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## **MEA-Scope**

Micro-economic instruments for impact assessment  
of multifunctional agriculture to implement  
the Model of European Agriculture

### **STReP**

**Priority 8.1 "Developing further the  
multifunctionality concept and making  
it operational as a policy instrument"  
Policy Oriented Research**

## **Deliverable D3.1 The MEA-Scope modelling approach**

Internal working paper  
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## **1 INTRODUCTION**

This working paper describes the modelling approach followed in the MEA-Scope project. In addition each of the three model's capabilities with regard to modelling and capturing different aspects of multifunctionality is presented and discussed. In addition we present the models' capabilities with respect to multifunctionality impact assessment.

Mainly driven by WTO negotiations, multifunctional agriculture and landscapes have moved into centre of attention within several international institutions and organisation (FAO, EU, OECD). For example, the OECD Agricultural Ministers adopted multifunctionality as a policy principle at their meeting of 5-6 March 1998 (OECD 2001). The concept has since played a part on the international political agenda when agriculture production is debated.

The non-commodity outputs of agriculture had long been recognised as an important part of the impacts and the contribution to the surrounding environment. However, the concept of multifunctionality and its political recognition gave the positive as well as negative externalities of agricultural production a collective notion. Multifunctionality however not only covers characteristics of farm production alone. It underpins at the same time the importance of our normative preferences regarding the development of the cultural landscape.

In this sense, multiple roles (functions) can be assigned to agriculture. Agriculture will, beyond its primary function of supplying food and fibres affect the proximities directly and indirectly in a number of ways, and all of its effects should be taken into account before new policies are enunciated. The policies need to reflect a desirable balance of all the different normative interest in the utilisation of the rural area. The Common Agricultural Policy (CAP) aims at higher international trade compatibility while at the same time ensuring that social, environmental and consumer concerns are taken into account. Moreover, there should be given room for a sustainable development of the agriculture of EU. Sustainable development of the rural landscapes thus is a multidimensional environmental and societal complex operating on different spatial and temporal levels simultaneously.

The decision-makers of CAP therefore need tools to investigate the consequences of their policies in a multidimensional setting which takes both the direct as well as indirect effects into consideration. The MEA-Scope is such a tool. It is a framework to convey information from science to the decision-makers of CAP about the impact of policy decisions on the multiple functions of agriculture. To do so, the MEA-Scope project follows three tracks. One is to define and operationalise the concept of multifunctionality and to devise a set of indicators. The second track is to combine three distinct models to capture different

environmental, economic and social facets of multifunctionality. In addition the models should incorporate as many indicators as possible devised in the first project track. And finally, the modelling framework is to be tested on seven case study regions for which results are presented specifically for beef production systems. Modelling results derived at the individual farm scale are upscaled to the scale of the landscape. This paper is specifically focussing at the second track that is the specific modelling approach followed in MEA-Scope. In section 2, a list of the abilities of the MEA-Scope tool given. Section 3 presents the target capabilities of the MEA-scope hierarchical modelling approach including indicators as well as a short introduction to the three micro-economic models AgriPoliS, MODAM and FASSET is given. In section 4 the structure of the combined model is presented. The data interface between the individual models is presented. In section 5 an overview of the input data requirement is given. An in depth presentation of the three models is given in the appendix. It is all being finalised in a summary.

## **2 GOAL OF THE MODELLING**

The MEA-Scope tool which is to be developed as part of WP3 is based on three validated agronomic and economic models. The specific goal and scope of the MEA-Scope tool is to

- incorporate different spatial and temporal dimensions in the same investigation,
- be able to look at the whole region and at details of individual farms in the same analysis,
- investigate a multifunctional set of parameters,
- adapt the tool to seven specific regional settings,
- create a common methodology that the underling models are operating on,
- insure that the underling parameters such as technology are hierarchically integrated in the individual models. So more detailed descriptions are clustered into more aggregated parameters used at the less detailed levels.

The MEA-Scope model will constitute the point of departure for a number of possible analyses of the rural development in the selected regions. The model is the basic tool, which enables us through a reduction and abstraction of reality to investigate for patterns otherwise undetected. The MEA-Scope model can be used in problem solving and as a support tool for decision-making.

### 3 TARGET CAPABILITIES OF THE MEA-SCOPE HIERARCHICAL MODELLING APPROACH

The MEA-Scope modelling approach is based on the combination of three distinct models, each of which has been focussing on specific aspects of the agricultural system. Table 1 lists the key characteristics of each model. Details on each model can be found below.

**Table 1: Brief description of AgriPoliS, MODAM, and FASSET**

<b>AgriPoliS</b>	
<b>Original Scope</b>	Policy evaluation tool made to investigate structural change in the agricultural sector.
<b>Characteristics</b>	Spatial and dynamic agent-based model of regional agricultural structures. Rooted in agricultural Economics. Consist of a large number of individually acting autonomous farms. Indirect interactions through land market. Production activities at the farm level are aggregated.
<b>Multifunctional indicators</b>	Economic production, Structural development, Land market.
<b>Scale</b>	Regional scale (meso-level) with indirect interactions between farms
<b>Basic unit of time</b>	One period = one financial year.
<b>MODAM</b>	
<b>Original Scope</b>	Policy evaluation tool to investigate policy effects on the decision behaviour of farmers and the corresponding environmental effects.
<b>Characteristics</b>	A hierarchical specialist developed database structure able to generate linear programming farm models and through use of fuzzy-logics investigate trade-offs between economic and ecological goals. Disaggregated with regard to farm-level production activities.
<b>Multifunctional indicators</b>	Groundwater, Nitrate leaching, Wind and Water Erosion, Habitats and Biodiversity, Socio-economics, Trade-off techniques, GIS Output Files.
<b>Scale</b>	Regional scale or farm level (aggregated level).
<b>Basic unit of time</b>	One period = one financial year
<b>FASSET</b>	
<b>Original Scope</b>	A whole-farm model that simulates the relationship between agricultural production, economics and pollution. Policy evaluation tool. Made mainly to investigate nutrient flows (N) and pollution including nitrate leaching, ammonia emission and the emission/absorption of greenhouse gasses.
<b>Characteristics</b>	Whole-farm model where farmers are maximising yearly income. Rooted in agronomy and soil science. Individual crop rotation plans are incorporated. Disaggregated model.
<b>Multifunctional indicators</b>	Modelling the nutrient flows, Nitrate leaching, greenhouse gas emission, hydrogeology (watershed analysis), Pesticide and energy use.
<b>Scale</b>	Farm level.
<b>Basic unit of time</b>	One period = one day (however evaluated on a yearly basis).

Each individual model covers some aspects relevant in the context of multifunctionality impact assessment. For example, whereas AgriPoliS explicitly aims at modelling dynamics aspects of structural change, it takes a rather aggregate approach at modelling the organisation of individual farms and production effects. With regard to this, MODAM takes a much more

disaggregated approach, but in a static context. FASSET, on the other hand, simulates nutrient flows and pollution on the basis of daily time steps, which neither AgriPoliS, nor MODAM is able to do.

When observing the capabilities, specialisation and timely dimension of each model, it hence is appealing to link the models. By linking the three models the capabilities to model multifunctional aspects of agricultural systems extend into two directions:

1. to combine the individual strengths of each model and obtain a more complete model of the agricultural systems under investigation with regard to spatial, analytical and temporal aspects.
2. to cover a wide range of those multifunctionality indicators identified in WP 2 and demands put forward by end-users (WP 6) as well as to analyse model results with regard to these.

These will be further elaborated in the following sections.

### **3.1 Target capabilities with regard to spatial, analytical, and temporal aspects**

The three models AgriPoliS, MODAM and FASSET are combined in a way that allows the analysis of interdependencies and feedbacks at different analytical levels. As agriculture on one hand is a long-term activity and on the other hand has to react on short-term events on markets or with respect to the weather, it encompasses different temporal levels. At the same time spatial interactions are of importance at different levels: e.g. matter flows depend strongly on specific site conditions, while the survival of the stork depends on the management of a landscape and the development of a farm depends on the regional possibilities to hire land and labour.

- MAYBE ADD FIGURE HERE -

To examine the multifunctionality of agriculture these different temporal and spatial aspects should be addressed in an appropriate way. The way to link the models describes the MEA-Scope hierarchical modelling approach which we will present below.

### **3.2 Target capabilities with regard to multifunctionality indicators**

The scientific background for developing the MEA-Scope model is related to the fact that the EU's Model of European Agriculture takes a multifunctional perspective of agriculture and land-use. However, policy makers lack analytical tools to assess the impact of policy options in a multifunctional perspective.

As the aim of the model is to fill the analytical gap policy-makers faces, it is necessary to know the needs of the political level. In order to determine these needs, WP 6 of the project has organised an end-user-workshop. The hope is to develop the MEA-Scope model in a reciprocal way between the abilities of the three original models, the linked model, and the needs of the end-users.<sup>1</sup> The following points summarise the main results of the first end-user workshop.

The spatial dimension of environmental issues in the landscape was one of the matters often in question. The need for tools operating on different scales simultaneously seemed to be a repeated issue. This was expressed within the economic issues (private vs. public goods), environmental issues (farm, landscape and spatial effects of production and policies), subsidiarity (community, local, regional and national policy assessment tools) and policy instruments design (move from farm scale to landscape scale instruments).

There was a concrete question to be addressed: “is decoupling a move away from multifunctionality?” as well as a request for easily understandable explanations of the indicators used. However the final selection of indicators used in the MEA-Scope model is still to be decided.

In addition to end-user demands, the development of the MEA-Scope tool is also guided by the identification of multifunctionality indicators, which is part of the work done in WP2. The indicators relevant in this study are chosen by first making a literature study of existing indicator systems. Redundant indicators and indicators irrelevant for this study are reduced out. The abbreviated list is compared to the list of indicators that the three models are able to produce as well as the requests of the end-users. In the end, in the final list the indicators weighted against the data availability and their scalability to evaluate their performance. For more information see “MEA-Scope-Indicators” the working paper from WP 2.

As at this point in time, the indicator list is still under development. However, based on a first list of indicators, each modelling group (IAMO, ZALF, DIAS) has commented on the indicators which the models as of September 2004 include, and which are planned to be included in the course of the project. A condensed overview of the indicators considered is presented in Table 2.

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<sup>1</sup> Throughout the duration of the entire project, there will be a number of end-user workshops. The first workshop was held in Brussels at the 15 of September 2004. The aim of the first workshop was partly to

**Table 2: An overview of the main indicator groups and the models best covering the particular group. X marks represent current indicators, and (●) are indicators which are planned to be included.**

<b>Indicator groups</b>	<b>AgriPoliS</b>	<b>MODAM</b>	<b>FASSET</b>
Structural characteristics	X●		
General economic characteristics	X		
Socio-economic indicators	●		
Farmers' age	●		
Alternatives to agricultural activity	●		
Commodity Outputs (COs)	X	X●	
Crop and livestock production activities			X
Crop production activities		X●	X
Livestock production activities		X●	X
Crops and Livestock		X●	X
Inputs		X●	X
Policy Framework	X●	X●	
Climatic and soil conditions			X <sup>2</sup>
Non commodity outputs (NCOs)			
Abiotic resource protection		X <sup>1</sup>	
Air		X <sup>1</sup>	X
Soil		X <sup>1</sup>	X <sup>2</sup>
Water		X <sup>1</sup>	X <sup>2</sup>
Biodiversity		X <sup>1</sup>	
Habitats		X <sup>1</sup> ●	
Landscape		● <sup>1</sup>	
Human Health and other Concerns		(● <sup>1</sup> )	

Notes: A detailed indicator list can be found in the appendix. <sup>1)</sup> expert knowledge based fuzzy models  
<sup>2)</sup> mechanistic models of water and soil process

Table A-4 to Table A-6 in the appendix list present and planned indicators in AgriPoliS, MODAM and FASSET presented.<sup>2</sup> Each individual indicator is divided into three groups: present, planned or under consideration, all with respect to the current version of the model. At the same time it is shown if the indicator is present in the input data, whether it is modified in the model through runtime or if the indicator is created in the model at run-time. The planned and considered indicators are part of the on-going adjustment of the MEA-Scope model to the needs of a multifunctional investigation.

present the MEA-Scope model to potential end-users and partly through brainstorm and discussion to achieve an understanding of their interests. For more information see WP6 working paper.

