The agricultural world in equations

An overview of the main models used at LEI

LEI WAGENINGEN UR

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Contents

Preface

The main assets of our research institute are the expertise of our researchers, the data carefully collected and maintained in our databases, and our computer models that add value to the data and persist and operationalise the researchers' expertise. This report presents an overview of operational models, which have been and can be deployed in a broad range of research projects. These models are ready for use in future projects. They are developed and maintained by teams of researchers who incorporate new scientific insights, include recent knowledge about the systems being modelled, and adapt the models to emerging demands from society and policy makers. In many cases the original developers have left our institute, but their expertise persists in the models and continues to be extended by current modelling teams. The report serves two purposes. First, to provide an overview to employees, partners, and end users who are involved in, or interested in, modelling at LEI. Second, to provide a basis for strategic decisions with respect to investments and maintenance of models.

The models cover the domain of agricultural economics from the world market to individual producers' decisions, and address aspects such as the natural environment and sustainability. The methodological diversity reflects the variety of aggregation levels, time scales, and issues addressed. It includes general equilibrium modelling, positive mathematical programming, optimisation techniques, and multi-agent simulation. This report gives an overview of the state-of-the-art of modelling in our institute. The initiators of this work, Geert Woltjer and Irina Bezlepkina, added a section on model linkages that makes clear that none of these models stands on its own. All of the models are related to other models, and appropriate combinations of models can be deployed in research projects.

Although much work remains to be done, this report shows the advances that have been realised in the past decade. Further investments are necessary to maintain LEI's analytical position of the sector and, at the same time, keep up with the evolution of methodological insights and continue model quality standardisation. One of the organisational challenges we are faced with, is to develop a consortium in which this position can be sustained.

Prof. Dr R.B.M. Huirne
Managing Director LEI

1 Introduction

At LEI, several different quantitative models are being used. In many projects more than one model is used and in some cases information from one model is explicitly used in another model. This report attempts to sketch brief overviews of the main models used at LEI.

The report documents the model along the hierarchy as depicted in Figure 1.1, i.e. models ranging from a high to low regional or sectoral aggregation. MAGNET is a global general equilibrium model of the world economy with the country as the maximum level of detail. It describes the world economy as a whole. ORANGE is a national general equilibrium model of the Netherlands and its 12 provinces, with numerous details of the Dutch sectors.

At the next level are the models of the agricultural (and fishery) sector with a focus on Europe. The models AGMEMOD, CAPRI, HORTUS, and FISHRENT are focused on the European economy, where the rest of the world is one region. These models have a lot of detail in the agricultural sector, but have no non-agricultural sector. AGMEMOD models agriculture at a national level and estimates national equations that have a rough template in common, but allow for differences in functional form between countries. CAPRI models the agricultural sector in the EU-27 at Member State, NUTS 2 level and farm type level. A module covering the supply of agricultural and horticultural products in the EU-27 is iteratively linked to a market module. The market module covers bilateral trade of commodities between a large number of trading blocks. HORTUS models the horticulture sector only (and its branches) for the 27 European countries. FISHRENT focuses on the regional level. It was originally developed to estimate resource rents from European fish stocks. The analysis is at the level of a fishery: a combination of target species and the fleet segments fishing for these target species. In most cases fleet segments from different Member States are involved.

Next to ORANGE, the following models are developed for the Netherlands, but can in principle be applied elsewhere. DRAM provides much more detail of the agricultural sector in the Netherlands than CAPRI, which is available at the level of 66 regions and includes a manure market, specifically relevant for the Netherlands. MAMBO calculates manure and its environmental effects in great detail.

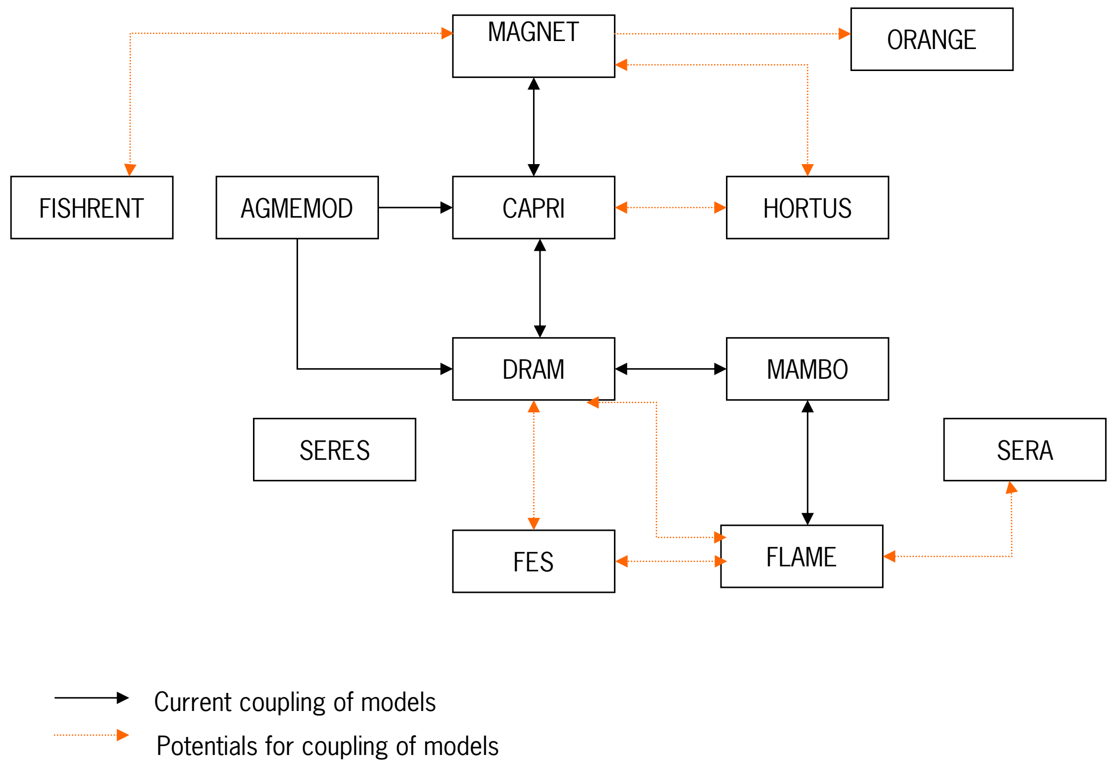
SERES has been designed for reserve sites in the Netherlands. It addresses the cost effectiveness of nature conservation policies. Also an agent-based model SERA operates at an area-specific level, taking into account interaction between farmers and can also use input from models at other levels. The bottom level of the presented models is the farm level. FES is an accounting model with a rudimentary investment equation. Model FLAME is under development but will be capable of simulating farm level behaviour for a wide variety of policy and market analysis purposes.

In this report the models presented in Figure 1.1 will be discussed in a general way. This will provide a basic idea of these models' possibilities, including the opportunities to link the models with each other. The models will be discussed according to the following general format:

- the objectives of the model: what can be analysed with the model;
- the essential mechanisms within the model;
- the required input;
  This includes a characterisation of the data in the base year, the coefficients and relevant information needed for scenario projections. The main sources of the data are sketched;
- the most important output of the model and how this can be used;
- the strengths and weaknesses of the model.

The report concludes with a chapter that outlines the existing and potential possibilities for model linking and indicates some techniques to scale the modelling results.

Figure 1.1 **Overview of models at LEI and their relationships**



2 MAGNET[1]

2.1 Objectives

MAGNET, i.e. Modular Applied GeNeral Equilibrium Tool, until 2010 called LEITAP (Woltjer, 2009), analyses the effect of changes in trade and agricultural policies on international trade, production, consumption, prices and use of production factors. The model is mainly used to simulate long-term scenarios and to analyse policy options within these scenarios. By coupling MAGNET with biophysical models such as IMAGE or CLUE, results about greenhouse gasses or biodiversity may be generated. The model is used for example to analyse the effects of the EU agricultural policy, including second-pillar policies, and biofuel policies.

2.2 Description

MAGNET has been developed at LEI, part of Wageningen UR (University and Research centre). The model is programmed in GEMPACK. Compared with the original version of the GTAP model at LEI it has been extended and stylised considerably. It has recently been reconstructed to make it modular.

The MAGNET model is based on the general equilibrium model GTAP (Hertel and Tsigas, 1997), which was developed at Purdue University in the US. MAGNET uses the carbon market and the rough characteristics of the production structure of the energy-variant of GTAP, GTAP-E (Burniaux and Truong, 2001). It uses the international capital flow accounting system of the dynamic GTAP model GTAP-DYN (Ianchovichina, 2000), and includes also some parts of the agricultural variant of GTAP, GTAP-AGR (Keeney and Hertel, 2005).

GTAP is a global computable general equilibrium model that covers the whole economy, including factor markets. The model uses a consistent database of world trade and production, the GTAP database. The regional aggregation is on a country level, where some countries are aggregated into larger regions.[2] The database distinguishes 54 sectors and 5 endowment sectors (skilled/unskilled labour, capital, natural resources, land). In order to have a model that can be calculated within a day, sectors and countries have to be aggregated, for example to 36 regions and 25 sectors. A programme has been developed to create these aggregations easily from the original database.

The GTAP model is a multi-regional, static, applied general equilibrium model based on neoclassical microeconomic theory. The standard model is characterised by an input-output structure (based on input-output tables of nations and groups of nations) that explicitly links industries in a value added chain from primary goods, over continuously higher stages of intermediate processing, to the final assembling of goods and services for consumption. A representative producer for each sector of a country or region maximises profits by choosing outputs and inputs of labour, capital, natural resources, land and intermediate goods. Each sector produces one type of output. The producer has a nested CES production function with constant returns to scale, where in the standard GTAP model only endowments have elasticities of substitution that are different from zero. Perfect competition is assumed in all sectors within a country. On an international scale goods from the same sector are not homogenous, which is represented by Armington elasticities for import of goods. Primary production factors land, labour and capital cannot move between sectors. Supply of labour, capital, and natural services is exogenous and these production factors are always fully employed.

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[1] Geert Woltjer (geert.woltjer@wur.nl), Marijke Kuiper (marijke.kuiper@wur.nl), Hans van Meijl (hans.vanmeijl@wur.nl) are contact persons for this model.

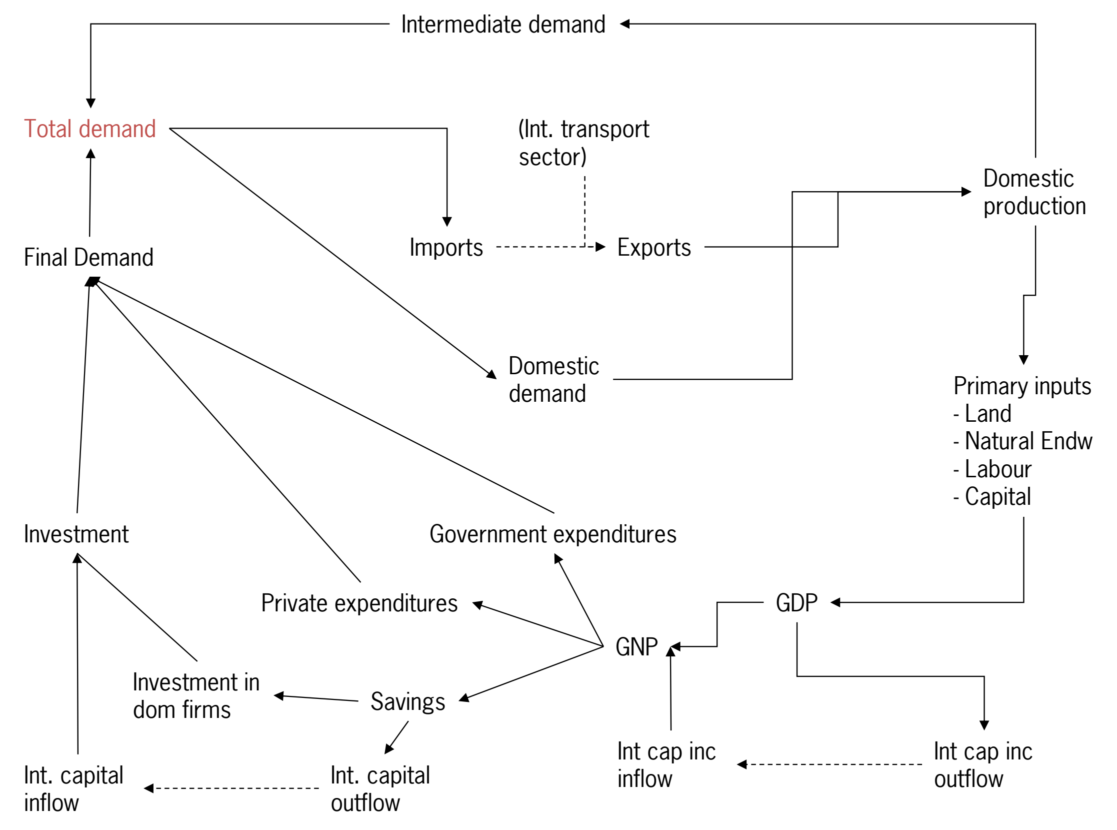
[2] In the GTAP7 database 108 countries and regions are available for the year 2004.

The MAGNET model includes many extensions compared with the standard GTAP model, which have been applied in various studies (Hermans et al., 2010; Neumann et al., 2011; Prins et al., 2011). The different extensions of the model can be switched on or off through a simple change in coefficients or through closure swaps:

- an integrated production structure, with energy, feed and fertiliser nesting dynamic international investment. This has for example been applied in the analysis of bio-fuels (Banse et al., 2008);
- production quota;
- EU-policy, including first and second pillar measures;
- land supply based on biophysical model outcomes from IMAGE (Bouwman et al., 2006; Eickhout et al., 2007) and Dyna-CLUE (Verburg et al., 2002; Verburg et al., 2006; Verburg et al., 2008). It distinguishes between marginal and average land productivity;
- substitution between different types of land (including forestry, see (Walker and Woltjer, 2011) in a dynamic way;
- dynamic mobility of capital and labour between agricultural and non-agricultural sectors;
- income elasticities of consumption as a function of PPP-corrected real GDP per capita;
- the GTAP-E carbon market.

Figure 2.1 presents the circular flow in the MAGNET model.

Figure 2.1 The circular flow in the MAGNET model (Woltjer, 2009) a)



a) GDP=gross domestic product; GNP=gross national product

2.3 Required input

2.3.1 Base period variables

The model uses the GTAP database. This consists of input-output tables that are adapted from tables supplied by countries, product demand by government and private households. All input-output tables and demand tables distinguish between imported and domestically produced products and before- and after-tax values. For international trade, total imported demand for products is allocated to countries, and also these flows are available before and after tax, where the difference between the value of the export of country A to country B and the imports of country B from country A (both at world prices) is the transport margin. This transport margin is allocated to the international transport sectors. We normally model those sectors as part of the service sector. Finally, the value of the capital stock and the value of depreciation is needed, where in the GTAP database it is assumed that the value of depreciation is always 4%.

For MAGNET some extra information is required:

- Area of land (km^2) per sector and country (for land supply),
- Total amount of land that is available and the price elasticity of land supply (for the endogenous land supply module);
- Population and PPP corrected real GDP per capita (to calculate consumption);
- International capital income flows, and preferably also international capital flows (for the model with international capital flows);
- Initial rewards in agriculture relative to its equilibrium value (for the dynamic labour/capital mobility module).

2.3.2 Parameters

MAGNET requires many essential coefficients:

- Consumption function parameters;
- Armington trade elasticities;
- Elasticities and relevant product sets for the input nests;
- CET elasticities for land supply, and parameters for the dynamic or static labour/capital flows between agriculture and non-agriculture;
- For the land supply module: Parameters for the land supply function and the function that determines the marginal productivity of land;
- For the biofuels directive: initial share of petroleum use in the transport sector; and energy content of different energy inputs in the petroleum and/or electricity sector;
- For international capital flows: shares of wealth reallocated per year, and the adjustment coefficients in dynamic capital flow equation;
- The EU agricultural policy model requires some specific parameters about allocation of second pillar funds and the productivity effect of investments in human and physical capital.

These parameters are sometimes based on econometric research or economic literature, and are sometimes best guesses.

2.3.3 Scenario projection variables

The most important variables needed in scenarios are:

- Population growth;
- Productivity growth (or GDP growth, where technology is distributed over sectors and inputs according to fixed proportions);[1]
- Growth of production factor supply.[2]

2.4 Model output

All the variables that are input to the model are also output. MAGNET is flexible in its time periods, but the minimum length of a period is one year. All value changes are decomposed in quantity and price changes. Important outputs are the percentage changes in prices and quantities of land use, employment, capital use, productivity, production, trade, intermediate input use and consumption. There is a tool available (GEMSE_Analist) to generate regional and sectoral aggregates of the outcomes and to define a lot of indicators derived from the data. Examples are farm income, EU agricultural budget, and changes in real exchange rates.

2.5 Strengths and weaknesses

The model uses a consistent database for the whole world and provides a complete and internally consistent description of the world economy. Both price and quantity changes are in, but not the quantities in physical units (tonnes, et cetera), although these can be easily added for the sectors where a useful quantity indicator (such as tonnes of wheat, tonnes of coal, et cetera) is available. For energy inputs there is already a consistent database available with quantity information and also for greenhouse gasses generated by the energy sectors there is a database available.

In order to make the database consistent, the original data have been distorted (changed compared with the originally delivered data) and a lot of information has been filled in. For example, the allocation of agricultural value added over capital, labour and land is done in a very ad hoc way. Most users of the model are not aware of these rules used in creating the database. The differences in quality of the data are not very visible, although most procedures to create the data have been described somewhere. Improvements of the lucidity of the relationship between the GTAP database and the data on which it is based would be beneficial.

The MAGNET land supply curve approach provides the opportunity to analyse land use effects of policies over the whole world. The current implementation is very rough, but work is going on for improvement. The energy part provides the opportunity to analyse for example the effect of biofuel policies. The energy nest is very flexible, but the fixed coefficients within this nest as well as the calibration of the coefficients is very ad hoc. The same holds for the feed and fertiliser nests in the agricultural sectors.

