A tool for agri-environmental policy decisions

Using a spatial explicit agent-based modelling approach

LEI WAGENINGEN UR

A tool for agri-environmental policy decisions

Using a spatial explicit agent-based modelling approach

Marie-José Smits
Marleen Schouten

LEI memorandum 12-031
April 2012
Project code 2272000149
LEI, part of Wageningen UR, The Hague

LEI is active in the following research areas:

Agriculture & Entrepreneurship

Regional Economy & Land Use

Markets & Chains

International Policy

Natural Resources

Consumer & Behaviour

A tool for agri-environmental policy decisions; Using a spatial explicit agent-based modelling approach
Smits, M.-J. and M. Schouten
LEI memorandum 12-031
21 p., fig.

Project KB-14-011-003, 'FIONA Status A'

This research project has been carried out within the Knowledge Base research Task for the Ministry of Economic Affairs, Agriculture and Innovation, Theme: Sustainable development of the green-blue space.

This publication is available at www.lei.wur.nl/uk.

LEI is ISO 9001:2008 certified.

Contents

Preface

From FIONA to a spatial-explicit agent-based modelling approach

Throughout the years, the role of farmers in securing environmental services from farmed landscapes has been supported through agri-environmental schemes. The farm management model FIONA (Farm-scale Integrated Optimisation model of Nature and Agriculture) was developed at LEI, and has been applied in several projects with regard to agri-environmental schemes. FIONA is an optimisation model focused on different forms of nature management on cattle farms. FIONA maximises the farm's economic income within a set of restrictions characteristic of the structure of the farm under consideration.

An increasing demand for spatial visualisation on landscape level and research questions with respect to farmer interactions has triggered a new approach: While taking into account spatial dynamics, institutional dynamics in land ownership and intensity of land use, the Spatially Explicit Rural Agent Based Model (SERA) has been developed by Marleen Schouten, Nico Polman and Eugène Westerhof at LEI. The model has been established 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. The model has similar components comparing to FIONA, dealing with a farm module, a soil nutrient module and a fodder accounting and land-use module; main differences are the use of a spatial explicit land market, farmers' interactions and the possibility to make adaptive behaviour of farmers spatially explicit. This document builds on Schouten et al. (2011) and presents the possibilities of SERA in the light of Agri-Environmental decision making.

Within the Common Agricultural Policy (CAP) much attention has been paid to the integration of nature objectives in agriculture. This has resulted among others in the increasing importance of agri-environmental schemes. Recently, agri-environmental policy questions are directed increasingly towards the balance between economic and ecological objectives within a region. How can we keep up with these developments with our model systems? The agent-based model SERA may be suitable in this context.

L.C. van Staalduinen MSc
Managing Director LEI

1 Introduction

1.1 Policy background

One of the ambitions of the European Commission is to have a better integration of nature objectives in agricultural policy. For example, the budget for agri-environmental schemes has been continually increased the past twenty years. Furthermore, in 2011 the European Commission (EC) proposed that from 2013 onwards income support of farmers is (more) connected to natural targets. Next, in the Netherlands, a decentralisation process from government to provinces is ongoing, especially concerning nature policy. The provinces prefer a more regional approach of nature and landscape issues. Concerning nature and landscape elements on agricultural land, the aim is for more responsibility for agrarian nature cooperatives. The objective is that agri-environmental programmes are not applied on isolated plots, but are integrated into the whole farming system and even within a region. Both the provinces and the central government are steering towards a regional approach, where agrarian nature cooperatives receive a budget linked with a nature target, which they may employ in their own way. There is an ongoing debate with the EC on the opportunities to do so within the CAP.

1.2 Objective

The objective of this document is to improve the analytical tools towards policy issues at the interface of agriculture and nature targets, which can be evaluated at a regional scale addressing spatial coherence. Special attention is paid to the agent-based model developed by M. Schouten et al., named SERA.

Specific to SERA is:

a. The model is based on the behaviour of agents (in this case farmers) and interaction between agents. Concerning the behaviour of farmers the focus is on their decisions towards nature and landscape elements on the farm;
b. Both environmental and business objectives are weighted;
c. The model is spatially explicit, i.e. it can be used to clarify where certain agri-environmental packages can be best applied, from the perspective of ecological effectiveness.

