Institut für Agrar- und Ernährungswissenschaften
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Agriculture in a regional, spatial and dynamic context: An agent-based representation of policy response

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Diplomagraringenieur Martin Damgaard
geb. am 19.05.1970 in Kopenhagen, Dänemark

Gutachter:
Prof. Dr. Alfons Balmann
Prof. Dr. Thomas Berger
Prof. Dr. rer. pol. Heinz Ahrens

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This dissertation is dedicated to my dear wife, Tina.
Thank you for your love, support, and understanding.

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Acronyms

ABM	Agent-based modelling
AEI	Agro-environmental indicators
AEM	Agri-Environmental Measure
AEP	Agri- Environmental Payment
AgriPoliS	An agent-based model with the full title: Agricultural Policy Simulator
BAS	Name of a policy scenario
BEFM	Bio-Economic Farm Model
BZ	German soil quality classification system (Bodenzahlen)
CAP	Common Agricultural Policy (EU)
COs	Commodity outputs
DEA	Data Envelopment analysis
EC	European Commission
EIA	Environmental Impact Assessment
ERM	Environmental Risk Mapping
EU	European Union
FADN	European Farm Accountancy Data Network
FAO	Food and Agriculture Organisation of the United Nations
FASSET	A model with the full title: Farm ASSEssment Tool
GIS	Geographical Information System
ha	hectare
ISO	International Organization for Standardization
km	kilometre
km^2	Square kilometre
KTBL	German association for technology and Structures in Agriculture (Kuratorium für Technik und Bauwesen in der Landwirtschaft)
LCA	Life Cycle Analysis
LCC	Land Capability Classification
LP	Linear Programming
LU	Livestock units

LUCC	Land-use and land-cover change
m	metre
mDGP	model data-generating process
MEA	Model of European Agriculture
MEA-Scope	EU funded project with the full title: Micro-economic instruments for impact assessment of multifunctional agriculture to implement the Model of European Agriculture
MODAM	A model with the full title: Multi-Objective Decision support tool for Agroecosystem Management
NCOs	non-commodity outputs
OECD	Organisation for Economic Cooperation and Development
OPR	Ostprignitz-Ruppin
REF	Name of a policy scenario
rwDGP	real world data-generating process
S1	Name of a policy scenario
S2	Name of a policy scenario
S3	Name of a policy scenario
UAA	Utilized Agricultural Area
UN	United Nations
WTO	World Trade Organization

1 Introduction

1.1 Objectives of the study

The morning sun climbs slowly its way up over the trees surrounding the wheat field. Its first gentle glimmer of light is penetrating the green mosaic of leaves only to be reflected in the morning dew still clinging to the straws. A genial choir of small birds greets the day welcome with their morning hymns. This calmness of site gives an impression of a romantic quiet and comfortable living.

The noise from a passing truck breaks the illusion. It reveals itself as a large double-deck pig transporter rushing off with its latest capture. The noise hasn't died out before it is taken over by an approaching tractor. Long before the tractor passes the air is full of a thick smell of pesticides. You can feel on your breathing the effectiveness of the substance aimed at killing the pests.

In the slipstream of the tractor is a battle on life and death taking place among the insects. A battle perhaps similar to the desperate struggle against clouds of mustard gas that took place here during the First World War. You dwell a bit with the thought of how your grandfather found his last resting place here. Maybe you should show your children the place once you have …

A short glance on your watch and you know it is time for work. As you once more look over the fields, you wonder how to optimise the utilisations of the natural resources so the society's collective interests in the landscape are met.

In the same way as the individual understanding and interpretation vary with focus and frame of mind, it is essential for the scientific analysis to recognize that the focus and the perception of the object studied is important for gaining new insights as well as raising relevant questions. Sometimes a small change in the approach to a field can help to raise one's eyes to realize new connections.

It is such a small change in focus this thesis is based upon. By zooming out from the perspective of the individual frame without going so far as to see the reality through spectacles of aggregated dimensions. Stopping in between, where the interactions and dependences on the individual farms, communities or districts are still clear. That is where we start in an attempt to understand the dynamics taking place in the development of the European agricultural sector.

1.2 The purpose of this study

Imagine a small amphibian making its way through the outskirts of the wheat field. Its actions are probably based on some kind of optimisation no matter whether it solely reflects instincts or if some kind of deliberate action plays a part. The roaring noise from the approaching tractor is likely to tell it: Danger approaching. Some frogs will try to run away while others stand still. Evolution and/or experience tell them to. Once the tractor has passed and the noise has disappeared life is returning to normal. If insects start falling from the sky around our chap both evolution and experience will tell it to eat. However, the accumulation of pesticides from the insects may eventually harm the amphibian. The farmer driving the tractor and spraying the pesticides has of course no intention of hurting the amphibian. He has to optimise his economic return from the field and his economic return depends only partly on his ability to produce efficiently. The presence of a similar good supplied by others as well as the demand for his produces will determine the price he will get for his production.

The legislative claims as well as public support schemes may set firm boundaries for his actions.

These claims and schemes may very well be formulated by a civil servant sitting in her office in Brussels, considering how to save amphibians like our small chap.

Each one of these individuals is an entity, which seeks to optimise his, hers or its situation by acting in relation to their individual strategies. These strategies are shaped in constant interaction with the surrounding environment. None of these individual agents will be in a situation where they perfectly can survey the actions of all the others. All are acting on a more or less solid ground of information, yet always imperfect information.

The individual decisions are made within a framework of boundaries. These limits on the room of action are created by the immediate vicinity as well as actions taken far away. Decisions made far away can, if they are sufficient in number and significance, tickle down and influence the livelihood of the small amphibian making its way through the wheat plants.

It is of this highly complex setting that we aim to make sense. The dynamic development of the cultural landscape is shaped through the actions of a large number of individuals. Each of them sensing a part of their environment and acting upon it in the hope of promoting their interests. Some of these individuals are directly attached to the physical area (such as the farmer and the amphibian) while others only indirectly influence the development by setting up the framework conditions for the cultural landscape (such as the civil servant sitting in Brussels). The land resource is the common denominator binding their actions and interests together.

The individual unit of land can serve a large number of functions. The exact number of functions changes with both the perspective, as well as the scale in space and time.

Growing demand for land used for production, residence, dumping of waste, habitats, ecosystem services, and recreation makes integration of more functions into the same area seem like a feasible solution.

Multifunctional land use recognizes the society's collective interests in the landscape and attempts to promote responsible production patterns reflecting these demands. Specialisation within agricultural production systems (as well as other uses of the land) will without question still take place in the years to come. However, the framework conditions for the production set by the society are likely to reflect the diversified interest in the land resource.

European Common Agricultural Policy (CAP) is an important component in these framework conditions and will undoubtedly contribute to the reshaping of the rural European landscapes. Although the actual implementation of the CAP differs among the member states the main political objectives are commonly determined. The focus of the future rural development policy in the European Union (EU) for the next financial perspective period (2007 to 2013) covers three main areas. These are:

"Competitiveness of the agricultural and forestry sector (axis 1):

Increasing the competitiveness of the agricultural sector through support for restructuring following CAP reform, further opening of markets and taking into account the restructuring needs in the new Member States (rural areas have a significantly lower income than the average, an ageing working population, and a greater dependency on the primary sector);

Environment / land management, agriculture and forestry –the main land users (axis 2):

Enhancing the environment and countryside through support for land management (including rural development actions related to "Natura 2000" sites) to ensure that agriculture and forestry make a positive contribution to the countryside and the wider environment.

Wider rural development –placing agriculture and forestry in their rural context (axis 3):

Improving the quality of life in rural areas and promoting diversification of economic activities through measures targeting the farm sector and other rural actors (to address such problems as poor access to basic services, social exclusion, and a narrower range of employment options), to help maintain the attractiveness of the EU's diverse rural areas (remote, intermediate and peri-urban) and their cultural heritage, and to foster the link between agriculture and forestry and other sectors of the local economy."

(EU 2004)

To implement the objectives of the CAP and actually achieve the aims set is of course an ambitious and difficult task. The decision-makers of CAP therefore need tools to investigate the consequences of their policies in a multidimensional setting, which takes both the direct as well as the indirect effects into consideration. This thesis is a part of the effort providing such a tool. One of the goals of the MEA-Scope project within which this thesis is made is to convey information from science to the decision-makers of CAP concerning the impact of policy decisions on the multiple functions of agriculture.

1.3 Research objectives

This research was done as part of a larger project with the acronym MEA-Scope[1], which was funded under the Sixth framework programme priority by the EU. The main objective for the MEA-Scope project is "*The MEA-Scope project aims at developing an integrated framework for the assessment of the multifunctionality impacts of CAP reform options*" (MEA-Scope 2003; MEA-Scope 2004). The work presented in this thesis is closely related to the objective of the project. Here the focus will be on the further development of - and findings with - the agent-based model AgriPoliS [Agricultural Policy Simulator] (Balmann 1993; Balmann 1995; Balmann 1997; Happe 2004) within the MEA-Scope framework.

[1] The projects full title is: Micro-economic instruments for impact assessment of multifunctional agriculture to implement the *Model of European Agriculture.*

This thesis investigates the impact of CAP reform options on the structural change in the agricultural sector. Particularly with a focus on the spatial and temporal results of different CAP reform options.

The thesis can hereby contribute to the understanding of the drivers behind the structural change in the agricultural sector and their multifunctional impact on the rural landscapes.

The spatial characteristics and site conditions determine the farms' production potential and its influence on the surrounding environment. So multifunctional agricultural analysis requires to be considered in a given spatial and temporal framework. The number of functions possibly supplied by an area depend upon the spatial extent of the area and the spatial as well as the temporal scale used in the analysis. At the same time a large number of the functions investigated are depending on site-specific characteristics.

This is in correlation with two basic features of economical phenomena: Individuality and locality. The tenet of locality means that every interaction has some location and some range of effect, leading to interdependency between the market actors in an agro-economical production. Introducing interdependency in economic models is an attempt to capture the room of simultaneous actions in which decisions are made. Beyond affecting itself simultaneously the actions of a single unit will affect all others, which are interacting with this unit. At the same time all the actions of these units are influencing the first unit.

The dynamic development of the rural landscapes is therefore a multidimensional environmental and societal complex operating on different spatial and temporal levels simultaneously. It is in this light the developments presented in this thesis need to be understood. The agent-based model AgriPoliS is further developed in the endeavour to capture elements of this complex. Moreover the model is adapted to a number of regional case study areas. The questions raised will be investigated through a number of numerical experiments rather than through formal theoretical discussion of agricultural policies.

In pursuit of the general objective of this thesis the first sub-goal is to understand the insights that the concept of multifunctional agriculture provides and the requirement on models of CAP-reform options that the concept prescribes. The second sub-goal is to extend the capabilities of AgriPoliS to capture spatial characteristics of a landscape and to allow the model to act upon this information.

The spatial recreation in a reliable representation of the complex reality is one of the challenges in creating empirically founded agro-economical farm models. So how can spatially explicit models that make use of individual farm accountancy data sources such as the European Farm Accountancy Data Network (FADN) recreate a landscape including the location of the farms in a plausible way?

Before investigating the impact of different CAP reform options it is likely to consider the question: How reliable is the simulation model? Therefore it is a sub-goal to investigate both the capabilities of the extended AgriPoliS as well as the ability of the model to reproduce the structural change experienced historically.

Having investigated these questions one can finally ask: How does the same CAP reform affect the development in the agricultural sector in different European landscapes? How is farm structure changing subject to differences in the agricultural policies?

The goal is hereby to develop insight into the impact of CAP reforms and thereby make a contribution to the understanding of the drivers behind the structural change in the agricultural sector.

It is important to underline that the findings presented within this dissertation are all based on results produced by AgriPoliS. This entails that only traditional agricultural economic indicators are investigated here. For other aspects e.g. environmental indicators please see Piorr and Müller (2009).

1.4 Outline of the thesis

The structure of the thesis is following the same line of thought as presented in the previous section. The thesis begins by laying the foundation of the research in the theoretical connexion of multifunctionality in which the numerical experiments have to be understood. The background for multifunctionality as well as a conceptual study of multifunctionality is presented in *Chapter 2* "Introduction to theory".

The concept of multifunctionality calls for a holistic analysis how different CAP reform options investigated are effected. Different analytical techniques that enable the user to produce insights into multifunctional analysis are of different nature. Therefore the theoretical understanding of multifunctionality is leading to a short overview of the analytical techniques most commonly used within this line of research in *Chapter 3* "Theory in use".

The aim of this overview is also to provide a general foundation for the understanding of the model, its characteristics as well as the analytical techniques used in the investigation of the results produced. Combined this provides the necessary background for presenting the actual modelling procedure used in the MEA-Scope project as well as introducing AgriPoliS as such. All this is presented in *Chapter 4* “Modelling multifunctionality”. This chapter is largely based on (Damgaard et al. 2006).

The reason behind introducing greater spatial accuracy into AgriPoliS is based on the introduction of the modelling procedure chosen within the MEA-Scope project as well as the insights into the demands for multifunctional agriculture places on modelling. In *Chapter 5* “GIS and AgriPoliS” the consideration behind this choice as well as the actual procedure chosen is presented. The introduction of better spatial consistency with the investigated study areas creates new challenges for the adaptation of the model to a case study area. AgriPoliS makes use of individual farm accountancy data sources such as found in the FADN-samples. From data of this sensitive nature all spatial characteristics are removed intentionally before made available for research. Therefore the spatial recreation of the farm location within the investigated regions constitutes a challenge for the spatial explicit modelling. This issue is therefore addressed. The model’s response to the incorporation of the greater spatial accuracy is investigated as a spatial sensitivity analysis is presented. The section 5.3.1”The arable / grassland method” is based on collaboration with C. Kjeldsen and 5.3.2 “The context-dependent analytical approach” is based on collaboration with F.Ungaro.

In *Chapter 6* “Validation of AgriPoliS” a calibration and validation of AgriPoliS is presented. Back-casting has been used as the validation technique and the validation of AgriPoliS provides insights into the strengths and weaknesses of the model.

This is useful knowledge when “Spatial analysis of the results from AgriPoliS” is presented in *Chapter 7*. Here three regions and their implementation into AgriPoliS first are presented.

The three regions are:

Ostprignitz-Ruppin, Germany

Mugello, Italy

River Gudenå watershed, Denmark

Each of the three regions constitutes different aspects of the agricultural sector found within EU.

The five different policy scenarios investigated are introduced and each of the three regions undergoes a spatial analysis of the structural change taking place in the regions as a result of the policies. The adaptation of the regions to AgriPoliS is made in collaboration with A.Osuch and K.Happe.

Finally *Chapter* 8 summarises the thesis.

2 Introduction to theory

2.1 Introduction

Although the idea of multifunctionality in agriculture has been debated internationally for more than two decades (Brandt and Vejre 2004; 2005; Ollikainen and Lankoski 2005) and numerous definitions of multifunctional agriculture have emerged, however, no one is generally accepted.

Beyond its primary function of supplying food and fibres agriculture will affect the proximities directly and indirectly in a number of ways, and all of its effects should be taken into account before new policies are enunciated.

The concept of multifunctionality is used within landscape management (Lange; Dramstad et al. 2001; Tress et al. 2001; Otte et al. 2007), forestry (Andersson et al. 2000; Farrell et al. 2000; Merlo and Rojas Briales 2000; Sparovek et al. 2002; Parviainen and Frank 2003) as well as agricultural production (OECD 2001b; Peterson et al. 2002; Randall 2002; Vatn 2002; Casini et al. 2004). In the following the use of multifunctionality in relation to agricultural production will have our main attention.

2.2 Multifunctional –but what is a function?

The word "function" is an integrated part of everyday language and therefore most people will have some kind of understanding of the concept. This comprehension is, however, seldom so robust that it can serve as the foundation for giving subsidies to farmers or enter into an agreement in the international negotiations at World Trade Organization (WTO). So, when the multifunctional nature of the agricultural production is emphasized as the justification behind continuation of subsidizing (or rewarding) farmers, then a clear understanding of functions is needed. Such an understanding has naturally to be related to the functions of the landscape. It does not include the use of the word in mathematics, social life, computing or any other area with a unique meaning of functions. Though multifunctionality is widely debated this basic question is unfortunately seldom addressed. Even among the few definitions there is a large variation in the understanding. Here two different definitions of functions will be quoted to show the spread among them.

Brandt & Vejre (2004) defines a function as

"The capacity (of a driver) to change the land units in a more or less given direction, or the capacity to maintain the land unit in a given state that is the capacity to master (aspects of) the structure and change of a landscape".

The MEA-Scope project defines functions as

"The factual or potential provision of material or immaterial goods and services that satisfy social expectations, meeting societal demands/needs through agricultural sector structure, agricultural production processes and the spatial extent of agriculture."

(Casini et al. 2004)

The two definitions reflect clearly the different scientific areas in which the definitions are made, multifunctionality of landscape management and multifunctional agriculture respectively. In landscape management functions are traditionally defined as interactions between spatial elements such as flow/flux/streams of energy, material, organisms or information (Forman 1995). In the multifunctional agriculture the economic activities are in the focus and functions are normally understood as commodities produced independently of their nature. The commodities may often later be differentiated between primary and secondary goods or commodities and non-commodities, products and services, public and private goods or as externalities of the regular production.

In spite of their differences both definitions illustrate that in multifunctionality a stronger weight is given to the daily meaning of functions as "a mode of action or activity by which a thing fulfils its purpose" (Thompson_Dictionary 1995) rather than the classical input output relationship to which functions often relate in science. This underlines the strong demand oriented element built into multifunctional land use.

To make the rather abstract notion of functions more comprehensible, four major categories of functions related to land use are presented to specify the meaning of functions. Categorizing functions of multifunctionality in separate groups violate the nature of the concept. One should therefore be careful not to see these categories as clearly differentiated groups of functions, but rather the same elements in other connexions. The overlapping of functions is particularly important for a multifunctional understanding of the environment.

Ecological functions: The ecological functions of a landscape would normally involve terms such as biodiversity, wildlife habitats, storage, buffering, clearing and migration.

Production functions: Production functions involve production of food, fibres and renewable energy as well as insuring employment and incomes in the rural areas.

Service functions: Service functions could include tourism, recreation and education

Transcendental functions: Functions which require a cultural or educative filter before their importance can be appreciated. Some landscape is of historical, cultural or religious importance and these functions fall into this category.

Though the examples mentioned in the four categories by no means are exhaustive for what is included under the term of multifunctionality, the examples still demonstrate the holistic nature of multifunctionality. Therefore it is difficult to give a comprehensive list of what is included under the term. The complex interrelationship between the innumerable functions embedded in the landscape should ideally all be taken into account in order to reveal the dynamic effects of human actions in the environment.

2.3 Space, time and scale

To state that a given landscape is multifunctional is close to being a tautology. It is hard to imagine a truly monofunctional landscape. If a given area appears to be monofunctional it is likely to be a matter of the spatial and temporal scale in which the area is investigated. The scale of the investigation is therefore important for the understanding of multifunctional landscapes. Unfortunately, there is not a single correct scale with which one can capture the dynamics among all the elements in a landscape. The dynamics of the bacteria in the soil operate on much smaller spatial and faster time scales than is useful when investigating the dynamics among plants and animals, which again differs from the dynamic development of the landscape. However, though the scales differ they are often interconnected and influencing the possible dynamic development of each other. The interdependency between the elements makes it difficult to determine a priori the importance of the individual elements. This makes it hard to choose the right indicators. The all-embracing nature of multifunctional agriculture makes it difficult to move from the concept to an operable interpretation. A pragmatic demand oriented approach built into most monitoring of multifunctional landscapes solves, however, normally this difficulty. The requested functions are often reduced to a manageable number and consist e.g. of monitoring a number of regional specific vulnerable animals or plant species. The scale used is thereby implicitly given. This is, however, only true when the findings are viewed isolated; once the findings are compared with other findings the scale will once more influence the results.

How the degree of multifunctionality changes with the scale is best illustrated through the use of the classification of multifunctionality introduced by Brandt & Vejre (2004). By taking a spatial viewpoint Brandt & Vejre (2004) defines three general types of multifunctionality.

A. **Spatial segregation**: multifunctionality as a spatial combination of separate land units with different (mono) functions.
B. **Temporal segregation**: multifunctionality as different functions devoted to the same land unit, but separated in time.
C. **Spatial integration**: multifunctionality as the integration of different functions in the same unit of land (or overlapping units of land), at the same time ("real multifunctionality").

(Brandt and Vejre 2004)

The three types of multifunctionality are illustrated in Figure 2.1. These three general types help in differentiating basic characteristics of a multifunctionality area at the same time as they elucidate the effect of different spatial scales. For type A –spatial segregation is the spatial scale influential of the number of functions found in the area. In contrast to this is type C –Spatial integration, where the result is scale invariant.

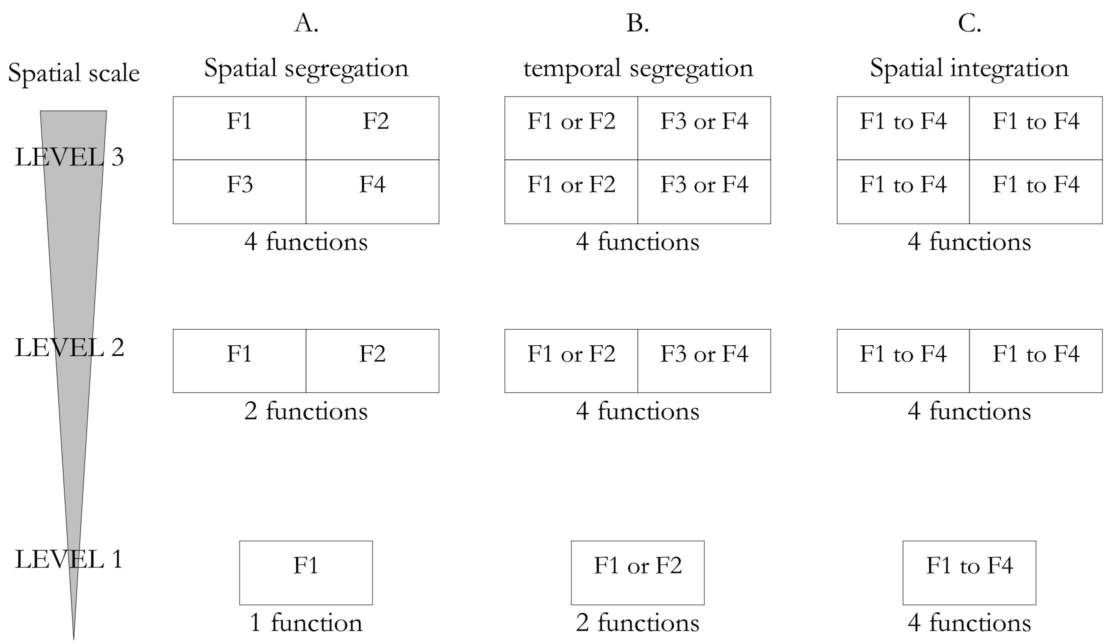


Figure 2.1: Three types of multifunctionality measured at different spatial and chronological levels. A: spatial segregation. B: temporal segregation and C: Spatial integration (Brandt and Vejre 2004)

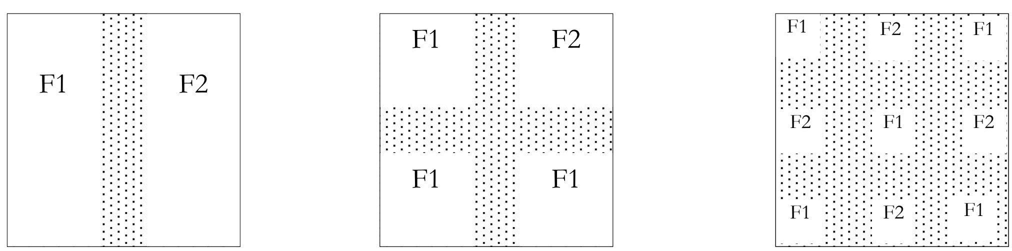


Figure 2.2 The influence of landscape heterogeneity on the degree of landscape multifunctionality. Two spatially segregated functions F1 and F2. The dotted area is the area of interaction between F1 and F2. This border area increases by the amount of borderlines between the two functions. (Brandt and Vejre 2004)

A clear distinction between these types of multifunctionality will be difficult to establish in practice. Even in the extreme case of spatial segregation there will always be a boundary where one functional frontier meets the next. At the frontier there is likely to be a conflict between the areas of the two functions. This border area increases by the amount of borderlines between the two functions, as can be seen from Figure 2.2. This means the heterogeneity of the landscape will also reflect back on the degree of multifunctionality. From a multifunctional perspective this increase in overlapping areas will raise the degree of multifunctionality as the spatially segregated functions (type A) dissolves into spatially integrated functions (type C).

In real landscapes the area of different landscape functions will neither be equally distributed nor located at a clearly demarcated and fixed spot as in the theoretical case. Landscapes and their functions are dynamic by nature and will continuously change. Both the ecological, production and service functions can therefore be described profitably in terms of networks capturing the intricate web of connections among the units of which they are made. Thereby is it possible to avoid the clear separation between different functions and the elements of which they consist. Multifunctionality emphasizes exactly that most of the functions and their elements are overlapping in reality.

The environmental functions imbedded in the agricultural landscape are seldom following a simple linear response as a naïve interpretation of joint-production in multifunctional agriculture might indicate. The spatial level of an investigation determines to a large extent the type and quality of biodiversity reasonable to expect. Ecologists have divided the space into three main categories: the field level (α diversity) the landscape level (β diversity) and larger scale (γ diversity). Any higher scale has naturally to include all species found at a lower level ($\alpha \subseteq \beta \subseteq \gamma$). In this particular study the field, farm and landscape levels are investigated.

2.4 The background of multifunctionality

Multifunctionality was born as a political concept. Various authors mention that the use of the concept multifunctionality started in the beginning of the 1990s (Bohman et al. 1999; DeVries 2000; Tait 2001). However, none of them has any direct references. Rodríguez *et al.*(2004) shows that the line of thought was already present in a communication of the European commission called "The future of rural society" from 1988, though the actual term multifunctionality was not mentioned. With certainty the term was introduced to the international debate in the Rio declaration on sustainable development in 1992 in Agenda 21 Chapter 14.4.