The model is very general in character and has a tendency to use constant elasticities as much as possible. For some important parts, such as consumption, some improvements have been made in MAGNET, but the empirical foundation remains weak. The Armington approach to international trade allows for bilateral trade, but it simplifies competition a lot and it is not automatically guaranteed that the results are consistent with quantitative supply balances in agriculture, while if Armington elasticities are fixed,

[1] For instance, primary agriculture has four times as much technological change as the service sector; land productivity growth in most cases is exogenously derived from FAO projections.
[2] Sometimes simplified by the assumption that skilled and unskilled labour supply growth with population, and capital stock with GDP (not required in a model with international capital dynamics).

small flows will never become very large. For both problems there may be opportunities to improve, but these drawbacks should be taken into account when interpreting of results with the current model version. In summary, the MAGNET model is very strong in having a consistent accounting system for the whole world and for its ability to incorporate indirect effects of policy measures on land use, income, welfare and production. The drawback is the heroic assumptions that have to be made both in constructing the database and developing a general model. The model helps to think consistently, but the user should be aware that the size of the effects may be influenced by the choice of parameters and functional forms.

3 AGMEMOD[1]

3.1 Objectives

AGMEMOD stands for 'AGricultural MEmber states MODelling' (http://www.tnet.teagasc.ie/agmemod/). Since 2001, it has been developed by the AGMEMOD Partnership, a consortium of national university institutes and research agencies from EU countries and potential accession countries (Chantreuil et al., 2011). The work was supported by public funds from the Commission, through the 5th and 6th Framework Programmes (Chantreuil and Le Barbenchon, 2009) and by financial contributions of the IPTS.

AGMEMOD's main objective is to capture the heterogeneity of European agriculture across EU Member States, while enabling simulations of the CAP and national agricultural policies in a consistent and harmonised way. Yearly projections are conducted for each commodity and country for a ten-year time horizon. These serve as baselines for impact analyses of policy changes.

3.2 Description

AGMEMOD runs and solves in a GAMS environment (Leeuwen et al., 2008). It is a dynamic, partial, multi-country, multi-market equilibrium system. It can provide significant detail on the main agricultural sectors in each EU Member State. Most equations have been estimated econometrically at the individual Member State level. Where estimation was not feasible or meaningful, parameters have been calibrated. The country models contain the behavioural responses of economic agents to changes in prices, policy instruments and other exogenous variables on the agricultural market. Commodity prices clear all markets considered.

A bottom-up approach has been used to integrate country models into AGMEMOD. Country models are based on templates. These templates give flexibility to reflect the differences in agricultural systems, but guarantee that the country models can be integrated into a composite EU model. Analytical consistency across the country models is essential to combine them and it also facilitates the comparison of policy impacts across different countries. Figure 3.1 presents this combined structure of AGMEMOD.

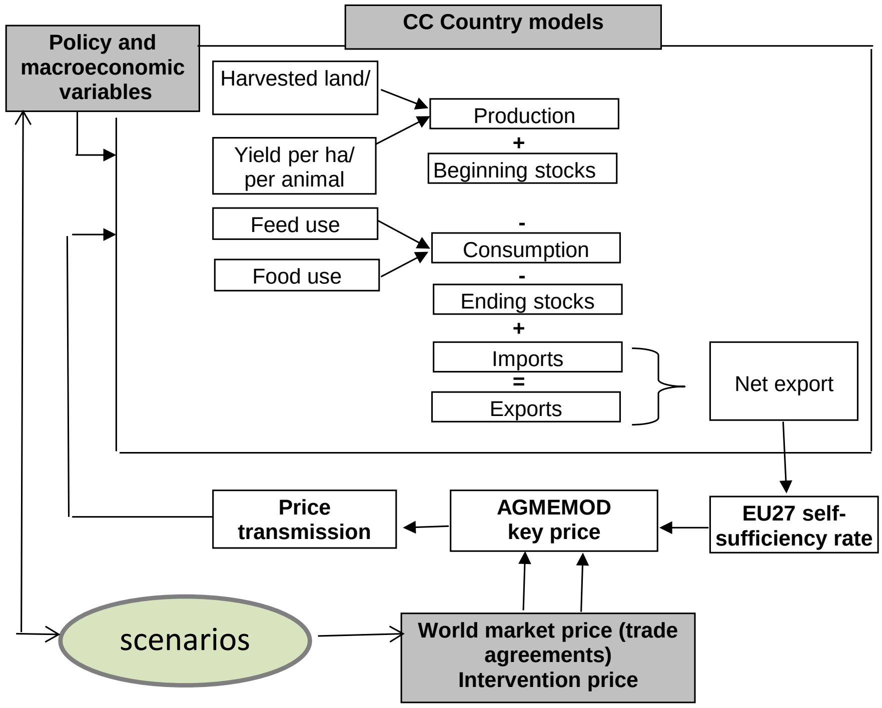
The modelling systems' projections are validated by standard econometric methods and through consultation with experts who are familiar with the agricultural market in the regions under study.

The AGMEMOD model includes the expertise of an extensive network of economists collaborating across the EU. This growing network brought together a level of pan-national expertise that would have been difficult to assemble otherwise. Their activities are supplemented by the assistance of national experts in commodity markets in the individual countries, who frequently review the models and projections produced by the national modelling teams (Salamon and Salputra, 2008).

The current AGMEMOD 4.0 version consists of the EU Member States (with the exception of Malta), the non-EU countries Croatia and the Former Yugoslav Republic of Macedonia, Turkey (AGMEMOD Consortium, 2010), Russia and Ukraine (AGMEMOD consortium, 2011). Models for Brazil and Kazakhstan are under development.

[1] Myrna van Leeuwen (myrna.vanleeuwen@wur.nl) coordinates the model development as well as the AGMEMOD consortium.

Figure 3.1 **The structure of AGMEMOD**



3.3 Required input

3.3.1 Base period variables

Data requirements for AGMEMOD are high, as time series for the parameter estimations are required to cover not only the supply side of agriculture but also different type of usages as well as processing. Each country model is based on a database of annual time series, covering, when possible, a period from 1973 to the latest available year. AGMEMOD's database includes balance sheets for all primary agricultural commodities and most food processing commodities, generally including opening and ending stocks, production, imports, human food consumption, exports, feed use, processing and industrial use for primary agricultural commodities and for many products also for the first processing level. Where possible the AGMEMOD Partnership uses Eurostat sources such as AgrIS (Agricultural Information System) and NewCronos.

An additional dataset captures the evolution of CAP policy instruments, such as direct payment instruments and support.

3.3.2 Parameters

For each commodity in each country agricultural production as well as supply, demand, trade, stocks and domestic prices are derived from econometrically estimated equations. One element of the supply and demand balance for each commodity is used as a closure variable to make the balance consistent. The functional forms of the estimated equations may differ between countries and commodities. In this way the equations can be adjusted to differences in institutions or data availability. All the country models are revised regularly.

3.3.3 Scenario projection variables

The AGMEMOD incorporates the following exogenous variables for the scenario projections:
- world prices for each commodity, currently based on the FAPRI March 2009 Outlook, which uses the FAPRI modelling system (Salamon and Salputra, 2008) for its projections;
- policy instruments, such as national envelopes, historical and regional payments, coupling and modulation rates, intervention prices and quotas (Erjavec et al., 2011; Salputra et al., 2011);
- macroeconomic variables, such as growth rates of population and real GDP per capita, inflation, exchange rates, with their exogenous projections mostly obtained from the national statistical services in the Member States or internationally recognised macroeconomic forecasters.

3.4 Model output

AGMEMOD provides output for the following agricultural commodities:
- cereals (soft wheat, durum wheat, barley, maize, rye, other grains);
- oilseeds (rapeseed, sunflower seed, soybeans, cotton seeds, vegetables oils and meals);
- livestock and meat (beef and veal, pork, poultry, sheep and goats);
- milk and dairy products (butter, skimmed milk powder and cheese);
- fruits and vegetables sector (tomatoes, oranges, apples, olive oil);
- industrial crops (sugar beets tobacco and cotton) and potatoes;
- bioethanol (from grains) and biodiesel (from oilseeds).

Baseline and scenario projections results cover:
- the individual EU Member States: Austria, Belgium (including Luxembourg), Denmark, Finland, France, Germany, Greece (including Cyprus), Ireland, Italy, the Netherlands, Portugal, Spain, Sweden, the United Kingdom, the Czech Republic, Bulgaria, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, the Slovak Republic and Slovenia;
- EU27 as a whole (27 Member States from January 2007);
- non-EU Member States: Croatia, Macedonia, Turkey, Russia and Ukraine.

3.5 Strengths and weaknesses

The main strengths of AGMEMOD are:
- strong and broad European network of research economists working in the field of agricultural policy analysis;
- strong panel database behind the model;
- integrated software to estimate equations and put the results into the model;
- transparent structure in GAMS model code, which leads to relatively low entry costs for new model users;
- researcher-friendly programming tool, which helps to run scenarios and to compare scenario results;
- low requirements in computation time and computer hardware;
- easily extendible with new commodities and new countries;
- applicable to several studies for IPTS-JRC: in analysing CAP reform scenarios (2007), dairy policy scenarios (2008), extension with Turkey. Russia, Ukraine and Kazakhstan (AGMEMOD Consortium, 2011).

The main weaknesses of AGMEMOD are:
- no feedback of the EU with the Rest of the World (small country assumption);
- exogenous land prices;
- the influence of the oil price is not included in bio-energy demand and supply functions;

- equations are estimated separately, not as a system;
- it does not capture a harmonised agricultural income model.

4 CAPRI[1]

4.1 Objectives

The Common Agricultural Policy Regional Impact model (CAPRI, http://www.capri-model.org/) calculates the effects of EU agricultural and trade policy on European agriculture. The model calculates effects on production, income, markets, trade and the environment from a global to a regional scale. The model has the opportunity to downscale crop shares, yields, stocking densities and fertiliser application rates to 150.000 homogeneous soil mapping units. This can be very useful for environmental impact assessments.

The CAPRI modelling system consists of specific data bases, a methodology, its software implementation and the researchers involved in their development, maintenance and applications.

4.2 Description

CAPRI is a global agricultural partial equilibrium model with a focus on the EU27, plus Norway and the Western Balkans. The CAPRI model consists of two interlinked components: individual regional non-linear programming models per NUTS 2 region covering up to ten farm types, and a global trade model.

The supply module of CAPRI consists of a total of 1,888 independent mathematical supply models for the EU-27, of which 1,823 are farm type models, and 65 are NUTS 2 supply models. These models cover around 50 crop and animal activities for each of the farm types and include around 50 different inputs and outputs (Gocht et al., 2011).

The CAPRI global market model is a comparative static spatial global Multi-Commodity model. It covers 47 primary and secondary agricultural products and models bi-lateral trade between 60 countries grouped in 28 trade blocks.

The CAPRI market model is iteratively linked in a transparent and consistent way to the layer of non-linear regional mathematical programming models.

The supply module consists of independent aggregate non-linear programming models representing activities of all farmers of a farm type in a region. The data are based on the Economic Accounts for Agriculture (EAA). The farm models have fixed input-output coefficients for each production activity with respect to land and intermediate inputs. Normally a low and high yield variant for the different production activities are modelled. Requirements regarding NPK balances and feeding requirements of animals are taken into account. A land supply module allows for land leaving and entering the agricultural sector and transformation between arable and grass land in response to relative price changes (Jansson et al., 2010).

Labour and capital costs are captured by a non-linear cost function (the so-called Positive Mathematical Programming (PMP) methodology; see the description of DRAM). These non-linear cost functions are calibrated in such a way that they mimic the base data and capture information about supply elasticities. The models allow for a lot of detail in CAP subsidies. A special component is made to capture the complex sugar quota regime. This component maximises expected utility from stochastic revenues. Prices are exogenous in the supply module and provided by the market module. Grass, silage and manure are non-tradable and receive accounting prices based on opportunity costs.

The market module consists of a component for marketable agricultural outputs and a specific sub-component that models the feed market. The sub-module for agricultural outputs is a global, spatial multi-commodity model. Bi-lateral trade flows are modelled using the Armington assumptions (Armington,

[1] The description was made jointly with Thorbjorn Jansson, who is currently working at the Swedish University of Agricultural Sciences. John Helming (john.helming@wur.nl) is a contact person for this model at LEI.

1969). The behavioural equations for supply, feed, processing and human consumption have flexible functional forms. Calibration algorithms make the coefficients in these functions consistent with micro-economic theory.

Policy instruments in the market module cover Product Support Equivalents and Consumer Support Equivalents (PSE/CSE) from the OECD, (bi-lateral) tariffs, the Tariff Rate Quota (TRQ) mechanism and, for the EU, intervention stocks and subsidised exports. This sub-module delivers prices used in the supply module and allows for market analysis at global, EU and national scale, including a welfare analysis.

As the supply models are solved independently at fixed prices, the link between the supply and market modules is based on an iterative procedure. After each iteration, during which the supply module works with fixed prices, the constant terms of the behavioural functions for supply and feed demand are calibrated to the results of the regional aggregate programming models aggregated to a country level. Solving the market modules then delivers new prices. A weighted average of the prices from past iterations defines the prices used in the next iteration of the supply module. Equally, in between iterations, CAP premiums are re-calculated to ensure compliance with national ceilings.

CAPRI uses templates that are filled with different parameter sets for different regions and products. This reduces maintenance costs and makes results comparable across products, activities and regions. The modular setup also allows for independent use of the different components.

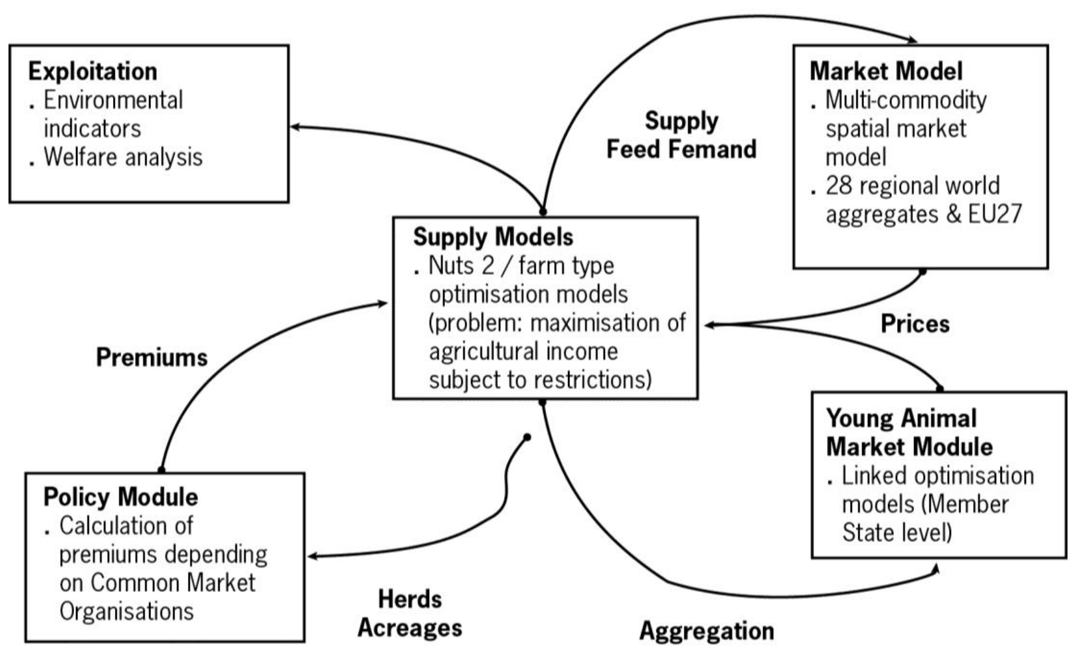
The model has a lot of flexibility because of its modular approach (see also Figure 4.1). Regional supply models may be used without the market model, while the market model works also without the explicit farm models. The model can be used both in a comparative dynamic as a static way.

An extensive post-model analysis is provided. Income indicators are calculated consistent with the EAA methodology. A welfare analysis is possible. A detailed account of the first pillar CAP outlays is available. NPK balances are calculated, while climate relevant gases are computed consistent with the guidelines of the Intergovernmental Panel on Climate Change (IPCC). Spatial down-scaling of crop shares and yields, animal stocking densities and fertiliser use to clusters of 1 x 1 km land grid cells creates the possibility to link CAPRI with the bio-physical model DNDC. Model results are presented as interactive maps and as thematic interactive drill-down tables.

The maintenance of CAPRI is based on the open-source network concept. Databases and model code, including the GUI, are hosted on the software versioning and repository system (SVN) server, from which they can be downloaded and incrementally updated. Selected developers may also commit changes to the server.

> 'The CAPRI modelling system may be defined as a "club good": there are no fees attached to its use but the entry in the network is controlled by the current club members. The members contribute by acquiring new projects, by quality control of data, new methodological approaches, model results and technical solutions, and by organising events such as project meetings or training sessions. So far, the network approach worked quite successfully but it might need revision if the club exceeds a certain size.' (Britz and Witzke, 2008)

Figure 4.1 **The CAPRI model chain**



Source: Britz et al. (2007).

4.3 Required input

Wherever possible, the data bases exploit well-documented, official and harmonised data sources, especially data from EUROSTAT, FAOSTAT, OECD and extractions from the Farm Accounting Data Network (FADN). Specific modules ensure that the data used in CAPRI are mutually compatible and complete in time and space. They cover about 50 agricultural primary and processed products for the EU, from farm type to global scale including input and output coefficients.