SERA can be used to analyse questions about effective and efficient management of nature and landscape elements on farms. Farmers (agents) take individual decisions on agri-environmental schemes, but the ecological effectiveness of their decisions is determined by what colleagues do and the linkages of agri-environmental management to the (natural) environment. Indeed, the effectiveness is affected by spatial coherence of the management activities and the environment (i.e. neighbouring Natura 2000 sites). The farmer decides individually, mainly based on farm business goals, and the type and the location of currently owned land. However, the public interest lies in the ecological effectiveness of the contracted agri-environmental schemes which is the result of the interaction between the individual decisions and the environment (emerging behaviour). New elements of scheme design can be introduced which include ecological effectiveness.

1.3 Overview of the paper

In chapter 2 we focus on policy issues at the borderline of agriculture and nature/environment/landscape. We describe policy developments which imply a comparative assessment of agricultural production and nature conservation. We start with policy issues at the EU level, and then continue with the national and regional level. Chapter 3 is devoted to agent-based models applied to agriculture, especially SERA. Furthermore, a description of SERA and the model input and output are given. Chapter 4 concludes with an overview of the possibilities of SERA to answer relevant policy questions in the future. We point out future model extensions of SERA which can be relevant in the context of agricultural policy reforms and also discuss some alternative modelling approaches.

2 Overview of policy developments

2.1 CAP reform, proposals from the European Commission

On 12-10-2011 proposals of the European Commission on future CAP reform were published. [1] The following changes are relevant to this project.

Proposed changes within the first pillar of the CAP
In order to reinforce the ecological durability of the agricultural sector and enhance the efforts of farmers, the European Commission is proposing to dedicate 30% of direct payments to practices that enable optimal use of natural resources:

- Maintenance of permanent pasture;
- Crop diversification;
- Minimal 7% of the agricultural land (except for permanent grassland) is used as ecological focus area, i.e. is used for the preservation of ecological reserves and landscapes.

Proposed changes within the second pillar of the CAP
The special nature of each territory should be taken into account and agri-environmental initiatives at national, regional and local level encouraged. In order to do this, the Commission is proposing that the preservation and the restoration of ecosystems and the fight against climate change, together with the effective use of resources, should be two of the six priorities of rural development policy.

Concerning the integration of agricultural with nature objectives, especially the proposed changes within the first pillar are relevant. Actually, for this study, the ecological focus areas (7% measure) is most interesting. The initial reaction of the Dutch government on this proposal of the EC was to suggest more flexibility concerning the implementation to improve effectiveness.

> 'By choosing obligated measures for each farm within the EU member states the commission overreaches oneself. The Netherlands want a flexible menu with green services. This of course within a framework of the EU which prevents unfair competition. In this way member states can choose the most effective measure which fits best within the country and the farms', according to the State Secretary Bleker.[2]

There is an ongoing discussion in the Netherlands on how to imply the ecological focus areas in the most effective and efficient way. Part of this discussion is whether regional differentiation will be more effective. Actually, one wants to convince Brussels that a spatially well-considered implementation of the measure will lead to a higher ecological effectiveness, which makes it possible to apply less than 7% of the agricultural land without decreasing the ecological results.

2.2 Manure regulations

In the Netherlands there is an increasing surplus of manure. The regulation of the EC concerning ecological focus areas may even further increase this surplus if farmers are not allowed to apply manure on these

[1] http://ec.europa.eu/enterprise/newsroom/cf/itemlongdetail.cfm?item_id=5484&lang=en
[2] http://www.rijksoverheid.nl/nieuws/2011/10/12/bleker-plannen-nieuw-europees-landbouwbeleid-niet-vernieuwend-genoeg.html

ecological focus areas. There is still a lack of clarity, but the amount of land on which farmers are allowed to apply manure may decrease due to this new regulation.

In September 2011 a vision for future manure policy was sent to the Dutch Parliament. Part of the plan is that an increasing part of the surplus of manure of a farm has to be processed at a certified factory. There will be regional differentiation within the regulation, but in general it will mean that manure surplus will become more expensive for a farmer.[1] The increase of expenses to reduce the manure surplus will have consequences for the interest of farmers for agri-environmental schemes since often measures within an agri-environmental imply that farmers are not allowed to apply manure on the plot involved.