"Agricultural policy review, planning and integrated programmers in the light of the multifunctional aspect of agriculture, particularly with regard to food security and sustainable development"

(UN 1992)

The chapter is titled -”Promoting sustainable agriculture and rural development”. This means that the first international recognition of the concept was related to agricultural policies and the multifunctionality of agricultural production.

The Food and Agricultural Organization of the United Nations (FAO) recognized multifunctionality at its World Summit 1996 where multifunctionality is mentioned in “the Rome Declaration on World Food Security” where a number of countries endorsed:

“we will pursue participatory and sustainable food, agriculture, fisheries, forestry and rural development policies and practices in high and low potential areas, which are essential to adequate and reliable food supplies at the household, national, regional and global levels, and combat pests, drought and desertification, considering the multifunctional character of agriculture”

(FAO 1996)

Here multifunctionality is once more related to agricultural production. FAO has clarified their understanding of multifunctionality during the conference “Multifunctional Character of Agriculture and Land” (FAO 1999). As a result multifunctionality for FAO primarily deals with sustainable resources’ utilization and less with trade considerations, as a number of nations has advocated during the negotiation within the WTO. Non-trade concerns were mentioned already in the “Agreement on Agriculture” preamble from the Uruguay-round in 1994 without using the term multifunctionality.

The use of the term multifunctionality has in fact never met great sympathy in large groups of nations. They view multifunctionality as a cover for maintaining the current agricultural trade obstacles unaltered.

The Organisation for Economic Co-operation and Development (OECD) Agricultural Ministers adopted multifunctionality as a policy principle at their meeting of March 1998 (OECD 1998; 2003b). Much of today’s understanding of multifunctional agriculture is based upon the early contributions made by the FAO (1999; 2000) and particularly the OECD (1999a; 1999b; 2001a; 2001b; 2003b). But one of the strongest advocates for the need of a multifunctional development in the rural environment is the EU. Multifunctionality was written in the CAP in the “Agenda 2000” agreement at the European counsel meeting in Berlin 1999. Here it is mentioned:

“The content of this reform will ensure that agriculture is multifunctional, sustainable, competitive and spread throughout Europe…”

(EC 1999)

For the EU multifunctional understanding of the landscape and the land use is closely related to the aim of ensuring a sustainable development. The relationship between sustainability and multifunctionality is better demonstrated in later statements from the EU such as:

"...the modernization and sustainability of agriculture and forestry, including their multifunctional role in order to ensure the sustainable development and promotion of rural areas"

(EC 2002)

Here multifunctionality is understood as a mean to ensure sustainable development. The EU recognizes the need for supporting the positive externalities related to agricultural production including both social and environmental effects. The lack in scientific tools to investigate the multifunctionality of the land use has, however, been one of the hindrances the EU has faced in promoting the concept.

The recognition of the term multifunctionality by the political elite has created a useful attention towards a more holistic and diversified understanding of the rural area utilisation. Unfortunately the same attention has also meant that multifunctionality as a term has at times developed into a more or less empty buzzword. Therefore it is important to look beyond the discourse's smoke. The differences in the understanding of multifunctionality between the mentioned major players in the international political debate underline the difficulties in practically applying the understanding to a real case. The political origin of multifunctionality has meant that the scientific justification and strength of the concept only slowly has grown with its practical implementation. From the point of view of theoretical economics it is still a weak concept. Most of its economic foundation builds upon more recognized economic notions from welfare economics. The lacking general definition makes it difficult to pinpoint its unique contribution. However, multifunctional agriculture is an active part of today's political and practical reality. Because multifunctionality is used as the justification behind a substantial change in the conditions for agricultural production, it is necessary to have a scientific understanding of the concept.

2.5 The use of multifunctionality within different scientific fields

A number of definitions of multifunctionality exists as the previous examination of the historical background also elucidates. The literal meaning of multifunctionality is that at least two functions at the same time can be ascribed to the same object. The object in this case is a spatial location.

Beyond the first banal meaning of the multifunctional nature of a landscape, it is unclear exactly what is included by multifunctionality and what is not.

One of the reasons for the large number of definitions arises from the numerous ways the term has been used within different scientific fields. Multifunctionality has been widely used within the agricultural sciences (OECD 2001b; Peterson et al. 2002; Randall 2002; Vatn 2002; Casini et al. 2004) as well as within forestry (Andersson et al. 2000; Farrell et al. 2000; Merlo and Rojas Briales 2000; Sparovek et al. 2002; Parviainen and Frank 2003) and landscape management (Lange; Dramstad et al. 2001; Tress et al. 2001; Otte et al. 2007). The nature of the term makes it appealing and probably even necessary to work interdisciplinary with the investigated regions. However, the adaptation of multifunctionality to the different fields is not unproblematic. Each of the areas has contributed with definitions adapted to their specific line of thinking. To demonstrate this we will shortly outline the characteristics of the different uses of multifunctionality within the agricultural sciences, forestry and landscape planning.

2.5.1 Multifunctional agriculture

Most of the applications within agricultural science take an economic and activity founded approach to the definition of multifunctionality. The early work of FAO (1999; 2000) and OECD (1999a; 1999b; 2001a; 2001b; 2003b) has strongly influenced the debate. Particularly the OECD (2001b) contributed to the strong economic and production oriented focus. OECD (2001b) has the following definition of multifunctionality:

*"**multifunctionality** refers to the fact that an economic activity may have multiple outputs and, by virtue of this, may contribute to several societal objectives at once. Multifunctionality is thus an activity oriented concept that refers to specific properties of the production process and its multiple processes"*

(OECD 2001b pp.11)

This definition by the OECD is important, as it is probably the most quoted definition within multifunctional agriculture. Most other definitions within multifunctional agriculture tie also a firm connection between the agricultural production and the provision of multiple functions (e.g. DeVries 2000; Casini et al. 2004).

Much of the vocabulary used in describing multifunctionality is drawing upon economic concepts such as commodity outputs (COs) and non-commodity outputs (NCOs) or public and private goods or externalities. This focus on production indicates that the main interest lies at the farms. This is maybe at the expense of the interest expressed in the agri-environmental strategies (Whitfield 2006). This order of priority is often revealed through the tendency to rank the production function as the primary function and any additional functions in form of services or products as secondary (see e.g. Mittenzwei et al. 2007). Furthermore, the economic term “joint products” (or jointness) is frequently used in multifunctional agriculture as an argument for both making this distinction as well as serving as a justification for continued subsidies. Joint products occur when a single productive process results in the production of two or more products, e.g. the rearing of cattle produces both meat and hides. In multifunctional agriculture the single productive process is resulting in the production of privately demanded goods along with goods for which markets do not exist or function unsatisfactorily. This means that the assumed jointness in the agricultural production can at times justify the ranking of the primary- and the secondary functions of the production. However, this requires that the outputs are joint (less intensive productions practices to ensure the survival of a given species is not joint production as the single productive process does not result in the production of both products, but only indirectly helps survival of the species), one should also note the degree of jointness. Most types of joint products in multifunctional agriculture are not produced at an immutable fixed relationship. So when subsidies are given for joint production then the quantities of the secondary functions produced are likely to vary between farms and production practices as well as over time. Therefore when addressing multifunctional agriculture it is suitable to make a distinction between the goods that are jointly produced along with traditional agricultural production and the production independent outputs, some times mentioned as the co-commodity production. The last one can be promoted by public support due to market failure; however, does not necessarily involve the agricultural sector.

2.5.2 Multifunctional forestry

Forestry was mentioned early in the international debate on multifunctionality as an example of another production system which also had characteristics enabling it to be multifunctional (OECD 2001b). The multifunctional nature of forestry has, however, been recognized long before. But different terms such as “multiple- purpose forestry” or “multiple use forestry” have normally been used to describe this. The substance covers, however, the same fundamental thought: That more functions can be ascribed to the same area. The fundamental differences in production time and practices are naturally reflected in the possibilities of adjusting the production to the demanded functions. Both spatially segregated functional forestry (divide the forest into areas for production, forest for recreation, and areas for biodiversity) and spatially integrated functional forestry (all desired functions in the same spatial area) are practiced.

The priority given the different functions seems more equally distributed in forestry than seen in multifunctional agriculture. Neither the economic, recreational nor ecological functions are labelled as the primary functions. The three dimensions of functional interest enter into considerations on a more equal basis.

2.5.3 Multifunctional landscape management

A large share of contributions to the field of multifunctionality is offspring from the tradition of landscape science. The societal objectives formulated through the concept of multifunctionality are closer related in their core to landscape science and its more holistic perceptive of the landscape than traditionally found within agricultural sciences. Where the point of origin in multifunctional agriculture generally is the farm and its production, the point of reference in landscape sciences is naturally the landscape and with a stronger focus on the use of the physical area. As e.g. the definition of Brandt *et al.* demonstrates:

"...multifunctional landscape refers to the plural and simultaneous use of an area for several purposes; an area thus that serves different functions and combines a variety of qualities"

(Brandt et al. 2000 pp.63)

By focusing on the use of the landscape a larger variety of interests in the developments of the rural landscape is often considered. Taking the unit of area rather than the unit of production as starting point for the investigation results in a different understanding of the process in focus. As the previously presented definition of functions by Brandt and Vejre (2004) demonstrated landscape management is often more process oriented. Processes can represent flows of energy, material, organisms or information. The definitions of multifunctionality in landscape science are often more detached from the farm production. Therefore the different landscape functions are often given a more even importance than within agricultural sciences where the economic production plays a large role.

2.6 The relationship between multifunctionality and sustainability

Multifunctional agriculture is often portrayed as a path towards sustainable development. Sustainability also being a politically born concept has been enshrined as guiding principle in several international agreements and action plans.

Sustainability refers *"to the use of resources, human, natural and man-made, in ways that allows current generations to satisfy their needs without jeopardising the capacity of future generations to meet theirs."*

(OECD 2001b pp.11)

The immediate distinction between multifunctional and sustainable agricultural development is the different perspective of the two concepts. Often pointed out is the goal-oriented nature of sustainability (OECD 2001b), in contrast to multifunctional agriculture where the process of the production is in centre of the attention. In declarations of intent sustainability is essentially a goal-oriented concept. As guiding principle in multifunctional production sustainability offers the framework conditions within which the optimal production pattern should be found. Multifunctional agriculture underlines the importance of including the societal interest in the development of the landscape. Changes in the demanded realization of a sustainable development will therefore have to be included in multifunctional production. The sustainable development is on the other hand not conditioned by the characterization of the agricultural production as multifunctional.

2.7 The theoretical framework of multifunctional agriculture

Multifunctional agriculture has much of its theoretical origin in the understanding of externalities, public goods and joint production. The theoretical understanding of these areas will therefore be introduced. The theory of multifunctional agriculture has, however, developed its own terminology, which underlines the connection to agricultural production. Therefore the main notions within the theoretical understanding of multifunctional agriculture will be presented and linked to the existing economic theory.

2.7.1 Externalities

Though the word and precise content of multifunctionality is of a recent date the issues covered and their theoretical background are not new to the economic discipline. Likewise externalities have long been a household term to which prominent names like Pigou, Samuelson and Arrow have made contributions.

In economics an externality covers the situation when a decision causes costs or gives benefits to individuals or groups other than the agent making that decision. This means that the decision-maker does not include all the costs or benefits of his action when calculating the optimal quantity consumed. The competitive market is therefore unable to reach the social optimum. Already in the work of Pigou (1932) examples related to the agricultural sector were used. So the recognition of externalities related to agricultural production is not new. Neither is the recognition of society's collective interests in promoting production of some given externalities at the same time as reducing others. It is therefore useful to repeat shortly the most general findings within this area (for a more complete treatment of the subject see e.g. Cornes and Sandler (1996)). It should be underlined, that the theoretical framework to be presented will, in the eyes of many, only leave little or no room for the more normative understanding of multifunctionality. This must not be understood as a brusque of the more normative approaches, but simply a useful conceptualisation of the more positivistic aspects of multifunctionality.

First a classical formulation of externalities ascribed to Arrow (1970) will be presented. Here the externalities are formulated into the individual utility function and the firm's profit function. His formulation of externalities may be described as follows: In a competitive equilibrium with a full set of markets every quantity of a product desired by any individual -and that is determined by the action of agents -will have a competitive price attached. This means that the indirect utility function of individual i and profit function of firm j can both be written as a vector of all the prices **P** and a exogenous (endowment of commodities and technology available, respectively). However, in the case of externalities will the functions look like the following:

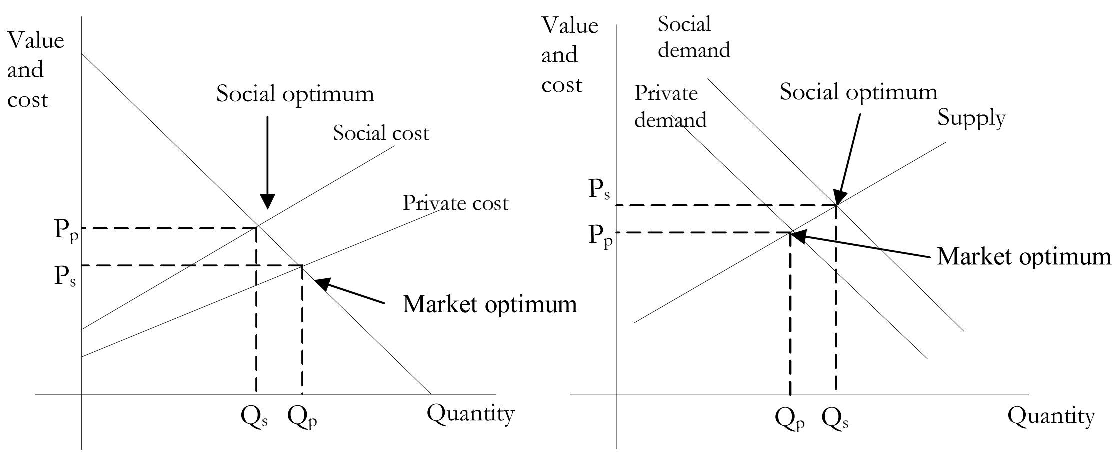
Individual i's indirect utility function:

$$V^i = V^i(\mathbf{P}, \Omega^i, \mathbf{A}^i), \qquad (2.1)$$

Where Ω^i is the exogenous endowment of commodities and $\mathbf{A}^i$ is a vector of actions by others. In the same way for the firm j's profit function:

$$\Pi^j = \Pi^j(\mathbf{P}, T^j, \mathbf{A}^j), \qquad (2.2)$$

here T^j is the exogenous technology available and $\mathbf{A}^j$ is again a vector of actions by others. For the individual utility function and the firm's profit function the dependency on the actions of others in this formulation is underlined. The attention in multifunctional research is, however, directed towards the decisions leading to the externalities. Hereby it is the aim to be able to optimise the actions causing the externalities in such a way that both the individual utility and firm's profit functions summarised over the entire population and number of firms are affected in the least harmful way. This can be presented in aggregated form in the standard supply and demand diagram. This, however, builds upon the assumption that the externalities can be monetized. Such an assumption is not easily obtainable with most externalities considered in multifunctional agriculture. In addition to the private supply and demand the social supply or demand curve is added to the diagram. The private supply and demand in a competitive market is equal to the marginal private cost or benefit. Where as the social curve is the true cost or benefit that the society as a whole is experiencing. External costs are normally referred to as negative externalities and external benefits as positive externalities.



Supply / demand with external costs

Supply/demand with external benefits

Figure 2.3a and 2.3b: Difference between social optimum and market optimum in case of externalities. 2.3a supply and demand curves with external costs. 2.3b supply and demand curves with external benefits. (Cornes and Sandler 1996; Wikipedia 2007) with own modifications.

From both diagrams in Figure 2.3a and 2.3b it is obvious that there is a difference between the social and market optima, which is the justification of the public intervention. The aim of a public intervention would be to internalize the externalities into the price so that it is equal to the marginal social cost and benefits. This is known as a Pigouvian tax/subsidy scheme (Cornes and Sandler 1996).

A Pigouvian tax/subsidy scheme is equal to the marginal social cost/benefit of the externalities. That is MPC+T= MSC, where MPC is the marginal private cost, T the tax and MSC marginal social cost. With positive externalities T is negative. Hereby a more efficient allocation of the resources would be ensured (Cornes and Sandler 1996).

2.7.2 Introduction to public goods

Pure public goods have two basic properties – nonrivalry and nonexcludability. Pure public goods possess these properties absolutely. As the support as well as the benefit of it is often restricted to small jurisdictions one will normally make a further distinction and talk about local pure public goods[2]. This means that there will be some kind of excludability. The nonrivalry means that the consumption of the good by one individual does not reduce the quantity available to others. Though it may be difficult to find a good example related to multifunctionality that can comply with the theoretical extreme of the definition, a beautiful landscape might work as an illustration. Most people will enjoy walking in such a landscape and until a certain critical level; this enjoyment is independent of the number of others, who also have enjoyed the area. The provision of such goods is naturally in the society's interest. There are of course a number of other reasons for creating public goods such as nonconvexity in the production function but the argument for supporting multifunctional agriculture is normally given in the framework of nonrivalry.

Let us therefore sketch the difficulties in finding the Pareto-efficient allocation of the resources in an economy composed by private and (local) pure public goods. The Samuelson condition gives the requirement that an allocation of a pure public good must satisfy to be Pareto- efficient:

$$\sum_{i=1}^{n} MRS = MRT \tag{2.3}$$

where MRS is the marginal rate of substitution between a pure public good and a private good, MRT is the marginal rate of transformation between these two goods, and n is the total number of persons in the population. To reach this allocation is, however, difficult (Atkinson and Stern 1974; Cornes and Sandler 1996).

[2] Local pure public goods are also at times designated impure public goods.

The Nash-Cournot equilibrium is often used in the literature on pure public goods and illustrates very well one of the central issues in question. For simplicity we are considering an economy consisting of two consumers. They have individual preferences and incomes. The total quantity of public goods Q is determined by their individual contributions. Though they can contribute differently to the public sector the price of acquiring a unit of public good p_Q is the same for both of them. We assume that there is only one private good, the price of which is unity throughout. This means that each individual has to decide how much to contribute to the public goods. Each individual has therefore the following utility function to optimize:

$$\underset{\{y^i,q^i\}}{\text{Maximize}}\ \{U^i(y^i,q^i+q^j) \mid y^i+p_Q q^i = I^i\},\quad \text{i,j = A, B; i} \neq \text{j.} \qquad (2.4)$$

where the utility of individual i is determined by the amount of private goods y^i and the amount of public goods she consumes (q^i+q^j). Here q^i is the amount supplied by her self and q^j is the amount the other person supplied. Under the restriction that she uses her full income I^i on the two products. If the two persons can decide on a quantity to contribute to the public goods Nash equilibrium can be found. The two utility functions $\vec{U}^i(q^i,q^j;p_Q,I^i)$ are in Nash equilibrium if the pair of quantities $(\hat{q}^A,\hat{q}^B)$ satisfies:

$$\vec{U}^i(\hat{q}^i,\hat{q}^j) \geq \vec{U}^i(q^i,\hat{q}^j) \quad \text{for all feasible } q^i,\quad \text{i, j = A, B; i} \neq \text{j.} \qquad (2.5)$$

so that each individual's chosen contribution is a "best response" to the other's. This point out the difficulties. Each of the players will benefit from paying as little as possible to the public goods at the same time as the other player should make a substantial contribution (2.4). Both of them know that once they have chosen their contribution level they will also have elucidated their budget constraint and preferences to the other player. As they both will pursue their best possible strategy in the full knowledge of the others' strategy they will reach the Nash equilibrium. This equilibrium will, however, only seldom be Pareto-efficient as the lock-in of the players prohibits them from dynamically adjusting their contribution to the optimal level. The consumers can hereby take advantage of the public goods without contributing sufficiently to their creation. This is widely known as the "free rider problem" and is occasionally named the "easy rider problem" as the contribution can be larger than zero though still too small (Cornes and Sandler 1996).

The private goods contrast the pure public goods. These are the most predominant type of goods and are characterized by including both rivalry and excludability. In between these two extremities there is an additional categorisation made with goods possessing a mixture of the properties. *Open Access Resources* are characterised by nonexcludability and rivalry and often lead to overexploitation (the "tragedy of the commons" is the typical example). *Common Property Resources* are locally shared and managed goods. This means that nonrivalry and nonexcludability in the local community rules, however, towards the rest of the society the goods are not obtainable, as there exists rivalry and excludability. *Excludable and Non-Rival Goods* and *Club Goods* are both likely to be serviced by the private sector. Club goods have a number of additional characteristics i.e. that membership must be voluntary and members and non-members must be differentiable.

2.7.3 Joint production

The characteristics of the joint production of the COs and NCOs are important to understand in multifunctional production. Joint production refers classically to products, which cannot be produced separately, but are jointed by a common origin. Often used examples include wool and mutton from sheep; wheat and straw; or oil and meal from soybeans. Common for these examples are that the proportions between the different products can only vary within a narrow range. This is, however, not always the case; other types of joint productions can vary more widely in response to relative price changes and market demand.

Joint production is given where two or more outputs produced by a firm are interlinked (OECD 2001b annex 1). The economic literature counts three possible origins for joint production (OECD 2001b; Vermersch 2004):

- Biological or technical interdependencies in the production process
- The existence of non-allocable and /or quasi-public inputs which provide economies of scope
- The existence of allocable inputs which are fixed in the short run

At times a fourth possible origin for joint production is mentioned (Vermersch 2004), that is:

In the situation of uncertainty both at the demand and supply side of production, the intertemporal management of productive risks justifies the multiple output character.

The different origins of joint production are in reality rarely found in their pure form. But rather as a combination of various proportions of the four possibilities. The distinction is, however, theoretically useful. Biological or technical interdependencies in the production process mean that the production function of one product not only depends on the inputs allocated to this product but also on the amount produced of other jointed outputs.

A joint production of outputs, $Y_j (j = 1,.,.,.,m)$ with inputs $X_i = (i = 1,.,.,.,.,n)$ can be described by an implicit transformation function:

$$F(Y_1,...Y_m; X_1,,,, X_n) = 0$$

ensuring that non-joint production does not apply.

In the case of technical interdependencies in the production process one output depends not only on the inputs allocated for this particular product, however, also on the level of the other output. That can be written in the following way:

$$Y_1 = F^1(Y_2, X_1); \quad Y_2 = F^2(Y_1, X_2); \quad X_1 + X_2 = X \qquad (2.6)$$

The above-mentioned examples of joint production are mainly of the second type of origin. Non-allocable means that the inputs cannot be assigned specifically to each output and therefore the farm produces more than one output. Denoting the non-allocable input Z, we have:

$$Y_1 = F^1(Z); \quad Y_2 = F^2(Z); \qquad (2.7)$$

Land is an example of an allocable input, which is fixed in the short run for the enterprise and on which more outputs depend. Each output has its own production function, which, however, draws on the same pool of fixed resources. This means that an increase in the production of one output reduces the resources available for the other outputs. It could be expressed as follows in the single input, two-output case:

$$Y_1 = F^1(X_1); \; Y_2 = F^2(X_2); \; X_1 + X_2 = X \qquad (2.8)$$

The notion of joint production relates to the production function of the firms. In order to better understand the actions of the different economic agents it is useful to characterize the joint production situation in terms of the firm's cost structure. In the case of joint production the firms are often facing economies of scope. Economies of scope refer to scale efficiencies primarily associated with the number of different types of products an enterprise handles[3]. Economies of scope are the decreased or increased cost associated with each

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[3] Increasing or decreasing the scale of production of a single product type is referred to as economies of scale

product as the number of different types of products increases. This can be the case when the capital used for marketing, distribution or in this case cost of production is diffused over an increasing number of different types of products. In the case of joint production this means that there are economies of scope when the cost of producing a given group of outputs $Y_1,\ldots, Y_m$, is of the following nature:

$$C(Y_1) + C(Y_2) + C(Y_3) + \ldots + C(Y_m) > C(Y_1, Y_2, Y_3 \ldots Y_m) \qquad (2.9)$$

That is, it is less costly to produce the outputs jointly than separately. In the first two cases of joint production the farms that are facing such a cost structure will continue to produce jointly. This is, however, not necessarily the case when allocable inputs are fixed only in the short run. Then the joint production needs to be at least as profitable as the non-joint production of either of the products. This last condition underlines the need for internalising the social cost and benefits associated with joint production. As the public goods or externalities related to a given production do not have market-determined prices connected to them, the farmer will have little incentive to continue joint production if no public policy intervention takes place.

The existence of allocable inputs that are fixed in the short run is generally agreed as the main course for joint production of private food outputs in the agricultural sector (OECD, 2001). This does not necessarily mean that it is also the case for NCOs. One could, however, presume it is the case as the production of NCOs is also likely to be affected by the fixed land base. This would mean that the joint production of NCOs would be of the type most vulnerable to farmers' choices in the face of input constraints. So that the level of compensation or tax could make it more efficient to separate the production in the long run and that joint production only is a short term phenomenon.

2.7.4 Commodity and non- commodity outputs (and the provision of NCOs)

Non-commodity outputs are the externalities of agricultural production, publicly demanded, without a functional market present. This means that for negative externalities a reduction of the externality is the demanded NCO. The commodities of agricultural production are in the understanding of multifunctional production only the privately demanded goods. Though the public intervention aims to create an artificial demand for the NCOs these outputs are not changing their status into commodities as a consequence of the support. Besides the evident need to linguistically being able to differentiate between the products, the public payment schemes are only indirectly paying for the individual NCO without any direct price determination. As there are no functioning markets for the NCOs there is no price determination for the individual outputs. Finding the right price is, however, essential in order not to experience welfare losses. Therefore the valuation of the NCOs as well as indicators is an active research area (Peterson et al. 2002; Madureira et al. 2007; Randall 2007).

Not everybody associates the production of NCOs directly to externalities of agricultural production. This is elucidated through some of the examples of NCOs mentioned such as “cultural heritage” or “rural development”. None of which is the direct result of a given agricultural production practice, merely indirectly influenced by the structural development of the sector. This means that the common use of the term NCO often covers more than traditionally would be ascribed to joint production or externalities.