<sup>2</sup> The file "MEA indicators that can be used by 3 models.xls" which can be found on the internal web-site contains a detailed listing of all currently implemented and potential indicators.

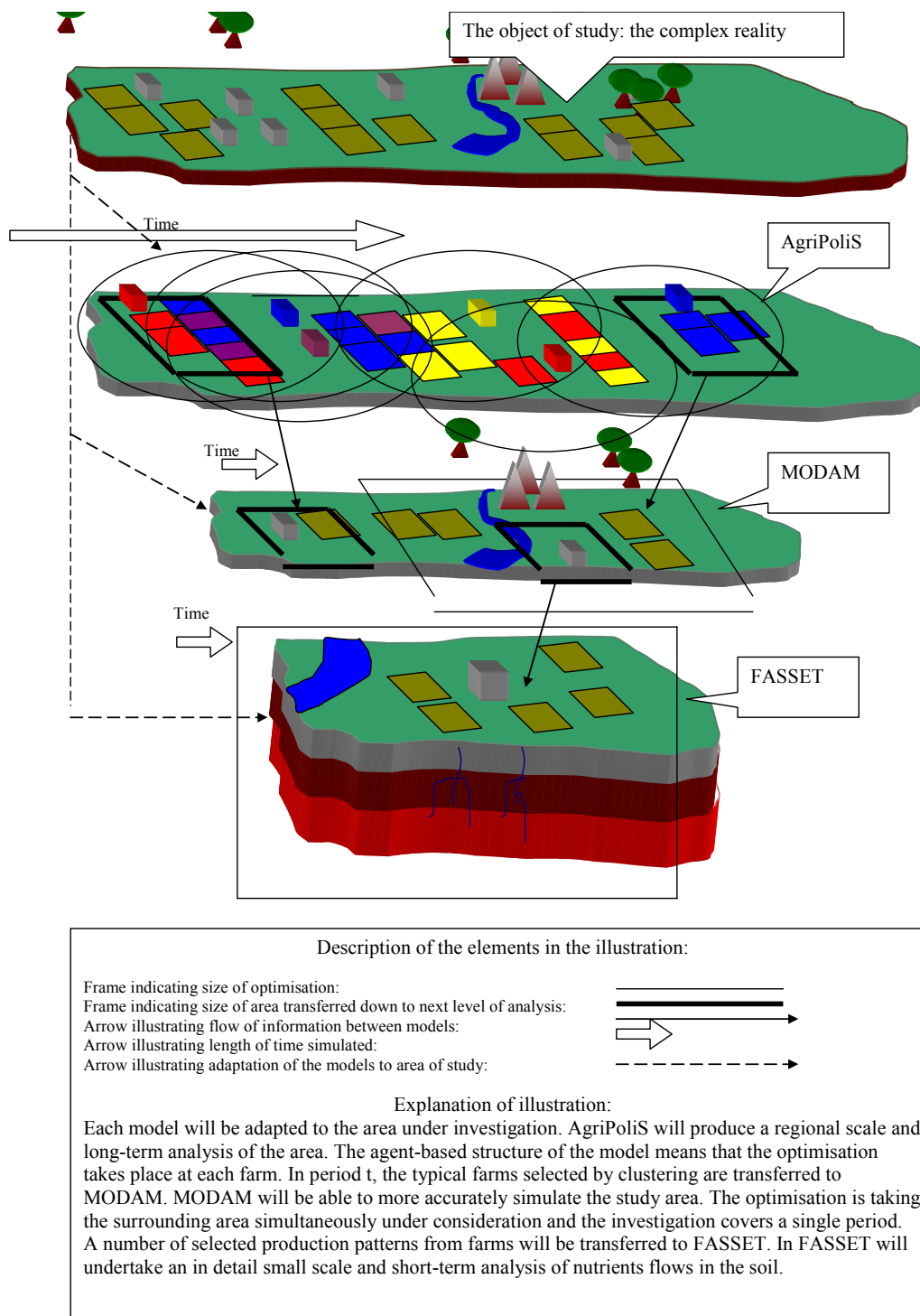
By comparing the abilities of the present models with the developed understanding of multifunctionality it is possible to pin point the strength of the model as well as targeting new areas for investigation. Both the list of input data and the indicator list are at the same time part of the adjustment of the three individual models making them able to work as a collective whole. It is important that the scales and factors used in the three models insure that they are working as a connected narrative. The degree of detail the models operate with differs which means that not all parameters can be identical. Instead it is important that more aggregated parameters in a considered manner reflect sections of more detailed descriptions. This will allow the combined model to operate on different scales simultaneously in the selected regions.

#### **4 DESCRIPTION OF THE HIERARCHICAL MODELLING APPROACH**

In order to achieve first results as soon as possible after the project start, we have chosen to follow a two-phase approach in which phase one focuses on linking the models and creating common interfaces. Phase two will focus on introducing feedback mechanisms between the models to make the top-down approach into a bottom-up approach. Moreover, during this phase multifunctionality indicators that go beyond what is currently implemented in the models will be of interest. During this phase, the model approach will also be closer adjusted to the agricultural in the specific case study region. For this, a close collaboration with the regional partners will be necessary.

##### **4.1 Phase 1: AgriPoliS → MODAM → FASSET**

The first phase follows a top-down modelling approach concluding from large scale and long-term analysis to the framework conditions at small scale and short term and from detailed farm planning to matter flows in the soil. Figure 1 shows this. During the first stage, each of the three models is taken as it is currently in use. This includes also the way in which the models are initialised. In other words, during this stage, we focus on linking the models and establishing interfaces, but do not place particular emphasis on introducing additional capabilities to cover multifunctional aspects of specific regions.



**Figure 1: The first-step MEA-Scope hierarchical modelling approach.**

As can be seen from the illustration, the three models will first be adapted to the study area. At the top, AgriPoliS is situated. Selected farm definitions are passed onto MODAM. The task of MODAM is to study the farm organisation as well as consequences on environmental indicators in greater detail also by passing on data to FASSET. In the following, for each model we describe what takes place at each model stage and how information from one stage is passed on to the next stage (see Figure 2).

**Interface 1 MODAM → AgriPoliS (Before the first period)**

- economic coefficients of production activities

**Interface 2 AgriPoliS → MODAM (After each 5 periods in AgriPoliS)**

- farm capacities and prices for typical farms at specific locations.

**Interface 3 MODAM → FASSET (After each period in MODAM)**

- allocation of production activities to specific locations
- ecological coefficients of production activities (timing, workstep, amounts ...)

**Figure 2: Data passed on to the next model stage in phase 1**

The top-down approach we follow at this stage neglects in the first place feedbacks from micro processes to macro processes, which will be addressed in the second phase of the project. By enabling the three models to collaborate they constitute a strong tool to investigate the consequences of different aspects regarding agricultural production as the output files reflects the diverge results of the policies investigated.

**4.1.1 Step 1: AgriPoliS**

The regional landscape which is initialised in AgriPoliS is synthetic, but it aims to represent key characteristics of the true underlying region/landscape. In AgriPoliS the focus is on representing the regional farming structure as well as the diversity of farms with regard to their types, size, age, and factor endowments.

*Representation of the region and farms*

A description of the regional farming structure based on IACS / FADN data and/or expert knowledge will constitute the point of departure for creating the synthetic computer-generated versions of the regions/landscapes. The structure of all the farms in the region will through a calibration procedure result in a number of typical farms. These typical farms constitute the foundation from which AgriPoliS randomly reconstructs a statistically similar representation of the region. Each typical farm forms a template to which individual characteristics are assigned and thereby aims to re-create the heterogeneity of real farms.

The spatial location of the farms is also contributing to individualising the farms. The farms are randomly located in a spatially explicit representation of the study area. The typical farms are randomly distributed (location of the farm and the land) to a spatial explicit region. A GIS raster of the region – which is based on regional GIS maps (so that spatial characteristics can

be related to specific sites) is planned to be developed. At the current state, this area representation is state in AgriPoliS rather crude, but is one of the items we are planning to develop in the scope of this project.

Within this environment, each farm seeks to optimise its profits and thereby create a competitive pressure for the land resource. The farms compete for the available plots through the land market. The internal competition as well as the political framework conditions constitutes the dynamics of structural change that forms the changes in the region. The structural development of the region will be simulated.

#### *Simulation and data output*

AgriPoliS will be simulated for 20 time periods (corresponding to 20 financial years) for all 7 regions. The simulation output produced by AgriPoliS includes a large number of mainly economic variables which resemble the data of a balance sheet. In addition, investment and production data is recorded. In general, data is recorded for each farm in the region at each time step.

AgriPoliS has its strength within the economic sphere rather than understanding agricultural production from a more agronomical prospective. This means that the production of the individual farms is described on an aggregated commodity output level without truly incorporating non-commodity outputs.

#### *Link to MODAM*

During this modelling phase, AgriPoliS will be stopped in periods 3, 6, and 15 (just a suggestion, implemented time periods should be dependent on the kind of changes occurring in AgriPoliS, only after considerable changes in the structure of the farms a stop to run MODAM and FASSET is useful !!!!) and the farming structure is analysed in the respective period. From all farms in each of the three periods, a number of representative farms will be selected. Currently, we are trying out factor and cluster analysis to identify these representative farms. As beef production is at the centre of the entire product, one of the selection criteria will be farms involved in beef production. The specification of these farms is passed on to MODAM for further analysis.

### **4.1.2 Step 2: MODAM**

Modam will be run at the reference time and at distinct times during the simulation runs of AgriPoliS when considerable changes in the farm structures occur. At these points in time MODAM will receive from AgriPoliS the structural data of a number of typical farms to

optimize the farm production plan, based on detailed and site specific production activities (for 7 regions). As production activities are described in a more detailed and differentiated way, ecological evaluation tools can evaluate ecological impacts of the production activities. Thus, MODAM is able to calculate both the optimized allocation of production activities and, simultaneously, the aggregated index values of the ecological assessment.

#### *Data received from AgriPoliS*

- Structural data of a number of typical farms: During the simulation process of AgriPoliS, some structural data will be transferred to MODAM, for a more detailed simulation of the land use effects. It is planned to stop the AgriPoliS simulation at points where the structural change of the farms of a region become obvious. For example, if the number of farms change, a changing impact on the environment by the farms is expected. Similarly, a change in livestock production will have an impact on emissions of a farm. Therefore, data on the size and organisation of farms at certain time spot will be transferred to MODAM for a new assessment of agriculture's multifunctionality.
- Scenario definitions in the form of market prices and policy instruments: Furthermore, scenario definitions used in AgriPoliS will be transferred to MODAM in order to use the same sets for simulation runs. These settings comprise data like market prices and assumptions on policy instruments.

#### *Representation of the region and farms*

- Typical farms to represent the regions' agricultural production potential: While AgriPoliS uses a more comprising set of farms, covering the farms of the whole regions, MODAM will use only a limited number of typical farms to represent the regions' agricultural production potential. However, the description of each specific farm is more detailed. Each working step of a cropping practice is described, allowing for a specific assessment of its environmental impact. Furthermore, this assessment is also site-specific, since it is important where a cropping practice takes place. A MODAM farm is represented by cropping practices, livestock activities and the farm capacities (e.g. labour, machinery, land).