4.3.1 Base period variables

The database of CAPRI is created in three steps:

1. CoCo - Completeness and consistency. This module creates a complete (no gaps) and consistent (satisfying the CAPRI physical and economic equations) database at member state level from about 20 years back to the most current date. Key sources are EUROSTAT for agricultural production and yields as well as the Economic Accounts for Agriculture (EAA).
2. CAPREG - Regionalisation of the CoCo database. Based on the REGIO database on production and yields at a NUTS2 level, the CoCo database is broken down into regions. CAPREG also uses engineering information to estimate fertilisation and animal feeding per production activity and region, and manually collected information from EC regulations on direct payments and quotas to calculate gross value added and income. CAPREG uses a three year average around the base year to prevent that temporary differences influence the base data too much. The supply models are calibrated at that point.
3. GLOBAL - Creation of a harmonised global database on bilateral trade flows and trade instruments. GLOBAL processes data from FAOSTAT.

4.3.2 Parameters

CAPRI contains a large number of parameters, especially concerning the biophysical processes involved in animal feeding and fertilisation. The core parameters in the simulations are the behavioural parameters for supply and demand:

1. Supply elasticities. The behaviour of producers is governed by a quadratic cost function. The parameters are based on regionalised time series produced by CAPREG using a Highest Posterior Density (HPD) estimator that includes the first order conditions of the supply model and weak priors for own-price elasticities.
2. Demand elasticities. The parameters of the Generalised Leontief expenditure system are obtained by a HPD using synthetic elasticities as priors and the demand system equations and economic theory (curvature, et cetera) as estimating equations.
3. Armington substitution elasticities for imports versus domestic products are set manually to synthetic values or to values prescribed by the scenario definition.

4.3.3 Scenario projection variables

For the baseline scenario, the model is recalibrated to a projection that is generated by a combination of the module CAPTRD (for the supply model) and CAPMOD (for the market model).

1. CAPTRD is making a projection of the CAPREG database to a selected future year. The projection is based on, in order of significance: (a) the Agricultural Outlook of the Commission, (b) exponential trends fitted to the CAPREG data (for a regional breakdown), (c) a simulation of the baseline policy in the base year, and (d) expert information, especially where (a) is not present and (b) and (c) fails.
2. CAPMOD contains procedures for projecting the market model base data of GLOBAL to a future year. It is based on: (a) Supply utilisation accounts from FAO, (b) Projection from AT2030 of FAO, (c) Trade flows from FAO, (d) COCO/CAPREG data for the market model, (e) population data, (f) growth rates from CAPRI, plus the requirement that the model calibrates in the future point (model equations)
3. Agricultural policies, essentially:
    - (a) payment ceilings in physical or economic terms,
    - (b) payment amounts
    - (c) eligible activities,
    - (d) set-aside rates,
    - (e) quotas for milk and sugar,
    - (f) intervention prices
    - (g) WTO limits on intervention and export subsidies,
    - (h) ad-valorem and specific tariffs,
    - (i) trigger prices,
    - (j) minimum border prices,
    - (k) global and bilateral tariff rate quotas with associated volumes and tariff rates.

4.4 Model output

All the components of CAPRI may generate useful output. The supply module generates information about activity levels (hectares, animals), feeding, fertiliser use, and sales. The market model generates trade flows, production, use of agricultural products by the processing industry, animals and humans, bioenergy use, market, producer and consumer prices, profit margins, prices of milk fat and protein, export subsidies, tariffs, and intervention purchases and stocks.

Many additional indicators are computed, including agricultural income, consumer welfare, CAP budget effects (disaggregated into individual payments, intervention and export subsidies), processor profits, nutrient balances at soil level, greenhouse gas inventories, self-sufficiency in agricultural products, labour and energy indicators.

4.5 Strengths and weaknesses

CAPRI has a lot of sectoral and regional detail in the agricultural sector, enabling simulation of agricultural policies in a unified manner for NUTS 2 regions in the EU. No other model can do that. The good regional detail is matched by endogenous world trade and prices with a theory-consistent demand system.

The modular setup makes it very suitable for extension, but the way many modules are programmed makes the model difficult to handle and interpret, requiring considerable expertise.

The model includes explicit technological assumptions, facilitating implementation of technical constraints on fertilisation, feeding or land use. Nevertheless, the model only contains *variable costs* explicitly, whereas fixed costs are subsumed by a quadratic cost function. The quadratic function is estimated based on time series (Jansson and Heckelei, 2009), and ensures perfect calibration on the base year as well as realistic supply responses in the medium term. The quadratic function may also be calibrated on elasticities derived from other models or mechanisms, and thus be used in linking.

The model is in fact a combination of supply models and a market model. This means that the model itself provides an advanced way to link models that may be an example for linkage between other models. As with the GTAP database the advantage of the CAPRI database is its consistency, the disadvantage that sometimes heroic assumptions are required to make the database consistent and complete.

CAPRI is a club good for technical reasons. A tremendous investment in human capital is required in order to join the club. The club good character makes it difficult to attract new researchers, but also works as a quality control for studies with CAPRI.[1]

[1] GTAP, for instance, can be bought and run without restrictions

5 HORTUS[1]

5.1 Objectives

HORTUS (HORTicultural Use and Supply) has been developed to calculate implications of changes in policy variables such as import barriers and energy taxes (Bunte and van Galen, 2005). HORTUS is also used to make projections of future developments of Dutch and European horticulture.

5.2 Description

HORTUS is an applied partial equilibrium model for European horticulture. It uses the basic economic structure in GTAP, but as a partial equilibrium model includes a lot of detail in horticulture and leaves out the sectors outside horticulture. It is programmed in GEMPACK, as are GTAP and MAGNET. The world is divided into the countries of the EU25 and the rest of the world. The horticulture sector is divided into 10 types of fruit, 12 types of vegetables and 4 ornamental products.

Demand for horticultural products in a region is modelled as a nested CES function, where demand for processed products is modelled separately. The income elasticity of demand for the product group 'vegetables and fruits' determines the available budget, where the shares of the products are determined by the CES function. The price and income elasticities for ornamentals are modelled per product group. As in GTAP and CAPRI, demand per product is split into demand for imported and domestic demand based on relative prices (Armington assumption), as is the distribution of imported demand over regions.

Supply is determined by a nested CES production function, where the top nest with value added and all intermediate inputs has fixed coefficients, and the value added nest has a positive elasticity of substitution. The total number of hectares for horticulture is exogenous to the model, while labour and capital are perfectly mobile at exogenous wage and rental rates.

In contrast with standard CGE models, HORTUS explicitly splits out the quantities and prices in the database. This is possible because the products are at a very low aggregation level and can be standardised. The commodity balance is the essential equation, where the sum of production and imports equals the sum of exports, consumption, industrial use and other uses in a country. Because the model is closed on a global level, the sum of imports equals the sum of exports in the world.

5.3 Required input

5.3.1 Base period variables

The model needs as starting values:
- supply balance sheets, in tonnes, relating production, imports, exports, human consumption and other uses for every product and region identified;
- bilateral trade data consistent with aggregate imports and exports from the supply balance sheets;
- producer and export prices. At this stage, only export prices are used in the model;
- cost shares of intermediary inputs, labour, capital and land use for every product and region identified.

Most data are from FAO, WTO/ITC and Eurostat, where some explicitly described procedures have been used to make the data consistent.

[1] Frank Bunte has developed and manages the model (frank.bunte@wur.nl) jointly with Michiel van Galen (michiel.vangalen@wur.nl).

5.3.2 Coefficients in the model

The model needs price and income elasticities for the demand functions, elasticities of substitution for the inputs for production, as well as Armington elasticities for import-domestic and import-import substitution.

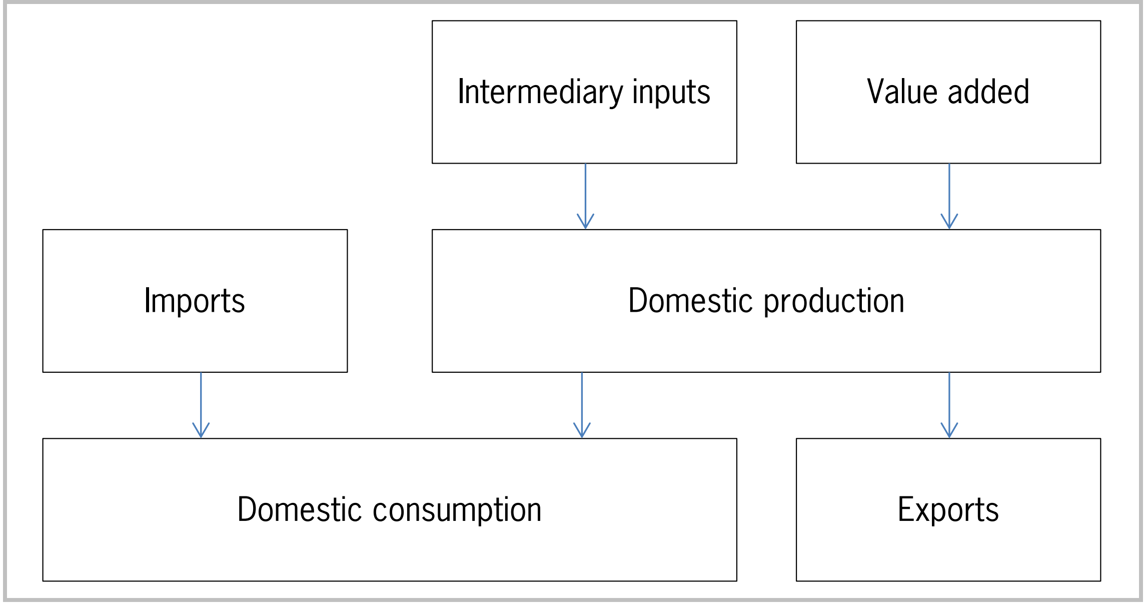
5.3.3 Scenario projection variables

For scenarios, the following variables must be shocked: Changes in prices of endowments and intermediary inputs, growth of population and income per capita, technological change in horticulture, changes in tax and subsidy rates on consumption, imports, exports and production, changes in international transport costs and changes in acreage available for horticulture.

5.4 Model output

The model predicts prices for production, sales, import, export and consumption of horticulture products, production, consumption, industrial use and bilateral trade of horticultural products, demand for land and intermediary inputs by the horticulture sector.

Figure 5.1 Overview of HORTUS model



5.5 Strengths and weaknesses

In contrast with the other partial equilibrium models used at LEI, the model includes capital, labour and land. This makes the model more suitable for long-term projections. The documentation of the data procedures is well-developed.

A drawback of the current model is that the coefficients are rough guesses and lack empirical foundation. This can be done in the future. At this moment one has to be careful in interpreting the magnitude of the calculated effects. The model requires projections of the rest of the economy.

6 FISHRENT[1]

6.1 Objectives

The FISHRENT model was developed as a part of the EU-funded study *Remuneration of spawning stock biomass* (Salz et al., 2010) on the basis of earlier experiences of the team in bio-economic modelling, inter alia EIAA, BEMMFISH, TEMAS, AHF and other models which were evaluated within the project *Survey of existing bio-economic models* (Prellezo et al., 2009). FISHRENT is a full-feedback model, containing independent procedures for the development of the stock (stock-growth function), production and effort (production and investment function). Consequently, the model can shift according to the most restrictive constraint, be it the total available effort of each fleet segment or the TAC (Total Allowable Catch)/quotas of specific species. This approach allows for simulation of the economic performance of individual fleet segments independently of each other over a long period of time (Salz et al., 2011).

The model comprises six modules, each focusing on a different aspect of the functioning of the fisheries system: biology (stocks), economy (costs, earnings and profits), policy (TACs, effort and access fees), behaviour (investments), prices (fish and fuel) and an interface linking the modules together. Input, calculation and output are clearly separated. The model produces a standard set of graphics, which provide a quick insight into the results of any model run. All output of the model runs can be exported to database software for further analysis.

6.2 Description

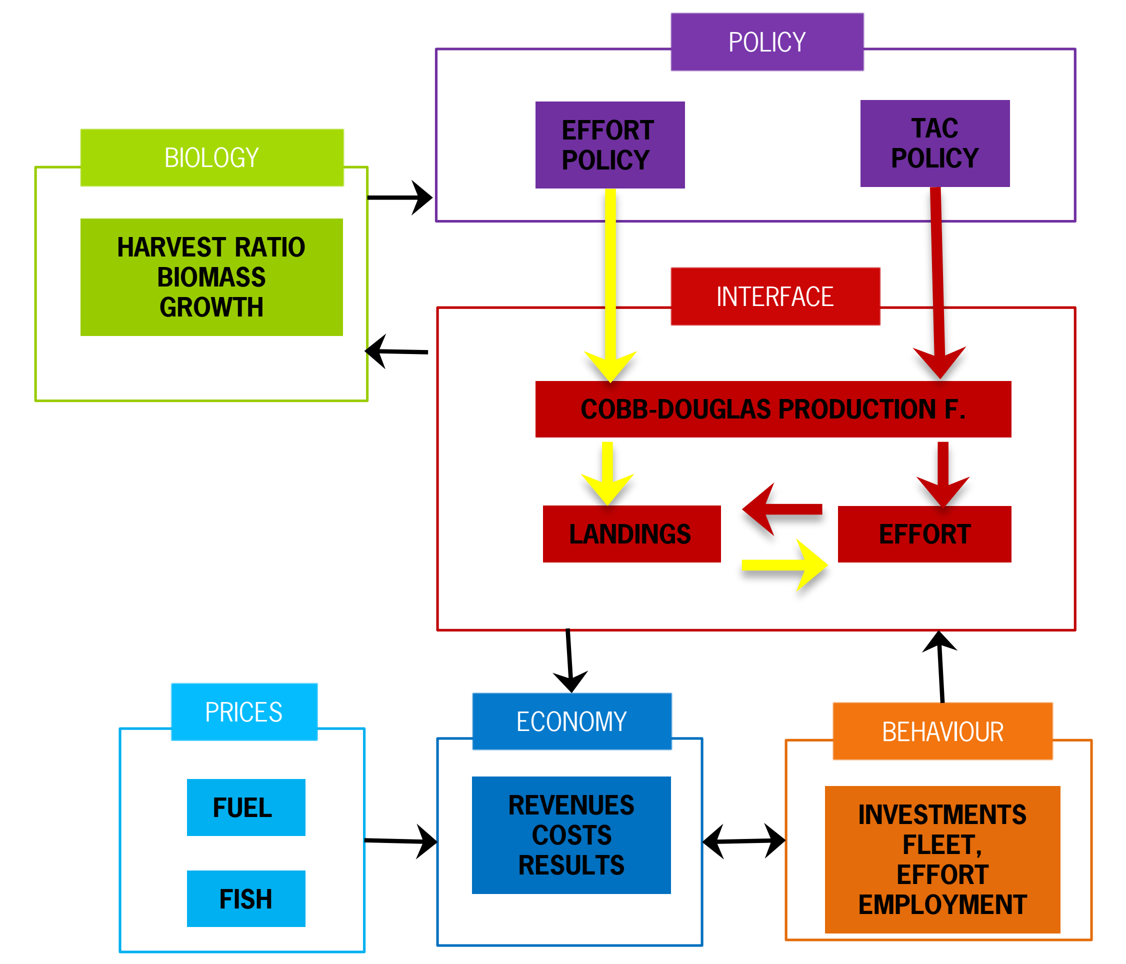
The FISHRENT model is a generalised multi-species multi-fleet simulation and optimisation model, built in Excel. The basic version contains eight fleets and eight species and runs for a period of 25 years. The dimensions of the model can be flexibly reduced or expanded. The model is structured in six modules: biology, economy, interface, prices, behaviour and policy. In addition, the Excel model contains a module with the totals, summing variables over fleets or species. The general structure of the model and its modules is presented in Figure 6.1:

- The biological module contains the stock-growth function.
- The economic module contains the economic performance of the fleets.
- The interface module is the core of the model containing the bio-economic production functions for each combination of segment and species. This module reflects the interaction between the fishing fleet and the fish stocks.
- The price module contains fish prices, price elasticities and the possibility to adapt the price of fuel.
- Behaviour module determines the (dis)investment behaviour of the fleet, according to the realised economic performance.
- The policy module contains six policy options based on different approaches to management by TACs and effort including an option of open access fishery.

The feedbacks within the model allow for a dynamic simulation. The main application of the model is to make scenario analyses of policy options.

[1] At LEI the model is managed by Erik Buisman. Heleen Bartelings (heleen.bartelings@wur.nl) and Katell Hamon (katell.hamon@wur.nl) are working on further development of the model.

Figure 6.1 **Integrated modules of the FISHRENT model**



Source: Salz et al. (2011).

Biological module

The biological module contains three relations:

- Stock-growth relation (called recruitment) - a 3rd degree polynomial function, but only the 2nd degree is used in the current applications.
- Biomass function - the sum of biomass in the previous period pus recruitment minus catch. Furthermore, assumed discards of undersized fish are subtracted.
- Harvest ratio - ratio between biomass and total catch. Harvest ratio is a proxy for fishing mortality.

Policy module

The policy module determines the level of landings or effort. It contains a set of decision or selection rules regarding landing and then effort is determined. Running the model starts with a choice of TAC (Total Allowable Catch) or effort policy. Payment for access is also a policy option, but this is incorporated in the economic module, as its effect does not pass through the interface module.

Furthermore, the policy module contains two other features:

1. Constraints on maximum change of TAC from one year to another, the +/-15% applied in various EU recovery and management plans (harvest control rules)
2. The 'policy intensity factor' reflects the extent to which policy decisions follow the biologic advice. A value below 1 implies that the policy is more restrictive than the biological advice. In contrast, a value above 1 means that policy concludes on higher TACs than the biological advice proposes. This factor

allows simulating the consequences of taking into account 'socio-economic dimensions' of taking restrictive management measures.