3 Theory in use

3.1 Analytical tools and multifunctionality

The modern agricultural production is to include more than the traditional commodity outputs when politically evaluated. The agricultural production system is producing both public and private goods simultaneously and multifunctionality is stressing the importance of all produced goods. Moving from the notion of multifunctionality toward an operational instrument has, however, proven to be difficult. In this pursuit a number of different methodologies is used e.g. econometrics and DEA-analysis. Rather than to give an adequate review of all used methods the focus point will here be on the use of simulation models to investigate multifunctionality of agricultural production. The all-embracing nature of multifunctional agriculture requests that a large variety of issues are simultaneously addressed. A number of simulation models have been developed in the hope of being able to meet this need. The role for simulation models of the multifunctional agricultural production can generally be illustrated by a slightly changed version of Schanze's (2003) portrait of the management of landscapes in a multifunctional setting (Figure 3.1). The figure should be understood in the following way. Looking at the top of the figure: The need for modelling starts with a region or landscape submitted to European and national policies and regulations. Apart from the political process a decision process of the landscape development is taking place. It involves initial identification of the values and targets worth aiming at. This is illustrated by the dotted line at the left pointing to the box of values and targets. Within a multifunctional framework it involves ecological, social and economic interests. In order to achieve these politically defined goals different regulative measures may be considered. However, their effects have to be evaluated. This is illustrated by the second dotted line. This leads to a request for simulation models. The initial state of the systems under investigation will have to be described and empirical data collected. This initialisation of the model has to include all the ecological, social and economic interests covered by the multifunctional analysis. The different interlinked layers within the initial state box illustrate this point. Then a number of scenarios can be formulated; both to investigate the effects of the different regulative measures as well as different influences from the outside world e.g. changes in prices or global warming. The projected results should then be evaluated and compared.

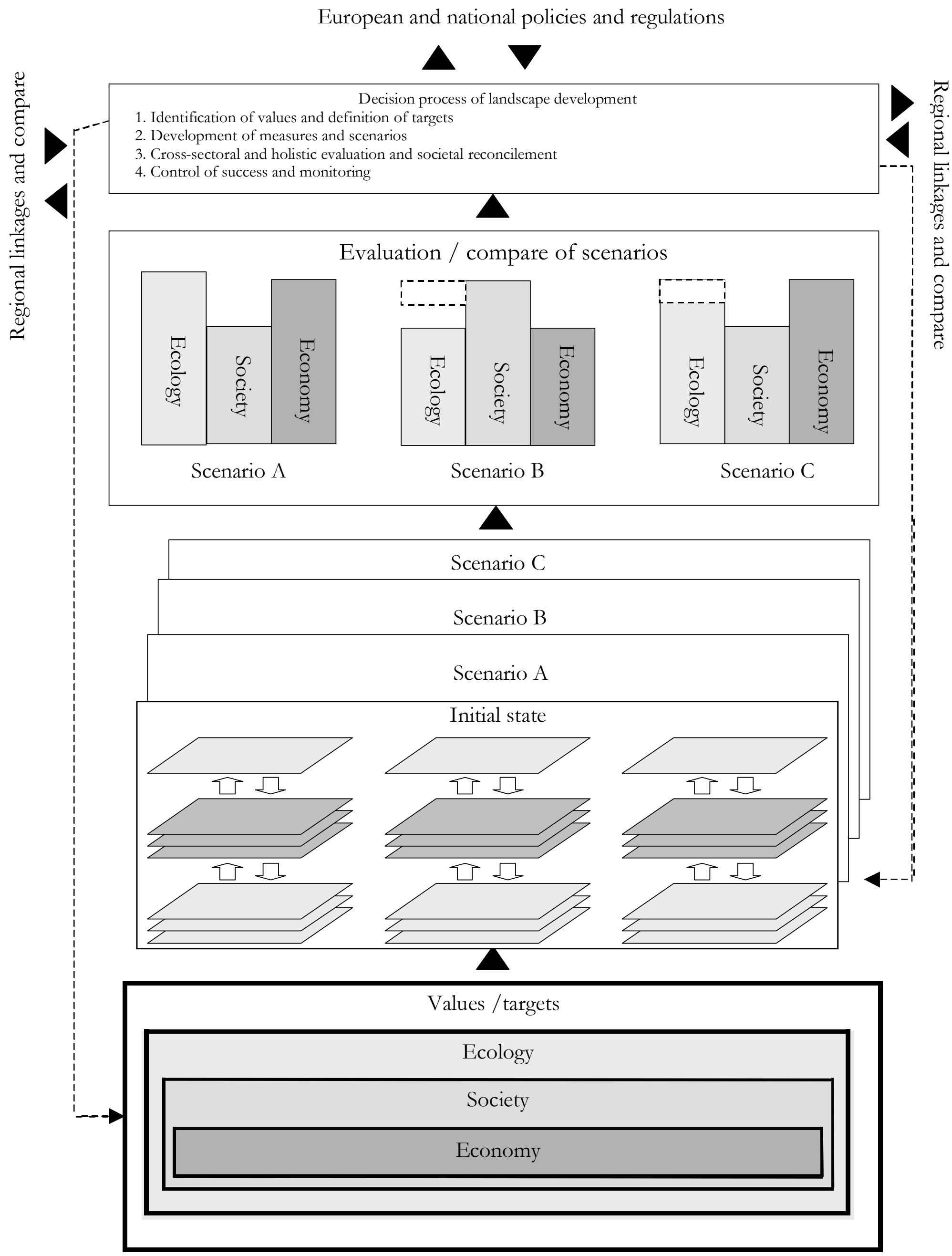


Figure 3.1 a slightly changed version of Schanze's (2003) portrait of the management of landscapes in a multifunctional setting

As with any multiobjective optimization a common scale of the objectives under investigation must ideally be created. The lacking market valuation of the NCOs means that a different unit of measurement is needed to weight the public priorities. Different notions are used for such an overall encapsulating unit of measurement. Hopefully the evaluation points towards a given scenario as the optimal one (as scenario A in the case of the illustration). However, this is seldom the case. Therefore it is likely that the whole process repeats itself.

The role of the simulation model is to tie the values and targets identified by the society for a given landscape /region together with the measures developed by testing it through alternative scenarios. "*Simulation models are therefore used as computational laboratories to study the evolution of agricultural structures under controlled experimental conditions*" (Happe 2004).

Far from all models aiming at providing an ex-ante assessment covering both the economic and environmental aspects of agricultural production and the utilisation of the rural landscape have used the term multifunctionality to describe their enterprises. So rather than excluding them from this review due to a label a short presentation of different modelling types for environmental impact assessment will be given. To a large degree the presentation will be based on a review article by Payraudeau and Werf (2005). This is then supplemented by an examination of different Bio-economic farm models. The latter part is also largely based on a review article (Janssen and van Ittersum 2007). Both articles are recommended if an in-depth treatment of the topic is required.

With some justification the large variety of models within this sphere can be reduced to six different types of methods. In spite of the fact that the list is neither exhaustive nor all models fall within these clearly demarcated categories it can provide an insight into methods the most frequently used. The seven categories used here are: Bio-economic Farm Models (BEFMs), Agent-based modelling (ABM), Multiple linear programming (LP) approaches, Environmental impact assessment (EIA), Environmental risk mapping (ERM) and Agro-environmental indicators (AEI).

Each of these modelling methods will be introduced and their relationship to the modelling of multifunctional agriculture will be presented.

It is, however, important to underline that the different categories should only be taken as rough guidelines rather than being real separations of the models. To illustrate how large an overlap there is between the different modelling categories we will first categorize the model we currently adapted, namely AgriPoliS. AgriPoliS is an ABM where the actions of the individual agents are found as a mixed-integer optimization problem using recursive linear programming (a type of LP). When the model is used as a part of the MEA-Scope model (that means it is interlinked with two other models which capture the farming processes and the joint production of non-commodity outputs in greater detail) it is a BEFM making use of AEI for ex-ante assessments of EIA as well as ERM.

The main reason for this rather odd rattling off of different categories to which it is possible to interpret AgriPoliS is due to the nature of the different methods. Both BEFM and ABM cover simulation models. LP is an optimisation technique, here including also regional modelling approaches based on LPs covering multifunctional agriculture. ERM is a mapping technique. EIA is a formalised environmental assessment approach. Finally AEI is a group of approaches based on indicators.

Our main focus will be on the simulation models; however, as the AgriPoliS example showed all the mentioned methods are parts of simulations within multifunctional agriculture.

3.1.1 Bio-economic Farm Models (BEFMs):

Bio-economic Farm Models is not a term generally accepted. Instead of this there is "*a wide range of terms used for the same type of models. Publications use terms such as 'bio-economic', 'ecological-economic' or 'combining the environmental and economics' referring to the integration of economic and biophysical processes and models*" (Janssen and van Ittersum 2007). Besides combining the economic and biophysical processes in a model the point of origin for the models is the agricultural production.

This is also reflected by the definition of a BEFM given by Janssen and van Ittersum (2007): "*a model that links formulations describing farmers' resource management decisions to formulations that describe current and alternative production possibilities in terms of required inputs to achieve certain output and associated externalities.*" (Janssen and van Ittersum 2007). It is, however, important for the understanding of the definition to underline that the farmer mentioned (as well as the farm in the name of the term) does not necessarily refer to the modelling of individual real farms. Some of the models included under the term describe whole regions as a single hypothetical farm, which then is optimising its resources (e.g. the land and stable capacity) as a single entity. The main body of models within multifunctional agriculture falls within this category. We will therefore revert to it after the presentation of other groups with an account more in depth.

3.1.2 Agent-based modelling (ABM):

The agent-based study of economic systems has been pioneered by e.g. Conte et al. (1997), Epstein and Axtell (1996), Gilbert and Troitzsch (1999), Axelrod (1984; 1997). There are a number of different definitions of agent-based modelling. The following quotation gives a fairly adequate and well-formulated definition.

"An agent-based model is a computational model that represents individual agents and their collective behaviour…. An agent is a persistent thing that has some state we find worth representing, and which interacts with other agents, mutually modifying each others' states. The components of an agent-based model are a collection of agents, and their states, the rules governing the interactions of the agents, and the environment within which they live. (The environment need not be represented in the model if its effects are constant.)"

(Shalizi 2006 pp.65)

Agent-based modelling has been applied to a large number of disciplines (such as physics, biology and social sciences), however, we will focus the attention upon models in the intersection between economics and land use systems.

Most of the agent based modelling activities within this area are centred around the land use /land cover change (LUCC) community. Agent-based models have been a substantial part of their contribution, however, also other model types such as dynamic system models (Evans et al. 2001) and cellular automaton models (Tobler 1979; Balmann 1997; Li and J.F.Reynolds 1997; Clarke and Gaydos 1998; Mesina and Walsh 2001) have been investigated.

Agent based modelling and cellular automata models originate from the same modelling tradition. One important characteristic of ABMs, which distinguishes them from Cellular Automatons, is the potential asynchrony of the interactions among agents and between agents and their environments (Parker 2003).

Agent-based computational economics are building upon two basic features of economical phenomena: Individuality and locality (Damgaard 2002). The tenet of locality means that every interaction has some location and some range of effect, leading to interdependency between the market actors in an agro-economical production. The phenomenon detectable at an aggregated level of systems is in agent-based modelling framework understood as the result of individual actions and interactions that should therefore be recreated in models incorporating such features. For instance, individual farms or plots of land should be made explicit in farming models, rather than the clumps of farms often seen in a "top-down" approach where the parameters describe the higher hierarchical levels of the system. (Balmann 1997; Damgaard 2002)

Bottom-up modelling of market processes builds upon the notion that macro-dynamics emerge as the outcome of micro-dynamics involving a large number of individually acting agents and therefore best can be understood when modelled as such. Agent-based models do also constitute an attempt to capture the room of simultaneous actions in which decisions are made. Besides affecting itself simultaneously the actions of a single agent will affect all others, which are interacting with this agent. All the actions of these agents are at the same time influencing the first agent. More traditional economic models are based on dependency where one action is followed by another action in separated steps.

As a result of the locality mentioned above the interdependent units are presumed to be spatially correlated. The spatial correlations are central to the formulation of the models. The emphasis on the spatial relationships applies to farm production as well as to human interrelation in a broad sense.

The relations between the interdependent units are influenced by the quantity and quality of information available for each unit when making its decisions. Therefore the effect of spatial spreading of the information upon which the decision-making units base their choices is also important. This is then linked to another central theme within agent-based modelling, namely the modelling of the decision making unit and the rationality behind its actions. The interactions between the agents make their environment too complex for strictly rational decisions. Therefore most models operate instead with boundedly-rational agents, where the actions are based on spatial and- /or temporal knowledge or principles of rationality. The dynamic nature of the models makes the agents' ability to adapt to new conditions important for many models. Therefore agent-based modelling has been used in a broad range of representations of learning processes of computational agents. These include reinforcement learning algorithms (Barto et al. 1995; Kaelbling et al. 1996; Bell 2001; Bonarini 2001; Nicolaisen et al. 2001), neural networks (Grossberg 1988; Watts and Strogatz 1998; Bunn 2000; Terna 2000; LeBaron 2001; Schlesinger and Parisi 2001), genetic algorithms (Grefenstette 1986; Balmann and Happe 2001; Balmann and Musshoff 2001; Choi et al. 2001; Nicolaisen et al. 2001; Deb et al. 2002; Kulkarni et al. 2004; Wang et al. 2005), genetic programming ((Chen and Yeh 2001; 2002; Papavassiliou et al. 2002; Chen 2005; Manson 2005), and other evolutionary algorithms.

Similarly the evolution of behavioural norms has been investigated. The interactions of agents obeying simple rules may create collective behaviours similar to norms as seen in real life. A classical example could be the segregation-model first proposed by Schelling (1978) where social segregation is emerging through local chain reactions of agents which will move if less than one third of their neighbours are of the same social background.

It is obvious to investigate the formation of networks and their economic effects based on the quantity and quality of information available for each agent. Agent-based modelling is therefore crossing into the study of networks with techniques from graph theory, network analysis and the economics of transaction cost.

Agent-based modelling has also been used to e.g. model organizations, design of computational agents for automated markets and to make parallel experiments with real and computational agents.

In the intersection between economics and land use systems the modelling technique, though growing in popularity, is still a relatively novel practiced form of modelling (Parker et al. 2003). However, with the growing number of programming tools for agent-based modelling as well as the rising number of publications demonstrating the advantages of the modelling technique more research groups are using this type of modelling.

Almost all ABMs used with multifunctional analysis today are a subset of the BEFM group. ABM is, however, given a separate category due to its different focus and approach compared to the more traditional BEFM.

3.1.3 Multiple linear programming (LP) approaches:

Multiple linear programming approaches cover a series of optimisation techniques based on linear programming. Linear programming problems involve the optimisation of a linear objective function, subject to linear equality and inequality constraints.

Linear programming has been a widely used tool in agricultural economics (Heady 1954; Day 1963; Day and Cigno 1978); especially when it comes to describe the behaviour of individual decision makers. The choices of the individual decision maker may then later be aggregated at the regional or sectorial level in order to evaluate different policy options. Another widely used option is to represent a whole region or sector as a single hypothetical farm that is optimised as a single entity. The linear programming models are often used because of their robustness and the fact that they are less demanding when it comes to availability of data than econometric models.

The modelled entity, being a single farm or a whole region, is represented as a linear combination of technical coefficients (also designated input-output coefficients) that express the contribution of a given activity to the objective function. The pool of activities represents the entire room of potential production activities present in the location. The technical coefficients represent discrete estimates stating the amount of input needed to achieve a certain output and the associated economic and environmental effects (Janssen and van Ittersum 2007) That means that the production of a given activity such as wheat production is broken down into its single components, such as land, labour or nutrients and each one is ascribed a technical coefficient representing the input-output relationship. The input-output relationships between different activities are seldom linear functions. Both the biophysical and economic rules that determine the transformation of inputs into outputs for a given activity are generally non-linear (ten Berge et al. 2000). The production functions are also normally of a non-linear nature. In order to represent this in the best possible way several activities should ideally be introduced each one with a technical coefficient representing a point on the production function. Leontief production functions are normally used to find these technical coefficients. A Leontief production function operates with fixed proportions in the inputs (Leontief 1947). That means that the Leontief production function is a discrete function.

This discreet nature of the Leontief production function makes it impossible to represent an economy of scale with coefficients deriving from the same continuous production function; but each of the Leontief functions represents a scale specific production possibility of this particular and continuous production function. So in the same way as a new stable will mean an abrupt increase in the stable capacity, and most likely an increase in the production per labour unit, the simulated production function will be represented as independent production possibilities.

As resources are limited the farms are therefore subjects to constraints represented through the farms' capacities. The farm capacity is the maximum or minimum amount of a given input or resource that can be used. The capacities can also be used to create restrictions that mimic legislative - or agronomical requirements such as a maximal level of fertilization and animal feeding requirement constraints. Thereby a number of implausible results are prevented and the credibility of the optimisation is enhanced.

This system of activities and constraints is then an optimised subject to the objective function. The objective function represents the user-defined goal for the production. The objective most frequently used is profit maximisation.

Linear programming problems are widely used within simulations and analysis of multifunctional agriculture. The technique allows for the consideration of numerous functions into the farms' individual decision-making as well as the incorporation of the associated economic and environmental effects of its actions. The nature of agricultural production and landscape management makes the ability to associate a broad variety of possible activities to an individual decision maker subject to given constraints compelling. It allows one to find the optimal utilisation of own resources within a large set of possible options similarly to the optimisation process facing the farmer or regional decision maker. Therefore most of the traditional BEFM is making use of LP-optimisation to such an extent that one could debate the need for both categories. However, as neither group covers the other entirely both are maintained.

3.1.4 Environmental impact assessment (EIA):

Environmental impact assessment is a method to

"…identifying the likely consequences for the biogeophysical environment and for man's health and welfare of implementing particular activities and for conveying this information, at a stage when it can materially affect their decision, to those responsible for sanctioning the proposals"

(Wathern 1990 pp.6).

In the following the focus lies in the content of EIA rather than the communicative element also contained in the definition. The word "impact" is central in understanding the method. An impact has both a spatial and a temporal component and can be described as the relative change in the investigated parameter with or without the event (Lee 1983). The non-static nature of the environmental system means that the normal dynamic development of the involved parameter has to be left out. This method is standardised and consists of several stages from the recording of the emissions to the decision-making by the authorities (Payraudeau and van der Werf 2005) as the definition expressed. Environmental, economic and social aspects have to be taken into account. The actual parameters used are often indicators based on either scientific average values or expert judgment. The geographical delimitation varies and often techniques such as fuzzy logic tools are added to the assessment in order to soften the harsh parameters used to reflect a biological reality (Mendoza and Prabhu 2004; Boclin and Mello 2006).

3.1.5 Environmental risk mapping (ERM):

This category covers to some degree two individual methods merged into one category. That is the environmental risk management (Lave 1984; Failing et al. 2007) or assessment (Finizio and Villa 2002)on one hand and environmental mapping (Giupponi et al. 1999) on the other. Both the maintenance of a manageable number of categories as well as the relatedness leads to this single category.

Risk assessment is measuring the magnitude of the potential loss, and the probability that the loss will occur. Environmental risk assessment is commonly understood as the mean assessment of risks to human exposures in the environment at large. This is even at times narrowed down only to include risks to human health. On the other hand ecological risk assessment is used for risks to non-human communities and populations. However, here it is all grouped under the same label. The objective of the method is to define, measure and to some extent manage the risks associated with human pressures on the environment and its feedback on the human population. This involves the ability to spatially associate a given risk. The ability to superimpose several sets of spatial information through the use of Geographical Information System (GIS) helps not only in determining risk-associated areas (Gupta et al. 2002) but also to e.g. locate potential habitats for different vulnerable species. Techniques such as the method of moving windows are used for such analysis. Mapping results demand, however, that the information in the different layers is given weights relative to each other. This is particularly the case for multifunctional analysis. Multifunctional agricultural production involves multiple measures of performance, or objectives that have to be optimized simultaneously. In practice, some of these objectives may be conflicting. An example is the economic and production related decisions on the farm, which are often made at the expense of environmental objectives. Similarly, when assessing the environmental risks some hazards are reinforcing each other while others reduce the effect of each other. The interrelated nature of different risks makes it particularly important to consider the appropriate weighting techniques.

3.1.6 Agro-environmental indicators (AEI):

The use of AEI itself does not constitute the definition of an evaluation method (Payraudeau and van der Werf 2005). An indicator is an indirect measure of a broad concept or system that can't be measured directly. Generally, a measure used to determine, over time, performance of functions, processes, and outcomes. Agro-environmental indicators are used to characterize the functioning of an agro-environmental system, by measurable means. The size of the system, the complexity of the interactions involved, or the difficulty and cost of the measurements make it virtually impossible to monitor the system in its full detail. Indicators should be based on data that are timely, accurate and of known quality. Agro-environmental indicators are also used as a tool for communication. Simplifying the large variety of parameters to a manageable number of indicators makes information about ecosystems and the impact of human activity on same more comprehensible. AEI used within multifunctional analysis is often with reference to the early work of OECD (1993).

The OECD (1993 pp. 5) indicates two major functions of environmental indicators:

- "*They reduce the number of measurements and parameters that normally would be required to give an exact presentation of a situation. As a consequence, the size of an indicator set and the level of detail contained in the set need to be limited. A set with a large number of indicators will tend to clutter the overview it is meant to provide.*
- *They simplify the communication process by which the results of measurement are provided to the user. Due to this simplification and adaptation to user needs, indicators may not always meet strict scientific demands to demonstrate causal chains. Indicators should therefore be regarded as an expression of 'the best knowledge available".*

Three basic criteria for the selection of indicators are used in OECD's work: policy relevance and utility for users, analytical soundness, and measurability (see page 30). According to the OECD (1993), these criteria describe 'ideal' indicators: possibly not all of them can and will be met in practice. The OECD criteria are made with empirical investigations in mind. When indicators are used in the analysis of simulation models the criteria are still valid though they should be interpreted differently. Analytical soundness reflects back towards the model and theoretical understanding of the system. In relation to the simulation models measurability means both the availability of empirical input data from the region to adapt the model to the site specific conditions as well as the ability to validate the output results.

3.2 Bio-economic Farm Models revisited

The relationship between agro-environmental indicators and simulation models leads us back to our point of departure: The simulation models and multifunctionality. As previously mentioned the main body of models within multifunctional agriculture is found within the category of Bio-economic Farm Models. We will therefore revert to them in order to reflect upon their characteristics and their effect on the multifunctional analysis of the rural landscape and the agrarian sector.

3.2.1 Decision making –the objective function

In the paper of Janssen and van Ittersum (2007) 48 BEFM are analysed. Objective functions were used in 42 of them. In 23 of them simple profit (income, net revenue etc.) maximization was used as the objective, 5 deducted some risk factors (e.g. risk as avoidance of income variability) of the profit maximization, 5 maximized expected utility (e.g. by including long term goals) and 9 used multi-criteria optimisation approaches. The numbers show first of all that the large majority of BEFM is using mathematical programming or optimisation models based on LP's. Secondly, within the group using objective functions the maximization of the economic self-interest is the dominating goal for the decision-making unit. This means that beyond the pure economic aspect the multifunctional interest will only enter the decision-making units optimisation indirectly through regulative measures expressed through the linear equality and inequality constraints. This is likely to be a very reasonable assumption; however, it does underpin the production related understanding often found in multifunctional agriculture.

3.2.2 Risk

Agricultural production involves risk and uncertainty both related to the economic and environmental outcome of the decisions taken. This is due to outside given factors such as the weather, prices and biological responses to the production practices among other things (Martins and Marques 2007). Similarly, when a farmer has the choice to adapt to a politically promoted production pattern, whether it is induced through subvention or not, then the decision involves a risk component. Modelling different regulative measures related to multifunctional agricultural production makes it therefore relevant to consider the risk component in a given model (Cocks 1968). This risk component is often indirectly embedded in the construction of the model even if risk wasn't integrated in the planning of the model (Thompson 1982). The most widespread example is the risk neutrality that the use of average data assumes. Average data reduces the variation within factors such as prices and the weather as well as homogenizing the spread out of factors such as the biological responses.

A useful distinction is between embedded and non-embedded risks (Dorward 1999). Embedded risk means that the decision maker has the opportunity to exercise some control of the risk he is facing, where non-embedded risk is related to uncertainties beyond the control of the decision maker such as price developments or the weather. Both types of risk should ideally be incorporated into the modelling. As the non-embedded risk lies outside the control of the decision maker it should therefore be modelled by investigating the structural effect of non-average weather data or price fluctuations. The embedded risk is often harder to incorporate. The farm's risk profile should be mapped and far more importantly a sequential decision problem should be constructed where embedded risk (and tactical) considerations enter into the optimisation.

3.2.3 Time and space

The spatial and temporal scale in which the area is investigated has an influence on the degree of multifunctionality a given location can be said to have (Brandt and Vejre 2004). The way a given model incorporates both dimensions is therefore important for its ability to model multifunctional agriculture (Brandt and Vejre 2004).

Most of the investigated BEFM in the review of Janssen and van Ittersum (2007) are based on static LPs and time is therefore simulated as a single production period. A few of these models incorporate different time frames for the different production steps involved in producing a given crop so the environmental pressure during the course of the year is considered. Mainly as rough declarations of the earliest - and latest ones a given production can take place based on experience. The actual course of the production year is not simulated as such. That means that e.g. variation of the weather and its environmental effects is not playing a part (Wijngaard 1988). A number of other models are based of different types of dynamic LP's and are therefore better able to incorporate the temporal dynamics within agricultural production. The temporal focus is, however, on the dynamic development within several production periods rather than on the course within a single production year. This priority is of course reasonable considering in the investigation of different regulative measures. The structural development taking place due to a political indicative in a given region will often stretch its effects further than the year of introduction.

The dynamic models can be subdivided into recursive models, inter-temporal models, dynamic recursive models and stochastic programming models

(Blanco Fonseca and Flichman 2002). A recursive model optimises each production period separately but runs over more production periods as the end values from the former period works as the starting values for the next period. Inter-temporal models optimise over the whole time period while considering the single time periods e.g. maximizing the farms' income over a 25 years period while treating time through the use of a discount rate. Dynamic recursive models combine the two perspectives. The farms optimise over the whole time period while still using values from the former period as the starting values for the next period. Stochastic programming models optimise each production period separately, however, subdivide the single year into smaller units in order to take e.g. the stochastic variation of the weather into account.