#### *Policy scenarios*

- Scenarios with different market and policy conditions will be simulated and their impact on the multifunctionality of agriculture will be assessed. Within the

optimisation process, different scenarios with different market and policy conditions will be simulated and their impact on the multifunctionality of agriculture will be assessed. These scenarios can be implemented as restrictions on certain land use activities, or by changing the framework of in- and output prices and subsidies. Since MODAM is built up in a modular way, changes at the final LP-matrix are rather easy to implement.

### *Data output*

MODAM produces output data in several fields:

- The allocation of site specific crop production activities (based on long term averages) to types of sites within each raster point covered by the respective typical farm (shares; not crop rotations): The data output of the MODAM model is based on the LP-result table, completed with additional queries allowing for a more comfortable display of the specific results. The resulting allocation of cropping activities of a farm will be input to the FASSET model. For each soil type a number of cropping practices with different shares are allocated. These shares represent the long term average distribution of crops under given framing conditions.
- Calculation of economic indicator values: The economic indicators calculated by MODAM are the following: (a) gross margins of production activities, (b) Total gross margin, (c) Labour demand in regions.
- Calculation of ecological indicator values: The calculation of the ecological indicator values, based on expert knowledge is implemented in a fuzzy tool. Up to know, assessment modules are available for 5 abiotic and 5 biotic indicators. The elaboration of additional indicator-based assessment schemes related to animal production is intended.
- the following indicator assessments (related to crop production) are already available:
  - abiotic:
    - risk of nitrate leaching
    - risk of nutrient entries into ground and surface water
    - risk of pesticide entries into ground and surface water
    - ground water recharge potential
    - risk potential for water erosion
  - biotic:

- impact on the habitat potential for skylarks
- impact on the habitat potential for field hares
- impact on the habitat potential for amphibians (red belly toad)
- impact on the habitat potential for hover flies
- impact on the habitat potential for wild flora species (fall germinating)
- the following additional indicator assessments are planned:
  - animal welfare
  - energy input
  - greenhouse gas emissions
  - ...

#### *Link to FASSET*

- structural data of a number of typical farms

### **4.1.3 Step 3: FASSET**

Based on farm type information (livestock housing and manure storage facilities, number and type of animals, fodder plans etc.), and the allocation of crop and grassland production activities of MODAM to specific raster points (and specific types of sites within each raster point), FASSET simulates an operational, weather and soil-based land use plan. In the scope of this project we plan to develop a model for calculating cropping sequences based on shares of crops delivered from MODAM. Then, FASSET is capable of generating the cropping sequence itself. In addition we develop the capacity to choose between distributing a given amount of fertilizer and manure between crops or deciding the optimum amount of fertilizer used.

- Calculation of production indicator values
  - Site specific crop yields
  - Livestock production (Milk and meat)
  - Fodder imports
  - Fossil energy use
- Calculation of ecological indicator values:
  - Soil matter flows
    - Nitrate leaching
    - Ammonia volatilisation

- Greenhouse gas emissions
- Phosphorous balance
- Soil organic matter and Carbon balance
- Matter flows related to livestock housing and manure storage
  - Ammonia volatilisation
  - Greenhouse gas emissions
- Calculation of ecological indicator values based on “intersection” of the biological typology of sites (GIS) and the crop production information from MODAM.
  - Extensive grassland management
  - Claudia Sattler: see table below:
- Comparison and validation with ecological indicator values from the regions:
  - Nutrient balances (Measured contra modelled)
  - Nitrate leaching levels (Measured contra modelled)
  - Fodder imports (Accounted versus modelled)
- Disaggregating of model results:

#### *Data received from MODAM*

- Farm type information (livestock housing and manure storage facilities, number and type of animals, fodder plans etc.)
- The allocation of crop and grassland production activities

#### *Representation of the region and farms*

#### *Policy scenarios*

## Data output

### 4.2 Further developments of the MEA-Scope model

The first aim is to make a functional version of the MEA-Scope model using the described top-down modelling approach. In the following will proposals for further developments be presented.

The current versions of the three underlining models is however unable to simulate all the politically desirable target points. The original models have all been focusing on specific parts of the rural area. However, the interest of the public covers also subjects, which falls outside these areas. It is therefore our plan to extent the numbers of indicators. The hope is to be able to cover more issues politically debated. MODAM will be extended to cover air pollution, landscape characteristics and more indicators on biodiversity and habitats. It is also considerate to extend AgriPoliS' capabilities with a number of social-economic indicators. Mainly resignation and retirement of labour from the agricultural sector to the surrounding areas are contemplated. The modelling of nutrient flows and production consequences of differing intensities of grassing is furthermore planned to be included in FASSET. This is relevant because low-intensive grassing can be an effective measure to preserve biodiversity while maintaining production activity in regions with many permanent grassland areas.

### 4.3 Phase 2: Feedbacks and additional regional-specific multifunctionality indicators

The modelling approach is also considered to undergo further development. The following, not finalised ideas have been discussed.

By incorporating feedback mechanisms from the models ranking lower in the hierarchical structure to the more aggregated models will the model maybe able to implicate e.g. the exact nutrient balances in a given plot into the production capacity of this individual farm. Another example could be modelling consequences of restrictions targeted to certain farm types or to certain geographical areas with special interests (for example special interests in nature protection, groundwater protection, rural development, cultural heritage etc.). Also consequences of conversion to organic farming might be interesting to investigate for certain areas or certain farm types. However, as we operate with typical farms when going from the aggregated level and into details, holds this approach a number of inbuilt obstacles. This modelling approach will not be able to generate detailed data for all farms in all the selected

regions and it is therefore to be tested whether we will be able to generate conversion rules (for specific, relative weighting factors for each farm type). These conversion rules will have to be able to automatically adjust the parameters from the typical farms to the individual farm and its setting.

However, a large number of scientific as well as politically relevant questions can also fruitfully be addressed with the presented top-down version.

#### **4.4 Policy scenarios**

The model is simulated for different policy scenarios

The simulated region is then submitted to different policy scenarios, in order to analyse their effects in a multifunctionality setting. The policy scenarios will set the framework conditions within which the farms will optimise their individual actions. The different policy scenarios can be used for both projections for the agricultural and environmental development of the selected regions as well as investigations into effects of different political tools. At the same time can other possible investigations be imagined. One possibility was already mentioned at the end-user workshop: “is decoupling a move away from multifunctionality?” This question can be analysed for the different regional schemes, structural composition and settings. Another example could be to let the different regions compete against one another. In this way can the structural development inflict upon the regions due to external forces be determined.

## **5 DATA COLLECTION**

The three models needs to be adapted to the different study areas. The adaptation is based on empirical data from the regions set for investigation. Many basic qualities of the areas will commonly be used. However as the three individual models main focus differs is it also reflected in the characteristics of the input data needed.

This section will present the data requirements of each individual model. By presenting the empirical foundation for the simulation models can an impression of the degree of detail the combined MEA-Scope model will operate with be obtained.

## 5.1 AgriPolis

### 5.1.1 Adapting AgriPoliS to the different regions

In order to adapt AgriPoliS to the selected study areas, the model need the specific structural characteristics of the area under investigation. Two different datasets are required for the model to fit the region: the first one at the regional level and the other one at the individual farm level.

An overview of AgriPoliS data requirements is presented in the following two sections. A more detailed description of the data requirements can be found on MEA-Scope homepage in WP3's download section (folder "data").

### 5.1.2 Regional data

The first dataset should roughly describe the main structural characteristics of the region and the main productions which can be found there. As the regions differ from one another, these data will thus be different. They have to reflect the activities taking place in the region and will therefore evolve in the framework of the model with respect to the study area. The following table is an example of possible regional characteristics, the region being a German one in this case. The cooperation with local representatives will allow to build the most suitable dataset for the corresponding region. It can be then decided that other characteristics are more relevant to describe the region : other animal species (e.g. no ewes in the region, presence of poultry, etc.), other classes of farm size, other legal forms, or other farm types present in the region. When possible, and especially regarding the aim of the project, different beef productions systems can be distinguished, depending on the sufficient number of farms in each of them.

**Table 3: Example of a list including regional characteristics**

	Value	Source	Year
<b>General characteristics</b>			
Number of farms	<i>Each case study area is particular. These very general characteristics should change from one region to another.</i>		
Utilized agricultural area (UAA)			
Beef cattle older than a year			
Dairy cows			
Other cows			
Ewes			
Other sheep			
Breeding sows (>50 kg)			
Pigs for fattening (>20 kg)			

<b>Structural characteristics</b>	
<b>Number of:</b>	
Individual farms	<i>Also, different legal form can be found in the case study areas (e.g. "moral persons" in Germany).</i>
Partnerships	
Others	
<b>Total UAA of all the farms belonging to the following category:</b>	
Individual farms	<i>Their occupation of the land is a very important structural indicator.</i>
Partnerships	
Others	
<b>Area</b>	
Arable land	<i>This distinction can give clues about the occupation of land of herbivore species.</i>
Grassland	
<b>Number of farms specialized in:</b>	
Field crops	<i>The "Grazing livestock" and the "Mixed" types can also be split into several subtypes.</i>
Milk	
Grazing livestock	
Granivores	
Mixed (crops and livestock)	
<b>Total UAA of all the farms specialized in:</b>	
Field crops	<i>This classification roughly helps to appreciate the capitalistic intensity per hectare, and this from one region to another.</i>
Milk	
Grazing livestock	
Granivores	
Mixed (crops and livestock)	

<b>Number of farms in different size classes</b>	
10 - 50 ha	<i>This classification helps to appreciate the general farming structure of the region.</i>
50 - 100 ha	
Etc.	
<b>Total number of pigs for fattening for all the farms of the following category:</b>	
Below 50 heads per farm	<i>The method is to: first select all the farms owning pigs; then, split them into the different categories as mentioned on the left column; and finally add all the pigs for fattening owned in total by all the farms of the considered category. Once again, the classification should fit the reality.</i>
50 - 200 "	
200 - 500 "	
500 - 1000 "	
1000 - 2500 "	
Above 2500 "	
<b>Total number of sows for all the farms of the following category:</b>	
Below 100 heads per farm	<i>It helps to appreciate the regional structure of cattle breeding, and the animals chosen to do this have to be the more representative of the region, as listed in the "General characteristics" part of this table.</i>
100 - 200 "	
200 - 500 "	
500 - 1000 "	
Above 1000	

<b>Total number of dairy cows for all the farms of the following category:</b>	
Below 50 heads per farm	<i>Same as above, but for dairy cows, if present in the region and representative of its breeding cattle structure.</i>
50 – 150 “	
150 – 250 “	
250 – 500 “	
500 – 1000 “	
Above 1000	

### 5.1.3 Farm data

A second dataset, at the individual scale, is then to be filled in. A set of farms is selected from this individual dataset, which size/breeding cattle structure/farm type fits the best the main regional characteristics described above. Previous adaptations of AgriPoliS to specific areas have been done with the use of either FADN or IACS databases. If IACS database is used, rather slightly different data than the ones presented in the following are needed (please contact us for more information).

Fitting the individual data of these “typical farms” selected with the regional data is what is called "upscaling". It aims at representing the main farm types of the region, so all types of farming represented in the region -and representative (at least five farms per type in the original dataset), should be kept.

The two data sources, the regional and the individual ones, must be consistent one with the other to produce decent results.

For the upscaling process, AgriPoliS only needs the yellow coloured data. But more information is needed for the representation of the selected typical farms. These data are coloured in green. The blue coloured cells might be useful to get a better idea on the farms, but they are not necessary for running AgriPoliS.

