilization

In the Midi-Pyrénées region, to calculate the amount of nitrate requirement by crop the following two criteria is considered:

- **reasonable yield prevision**: in this study the average yield reported in the survey for current activity (from 1998 to 2002) is considered as a potential yield (Table A.1).

Table A.1– Potential yield (t/ha) of the main crops by soil type in the Midi-Pyrénées region (survey, 2006)

	Soil			
	Boulbène		Terrefort	
	rainfed	irrigated	rainfed	irrigated
Soft wheat	5.1	-	4.7	-
Durum wheat	-	-	3.7	-
Sunflower	-	-	2.4	-
Barley	3.7	-	3.7	-
Maize grain	-	11.0	6.5	11
Rape	1.9	-	2.5	-
Soya	-	3.0	2	3.3
Peas	3.5	4.7	3.5	4.5
Oats	2.7	-	2.7	-
Fallow	-	-	-	-
Maize fodder	-	11	11	-

- **soil nitrogen pool** which depends on the nature of soil, the type of previous crops and the annual rainfall variability.

Thus, the amount of nitrogen needed by crop will be calculated in three steps:

1- Nitrogen requirement according to the target yield = the amount of N-NO3 requirement to produce a unit of yield (Table A.2)* potential yield (Table A.1).

Table A.2- Nitrogen requirement (kg/ha) to produce 1t/ha of yield or biomass (for forage crop) (reference).

Oats/barley	Durum wheat	Soft Wheat	Rye	Colza	Grain maize	Silage maize	Sorghum grain/	Sorghum/ silage	sunflower
3.1	45	40	37	87	30	17.8	35	16.2	56

2- Soil nitrogen pool = soil N residue from the previous crop (Table A.3, A. 4, A.5) + mineralization rate (Table A.6) + grassland effect (Table A.7).

Table A.3- Soil nitrogen stock identified by crop, previous crop and soil type (boulbène, terrefort) in the Midi-Pyrénées region for the autumn crops: soft and durum wheat, barley, oats, and colza.

Characteristics of previous crops			**Soil**	
Previous crops	Yield (t/ha)	Amount of nitrogen (kg/ha)	Terrefort	Boulbene
Sunflower	2.3	0-40	15-40	10-30
Maize	9.0	140-200	20-60	5-15
Maize	11	160-220	5-30	5-10
Sorghum	8.0	130-180	5-25	5-20
Rape	2.5	120-160	60-85	45-65
Soya	*	0	60	50
Peas	*	0	70	55
Soft wheat	5.5	120-180	15-60	10-45
Durum Wheat	5.5	160-230	50-95	40-70
Barley	7.0	120-180	15-60	10-45
Oats	3.6	120-180	15-60	10-45

Table A.4- Soil nitrogen stock identified by crop, previous crop and soil type (boulbène, terrefort) in the Midi-Pyrénées region for the spring crops: maize, sorghum and sunflower.

Characteristics of previous crops			**Soil**	
Previous crops	Yield (t/ha)	Amount of nitrogen (kg/ha)	Terrefort	Boulbene
Sunflower	2.3	0-40	5-25	5-10
Maize	9.0	140-200	10-35	5-15
Maize	11	160-220	5-20	5-10
Sorghum	8.0	130-180	5-15	5-10
Rape	2.5	120-160	30-50	15-25
Soya	*	0	40	25
Peas	*	0	45	25
Soft wheat	5.5	120-180	10-45	5-20
Durum Wheat	5.5	160-230	30-50	15-25
Barley	7.0	120-180	10-45	5-20
Oats	3.6	120-180	10-45	5-20

Table A.5- Soil nitrogen stock identified by crop, previous crop and soil type (boulbène, terrefort) in the Midi-Pyrénées region for grassland (kg/ha)

	Type of grassland		
	Pasture	Ensilage	Pasture+ensilage
Soil without vegetation cover	0		
Fallow	10-20		

Table A.7- Mineralization by soil type (kg/ha).

	Irrigated crop	Dry crop
Boulbene	120	80
Terrefort	90	60

3- the amount of nitrogen from N mineral fertilization = Nitrogen required according to the potential yield – Soil nitrogen pool.

Considering those formulas and tables, the following Table (Table A.8), comparing the amount of nitrate fertilizer used for the main current and alternative activities

Table A.8- Nitrate requirement for alternative activities (calculated using the above tables and formulas) and established from the survey for current activities.