The spatial component of BEFM is of large importance for the environmental assessment (Girt 1978; Beaumont 1982; Berger 2001). However, the spatial dimension is at times neglected in BEFM's. Some models allow the results from the simulations to be projected into maps. This is a possibility if the location of the individual farm simulated or single hypothetical farm representing the whole region is known. Such projections enable further spatial analysis of the results to take place e.g. by estimating environmental effects on neighbouring areas. But the model itself still disregards the spatial dimension of agricultural production. The optimisation is done without taking the actual location of the single fields and the resulting transportation cost into account. Transportation cost is rather calculated on some kind of average values. In recognition of the importance of the spatial dimension a number of models are integrating GIS and other spatial explicit components. This is demanding access to GIS-maps or other geographical information. On top of this it is important that the geographical information enters into the model as part of the information upon which the calculations are based rather than purely as a visual surface. This also means that the spatial component of BEFM's needs to undergo the same scrutiny as the other parts of the models. This includes spatial sensitivity analysis as well as other validation techniques.

3.2.4 Agricultural activities

The type of production an individual farm undertakes influences the impact that this particular farm has on the local environment. The types of activities and the way in which they are represented in a BEFM are therefore important for the models' reliability in a multifunctional analysis. The majority of BEFM builds on LP-optimisation techniques and the agricultural activities are therefore represented as a linear combination of technical coefficients (Ruben and Ruijven 2001).

An agricultural activity consists of a technical coefficient expressing the contribution to the objective function as well as other coefficients describing the production technology involved in the management of the activity (Ittersum and Rabbinge 1997; Ruben and Ruijven 2001; Hengsdijk and Ittersum 2002; Hengsdijk and Ittersum 2003). Examples of agricultural activities could be a maize-wheat-potato rotation, sugar beets, dairy cows or participation in an agro-environmental program. The pool of activities represents the entire room of potential production activities available at the location (Ittersum and Rabbinge 1997; Hengsdijk and Ittersum 2002). Both the quality and quantity of the agricultural activities included in the model strongly influence the models' credibility. Most technical coefficients are based on sources of information such as national statistics, farm management handbooks, census data, field trails and research farms. One of the difficulties with large LP-models and technical coefficients is that it is hardly possible for the scientific community to test and assess their validity. The amount of data used in this kind of modelling makes it hard for people outside the modelling group to reproduce the results. This is of course a common problem within all kinds of scientific computing, however, unlike the scientific fields with a longer tradition for large models there is not developed clear practices within the BEFM-community to deal with this issue.

The pool of activities expressed through technical coefficients represents the entire room of potential production activities modelled. To enable the individual farms to diversify their production types and technologies sufficient feasible alternative production types and technologies need to be included in the model in order for the model to react in a credible manner. Modelling policy changes mean that the potential new income generating activities have to be described through technical coefficients even before adapted into practise. At the same time the LP-models are often reacting too strongly on marginal gains produced through alternative production types. A real farmer needs some learning time and has some mental resistance to overcome before entering into new production types which is not the case for an optimisation algorithm. Different ways of incorporating such considerations into the models have of course been attempted. The problem has also another angle to it when investigating multifunctional agriculture. As the scope of the analysis is widening the technical coefficients need to express all the other dimensions that agricultural production will influence. Farm optimisation means that e.g. environmental conditions that the individual farm directly brings about through its activities can be quantified (Berger et al. 2006), however, this is less the case with effects caused by the interplay of a number of independent farms and agents. A number of environmental hazards depend upon a correlation between a series of events to occur e.g. the groundwater quality is seldom only affected by the actions of a single person but depend on the actions of several persons over time and is also influenced by weather, soil composition as well as other factors. The coordinated effect of several farmers' actions is therefore at times underestimated.

Some of the multifunctional effects of agricultural production tend to be of a less quantifiable nature e.g. the aesthetics of a landscape and they are therefore difficult to incorporate in the models.

4 Modelling multifunctionality

4.1 Introduction to the MEA-Scope hierarchical modelling approach

4.1.1 Introduction

As this research was done as part of the larger project with the acronym MEA-Scope (MEA-Scope 2004), it is motivating for the understanding of the research presented here to understand the main features of the project as such. Therefore the objective for the MEA-Scope project along with the chosen modelling approach is presented (for more information see (Damgaard et al. 2006)). In order fully to appreciate the MEA-Scope modelling approach a short introduction to all three models involved: AgriPoliS, MODAM and FASSET is given.

4.1.2 Motivation

Common Agricultural Policy (CAP) reform aims at higher international trade compatibility and at the same time ensures that social, environmental and consumer concerns are taken into account as well as gives room for a sustainable development of the agriculture of EU. Sustainable development of the rural landscapes is a multidimensional environmental and societal complex operating on different spatial and temporal levels simultaneously. The decision-makers behind CAP need therefore tools to investigate the consequences of their policies in a multidimensional setting, which takes into consideration the direct as well as indirect effects.

The MEA-Scope is such a tool. It is a framework to convey information from science to the decision-makers behind CAP. Based on the EU's *Model of European Agriculture* (MEA) the aim of the MEA-Scope project is to create a model, which is able to incorporate, the ecological, social, structural as well as the economic effects of European agricultural development. The MEA-Scope modelling approach is based on three agronomic and economic simulation models. The core of the MEA-Scope is to adapt these three models of different nature and with varied perspective to work together.

By enabling the three models to collaborate they will constitute a strong tool to investigate the consequences of different aspects regarding agricultural production as the output files reflect the results of the policies investigated. The combined models have been adapted to 7 representative European landscapes within the project.

Linking the three models allows the capabilities of the models to extend by combining the individual strengths of each model and obtain a more complete model with regard to spatial, analytical and temporal aspects. At the same time the combined model will also be able to cover a wide range of multifunctional indicators that are simulated in the respective models and thereby be able to analyse the effects of different CAP-reform options in a multifunctional framework. In doing so, we aim at providing more comprehensive results on multifunctionality impact assessment that span different levels of scale (regional and farm level) as well as different domains (economics and environmental sciences).

The objective of this chapter is to provide the necessary background for understanding the scope of the modelling part of the MEA-Scope project. Therefore the capabilities of the three individual models are presented. Then a short guideline for the creation of the combined model is introduced.

4.2 Introduction to the models

In order to be able to investigate the consequences of different support mechanism we need tools that take both the direct as well as indirect effects into consideration in a multidimensional setting. The MEA-Scope model is an attempt to provide such a tool.

The MEA-Scope model is a framework of three models independently developed joint in a hierarchical structure. Each individual model is described in detail elsewhere (AgriPoliS: (Balmann 1993; 1995; 1997; Happe 2004; Happe et al. 2004; Happe et al. 2006a; Kellermann et al. 2007) MODAM: (Meyer-Aurich et al. 1998; Zander et al. 1999; Zander and Kächele 1999) and FASSET: (Jacobsen et al. 1998; Berntsen et al. 2003)). Only a brief description of the unique characteristics of each model is given here.

4.3 AgriPoliS

The agent-based model AgriPoliS (Agricultural Policy Simulator) is a normative spatial and dynamic model of regional agricultural structural development. The model explicitly takes into account actions and interactions (e.g. rental activities, investments, and continuation of farming) of a large number of agents acting individually.

The model consists of *N* individual farms evolving subject to their actual state and to changes in their environment. This environment consists of other farms, factor and product markets and space. It is all embedded within the conditions of the technological and political settings.

For the purpose of AgriPoliS an agent is defined as an entity that acts individually, senses parts of its environment and acts upon it. Each agent in AgriPoliS corresponds to a single farm or agricultural holding.

In each time period the individual farm *n* will optimize its expected farm household income y_n^{ex} subject to a number of restrictions. That can, simplified, be expressed as:

$$\max y_n^{ex}(\mathbf{x}, \mathbf{p^{ex}}, \mathbf{c}, \mathbf{A}, \mathbf{I}, \mathbf{r}, MP, D, RE, L, BC, IC, ...) \qquad (4.1)$$

with

$$y_n^{ex} = \mathbf{x}'(\mathbf{p^{ex}} - \mathbf{c}) + IR + S + W - RE - MC - D - OV - TC - IC - HW$$

$$\text{s.t. } \mathbf{b} \geq \mathbf{x'r} \qquad \text{with} \quad \mathbf{r} = (r_1, ..., r_I, ..., r_H, .., r_j)$$

$$\mathbf{x} \geq 0$$

where **x** is the production activities, $\mathbf{p^{ex}}$ is the expected product prices, **c** is the variable production cost, **A** the investment cost, **I** is the investment alternatives, **r** the factor demands, and **b** is the factor capacities, all expressed as vectors of all possible states. MP is manpower hours, D is depreciation, RE is rent paid, L is liquidity, BC is the borrowed capital, IC is interest paid, IR is interest on working capital, S is support payments, W is off-farm income, MC is maintenance cost, OV is farm overhead, TC is transport costs and HW is wages paid.

This problem is solved as a mixed-integer optimisation problem using recursive linear programming including integer activities.

From the solution of the linear programme, investment activities as well as production factor shadow prices can be derived (Kellermann et al. 2007). The decision-making of a farm is bounded rational since decision-making is myopic and strategic aspects are only included in a rudimentary manner (Kellermann et al. 2007). For example the expected actions of other farms are not included in the individual farms optimisation of the expected farm household income.

The individual farm agents are indirectly affecting the room of actions of other farm agents through the land market as they simultaneously can bid for the same plots of land. The auction for land (as well as other shared resources such as transaction of products) is coordinated by collecting and comparing bids and allocating the free resource to the highest bidder. Farm agents' bid for particular plots of land depends on the shadow price for the plot, the number of adjacent farm plots and the distance-dependent transport costs between the farmstead and the plot. When nothing else is mentioned second-price auction is used.

It is all taking place in a 2-dimensional space where each individual plot represents a standardised spatial entity of a specific size. In this representation, all factors that do not directly relate to agriculture and land use (roads, rivers, etc.) have been eliminated. In the normal version of AgriPoliS the cells represent agricultural land as either grassland or arable land. The total land of a farm agent consists of both owned and rented land. Land is heterogeneous with respect to its location in space and with respect to its quality. It is as previous mentioned all embedded in a technological and political environment. Agricultural (and environmental) policies affect the farm at different instances such as prices, stocking density, direct payments, or interest rates.

In AgriPoliS, the land market is the central interaction institution between agents.

It is of particular relevance here, as our focus on jointly produced output also emphasizes the allocation of land as the fundamental resource for multifunctional agriculture.

The task of AgriPoliS is mainly to give the MEA-Scope model its ability to predict the regional structural development subject to different political scenarios. The dynamic agent-based nature of AgriPoliS allows the individual farm to change its fundamental characteristics such as size, production type and equipment in response to changes in its local conditions as well as the overall political decided settings. This ability to react on impacts from different levels of scale simultaneously allows the creation of the competitive environment investigated.

To understand how the agents and their actions interplay as well as the way in which this process is synchronized, Figure 4.1 provides an overview of the dynamics of the model and the course of events during one simulation period.

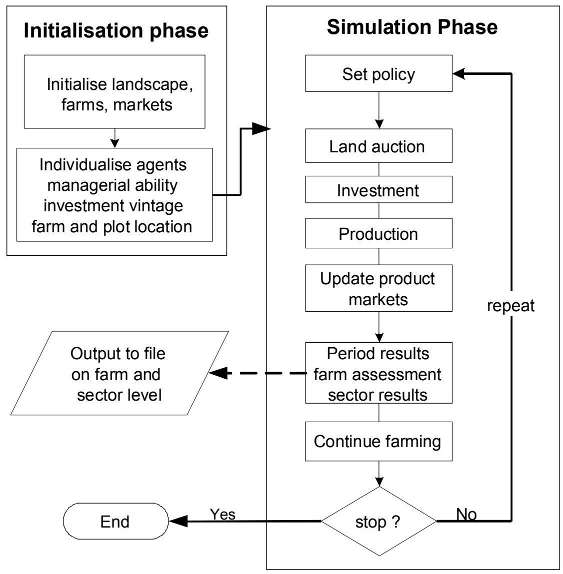


Figure 4.1: Model dynamics and course of events during one period (Happe 2004)

4.3.1 AgriPoliS and economic theory

Each individual farm or agent in AgriPoliS is based on empirical data.

The modelling approach is based on the (short run) cost function of the individual farm. We assume that all the farms are price-taking firms. By knowing the cost function of the farm the marginal cost function can be derived when the farm is assumed to profit maximise. The assumption of profit maximisation gives the supply function of the farm.

The cost function C of the individual farm is:

$$C = C(\mathbf{w}, \mathbf{y}, \mathbf{b}) \qquad (4.2)$$

where **w** is an *N*-vector of input prices of variable input, **y** is an *M*-vector of output, and **b** is a *K*-vector of quasi-fixed inputs. The marginal cost function is expressed as:

$$MC_m \equiv \frac{\partial C}{\partial y_m} \quad (\text{m}=1..M) \qquad (4.3)$$

for a given output m.

Following the condition of profit maximisation means that the supply function is determined by the marginal cost function, that is:

$$MC_m(\mathbf{w}, \mathbf{y}, \mathbf{b}) = p_m \quad (\text{m}=1\ldots M) \qquad (4.4)$$

where p_m is the price of output m.

The market supply function is the sum of all the individual farms supply functions and can be found by horizontally aggregating the individual supply functions. In the case of J farms that is:

$$y = \sum_j y_j = \sum_j s_j(p) = S(p) \qquad (4.5)$$

The supply function for a given modelled region can thereby be estimated for a given set of products by varying the demand function through the price and under the assumption of farms being price takers. The latter is a reasonable assumption if one considers the farms as being part of a competitive market.

Applying the Shephard Duality theorem (Diewert 1971) means that any technology may be equivalently represented by a cost function or a production function. Any concept defined in terms of the properties of the production function has a "dual" definition in terms of the properties of the cost function and vice versa. As Diewert (1971) shows this is also the case for a generalized Leontief production function.

That means by taking the cost function (4.2) of the individual farm and applying it to a single output one can establish the input-output relationship for this product. The non-linear nature of the normal production functions makes it hard to represent them in their full therefore Leontief production functions are used. A Leontief production function operates with fixed proportions in the inputs (Leontief 1947). This means that the Leontief production function has constant returns to scale. In order to model the economies of scale the production function is represented as several independent activities each with a technical coefficient representing a point on the production function.

In practice each product is broken down into its single components, such as land, labour or nutrients and each one is ascribed a technical coefficient representing the input-output relationship. Hereby the restrictions that the individual farm faces can be found and the optimisation of its expected farm household income be estimated. The scale of the production function is represented through a number of investments options.

4.4 MODAM

Modelling the multiple objectives embedded in multifunctional land use requires a profound and diversified knowledge especially of the relationship between agricultural production and its effects on the natural environment. Therefore the individual farms are further investigated in MODAM.

The MODAM (Multi-Objective Decision support tool for Agroecosystem Management) model is developed to simulate interdependencies between achievement of economic and ecological goals as a function of agricultural policies.

MODAM consists of a set of relational databases and analytical functions, which allow computing the economic returns and environmental impact of the land use alternatives. Due to its modular and hierarchically linked structure MODAM offers high flexibility with respect to the number and type of farms, sites and production techniques.

A descriptive data collection of production activities for the region constitutes the fundament for allowing economic and ecological analysis of the different production activities. Within MODAM more than 1200 different production practices have been described and analysed. Among the about 400 cropping practices there are an even distribution between conventional and organic farming. For each cropping practice the cost and benefits in both an economic as well as an ecological sense are computed. In order to be able to evaluate the ecological effects of different production practices MODAM is able to create a trade-off function between different possibilities for the simulated farms.

By taking the site-specific characteristics of the study area into account along with the farms' cropping practices for every combination of 10 environmental objectives (e.g. nitrate leaching or protection of amphibians) a degree of goal achievement will be determined. In order to be able to balance the economic and ecologic interests against one another a fuzzy logical tool is used. This partial analysis creates the foundation for the built-in LP-generator to create a multiple goal linear programming model of the investigated farms.

Environmental objectives can easily be included and different levels of goal achievement can be simulated. This means that MODAM can be used for the simulation of goal driven scenarios to show the effect of ecological restrictions on economic performance as well as to show the impact of policies on economic and ecological performance of farms for policy driven scenarios.

The results are presented in the form of trade-off functions between different ecological and economic goals and in the form of land use maps. The spatial dimension of allocated land use patterns can be analysed and visualised by geographic information systems.

The main advantage that MODAM brings to the MEA-Scope model is its detailed and extensive description of the interplay between production practices and environmental effects along with its ability to balance the different interests. The multiple goal linear programming models are suited to find the desired balance between non-commodity output and commodity production in multifunctional agricultural production.

Multifunctional agricultural production involves multiple measures of performance, or objectives that have to be optimized simultaneously. In practice, some of these objectives are, however, conflicting. As an example the economic and production related decisions are often based on a compromise of environmental objectives. With MODAM's multiple goal linear programming technique and the creation of trade-off functions this problem can be met.

Within the reasoning for supporting multifunctional land use there is a component of risk adverse behaviour. A sustainable development means also avoiding any sudden and unpredictable changes in the local landscapes. The public's willingness to pay for multifunctional land use is also motivated in a wish to avoid the negative externalities imbedded in intensive agricultural production. The demand for clean drinking water is an obvious example. When addressing this demand more uncertain elements such as the weather will play an active part. Neither MODAM nor AgriPoliS incorporate the fluctuations in the weather patterns. Both models lack also the ability to follow the movements of nutrients down through the soil.

FASSET accounts for this dimension.

4.5 FASSET

FASSET is a farm-scale model and the sources of pollution described include nitrate leaching, ammonia emission and the emission/absorption of greenhouse gasses. Other sources of pollution are only peripherally described e.g.

phosphate is described in terms of field/farm balances and pesticides are considered in terms of the amount used.

The model runs with a daily time step and uses daily meteorological data.

The fields consist of one or more patches, each describing an area that can be considered to be homogenous e.g. an area of one particular soil type. The soil is envisaged as consisting of a number of vertical layers. The first is a surface layer, followed by as many additional layers (of user defined thickness) necessary to describe the soil down to the maximum rooting depth of any expected crop. Within each layer, the dynamics of organic matter, water, and N and C turnover are described. The crops are modelled so that they include the interception of light and its conversion into dry matter. The partitioning of dry matter into root, shoot and storage organs as well as the death of shoot and root material are also included. The uptake and transpiration of water and the uptake of nutrients from the soil is also present.

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

Each individual model covers some aspects relevant in the context of multifunctionality impact assessment. For example, whereas AgriPoliS explicitly aims at modelling dynamic aspects of structural change, it takes a rather aggregate approach at modelling the organisation of individual farms and production effects. With regard to this, MODAM takes a much more disaggregated approach, but in a static context. FASSET, on the other hand, simulates nutrient flows and pollution on the basis of daily time steps, which neither AgriPoliS nor MODAM is able to do.

Box 4.1: Summary AgriPoliS

AgriPoliS
Original Scope: Policy evaluation tool made to investigate structural change in the agricultural sector.
Characteristics: Spatial and dynamic agent-based model of regional agricultural structures. Rooted in agricultural Economics. Consist of a large number of individually acting farms. Indirect interactions through land market.
Multifunctional indicators: Economic production, Structural development, Land market. **Scale:** Regional scale (meso-level) with indirect interactions between farms.
Basic unit of time: One period = one year.

Box 4.2: Summary MODAM

MODAM
Original Scope: Policy evaluation tool to investigate policy effects on the decision behaviour of farmers and the corresponding environmental effects.
Characteristics: A hierarchical database structure able to generate linear programming farm models and through use of fuzzy-logics investigate trade-offs between economic and ecological goals. Disaggregated model.
Multifunctional indicators: Habitats and Biodiversity, Socio-economics, Trade-off techniques, GIS Output Files.
Scale: Regional scale or farm level (aggregated level).
Basic unit of time: One period = one year.

Box 4.3: Summary FASSET

FASSET
Original Scope: A whole-farm model that simulates the relationship between agricultural production, economics and pollution. Policy evaluation tool. Made mainly to investigate nutrient flows (N) and pollution including nitrate leaching, ammonia emission and the emission/absorption of greenhouse gasses.
Characteristics: Whole-farm model that simulates production. Rooted in agronomy and soil science. Individual crop rotation plans are incorporated. Disaggregated model. **Multifunctional indicators:** Modelling the nutrient flows, nitrate leaching, ammonia and greenhouse gas emissions, hydrology, pesticide and energy use.
Scale: Farm level.
Basic unit of time: One period = one day (however, evaluated on a yearly basis).

4.6 Description of the MEA-Scope modelling approach

Combining the three individual models in a consistent and meaningful manner is central for the realisation of the MEA-Scope tool. A hierarchical modelling approach has been chosen for achieving this.

Hereby the three models AgriPoliS, MODAM and FASSET are combined in a way that allows the analysis of multifunctional indicators at different analytical levels. As agriculture on one hand is a long-term activity and on the other hand has to react on short-term events on markets or with respect to the weather, it encompasses different temporal levels. At the same time spatial interactions are of importance at different levels: E.g. matter flows depend strongly on specific site conditions, while the survival of the stork depends on the management of a landscape and the development of a farm depends on the regional possibilities to hire land and labour. To examine the multifunctionality of agriculture these different temporal and spatial aspects should be addressed in an appropriate way. The hierarchical modelling approach is a top-down approach combining large scale and long-term analysis with the ability to investigate the daily actions of an individual farm. The individual farm is the unit that combines the three models. Each model has been adapted to the investigated areas. AgriPoliS will simulate at regional scale a long-term prediction of the structural development. In the model the regional farm structure as well as the economic framework conditions are recreated. The agent-based structure of the model means that the optimisation takes place at each farm. Thereby each farm will evolve due to its initial conditions, the local competition for land and the regional economic framework conditions. All the farms will be further investigated in period t. These farms are individually transferred to MODAM. MODAM will be able to simulate more accurately the production of the farm and its environmental effects. The investigation covers a single period. The task of MODAM is mainly to study the consequences of the farming on environmental indicators in greater detail. The farms' production patterns from MODAM will be transferred to FASSET. In FASSET the production of the selected farms will be simulated with a daily time step. The short-term and small-scale simulation allows temporal peaks of nutrient flows in the soil to be detected. The hierarchical modelling approach is constructed in such a way that the temporal and spatial dimensions change down through the linked models, however, without changing in the individual farms which link the models together. This is illustrated in Figure 4.2.

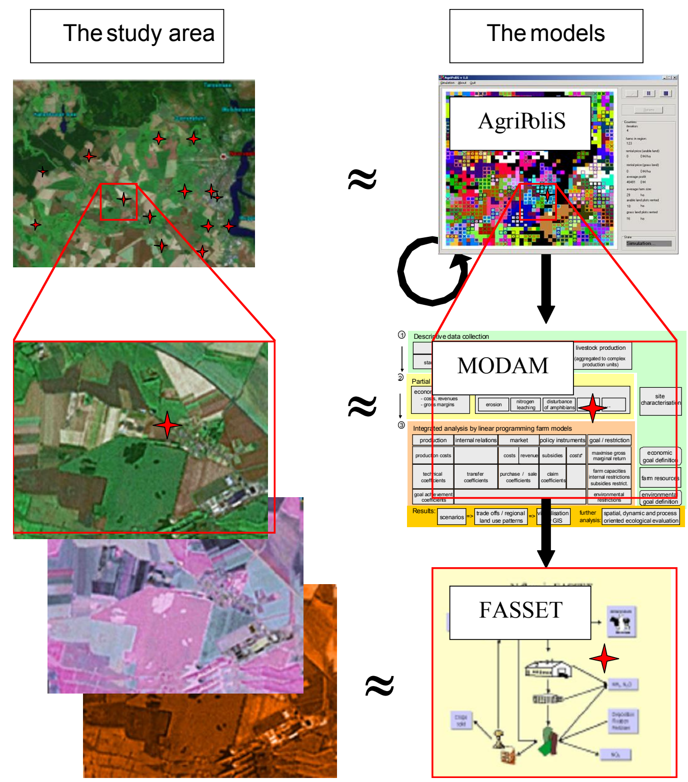


Figure 4.2:Illustration of the MEA-Scope modelling approach. (Damgaard et al. 2006)

Left in Figure 4.2 the real study area is represented by a number of satellite photos (over the German study area, however, neither scale nor location of farms resemble anything real as the Figure 4.2 is only made for illustrative reasons). To the right the different models and their hierarchical order are shown. Each red star is intended to represent an individual farm.

The AgriPoliS recreates the regional multiplicity of farms. At time t each of the selected farms individually will be transferred down through the hierarchical modelling structure and the procedure repeated for the number of individual farms set for investigation.

4.6.1 Target capabilities with regard to multifunctional indicators

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

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

The model has been adapted to 7 representative European landscapes, which can be seen on the Map 4.1 below. In this dissertation the focus will be on the case study areas in Germany, Italy and Denmark as well as few remarks about the Slovakian area.

Map 4.1 The MEA-Scope study areas. (Kjeldsen 2007)

The input requirements of the three models have been collected and compared in order to reduce the amount of data demanded. The selected input data is the minimum requirement of data needed for the three models to simulate the regions in a consistent and satisfying manner. The minimum input data required is a subset of the ideal data requirements. The list of required input data was then compared and any doubles was left out. Additionally input data was added to the list by comparing the modelling abilities to both the regional and the MEA-Scope specified needs. The combined list constitutes the common input data. An Excel form has been used to collect the structural characteristics of the regions. Two database input structures have been developed to ease the collection of technical and production related data. One input structure for the animal production and one for crop production. Each of these data survey forms have been attached to an instruction video. The three individual models draw on the same pool of empirical data from which the models are adapted to the regions. However, as the focus and degree of detail differ between the models there is also model specific input data. To ensure the best utilisation of the data each modelling team has had the responsibility for the input data most suited for their model. Some of the data could be used directly by all models (e.g. the interest rate), however, others were first pre-processed before exchanged (e.g. individual accountancy data and regional statistics into “typical farms”).