The policy choice is made within a multi-species context and therefore the policy must decide whether the most or the least restrictive biologic advice (in relation to harvest ratio of a given set of species) should be taken as a starting point. For example, species 'A' may be relatively abundant, but effort which could be allowed on this species may lead to overfishing of a species 'B'. If, however, species 'B' is taken as a reference point of the policy, this will lead to underutilisation of species 'A'. The policy module contains six policy choices, which precisely highlight these policy dilemmas:

- TACmin - The most restrictive TAC is used to determine the level effort which the fleet can exert. This may lead to underutilisation of other species.
- Effortmin - The most restrictive effort level is allowed, which leads to relatively low catches.
- TACmax - The least restrictive TAC is used to determine the level effort which the fleet can exert. This may lead to overfishing of other species.
- Effortmax - The least restrictive effort level is allowed, which leads to relatively high catches.
- Open access - Fishery is driven by economic incentives. Neither TAC nor effort constraints are imposed.
- Min min - This is the most restrictive policy. In this option, Effortmin is compared to effort level, which follows from TACmin and the lower of the two is selected. This choice is made in each year separately, which means that throughout the simulation period, different species and different types of policies determine the outcomes.

Effort which follows from an 'Effort policy option' is inserted in the production function and generates catch. When a 'TAC police option' is selected, then a corresponding level of effort is calculated from an 'inverse production function', where effort is the endogenous variable.

Both effort and TACs are derived from the present and target harvest ratio in combination with other variables in the model.

Policy formulas contain a PIF ratio (Policy Intensity Factor). PIF is included in the Drivers sheet. PIF allows the policy to be more or less restrictive than the simulated biological advice. A distinction is made between PIF for effort or PIF for TAC-based policy.

Interface module

The interface module determines the level of catch and effort, which are subsequently input to the economic module and catches form feedback to the biologic module. It contains conditional choices of effort, which are described in detail in Chapter 3.

The interface module contains seven functions for each combination of fleet segments and species:

1. Catch - based on a standard Cobb-Douglas production function. The power of 'effort' variable contains an additional parameter which represents the technological progress.
2. Effort - inverse production function, using catch as input to determine required effort.
3. Discards - over-quota catch is discarded. Catch is confronted with 'Target landings' (segment share of TAC, see policy module) and if catch exceeds Target landings, part of the excessive catch can be discarded. An assumed value of a discard parameter determines which percentage is discarded and consequently also how much is landed, albeit illegally. Discards of undersized fish are accounted for in the catchable biomass equation, as a fixed percentage of catch. These discards occur only in case of output (TAC) driven policy.
4. Landings - difference between catch and discards.
5. Target landings - share of segment in the total sustainable catch (TAC).
6. Choice of effort in relation to policy - level of effort depends on policy choice and maximum effort which the fleet can exert. When the policy is TAC driven, then the model calculates the required effort with the inverse Cobb-Douglas production function. If the policy is effort driven, then effort is adapted proportionately with the required adaptation of the harvest ratio to the target harvest ratio.

7. Comparison of effort allowed by policy and maximum effort feasible for the fleet. After determination of the level of effort from one of the two policies, it is checked against the maximum level of effort feasible for the fleet and the lower value is selected.

The selected production function in the interface is a Cobb Douglas production function in which fishing effort in terms of days-at-sea and catchable biomass determines the catches. Technical progress is included in the production function. Through these selection procedures it is possible to integrate input and output driven policy into one model.

Economic module

The economic module contains the following relations:

- Revenues - sum of landings times prices. Prices can be adapted to qualities attained by different segments.
- Fuel costs - depend proportionately on fishing effort. Can be adapted by changing the fuel price, either once (instantaneously) or trend-wise (annual change).
- Variable costs - depend proportionately on fishing effort.
- Crew costs - based on a share of revenues and if appropriate taking account of fuel and/or variable costs.
- Fixed costs - are a fixed value per vessel. Change with the size of the fleet.
- Capital costs - as fixed costs, constant per vessel, changing with size of the fleet.
- Gross cash flow - according to definition.
- Profit - according to definition revenues minus all costs.
- Payment for access - allows for different kinds of payments:
  - Lump-sum;
  - Share of profit;
  - Payment per unit of effort;
  - Share of revenues per species;
  - Profit after payment for access.
- Gross value added - according to definition.
- Fuel use - fuel costs divided by fuel price.
- Break-even revenues - according to definition. Break-even revenues drive the investment function. Therefore crew costs are considered as fixed costs, on the basis of the expectation that fishing may not be an attractive profession at a level of income lower than the level realised in a given year.

The economic module also generates net present values of profit and gross value added over 15 and 25 years. This distinction between two periods was introduced in particular in relation to the optimisation runs of the model. When a model is run for 15 years and profit or gross value added are maximised over that period, the model will tend to fish out all the stocks at the end of the period as it does not take into account what happens beyond that time horizon. This is evidently not desirable. This problem has been resolved by 'optimising' over a period of 25 years, but using the net present value of the first 15 years only. In this way destruction of stocks is avoided within the first 15 years.

Behaviour module

The behaviour module simulates the level of fishing effort trough changes of the number of vessels and/or the number of days-at-sea per vessel. It contains the following relations:

- Fleet (number of vessels) - the fleet of the preceding year plus or minus investments (fleet change).
- Days-at-sea/vessel - operational - total effort (see policy module) divided by the number of vessels.
- Days-at-sea/vessel - maximum - assumed value. This can be annually adapted by an assumed parameter. Together with the number of vessels it determines the maximum effort of a segment.
- Maximum effort (Fleet * days) - follows from fleet and maximum days-at-sea per vessel.

- Investment (number of vessels) - it is assumed that the fleet changes, i.e. (dis)investments take place, proportionately to the ratio between the break-even revenues and the realised revenues, which is adapted by the share of profits dedicated to investments. However, maximum limits to annual increase or decrease of the fleet can be imposed in terms of the percentage change of the fleet. The two limits can be different, which creates asymmetric (dis)investment behaviour. Furthermore, size of the fleet is reduced when the capacity utilisation falls below an assumed level. This means that it is assumed that investments take place only when the capacity utilisation is above this level.
- Nominal employment - number of vessels times average crew.
- Full time employment - nominal employment, corrected with the ratio of operational/maximum days-at-sea.

Price module

Price module contains two equations:

1. Prices of fish, which include price elasticity for each species. Furthermore, price differentials for specific segment-species combinations can be accounted for using specific parameters.
2. Fuel price can be adapted with one-time rise or continuous annual trend.

6.3 Required input

The model requires input data on individual fleets and species as well as the choices regarding scenario and policy options. Next to specification on the choice of policy options, Policy intensity factor (PIF) i.e. to which extent the manager will follow the biologic advice or enforce the policy restrictions (harvest control rules), names of the relevant species and segments, the discount rate per segment, which may serve as a proxy for shadow valuation, the model processes the following input data:

- Economic DCF data (Data Collection Framework). These data are available for most EU fleet segments.
- Stock data: SSB (Spawning Stock Biomass) and historical catches of target species. These data are available from ICES for most important species in EU fisheries.
- TAC for target species.
- TAC shares of fleet segments analysed in the model.

6.4 Model output

- Net present value of gross value added, profit and payment for access over 15 and 25 years.
- Selected graphics showing the development of the main indicators over the simulated period of 25 years:
  - Biological: biomass, sustainable catch, stock growth;
  - Economic: landings, revenues, gross value added and profit;
  - Technical: fleet size and effort (days-at-sea).

6.5 Strengths and weaknesses

Strengths

- Integration of simulation (of different management strategies) and optimisation (to determine optimum value of resource rent and other variables).
- Integration of output- and input-driven approaches, so that one model could be consistently applied to different situations in the EU, particularly the Atlantic and the Mediterranean/Black Sea areas.
- Accommodation of multi-species/multi-fleet fisheries, with flexible number of species and segments.
- Close link to available economic and biological data, to allow empirical applications.

- Balanced composition between various components: biology-economics-policy.
- Dynamic behaviour over a long period, including stock-growth, investment and effort functions, to allow simulation of adjustment paths to an optimum.
- Flexibility for applications of various types of relations (e.g. different stock-growth functions, approaches to payment for access, et cetera).
- The base year as well as the time horizon of 15 years can be adjusted easily.
- The model has been built in Excel, which makes it accessible for most users. The model is continuously further developed at LEI. The model interface is now operational in GAMS as well as in R-software.

Weaknesses
The original Excel model does not include a spatial module and the biological module lacks an age-structured model for stock growth. This is now being further developed in the GAMS version of the model.

7 ORANGE[1]

7.1 Objectives

ORANGE is a national Computable General Equilibrium (CGE) model of the Netherlands with a broad sectoral differentiation for conducting policy and market analysis. The purpose of the ORANGE model is to provide a tool to analyse the effects of changes in policy and market conditions on the allocation of commodities and factors in the Dutch agro-food and non-agro-food sectors. Recently, the model has been used to consider the medium-term impact of a shift towards the use of biobased plastic inputs in the Netherlands (Nowicki et al., 2010). A regionalised version of the ORANGE model is available as well. The regional extension downscales the effects of national and international policies to the twelve provinces of the Netherlands (NUTS 2 level).

7.2 Description

ORANGE is developed at LEI and is adapted from the pared down version of a large scale CGE model of the US: the MiniUSAGE model (Dixon and Rimmer, 2005) which is itself a development of the MONASH and ORANI models from the Centre of Policy Studies at Monash University, Australia. The name ORANGE comes from (*OR*) *A*pplied *N*etherlands *G*eneral *E*quilibrium.

ORANGE is an economy-wide computable general equilibrium model of the Netherlands. The starting point for the development of the ORANGE model is the Mini-USAGE CGE model as documented in Dixon & Rimmer (2005). Computable General Equilibrium models have strong theoretical foundations in Microeconomic theory and general equilibrium theory. As such they are often referred to as 'theory with numbers'. The treatment of consumer choice and the production decision are derived directly from core microeconomic theory. The solution of the model is developed from Walrasian general equilibrium theory. A notable departure from standard neo-classical theory is the treatment of trade and the adoption of the Armington assumption which allows for imperfect substitutability between domestic produced goods and imports. CGE models such as ORANGE provide a complete, consistent and detailed description of national multi-sector and multi-commodity input and output structures.

The focus of ORANGE is on interactions between agro food and non-agro food sectors through relations across production, consumption, investments, trade and factor markets. ORANGE is aimed to concentrate on the effects of policy and market changes on the performances of single sectors and the macro economy as a whole. The model takes into account inter-relationships between agro food and non-agro food sectors through input-output relations, factor markets and trade markets. The general equilibrium nature of the model means that ORANGE describes simultaneous market equilibrium for a broad range of sectors, which means that there is a feedback between e.g. the agricultural industry and the rest of the economy.

The ORANGE model contains some extensions to the model code to capture particular features of the Dutch economy. Specifically, re-exports, land supply, the biobased economy and regional impacts. Re-exports are an important part of the import demands of the Netherlands. As such, the components of the model referring to exports have been extended in order to cover the source dimension whereby the exports of imports (re-exports) and export demand for domestically produced goods can be separately identified. As the ORANGE model is developed to examine the impact of shocks on agriculture and the interaction of agricultural and non-agricultural sectors, the model is extended to include land as a separate factor with a land supply function. A further purpose of the model is to analyse the effects of the use of

[1] Myrna van Leeuwen (myrna.vanleeuwen@wur.nl) and Andrzej Tabeau (andrzej.tabeau@wur.nl) are contact persons for this model.

biomass by non-agricultural sectors such as the chemical industry. To achieve this, the model has been extended to allow for substitution between non-biobased and biobased commodities. The modelling of regional impacts is achieved using a tops-down approach following the method outlined in Dixon and Rimmer (Dixon and Rimmer, 2005).

The ORANGE model currently covers 145 commodities and activities that use three factors (land, labour and capital) to produce goods that are consumed by other firms (through intermediate or investment demand), a representative household, the government or by consumers in other countries (exports). The set-up of the model maintains a complete separation between data and model to allow for easier updating of the data. The pre-processing phase that compiles the database of the model from a broad range of data is programmed in GAMS whereas the model itself (including the regional module) are programmed in GEMPACK. The model can be solved comparative statically or dynamically.

7.3 Required input

7.3.1 Base period variables

The ORANGE model is built upon an extensive database of economic data drawn from multiple sources. Together, the data provide a 'snap-shot' of the economic flows and stocks in the Dutch economy in a given year. The base year of the model is currently 2005. The core of the database is a detailed input-output table for the Netherlands supplemented with data government account, household account, current account and macroeconomic data. The detailed input-output table is compiled annually by LEI from the input-output table of the National Accounts produced by Statistics Netherlands. The extended table provides greater detail on the agricultural and food processing sectors. The additional data are taken from the National Accounts data, agricultural census data, financial accounts data and employment data.

Each of the matrices of demand (intermediate, investment, household and government consumption and exports) is required in basic prices with an accompanying matrix of commodity tax/subsidies payments on sales. Margins matrices are also explicitly needed for the calibration of the model. A Make matrix is also required and has both on and off-diagonal elements in the ORANGE model indicating the presence of secondary production in the model. The model requires that demands for commodities for investment purposes are specified by industry. Typically, however, only the investment demand for each commodity is given in the National Accounts. The disaggregated matrix of industry investment demands is constructed using a spreading method, taking into account additional information on investment by industry which must also be provided. Finally, the available supply of land in the Netherlands must be specified to parameterise the land supply function.

7.3.2 Parameters

The ORANGE model requires many parameters values to parameterise the functions in the model. In particular the values of substitution between primary factors, Armington elasticities between domestically produced goods and imports, the ease of transformation between products produced by domestic firms, and export and import elasticities must be specified. The parameters of the consumption function must also be provided. The degree of substitutability between biobased and non-biobased products must also be specified for the biobased component of the model along with the parameters for the land supply function. The regionalisation module requires information on the distances between regions, sectoral employment by region and the share of demand (by household, government, exports and imports) accounted for by each region.

As with the MAGNET model, these parameters are based on econometric research or economic literature where possible but may be 'best guesses' where there are no available data.

7.3.3 Scenario projection variables

The growth path of the model is driven by exogenously specified changes in key variables. The key variables for scenario projections are population growth, employment growth, changes in household, export and government demand, and GDP growth. Typically, the baseline of the model is calibrated with an exogenous level of GDP growth which yields a corresponding growth path for technology. The growth in technology is then set as exogenous leaving changes in GDP to be endogenously determined by the model.

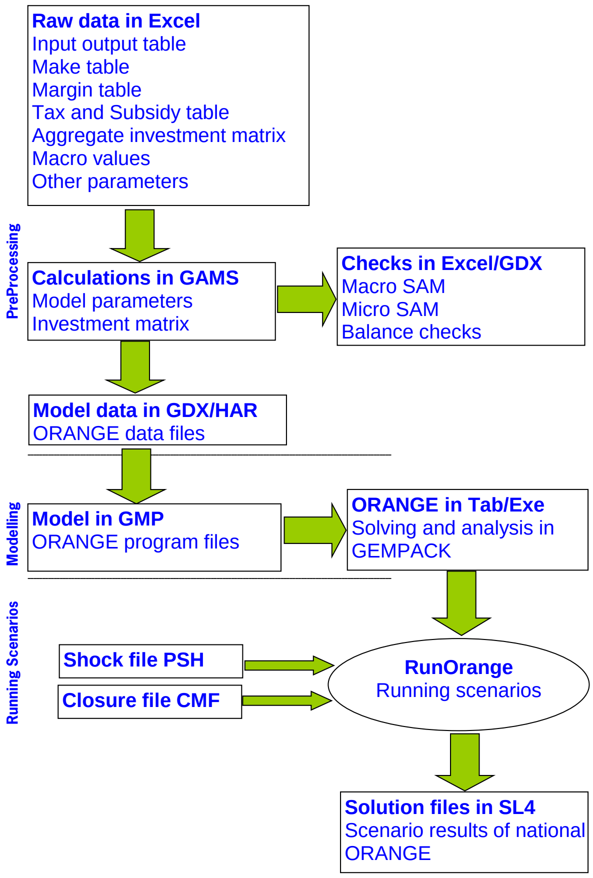
7.4 Model output

The ORANGE model generates impacts on prices and volumes for all sectors, factors and households in the model at the national level and at the 12 province levels by a top-down method. Moreover it provides an overview of the impact at the macroeconomic level. Most results are expressed in percentage changes with the results for variables that may take a negative value expressed in standard changes.

Given the broad spectrum of results produced by the model, the main variables of interest depend on the scenario. For example, the main results of interest for a scenario examining the impact of a shift towards biobased inputs of plastics are the change in the output of industries supplying the biobased and non-biobased inputs and the impact on industries that supply the inputs to the biobased industry, namely agriculture and the biorefinery sector. In this scenario, the degree to which the increased demand for agricultural inputs was satisfied from domestically produced goods and/or imports was also of interest.

Figure 7.1 presents a schematic overview of the model processing activities.

Figure 7.1 Structure of the ORANGE model



7.5 Strengths and weaknesses

The standard advantages and disadvantages of computable general equilibrium modelling apply to the ORANGE model. The advantages of using a CGE framework for policy analysis include the high level of sectoral detail, the ability to capture first-round and higher order effects (general equilibrium effects) and the ability to conduct ex-ante analyses. The weaknesses of the approach typically lie in the validating of the parameter values used to calibrate the functions of the model.

The ORANGE model also has strengths and weakness compared with other models within the class of single country CGE models. The first advantage of the ORANGE model compared with other national CGE models is the full separability of data and model code which allows for relatively easy updating of the data. Second, the ORANGE model has been developed out of a well-established modelling tradition which allows the ORANGE model to benefit from existing model extensions including the regionalisation module. Third, the ORANGE can be easily extended with add-ins. As an example the national ORANGE model has been extended with a regional component, which can be (de)activated depending on the purpose of the research topic. Finally, the ORANGE database is constructed in such a way that it is compatible with the structure of MAGNET and GTAP. The weaknesses of the ORANGE model compared with other single-country CGE models include the assumption of perfect competition among firms and the tops-down treatment of regional effects which does not allow regional policies to be considered.

8 DRAM[1]

8.1 Objectives

DRAM, Dutch Regionalised Agricultural Model, models regional and national agricultural production and the interactions between agricultural activities through input and output markets. DRAM concentrates on the effects of policy changes on input allocation, agricultural production, prices of animal manure and agricultural income on sector and regional level. A detailed description of the principles of DRAM can be found in Helming (2005) and Helming and Reinhard (2009). A detailed description of an updated version can be found in Bouma et al. (2006).