2.3 Agreement between the Dutch government and IPO

On 20-9-2011 an agreement was signed between the Dutch government and the coordinating organisation for the provinces (IPO). However, this agreement is under discussion because some provinces refuse to sign it. The agreement shows however the direction in which the government wants to continue the decentralisation process on the Ecological Main Structure (EMS).

The most important elements of the agreement in this context are:

- The provinces become responsible for EMS (in Dutch: EHS), they become also responsible for agri-environmental schemes within the EMS;
- The government will be responsible for agri-environmental schemes outside the EMS;
- In principle agri-environmental measures outside the EMS are financed within the first pillar of the CAP (see proposed changes of the first pillar, especially the ecological focus areas). Attention is paid to a collective approach.

In this context it means that it makes a difference whether a case study area is located inside or outside the EMS. Furthermore, it shows that outside the EMS ecological focus areas may take over the role of agri-environmental schemes.

The government decided to finalise the EMS in the more compact form than scheduled before. The aim is to obtain less land for nature conservation organisations than previously foreseen. Instead of obtaining land to converse it into nature conservation areas, the government wants nature conservation measures for farmers and other private landowners. A consequence is that when agricultural nature management programs outside the EMS are financed within the first pillar, in principle, more budget becomes available for agri-environmental schemes within the EMS, given that the provinces are willing and able to co-finance.

2.4 The provinces and nature policy

As a result of the decentralisation process, the system for agri-environmental schemes has been adapted. The name of the system has been changed from Programma Beheer to Stelsel voor Natuur en Landschapsbeheer (SNL). The government was responsible for Programma Beheer, and the provinces are now responsible for SNL. The main ideas behind SNL are:

- Integrated regional approach;
- Less details and more steering on outlines;
- Simplification of the financial system.

Most relevant here is the regional approach which is central within SNL. Furthermore, one want to give more responsibility to the farmers and steer less on details.

---

[1] http://www.rijksoverheid.nl/onderwerpen/mest/nieuws/2011/09/28/nieuw-stelsel-voor-evenwicht-op-mestmarkt.html

(SNL is the responsibility of the provinces. However, the government steers towards the direction that agri-environmental schemes outside the EMS become the responsibility of the government again. It is not clear yet what this means for SNL.)

2.5 Visions towards collective agreements

Within the Netherlands there are about 130 agrarian nature cooperatives. Around 55% of the agrarian land is covered by the cooperatives. The agrarian nature cooperatives are graduated changing from organisations focusing on the administrative process concerning agri-environmental schemes towards organisations that manage nature and landscape objectives within a region. Instead of implementing measures one increasingly develops and manages measures, whereas the overall objectives are outlined by the authorities. Farmers prefer to define the required actions themselves, based on overall objectives defined by the authorities.

Currently, experiments are ongoing within four pilot projects with self-management by agrarian nature cooperatives. The cooperatives get the opportunity to show that they are able to manage nature or landscape objectives on agricultural land in their region, given a certain budget. They will be evaluated this year on their effectiveness and efficiency. One of the pilot areas is Winterswijk. Winterswijk is also a case study for SERA.

The Dutch government evaluates the possibility to apply more collective instead of individual agreements concerning agri-environmental schemes. The ministry of EL&I states that one wants to examine the possibility to increase role of environmental cooperatives concerning innovation, agrarian nature conservation and multifunctionality. The basic idea is that the introduction of collective contracts for CAP measures will execute the measures more effectively. The idea of collective agreements is applicable both to first pillar measures (especially the so called ecological focus areas) and second pillar measures (mainly agri-environmental schemes). The question is whether the Netherlands will find a positive response within the EU for this idea.

3 Description of SERA[1]

3.1 Introduction to ABM

Agent-based models have become a popular method of modelling complex real world systems in the land-based sector. Matthews (2007) summarises the advantages of agent-based models as follows:

> 'Specific advantages of agent-based models include their ability to model individual decision making entities and their interactions, to incorporate social processes and non-monetary influences on decision-making, and to dynamically link social and environmental processes.'

This chapter builds on Schouten et al. (2011) and presents the Spatially Explicit Rural Agent Based Model (SERA), which is currently being developed by Marleen Schouten, Nico Polman and Eugène Westerhof at LEI. An extensive model documentation can be obtained by contacting the developers of SERA.