		N mineral fertilization (kg/ha)	
Rotations	**Soil**	**alternative**	**current**
Soft wheat-soft wheat	B	95	200
Maize grainirrig-maize grainirrig	B	155	250
oats-oats	B	75	150
Maize grainrain-maize grainrain	B	100	150
Soft wheat-peasirrig	B	85	150
Soft wheat-soyairri	B	90	150
Soft wheat-fall	B	120	200
Barley-Barley	B	92	150
Soft wheat-soyarain	B	90	150
soft wheat-peasrain	B	85	120
Soft wheat-soft wheat	T	160	200
Maize grainirrig-maize grainirrig	T	220	250
oats-oats	T	95	150
Durum wheat-Durum wheat	T	92.5	200
Soft wheat-peasirrig	T	150	150
Soft wheat-soyairri	T	160	150
Soft wheat-fall	T	200	200
Durum wheat-sunflower	T	147.5	200
Barley-Barley	T	80	150
Soft wheat-soyarain	T	160	200
soft wheat-peasrain	T	150	200

ii- the amount of nitrogen from livestock manure fetilization

the amount of Nitrogen from manure fertilization = amount of nitrate in the manure* equivalent coefficient of available nitrate* amount of manure.

Table A.9 - Main rotations and the yield of each crop by rotation and soil type (site class) in the Midi-Pyrénées region.

siteclass	sequence	position in rotation	Crop name	Yield (t/ha)
argilo-calcaire	wheat - sunflower	1	wheat	5.5
argilo-calcaire	wheat - sunflower	2	sunflower	2.4
argilo-calcaire	wheat - wheat	1	wheat	4.7
argilo-calcaire	wheat - wheat	2	wheat	4.7
argilo-calcaire	durum wheat - durum wheat	1	durum wheat	3.7
argilo-calcaire	durum wheat - durum wheat	4	durum wheat	3.7
argilo-calcaire	barley - barley	1	barley	3.7
argilo-calcaire	barley - barley	2	barley	3.7
argilo-calcaire	corn (maize grain non-irrigated) - corn (maize grain non-irrigated)	1	corn (maize grain non-irrigated)	6.5
argilo-calcaire	corn (maize grain non-irrigated) - corn (maize grain non-irrigated)	2	corn (maize grain non-irrigated)	6.5
argilo-calcaire	wheat - soybean	1	wheat	5.1
argilo-calcaire	wheat - soybean	2	soybean (grain irrigated)	3.0
argilo-calcaire	wheat - pea (grain irrigated)	1	wheat	5.8
argilo-calcaire	wheat - pea (grain non irrigated)	2	pea (grain no irrigated)	4.7
argilo-calcaire	oats - oats	1	oats	2.7
argilo-calcaire	oats - oats	2	oats	2.7
argilo-calcaire	tobacco	1	tobacco	2.5
boulbene	wheat - wheat	1	wheat	5.1
boulbene	wheat - wheat	2	wheat	5.1
boulbene	barley - barley	1	barley	3.7
boulbene	barley - barley	2	barley	3.7
boulbene	corn (maize grain irrigated) - corn (maize grain irrigated)	1	corn (maize grain irrigated)	11.0
boulbene	corn (maize grain irrigated) - corn (maize grain irrigated)	2	corn (maize grain irrigated)	11.0
boulbene	wheat - soybean (grain irrigated)	1	wheat	5.5
boulbene	wheat - soybean (grain irrigated)	2	soybean (grain irrigated)	3.0
boulbene	wheat - pea (grain irrigated)	1	wheat	6.3
boulbene	wheat - pea (grain irrigated)	2	pea (grain irrigated)	4.7
boulbene	oats - oats	1	oats	2.7
boulbene	oats - oats	2	oats	2.7
boulbene	tobacco	1	tobacco	2.1

Table A.10 Comparison of the crop pattern for the Agenda 2000 and the 2003 CAP reform in the farm type I of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Agenda 2000 [2001]	2003 CAP reform [2013]
APLE	**S106**	**Tr**	**CURR**	0.24	0.24
GRSS	**S106**	**low**	**CURR**	3.81	3.81
MAZE	**S106**	**Tr**	**CURR**		5.67
MAZE	**S106**	**Ti**	**CURR**	29.49	16.22
MAZE	**S107**	**Ti**	**CURR**	5.60	9.54
OATS	**S107**	**Tr**	**CURR**	3.15	14.10
PEAS	**S107**	**Tr**	**CURR**	2.91	2.81
RAPE	**S107**	**Tr**	**CURR**	2.19	1.89
SOYA	**S106**	**Ti**	**CURR**	2.98	1.41
SOYA	**S107**	**Tr**	**CURR**		0.90
SUNF	**S107**	**Tr**	**CURR**	14.28	12.77
TOBA	**S106**	**Tr**	**CURR**	0.32	0.32
TWIN	**S106**	**Tr**	**CURR**	3.10	3.10
WBAR	**S106**	**Tr**	**CURR**	4.10	3.46
WBAR	**S107**	**Tr**	**CURR**		0.90
WDWH	**S107**	**Tr**	**CURR**	17.30	12.32
WSWH	**S107**	**Tr**	**CURR**	13.12	13.15
FALL	**S106**	**Tr**	**CURR**	1.53	11.35
FALL	**S107**	**Tr**	**CURR**	9.82	