<b>General information on the farm</b>	Unpaid labour input
Organisational form of the holding	Unpaid labour input
Type of farming	Total Utilised Agricultural Area (UAA)
Organic farming	UAA in owner-occupation
Irrigated area	Rented UAA
Altitude zone	Arable land
Structural Funds area	Grassland
Areas with environmental restrictions	Cereals
	Other field crops
<b>Structure and yield</b>	Vegetables and flowers
Economic size in European Size Units	Vineyards
Total labour input	Permanent crops
Labour input	Orchards
	Olive groves

Other permanent crops
Forage crops
Set aside
Male cattle 12-24 months
Dairy cows
Other cows
Ewes
Other sheep
Breeding sows
Pigs for fattening

**Costs**

Total farming overheads
Machinery & building current costs
Energy
Contract work
Other direct inputs
Depreciation
Total external factors
Wages paid
Rent paid
Interests paid

**Subsidies**

Total subsidies – excluding on investments
Total subsidies on crops
Compensatory payments/area payments
Total subsidies on livestock
Other subsidies
Environmental subsidies-c.u.
LFA subsidies-c.u.

**Balance sheet**

Total assets
Total fixed assets
Agricultural land
Land, permanent crops & quotas
Permanent crops
Buildings
Machinery
Total liabilities

**Income**

Total output
Gross Farm income
Family Farm Income
Farm Net Value Added

**Financial indicators**

Net worth
Change in net worth
Gross investment
Net investment

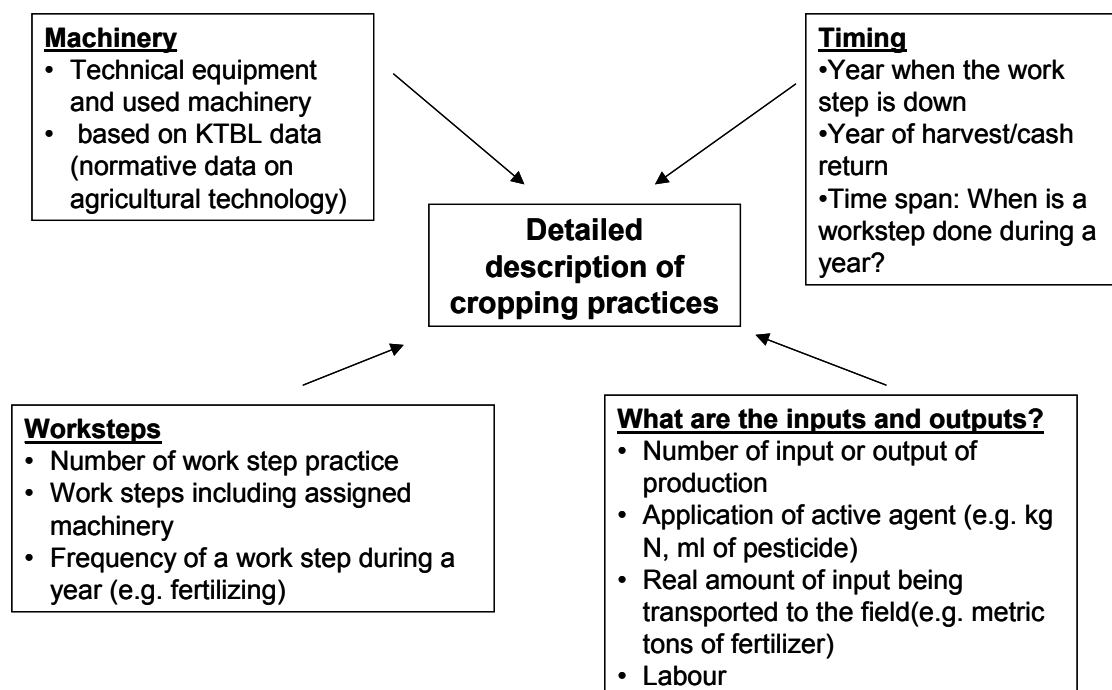
AgriPoliS would need some aggregated production and prices data on top of the tables presented above, however these data should be easily available.

## 5.2 MODAM

### 5.2.1 Production descriptions

The economic and ecological evaluation modules of MODAM require a highly detailed description of production activities by numerous technical and economic coefficients, which we expect to be delivered by production experts. The following table/figure illustrates part of the data needs of MODAM for an appropriate description of arable production practices:

	date	Workstep and machine	Width m	Power HP/ KW	Work efficiency ha/h	Item/ variety/ contents	amount E/ha	Costs/ €/ unit	Paid Labour costs	Seasonal work
Tillage										
Seed										
Fertilizer										
Pest management										
Harvest										
Grain										
Straw										
Transportation										



The same type of information is required for grassland production. The livestock production has a quite different structure, describing the animal husbandry systems throughout the year on the basis of herd size and composition, stables and their equipment and feeding activities.

We planned that the production activities will be investigated by ZALF for the German test region, where an appropriate questionnaire will be developed and tested.

For the other regions, we will develop a questionnaire, that should be filled by country experts. a database supported version will be provided, that can be filled directly and that gives template values (e.g. for worksteps, machines or yields) . to choose from.

## **5.3 FASSET**

### **5.3.1 Natural conditions for farm production etc.**

In addition to the adapted data, received from MODAM, FASSET needs specific inputs on:

- The soil types (Texture, chemical composition and profile description), where the different type of farming takes place.
- Daily methodological data for a period of for example 10 years for each location.
- Data on field sizes and distances from farm building to the fields
- Fodder imports (Type of fodder stuffs and fodder types feeded to the different livestock types defined)
- Crop rotation and fertilisation practice
- Grassing intensities

## **6 SUMMARY**

The objective of this working paper was to illustrate and discuss the capabilities of the micro-economic models including a guideline for model adjustments of the micro-economic models. As well as give a definition of target capabilities with respect to multifunctionality impact assessment. The hierarchical modelling approach is described based on an introduction to the three individual models: AgriPoliS, MODAM and FASSET. The input data requirements for the models to insure adaptation of the models to the selected regions were presented. The end-uses needs was briefly sketched and an examination of the indicators that the models are able to produce. Finally are the capabilities of the combined model introduced as well as a number of possible analyses.

## **7 REFERENCES**

OECD (2001), Multifunctionality: Towards an Analytical Framework, OECD, Paris.

## 8 APPENDIX I: THE THREE MODELS: AGRIPOLIS, MODAM, AND FASSET

Simulation studies have a long tradition in agricultural economics, which can *inter alia* be explained by the relatively good access to disaggregate data and the high demand for policy simulation by political and administrative bodies.

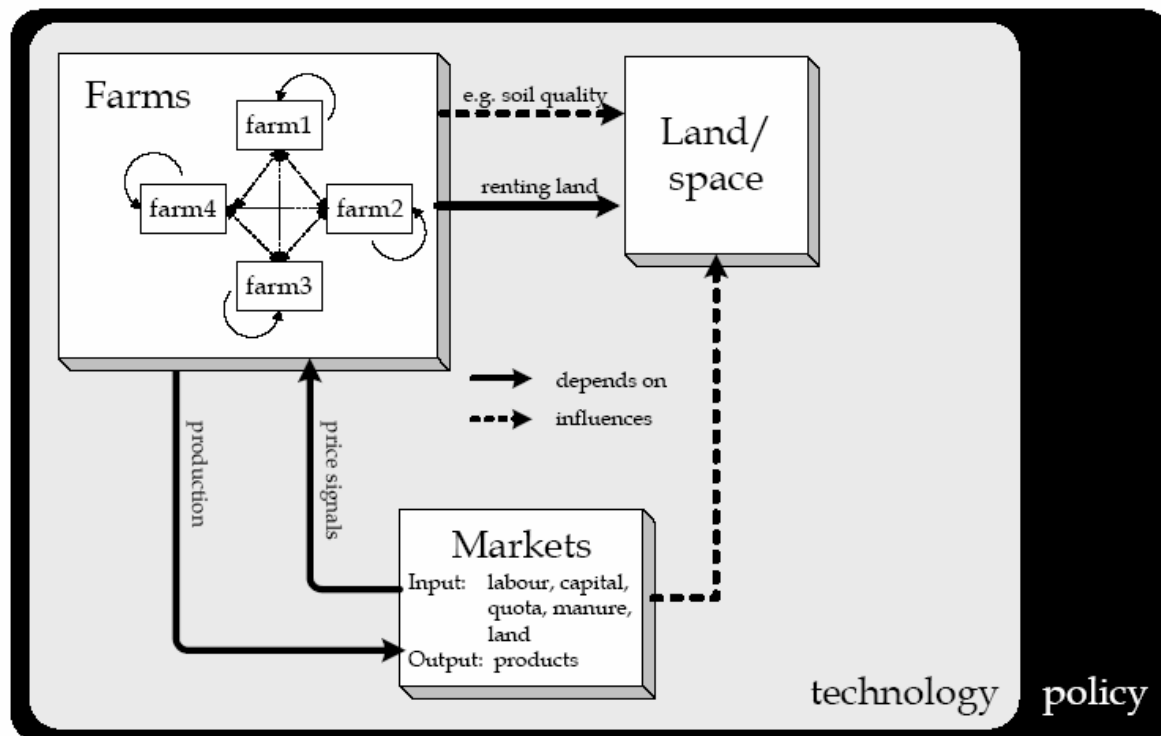
However, recognizing that computer models always show an idealized perception of a defined part of reality is it necessary to clearly demarcate the part of the system investigated. This will constitute the foundation for a later description of the MEA-Scope model. Hereby are we able to clarify the synergy effects as well as the ability of the combined model. Each individual model will be presented with a small description and a textbox, in which catchwords outline the most important characteristics of the model.

### 8.1 AgriPoliS

AgriPoliS (Agricultural Policy Simulator) is a spatial dynamic agent-based simulation model of regional agricultural structure. The core of AgriPoliS is the understanding of a regional agricultural structure as a complex evolving system.

#### 8.1.1 Introduction

The AgriPolis perception of a regional agricultural system is shown schematically in Figure Figure 3. The figure shows the interactions between the three central components of agricultural structures: farms, markets, and land. A number of individual farms evolve subject to their actual state and to changes in their environment. This environment consists of other farms, factor and product markets, space, which are all embedded within the technological and political environment. Farms, land, and markets either directly depend on each other or they exert influence on each other. A direct dependence implies that one component cannot exist without another. The mutual dependence between farms, land, and markets results from the fact that farms require land and production inputs purchased on markets. Markets for agricultural products obviously depend on farm produce. In contrast to this, the state of land is influenced by farm and market activity, e.g. by land management.



**Figure 3: Conceptual framework of AgriPoliS**

Representing this system using the abstraction of an agent-based system is appealing, not only because it suggests itself to interpret farms as individual agents. Also markets - be it product or factor markets and in particular the land market - can be interpreted as agents that bring together and co-ordinate market activity.

### 8.1.2 Agents involved

For the purpose of AgriPoliS an agent is defined as an entity that acts individually, senses parts of its environment and acts upon it.

There are two types of agents in AgriPoliS, farm agents, and market agents. Of the two kinds of agents considered, the farm agent is most important. One farm agent corresponds to one farm or agricultural holding.

### 8.1.3 Farm agent actions and behaviour

Farm agents can produce a selection of goods that are typical for the study region. In order to produce, farm agents utilise buildings, machinery, and facilities of different types and capacities. With respect to this, AgriPoliS implements economies of size as with increasing size of production, capital costs per unit of production decrease. Moreover, labour is assumed to be used more effectively with increasing size. Farms can rent land, production quotas, and manure disposal rights. Labour can be hired on fixed terms or on a per-hour basis, vice versa

farm family labour can equally be offered for off-farm employment. To finance farm activities and to balance short-term liquidity shortages, farms can take up long-term and/or short-term credit. Liquid assets not used on-farm can be saved. A farm quits production and withdraws from the sector if either equity capital is zero and the farm is illiquid or if opportunity costs of farm-owned production factors are not covered.