To capture spatial and institutional dynamics in land ownership and intensity of land use, an agent-based model (see i.e. 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 the behaviour of individual farmers at the micro-level, 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 spatially explicit ABMs are to simulate impact of rural development policies; for evaluation/simulation of water management policies on a regional, spatially 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.

3.2 Description of the model

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.

[1] Authors for SERA at LEI: Marleen Schouten (Marleen.Schouten@wur.nl), Nico Polman (nico.polman@wur.nl) and Eugène Westerhof (eugene.westerhof@wur.nl).

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 parcel's contribution to the farm income, given limited 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 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 be representing 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 an 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 spatially 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.

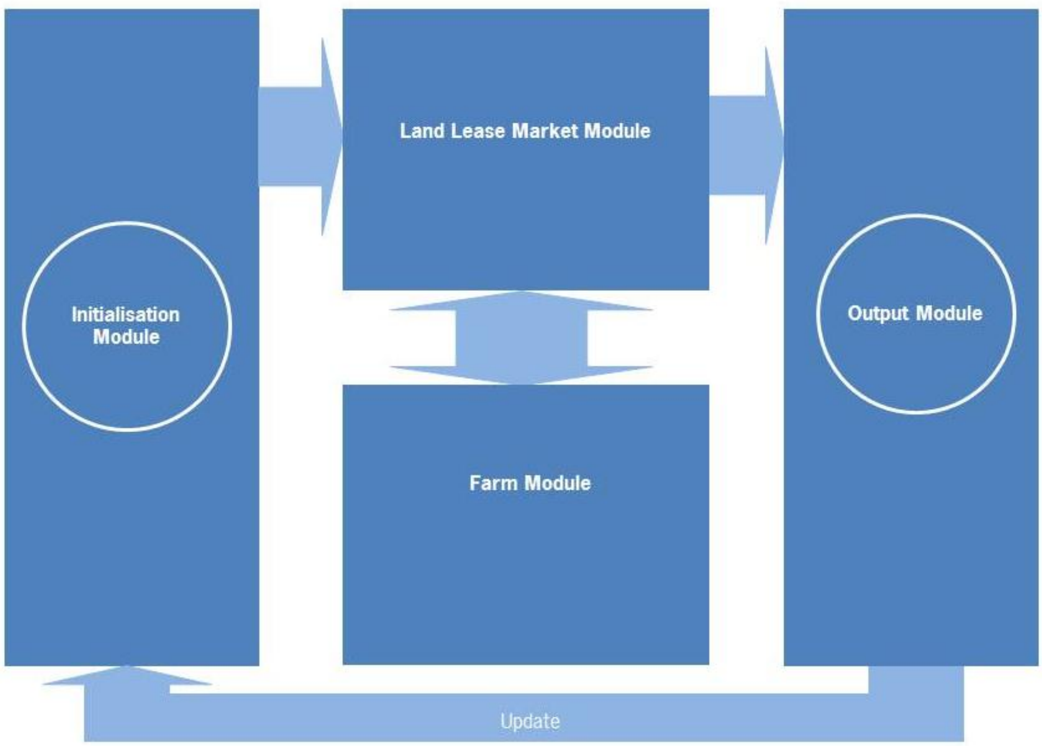
3.3 Required input

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.

3.4 Model output

Figure 3.1 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.

Figure 3.1 **Course of events during one simulation period in SERA**



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 updating farm attributes and regional attributes in the next period.

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.

4 Potential applications of SERA for policy analysis[1]

4.1 Strengths and weaknesses of the approach

The model presented in chapter 3 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. The developers of SERA therefore created a list with future model extensions for SERA, which is presented in section 4.2.

A caveat of the model 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.

4.2 Future model extensions

During the modelling process, different ideas were raised to extend and to improve the model. Also reviewing existing agricultural ABMs resulted in some inspiring ideas for future model extensions (Happe, 2004, Möhring, 2010, Adensam, 2007 and Berger, 2001). In this section a list is given of extensions which could be of high value for SERA in the future. First of all, we want to denote that the model is built in a modular way; this means that parts of the model can be combined with new modules or other modules. In this way, the model can be easily adjusted to another region, i.e. an arable region, by adding a crop rotation module and adjusting the decision rules of the individual agents. However, these decision rules must be evidence-based and tested during the development of the model.