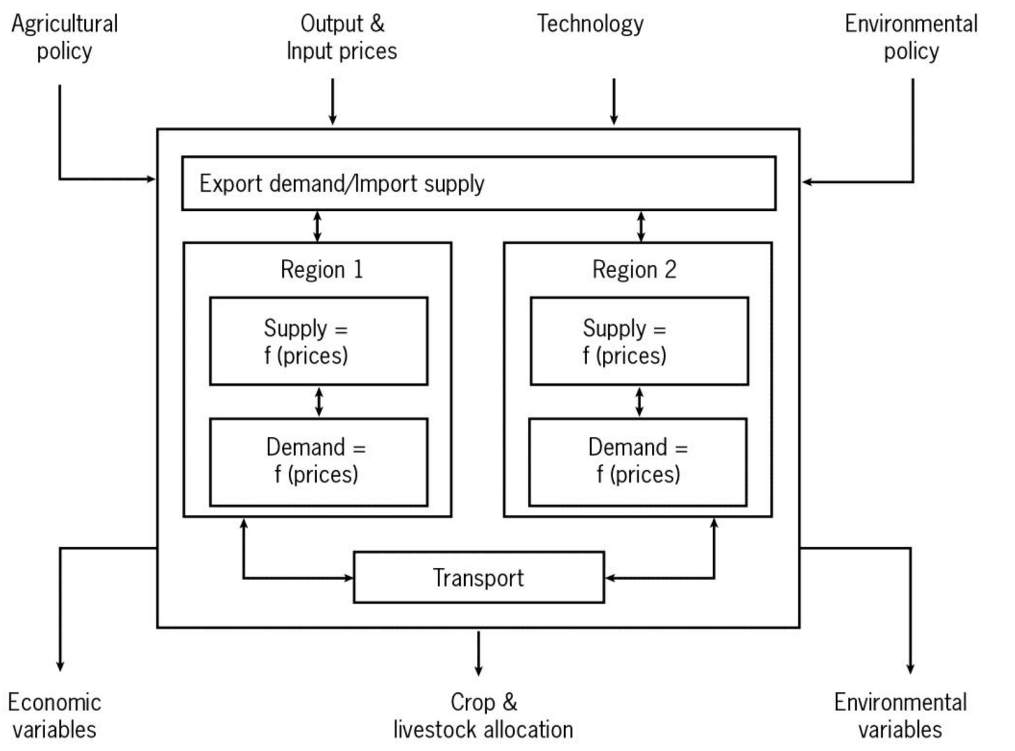
8.2 Description

DRAM is a mathematical programming agricultural sector model, which was first developed at LEI in the late 1970s and early 1980s. DRAM belongs to the class of comparative static, partial equilibrium mathematical programming models. Partial equilibrium means that DRAM describes a market equilibrium for some selected (agricultural) input and output markets (e.g. manure market) and there is no feedback between the agricultural industry and the rest of the economy. Moreover, comparative static equilibrium models assume that production and consumption fully and instantaneously adjust to policy changes until a new equilibrium is found. Comparing this new equilibrium with the initial situation shows medium term policy effects. Hence, comparative static equilibrium models do not show a time path. Partial equilibrium models cannot be used to simulate cumulative responses to a policy change. Moreover, whether this new equilibrium is actually reached also depends on the assumption that exogenous variables remain constant during the adjustment period.

The model is calibrated to observed activity levels using the method of Positive Mathematical Programming (PMP) (Howitt, 1995). With PMP it is possible to overcome the normative character of the mathematical programming model. The central hypothesis of PMP is that resource allocations that are not constrained by resources or empirical constraints, result from first-order conditions of profit maximising behaviour. The most important contribution of PMP is that these types of models calibrate precisely to observed activity levels, but are free to respond to changes in competitive equilibrium induced by policy or resource changes (no flexibility constraints).

1 John Helming (john.helming@wur.nl) has developed and manages the model at LEI.

Figure 8.1 **Schematic representation of DRAM**



8.2.1 Optimisation

The core of DRAM, described in the centre of Figure 8.1, is an optimisation block that maximises total profits from agriculture with the restriction that economic, technical, environmental, spatial and policy constraints are respected. Here, profits are defined as revenue minus total variable costs. The basic underlying assumption is that farmers' behaviour can be described by the maximisation of profits from individual agricultural activities. Profits are maximised simultaneously across all farms to take into account the relationship between market effects and farmers' behaviour. Simultaneous optimisation of farm profits assumes an optimal allocation of agricultural inputs and outputs across the farms, so that profits from agriculture at the national level are maximised. This optimal allocation of inputs and outputs is achieved when marginal costs are greater than or equal to marginal revenues for all agricultural activities in the model.

8.2.2 Technology

To keep the size of the model manageable and because of data limitations at the farm level, DRAM aggregates technologies of individual farms to the regional level. Because of nonlinearities at a very disaggregated level, the requirements of exact aggregation are that resource availability, technical possibilities and objectives between farms within a region are comparable. Due to these requirements aggregation bias is unavoidable in sector models. It can be argued that the aggregation bias is different for different farms and agricultural activities as some farms and activities are more specialised and homogenous than others.

In DRAM every region is treated as one farm. The current model can choose between 12 regions (provinces) and 66 agricultural regions. Within each region, sixteen arable crop activities, three fodder crop activities (grass, maize and other), 5 intensive livestock activities (fattening calves, sows, fattening pigs, laying hens, meat poultry), 2 beef cattle activities (male and female beef cattle) and eight types of dairy cow activities are distinguished. In the current version of DRAM, the arable crop activities are split such that they can be produced by two different technologies, supplying the same quality of arable product. The agricultural activities produce different types of manure, roughage and young animals. Roughage and young animals can only be used by other agricultural activities within the same region or exported abroad. Animal manure can be traded between three trading regions within the Netherlands or exported abroad. Technical (input-output) and economic variables and parameters per agricultural activity are differentiated per region as far as possible, given data limitations.

Regional differentiation of technical coefficients is especially important for crop production because of the differences in soil type per region and the important relationship between soil type and yield. Moreover, milk is produced through 8 types of dairy cow activities, with type and region specific input-output coefficients. Producers may switch between the different types of dairy cow activities (technologies) depending on relative prices and still produce the same quantity of milk. The same switch is possible for the two alternative technologies distinguished per type of arable activity.

Region specific fertilisation requirements of the crops can be fulfilled a) by application of nutrients from mineral fertiliser only b) by application of animal manure only c) by application of both mineral fertiliser and animal manure. Technical restrictions on the total application of animal manure per crop are included to take into account limited acceptation of animal manure because of possible effects on product quality, uncertainties about weed seed in animal manure, uncertainties about nutrient concentration, availability of equipment and land compaction if supplementary mineral fertiliser applications are needed.

Large-scale manure processing is also an option to solve the problem of excess manure. Prices of large scale manure processing are different per manure type and are provided exogenously.

8.2.3 Markets

Prices of outputs and inputs are treated as exogenous variables, as they are assumed to be determined at the internal EU market or world market. For agricultural inputs and outputs the small country assumption is applied. Prices of the intra-sectorally produced inputs (manure, young animals and roughage) are partly endogenous within DRAM. They can be traded between regions and internationally. In case these inputs are traded between regions, the prices are linked between regions and price differences cannot exceed transport costs. The small country assumption is also applied to export and import prices: export- and import prices of intra-sectorally produced inputs are fixed.

It is easy to create endogenous output prices (Helming, 2005). This might be important for some arable crops such as consumption potatoes, seed potatoes, marketable crops (e.g. grass seeds) and onions, all vegetable crops and flower bulbs. For these outputs either the market share of the Netherlands is relatively large or the time between production and consumption is relatively short due to high transport and storage costs. An inverse linear demand relationship can be used to create endogenous prices. At the moment this is not implemented in DRAM.

8.2.4 Fixed inputs

Fixed inputs in the model are land and quotas. Agricultural land and quota for sugar beets are fixed at the regional level, while quotas for milk and starch potatoes are fixed at the national level. Fixed inputs in DRAM are valued by shadow prices on the regional or national balances. The shadow price of a fixed input shows the increase in the objective function as a result of a marginal increase in a fixed input. It is assumed that capital and labour are not restrictive at the industry level and are therefore not included in DRAM.

8.3 Required input

The model needs information about the firms that combined are the regional farms: number of animals, area of crops, input and output prices.

Further, there must be information about:

- productivity per agricultural activity (tonnes per ha per year; tonnes per animal per year);
- variable costs per agricultural activity (euros per year per animal or hectare);
- prices of N and P from fertiliser (euros per kg);
- EU subsidies (euros per year per hectare or animal);
- cost of applying manure (euros per m^3);
- cost for large-scale manure processing (euros per m^3);
- costs of import of roughage, young animals and manure
- revenues of exports of roughage, young animals and manure;
- distance between regions (km).

The model needs balances, i.e.:

- regional milk quota;
- total area of agricultural area;
- production rights for pigs and chicken;
- yearly produced and demanded number of young animals (animals per animal per year);
- produced and used roughage per animal and hectare;
- manure and nutrient production per animal;
- percentage of manure production in stable;
- emission of N in stables;
- requirements for nutrients per crop per region;
- percentages of nutrients in manure that are effective;
- and the ratio between acceptable manure and legally allowed manure.

The Farm Information Network (BIN), the FADN for the Netherlands, provides information about technical and economic information per activity. The Agricultural Accounts from the Dutch Statistical Office provide areas of land use and size and composition of the amount of livestock, while supply elasticities per activity are derived from the literature.

8.4 Model output

Per region and technology the model generates information on an annual base about:

- Shadow prices of land, manure and roughage (€/ha/region, €/m^3/region);
- Amount and composition of the livestock sector (number of animals per region);
- Land use (ha per crop per region);
- Gross margin (€ per technology per activity per region);
- Production of animal manure and nutrients in animal manure (m^3, kg N, kg P);
- Application of animal manure and nutrients in animal manure (m^3 or kg N or kg P per ha per crop per region);
- Application of N and P from mineral fertiliser (kg N or kg P per ha per crop per region);
- Emission of ammonia from different sources (kg NH_3).

8.5 Strengths and weaknesses

Strengths

The driving forces behind DRAM are derived from standard economic theory. This improves the transparency of the model and the interpretation of the results. The application of the PMP approach enables the model to almost exactly reproduce observed activity levels in a base year.

Agricultural sector models such as DRAM provide a complete, consistent and detailed description of regional agricultural production (multi-sector and multi-commodity) and include the modelling of joint resources. These are resources that are used by different production activities but whose availability is limited in the agricultural sector, especially land and manure application capacity. These balances enable the model to take into account the dampening effect of changes in (shadow) prices as a result of changes in supply.

Agricultural sector models also offer the opportunity to analyse correlations between environmental themes, for example the link between manure production and related manure surpluses at regional and national levels and the use of pesticides.

An important strength of DRAM is the interdisciplinary approach. This provides the opportunity to model in great detail the link between environment and economy and the correlations between different environmental themes. The following features of DRAM are important in this regard:

- ability to incorporate a wealth of physical detail (land availability and heterogeneity);
- behavioural response is strongly influenced by the physical structure;
- detailed description of regional agricultural production (multi-sector and multi-product approach)
- detailed modelling of nutrient production and use which is relevant for analysis of the manure policy;
- regional desegregation which is relevant because of differences in direct payments per region and structural and environmental differences;
- possibility to include constraints on groups of activities to mimic farm types instead of just single activities;
- use of economic, technological and environmental information.

Last but not least, it is easy to include more agricultural sectors into the model.

Weaknesses

In DRAM individual farms are aggregated to different technologies per region. The disadvantage of this more aggregated approach is that differences at the level of individual farms are not fully accounted for. Individual farms differ with respect to the availability and quality of fixed inputs including quality aspects such as soil types. There can also be considerable structural, technical and managerial differences. The regional farm approach in DRAM leads to biased results, as the underlying nonlinearities are not fully taken into account. To reduce aggregation bias, DRAM mimics farm behaviour by disaggregating agriculture, specifying different technologies and imposing constraints on activities.

Aggregated regional models implicitly assume that crop and livestock production and the related environmental effects are evenly distributed across the region. Depending on soil and climatic variability and differences at the farm level for example, the spatial distribution of an environmental impact may be quite heterogeneous and the real externalities might be over- or underestimated at aggregated levels. At spot level, complex biophysical models enable detailed descriptions of nutrient and chemical flows in agriculture.

A policy model requires up to date information. DRAM's data requirements are met by the combined use of Agricultural Census, FADN and a wide range of other data. DRAM's extensive data requirements mean that updates are costly and requires broad expertise. Potential data problems especially occur in the category of environmental data, e.g. manure acceptation, manure transport, manure application costs, transport costs, workability of nutrients in manure, the amount of manure produced in the field and in animal sheds and manure prices.

Given the importance of sunk costs in agriculture and the fact that many policies have a long implementation period, a dynamic version of DRAM might be necessary if transition and development paths are of interest. Also, an important characteristic of agriculture is the relatively long time between the moment of decision-making and actual supply response.

9 MAMBO[1]

9.1 Objectives

At the beginning of the 1980s, LEI started with the development of the 'Manure model' (Wijnands and Luesink, 1984). MestAmm, the model used since 1989 (Luesink and van der Veen, 1989), was replaced by MAM since 1997 (Groenwold et al., 2002). Problems faced by farmers with the removal of manure from farms and the related problems of acidification and eutrophication, made the model an important instrument for policy evaluation and research. The model has been used extensively for the evaluation of policy measures and to monitor the manure streams and the emission of ammonia. Due to technical limitations of the MAM model and difficulties to incorporate significant changes in policy measures, since 2008 a new manure model called MAMBO is used. MAMBO can be used to calculate nutrient flows, ammonia emissions and the greenhouse gasses methane, dinitrogenoxide and nitrogen oxide (Luesink and Kruseman, 2007; Kruseman et al., 2008a; Kruseman et al., 2008b). It has recently been used in calculating national ammonia (NH_3) emissions from agriculture in different European countries (Reidy et al., 2008; Reidy et al., 2009).

9.2 Description

Five key processes regarding animal manure are included in MAMBO (Figure 9.1)
1. Manure production on farms;
2. Maximum allowed application of manure on farms within statutory and farm level constraints;
3. Manure surplus at farm level (production minus maximum application amount);
4. Manure distribution between farms (transport);
5. Application of manure resulting in soil loads with minerals.

The first three processes are calculated at the farm level, whereas manure distribution is calculated at the level of 31 predefined manure regions. Soil loads are calculated at municipality level.

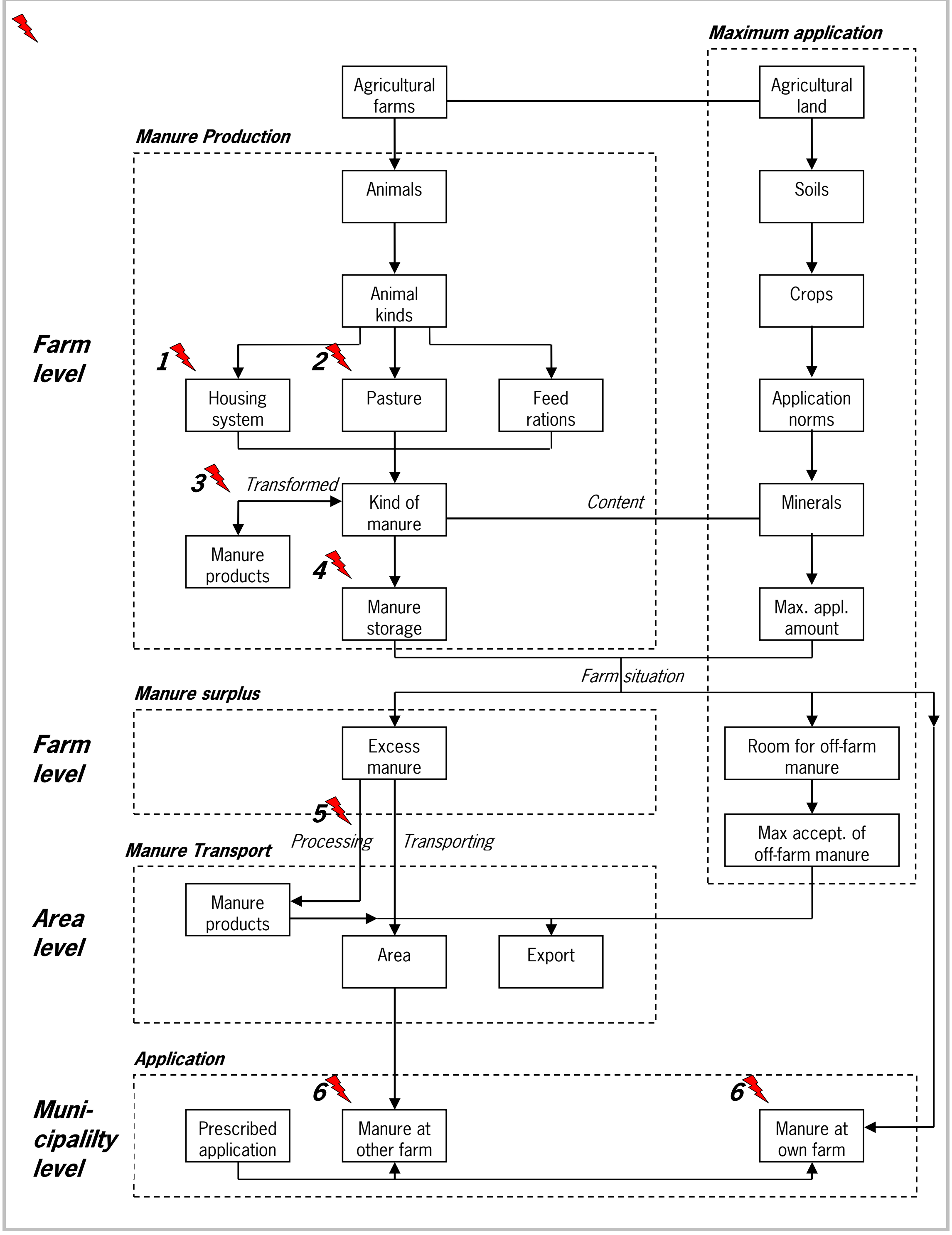
9.2.1 Manure production

Sources of manure are distinguished based on the following parameters:
1. Type and number of animals;
2. Type of feed;
3. Housing facility (yes = housed, no = pasture);
4. Type of housing facility used.