S106: soil boulbène (clay-loam) Source: model results
S107: soil terrefort (calcareous clay)
Tr: rainfed technique
Ti: irrigated technique
Low: low intensity production technique associated to grassland)
CURR: current

Table A.11 Comparison of the crop pattern for the Agenda 2000 and the 2003 CAP reform in the farm type II of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Agenda 2000 [2001]	2003 CAP reform [2013]
APLE	**S106**	**Tr**	**CURR**	0.47	0.47
GRSS	**S106**	**low**	**CURR**	1.86	1.86
MAZE	**S106**	**Tr**	**CURR**	0.38	7.42
MAZE	**S106**	**Ti**	**CURR**	23.22	10.70
MAZE	**S107**	**Ti**	**CURR**	3.50	8.97
PEAS	**S107**	**Tr**	**CURR**	4.39	6.07
RAPE	**S107**	**Tr**	**CURR**	1.40	1.46
SOYA	**S106**	**Ti**	**CURR**	3.65	
SOYA	**S107**	**Tr**	**CURR**		2.70
SUNF	**S107**	**Tr**	**CURR**	12.63	10.49
TOBA	**S106**	**Tr**	**CURR**	0.87	0.87
TWIN	**S106**	**Tr**	**CURR**	4.92	4.92
WBAR	**S106**	**Tr**	**CURR**	1.57	4.05
WBAR	**S107**	**Tr**	**CURR**		2.70
WDWH	**S107**	**Tr**	**CURR**	11.43	6.75
WSWH	**S107**	**Tr**	**CURR**	12.30	13.17
FALL	**S106**	**Tr**	**CURR**		6.65
FALL	**S107**	**Tr**	**CURR**	18.92	12.27

Source: model results

Table A.12 Comparison of the crop pattern for the Agenda 2000 and the 2003 CAP reform in the farm type III of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Agenda 2000 [2001]	2003 CAP reform [2013]
APLE	**S106**	**Tr**	**CURR**	0.07	0.07
GRSS	**S106**	**low**	**CURR**	7.01	7.01
MAZE	**S106**	**Ti**	**CURR**	6.21	5.68
PEAS	**S106**	**Tr**	**CURR**	5.49	6.73
PEAS	**S106**	**Ti**	**CURR**	0.33	
PEAS	**S107**	**Ti**	**CURR**	0.13	0.88
RAPE	**S106**	**Tr**	**CURR**	1.62	1.14
SOYA	**S106**	**Ti**	**CURR**	7.80	7.38
SUNF	**S107**	**Tr**	**CURR**	33.95	41.30
TWIN	**S106**	**Tr**	**CURR**	2.06	2.06
WBAR	**S106**	**Tr**	**CURR**	2.39	3.50
WDWH	**S107**	**Tr**	**CURR**	31.56	20.46
WSWH	**S106**	**Tr**	**CURR**	6.64	6.06
WSWH	**S107**	**Tr**	**CURR**	6.51	9.52
FALL	**S106**	**Tr**	**CURR**	11.50	11.50