In Figure 4.4 a schematic representation of the inputs and outputs in the combined model is presented. The input data is shown at the same level as the team responsible for them. The white arrows illustrate the data flow in the hierarchical modelling approach. At the same time as the individual farm data are part of the output created by AgriPoliS and MODAM they are also the common denominator linking the model together.

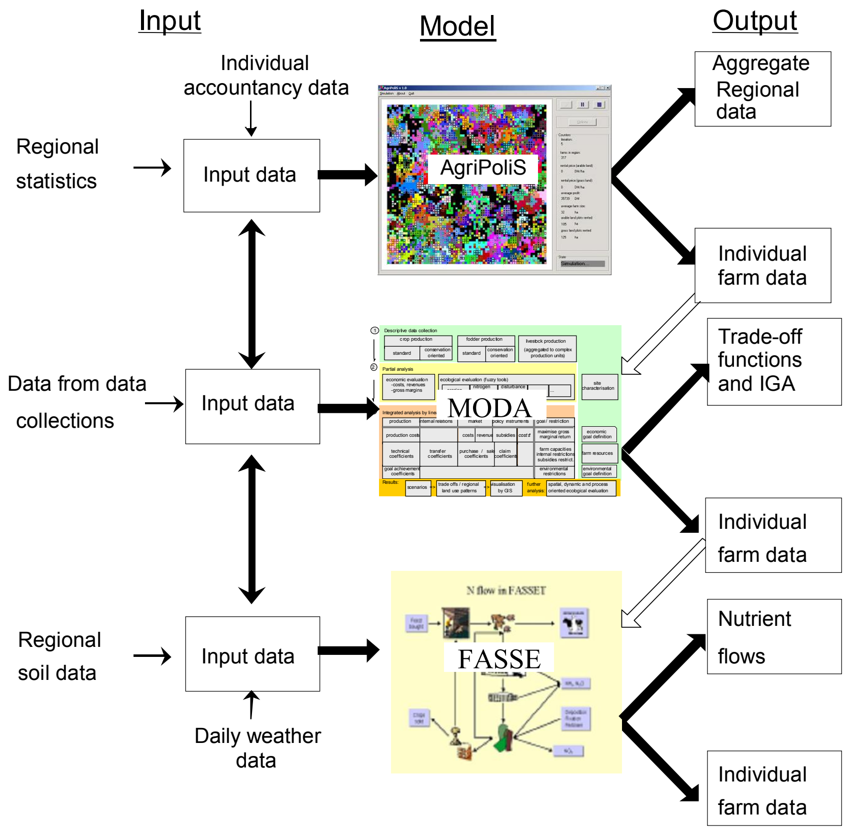


Figure 4.3 Schematic representation of the inputs and outputs in the combined model. (Damgaard et al. 2006)

The results of the modelling procedure have been published (e.g. Happe et al. 2006; Dalgaard et al. 2007) and a book with the combined work has been released (Piorr and Müller 2009).

5 AgriPoliS and GIS

5.1 Why GIS in the AgriPoliS and MEA-Scope model

A multifunctional agricultural analysis must take place in a given spatial and temporal framework. The number of functions possibly supplied by an area depends upon the spatial extent of the area and the spatial as well as the temporal scale used in the analysis. At the same time there are a large number of the functions investigated, which depend on site-specific characteristics.

The effects of a given agricultural production practice on the groundwater depend on the soil profile, the livelihood of a given amphibian depends on the access to suitable waterholes to spawn, the historical, cultural or religious importance of a given area depends upon its location. Finally, agricultural production is unavoidably tied to a location in space. The type and level of production is influenced by the spatial location. Therefore it appeared reasonable to incorporate Geographic Information System (GIS) into the MEA-Scope modelling approach.

5.2 Introducing site characteristics into AgriPoliS

AgriPoliS constitutes the first step in the hierarchical modelling approach. It models regional structural change in agriculture. This makes the model's capability to reproduce the different regional landscapes in a realistic way important. As the model has previously been used for economic analyses, the model's ability to simulate landscape characteristics has been less developed. The analysis of multifunctionality showed the importance of site and landscape characteristics. In addition, in order to be able to model multifunctional agricultural production in cooperation with the two more agronomical founded models FASSET and MODAM, improvements on this point were needed. In the original version of AgriPoliS the spatially heterogeneous land qualities were reduced to two land types, namely grassland and arable land. The frequency of the two land types was empirically founded, yet randomly distributed in the region. Although this may be sufficiently accurate for economic simulations it did not provide the degree of precision we aimed for within MEA-Scope given the importance of the landscape. We hence introduced a higher diversification of the model landscape to account for site differences. This constituted the main area of improvements for AgriPoliS.

The original AgriPoliS underwent a thorough inspection where all the references to the two original landscape characteristics were located and changed into a vector structure. The vector structure allows the user to define the needed number of landscape characteristics through the input file. This means that the number of possible site characteristics is no longer restricted to arable and grassland, but can be defined according to regional needs.

Each landscape characteristic introduced into AgriPoliS can describe bio-physical qualities such as the soil-type and slope as well as humanly determined characteristics such as administrative borders (e.g. Natura 2000 areas). The landscape characteristic has to be defined by its economic influence on the farms choices.

The number of site characteristics influencing the economic variability of the simulated farms in AgriPoliS was determined for the different regions. The determination was based on the empirical data accessible, the theoretical requests and the capabilities of the combined models (to ensure consistency in the simulated data the landscape types should be the same in all models). Based upon these findings a standard input file for AgriPoliS was developed.

An important limitation of these landscape characteristics is that the farms continue to calculate the transportation cost in a pure Euclidean sense that is without considering the landscape specifics between the farm and the field.

Two different methods for incorporating the spatial dimension of the agricultural production into the model were developed. The first version is a stylised version to allow the user to develop his own hypothetical landscapes and thereby being able to test the influence of the spatial component under controlled conditions. The second version incorporates different layers of real GIS-maps and thereby allowing the model to make the simulations in the real spatial landscapes.

The stylised version will be introduced first and followed by an introduction to the GIS-based version.

5.2.1 The AgriPoliS landscape generator

In the AgriPoliS landscape generator the landscape characteristics are spatially distributed in the modelled region based on parameters given by the user through the input file. To each landscape characteristic in the “landscape characteristic location”- interface three numbers are attached as seen in the Table 5.1.

Name	Range
Share of plots to the north	1-100
Share of plots to the west	1-100
Variation	1-100

Table 5.1: Name and range for input variables for the AgriPoliS landscape generator.

The term "share of plots to the north" and "share of plots to the west" is an attempt to let the user define where most plots of this type should be located on the north-south and the west-east axis. The range specifies the percentage of the whole axis where the location is. The "variation" is a scale of how large the spread should be. The demarcation "variation" is chosen purposely to mark the difference from the normal use of the notion spread. The variation is used in the first phase of the location procedure. The procedure finds the user defined location. Then a randomly chosen spot is found and the variation demarks the weight the two locations are given. The scale goes from 1, which means no variation (=only the user defined location is given a weight) to 100 as maximum variation (= only the random location is given a weight).

Once the weighted location between the two original spots is found the procedure will go to the next phase. A Gaussian distributed variable is multiplied to the location in order to add some fuzziness to the location and if the location is preoccupied the neighbouring cells will be tried. The routine will be repeated if also these plots are taken, until a free spot is found. Hereby the user has the possibility to construct the hypothetical landscape by adjusting the parameters. Examples on this and a more practical description are given in Appendix A.1 "the use of the AgriPoliS landscape generator".

Once the hypothetical landscape fits to the users' needs the farms will be distributed in the area in such a way, that their empirically found spatial character trait such as number of fields of a given soil type is reproduced in the model. In the next section "The GIS-based version" is the actual procedure by which the farm locates its fields described in greater detail.

The creation of 2-dimensional output files ensures the user an easy possibility of investigating the results. This stylistic GIS interface can easily be changed into GIS input data if further spatial explicit information should be added. A description of the created 2-dimensional output files is listed in Table 5.2. The same files are written out in the case of the GIS-based version.

5.2.2 The GIS-based version

"A Geographic information system (GIS) is a system for capturing, storing, analysing and managing data and associated attributes which are spatially referenced to the earth"

(Wikipedia 2007, June 2)

This means that GIS is a tool focusing on representations of a given state of the landscape in its accurate spatial location. As the focus of the MEA-Scope modelling tool in general and AgriPoliS in particular is on the changing processes taking place due to states of the landscape and the current structure of the agricultural sector with the aim of building the model on the most detailed and accurate empirical data. These facts have reinforced the desire to incorporate GIS into the AgriPoliS. The hierarchical modelling procedure ensures that the subsequent models can also utilise the maps produced by AgriPoliS.

The GIS module, built into AgriPoliS, needs therefore to be able to utilise varying levels of geo-referenced information. The maps[4] have to be in a raster format and all maps in a given region have to have the same dimensions. Each bit in the raster is in the following designated "sight" as the spatial extent that each bit represents varies with the regions.

AgriPoliS requires an input file providing the economic and production related data. In addition to this a number of optional GIS maps can be added. Though the maps are optional the ordering of the maps and the information they provide is not optional as the more detailed maps build upon the information provided in the previous maps. That means it is possible to choose the amount of maps used by the model in a given region, however, one cannot e.g. provide the location of farms without previously having provided a map of the regional landscape.

In the following the individual maps will be presented in the order that they should be provided to the model if it is expected to utilise its full range of possibilities to integrate GIS-maps.

[4] The word "map" is here used to describe what others might refer to as layers of information. However as the information needs to be provided in separate maps for the model to read the information, maps seemed to be the right description and is therefore used throughout.

The regional sight characteristics map:

The regional sight characteristics map is given this rather odd name, as it is neither truly a map of the landscape nor a map of the soil, however, draws upon both. Only the area used or intended for use in agricultural production should be given a value. This includes the location of farmsteads. All other areas are only the following influencing the model through transportation costs. The Euclidean distance from the farmstead to the fields and thereby the transportation cost includes both agricultural and non-agricultural areas in the calculation. However, without giving any quality to the landscape between the farm and the field in any qualitative way. The area used or intended for agricultural production is given a value referring to the sight characteristics in this location. The sight characteristic can describe bio-physical qualities such as the soil-type and slope as well as humanly determined characteristics such as administrative borders (e.g. Natura 2000 areas). The sight characteristic is given a value starting with zero in the same order as the sight characteristics are listed in the input file providing the economic and production related data. Hereby a link is established between a given location and its economic influence on the farms' choices. If no other maps are provided it is important that the number of sights of a given type in the map is larger than or equal to the area of fields of this type that the farms are given via the input file.

The Natura 2000 map:

This map is truly optional as the information neither influences the following maps nor the results of the AgiPoliS model as such. It influences, however, the results of the combined MEA-Scope tool. Natura 2000 and other similarly designated sensitive areas are important for understanding the effects of the agricultural production in a given area. It is therefore essential that the two models capable of estimating the environmental effects of the agricultural production know which farms hold these plots. The Natura 2000 map is read into AgriPoliS so that it can report to the other models which farms are influenced by the sensitive areas and thereby ensures that it affects their production pattern. Sensitive areas outside the area used or intended for agricultural production will be included in the analysis after the simulation through the use of GIS. However, they do not influence the model during simulation. The value one indicates that the sight is part of a sensitive area; all other areas are given the value zero.

The farm location map:

As the name indicates the farm location map is a map of the location of the individual farmsteads. The location of a farmstead is assigned the number of the farm, starting with the number one and then given an ascending number until the location of the last farm. It is important that the order of the farms in the map is exactly the same as in the input file. All other sights are given the non-data value. It is also important that the farmstead location is part of the regional sight characteristics map, and not part of the field location map if such a map is also used. The actual location of the individual farmstead is provided in one of the seven regions modelled, namely Denmark.

For three additional regions the location is estimated and a thorough presentation of the methods used in this case will be provided for in a separate section.

The field location map:

The field location map allows for the spatial location and the number of fields each individual farm possesses or rents to be read into the model. The distinction between rented and owned land is important for the economic viability of the individual farm. Therefore the individual sight is given a value consisting of the number of the farm (as defined above) to which it should be assigned as well as a value deciding whether the site is owned or rented. In the case of rented land the value is = farm_number + 100000 and for owned land it is = farm_number + 200000.

The size of the number is intentionally chosen to be a large number so that the farm number does not interfere (unless we would model 100000 farms or more in one model, which is unlikely).

The ability to geo-referencing the location of the fields for the individual farm is used not only for the cases where the GIS map of the real situation is available.

An artificial field map can be constructed if the real field location is not available. However, it involves several steps particularly in cases where more sight characteristics than the original two ones, arable and grassland, are used.

The FADN-farms that our farm typology builds upon have only empirical data for the amount of arable and grassland in use. This means that the empirical data defining the farms do not reveal how to distribute the farms on the additional sight characteristics. Therefore a map only consisting of arable and grassland is made. The farms distribute the fields among themselves based upon the empirically given share of arable and grassland and their location relative to a given spot. Once the fields are distributed and the first output maps have been written the model is stopped. The model is then restarted this time, however, with the extended sight characteristic map and the freshly produced field location map. The farms are hereby assigned the sight characteristics due to the location of their fields. This procedure ensures that the sight characteristics are assigned to the individual farm due to the spatial location of the farmstead. This holds a number of advantages.

It seems likely that the geographical location of the farmstead has a significant influence on the location of the farms fields. From the modelling perspective it helps to diversify and individualise the farms modelled. Two farms of the same type and thereby identical in production capacities and structure will through this allotment of land probably end up with a different composition of soil types and thereby production opportunities as well as different transportation cost associated to the individual sights. During the simulation such a small variation in the initial situation may lead to different paths of development for the two farms. The larger heterogeneity in the modelled farms seems first of all intuitively more in line with the reality, while at the same time it means the model is testing the economic abilities of a larger sample of farms.

The individualised farm data file:

The standard input file providing the economic and production related data normally describes a number of farm types that constitute the model farms if multiplied by a weight factor. The present input file is limited to work with a maximum of approximately 250 farm types. The farms will be read into the model in a given order and due to the weight factor farms of the same type will follow each other. Neither the limitations in numbers nor the fixed succession of the farms fit necessarily a given region and its geo-referenced information. Geo-referenced information is seldom organised in accordance with farm classes but rather according to some spatial rules. The individualised farm data file allows the user to read in the needed farm information on an individual farm level. The farm can be read in the order defined by the GIS-maps and there is no limitation to the number of farms one can read in this way. This allows that the model can be calibrated to real individual farms rather than farm types when the information is available.

GIS output maps

To calibrate the model to a given region through the use of geo-referenced information is of course only one part of utilising the advantages of GIS.

Similarly important is the possibility to view and analyse the results in a spatial setting. Therefore AgriPoliS is extended with the possibility of producing GIS-raster files as output. The raster output files have the same simple structure as the input files where different types of information are divided into separate maps rather than as different layers in the same single map.

The creation of 2-dimentional output files allows the user to investigate the simulation results in a more intuitive way. At the same time it opens up for a large set of spatial analysis methods. A possibility is to relate the output files to further spatial explicit information that the models do not take into account by themselves but which are important for the multifunctional analysis. Obvious examples could be the location of forests, wetlands or other areas important for the biodiversity. Certain animal species require different types of habitats to be within a given distance from each other. For example it is necessary for some amphibians that the breeding habitat and the hibernation habitat are within a maximal distance of roughly 560 m from each other.

By having additional information about the location specific characteristics and through the use of techniques such as “moving window” (Deumlicha et al. 2006) ability of the areas to preserve a given amphibian species can be estimated. Moreover, the changes in the agricultural sector and its influence on the ability of the areas to preserve the amphibian can also be estimated.

A description of the created 2-dimensional output files is listed in Table 5.2.

Name of output file	Description	Data
DistanceCostMap	Displays for each plot the transportation cost the owner of the plot has by using it.	For each period
LandRentedByAgent-Map	Display the farm number of the farm utilising the individual plot (for plots nobody utilises and non-agricultural areas the value is= –1)	For each period
Ownership	Display the farm number of the owner of the plot (if the plot is rented or non-agricultural area the value is =-1)	For each period
RentMap	Display the rent paid for the individual plot (rent for owned land and non-agricultural area is = 0)	For each period
SoilMap	Displays for each plot its type of landscape characteristics.	For the first period only
StateMap	Display the non-agricultural area (-1), the idle plots (0), the rented plots (1), the farmstead (2) and the owned plots (3)	For each period

Table 5.2: Description of 2-dimensional output file for extended AgriPoliS.

By combining the information from the GIS-output maps and the different output files a detailed spatial analysis of the structural development in the region can be made.

Through the GIS-output maps the spatial location of each individual farm and its fields is known. At the same time all the actions of each individual farm are recorded in the normal output files; being it: Production related data, economic data or the investments taking place on the farm. This information can of course be combined with the maps so that one can spatially see and analyse all the individual data which AgriPoliS produces.

The spatially heterogeneous land qualities and socio-economic aspects of the area introduced through the initialisation of the modelled region in AgriPoliS also allow the two following models to be more spatially explicit.

Therefore the GIS-output files produced by AgriPoliS are transferred along with the other output files to the two subsequent models in the hierarchical modelling procedure.

5.3 Procedure for placing farms spatially in a region

The challenge of recreating valid or reliable spatial contexts when modelling agricultural development on landscape level is a known issue among modellers. The issue in question is to determine how to make the best representation of the spatial context within which agricultural enterprises are embedded. Spatial context matters in many ways when modelling agricultural landscapes.

Individual farm accountancy data sources such as the European Farm Accountancy Data Network (FADN) include no specific information on the spatial location of farms. However, spatial characteristics and site conditions determine the farms' production potential and its influence on the surrounding environment. Spatially explicit models that make use of the FADN data such as AgriPoliS need to be able to recreate a landscape including the location of the farms in a plausible way. The spatial allocation approach has to take its point of departure in the regional available data. Common for all regions is, however, that the farm's economic status either directly or indirectly builds upon "representative" farms from the FADN-database.

An introduction to how the single representative FADN farms are chosen will be given before investigating the individual methods of spatially recreating the regional structure in the different case study areas. This selection method is commonly used in all modelled regions. The approach was first created by Balmann et al. (1998) and further developed by Kleingarn (2002) and

Sahrbacher (2003). This description draws also on the work of Kellermann et al. (2007).

The AgiPoliS model needs accountancy data for individual farms; however, the sensitive nature of such data makes it difficult to obtain these data. Therefore it is necessary to use the weighting or up-scaling procedure explained in the following.

First a useful data source with accountancy data is found covering the close relationship between the individual farms and the farms empirically observed in the region ready for investigation. Farm Accountancy Data Network-data is used for all regions. The FADN-data is based on a large sample of farm accounts collected in each of the member states of the European Union every year. From this base sample a number of so-called "representative" farms are found. Each with an extrapolation factor constructed in such a way that the farms provide a representative sample for the commercial farms in a given area. The extrapolation factor incorporates the regional characteristics, the economic size and type of farming found in the whole collection.

A FADN-sample is composed of these so-called "representative" farms. The area that the FADN-sample is constructed to represent is normally larger than the regions set to be modelled in AgriPoliS and MEA-Scope. That means that the attached extrapolation factor from FADN cannot be used uncritical.

Secondly, statistical data on the characteristics of the modelled regions is collected and a list of statistical goal criteria, or regional capacities, for the base year is defined. The list will normally consist of characteristics such as the number of farms, farm size distribution, the distribution between different production types and ownership structure as well as the number of livestock. As some of the characteristics are more important than others in recreating the regional farm structure they will be given an order of priority.

Thirdly, minimizing the squared deviation from the observed goal criteria given by the agricultural statistics and the sum of individual farms from the FADN-sample by assigning the individual farms weights. Thereby the best possible representation of the regional structure is found. The farms deduced through the use of this approach are labelled "typical farms".

The approach is presented in mathematical terms in Appendix A.2 based on Kellermann et al. (2007).

Once the typical farms for a given region have been found they will have to be spatially ascribed to the regional input maps. The four different methods used within the MEA-Scope project will be presented in the following. The method chosen was driven by the empirical data available in the respective region. As the FADN contains private accountancy data it is vital not to be able to link the sensitive information to a given individual at a given spatial location. Therefore in the FADN data there are only little information, which could help link the individual farm to some kind of spatial characteristics. The different methods are developed in order to utilise this sparse spatial information to locate the individual farms.

A short overview of the four methods will first be provided followed by a presentation more in depth.

The arable / grassland method: (used in the German case study area): The areas of arable and grassland that the individual farm has in its production appear in the FADN data. These areas are production-related rather than categorized in accounts with the soil quality. The method assumes that grassland production does take place on lower quality soils than used for arable production. The spatial location of farms should therefore be located in an area where the soils suited for arable and grassland production are available near the farmstead in the same proportion as seen in the FADN-data.

The context-dependent analytical approach: (used in the Italian case study area): The location of a farm in space is not an individual event independent of all other farms or structures in the vicinity. The historical process involved in creating the present agricultural structure is an interlinked process where the geographical characteristics of an area in form of transport possibilities, access to resources and other needs for the farm as well as the presence of other farms and companies has influenced the location of each single farmstead. Often local experts will be able to locate a given farm type to a small part of the region simply because farms are not randomly distributed in space but tend to cluster around certain areas. This means that we should be able to utilise this information, when we are going to recreate the distribution of farms in a given region. An additional GIS-map of a given area can help by reducing the possible space where the farms could be located.

This reduced area is subject to the **arable / grassland method** described above.

The field map method: (used in the Slovakian case study area): Though the individual farms in a given location are seldom represented in GIS-maps as such, the individual fields within a region may be recorded. The actual size of the field as well as the composition of soil types are thereby known and can work as the foundation for spatially locating the farms. In this particular case the location of stables in the region was also known and therefore used in the location of farms.

The empirical method: (used in the Danish case study area): The data availability differs for regions. However, even in the case where all production related data, maps of the individual farms and their fields are available the task of ascribing the FADN-data to the farms is still difficult. The FADN-data is normally a sample for a larger region. Minimizing the squared deviation from the observed goal criteria from the agricultural statistics and the individual farms from the FADN-sample can ensure the statistical properties in the modelled region. However, the individualised farm version requires that all farms in the region are ascribed accountancy data based on the FADN-sample. Therefore the last presented method is describing the chosen procedure for making an individualised farm model based on all production related data as well as maps of the individual farms and their fields.

5.3.1 The arable / grassland method:

We have chosen to focus on what we positively know about the spatial characteristics of the farms in all of the case areas, namely the distribution between arable and grassland on the individual farm types. Our assumption is here that farms with a given structural composition, calculated as the index value of the ratio between grassland and total farm area, should be located within parts of the landscape that exhibits similar structural characteristics. In the farm data sets the calculation is fairly straightforward as expressed by the following equation:

$$I_{100} = GA_{1...n} / TA_{1..n} * 100 \qquad (5.1)$$

Where I_{100} is the grassland index value, $GA_{1...n}$ is the area with grassland for farm 1 to n and $TA_{1..n}$ is the total area of farm 1 to n. When this indexation is applied on the land use maps for the case areas, the challenge is that the calculation must be done in a neighbourhood relative to the smallest unit in the map in question. In order to achieve that the FOCALSUM function in ArcGIS Spatial Analyst was applied on the land use classification to calculate the index value. The FOCALSUM function sums the values of adjacent cells within a given neighbourhood, as illustrated below.

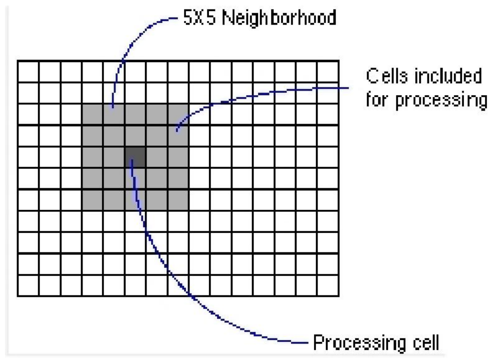


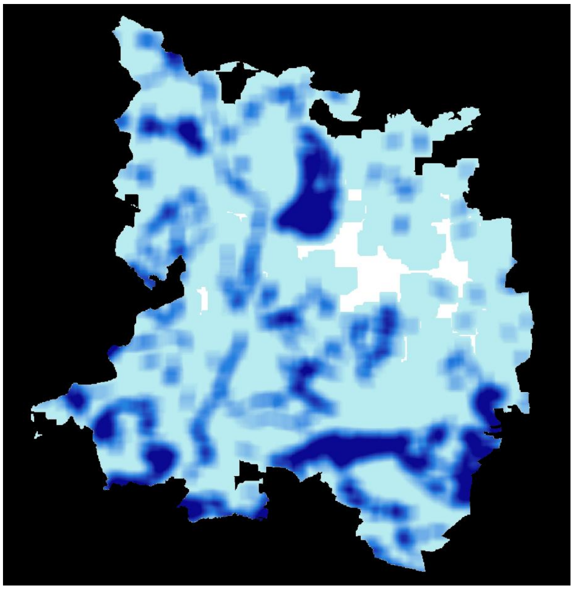
Figure 5.1: The FOCALSUM function in ArcGIS Spatial Analyst. (Kjeldsen 2007)

In the present context, neighbourhood size was set to a rectangle of 20*20 grid cells in a 100 m grid, which makes neighbourhood size 400 ha. The land use classes were prior to the calculation reclassified, so the value calculated would express the share of grassland in the neighbourhood.