Farm agents, the central agents of AgriPoliS, are assumed to act autonomously and to maximise farm household income. For this, production and investment decisions are made simultaneously based on a recursive linear programme including integer activities (e.g. Hazell and Norton 1986). From the solution of the linear programme, shadow prices of production factors can be derived.

New investments affect production capacities for the operating lifetime of the investment. This implies investment costs to be sunk. Farms are handed over after a given number of periods. In case of such a generation change, opportunity costs of labour increase. Accordingly, continuation of farming can be interpreted as an investment into either agricultural or non-agricultural training. Farm agents differ not only with respect to their specialisation, farm size, factor endowment and production technology, but also with respect to the person of the farmer, and particularly with respect to managerial ability.

#### **8.1.4 Representation of the spatial, technical and political environment**

One individual plot represents a standardised spatial entity of a specific size (initially 2.5 ha) that can take different states. In this representation, all factors that do not directly relate to agriculture and land use (roads, rivers, etc.) have been eliminated. The cells represent agricultural land that in the present version is either grassland or arable land. More land types will be developed in the course of this project. The total land of a farm agent consists of both own and rented land. Land is heterogeneous with respect to its location in space and with respect to its quality.

The technological environment is given by technologies of different vintages and technical standards. Over time, technology is assumed to underlie a constant progress created in the upstream sector, but not on farms itself. Farm agents are assumed to benefit from technological progress by way of realising additional cost savings. The political environment represents the third building block of a farm agent's external environment besides space and technology. Agricultural (and environmental) policies affect the farm at different instances such as prices, stocking density, direct payments, or interest rates.

Agents in AgriPoliS interact indirectly by competing on factor and product markets. Interaction is organised by market agents that explicitly coordinate the allocation of scarce resources such as land or the transaction of products. Direct interactions between agents, for example for directly negotiating on land, are not yet considered.

In AgriPoliS, the land market is the central interaction institution between agents. It is of particular relevance, as farms very often cannot grow independently of land. Therefore, AgriPoliS considers a land rental market, but does exclude a sales market for land. Land available on the land rental market either stems from farm agents that have quit production altogether or land is available because rental contracts were terminated. Farm agents' bids for particular plots of land depend on the shadow price for land, the number of adjacent farm plots and the distance-dependent transport costs between the farmstead and the plot. The auctioneer collects bids, compares them, and allocates plots to farm agents. The auction terminates when all free land is allocated or if bids are zero. As both arable land and grassland are considered, the auction process alternates between these two land qualities. The land rental market procedure will be changed when more soil types are introduced.

Following the initialisation phase, the simulation phase starts with setting the political framework conditions that is valid during the subsequent simulation period.

### **8.1.5 Production activities**

Production activities in AgriPoliS are distinguished into livestock production (e.g. fattening pigs, turkeys), plant production activities (e.g. cereals, sugar beets, grassland), short-term capital activities (e.g. short-term borrowing), short-term labour activities (e.g. short-term hiring), and 'additional' activities. Though MEA-Scope is focusing on beef production, AgriPoliS will all production types include. This is done in order to be able to replicate the study area as realistic as possible. Most livestock and plant production activities are marketable activities. Exceptions are grassland production activities and silage maize which serve as intermediate products for livestock production. Additional activities relate to those activities besides capital and labour which are needed to balance capacities in the short-run. This includes, for example, manure disposal, contracting, or milk quota lease. Products are managed by the farm agents in a product list that keeps track of the total units produced as well as the gross margins associated with each product. Product prices change in response to developments on the product markets. Variable unit production costs are affected by technical progress, on the one hand, and by the individual managerial ability of a farm agent on the other hand.

## 8.2 MODAM

To determine pathways of sustainable development of rural landscapes, especially in the relationship between agriculture and its natural environment a profound knowledge of this complex system and its behaviour under different socio-economic conditions is necessary. MODAM was developed to simulate interdependencies between achievement of economic and ecological goals as a function of agricultural policies. MODAM consists of a set of hierarchically linked modules, which can be described in three levels. At the first level, production activities are described in a way that allows economic and ecological analysis of these techniques. The second level analysis the cropping practices for their costs and benefits in an economic as well as ecological sense. This will be extended in MeaScope by new tools, to analyse animal production activities. The third level consists of multiple goal linear programming models of farms, which are build by a LP-Generator. It allows the construction of individual farm models, as well as farm types or regional models. The tool generates two types of simulation runs: (i) goal driven scenarios show the effect of ecological restrictions on economic performance and (ii) policy driven scenarios show the impact of policies on economic and ecological performance of farms. The results are presented in the form of trade-off functions between different ecological and economic goals and in the form of land use maps. The spatial dimension of allocated land use patterns can be analysed and visualised by geographic information systems.

MODAM is used in different research projects of the 'Centre for Agricultural Landscape and Land Use Research' in Müncheberg. Results discussed here, were elaborated within the BMBF-DBU financed joint-project 'Schorfheide-Chorin'.

Within MODAM currently about 200 cropping practices for conventional farming and 200 for organic farming have been described and analysed. For every combination of 10 environmental objectives (e.g. nitrate leaching or protection of amphibians), relevant types of sites, in the research area and the mentioned cropping practices the degree of goal achievement is determined. Results of simulation runs of the farm model show the trade-off's e.g. between the risk of nitrogen leaching and total gross margin of the simulated farms. For Northeastern German conditions it could be shown for most of the environmental objectives that increases in goal achievement up to 50% from the actual situation are possible, while gross margin losses are low. This is mainly caused by the effect of a spatial reallocation of cropping practices, which allows under heterogeneous site conditions an increase in ecological goal attainments. Those sites with a high risk of negative impact on a specific

environmental objective are taken from those fields that exhibit high sensitivity for the objective in question. The losses in total gross margin represent the private costs for i) changes in the specific intensity, ii) the combination of production factors and iii) changes in the organisation of the farm. Additional costs of the private and the public sector due to the transfer of information or due to the development and controlling of regulations were not included there.

Analysis of policy driven scenarios showed the importance of a profound analysis of the effects on environmental objectives if subsidies are newly defined.

To support a spatial, nature protection oriented evaluation of land use scenarios, a recursive-dynamic version of the model was developed. This computer intensive model delivers one cropping practice for every field and for every scenario for six subsequent years. This allows spatial and dynamic analysis of the effects of scenarios on objectives of nature and environmental protection.

The multi-objective decision support tool MODAM appears to be a highly flexible tool concerning the number and type of farms, sites and production techniques. Environmental objectives can easily be included and different levels of goal achievement can be simulated. Because of limited computing capacities, not all of these options can be explored to a maximum and at the same time. Nevertheless, MODAM is well suited for single farm analysis as well as for regional models, for static as well as dynamic approaches. It allows rapid adoption of the model and rapid calculation of scenarios. Therefore, MODAM is suited for use in interactive environments with users which are interested in repeated runs with little changes in the goal function, prices, subsidies or also technical coefficients of the production practices. The results can be used for policy decisions as well as the strategic planning of individual farmers.

### **8.3 FASSET**

FASSET is a farm-scale model that simulates many of the characteristics important to society today; production, economics and pollution. The sources of pollution described include nitrate leaching, ammonia emission and the emission/absorption of greenhouse gasses. Other sources of pollution are only peripherally described e.g. phosphate is described in terms of field/farm balances and pesticides are only considered in terms of the amount used. FASSET is a dynamic, deterministic model i.e. it can simulate changes over time but will always give the

same outputs when presented with the same inputs. The model uses a daily time step for most simulations.

Version 1 of FASSET described only pig and arable farms but included a linkage to an economic optimisation model that simulated crop rotations and fertiliser/manure use. The latter was programmed in GAMS whilst FASSET was programmed in C++. This construction proved difficult to implement and maintain so has been omitted from Version 2 in favour of the progressive inclusion of decision-making within FASSET itself. FASSET v 2 has been extended to describe dairy and beef cattle.

FASSET is constructed in modular form. The main groupings of modules are those describing fields, equipment and structures, and management (Fig 1). The use of object oriented programming techniques means that the model can be readily adapted to a wide range of farms with, for example, different numbers of fields or animal housing types.

FASSET runs with a daily time step and uses daily meteorological data.

### **8.3.1 Field module**

In theory, a farm can have an unlimited number of fields, although in practice, the number is limited by the memory capacity of the computer used. The field consists of one or more patches, each describing an area that can be considered to be homogenous e.g. an area of one particular soil type. The main attributes of the field are its area and the distance to the farm buildings (used in the calculation of time and fuel use for field operations).

### **8.3.2 Patch module**

The patch module consists of two major submodules, one describing the soil and the other describing the crop or crops. The main attribute of a patch is its area.

### **8.3.3 Soil module**

The soil is envisaged as consisting as a number of vertical layers. The first is a surface layer, followed by however many additional layers (of user defined thickness) are necessary to describe the soil down to the maximum rooting depth of any expected crop. Within each layer, the dynamics of organic matter, water, and N and C turnover are described.

### **8.3.4 Crop module**

The crop module describes the following:

- The interception of light and its conversion into dry matter.

- The partitioning of dry matter into root, shoot and storage organs.
- The death of shoot and root material.
- The uptake and transpiration of water.
- The uptake of nutrients from the soil.

More than one crop can be present at any one time. If more than one crop is present, the crops compete for light, water and nutrients.

### 8.3.5 Animal module

All animals must be associated with a location in an animal house. This is to enable the model to correctly route the manure produced. For further details, see Animal housing.

### 8.3.6 Pig module

The pig herd consists of mating sows, pregnant sows, lactating sows (including suckling piglets up to weaning), weaners, finishers and replacement sows. The pig production is modelled as a steady state process rather than following the cycles of production. For example, if the farm produces  $N$  pigs of weight  $kg$  per year, the time spent as weaners and finishers is  $t_1$  and  $t_2$  respectively, and there are 365 days in the year, then the average number of weaners present on any day  $N_w$  is  $N_w = \frac{Nt_1}{365}$ . Likewise, the number of finishers present on

any day ( $N_F$ ) is  $N_F = \frac{Nt_2}{365}$ .

The number of piglets, weaners, finishers and replacement sows produced each year is input by the user, as is the weight and chemical composition (e.g. N, P) at the start and end of these categories. The number of sows present and their start and end weight is also input by the user.

The diet of each category of pig is input in terms of the amount of each feedstuff consumed each day. The model maintains a database of pig feeds, containing a variety of nutritional information, such as the digestibility and N content. This information is used to define the nutritional value of imported pig feeds. If the pig feed is taken from on-farm storage, the nutritional information is modified where appropriate to reflect the quality of the feed in that storage.

The amount of dung and urine produced by the animals is calculated from the number present and the volume produced per animal; this amount is defined by the user for each type of pig.

The user also defines the default chemical characteristics of dung and urine produced by the animals. Although for N, the excretion is calculated from the feed N consumed and the N partitioned to production. The partitioning of N between dung and urine is based on the digestibility of the animal diet.

### **8.3.7 Cattle module**

Unlike the pigs, the cattle herd consists of one or more individual cows or cow types (i.e. typical animals that represent more than one individual). The herd structure is defined in terms of a number of animal groups. For dairy herds, the groups consist of first and second year heifers and mature animals. For beef herds, the groups are followers ( $\leq 2$  years) and mature animals. In each case, the user defines the numbers in each group, as is the maximum age of the mature animals. At start-up, the model distributes the number of animals in each group evenly through their age range. Throughout the simulation period, animals reaching the maximum age for a group, are replaced with new animals of the minimum age.