Running policy scenarios for the new CAP

Policy scenarios for the new CAP can be run by modifying the decision rules according to the new scenario. New scenarios can be run with respect to:

- nature conservation (size of assigned parcels, ecological quality of parcels),;
- quality and change in management types;
- effects of milk quota abolishment on the land use in the area (what is the effect on nature?);
- new nitrogen restrictions;
- the effects of innovation subsidies;
- the effects of the so-called 'megastallen' restriction to growth.

Networks

A potential extension of the model is to include networks among agents. This could be relevant with respect to information on the land market.

[1] The future model extensions discussed in this chapter are part of the SERA model documentation, which has been written by Marleen Schouten, Nico Polman and Eugène Westerhof.

Including new agents
Including new agents in the model increases system dynamics in the area of study. By including i.e. arable farmers (including crop rotation systems of PRI) it is possible to run the model in regions with a different character. By doing this, also the ecological and land-use functions will have to be changed.

By including recreational agents (hotel managers/ camping sites) a new dimension of the region is touched.

Including Agricultural Conservation Cooperations is an interesting way to look at networks and the benefits of rural networks as well as the effects on nature conservation and land use.

Transaction costs influencing the land market
In this version of SERA, the model was calibrated to a rural region in the eastern part of the Netherlands (Nationaal Landschap Winterswijk). With respect to the conditions given in that region, it was reasonable to assume well-functioning markets for products and production factors. However, the modelled market is far from being realistic and smooth. There is much evidence that market imperfections on land markets have a major influence on the development of regions throughout Europe. Imperfections are mainly due to high transaction costs, and the market power of large cooperations. In order to take his explicitly into account, we could introduce a transaction cost framework in a future version of the SERA.

External labour
It is assumed within the model that labour is supplied by the farm family and therefore it is not taken into account explicitly. A future model extension could focus on external hired labour on a fixed or hourly basis. We could also include off-farm labour in a future model extension, as a new source of farm and non-farm income.

Investments

To produce, a farm agent needs capital, both in the form of liquid funds to pay running costs, and in the form of fixed-asset capital (investments), which determines a farm agent's productive capacity. In this version of SERA, investments are not taken into account in the model. Future model extensions could contain investment decisions by farm agents, as well as the provision of external long-term borrowed capital. Also, investments in new technology which assume an improvement of production over time could be a possible model extension. Maintenance costs are also not taken into account in the model.

Managerial ability
Managerial ability of the farm agent is not taken into account in the model. It could be valuable to make agricultural production depending on managerial ability. This could be extended to investment decisions, et cetera.

Exchange information on land prices
For future versions we like to include the exchange of information among farmers on land prices and availability of land to make the model more realistic.
Future expectations about product prices, costs land prices, technologies, investment possibilities, policy changes

At this moment farm agents in SERA only take into account historical land prices in their decision making process. It would be an interesting task to include future expectations about prices, but also about policies.

Urban pressure
It would be interesting to simulate what the influence is of urban pressure on the rural dynamics in the rural landscape simulated in SERA. This can be done through inclusion of a GIS map on parcels which are also demanded by road constructors, project developers, or which are assigned by the municipality for building purposes. When including these developments as a new demander (agent) on the land market, new insights will be gained in land dynamics.

4.3 Urgent policy questions to be spatially addressed

For several policy issues SERA is of interest:

Ecological focus areas (first pillar)

How to implement ecological focus areas in an ecological effective and economic efficient way? For this a spatial model is needed, which takes into account farmers' decisions towards nature management and the environment. Furthermore, economic (farm business) and ecological objectives have to be weighted.

Agri-environmental schemes (second pillar)

Agrarian nature cooperatives become increasingly responsible for the implementation of nature and landscape programs, given overall objectives and given a certain budget. How can they plan agri-environmental schemes in the most effective and efficient way in their region?

Coherence between ecological focus areas and agri-environmental schemes
Ecological focus areas and agri-environmental schemes, when applied in the same region, can be complementary. In order to analyse the most effective and efficient way of implementation of both programs in a region, a spatially oriented model is needed which takes into account both farmers and ecological objectives.

Collective agreements
Both for ecological focus areas and agri-environmental schemes a discussion is going on whether collective agreements, instead of individual agreements, are an option. The advantage of collective agreements is that one is able to plan the concerned plots in a spatial effective way. A model like SERA can be of use in this planning process.