The manure can be excreted directly on the field, it can be stored or it can be processed at farm level into other products, such as dried manure or separation products, each with its specific ammonia and greenhouse gas emission characteristics.

1 Harry Luesink (harry.luesink@wur.nl), Gideon Kruseman (gideon.kruseman@wur.nl) and Tanja de Koeijer (tanja.dekoeijer@wur.nl) are contact persons for this model at LEI.

Figure 9.1 The Manure and Ammonia emission Model (MAM/MAMBO)



9.2.2 Maximum application amount

The maximum application of on-farm manure this determined by three factors: the total crop area of the farm, the type of crops grown on the farm, and the statutory application standards. The statutory application standards prescribe for each crop and soil type the maximum amount of minerals allowed to be applied.

The maximum amount of off-farm manure applicable on a farm depends on the amount of nutrients required to grow the crops, the actual use of on-farm manure, the price of manure and the farmer's willingness to accept off-farm manure (acceptation degree).

9.2.3 Manure surplus at farm level

In order to determine whether a farm has a manure surplus or room for off-farm manure, the manure produced on the farm is balanced against the maximum application amount of manure on the farm. In case of a manure surplus, the economic consequences of the surplus are minimised by finding the most appropriate type of manure for each particular farm.

9.2.4 Manure transport

A farm can get rid of a manure surplus by transporting it to other farms within the same region, other regions or other countries, either processed or unprocessed. This depends on demand for off-farm manure elsewhere and transportation cost. Transport cost between regions depends on distance. MAMBO minimises transport cost under the following restrictions:

1. Processing and export of manure may not exceed maximum capacities;
2. The regional manure mass balance must be satisfied;
3. The manure transport into any region is equal or less than the available room for off-farm manure for that region;
4. Manure is transferred from other regions only if the regional surpluses are insufficient to fill up the room for off-farm manure;
5. Manure is transported into other regions only if its surplus exceeds the maximum application amount for off-farm manure in the region of origin.

9.2.5 Soil loads with minerals

In MAMBO, the total mineral load of the soil depends on three factors: the application of on-farm manure, the application of off-farm manure and the application of mineral fertiliser. The Dutch farm accountancy data network provides only data about the use of mineral fertilisers at a regional level. These are downscaled to municipality level, using information about the time of manure application, the effectiveness of the nutrients and the amount of nutrients in the applied manure.

9.3 Required input

The lowest level of aggregation which is possible in MAMBO is the farm level. MAMBO can handle all other levels of aggregation that are an aggregate from farm level. For the five parts of MAMBO the next input data are required:

- *Manure production*
    - Type and number of animals
    - Feed rations
    - Total ammoniacal and organic nitrogen
    - Housing and grazing systems
    - Processing at farm level
    - Storage systems
    - Emission factors (ammonia and greenhouse gases) of housing, grazing and storage
- *Maximum application amount*
    - Hectares of crops
    - Soil type

  - Soil quality
  - Standards
  - Mineral effect coefficient
  - Minimum fertiliser amount
  - Amount of applicate manure or Acceptation degree
- *Manure excess*
  - No extra information required
- *Transport*
  - Export outside Dutch agriculture
  - Processing
  - Distance between regional areas
  - Distribution costs
- *Application of transported manure and artificial fertiliser*
  - Application technique
  - Season of manure application
  - Agriculture fertiliser standards
  - Emission factors (ammonia emission and greenhouse gases) by application of manure

9.4 Model output

Table 9.1 presents the main output categories of MAMBO. The level of aggregation provides some idea about the normal level of output. Aggregation to water bodies (in relation to the water framework directive), provinces, municipalities, nature areas or other regional divisions is possible if information about the distribution of individual farms over these regions is added to the database. The dimension of the output (Animal types, crop types, soil types, type of housing, storage system, application system, et cetera) is the same as the dimension of the input at every level of aggregation.

Table 9.1 Main reporting variables in MAMBO

Output variable	Unit	Level of aggregation
Number of animals and hectares	Units and hectares	Farm level National 31 manure regions Other regional division
Production of manure	Kg of manure and minerals per type of manure	Farm level National 31 manure regions Other regional division
Farm surpluses	Kg of manure and minerals per type of manure	Farm level National 31 manure regions Other regional division
Hectares without application of manure	Hectares	Farm level National 31 manure regions Other regional division
Destination of farm surpluses	Kg of manure and minerals	National 31 manure regions Other regional division Abroad

Table 9.1 (continued)	Main reporting variables in MAMBO	
Output variable	**Unit**	**Level of aggregation**
Ammonia emission animal manure and artificial fertiliser	Kg of emission from housing/grazing/storage/ processing/application per type of manure	Grid 5 * 5 km National 31 manure regions Other regional division
Emission of the greenhouse gases methane, dinitrogen oxide and nitrogen oxide	Kg of emission from feed ration, housing, storage and application (direct and indirect) per type of manure	National 31 manure regions Other regional division
Application of animal manure in kg/ha	Kg of minerals per crop and soil type, own produced manure and off farm manure	Farm level National 31 manure regions Other regional division
Emission of dust	Kg from housing	National 31 manure regions Other regional division
Application of artificial fertiliser in kg/ha	Kg of minerals per crop and soil type	National Other regional division 31 manure regions
Transport of manure within regions, between regions and abroad	Kg of manure and distance	National 31 manure regions Export
Processing	Kg of manure	National 31 manure regions
Costs and or earnings of manure distribution, processing and application	Euros per kg of manure type	National 31 manure regions Other regional division
Infrastructure	Number and size of storage types; Number and size of manure factories; Number and size of application units; number and size of transport units	National 31 manure regions Other regional division

9.5 Strengths and weaknesses

The MAMBO model calculates results based on a database of farms and regional information, with a focus on manure transport. The strength of MAMBO is the level of detail and the calculation at an individual farm level.

The MAMBO does not include economic behaviour except for the manure market. Therefore, to investigate scenarios or changes in policy the model needs inputs about these changes from elsewhere. Models such as DRAM or CAPRI can provide this type of information.

10 SERA[1]

10.1 Objectives

This chapter builds on Schouten et al. (2011) and presents the Spatially Explicit Rural Agent Based Model (SERA).

To capture spatial and institutional dynamics in land ownership and intensity of land use, an agent-based model (see (Parker et al., 2003) is developed to capture heterogeneity between agents (farmers) as well as dynamics through a spatial explicit model, specifically designed for simulations of the effects of agri-environmental policies on agricultural landscape level. Agent-based models (ABMs) within the specific agricultural context were pioneered by (Balmann, 1997) with the Agricultural Policy Simulator (AgriPoliS). ABMs allow representing economic and social systems as the result of individually acting agents. When applied to agriculture, they can simulate, at the micro-level, the behaviour of individual farmers, without the need of aggregating them in 'representative' agents, and then generate the macro (aggregate)-evidence. Furthermore, ABMs can catch the iterations of the heterogeneous farms when competing over common finite resources, such as land (Lobianco and Esposti, 2010). Potential applications of spatial explicit ABMs are to simulate impact of rural development policies; for evaluation/simulation of water management policies on regional spatial explicit scale; spatial explicit simulation of effects urban pressure on rural landscape; simulate effects of CAP reforms on the spatial rural landscape; simulate effects of different types of shocks (with economic, ecological and social character); et cetera.

10.2 Description

The core of this model is the understanding and modelling of an agricultural landscape as an agent-based system, thereby taking into account both the farmers' behaviour and the spatial configuration of the landscape. The model focuses on an actual agricultural region, and comprises a large number of individually acting farms that operate in the region, as well as farmers' interactions with each other and with parts of their environment. This model adds to the existing agricultural agent-based models, in that it provides a spatial-explicit landscape in which land ownership and (intensity of) land use is based on empirical data. Empirical data on individual farms and the existing regional landscape spatial structures have been initialised in the model. The model includes the application of agri-environmental schemes (AESs). This has to the best of our knowledge not been previously performed. The software code of this model is written in the object-oriented programming language Java using the open-source agent-based modelling framework Recursive Porous Agent Simulation Toolkit Symphony (REPAST, http://repast.sourceforge.net/).

In the following we present a basic overview of the model; those interested in the model code may directly contact the authors.

The current version of the model contains three types of agents, the TraderAgent, the Auctioneer and the Government. The model contains one such TraderAgent, the farmer. Every farmer has a Valuation Strategy that it uses to determine a (private) price for the goods it wishes to trade. Currently, the only tradable goods in the model are farmlands. The strategy used is organised through decision rules which keep track of the total number of parcels in use, the farmers' age, expectations about future land prices, as well as a number of financial indicators and changes as a result of the farm agent's actions. The farm agent keeps track of its nitrogen and feed production through balances at farm level. The most important decision rule of every farm agent is to calculate the parcels contribution to the farm income, given limited

[1] Marleen Schouten (marleen.schouten@wur.nl) jointly with Nico Polman developed the model while Eugene Westerhof built software around the model code. Nico Polman (nico.polman@wur.nl) and Eugene Westerhof (eugene.westerhof@wur.nl) are contact persons for this model at LEI.

rationality of the farm agents. According to Happe et al. (2006), this assumption is reasonable for agricultural enterprises in Western Europe, where farming systems that follow different behavioural objectives such as subsistence farming only play a minor role.

Different implementations can be used in the model for different aspects of the agent's 'daily operations'. The farm agent decisions are exclusively based on their own situation and on the expectations about land prices. When the profit contribution of a specific parcel is known, first decisions can be made by the farm agent with respect to trading land. Second, farmers who farm land that is eligible can submit a tender for enrolling in an AES. They base their tender price on opportunity costs.

The second agent currently in the model is the Auctioneer. The Auctioneer is a mediator between traders and can represent an actual person or organisation, or - in a more abstract manner - a market. The Auctioneer 'requests' traders to make offers to either express their willingness to buy or sell a good. The Auctioneer 'uses' a mechanism to match bids and asks to clear the auction. Currently, the model contains a mechanism that uses a heuristic to clear the auction in a number of iterations. It presumes that multiple buyers and sellers are present and parcels are heterogeneous (characterised by multiple attributes).

At the start of each auction the auctioneer informs the traders that the auction is open. Based on the outcome of the farm agent decision-making rules (does the agent want to buy or sell?), traders can respond by expressing interest in the auction. Next, the auctioneer requests all interested agents to provide the parcels they would like to sell with a related reserve price for these parcels. This reserve price is determined by the valuation strategy the agent is applying. Once all asks have been identified, the auctioneer request the interested agents to provide bids for the parcels on offer. A prospective buyer evaluates all available goods and is allowed to create one bid, for the asks that he or she values the most. Again, this is decided by the agent's valuation strategy.

After all bids have been collected, the auction mechanism matches bids and asks based on creation of the largest buyer/seller surplus (difference between bid price and reserve price). The auctioneer will inform the traders involved in an accepted bid, who then complete the transaction and are asked to provide new offers, or can update or retract their open bids and asks in the auction, based on their valuation and decision-making rules.

If there are still unaccepted asks left after the matching process, a new cycle or iteration of the auction is started, in which all participating agents are again asked to provide a bid for one of the remaining asks. The process continues until there are no asks left, or no more bids are made. The auctioneer will then inform all interested traders that the auction is closed. In order to calculate the transaction prices for all matched bids in the auction, the auctioneer uses a pricing policy in which the surplus is equally shared.

The spatially explicit landscape is represented by modelling actual parcels in the studied region. Within this spatial explicit environment, several institutional and bio-physical attributes are associated with each of these parcels: for each parcel the ownership is known, the parcel size, current land use and the possibilities for AESs. Decisions of the government on eligibility of parcels for AES is exogenous for the model. Also the parcel quality for farming is known and provides information about soil quality and crop suitability as well as ground water tables. In the model, we distinguish between three different types of land, namely grass land, maize land and parcels with AESs. For each parcel, the distance to the agent's farmstead is taken into account in the model.

Decision rules for the government agent on accepting parcels are included in the model. The government agent can either accept or reject an offer of a farmer to be contracted. The government can apply different strategies for accepting parcels. It can accept every parcel offered by farmers for AES which is the current policy standard. An alternative decision rule could be based on specific characteristics of parcels or bids of farmers which will be discussed below.

10.3 Required input

The model uses agricultural census data. The attributes on farm level are the farm structure, given in age of the farmer, type of farm, size and number of total owned and rented parcels. At parcel level, attributes are soil quality, crop suitability, information on ground water tables and land use which were used to integrate the production characteristics of individual parcels in the model. These characteristics are derived from Cadastral GIS-maps. At landscape level, attributes are number of farms in the region, spatial land characteristics, size and distance from the parcel to the agent's farmstead. These attributes do not change during the simulation period.

10.4 Model output

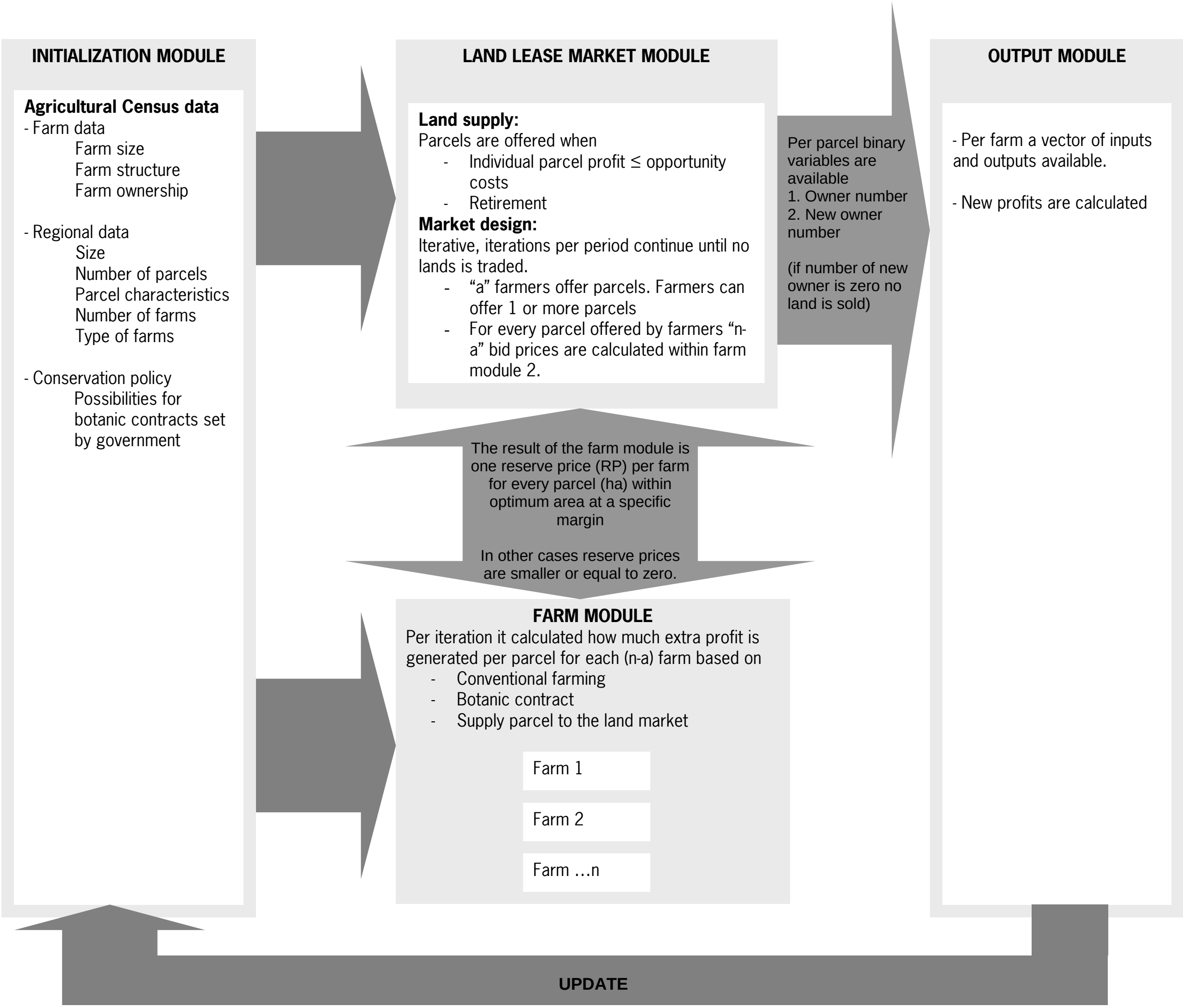
Figure 10.1 provides an overview of the dynamics of the model, and the course of events during one simulation period. The model consists of an initialisation module in which data is conditioned to be used in the model, a farm module allowing the calculations of farm income contribution, a land lease market module distributing the land among the farmers, and an output module. The initialisation module contains exogenous agricultural census data (reference year 2008). These attributes do not change during the simulation period. The determination whether conventional farming or an AES is chosen and the derivation of farm organisation takes place in the farm module. Each farm agent is equipped with a behavioural model that guides decisions and keeps track of the agent's internal state described by attributes such as age, location and size. According to their behavioural model, the individual farm agents evolve subject to their current state of attributes and to changes in their environment.

The results of the farm module for individual farms are merged in the land lease market module. A description of the land lease market module was given in the previous section. Finally the function of the output module is the conditioning of the model results for the next simulation period. Results on farm level as well as on the regional level are used for update farm attributes and regional attributes in the next period.