The growth, milk production and excretion of individual cows or cow types are modelled as a function of the energy and protein available, using the factorial system. This means that the energy and protein in the diet are partitioned in order to maintenance, pregnancy, lactation and growth. In the Danish system, intake of feed is a function of the amount and rumen fill of feed on offer and the intake capacity of the animal. The system is designed for constructing feed rations based on a calculated feed demand and not for describing diet selection, when the feeds on offer exceed requirements, or how the availability of grazed feed varies with herbage mass. FASSET follows the Danish energy and protein systems but assumes that production is constrained by the most limiting factor (energy or protein). Furthermore, it is assumed that animals select feeds in order of decreasing digestibility and continue to add feeds until the capacity rumen is achieved or there are no further feeds available. For grazed feed, the availability is made a function of the herbage mass.

### **8.3.8 Animal housing and manure storage modules**

#### *Animal housing module*

There can be zero, one or several animal houses on the model farm. Each animal house contains one or more animal sections. For example, a pig house could contain a section devoted to dry sows, sows with suckling piglets and weaned piglets. Within constraints of PC memory and speed, there can be an unlimited number of animal sections within a single animal house. Beyond maintaining a database of the animal sections present, the animal house

model simulates the exchange of air with the outside, for both forced-ventilated and naturally-ventilated situations.

Each animal type on the farm (e.g. weaners, mature dairy cows) must be associated with an animal section if they are housed at any time during a simulation period. Each animal section can have one or two types of flooring e.g. slats and solid flooring. The floors accumulate manure and emit ammonia, nitrous oxide, methane and carbon dioxide, each to varying degrees according to their type. Each floor in each animal section is generally associated with a manure store, either internal (such as a slurry pit) or external (such as a slurry tank or manure stack). The exception is for straw-based systems that accumulate the manure on the floor of the animal house itself. In this way, the animal sections ensure that the dung and urine deposited by the animals during their time in the housing is correctly routed. For example, it means that changes in the diet of an animal group that affect the composition of the manure produced, will be reflected in, for example, the ammonia emission from the relevant animal section, and the emissions and composition of the manure in the manure store.

#### *Manure storage module*

Manure can be stored as a liquid or a solid. Liquid manure can be stored in a tank or a lagoon. The model does not distinguish between the two types; the only difference between the two is in the surface area and the depth. The only processes simulated in the slurry store are the loss of ammonia by volatilisation and the change in water volume caused by precipitation and evaporation. Solid manure is stored in stacks or on the floor of the animal housing. The loss of ammonia is currently simulated very simply (using an emission factor) and the losses of methane, nitrous oxide and carbon dioxide are not simulated at all.

#### *Technical operations module*

Technical operations include all the major manual or automated operations on the farm. (Note: an exception is the time and/or expense of book-keeping. For a modern farm in Europe, this can be considered a major operation). The technical operations module has two major functions; to hold information that other modules need to know at the time the operation is carried out e.g. the depth of ploughing, and to calculate the use of resources associated with performance of the operation e.g. labour required, fossil energy used.

The technical operations are divided into two categories; field operations, housing and manure store operations.

### 8.3.9 Management

There is currently relatively little simulation of management as this was previously handled by the GAMS model. The most developed management submodule is of cattle feeding. Grassland management is currently being added.

### 8.3.10 Economics

The economics in the model are relatively basic and consist of two main elements; the gross margin, based on the costs of the various technical operations, and the investment costs of buildings and machinery.

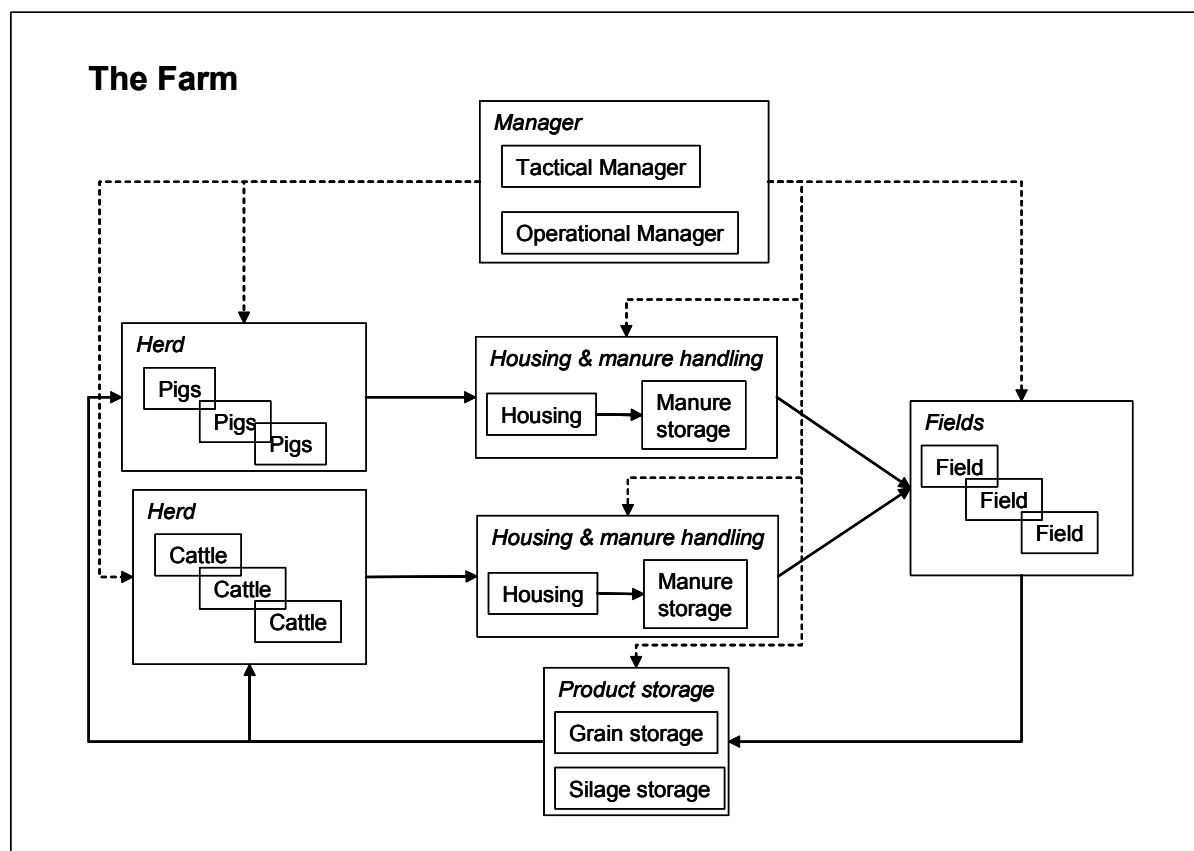


Figure 1: Outline of a Fasset farm

## 9 APPENDIX II: ADDITIONAL TABLES AND FIGURES

**Table 4: General list of indicators, which are or will be implemented in AgriPoliS. As it is a general list will it be possible to specify most indicators further into individual production types and other character traits of the farms.**

Type of indicator	Name of indicator	Present indicators	Planned indicators	Indicators under consideration	Present in the Input data	Modified in AgriPoliS through runtime	Created in AgriPoliS through runtime
<b>Scale of indicators</b>	<b>(Regional=R Individual farm level=F)</b>						
<i>Structural characteristics</i>							
R	Total number of farms in the region	X			X	X	
R	Total production in the region	X			X	X	
R+F	Composition of different production types	X			X	X	(x)
R	Arable land in the region	X			X		
R	Share of arable land utilized for production	X			(x)	X	
R	Pasture land in the region	X			X		
R	Share of pasture land utilized for production	X			(X)	X	
R+F	Leased land	X			(x)	X	
R+F	Production type and size	X			X	X	
R+F	Production structure	X			X	X	
R+F	Full-time farming	X			X	X	
R+F	Part-time farming	X			X	X	
R+F	Quit farming	X				X	
R+F	Hired labour	X				X	X
R+F	Perennial crops		X		(x)		
R+F	Explicit spatial position			X			
R+F	Age distribution	X				X	X
<i>Economics</i>							
R+F	Total amount of subsidies	X				X	(x)
R+F	Prices of output	X			X	X	
R+F	Demand for farm labour	X				X	
R+F	Farm size (hectares/turnover)	X			X	X	
R+F	Income off-farm labour	X				X	
R+F	Income on-farm labour	X				X	
R+F	Salaried labour (hours/year)	X			X		
R+F	Total amounts of price supports and subsidies obtained per year	X				X	
R+F	% income from off-farm activities	X				X	
R+F	% share of pluri-active farm households	X			X	X	
R+F	Average degree of mechanisation	X			X	X	
R+F	Average earnings per capita	X			X	X	
R	Average size of farms	X			X	X	
R	Average size of livestock farms	X			X	X	
R+F	Farm buildings	X			(X)	X	
R+F	Farm income	X			X	X	
R	Farm size distribution (area/output)	X			X	X	
R	Farm structures	X			X	X	
R+F	Intensity of production/enterprise	X				X	
R+F	Intensity of production/hectare	X				X	
R+F	Labour employed in agriculture	X			X	X	
R+F	Labour employed in livestock farming	X				X	
R	Number of farms (change in total number of farms)	X				X	

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R	Number of livestock farms	X		X	X
R+F	Volume of production	X		X	X
R+F	Average rent per plot	X			X
R+F	Average land price		X		X
R+F	Transport cost	X			
R+F	Liquidity	X		X	X
R+F	Equity capital	X			X
R+F	Borrowed capital	X			X
R+F	Income from interest	X			X
R	Interest rate	X		X	

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**Table 5: General list of indicators, which are or will be implemented in MODAM**

Please note: double indicators are excluded from the list and in case of several very similar indicators only one is listed (e.g. "Area under nature protection" and "Area under nature conservation" and "Protected areas" or "Area under agri-environmental support" and "Area enrolled in agri-environmental schemes" and "Area covered by AEP")

Type of Indicator	Indicator (Yucas list)	Indicator from Johannes' list of MODAM inputs)	Present Indicator	Planned Indicator	Indicator under Consideration	Input MODAM	Output MODAM		Remarks
							Modified	Created	
Scale R =Regio. F =Farm									
	<b>Structural Data</b>								
R+F	Area of agricultural land		x			x			
R+F	Arable land		x			x			
R+F	Grassland		x			x			
R	Area under organic farming		x			(x)?			
	<b>General economic characteristics</b>								
F	Farm buildings		x			x			
R+F	Farm size (hectares/turnover)		x			x			
R+F	Farm structures		x			x			
R	Average size of farms		x			x			
R	Average size of livestock farms		x			x			
R	Number of farms (change in total number of farms)		x			x			
R	Number of livestock farms		x			x			
R+F	Volume of production		x					x	
R+F	Farm income		x					x	
R+F	Livestock farming's input in GRP				x			x	
R+F	Soil prices		x			x			
	Land tenure		x			x			
R+F	Interest rate		x			x			
R+F	Labour employed in agriculture		x			x	x		
R+F	Salaried labour (hours/year)		x			x	x		
R+F	Unsalaries labour (hours or cost/year)		x			x	x		
R+F	Labour employed in livestock farming								
	<b>Commodity Outputs (COs)</b>								
	<i>Meat</i>		x					x	
	<i>Output of activities related to meat production</i>								
R+F	Fodder		x					x	
R+F	Milk		x					x	
R+F	Live cows		x					x	
R+F	Production of renewable energy				x			x	
R+F	Biogas generation from manure				x			x	AgChange
R+F	Tourism				x			x	
	<i>Output of other activities not related to beef production</i>								
R+F	Fodder		x					x	
R+F	Nature conservation				x			x	