Implementation of a restructured EMS (and Natura 2000)
To improve the spatial cohesion of EMS (and Natura 2000) sites, the application of SERA can be useful. The aim is to deploy agricultural nature management programs to improve the spatial cohesion of EMS, and for this, one has to calculate which agricultural plots are most interesting ecologically.

4.4 Alternative analytical tools and methods for area-specific policy questions

Agripolis
The agent-based model AgriPoliS (Agricultural Policy Simulator) (Balmann, 1997, Balmann, 2002) simultaneously considers a large number of individually acting farms, product markets, investment activities, as well as the land market, and has a simple spatial representation. The objective of AgriPoliS is to study the interrelationship of rents, technical change, product prices, investments, production and policies, structural effects resulting from these, the analysis of the winners and losers of agricultural policy as well as the costs and efficiency of various policy measures. As farms predominantly grow by renting land, AgriPoliS

only considers a land rental market. In AgriPoliS, all farmland is categorised as plots of the same size. Plots are not divisible, and their size is fixed during one simulation run. Accordingly, the size of a plot defines the smallest unit by which farm acreage can change. Initially, each farm agent is endowed with a certain amount of land consisting of owned and rented land.

CLUE-S

In this subsection a short description will be given of the possibilities that CLUE-S offers to conduct area-specific research. Main parts of the elaboration are taken from Verburg and Overmars (2009) and Verburg et al. (2002). Land-use change models are important tools for integrated environmental management. Through scenario analysis they can help to identify near-future critical locations in the face of environmental change. A dynamic, spatially explicit, land-use change model for the regional scale is: CLUE-S. The model is specifically developed for the analysis of land use in small regions (e.g., a watershed or province) at a fine spatial resolution. The model structure is based on systems theory to allow the integrated analysis of land-use change in relation to socio-economic and biophysical driving factors. The model explicitly addresses the hierarchical organisation of land-use systems, spatial connectivity between locations and stability. Stability is incorporated by a set of variables that define the relative elasticity of the actual land-use type to conversion. The user can specify these settings based on expert knowledge or survey data.

Main differences between CLUE-S and SERA are the unit of analysis and the agent interactions. The finest unit of analysis in CLUE-S is a grid, the size of which (1km*1km or 500km*500km) may vary depending on the data availability. SERA on the other hand, makes use of actual parcels using GIS maps. Through this method, more realism is included in the model. Another difference between the two models is the existence of agent interactions. Both models have a different focus. Where SERA is focused on the (spatially explicit) effects of agent interactions, CLUE-S focuses on land-use management.

Spatial Econometric Analysis

Spatial econometric analysis is the field where spatial analysis and econometrics intersect. In general, while econometrics focuses on theoretical models using regression analysis to estimate parameters, spatial econometrics is more refined. This type of analysis deals with interactions between different entities; using data observations and spatial econometric methods while incorporating spatial autocorrelation or neighbourhood effects (Cotteleer and Peerlings, 2011). With respect to spatial research questions in rural areas this method makes it possible to i.e. evaluate effects of zoning on the preservation of open space in rural areas, and to quantify the externalities that different types of land use impose on residential properties. Because each specific dataset requires specific data-handling methods, different econometric techniques are used to answer research issues regarding land use. Spatial econometric analysis could be used in addition to the SERA model and could serve as interesting input for SERA decision rules. As spatial econometric analysis focuses on land use, and the effects of neighbouring spatial elements, the SERA model could make use of this information in its interactions between rural agents, and their spatial environment.

Literature

Adensam, H., V. Gaube, H. Haberl, J. Lutz, H. Reisinger, J. Breinesberger, A. Colard, B. Aigner, R. Maier and W. Punz, *Landnutzung und landwirtschaftliche Entscheidungsstrukturen Partizipative Entwicklung von Szenarien für das Traisental mit Hilfe eines agentbasierten Modells*. Social Ecology Working Paper 93, 2007.

Balmann, A., 'Farm-based modelling of regional structural change: A cellular automata approach.' In: *European Review of Agricultural Economics* 24 (1997), pp. 85-108.