10.5 Strengths and weaknesses

The model presented in this chapter aims to map the individual decision behaviour of farmers as well as their spatial configuration in the surrounding landscape. Nevertheless, future work is needed with regard to the farm agents behaviour and the spatial configuration of the area in the model. A caveat is that potential public and private transaction costs of schemes are not taken into account. Further, it is assumed that all farmers with parcels that are eligible in public scheme will tender for their opportunity cost. With regard to the farm agents behaviour, their behaviour is limitedly rational, meaning that the decision making process of the farm agent is path dependent, and not globally optimising. Another extension is that investment activities as well as off-farm labour activities will be included in the model. Finally, thorough calibration and sensitivity analysis are part of the future work.

Figure 10.1 Course of events during one simulation period in SERA



11 SERES[1]

11.1 Objectives

SERES stands for SElection of REserve Sites. In the Netherlands more and more attention is given to the cost effectiveness of operative policies, and nature conservation is no exception. Cost effectiveness is defined here as the degree to which the policy succeeds in achieving either the maximum results that are possible given the budget, or the minimal costs that are possible given the demanded results. With regard to nature conservation the following research questions need to be addressed: How can an ecological network be designed so that either given the maximal budget as many species and nature types as possible are conserved, or all species are conserved at minimal costs, also taking into account the location of the reserve sites and spatial demands by the species?

11.2 Description

SERES has been developed under the QBGM (quality oriented generic GAMS modelling) framework. It has a modular structure and contains the following modules:
- Data management and consistency testing modules;
- Firm level efficiency coefficient calculation;
- Firm level modules with alternative firm specifications;
- Report writing tools.

To answer the main research question we need to know which results are theoretically possible on a given budget. In nature conservation this means selecting the right areas and the management thereof, as well as the best measures for demanded environmental improvement. The management and the environmental measures are, for cost effectiveness, assessed solely on their costs to achieve a predefined standard. Therefore, for any evaluation, the minimal data required is:
1. The areas available;
2. The nature types possible in every available area;
3. The costs of al area nature type combinations;
4. The contribution of areas to the conservation of species, given the nature type.

In 2006 the model HAMBO (Habitat Allocation to Maximise BiOdiversity) was developed. HAMBO (Groeneveld and Rudrum, 2008) was given the first three points of information, and for the fourth point was either given information on clusters of areas, or this was autonomously assessed based on spatial interaction between the selected areas

HAMBO can minimise the budget whilst ensuring the conservation of species according to several simplified spatial interaction rules. It was found these rules do not deliver the desired result, oversimplifying the problem from an ecological viewpoint, and at the same time pose a very difficult mathematical problem that can only be solved for small areas. It was therefore decided future work should use the information on clusters of areas which is mathematically simpler and ecologically more reliable. Even then the problem is too large to solve on a PC. Therefore an iteration procedure or an algorithm had to be incorporated so that the problem can be solved in smaller steps. This led in 2008 to a revised programme with a new name: SERES.

[1] Gideon Kruseman (gideon.kruseman@wur.nl) and Hans Leneman (hans.leneman@wur.nl) are contact persons for this model at LEI.

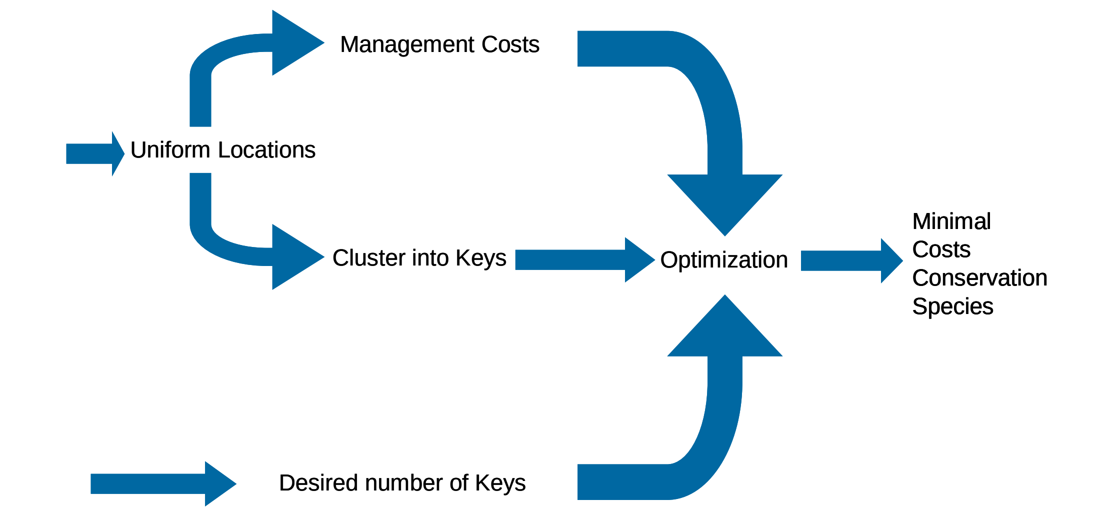
SERES works along the following lines: It selects available areas and for every area a nature type from a list of available options, taking the costs of the combination into account. Any demands set on the area of nature types that has to be in the solution can be assessed directly. Species are conserved by selecting clusters of area nature type options. Clusters are pre-defined information, and for a cluster to contribute to preserving a species it has to be selected completely. As this is too big a problem to solve in one optimisation species are optimised in groups, whereby each optimisation adds areas to the previous solution.

SERES takes into account the effect of umbrella species, species that through their conservation ensure complete or partial conservation of other species (Rudrum et al., forthcoming).

11.3 Required input

The information needed for the optimisation comes from two sources. The first is a database OKE (van Bommel et al., 2004; de Koeijer et al., 2006), constructed for this very purpose by LEI and Alterra, containing al possible nature in the Netherlands, the current situation in the area, and the costs of implementing nature there. The second is the result from the model LARCH (Pouwels et al., 2002; Reijnen et al., 2007). Using the OKE data LARCH constructs clusters of areas that are close enough to each other to hold a single population of a species. In the optimisation only the clusters large enough to hold a sustainable population, called a key, are used. Species are considered adequately protected if a given number of keys are selected. The needed number of keys is input coming from the same group that developed LARCH. Figure 11.1 depicts this data flow in SERES schematically.

Figure 11.1 **The overall calculation done by SERES**



11.4 Model output

The output consists of tables with information on the level of conservation of biodiversity based on key species. The optimal selection of reserve sites for biodiversity conservation based on costs minimising principles while meeting ecological criteria. In addition GIS information is created for mapping the results.

11.5 Strengths and weaknesses

The strengths of SERES:

- Modular structure and flexible model formulation;
- It can calculate cost effective selection of reserve sites using various criteria.

The weaknesses of SERES:

- Heavy data needs for some modules;
- Comparative static approach.

12 FES[1]

12.1 Objectives

Based on FADN data, LEI has developed an instrument for financial analysis of agricultural economic developments and policies: the Financial-Economic Simulation model (FES). The first FES model was developed by Machiel Mulder (Mulder, 1994). The FES model may be used to answer questions like:

- How many of the agricultural and horticultural holdings have a large chance to get financial difficulties in the near future?
- What characteristics of agricultural and horticultural holdings determine their chance on survival?
- How does a change in fiscal policy, or agricultural policy change the financial perspectives of agricultural and horticultural firms?
- What are the effects of the financial economic development of agricultural and horticultural firms on the tax payments of these firms?
- What are the effects of declining market prices on the income of agricultural firms?
- What are the effects of high energy prices on perspectives of the greenhouse sector?

12.2 Description

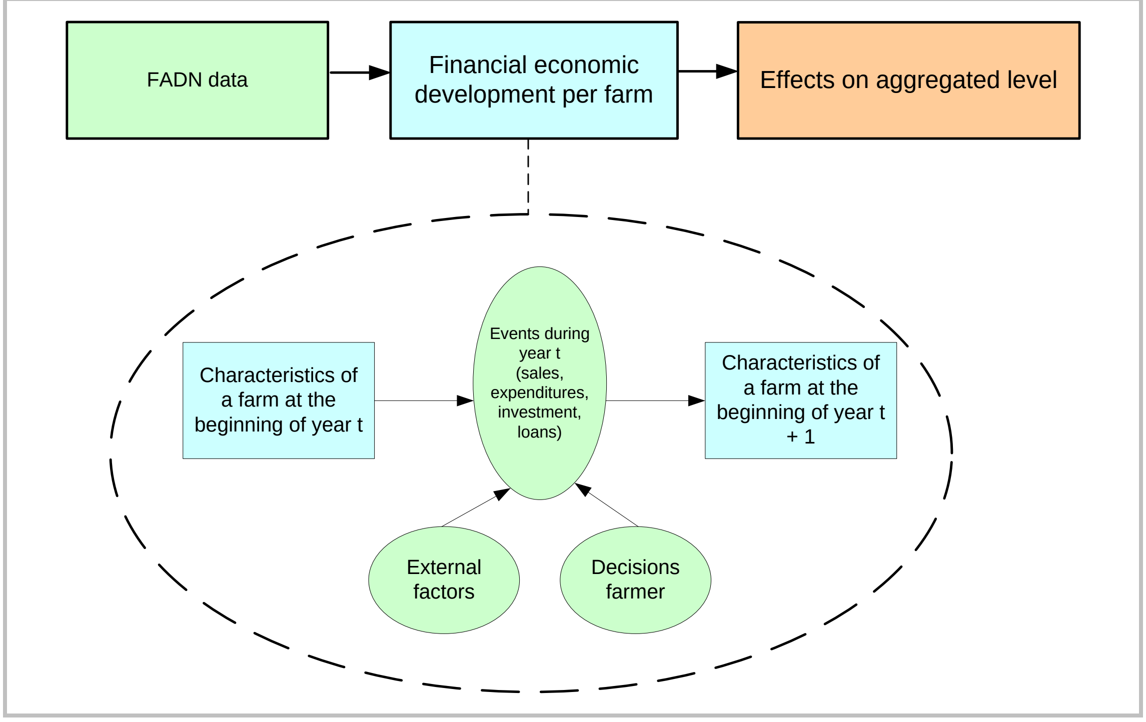
The model is about farms in the FADN database. Accounting is a reflection of the development of a firm in the past and its development possibilities in the future. Accounting is therefore an excellent framework for analysing the development of a firm. By means of simulation of the various possible yearly events, financial characteristics of a firm are updated from year to year (see Figure 12.1). Both the events during the various years and the financial characteristics at the beginning of each year are reflected in financial statements, the profit account and the balance sheet respectively. The financial characteristics of a firm consist of the value and composition of assets and liabilities and the modernity of the assets.

Examples of the yearly events which are simulated are farm expenditures, sales of products, tax payments, family expenditures, off-farm income, investments and loans. The events during the years are the result of a) the characteristics of the firm at the beginning of the year, b) the developments in the environment of the firm (e.g. in the sales market, the capital market and government policy) and c) the decisions of the farmers.

FES calculates for each farm in (a sample of) the FADN database results and scales the results up to relevant aggregates. FES calculates results on a yearly base, and the standard simulation period is between 5 and 10 years ahead. Although the original FES model was developed for the Dutch FADN, the latest version was developed for all FADN countries. In 2008, the model has been used for calculating the EU 15.

[1] Hennie van der Veen (hennie.vanderveen@wur.nl) has developed and manages the model at LEI.

Figure 12.1 Schematic presentation of the FES model



In many applications of FES the assumption is made that the farmers aim at continuation of the firm with the same size and activities at the same location as in the beginning of the simulation period. In those cases FES is directed to the question whether or not a farmer is able to continue his farm with given operational characteristics and certain supposed developments in the environment of the farm. In these applications the decisions of the farmer are only directed to 1) prevent liquidity problems and 2) to maintain the modernity of the buildings, installations, machinery and equipment.

12.2.1 Revenues and costs

The revenues and expenditures are determined by adjusting the technical and economic results reported by the FADN for assumptions concerning the development of prices and productivity and other external circumstances such as government intervention. The revenues and costs of the base year are calculated as a three-year average (normalisation). Prices are modelled as relative changes in revenues and not as absolute prices. The yearly cash flows consist of the farm expenditures, the sales of products, the financial expenditures, the tax payments, the family expenditures and the off-farm income.

12.2.2 Investment and financing

After calculating the operational cash flow, investment options are evaluated for the farms. In order to be able to continue his farm the farmer has to invest in replacement of the durable assets from time to time. In FES it is assumed that the farmer's wish to replace assets increases when modernity of capital stock declines. The modernity of the durable assets is determined by the book value of those assets and the market prices for new durable assets. The farmer's wish to invest depends also on the age of the youngest farmer: older farmers invest less in their farm.

Relevant investment options are derived from the model results itself by ageing of the fixed assets (replacement investments). Other relevant investment options are not calculated within FES. It is however possible to determine them outside the FES model. For example, in many applications of the model the

question is answered whether or not firms are able to finance certain environmental or animal welfare investments. The level of those investments is exogenously determined as follows:
- translating environmental governmental policy into standards for firm management per type of farming;
- comparing those standards per type of farming with the actual situation per firm;
- determining which adaptations in the firm management should take place in terms of costs and investments;
- determining the effects on returns of those possible changes.

Investment options are compared with the available internal financial resources. If those are sufficient, investment takes place. Otherwise, the possibility of borrowing is considered. For this reason the behaviour of banks with respect to the finance of agricultural firms is modelled within FES. If cash flow, solvency and collateral are sufficient, financing and investment takes place and the best investment option is chosen.

12.2.3 Liquidity problems

In case of liquidity problems the farmer is assumed to postpone redemption of loans. If that is not sufficient, the farmer can apply for an assistance loan. In case that the amount of liquidities is reduced to zero and an assistance loan is already applied for, the farm is technically bankrupt.

12.3 Required input

The model needs FADN data, and information about exogenous developments such as prices and policies.

12.4 Model output

The FES model is a financial economic simulation model. The main output variables are related to financial economic indicators such as income, solvency and the modernity of assets. Additionally information about the perspective of the farm is deducted from these indicators. The following categories are distinguished:
1. *Excellent* prospects. The farm has sufficient financial means to finance the necessary replacement investments. But also possibly mandatory investments or expansions can be financed;
2. *Good* prospects. The farm has sufficient financial means to finance the necessary replacement investments;
3. Acceptable *(average)* future. The farm still has liquidities available; however it has trouble financing the necessary replacement investments;
4. Very *moderate* future. Company has financial trouble. Good management and adjustments in spending could save this farm for the future;
5. Quitting farmers with a good company *(retiring, good)*: no liquidity problems. Desired replacements, which are limited given the fact that the farmer will stop, cannot be financed in all cases;
6. Quitting farmers with a less good company *(retiring moderate)*: farm has liquidity problems.
7. Poor future *(bad)*: big chance that this company will stop for financial reasons.

To translate individual farm outcomes to sector or national level, weights are used. Since individual farms are simulated, aggregation to different sectoral or regional levels is easy as long as enough farms are within the relevant sample.

12.5 Strengths and weaknesses

The FES model is based on real farm data and a consistent accounting scheme. When the farms in the database are properly weighted, distributional and total effects of policy measures can be analysed as long as these policy measures do not generate fundamental changes in the firms. The simulation method assumes that the farm does not change except for replacement investment. This implies that structural changes cannot be modelled, although some changes generated by other models such as DRAM or CAPRI may be used.

13 FLAME[1]

13.1 Objectives

FLAME stands for Firm Level Agrarian Model for (environmental/ecological) Economics. The objective of the model is to simulate farm level behaviour for a wide variety of policy and market analysis purposes. While the model calculates choice at the firm or household level, the model is not intended for analysis of individual firms or households, but rather by taking into account the heterogeneity within larger groupings.

LEI has a long tradition of modelling at firm level for policy assessment purposes. At LEI models have been developed within the organisation as stand-alone models and as part of collaborative endeavours. These models have been used for a variety of purposes.

Within the context of the EU there is a growing awareness that better use of FADN data should be made for policy analysis. The consortium headed by LEI concerning a FP7 call to that effect came in second place. The analysis we made there and our ideas and concerns still stand. We feel that part of the work planned within that project can be undertaken at LEI for the Dutch case with EU in mind, concentrating on our own expertise and knowledge.

There is an on-going effort to improve model quality; this includes making models more flexible, transparent while ensuring reproducibility of results. Two of the principle concepts are the separation of model code and data and the construction of models using a modular approach. This allows constructing a modelling framework that can capture the best features of a variety of models.

We recognise three starting points for the development of a set of modelling instruments:

1. Available models or model based procedures and data that need to be incorporated into the framework;
2. The research questions that need to be answered;
3. The conceptual and theoretical foundation of the subject matter.

13.2 Description

FLAME has been developed under the QBGM (quality oriented generic GAMS modelling) framework. It has a modular structure and contains the following modules:

- Data management and consistency testing modules;
- Firm level efficiency coefficient calculation;
- Firm level modules with alternative firm specifications;
- Report writing tools.

FLAME follows the basic principles of agricultural household modelling (Singh et al., 1986; Kruseman, 2000).

The alternative firm level modules capture existing knowledge within LEI. The expertise captured in the FIONA model (Groeneveld and Schrijver, 2006; Schrijver et al., 2008) has been incorporated into FLAME.

[1] Gideon Kruseman (gideon.kruseman@wur.nl) and Tanja de Koeijer (tanja.dekoeijer@wur.nl) are contact persons for this model at LEI.

13.3 Required input

The model needs firm level data, information on exogenous biophysical constraints, exogenous market constraints and information about exogenous institutional constraints including legislation, regulations, informal rules and policies.

13.4 Model output

The output of the model are values of firm or household level choice variables.
The results of FLAME can be used in other models, for instance multi-agent models for firm interactions at community or regional level.

13.5 Strengths and weaknesses

The strengths of FLAME:

- Modular structure and flexible model formulation;
- Relative ease of communication with other models through a complete separation of model code, data and run control variables.

The weaknesses of FLAME:

- Heavy data needs for some modules;
- Equilibrium effects are not calculated, this requires linkages with other models.