R+F	Other animals (meat, wool, eggs etc)		x					x	
R+F	Yield of crops		x			x			
R+F		In- and output prices	x			x			
R+F	Organic producer prices		x			x			
	<b><i>Crop and livestock production activities</i></b>								
R+F	Management practises		x			x	x		
R+F	Specialisation/diversification		x			x	x		
R+F	Organic farming		x			x	x		
R+F	Intensification and extensification of agricultural land use		x			x	x	x	
R+F	Extensive managed grasslands		x			x	x	x	
R+F	Traditional crop/livestock		x			x	x		
R+F	Traditional farming practises				x	x	x		
	<b><i>Crop production activities</i></b>								
R+F	Agricultural practises (ploughing, winter cover crops)		x			x			
R+F	Cultivation of fragile land				x	x	x		Definiton of "fragile" needed
R+F	Land management practises (share of the total crop area under environmental land management practises)				x			x	GIS
R+F	Leaving of crop residues on the field		x			x	x		
R+F	Soil cultivation techniques		x			x	x		
R+F	Use of integrated crop protection methods		x			x	x		
R+F	Acreage of cultivated crops		x					x	"= crop composition"
R+F	Acre/percentage of green cover crops		x					x	
R+F	Rotation system (% fallow, crops, grazing, tree cover etc per year)		x			x	x		
R+F	Land cover change		x					x	Scenarios
	<b><i>Livestock production activities</i></b>								
R+F	Grazing practises		x			x	x		
F	Grazing management e.g. days at grass - seasonal grazing		x			x	x		
F	Fencing or shepherding of livestock				x	x	x		
R+F	Land used for livestock-farming		x				x		
F	Manure management		x			x	x		
F	Manure spreading		x			x	x		
F	Manure storage		x			x	x		
F	Manure disposal				x	x	x		
F	Type and capacity of manure storage		x			x	x		
F	Type of spreading equipment		x			x	x		
F	Timing and number of slurry applications		x			x	x		
F	Number times per year that grass is cut		x			x	x		
R+F	Stocking density		x			x	x		

R+F	Distance of manure/fertiliser spreading from water courses/other landscape elements				x			x	GIS
R+F	<b>Crops and Livestock</b>								
R+F	Livestock composition		x			x	x		
R+F	Livestock concentration		x			x	x		
R+F	Monthly grazing density		x			x	x		
R+F	Size of the herd		x			x	x		
R+F	<b>Inputs</b>								
R+F	Fertiliser use		x			x	x		
R+F	Nutrient balance							x	
R+F	Pesticide use		x			x	x		
R+F		Machinery	x			x	x		
R+F		Labour	x			x	x		
R+F	Energy use		x			x	x		
R+F	Fodder	Fodder	x			x	x		
R+F	Degree of self sufficiency in feed				x			x	
F	Partition of feed		x			x	x		
R+F		Animals	x			x	x		
R+F	Cows		x			x	x		
R+F	Animal welfare			x				x	
R+F	Access to outdoor areas for animals		x			x	x		
R+F	Animal transportation				x	x	x		
R+F	Housing conditions		x			x	x		
	<b>Policy Framework</b>								
R+F		Less favoured regions	x			x			
R+F	Area enrolled in agri-environmental schemes		x			x	x		GIS/Scenarios
R+F	Used Agricultural Area (UAA) within protected sites (according to IUCN categories)				x	x	x		GIS
R+F	Environmental elements of CAP spending		x			x	x		EU support
R+F	Use of cross compliance instrument		x			x	x		Scenarios
R+F	Area under nature protection				x	x			GIS
R+F	Area of high natural value				x	x			GIS
R+F	Area of high nature value grassland etc.				x	x			GIS
R+F	Bird protection areas				x	x			GIS
R+F	Area under organic farming		x			x	x		
R+F	Total amounts of price supports and subsidies obtained per year	Direct farm payments	x			x	x		
R+F		Quotas (milk, sugar beets)	x			x			
R+F		Subsidies (crops, animals)	x			x	x		
R+F	Organic producer price premiums		x			x			
R+F	<b>Climatic and soil conditions</b>		x			x			
		Climatic zones (average precipitation, temperatures)	x			x			

R+F	Soil quality		x			x			
R+F	Relief			(x)		x			GIS
R+F	Wetlands				x	x			GIS
R+F	Land use suitability			(x)		x			GIS
F	Soil compaction				x	x			GIS
R+F	Soil type		x			x			GIS
	<b>Non commodity outputs (NCOs)</b>								
R	Regional levels for environmental targets			(x)		x			Study Regions
R	Regional levels of good farming practises			(x)		x			Study Regions
	<b>Abiotic resource protection</b>								
	<b>Air</b>								
F	Greenhouse gas emissions			x				x	
F	CH4			x				x	
F	CO2			x				x	
F	N2O			x				x	
F	Dust emissions			(x)				x	AgChange
F	Smell nuisance (NH3; S)			(x)				x	AgChange
	<b>Soil</b>								
R+F	Soil erosion risk								
R+F	Water erosion		x					x	
R+F	Wind erosion			(x)				x	AMA, Adaption
F	Maintaining land fertility, seed banks			(x)				x	AgChange
F	Humus balance			(x)				x	AgChange
F	Organic matter content			(x)				x	AgChange
F	Soil acidification			(x)				x	AgChange: pH
F	Nitrogen balance (per hectare)		x					x	
F	Nitrate surplus		x					x	
	<b>Water</b>								
R+F	Nitrogen leaching				(x)			x	Risk evaluation
R+F	Nitrate leaching		(x)					x	Risk evaluation
R+F	Water eutrophication		(x)					x	N+P
R+F	Risk of water contamination by nitrogen		(x)					x	Risk evaluation
R+F	Risk of water contamination by phosphorus		(x)					x	Risk evaluation
R+F	Risk of water contamination by pesticides		(x)					x	Risk evaluation
R+F	Ground water supply		(x)					x	Ground water recharge potential evaluation
	<b>Biodiversity</b>								
R+F	Beneficial crop patterns for flora and fauna		x					x	Examples
R	Flagship species				x			x	Examples
R+F	Number of stock of endangered breeds				x	x	x		
	<b>Habitats</b>								
R+F	Impact on the habitat potential for amphibians (red belly toad)		x					x	
R+F	Impact on the habitat potential for field hares		x					x	

R+F	Impact on the habitat potential for hover flies		x					x	
R+F	Impact on the habitat potential for skylarks		x					x	
R+F	Impact on the habitat potential for wild flora species (fall germinating)		x					x	
R+F	Diversity of Habitats				x	x	x		GIS
R+F	Aquatic and wetland habitats				x	x			GIS
R	Corridor and linkages between habitat types				x	x	x		GIS
	<b>Landscape</b>								
R	Landscape heterogeneity				x			x	AgChange
R+F	Landscape character linked to forms of land management that are economically at risk				x			x	
R	Length of boundaries between land cover types				x			x	GIS
R+F	Number of natural habitat types bordering at AU				x			x	GIS
R	Landscape value				x			x	AgChange
	<b>Human Health and other Concerns</b>								
R+F	Drinking water quality				(x)			x	AgChange
R+F	Food/raw material quality				(x)			x	AgChange
R+F	Food safety				(x)			x	AgChange
R+F	Release of GMOs				(x)			x	AgChange

**Table 6: Annual output from FASSET**

01.00	-Farm characteristics-	
01.01	Total area	ha
01.02	DE (old)	no
01.03	DE/ha (old)	no/ha
01.04	DE (new)	no
01.05	JB 1-4	ha
01.06	JB 5-7	ha
03.00	-Capital-	
03.01	Value of arable land	Dkr
03.02	Value of buildings & inventory	Dkr
03.03	Value of machinery	Dkr
03.05	Value of stored products	Dkr
03.06	Value of livestock	Dkr
03.07	Assets	Dkr
03.50	Value young cattle	Dkr
03.51	Value mature cattle	Dkr
05.00	-Gross margin-	
05.01	Gross margin	Dkr
05.10	Plant products sold	Dkr
05.11	W.wheat sold	Dkr
05.12	S.wheat sold	Dkr
05.13	W.rape sold	Dkr
05.14	S.rape sold	Dkr
05.15	W.barley sold	Dkr
05.16	S.barley sold	Dkr
05.17	Rye sold	Dkr
05.18	Oat sold	Dkr
05.19	Pea sold	Dkr
05.20	Potato sold	Dkr
05.21	Grass for seed sold	Dkr
05.22	Maize sold	Dkr
05.23	Beet sold	Dkr
05.24	Straw sold	Dkr
05.25	Roughage sold	Dkr
05.30	Sows sold	Dkr
05.31	Baconers sold	Dkr
05.32	Piglets sold	Dkr
05.33	Cast sows sold	Dkr
05.50	Young 1st year heifers sold	Dkr
05.51	Young 2nd year heifers sold	Dkr
05.52	Dairy cattle sold	Dkr
05.53	Beef cattle calves sold	Dkr
05.54	Mature beef cattle sold	Dkr
05.55	Milk sold	Dkr
05.70	Ha premium	Dkr
06.10	Plant production misc. costs	Dkr
06.11	Costs seed	Dkr
06.12	Costs mineral fertilizer	Dkr
06.13	Costs chemicals	Dkr
06.14	Costs fuel	Dkr
06.15	Costs electricity	Dkr
06.16	Costs imported manure	Dkr
06.30	Piglets bought	Dkr
06.31	Sows bought	Dkr
06.32	Costs feed and bedding	Dkr
06.33	Cost of vet and production control	Dkr
06.50	Young 1st year heifers bought	Dkr
06.51	Young 2nd year heifers bought	Dkr
06.52	Dairy cattle bought	Dkr
06.54	Beef cattle calves bought	Dkr
06.55	Mature beef cattle bought	Dkr
06.70	Costs hired hours	Dkr
06.80	Nlevy1 (mineral fertilizer)	Dkr
06.81	Nlevy2 (mineral fertilizer + imported feed)	Dkr
06.82	Nlevy3 (import-export)	Dkr
06.83	Nlevy4 (import-export) above level	Dkr

07.00	-Farm profit -	
07.01	Net profit	Dkr
07.02	Depreciation buildings & inventory	Dkr
07.03	Depreciation machinery	Dkr
07.04	Insurance buildings & inventory	Dkr
07.05	Insurance machinery	Dkr
07.06	Maintenance buildings & inventory	Dkr
07.07	Maintenance machinery	Dkr
07.08	Cost of machine contractors	Dkr
09.00	-Net profit -	
09.01	Total interest	Dkr
09.02	Total salary	Dkr
09.10	Total savings	Dkr
09.11	Earnings per hour	Dkr
09.12	Return on capital	%
11.00	-Store-	
11.10	W.wheat store	t
11.11	S.wheat store	t
11.12	W.rape store	t
11.13	S.rape store	t
11.14	W.barley store	t
11.15	S.barley store	t
11.16	Rye store	t
11.17	Oat store	t
11.18	Pea store	t
11.19	Potato store	t
11.20	Grass for seed store	t
11.21	Maize store	t
11.22	Beet store	t
11.30	Sows present	no
11.31	Baconers present	no
11.32	Piglets present	no
11.33	New sows present	no
11.50	Young cattle present	no
11.51	Mature cattle present	no
11.70	Slurry in slurystore	t
11.71	Dung in dungheap	t
13.00	-Labour-	
13.01	Total labour	hours
13.10	Labour, field	hours
13.11	Field-labour 0	Hours
13.12	Field-labour 1	hours
13.13	Field-labour 2	hours
13.14	Field-labour 3	hours
13.15	Field-labour 4	hours
13.16	Field-labour 5	hours
13.17	Field-labour 6	hours
13.18	Field-labour 7	hours
13.19	Field-labour 8	hours
13.20	Field-labour 9	hours
13.21	Field-labour 10	hours
13.22	Field-labour 11	hours
13.30	Labour, stable	hours
13.50	Labour, maintance and management	hours
15.00	-Areas-	
15.10	W.wheat area	ha
15.11	S.wheat area	ha
15.12	W.rape area	ha
15.13	S.rape area	ha
15.14	W.barley area	ha
15.15	S.barley area	ha
15.16	Rye area	ha
15.17	Oat area	ha
15.18	Pea area	ha
15.19	Potato area	ha
15.20	Grass for seed area	ha
15.21	Maize area	ha
15.22	Beet area	ha