Balmann, A., K. Happe, K. Kellermann and A. Kleingard, 'Adjustment costs of agri-environmental policy switchings: A multi-agent approach.' In: Janssen, M. (ed.), *Complexity and ecosystem management: The theory and practice of Multi-Agent Approaches*. Edward Elgar Publishers, Northampton, MA, 2002, pp. 127-157.

Berger, T., 'Agent-based spatial models applied to agriculture: A simulation tool for technology diffusion, resource use changes and policy analysis.' In: *Agricultural Economics* 25 (2001), pp. 245-260.

Cotteleer, G. and J.H.M. Peerlings, 'Spatial planning procedures and property prices: The role of expectations.' In: *Landscape and Urban Planning* 100 (2011), pp. 77-86.

Dol, W., *Small area estimation: a synthesis between sampling theory and econometrics*. Wolters-Noordhoff, Groningen,1991.

Happe, K., A. Balmann and K. Kellermann, *The Agricultural Plilcy Simulator (AgriPolis) - An agent-based model to study structural change in agriculture (version 1.0)*. Discussion Paper No. 71. Institute of Agricultural Development in Central and Eastern Europe (IAMO), 2004.

Happe, K., K. Kellermann and A. Balmann, 'Agent-based analysis of agricultural policies: An illustration of the agricultural policy simulator AgriPolis, its adaptation and behavior.' In: *Ecology and Society* 11 (2006).

Lobianco, A. and R. Esposti, 'The Regional Multi-Agent Simulator (RegMAS): An open-source spatially explicit model to assess the impact of agricultural policies.' In: *Computers and Electronics in Agriculture* 72 (2010), pp. 14-26.

Matthews, R., N.G. Gilbert, A. Roach, J.G. Polhill and N.M. Gotts, 'Agent-based land-use models: a review of applications.' In: *Landscape Ecology* 22 (2007), pp. 1447-1459.

Möhring, A., A. Zimmermann, G. Mack, S. Mann, A. Ferjani and M. Gennaio, *Modelling structural change in the agricultural sector - an agent-based approach using FADN data from individual farms*. 114th EAAE Seminar 'Structural Change in Agriculture', Berlin, Germany, April 15-16, 2010.

Parker, D.C., S.M. Manson, M.A. Janssen, M.J. Hoffmann and P. Deadman, 'Multi-agent systems for the simulation of land-use and land-cover change: A review. In: *Annals of the Association of American Geographers* 93 (2003), pp. 314-337.

Schouten, M., N. Polman, E. Westerhof and P. Opdam, *Landscape cohesion and the conservation potential of landscapes for biodiversity: evaluating agri-environment schemes using a spatially explicit agent-based modeling approach*. OECD Workshop on Evaluation of Agri-Environmental Policies, Braunschweig, Germany, 20-22 June, 2011.

Veen, H. van der, C. Daatselaar and M. Dolman, 2010. *Watergebruik in de agrarische sector 2001-2008, naar stroomgebied*. LEI, part of Wageningen UR, Den Haag, 2010, p. 27.

Verburg, P. and K. Overmars, 'Combining top-down and bottom-up dynamics in land use modeling: exploring the future of abandoned farmlands in Europe with the Dyna-CLUE model.' In: *Landscape Ecology* 24 (2009), pp. 1167-1181.

Verburg, P.H., W. Soepboer, A. Veldkamp, R. Limpiada, V. Espaldon and S.S.A. Mastura, 'Modeling the spatial dynamics of regional land use: The CLUE-S Model.' In: *Environmental Management* 30 (2002), pp. 391-405.

Vrolijk, H.C.J., W. Dol and T. Kuhlman, *Integration of small area estimation and mapping techniques: tool for regional studies.* LEI, part of Wageningen UR, The Hague, 2005.

Vrolijk, H.C.J., H.B. van der Veen and J.P.M. van Dijk, 2011. Sample of Dutch FADN Design principles and quality of the sample of agricultural and horticultural holdings. Report 2010-096. LEI, part of Wageningen UR, The Hague, 2008, p. 64.

LEI develops economic expertise for government bodies and industry in the field of food, agriculture and the natural environment. By means of independent research, LEI offers its customers a solid basis for socially and strategically justifiable policy choices.

LEI is part of Wageningen UR (University & Research centre), forming the Social Sciences Group with the department of Social Sciences and Wageningen UR Centre for Development Innovation.

More information: www.lei.wur.nl

LEI Memorandum 12-031