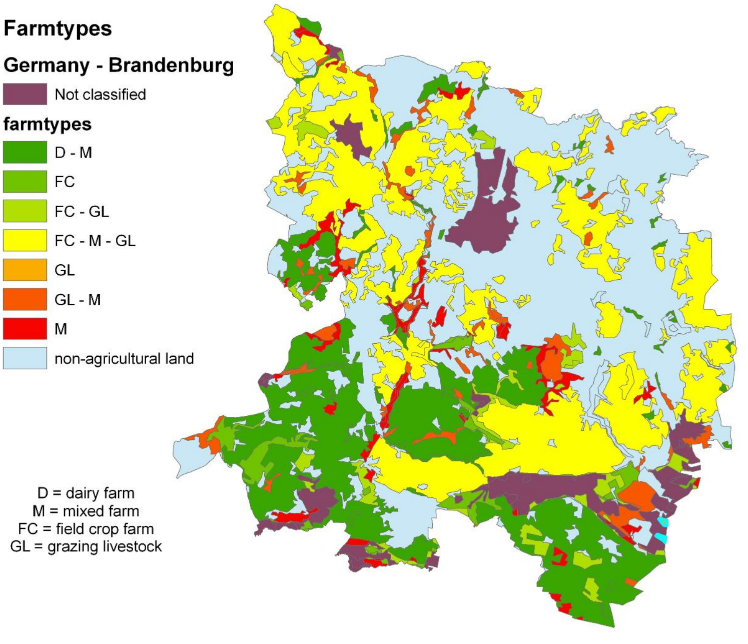
LUCLASS	Attributes	New value
0	Non-agricultural land	NoData
1	Arable land	0
2	Grassland	1

Table 5.3: Reclassification of land use classes to FOCALSUM calculation. (Kjeldsen 2007)

The calculation resulted in a map, which gives a fuzzy measure for the structural characteristics of the case areas. The example in Map 5.1 shows the result of the arable/grassland method calculated of the German area. The advantage of using a fuzzy measure is that an exact fit is not needed for aligning farm index values, which otherwise would prove very difficult to obtain in the actual map of the landscape. The next step was then to apply the calculated index values to the site map, which was calculated using the mean index value per site. The mean index values per site were then grouped in 10 intervals between 0 and 100, which adds to the fuzzy character of the measure.



Map 5.1: Grassland index value (0-100) for the German case area (dark blue = 100). (Kjeldsen 2007)



Map 5.2: The farm map for the German case area. (Kjeldsen 2007)

The same reindexation into 10 equal intervals between 0 and 100 was also applied to a first version of the tabular farm data for the German case area, and joined to the site map. This procedure produces the farmtype map, which can be seen below in Map 5.2. It should be noted that the total area of agricultural land in the German case area can be calculated to 157582 ha in total, when using the area which is described as agricultural land in CORINE. The total farm area from the farm-table (Table 5.4) sums up to 123978 ha which leaves us with 33604 ha of "missing" farmland.

In relation to the missing agricultural areas in the FADN data set, it can be seen that the distribution of farms within the farm tabular dataset differs from the distribution of land within the structural index value intervals (Table 5.4, below). One of the reasons for this deviation might arise from the assumption behind the spatialisation procedure that farms exhibit a relatively small degree of fragmentation. If the actual location of fields exceeds the neighbourhood size of 400 ha, the indexation of the land use map will give misleading results.

	FROM LAND USE MAP		**FROM FARM TABLE**	
Indexclass	**ha**	**% of area**	**ha**	**% of area**
10	65461	42	79250	64
20	47953	30	4620	4
30	8069	5	19915	16
40	7110	5	480	0
50	6696	4	17770	14
60	5135	3	285	0.2
70	6268	4	0	0.0
80	10551	7	0	0.0
90	255	0.2	0	0.0
100	83	0.1	1658	1
SUM	157582	100	123978	100

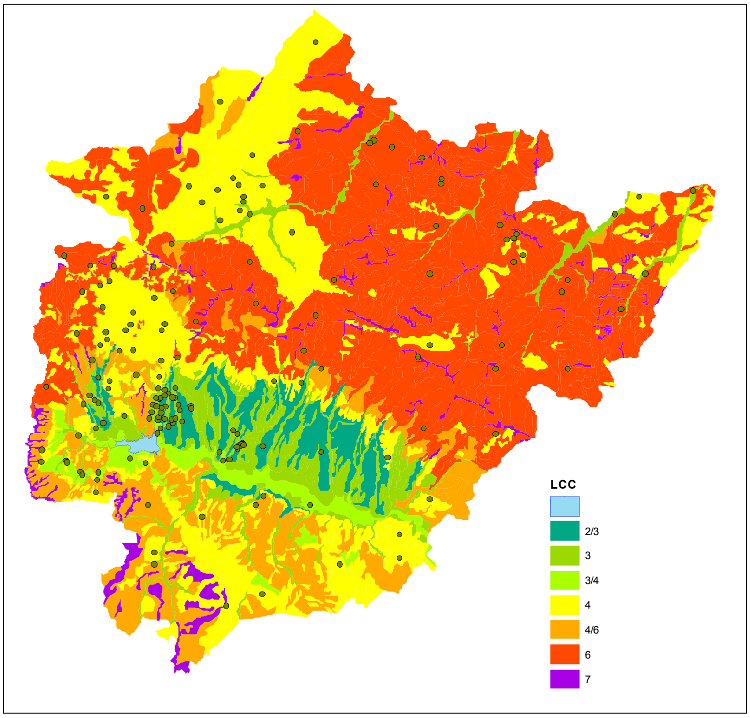
Table 5.4: Summary of areas calculated from land use map and farm tables, where the index class is the grassland index value (Kjeldsen 2007)

5.3.2 The context-dependent analytical approach:

The farm is often conceived as a self-sufficient thing-in-itself, before it enters into relations with other farms. However, the other farms affect the individual farm even before it is taking an active part in the economic activities. The physical environment is of course present in advance and sets firm limitations for the room of action thereby influencing back on the social structures developed in the setting. Therefore the location of a farm in space is not an individual event independent of all other farms or structures in the vicinity.

Where the arable-grassland method only utilizes information found in the FADN sample to locate the farmsteads in space this approach is also utilizing additional information available of the area to ensure a more realistic location. This means, however, that the approach makes use of a number of assumptions that will be presented here. Before the location of the farms can be found the map of the landscape characteristics has first to be constructed. The procedure used will initially be presented.

The detailed information particularly on the regional soil-quality, terrain and local production practice has to be converted to a manageable number of landscape characteristics that influences the pool of potential production activities present on the location. The influence of each landscape characteristic on the production potential has to be represented as a linear combination of technical coefficients that express the contribution of a given activity to the objective function. The technical coefficients represent discrete estimates stating the amount of input needed to achieve a certain output and the associated economic and environmental effects (Janssen and van Ittersum 2007). So though e.g. the real soil structure of the region is known in great detail the information entering into the combined modelling procedure will have to reflect the level of detail that the model is able to simulate. It is therefore important that the chosen landscape characteristics reflect most of the available information and only leave out details with minor influence on the production or the environmental effects. In the case of the Italian region a land capability classification (LCC) is therefore applied to the soil map of the region. Land capability classification shows, in a general way, the suitability of soils for most kinds of field crops. First both the agricultural soils and the non-agricultural soils are grouped in accordance with their limitations for field crops, the risk of damage if they are used for crops, and the way they respond to management. The distribution of these initial LCC classes in the territory of Mugello is shown in Map 5.3. As can be easily appreciated from the map, LCC class 6 dominates the territory with an area of 497 km^2 (44%), most of which is completely wooded. This territory is used mainly for pasture, rangeland, forestland, or wildlife habitat. Soils in this class are capable only of producing perennial forage crops. Next in extension is LC class 4, with 287 km^2 (26%). Soils in this class have very severe limitations that restrict the choice of plants or that require very careful management, or both. The limitations seriously affect one or more of the following practices: timing and ease of tillage, planting and harvesting, choice of crops, and methods of conservation. The soils are low to fair in productivity for a range of crops but may have high productivity for a specially adapted crop. Nevertheless they are mostly used for forage production or as grassland and permanent pastures.



Map 5.3. Land capability map of Mugello, 1:50.000 and soil profiles location. (Ungaro et al. 2006)

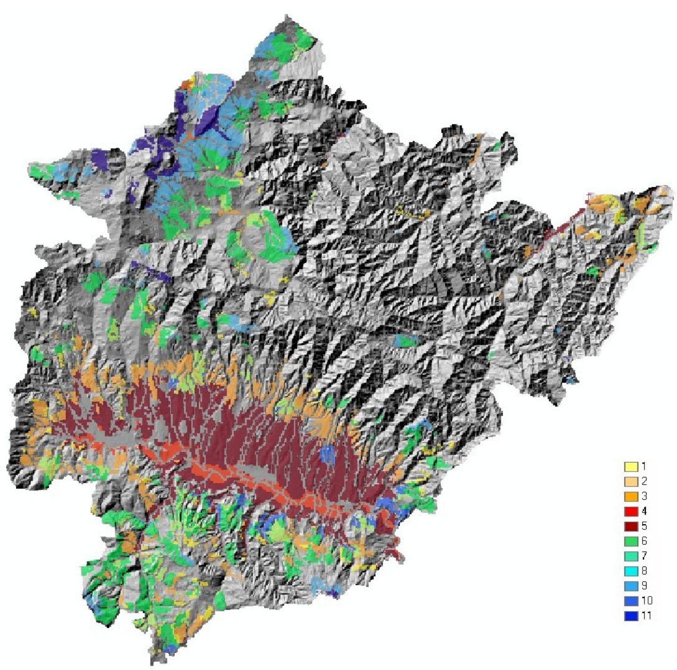
The landscape characteristics maps constructed via the land capability classification method are used as the foundation for inserting the farms into the virtual representation of the region.

As the LCC 6 and 7 are not suitable for agricultural production, they are left out of the used landscape characteristics map. The landscape characteristics map includes 8 different landscape characteristics; consisting of 4 landscape units for arable land (plain, terraces, low and high hills) and 4 grassland units (terraces, low and high hills, and high mountain). An overview is given in Table 5.5.

Field type	Landscape
0	Arable_Land_High_Hills
1	Arable_Land_Low_Hills
2	Arable_Land_Plain
3	Arable_Land_Terraces
4	Grassland_High_Hills
5	Grassland_Low_Hills
6	Grassland_High_Mountain
7	Grassland_Terraces

Table 5.5. Name of landscape characteristics used in the Italian region. (Ungaro et al. 2006)

The spatial distribution of the arable landscape characteristics and grassland landscape characteristics within the region is shown in the Map 5.4.



Map 5.4 The spatial distribution of the arable landscape characteristics and grassland landscape characteristics within the Mugello region (Ungaro et al. 2006)

Map 5.4 shows the spatial distribution of the arable landscape characteristics and grassland landscape characteristics. Please note that here 11 landscape characteristics are in contrast to the 8 mentioned above. As landscape characteristics Arable_Land_High_Hills, Grassland_High_Hills and Grassland_High_Mountain have been subdivided in this representation.

5.3.3 Map of farmstead location

AgriPoliS needs a map of farm location of the 1237 farms in the region. A complication in the making of such a map is that AgriPoliS does not model perennial crops. In the up-scaling procedure the areas for perennial crops possessed by the FADN-farms have been included as arable land. The data on perennial crops have been excluded from the statistics for the up-scaling. The different farmsteads are classified by AgriPoliS based on the ratio arable/grassland. According to AgriPoliS specifications, the farms of the study area have been divided into 5 different groups as a function of the arable land-grassland share:

1. Group 1, with 85-100% arable land within 10 cells' distance, 780 locations;
2. Group 2 with 85-65% arable land within 10 cells' distance, 24 locations;
3. Group 3 with 65-40% arable land within 10 cells' distance, 18 locations;
4. Group 4 with 40-20% arable land within 10 cells' distance, 246 locations;
5. Group 5 with 10-20% arable land within 10 cells' distance, 87 locations;
6. Group 6 with 0-10% arable land within 10 cells' distance, 206 locations.

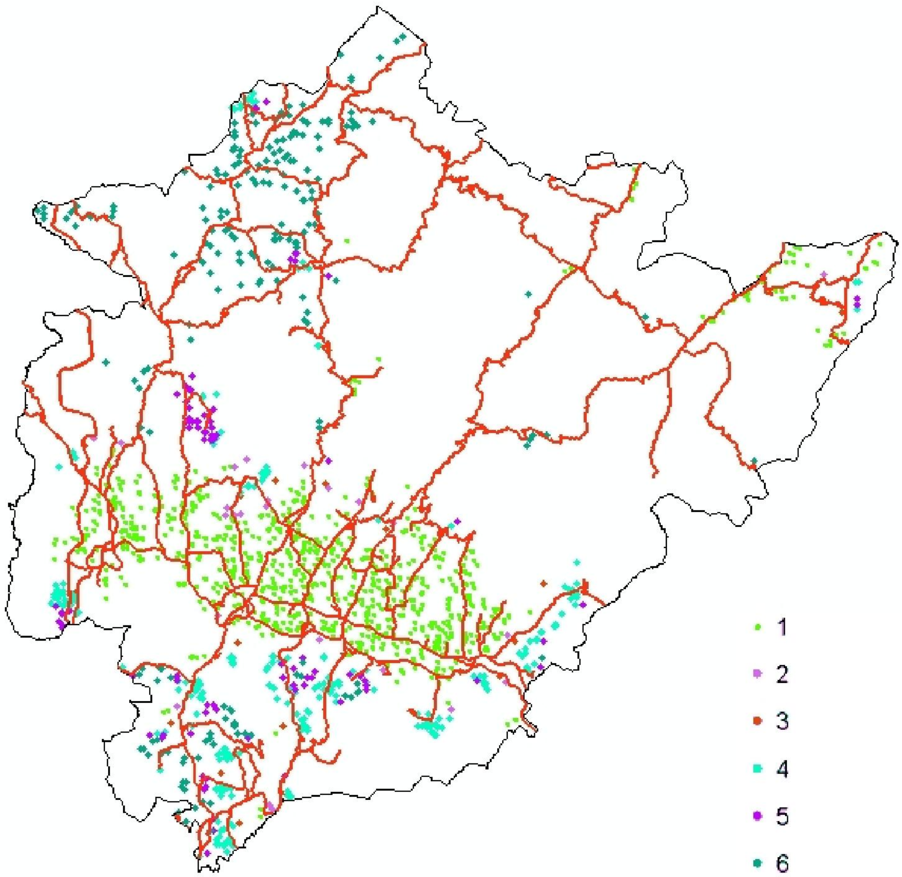
The consistence of the different groups is shown in Table 5.6; the coloured cells in the table indicate the farms that have got additional arable land due to its perennial crops. The number of farms to be allocated in the landscape has been augmented by 10% to allow for flexibility in the model.

Number	Number of TF in the region	Arable land	Grassland	Permanent crops	Share arable / grassland
Tot. ha		14,000	12,586	3,521	
1	18	2	0	0	1.000
2	6	39	0	0	1.000
3	178	3	7	0	0.300
4	47	0	50	0	0.000
6	43	3	14	3	0.176
5	140	0	8	0	0.000
7	11	40	44	0	0.476
8	8	11	109	0	0.092
9	5	45	32	9	0.584
10	28	19	149	11	0.113
11	18	72	0	6	1.000
12	15	60	0	0	1.000
13	22	88	30	13	0.746
14	17	72	0	1	1.000
15	137	3	0	0	1.000
16	4	51	0	4	1.000
17	46	4	13	0	0.235
18	225	20	0	0	1.000
19	62	3	0	0	1.000
20	4	22	0	7	1.000
21	62	3	0	0	1.000
22	138	3	0	0	1.000
23	3	67	0	0	1.000

Table 5.6: "Typical farms" used in the AgriPoliS for the Mugello region. The number of times they are in the region. Their arable land, grassland and permanent crops and arable/ grassland share. Farms with permanent crops are marked grey as their area for permanent crops has been added to the size of their arable land. (Ungaro et al. 2006)

Since there is no geo-referenced information available about the real position of farmsteads in the study area, a guided random allocation procedure was used.

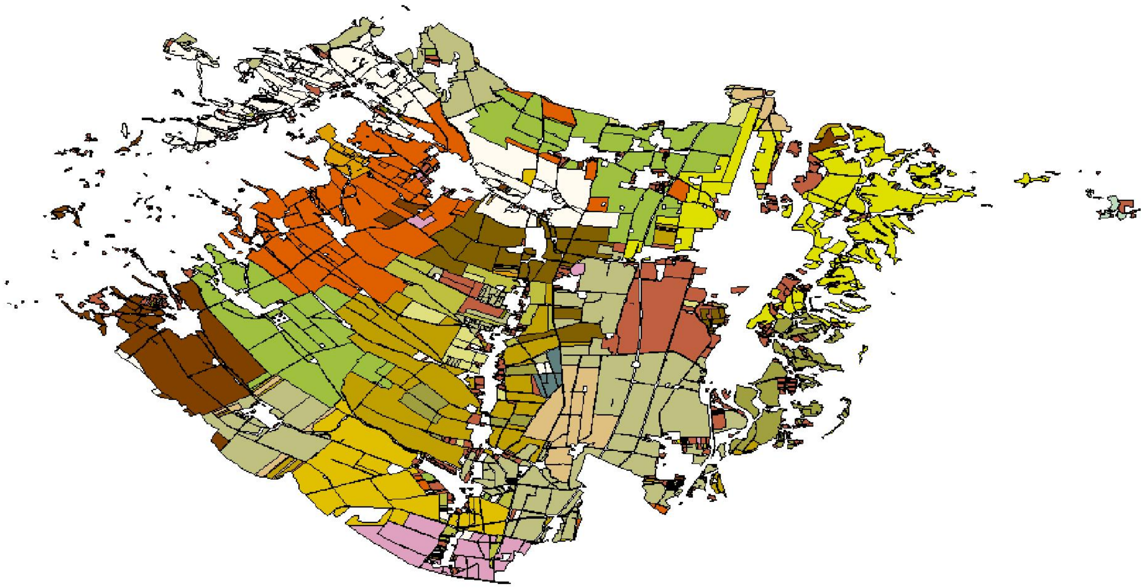
In order to ensure that the farms were placed in the vicinity of the paved roads, as farms need access to the road system, only areas within a maximum distance of 1 km to the nearest road were included as available area. Furthermore river network, road network, urban areas and other non-agricultural lands were left out of the area considered. So the farm type maps consisted of only arable and grassland areas, i.e. where farms are known to be. The final selection of the 1361 farmsteads was made randomly. The output map is shown in Map 5.5 along with the road network.



Map 5.5. Agripolis farm location map inclusive road network. (Ungaro et al. 2006)

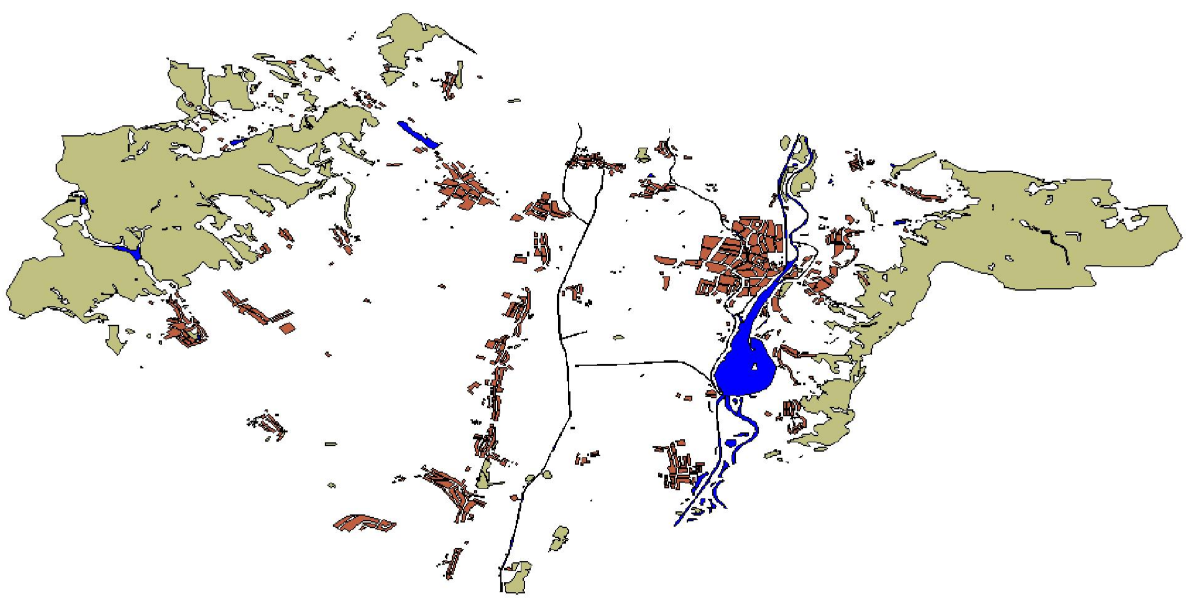
5.3.4 The field map method:

The empirical data available varies greatly between regions. Finding a plausible location for the farms in a given region should always be based upon the best available empirical data for this particular region. The data available in the form of GIS-maps have increased in recent years thanks to the advances in remote sensing. This means that the information detectable through e.g. aerial photography or satellite imagery is made increasingly available for the broader research community. The high resolution and progress within image processing makes it a valuable source of information. Large homogeneous areas such as fields are easy detectable. Therefore maps with field structure in a given area often are to be found. This was also the case for the Slovakian region (see Map 5.6).



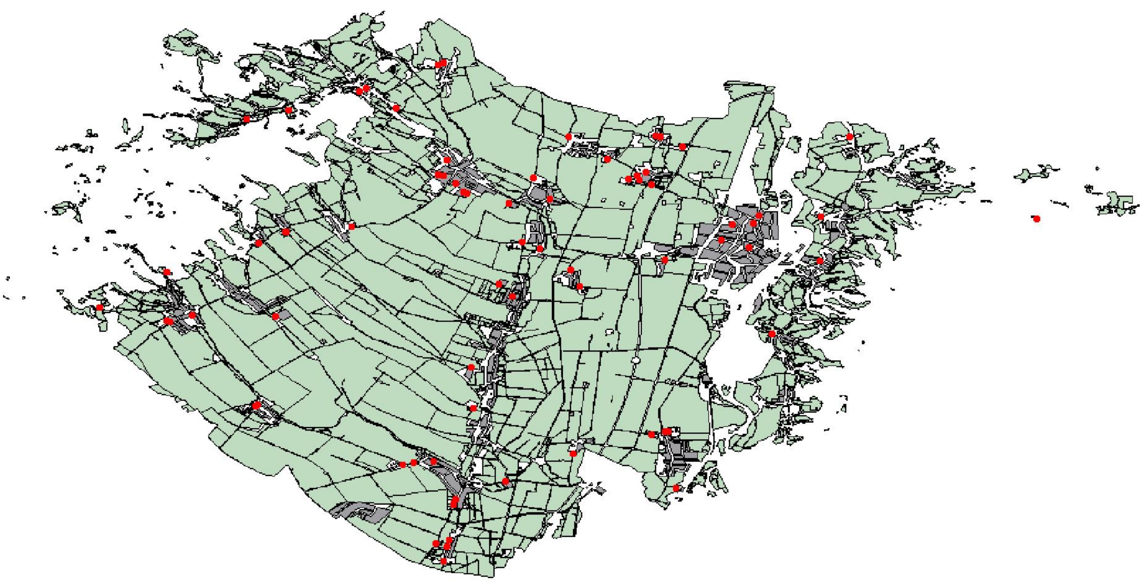
Map 5.6: LPIS field structure in the Slovakian case study area. Each colour represents the fields belonging to an individual farm (SSCRI)

Non-agricultural areas such as towns, waterways and abandoned land could be extracted from the map.



Map 5.7: Towns, waterways and forest in the Slovakian case study area. (GEODETIC_AND_CARTOGRAPHIC_INSTITUTE_BRATISLAVA-GCI)

The PIESTANY region counts 22 092 hectares of utilized agricultural area. 94% of this area is arable land against 6% of grassland.



Map 5.8: Location of animal stables marked with red points in the Slovakian case study area. (SSCRI)

The location of all the regions' animal stables was also mapped as seen in Map 5.8.

This information constitutes the foundation for recreating the spatial location of the farms in the region. As the maps were directly from the region the information here was given great importance. The FADN sample on the other hand covered a larger area and had therefore to be rescaled to fit the region. That meant that a statistically representative sample of the FADN farms was found for the Piestany region. The characteristics of the sub-sample of the FADN were optimised using statistical data covering the Trnava region resulting in a sub-sample with slightly different numbers relative to the information found in the maps. The number of animal producing farms was not in agreement with the number of stables empirically found. The sub-sample of the FADN-farms was therefore used, as a rough first estimate ensuring that the selection of the farm types was comparable to the farms found in the region. Based on this selection of farm types and the information found in the regional maps, a manual reselection and spatial location of the individual farms was conducted. The guiding principle for this farm location procedure was always to ensure that the most reliable empirical data were preserved.

Due to the small number of farms present in this region a manual farm location procedure was possible to undertake, however, this would not be a feasible option for any of the other regions simply because of their size. A large number of farms make it not only a very time-consuming operation; more importantly the number of combinations will fast exceed what is manageable for the human mind. The site characteristics found in the maps need to ensure that the majority of the locations are only suitable for a single type of farm from the FADN-sub sample. If more farms from the FADN-sub sample possess production characteristics that make it possible to ascribe them to the same spatial areas a manual procedure will quickly be ousted by some simple random procedure.

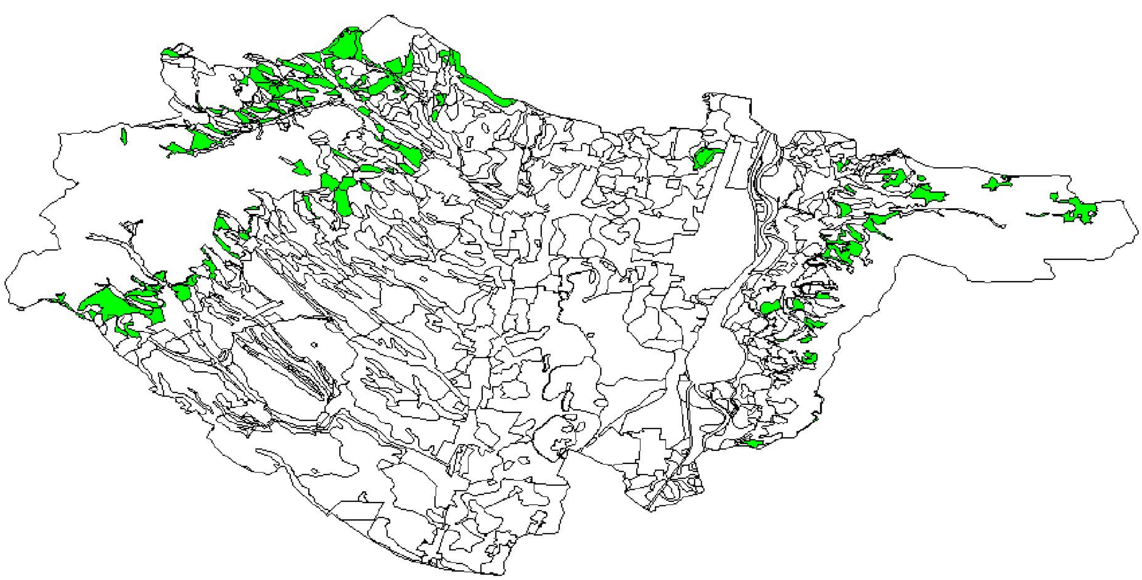
A map with the location of 125 individual farms should be constructed in this case. The farms from the sub-sample of the FADN-sample as well as the information from the maps regarding the real farms in the region were listed next to each other. In the case of the FADN-farms they were listed after they were multiplied by the extrapolation factor found in the regional-scaling procedure. The original regional-FADN sample consisted of 123 farms, two less than in the maps.