Source: model results

Table A. 13 Impact of Nitrate Directive (policy scenario) on the crop pattern of the farm type I of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Baseyear [2001]	Baseline [2013]	N. Directive [2013]
APLE	S106	Tr	CURR	0.24	0.24	0.24
GRSS	S106	low	CURR	3.81	3.81	3.81
MAZE	S106	Tr	CURR		2.63	
MAZE	S106	Tr	ALTE			2.31
MAZE	S106	Ti	CURR	29.49	17.74	
MAZE	S106	Ti	ALTE			17.90
MAZE	S107	Ti	CURR	5.60	6.50	
MAZE	S107	Ti	ALTE			5.54
OATS	S107	Tr	CURR	3.15	16.50	
OATS	S107	Tr	ALTE			18.97
PEAS	S107	Tr	CURR	2.91	2.87	
PEAS	S107	Tr	ALTE			2.35
PEAS	S107	Ti	ALTE			0.32
RAPE	S107	Tr	CURR	2.19	2.70	
RAPE	S107	Tr	ALTE			2.42
SOYA	S106	Ti	CURR	2.98	1.70	
SOYA	S106	Ti	ALTE			1.88
SOYA	S107	Tr	CURR		0.14	
SUNF	S107	Tr	CURR	14.28	11.99	
SUNF	S107	Tr	ALTE			11.69
TOBA	S106	Tr	CURR	0.32	0.32	0.32
TWIN	S106	Tr	CURR	3.10	3.10	3.10
WBAR	S106	Tr	CURR	4.10	4.69	
WBAR	S106	Tr	ALTE			4.67
WBAR	S107	Tr	CURR		0.14	
WDWH	S107	Tr	CURR	17.30	15.22	
WDWH	S107	Tr	ALTE			14.75
WSWH	S107	Tr	CURR	13.12	12.33	
WSWH	S107	Tr	ALTE			12.33
FALL	S106	Tr	CURR	1.53	11.35	
FALL	S107	Tr	CURR	9.82		
FALL	S106	Tr	ALTE			11.35

ALTE: alternative Source: model results

Table A.14 Impact of Nitrate Directive (policy scenario) on the crop pattern of the farm type II of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Baseyear [2001]	Baseline [2013]	N. Directive [2013]
APLE	S106	Tr	CURR	0.47	0.47	0.47
GRSS	S106	low	CURR	1.86	1.86	1.86
MAZE	S106	Tr	CURR	0.38		
MAZE	S106	Ti	CURR	23.22	14.41	14.41
MAZE	S107	Ti	CURR	3.50	0.20	0.35
PEAS	S107	Tr	CURR	4.39	5.12	5.23
PEAS	S107	Ti	CURR		0.67	0.60
RAPE	S107	Tr	CURR	1.40	13.67	13.36
SOYA	S106	Ti	CURR	3.65		
SOYA	S107	Tr	CURR		1.34	1.37
SUNF	S107	Tr	CURR	12.63	8.73	8.62
TOBA	S106	Tr	CURR	0.87	0.87	0.87
TWIN	S106	Tr	CURR	4.92	4.92	4.92
WBAR	S106	Tr	CURR	1.57	6.65	6.57
WBAR	S107	Tr	CURR		1.34	1.37
WDWH	S107	Tr	CURR	11.43	10.86	10.97
WSWH	S107	Tr	CURR	12.30	11.47	6.70
WSWH	S107	Tr	ALTE			4.92
FALL	S106	Tr	CURR		7.76	7.84
FALL	S107	Tr	CURR	18.92	11.16	10.14
FALL	S107	Tr	ALTE			0.94

Source: model results

Table A.15 Impact of Nitrate Directive (policy scenario) on the crop pattern of the farm type III of the Midi Pyrenees region

Crops	Soil type	Production technique	Production orientation	Baseyear [2001]	Baseline [2013]	N. Directive [2013]
APLE	S106	Tr	CURR	0.07	0.07	0.07
GRSS	S106	low	CURR	7.01	7.01	7.01
MAZE	S106	Ti	CURR	6.21	4.45	
MAZE	S106	Ti	ALTE			4.19
PEAS	S106	Tr	CURR	5.49	3.80	
PEAS	S106	Tr	ALTE			2.98
PEAS	S106	Ti	CURR	0.33		
PEAS	S107	Ti	CURR	0.13	3.81	
PEAS	S107	Ti	ALTE			4.06
RAPE	S106	Tr	CURR	1.62	9.22	
RAPE	S106	Tr	ALTE			10.16
RAPE	S107	Tr	CURR		2.92	
RAPE	S107	Tr	ALTE			1.22
SOYA	S106	Ti	CURR	7.80		
SUNF	S107	Tr	CURR	33.95	29.71	
SUNF	S107	Tr	ALTE			29.59
TWIN	S106	Tr	CURR	2.06	2.06	2.06
WBAR	S106	Tr	CURR	2.39	4.18	
WBAR	S106	Tr	ALTE			4.08
WDWH	S107	Tr	CURR	31.56	30.89	
WDWH	S107	Tr	ALTE			31.99
WSWH	S106	Tr	CURR	6.64	8.83	
WSWH	S106	Tr	ALTE			9.06
WSWH	S107	Tr	CURR	6.51	4.81	
WSWH	S107	Tr	ALTE			5.28
FALL	S106	Tr	CURR	11.50	11.50	11.50

Source: model results