14 Model linkages and scaling options

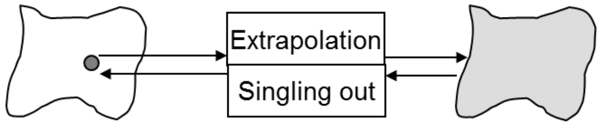
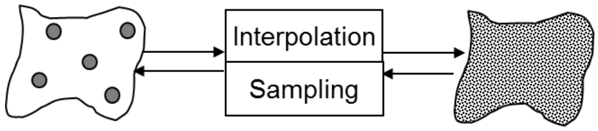
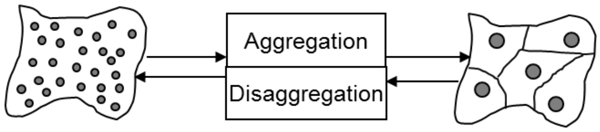
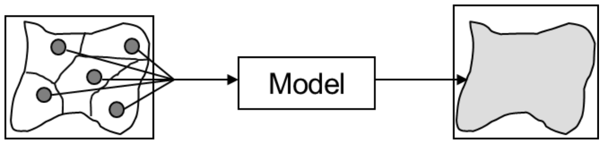
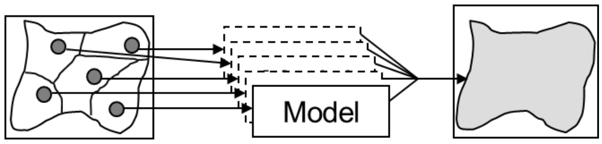
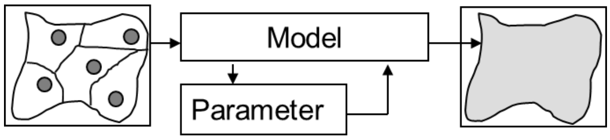
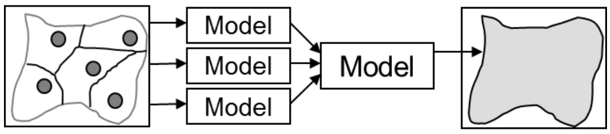
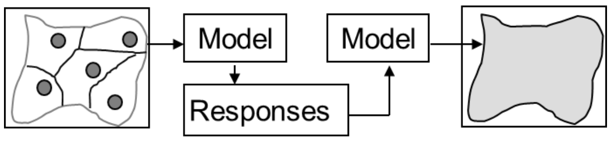
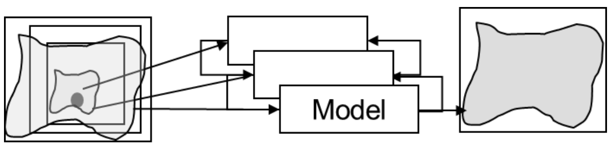
14.1 Spatial and temporal coverage of models

Each model presented in this overview operates on its own scale (globe, country group, country, region, area, farm) and offers model solutions (simulation results) for a specific time horizon. Following (Ewert et al., 2009), Table 14.1 distinguishes extent, i.e. the level at which the model operates and resolution, i.e. the finest unit of analysis.

Table 14.1 Spatial and temporal scales (extent and resolution) of models

Model	Spatial extent	Spatial resolution	Temporal extent	Temporal resolution	Sectoral resolution
MAGNET	World	country	2050	Year	57 sectors of the economy
AGMEMOD	EU27, Turkey, Russia, Ukraine, Macedonia, Croatia	country	2025	Year	Agricultural sectors
CAPRI	EU27	NUTS 2	2013 and 2020	Year	Agricultural sectors
HORTUS	EU27	Country	Year	Year	Horticultural sector
FISHRENT	Regional seas in Europe	Individual fleets	Year	Year	Fishery sector
ORANGE	The Netherlands	Country or 12 Dutch NUTS 2 regions	2025	Year	145 economic sectors
DRAM	The Netherlands	12 Dutch NUTS 2 regions or 66 agricultural regions	2025	Year	Livestock and arable sector
MAMBO	The Netherlands	Individual farms	Year	Year	Agriculture
SERA	Area	Agent	Year	Multiple years	Nature, Agriculture
SERES	Flexible, but developed initially for the Netherlands	Grid	Year	Year	Nature, agri-nature schemes
FES	FADN Farm types in Europe	Farm	Year	Year	Agriculture
FLAME	Flexible, but developed initially for the Netherlands	Individual farms	Flexible but usually Year	Flexible but usually Year or season	Agricultural sectors

Ewert et al. (2011) performed a conceptual analysis of the scale changes and methods of scale and model integration used for addressing complex integrated assessment problems in agri-environmental systems. According to Ewert et al. (2011), the classification of scaling methods distinguishes between the manipulation of data and the manipulation of models (van Oijen et al., 2009). Table 14.2 Further elaborates on the classification of scaling methods.

Table 14.2	**Classification of scaling methods a)**
Method	**Graphical representation**
I *Manipulation of data*	
Ia Extrapolation and singling out of data	
Ib Interpolation and sampling of data	
Ic Aggregation and disaggregation of data	
Id Aggregation/averaging of data - Input data (stratified)	
- Output data (stratified)	
II *Manipulation of models*	
IIa Modification of model parameters	
IIb Simplification of model structure	
IIc Derivation of response function	
IId Nested model	

a) The area symbol refers to a region with point observation(s) in the region symbolised with dot(s) that are transferred to the entire region depending on the method (arrows). Sub-region (e.g. Ib) indicate spatial aggregation of data.
Source: Ewert et al. (2011).

Below we list some examples of the scaling methods application, also practiced at LEI. First, we refer to interpolation and sampling (Ib). In agriculture, data from the Farm Accountancy Data Network (FADN) provides the most detailed and harmonised data on the economic performance of farms and are often used to estimate population characteristics (Vrolijk et al., 2011). The use of FADN data in regional studies is often problematic due to the low number of observations. Several methods have been developed (for example (Dol, 1991)) to use additional information to increase the reliability of estimates. Statistical matching method, also known at LEI as a software tool STARS, has been applied in various studies to make use of additional information from the census to make more reliable estimates in regional studies (Vrolijk et al., 2005; Van der Veen et al., 2010; Vrolijk et al., 2011). The basic idea behind the method is that sample farms are matched to population farms based on the imputation variables, i.e. variables which are used to decide whether a farm resembles a sample farm. The imputation variables should be known for all farms in the sample and the population and the distance between the population farm and the sample should be the smallest.

Next, we refer to upscaling and downscaling (IIc). Market level models, such as CAPRI or MAGNET, consider prices as endogenous variables and are able to capture price effects from simulated policies. However, market level models provide less detail in modelling agricultural production and production externalities than farm level models, and are therefore less suitable for integration with biophysical models. The primary reason for this is that most aggregate models derive the supply behaviour on the basis of representative cost or profit functions. A way of upscaling of farm supplies through newly established market prices that account for changes in supply has been achieved in linking farm model FSSIM - Farm Systems Simulation Model (Louhichi et al., 2010) and market model CAPRI in SEAMLESS project (Pérez Domínguez et al., 2009). The basic model linking principle of the EXtraPolation and Aggregation MODel (EXPAMOD) is to parameterise one model (CAPRI) using the simulated response behaviour of the other (FSSIM). EXPAMOD is, therefore, a statistical meta-model that describes the price-quantity responses of farms given specific farm resources and biophysical characteristics that are available EU-wide. A meta-model, in this context, is an approximation of the input-output behaviour of the underlying simulation model, i.e. it describes the main relationships between key FSSIM variables and the supply of products. Thus, the meta-model is estimated using simulated price-quantity data for farm types in regions for which FSSIM models exist and then applied to project supply responses of other farm types and regions.

The model MAGNET has already a very flexible system of (dis)aggregating spatial units (countries) into groups, as well as sectors and their groups. A downscaling procedure has been developed and applied enabling to disaggregate model output to regions (Woltjer et al., 2011). In this study the results from the model MAGNET that operates at country level are scaled down to NUTS 2 regions of the EU Member States to assess the effects of policy measures at a lower scale. The downscaling method builds up its complexity in a step-wise manner. It starts from a simple but consistent step assuming that regional percentage growth equals national percentage growth. Next, hypotheses are formulated regarding factors that may explain the inequality in the percentage growth and market equations are added to allow for adjustment processes. For example, both migration and allocation of production reacts on changes in wages and employment. Empirical work to quantify differences between regional and national growth developments is carried out. The results of such econometric panel data estimations are integrated into the dynamic equations of the downscaling method, but also information from the literature or experts can be used. The sectoral aggregation on NUTS 2 level depends on the available data.

Next section presents further details regarding the model linking that was achieved in various studies and thus illustrates how the scale and extent of a model chain can benefit the scope of the study if otherwise done with a stand-alone model only.

14.2 Model linkages

Work in several recent projects have advanced the linkages of models presented in this document with other models. The linkages that were necessary to extend the scope of analysis, are mainly done in a hard way, i.e. the results of one model are passed onto the next model. A few examples are listed below.

Verburg et al. (2009) present the results of linking MAGNET (former LEITAP) and the Integrated Model to Assess the Global Environment (IMAGE) is assessing impacts of trade liberalisation policies through economic and environmental indicators. MAGNET-CAPRI models have been conceptually linked in

SEAMLESS project (Jansson et al., 2009) and further used to e.g. investigate the effectiveness of post-2013 CAP measures as proposed in the Dutch Outlook (focusing on competitiveness, valuable areas and ecosystem services) as well as the effectiveness of base premiums (Helming et al., 2010).

AGMEMOD has been used in combination with DRAM and MAGNET in prospecting the Dutch agrofood sector in 2025 (Berkhout, 2011). For the various scenarios considered in that study, MAGNET provided a set of world price projections, which served as input for AGMEMOD. Then, AGMEMOD provided baseline and scenario projections for the main agricultural commodity markets in the Netherlands. Moreover, agricultural prices for Dutch agricultural crops as calculated in AGMEMOD were used to calculate (regional) Dutch farm sector incomes by DRAM.

CAPRI has been linked to many different models. For example in the SENSOR project the model has been linked iteratively with the macro-economic model NEMESIS , to the forestry model EFISCEN (Schelhaas et al., 2007) in the SENSOR project see (Jansson et al., 2008) as well as to Conversion of Land Use and its Effects (spatial land use and land cover change model CLUE, see (Britz et al., 2011). CAPRI has also been linked with the GHG, N and P emissions model (MITERRA, see e.g. (Velthof et al., 2009) to assess the agricultural N and P balances and NH_3, N_2, N_2O, NO_x, NO_3 and CH_4 losses to the wider environment in a uniform and integrated way for all member states of the EU-27 on regional scale. Outputs of CAPRI have been used in assessing the changes i*n* biodiversity by 2020 (Van Zeijts et al., 2011). For the future, one could envisage more links with CLUE, with manure trade models and with the TRansport of Animals and Meat model TRAM (Baltussen et al., 2010).

At this moment there are no explicit linkages with the model HORTUS, however it can easily re-use scenario assumptions as applied in models such as MAGNET and CAPRI. As far as one assumes that horticulture trade influences other trade and is influenced by other trade, it may be useful to include the partial equilibrium model HORTUS in the context of a general equilibrium model MAGNET.

The ORANGE model is not currently linked to any other models. However, the choice of model structure, programming language (GEMPACK) and data structure was made to facilitate easier integration with the MAGNET model in the future. A linked MAGNET-ORANGE model would give the benefits of being able to better model policies and shocks at the global level whilst retaining the sectoral detail at the national level.

DRAM model has been linked to market model CAPRI as well as to farm model FIONA - Farm Level Integrated Optimisation model for Nature and Agriculture (Groeneveld and Schrijver, 2006; Helming and Schrijver, 2008) to assess a set of nature-related policies (reduction of manure disposal, setting up buffer zone, compensation for higher water level, et cetera). DRAM is often used to assess the impact of changes in agricultural policy, translating these impacts to the farm level by MAMBO creates the possibility to model the effects at a detailed regional level. This is especially important in projects related to the water framework directive in which regional impacts are important. The linking between DRAM and MAMBO takes place by data exchange. The results of the number of animals and the area of crops at regional level from DRAM are inputs for MAMBO. The outputs from MAMBO about manure distribution at a regional level are inputs for DRAM. A few iterations of data exchange are sufficient to create consistency between the two models. DRAM and MAMBO (Vrolijk et al., 2008) have been linked to assess possible measures of emission reductions by 2020 and their economic and environmental effects.

There is a direct connection developed between MAMBO and STONE, MAMBO and OPS and MAMBO and APPROXI. The STONE (Wolf et al., 2003; (Velthof and van Grinsven, 2006) system was developed for evaluating the effects of changes in the agricultural sector and in policy measures on the leaching of nitrogen and phosphate to ground and surface waters in the Netherlands. The system was developed in particular for evaluations at the national scale, but may also be applied at the regional scale. MAMBO is used to calculate the soil loads and these output data are used in STONE to calculate the impact on ground and surface water (Velthof and van Grinsven, 2006). The Operational Priority Substances (OPS) model (Jaarsveld, 2004) calculates the concentration of ammonia in the air, the concentration of ammonia aerosol and the deposition of nitrogen. With MAMBO the ammonia emission from agriculture is calculated at grid level of 500 * 500 m, which then serves as input for the OPS model. APPROXI (Hennen, 1995) has been used in several studies dealing with projections on nutrients and economics for arable and dairy

farms. In forecast studies results of the APPROXI models can be used as inputs for MAMBO. The following outputs of the APPROXI models can be used as an input for MAMBO:
- number of cows, heifers and calves per regional area;
- average milk production per cow per regional area;
- the use of off-farm manure at cattle farms per regional area;
- the use of off-farm manure at arable farms per crop per regional area.

The MAMBO manure prices can be used as input in the APPROXI models.

SERA gives the opportunity to look at the dynamics of each individual farmer with other farmers in an spatially explicit way; it is also able to look at the interactions between farmers and their surrounding landscape (see also Schouten et al., 2011). With spatially explicit, it is meant that realistic parcels in an empirical landscape are included, based on SERA gives the opportunity to look at the dynamics of each individual farmer with other farmers in an spatially explicit way; it is also able to look at the interactions between farmers and their surrounding landscape (see also Schouten et al., 2011). With spatially explicit, it is meant that realistic parcels in an empirical landscape are included, based on GIS data. Due to its spatial explicit character it adds to other models within LEI at higher levels. SERA gives the opportunity to simulate different policy scenarios, policy interventions at a certain time period and therefore is an interesting way to look at policy evaluation. A potential linkage exists between SERA and FLAME to simulate (local) interactions between farmers taking into account farm level optimisation. SERA provides insight into the spatial dynamics of land and land use and includes an ecological perspective by focusing on the development of conditions for farmland biodiversity.

The FES model is often applied in combination with other models. (Smit et al., 2009) showed that it is possible to link models with the FES model to translate policies into income effect and other effects. Linkages with all kind of behavioural and technical models are possible, as long as the output can be translated to individual FADN farms and to financial parameters. This translation can either be done by including some calculation rules in the FES model or determining the effects per individual FADN sample farm outside the FES model and include these figures as input in the model.

SERES is a model that has a strong interaction with the ecological model LARCH and requires input from GIS applications. In turn the output of SERES is used in GIS applications.

FLAME is still under development but its design already assures for possible interactions with other models, for example MAMBO.

14.3 Concluding remarks

In 2000 Stijn Reinhard and Frank van Tongeren presented the concept of the LEI model funnel (Reinhard, 2000; van Tongeren, 2000). They proposed to develop a package of linked models, covering levels of aggregation from individual producer to world market. This report presents the current state-of-the art and it shows the progress that has been made. All levels in the funnel are covered, although the linkage is neither straightforward nor general; considerable effort is required for each project in which models are linked (Helming and Banse, 2008). Nevertheless, great progress has been made. The current set of models covers all levels of the funnel and its methodological diversity allows for the support of policy makers in a broad range of decisions and design problems.

Another field where progress has been made is quality management. Foppe Bouma's perseverance and tenacity have resulted in the implementation of model quality assurance in LEI's ISO 9001 quality handbook and has established a routine of annual audits. Foppe has retired, but the function of model quality assurance has been continued. Eugène Westerhof currently fulfils the function and coordinates the annual audits. Furthermore, the models are now being developed and maintained and documented by teams, so that the continuity of a model does not depend on a single person. Models survive the relationships of their original developers with LEI. Through quality assurance the models are ready for future challenges by policy makers in government and business.

A general issue emerging from the audit reports is the shortage of budgets for model maintenance. It is well-known that keeping a model up-to-date requires considerable effort and budget. Financing the necessary maintenance from external sources is virtually impossible. It is therefore surprising to see that most of the models described in the preceding chapters have a long history at LEI. Those models are kept up and running by high levels of commitment of the researchers. The continuing application of the models in research projects confirms the appreciation which our commissioners have for the models. That raises the question why financing of the maintenance is such a problem. Some of the models (MAGNET, AGMEMOD, CAPRI) are frequently developed and applied in the context of international consortia. This setting offers an opportunity to finance model maintenance. New ways to safeguard model maintenance have to be found for the other models as well, either in consortia of modellers or in consortia of model users.

This report has discussed a selection of frequently used models that cover most of LEI's domain. Completeness of the inventory of LEI models has not been pursued. Other models are operational or are currently being developed at LEI, usually for specific purposes. Some examples are the CO2 tool (footprint of supply chains in horticulture, (Hiller and Danse, 2009), TRAM (European transport of animals and meat, (Baltussen et al., 2010)), and LMM (monitoring of mineral balances). The playing field of modelling continues to move. New policy questions emerge and new scientific methodology evolves. We have to keep up with both. A methodological innovation is the application of agent-based models for the study of complex adaptive systems. An example is SERA (Chapter 10). Other work on agent-based models at LEI is reported by (Valeeva and Verwaart, 2011) and (Buurma et al., 2012). Much effort has recently been directed to farm level modelling using FADN data (FLAME, Chapter 13). Further investments are necessary to maintain LEI's traditional position in this field closely related to the sector, and, at the same time, keep up with the evolution of methodological insights. One of the organisational challenges we are faced with, is to develop a consortium in which this position can be sustained.

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