Ascribing the farms to a spatial location was done by a procedure involving a number of steps. First a dual optimisation where the best matching farms and location were ascribed to each other and secondly a frequency analysis was performed on the chosen farms. The frequency analysis was compared to the initial frequency analysis of the FADN farms regionally selected to see if the new selection had some kind of bias. At the same time the summarized values from the newly selected farms were compared with the regional statistics in order to ensure that the selection reflects the empirical data. This leads to the replacement of a number of farms and the repetition of the analysis implying that a number of farms had to be changed and so on. This repeated itself until a reasonable representation of the region was found.

At this point the FADN farms were matched to the values or information found in the maps, however, not to a given location as such. In the case of animal producing farms the location of all the regions animal stables was used as the guideline. The farmsteads were presumed to be located at the same location as the stables. The animal producing farms were then ascribed the nearest fields with the right size if more were available. In the case of the crop producing farms a small part of the fields was converted to the farmsteads.

This is most likely not in accordance with the real location of the farmsteads. However, it was chosen as no information was at hand and this was the least intrusive assumption. Another and even more rough assumption had also to be taken. The Slovakian region is, due to the technical data available, modelled with only two landscape characteristics, namely arable and grassland. The FADN-sample showed that a large number of the farms had some grassland related productions. The standard assumption of relating grassland production to the less productive soil types was, however, not possible in this case.

The grassland related landscape characteristics are located in the areas marked with green in Map 5.9, however, the farms involved with grassland production are located evenly over the whole region. Therefore two possible options for assigning grassland to the farms were available. Either all of the farms involved in grassland related productions should receive small chunks of the fields with low soil quality and thereby violating the empirical found field bounds or the farms should use they own fields for the grassland related production. The latter would mean that a given part of each of the involved farm land should be interpreted as grassland.



Map 5.9: Grassland related landscape characteristics in the Slovakian case study area marked with green. (SSCRI)

As the data from the Danish case study area suggested that most of the farms involved in grassland production activities are not located on grassland areas we choose to maintain the fields in their present form. The findings from the Danish study area suggest that the farms' choice of grassland related productions is reflecting other considerations than only the quality of the land such as time constrains or personal preferences. However, AgriPoliS needs a distinction between arable and grassland areas. For the farms involved in grassland production types a part of their fields is therefore changed in status from arable land into grassland. The composition of the fields is thereby reflecting the production found in the FADN-data. The spatial location of the area that changed status tends to be located in the upper left corner of the fields as a simple search algorism was used to locate the first possible location. The grassland area is then intentionally made as a single clump of land rather than scattering the land over the entire area of the fields. This is not likely to be realistic from a soil science perspective, however, presumably better reflecting the production perspective taken on the grassland production.

5.3.5 The empirical method:

The data availability differs for regions. However, even in the case where all production related data, maps of the individual farms and their fields are available the task of ascribing the FADN-data to the farms is still difficult. The FADN-data is normally a sample for a larger region. Minimizing the squared deviation between the observed goal criteria from the agricultural statistics and the individual farms from the FADN-sample can ensure the statistical properties in the modelled region. However, the individualised farm version requested that all farms in the region are ascribed accountancy data based on the FADN-sample. This last method describes therefore the chosen procedure for making an individualised farm model based on all production related data as well as maps of the individual farms and their fields.

In the case of the Danish region we have access to accurate information on: The spatial location of the farm and fields, the number of fields and their soil types as well as the number and types of animals. The machine capacity of the farm is assumed to fit the current production capacity. Based on the current production the machine capacity therefore is calculated and assigned each individual farm.

A sub-sample of the FADN-data was first adjusted to the regional statistics through minimizing the quadratic deviations between the regional statistics and the sum of farms characteristics times the new extrapolation factors assigned to the farms.

This sub-sample of FADN farms as well as all the farms from the region were then classified according to the same farm typology (Kristensen and Kristensen 2004). The typology is developed for Danish farming conditions and contains 31 different farm types. The typology utilises the detailed information on the farms to classify them using a decision tree technique. The economic values in the FADN farms are later converted into €/ha. The individual farms with the same farm type according to the farm typology are given this value times their ha of land and thereby converting the values back to values fitting their size of production.

This method takes into account that the FADN–farms have to be representative of the regional farms, that the different production types within farming have to be considered when transferring economic quantities and to implement finally the size of the production.

This means that each individual farm in the modelled version of the Danish case study area is unique in all its farm characteristics and that most of the values ascribed to the farms are empirically founded.

Hereby the real heterogeneity of the 2383 farms and 1865 farms present in year 1998 and year 2002 respectively, is captured by the model.

5.4 Introduction to recreating location from non-spatial data

As the presented methods in the previous section have illuminated the reproduction of the spatial location of farms from a FADN-sample is a complicated as well as an important issue for spatially explicit models building upon farm accountancy data. These methods have all been developed in an attempt to reproduce the farms' spatial locations based upon commonly available data sources. Another method could be to supplement the FADN sample with a field study in the region modelled.

Adapting AgriPoliS to a given region involves a number of steps in order to ensure that the real farm structure empirically found in the region is reflected in the model. The farms in the model need to reflect the right number of farms, the real size distribution, the real number of livestock found in the region, the real ownership structure as well as other statistical data from the region. To ensure this, the data found in the FADN-sample and the regional statistics are compared. The farms selected from the FADN-sample and their weights are found by minimizing the squared deviation between the regional statistics and the farms in the FADN-sample. This method ensures that the regional statistics are re-established in the model. The right statistical selection of farms does not tell, however, where the individual farms are located spatially. Therefore some kind of spatial information about the location of farms in the region is needed to locate the farms in a spatially explicit model. In the previous section the link between the selected farms and their spatial location was established through the information found in the data and maps. Another way of collecting spatial information in order to be able to establish this link is to supplement the remote sensing data with a field study in the modelled region. The following section is an investigation into the minimum sample size that such a field study needs in order to provide accurate information for the spatial recreation of the modelled region. The aim of this investigation is to get insight into the information needed to locate farms spatially in models. The results of this investigation have been presented at the International Farm Management Congress at University College Cork, Ireland, the 15th to 20th July 2007(Damgaard 2007).

5.4.1 Introduction to the problem of the location of FADN farms

To recreate a reliable representation of the complex reality is one of the fundamental challenges in creating empirically founded models. Numerous models are based on abstract representations of the underlying system and do not need the empirical foundation for investigating the characteristics of the object of study. However, once the findings from the models are used for policy recommendations, realistic and empirical founded models are preferred. Obtaining sufficiently empirical data for large regional models through personal field studies are seldom possible. Instead most models are relying on available data from databases or other collectively gathered information. The accuracy of these data differs, however. Many of the most adequate economic data are collected by the local authorities indirectly through the assessment of taxes or similar administrative issues. This means, however, that the most reliable data are at times restricted to ensure personal privacy. The European Farm Accountancy Data Network (FADN) is one of these large but restricted data collections.

Every year a large sample of farm accounts is collected in each of the member states in the European Union. From this base sample a number of so-called “representative” farms are found. Each is with an extrapolation factor constructed in such a way that the farms provide a representative sample for the commercial farms in a given region. The extrapolation factor incorporates the regional characteristics, the economic size and type of farming found in the whole collection. The term “representative” as well as the accuracy of the methodology is to debate within the scientific community (Beers et al. 2001; Meier 2004; 2005), however, will not be questioned here.

Spatially explicit models that make use of the FADN data need to be able to recreate a landscape including the location of the farms in a plausible way.

A few attempts based on indirect statistics have previously been published (Fais and Nino 2004; Fais et al. 2005). One of the most ambitious attempts is undoubtedly the work done by the Seamless project (Elbersen et al. 2006). The methodology developed here is also making use of statistics and remotely sensed data. However, the restricted nature of the FADN data sample makes it difficult to validate the findings. The present analysis is therefore taking a novel approach. Rather than working directly with the FADN-sample and thereby not knowing the underlying reality that the sample describes, this study is using a sample of 1871 farms located in the Danish watershed to river Gudenå. Both the exact location as well as production data for all the 1871 individual farms are known with similar categories as offered in the FADN sample, with the exception of the economic data present in the FADN sample.

Throughout the rest of this analysis we are assuming that the "representative" farms found in the FADN sample and their extrapolation factors create a perfectly fitting description of the 1871 farms found in the river Gudenå watershed. Although this assumption is rather unrealistic it is similar to the normal confidence one has to have in the FADN sample, when no other information is available. This perfect sample consists of the production data in our database of the 1871 farms, with the exception of the geographical references.

Our task is to investigate the sample size of farm locations required to ensure the ability to reproduce a reliable map of the region.

This is done by analysing the relative location between all the 1871 farms present in the Danish river Gudenå watershed. As we have detailed information about each of the farms we can categorise the farms in groups similar to what one would be able to do with farms from a FADN sample. By utilising the rich information that the FADN sample contains to create a multidimensional spatial set of requirements (such as the distance to the nearest dairy farm or to the 2nd nearest farm between 0 ha and 20 ha) that the farms on average have to achieve it is possible to reduce available locations down to a minimum. In this case we utilize data of the farm size, production type and number of animal units. The Danish case study area was chosen partly due to the data availability and partly due to the landscape characteristics. In contrast to a large number of other areas is this region lacking strong spatial indicators by which the space available for farm locations could be deduced. This becomes apparent when one compares the Danish river Gudenå watershed region with other regions where the landscape characteristics can help in locating the farms through e.g. the topography.

5.4.2 The outline of the analysis to reproduce the locations of farms

The location of a farm in space can be defined as an individual event independently of all other farms or structures in the vicinity. However, such an analytical framework would not only reduce the historical process in creating the present agricultural structure out of the empirical data it would at the same time also reduce a large part of the knowledge we have of the present farms.

Even the freedom of action of the present farms will to a varying degree be determined by its history regarding its actual state as well as by the actions and history of other agents in the area. So although it would be reckless to claim that the location of a given farm will directly tell us much about the neighbouring farms it can still reveal some elements of an indirect relationship between the farms. Often local experts will be able to locate a given farm type to a small part of the region simply because farms are not randomly distributed in space but tend to cluster around certain areas. This means that we should be able to utilise this information, when we are going to recreate the distribution of farms in a given region. In the case of FADN farms, however, the difficulty is that we always start off with a sample and seldom know what characterizes this particular selection. Therefore this investigation is conducted in such a way that influence of the sample size as well as the composition of the sample is analysed.

The incomplete knowledge one has in working with FADN data makes some kind of up-scaling or extrapolation of the location of all farms from the initial sample unavoidable.

We will here make use of a similar framework of thought as used in resampling techniques, such as jackknife or bootstrap as we investigate the possible level of error that such extrapolations might cause. At the same time we will utilise the rich information that the FADN sample contains to create a multidimensional spatial set of requirements that the farms on average have to achieve and thereby exploit the possibility to reduce the available farm locations down to a minimum. The procedure will therefore draw upon interrelationships between the farms rather than the spatial characteristics of the individual farm. It is often beneficial to include such spatial characteristics. For reasons of simplification these characteristics will not be included in the following.

Here only the interrelationship between the farms' spatial location is utilized as the location of the farmstead is viewed as a network of interrelated points in space. The network is represented as graphs that consist of a set of *vertices* (or nodes) connected by a set of *edges* (links). Here the vertices represent the farmsteads, and the links between the points represent the Euclidean distance between those farms. Each farmstead holds information about the farm size and the production system. This information is used to categorize a given farm's relationship to the 1870 other farms (such as the 2nd nearest dairy farm or the nearest farm between 51 ha and 100 ha). Therefore the edges are directed lines, as the interrelationship is not symmetrical. This means that the investigated network consists of 3498770 (or 1871*1870) links.

The investigation of the network is divided into the following two-step procedure: First the variability of an individual farm's spatial relationship is investigated with regard to variation in sample size and composition. Secondly the average values are investigated with regard to variation in sample size and composition.

To understand the chosen procedure it is important to remember that our enterprise is to investigate the minimum sample size of farm locations required to reproduce a reliable map of a given region. Therefore we will mimic the situation where one is collecting data in the field by varying the sample size and this has been repeated with different order of the farms at least ten times. The latter is done, as we can't be certain as to order of farms chosen if one is collecting the data in the field. Though the number of different selections of farms from a combinatory point of view hardly scratches in the surface of possible orderings, the sample size will still provide us with some insights into the variation one normally will encounter.

5.4.3 The analysis of the sample size requirements

We look at an individual farm by investigating the variability in the statistical properties in its relative location to all the other farms due to sample size and composition. This is done by taking approximately 10% of all the farms and for each of these farms calculating the Euclidean distance to all the 1871 farms in the region. For each of the 188 selected farms the most commonly used descriptive statistics (including: mean, median, standard error, 95% confidence level, standard deviation) has been calculated for sample sizes varying from 11 farms (the selected farm and 10 additional farms) and up to all the 1871 farms. This is done with an interval of 10 farms. In addition it is done for 11 different successions of the farms. The values are calculated based on the distance and no further categories have been made. The reliability of the values for each individual farm can be assessed through this calculation. This is important as the further analysis eliminates the uncertainty each individual farm constitutes in an incomplete sample. This uncertainty will, however, unavoidably be included in a sample solely building upon FADN data.

In Figure 5.3. a plot of the relative deviation of the mean as a function of the sample size is presented. In Figure 5.5 a plot of the relative deviation of the median as a function of the sample size presented. In the case of the relative deviation of the mean the first plot is supplemented by an additional plot (Figure 5.4.) of the frequency by which the different relative deviations occur. Please note the scale of the frequency plot, as the scales are not made with equal intervals.

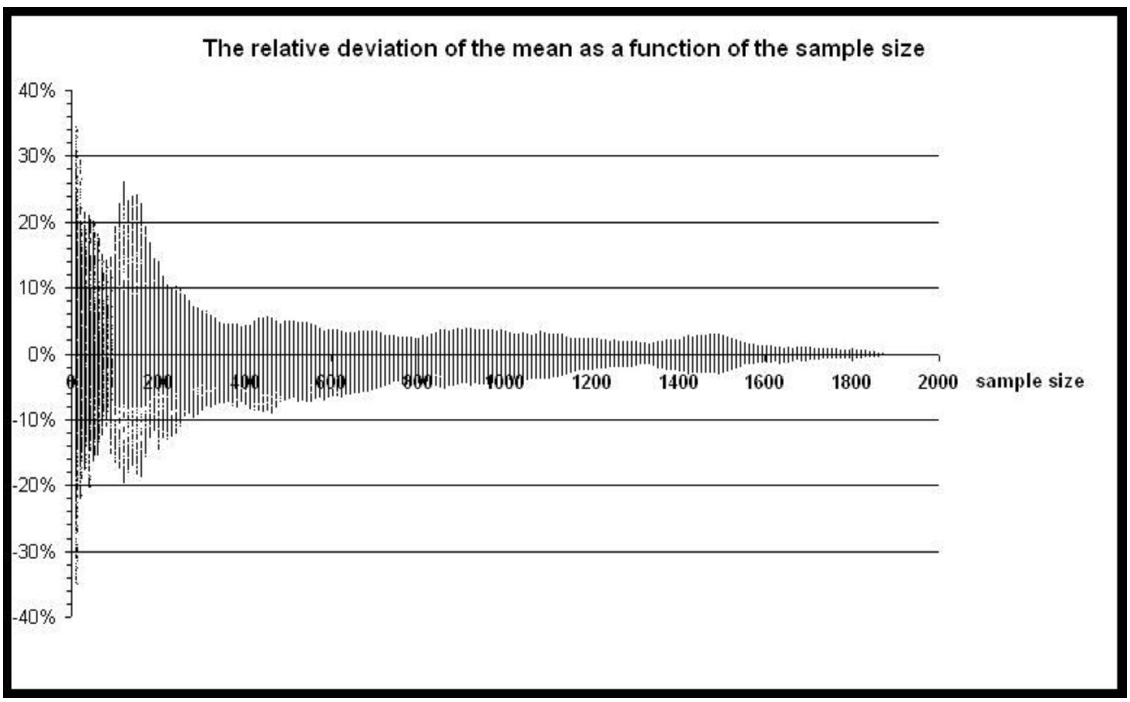


Figure 5.3. The relative deviation of the mean as a function of the sample size. Own calculations

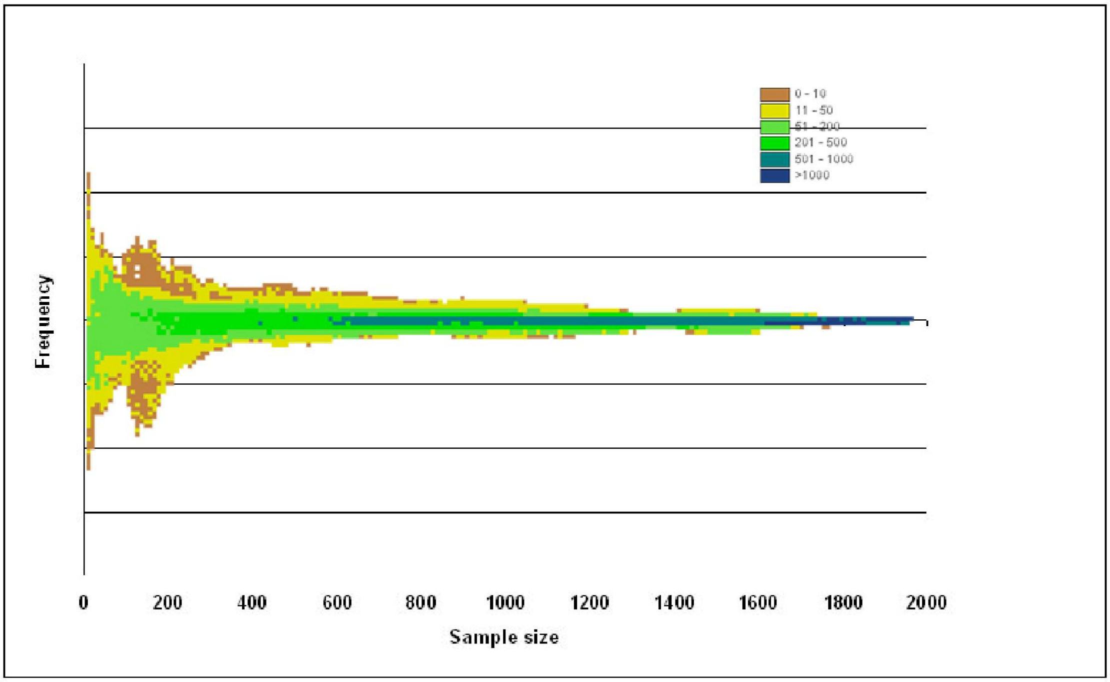


Figure 5.4 The frequency of the values of relative deviation of the mean. Own calculations.

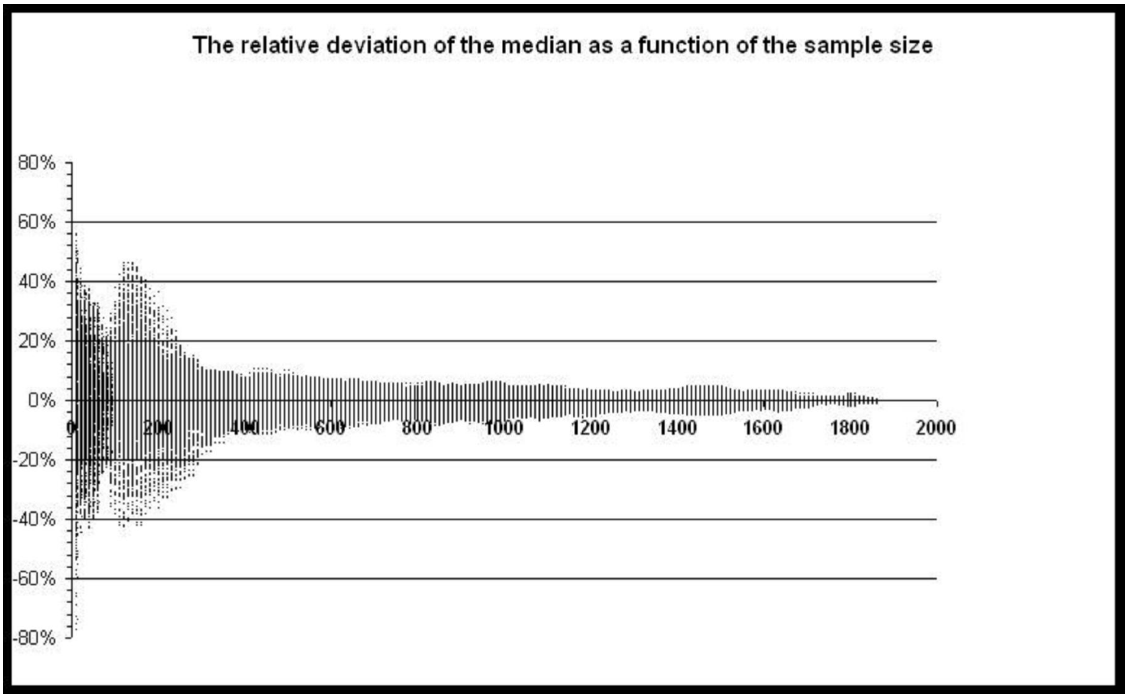


Figure 5.5. The relative deviation of the median as a function of the sample size. Own calculations.

Please note the difference in scales used in the plot for the relative deviation of the mean and the plot of the relative deviation of the median. Looking at figures 2-4 one can see that once the sample size is around 20% of the full sample (≈400 in this case) the individual farm values are generally reliable. Even earlier the majority of values are within a 10% span in the case of the mean. The median values are naturally fluctuating within a larger span, however, otherwise show similar structural characteristic. When working with samples of less than 10% of all the farms the fluctuations within the mean as well as median values are so large, that one hardly can trust ones findings to any significant degree.

The first part of the investigation has shown the reliability of the values for each individual farm, while varying the sample size and composition. In the real world this variability would be a part of the uncertainty entering into the average values now to be investigated. Here it would, however, only blur our findings. The entire network is therefore used in the second part of the investigation. Each of the 1871 farms knows now the Euclidean distance to all others. That means that the distance contributed by each individual farm is founded on perfect information.

The variations in the average values are only due to the size and composition of the selected sample. The further procedure is making use of the included production related data. As we know the production category for the farm working as our point of reference as well as all the other farms we have created a 2-D matrix with the categories seen in Table 5.7 on each side. In the case of the point of reference only the categories that the particular farm fulfils are in use.

Categories
All farms
0-20ha farms
21-50ha farms
51-100ha farms
101-200ha farms
More than 200ha farms
Plant production farms
1-50 animal unities
More than 50 animal unities
Pork
Dairy

Table 5.7. List of categories used in this study

For all the other farms the scheme is expanded by distance of the subcategories to the 1st , 2nd, 3rd , 4th and 5th nearest farm of the category as well as the average distance.

Below the two examples (Figure 5.6-5.7 and 5.8-5.9) will indicate what the ten different successions of farms produce. The two chosen examples are the distance to the nearest farm (Figure 5.6-5.7) and the average distance to all other farms (Figure 5.8-5.9).

In Figure 5.6 and 5.8 the nominal values are presented. The percentage deviation from the full sample is presented in Figure 5.7 and 5.9. The examples reveal mainly two general characteristics. First of all one can see the modifications that the selections produce. Secondly and more importantly is that the precision of course depend upon the number of farms falling into a given category. Only a fraction of the farms will influence the value of the nearest farm, whereas all other farms will affect the average value. This simple fact makes a large number of the categories possible for a given region questionable for the purpose considered here. If only a few farms fall into a given category the fluctuations for this group will simply be too large for full reliance on the results. However, instead of dismissing such findings altogether the different categories should be supplemented with a weight factor expressing the reliability. Such a weight factor can of course only be an estimate and may be based on studies similar to this one.