15.23 Barley/Pea area	ha
15.24 Grass ley area	ha
15.25 Grass/clover ley area	ha
15.26 Fallow area	ha
16.10 W.wheat area (harv. bef. 1/8)	ha
16.11 S.wheat area (harv. bef. 1/8)	ha
16.12 W.rape area (harv. bef. 1/8)	ha
16.13 S.rape area (harv. bef. 1/8)	ha
16.14 W.barley area (harv. bef. 1/8)	ha
16.15 S.barley area (harv. bef. 1/8)	ha
16.16 Rye area (harv. bef. 1/8)	ha
16.17 Oat area (harv. bef. 1/8)	ha
16.18 Pea area (harv. bef. 1/8)	ha
16.19 Potato area (harv. bef. 1/8)	ha
16.20 Grass for seed area (harv. bef. 1/8)	ha
16.21 Maize area (harv. bef. 1/8)	ha
16.22 Beet area (harv. bef. 1/8)	ha
16.23 Barley/Pea area (harv. bef. 1/8)	ha
16.24 Grass ley area (harv. bef. 1/8)	ha
16.25 Grass/clover ley area (harv. bef. 1/8)	ha
16.26 Fallow area (harv. bef. 1/8)	ha
17.00 -Yields-	
17.01 Gross output of plant production	Dkr
17.10 W.wheat yield (harv. bef. 1/8)	t
17.11 S.wheat yield (harv. bef. 1/8)	t
17.12 W.rape yield (harv. bef. 1/8)	t
17.13 S.rape yield (harv. bef. 1/8)	t
17.14 W.barley yield (harv. bef. 1/8)	t
17.15 S.barley yield (harv. bef. 1/8)	t
17.16 Rye yield (harv. bef. 1/8)	t
17.17 Oat yield (harv. bef. 1/8)	t
17.18 Pea yield (harv. bef. 1/8)	t
17.19 Potato yield (harv. bef. 1/8)	t
17.20 Grass for seed yield (harv. bef. 1/8)	t
17.21 Maize yield (harv. bef. 1/8)	t
17.22 Beet yield (harv. bef. 1/8)	t
17.23 Ryegrass yield (harv. bef. 1/8)	t
17.24 Clover yield (harv. bef. 1/8)	t
17.25 Fallow yield (harv. bef. 1/8)	t
18.10 Exp. W.wheat yield (harv. bef. 1/8)	t
18.11 Exp. S.wheat yield (harv. bef. 1/8)	t
18.12 Exp. W.rape yield (harv. bef. 1/8)	t
18.13 Exp. S.rape yield (harv. bef. 1/8)	t
18.14 Exp. W.barley yield (harv. bef. 1/8)	t
18.15 Exp. S.barley yield (harv. bef. 1/8)	t
18.16 Exp. Rye yield (harv. bef. 1/8)	t
18.17 Exp. Oat yield (harv. bef. 1/8)	t
18.18 Exp. Pea yield (harv. bef. 1/8)	t
18.19 Exp. Potato yield (harv. bef. 1/8)	t
18.20 Exp. Grass for seed yield (harv. bef. 1/8)	t
18.21 Exp. Maize yield (harv. bef. 1/8)	t
18.22 Exp. Beet yield (harv. bef. 1/8)	t
18.23 Exp. Barley/Pea yield (harv. bef. 1/8)	t
18.24 Exp. Grass/clover yield (harv. bef. 1/8)	t
19.00 -Livestock production-	
19.01 Bought sows	no
19.02 Bought piglets	no
19.03 Sold new sows	no
19.04 Sold baconers	no
19.05 Sold piglets	no
19.06 Sold cast sows	no
19.10 Feed for sows	t
19.11 Feed for baconers	t
19.12 Feed for piglets	t
19.30 Bought 1st year heifers	no
19.31 Bought 2nd year heifers	no
19.32 Bought dairy cattle	no
19.33 Bought beef calves	no

19.34 Bought beef cattle	no
19.35 Sold 1st year heifers	no
19.36 Sold 2nd year heifers	no
19.37 Sold dairy cattle	no
19.38 Sold beef calves	no
19.39 Sold beef cattle	no
19.40 Milk sold	Litre
19.50 Imported manure	t
19.60 Manure from sows	t
19.61 Manure from baconers	t
19.62 Manure from piglets	t
19.63 Manure produced by young cattle	t
19.64 Manure produced by dairy cattle	t
19.65 Manure spread on field	t
20.00 -Energy-	
20.01 Diesel consumption	l
20.02 Electricity consumption	KWh
20.03 Diesel consumption by contractor	l
36.00 W.wheat yield (harv. bef. 1/8)	kg N
36.01 S.wheat yield (harv. bef. 1/8)	kg N
36.02 W.rape yield (harv. bef. 1/8)	kg N
36.03 S.rape yield (harv. bef. 1/8)	kg N
36.04 W.barley yield (harv. bef. 1/8)	kg N
36.05 S.barley yield (harv. bef. 1/8)	kg N
36.06 Rye yield (harv. bef. 1/8)	kg N
36.07 Oat yield (harv. bef. 1/8)	kg N
36.08 Pea yield (harv. bef. 1/8)	kg N
36.09 Potato yield (harv. bef. 1/8)	kg N
36.10 Grass for seed yield (harv. bef. 1/8)	kg N
36.11 Maize yield (harv. bef. 1/8)	kg N
36.12 Beet yield (harv. bef. 1/8)	kg N
36.13 Ryegrass yield (harv. bef. 1/8)	kg N
36.14 Clover yield (harv. bef. 1/8)	kg N
36.15 Fallow yield (harv. bef. 1/8)	kg N
19.51 Imported cereals	t
19.52 Imported roughage	t
19.70 Exported roughage	t
19.71 Exported plant products	t
30.00 -Nitrogen-	
31.01 N from mineral fertilizer	kg N
31.02 N from deposition	kg N
31.03 N from seed	kg N
31.04 N from fixation	kg N
31.05 N from irrigation water	kg N
31.06 N from spread manure	kg N
31.07 N in urine from grazing	kg N
31.08 N in faeces from grazing	kg N
31.20 N removed in grain	kg N
31.21 N removed in straw	kg N
31.22 N removed in cut	kg N
31.23 N removed by cattle	kg N
31.40 Nitrate N leached	kg N
31.41 Ammonium N leached	kg N
31.42 N <sub>2</sub> from denitrification	kg N
31.43 N <sub>2</sub> O from denitrification	kg N
31.44 N <sub>2</sub> O from nitrification	kg N
31.45 Ammonia-N loss by spreading	kg N
31.46 Ammonia-N loss during grazing	kg N
31.47 N in surface run-off	kg N
31.60 N in standing crop/straw	kg N
31.61 Total soil/soilsurface N	kg N
32.10 N uptake from soil	kg N
32.20 N from roots incorporated into soil	kg N
32.21 N from straw incorporated into soil	kg N
32.22 N from leaf litterfall incorporated into soil	kg N
32.30 Gross N-mineralisation from soil org. matter	kg N
32.40 Nitrate N leached from leaching depth	kg N
32.41 Ammonium N leached from leaching depth	kg N

32.60 Organic N in soil	kg N
32.61 Mineral N in soil	kg N
32.62 AOM1 N in soil	kg N
32.63 AOM2 N in soil	kg N
32.64 SMB1 N in soil	kg N
32.65 SMB2 N in soil	kg N
32.66 SMR N in soil	kg N
32.67 NOM N in soil	kg N
32.68 IOM N in soil	kg N
33.01 N in feed for young cattle	kg N
33.02 N in feed for adult cattle	kg N
33.03 N in bought cattle	kg N
33.04 N grazed by cattle	kg N
33.20 N in milk	kg N
33.21 N in sold cattle	kg N
33.40 N in dairy cattle waste	kg N
33.41 N in young cattle manure	kg N
33.42 N in dairy cattle manure	kg N
33.60 N bound in cattle	kg N
33.80 Cattle manure N to pasture	kg N
33.81 Cattle manure N to animal housing	kg N
33.82 Meat production	kg N
34.01 N in feed for piglets	kg N
34.02 N in feed for sows	kg N
34.03 N in feed for baconers	kg N
34.04 N in bought pigs	kg N
34.20 N in sold pigs	kg N
34.40 N in sows manure	kg N
34.41 N in baconers manure	kg N
34.42 N in piglets manure	kg N
34.60 N bound in pigs	kg N
35.01 N from imported feed	kg N
35.02 N from imported manure	kg N
35.03 N from imported bedding	kg N
35.04 N from harvest to store	kg N
35.20 N in sold plant products	kg N
35.21 N removed from manure storage	kg N
35.40 NH4-N volatilisation from animal house	kg N
35.41 NH4-N volatilisation from manure storage	kg N
35.60 N bound in manure storage	kg N
35.61 N bound in stable manure	kg N
35.62 N in stored plant products	kg N
35.63 N in bedding	kg N
35.70 N bound in virtual store - temporary	kg N
35.80 N transf. from stable to store	kg N
35.81 N removed from stored plant products	kg N
40.00 -Carbon-	
40.01 Net crop carbon fixation	kg C
40.02 Carbon from manure	kg C
40.20 C removed in grain	kg C
40.21 C removed in straw	kg C
40.22 C removed in cut	kg C
40.23 C removed by cattle	kg C
40.40 CO2 soil respiration	kg C
40.60 Total carbon in soil	kg C
40.61 C in standing crop/straw	kg C
40.80 C from roots incorporated into soil	kg C
40.81 C from straw incorporated into soil	kg N
40.82 C from leaf litterfall incorporated into soil	kg C
40.90 AOM1 C in soil	kg C
40.91 AOM2 C in soil	kg C
40.92 SMB1 C in soil	kg C
40.93 SMB2 C in soil	kg C
40.94 SMR C in soil	kg C
40.95 NOM C in soil	kg C
40.96 IOM C in soil	kg C
41.01 C input into cattle	kg C
41.02 C in cattle methane production	kg C

41.03 C in cattle urine	kg C
41.04 C in cattle faeces	kg C
41.05 C in cattle CO2 production	kg C
41.06 C in milk production	kg C
41.07 C retained in cattle body	kg C
50.00 -Phosphorus-	
50.01 Phosphorus from mineral fertilizer	kg P
50.02 feed-P for sows	kg P
50.03 feed-P for baconers	kg P
50.04 feed-P for piglets	kg P
50.10 manure-P from sows	kg P
50.11 manure-P from baconers	kg P
50.12 manure-P from piglets	kg P
60.00 -Potassium-	
60.01 Potassium from mineral fertilizer	kg K
60.02 feed-K for sows	kg K
60.03 feed-K for baconers	kg K
60.04 feed-K for piglets	kg K
60.10 manure-K from sows	kg K
60.11 manure-K from baconers	kg K
60.12 manure-K from piglets	kg K
70.00 -Water-	
70.01 Rainwater	cubic meter
70.02 Irrigation	cubic meter
70.10 Percolation	cubic meter
70.11 Surface run-off	cubic meter
70.12 Evapotranspiration	cubic meter
70.20 Water in soil	cubic meter
70.40 Percolation from leaching depth	cubic meter
70.41 Water in soil to leaching depth	cubic meter
70.42 Bare soil evaporation	cubic meter
70.50 Precipitation	mm
80.00 -Pesticides-	
80.01 Herbicide consumption	TFI
80.02 Fungicide consumption	TFI
80.03 Insecticide consumption	TFI