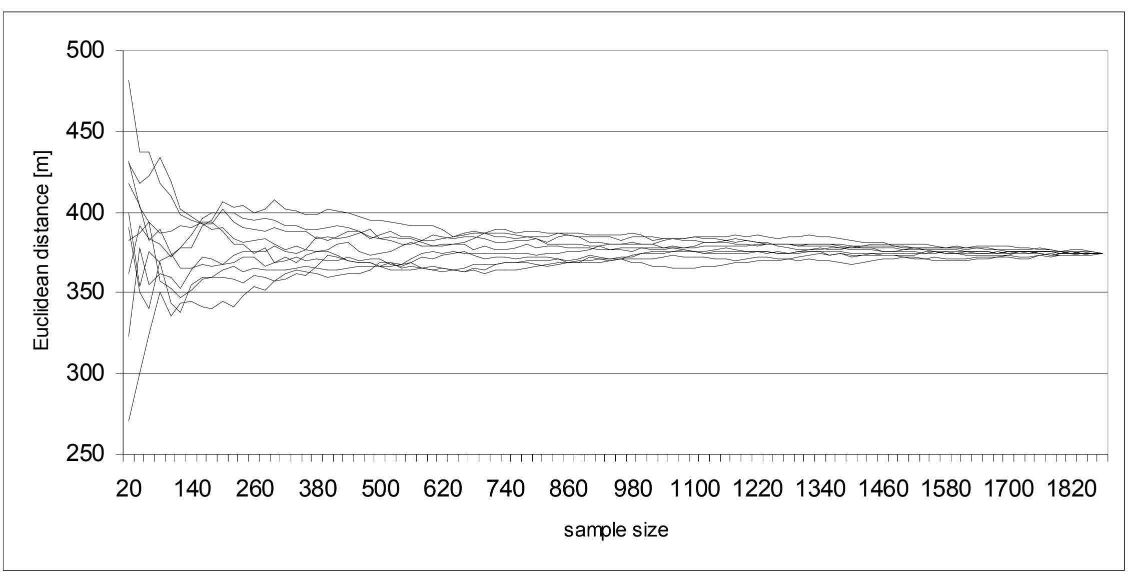


Figure 5.6. The deviation of the distance to the nearest farm of all other farms for ten different successions of farms

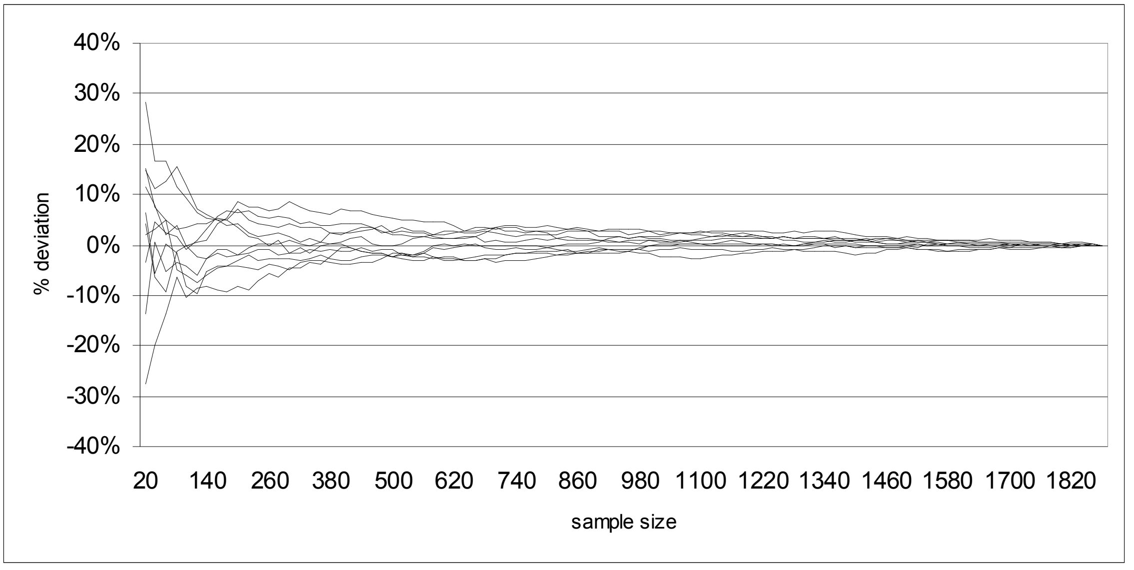


Figure 5.7 The relative deviation of the distance to the nearest farm of all other farms for ten different successions of farms.

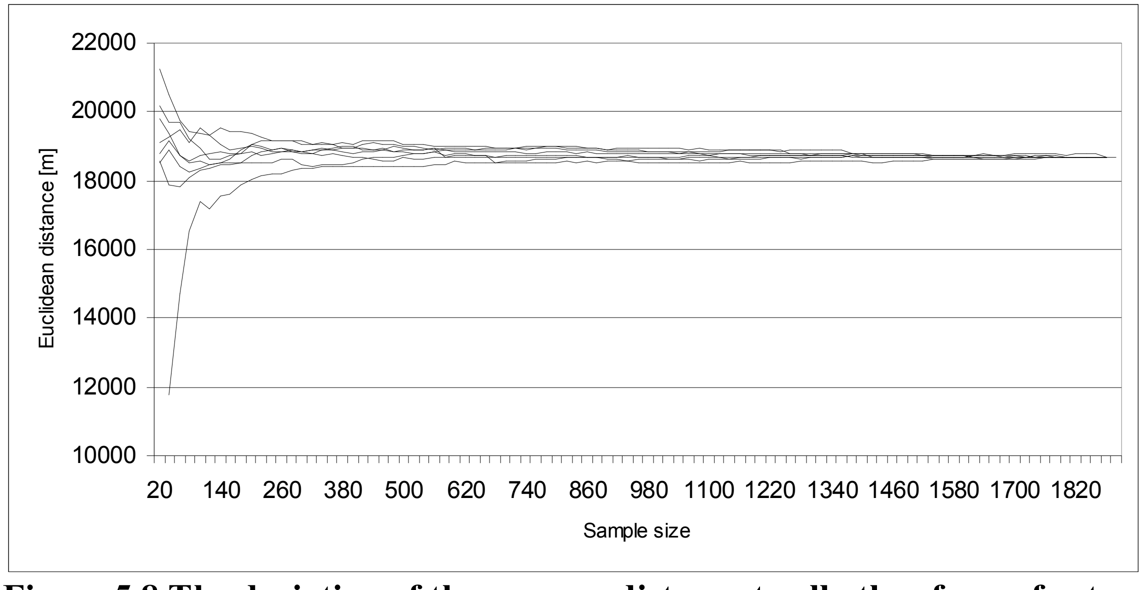


Figure 5.8 The deviation of the average distance to all other farms for ten different successions of farms.

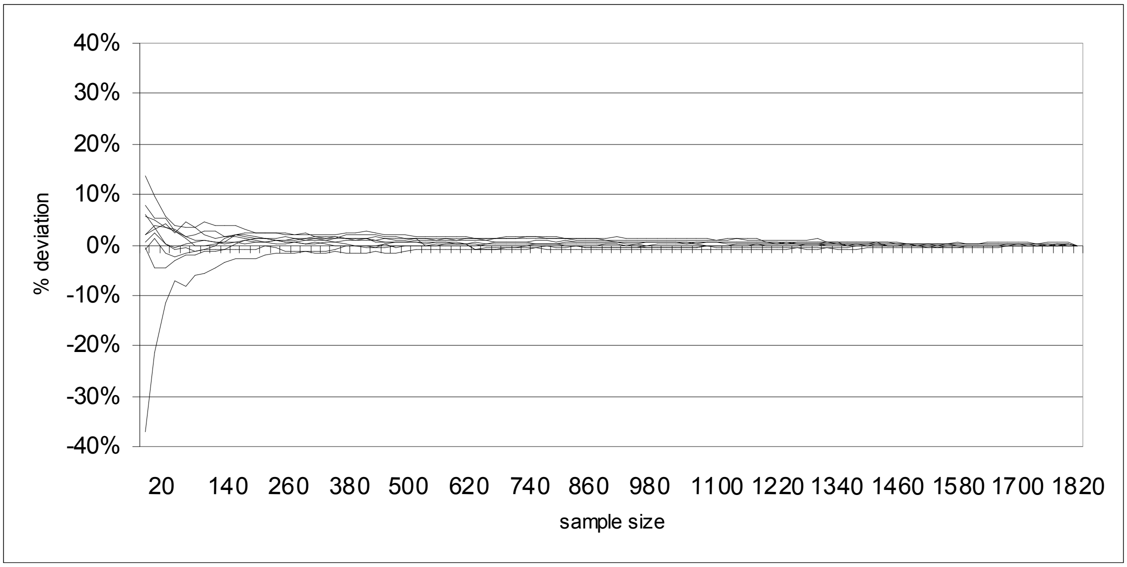


Figure 5.9 The relative deviation of the average distance to all other farms for ten different successions of farms.

As one can see from the above plots the different ordering of farms will fluctuate around the values for the complete region with a spread that diminishes with the larger sample size. This spread we have used to pass on the reliability of a number of the different categories (presented in Table 5.7) and results are shown in Appendix A.3. For the category "All Farms" as well as the five field size categories the relative difference between the maximum and minimum values is presented for the sample size 20, 100, 400 and 1000. This is done as a function of the average value for all the 11 categories used in this study.

From the shown values in Appendix A.3. one can see that the size of the fluctuations to a far larger degree depend on the farms chosen as the point of reference than the different categories under which the rest of the farms are categorized. This is because the differences between the tables are much larger than the deviations between the categories. Once more this is due to the number of the individual farms that fulfils a given type description. This is apparent when the values of the most common groups are compared with the less common groups, such as the 24,97% spread for the sample size 20 for 21-50 ha farms against the category "All farms" where as for the group >200 ha the value 466,76% is for the same. At the same time it is obvious that some groupings such as the group 0-20 ha farms and 21-50 ha farms produce better results than the “All farms” group. This demonstrates that some of the sub-groupings that may be made of the FADN sample can actually reveal better insights to the spatial distribution of the farms in a region than using only averaged considerations.

Neither the presented method nor the more commonly used methods based on indirect statistics and remotely sensed data will ever be able to recreate a 100% accurate location of the farms in a region as long as “representative” farms from the FADN sample are used. The challenge is to find the most reliable method. Each methodology has its strengths and weaknesses. The actual procedure of using the data holds another set of challenges. Guiding the location of farms by average values will of course produce false locations. The question is, however, whether it reduces mistakes to a larger degree than a random location procedure would produce. A question we hope to investigate in the near future.

5.5 Sketching the effects of a spatial sensitivity analysis of AgriPoliS

5.5.1 Introduction

The creation and adaptation of a simulation model to a given region involve ongoing considerations of the level of empirical details needed. On one hand is it important to include all influential parameters of the investigated system. On the other hand not to include more than these parameters as it may cause noise in the results of the model. To determine the influential parameters is, however, hard if at all possible and therefore the risk of overfitting the model is always present. It is therefore important to investigate the influence added empirical details have on the model. The advantage of incorporating the spatial dimension into the model goes beyond the model's ability to reproduce patterns found in empirical data. The visual representations of the simulated outputs help in understanding and communicating the results. But these secondary benefits must not be included at the expense of the quality of the results. AgriPoliS will therefore be tested for its sensitivity to the initial spatial location of the farmsteads and their fields.

Traditionally, sensitivity analyses are used to determine how sensitive a model's response is to changes in the values of the parameters of the model and to changes in the structure of the model. Thereby the sensitivity analysis helps to build confidence in the model and to help the modeller to understand the dynamics of the model better. There is a variety of sensitivity analysis techniques often used on individual input factors in single-dimensional models and time-series models. AgriPoliS has also previously undergone systematical analysis of its robustness to changes in factors such as technological change, managerial ability, short and long term interest rates on borrowed capital, interest rates on equity capital and the politically induced environment (Happe et al. 2006a; Happe et al. 2006b). The spatial sensitivity of models is, however, seldom investigated.

Spatially locating the real farmsteads and accessing the corresponding economic and production related data is a difficult task. Mostly only restricted data sources such as FADN-data are available and consequently it is not possible to ensure the right spatial location of a given farm. The individual farm's possibility of expansion is influenced by the location of the farm through the local competition for land. Both in a direct sense as the number of free plots in the vicinity depend on the neighbouring farms' willingness to sell as well as in an indirect way as the farms' bid for free areas are competing with the other farms, mainly from the local area. Transportation cost is deducted from the farm's bid for a given plot of land[5] and therefore the bids given by the farms in the vicinities are often relatively higher than farms far away. The economic strength of the farms in the neighbourhood is hereby influencing the individual farm's opportunities.

To investigate how the initial spatial location of the farmsteads and their fields influence the regional results ten maps of the Italian region have been constructed. In each of these ten maps the farms have the same amount of arable and grassland corresponding to the FADN-data; but the farmsteads and fields are located differently. For some of the farms there are variations in the area of the different landscape characteristics sub-types of arable or grassland that these particular farms possess. However, the regional characteristics stay the same in all maps. All other factors are kept unchanged between the ten different simulations.

This investigation with ten different maps is only sketching the scope of a spatial sensitivity analysis of AgriPoliS. However, in order to appreciate the incorporation of more realistic spatial characteristics into the model such a small investigation is needed. The above-mentioned ten maps are utilised rather than analysing the spatial sensitivity using Monte Carlo simulation techniques. Though the latter is more frequently used within traditional spatial sensitivity analysis this particular problem will not be applicable to such an investigation due to its set-up. The one-at-a-time approach in which only one input parameter at a time is selectively varied to determine its effect on the objective function would limit the sensitivity analysis to a small local area of the parameter space and at the same time only examine first-order effects so that the second-order effects between the parameters would not be detected. Furthermore no effect presumably would be detectable with so little variation in the regional farming structure. Even when the random variation would be applied to a few spatial zones as Hall et al. (2005) or a selected representative set of pixels or points such as Avissar (1995) or Dubus and Brown (2002) the variations would presumably not capture the large variations that the spatial location of the farms would give. The above-mentioned methods can be used to investigate the spatial sensitivity with regard to the spatial location of the different landscape characteristics and their influence on the model results. An example of such an investigation is therefore presented in the following.

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5 The farms bids are in reality determined by the shadow price for the plot, the number of adjacent farm plots and the distance-dependent transport cost between the farmstead and the plot.

The spatial sensitivity of the distribution of the different landscape characteristics is investigated. The Italian region has been chosen, as the spatial sensitivity in a mountainous region must be particularly large. Hereby the most extreme deflection due to the spatial sensitivity is investigated. The structural effects of such an investigation will express the farm's sensitivity to production opportunities relative to other farms rather than the induced effects of the lacking spatial information within the FADN-data.

In the case of the sensitivity with regard to the spatial location of the different landscape characteristics analysis is the investigation an example of such a procedure rather than a full spatial sensitivity analysis. Some of the most extreme cases are therefore chosen as examples. This is to ensure that the extent of the sensitivity to changes in the soil map is known. So rather than letting the landscape characteristics vary in a plausible manner whole types of landscape characteristics have shifted location. This is not showing the realistic variation of the landscape characteristics location, however, helps to understand the influence of the initial distribution of the landscape characteristics and can therefore also help in the interpretation of the spatial location of the farms.

For this analysis 30 soil maps were constructed were the landscape characteristic types within the group of arable land and within the grassland types shifted locations. This means that the soil maps were constructed without any resemblance to the real landscape apart from the fact that the areas with arable and grassland are unchanged. In Table 5.9 an overview of the combinations of the landscape characteristics is used in the analysis given. The numbers used in Table 5.9 represent each landscape characteristics in the real representation of the region as listed in Table 5.8:

Landscape characteristics	Number
Arable_Land_High_Hills	0
Arable_Land_Low_Hills	1
Arable_Land_Low_Mountain	2
Arable_Land_Plain	3
Arable_Land_Terraces	4
Grassland_High_Hills	5
Grassland_Low_Hills	6
Grassland_Low_Mountain	7

Table 5.8 Name and its corresponding number of the landscape characteristics used in the Italian case study area. (Ungaro et al. 2006)

In Table 5.9 the grey marked numbers in the second column (the location of the landscape characteristics) show the initial type of landscape characteristics by which another landscape characteristic has swapped place. That means that in map 2 the landscape characteristic 1 (Arable_Land_Low_Hills) is occupying the location of landscape characteristic 0 (Arable_Land_High_Hills) while type 0 occupies the location of type 4 (Arable_Land_Terraces) and so on.

		The number of the soil map																													
The location of the landscape characteristic		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
	0	0	1	2	3	4	0	0	0	0	0	0	3	0	0	1	1	1	2	2	0	0	0	0	0	0	0	0	4	4	4
	1	1	2	3	4	0	2	3	4	1	1	1	1	2	2	0	3	4	0	3	2	3	3	3	3	3	4	4	0	2	2
	2	4	3	4	0	1	1	1	1	3	4	3	4	3	4	2	4	0	1	1	1	2	1	4	2	4	3	3	3	3	1
	3	2	4	0	1	2	3	2	2	4	3	2	2	4	3	3	0	2	3	4	4	4	4	1	1	2	1	2	2	0	0
	4	3	0	1	2	3	4	4	3	2	2	4	0	1	1	4	2	3	4	0	3	1	2	2	4	1	2	1	1	1	3
	5	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7	5	6	7
	6	7	7	6	7	5	5	6	7	6	7	5	5	6	7	6	7	5	5	6	7	6	7	5	5	6	7	6	7	5	5
	7	6	5	5	6	7	6	7	5	5	6	7	6	7	5	5	6	7	6	7	5	5	6	7	6	7	5	5	6	7	6

Table 5.9 The combination of landscape characteristics used for the soil maps testing the spatial sensitivity with regard to the spatial location of the different landscape characteristics and their influence on the model results. The numbers marked grey in the second column are the real type of landscape characteristic by which another landscape characteristic has swapped place.

Modifying the maps by such a dramatic procedure will of course produce considerable variations in the simulated results.

By shifting the location of the landscape characteristics the farms' sensitivity towards their initial possession of different sub-soil types is investigated. The regions' share of different soil quality will at the same time differ. So in some of the artificially created landscapes larger areas are covered with better soils as in reality. In other simulations the opposite is the case.

5.5.2 Analysis of the 30 different allocations of landscape characteristics

In the first part of this investigation the benchmark is that both the 10 different farm locations and the 30 different allocations of landscape characteristics have to be measured against the region simulated with the presumed right farm location on the regional landscape characteristics. Here the benchmark simulation is subject to a continuation of an agenda 2000 support scheme. The agenda 2000 support scheme means that the subsidies given to certain products continue at the same level throughout the duration of the simulation. This means that the farms are not subject to any abrupt changes in their framework conditions. The region is subject to a stable development.

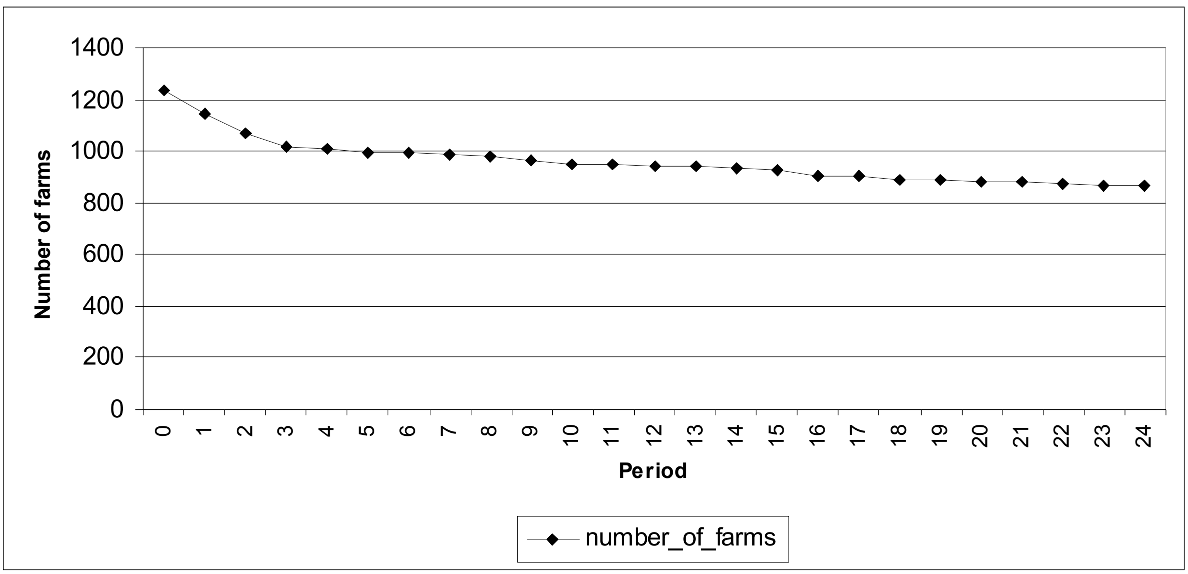


Figure 5.10 Number of farms in the benchmark case as a function of time. Own calculations

Though the region does not experience large abrupt changes from the political level the region will still undergo structural development. The competition between the farms will force some of the farms out of the sector while others will flourish and grow. The number of farms as a function of time is used as a simple, however, crude, indicator for the spatial sensitivity. Other indicators such as the characteristics of the active farms are likely to mirror merely the inconsistency between the farm type and its landscape characteristics artificially given. The region has initially 1237 farms in period 0 and in period 24 only 864 are left (as can be seen in Figure 5.10). These numbers conceal the variation in the different farm types. In Table 5.10 the decline in the number of farms within the different farm types is relative to their initial number for simulation period 0,5,10,15,20 and 24 shown:

%	0	5	10	15	20	24
O-FC1 (18)	100	100	100	100	100	100
IF-FC2 (15)	100	100	100	100	93.33	93.33
O-FC3 (22)	100	100	100	100	100	100
O-FC4 (17)	100	100	100	35.29	23.53	0
IF-FC5 (62)	100	93.55	87.1	79.03	66.13	64.52
O-FC6 (4)	100	100	100	100	100	100
IF-FC7 (137)	100	94.89	83.94	75.91	75.18	74.45
IF-FC8 (62)	100	98.39	88.71	82.26	79.03	77.42
IF-FC9 (138)	100	97.83	88.41	83.33	78.99	76.81
IF-FC10 (46)	100	97.82	97.82	95.65	84.78	82.61
IF-D11 (18)	100	100	100	88.89	77.78	77.78
IF-D12 (6)	100	100	100	100	100	100
IF-D13 (11)	100	100	100	100	100	100
IF-D14 (8)	100	100	100	100	100	100
IF-GL15 (47)	100	70.21	53.19	36.17	31.91	29.79
IF-GL16 (43)	100	95.35	81.39	69.77	62.79	58.13
IF-GL17 (140)	100	73.57	65.71	57.14	52.14	51.42
IF-M18 (5)	100	80	80	80	80	80
O-M19 (4)	100	100	100	100	100	100
IF-M20 (3)	100	100	100	100	100	100
IF-M21 (178)	100	4.49	2.24	2.24	1.123	0.56
IF-M22 (225)	100	97.33	92.89	92	87.11	87.11
IF-M23 (28)	100	89.29	89.29	89.29	89.29	89.29
Number of farms	1237	997	952	925	879	864

Table 5.10 The decline (in percent) within the farm types relative to their initial number for period 0,5,10,15,20 and 24 of simulation in the benchmark case.

As the different farm types are represented in the region in varying numbers the number of times each farm type is represented in the initial period is written behind their name in brackets and in the last row the total number of farms within each of the periods is shown.

Table 5.10 shows that some of the farm types such as O-FC1 and O-FC3 go through the simulation unaltered in numbers while others such as O-FC4 and IF-M21 almost completely disappear. The majority of farm types experience a decline in number of farms, however, without entirely disappearing within the duration of the simulation. It is against this structural development within the region that the 10 different farm location and the 30 different allocations of landscape characteristics will be benchmarked.

In the case of the 30 different allocations of landscape characteristics the locations of the farms are maintained as in the benchmark case, only the soil type below the farm and its fields will change. There are of course large variations in the number of farms surviving all 24 periods of simulation between the 30 different simulations. In general a considerably lower number of farms is enduring the full 24 simulation periods. This can be seen from Table 5.11 showing the average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 of the simulation.

Period	0	5	10	15	20	24
Average	1237	911.23	799.56	690	609.8	563.96
Median	1237	881.5	807	712.5	638	574
Maximum	1237	1000	956	879	827	797
Minimum	1237	853	664	518	400	339

Table 5.11 The average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 in the 30 different simulations with artificial landscape characteristics.

In Table 5.12 the average, median, maximum and minimum values are relative to the benchmark –1 shown in percent. The smaller number of farms within the simulation of the 30 different allocations of landscape characteristics is evident, when the number of farms in the benchmark case is compared to the maximum number of farms in the 30 simulations. The number of farms in the benchmark is higher in period 15, 20 and 24 (see e.g. Table 5.12). This strong decline in the number of farms in the landscape characteristics simulations is clearly an expression of the misfit between the farms and the landscape characteristics of their fields. Though allocation of the farms and their fields in the benchmark version also is an artificial construct, the matching between the landscape characteristics and the individual farm locations is done in a considered manner. Therefore the random relocation of the landscape characteristics is even in the cases where more productive land is given to the region as such not resulting in more farms. The farms' allocation is optimised with respect to the real landscape and therefore the artificial landscapes are hindering more farms to survive. This documents that the model is sensitive towards the landscape characteristics. At the same time it reacts on the different initial conditions without running into the pitfall of some obvious extreme such as all farms in the region closing.

Period	0	5	10	15	20	24
(Average /Benchmark)-1 (%)	0	-8.6	-16.01	-25.4	-30.62	-34.72
(Median / Benchmark)-1 (%)	0	-11.58	-15.23	-22.97	-27.41	-33.56
(Maximum / Benchmark)-1 (%)	0	0.3	0.42	-4.97	-5.91	-7.75
(Minimum / Benchmark)-1 (%)	0	-14.44	-30.25	-44	-54.49	-60.76

Table 5.12 The average, median, maximum and minimum values of the number of farms for the 30 different simulations with artificial landscape characteristics relative to the benchmark –1 shown in percent

The average, median, maximum or minimum number of farms hides once more the differences between the farm type ability to cope with the variations in the landscape characteristics. In Table 5.13 the decline within the different farm types is relative to their initial number for period 0,5,10,15,20 and 24 as an average over the 30 different simulations with different landscape characteristic shown.

%	0	5	10	15	20	24
O-FC1 (18)	100	95	91.48	91.29	91.11	91.11
IF-FC2 (15)	100	95.56	93.78	91.11	84.67	83.33
O-FC3 (22)	100	100	100	100	100	100
O-FC4 (17)	100	97.05	83.53	34.32	22.16	0.2
IF-FC5 (62)	100	99.25	88.39	76.29	61.61	52.69
O-FC6 (4)	100	83.33	80.83	80.83	75	75
IF-FC7 (137)	100	85.2	77.73	66	63	60.88
IF-FC8 (62)	100	99.4	84.73	71.29	58.06	50.38
IF-FC9 (138)	100	99.06	85.06	73.14	61.38	52.44
IF-FC10 (46)	100	93.48	82.54	70.87	60.8	55.21
IF-D11 (18)	100	100	99.81	85.74	77.78	72.78
IF-D12 (6)	100	100	100	100	100	100
IF-D13 (11)	100	100	100	100	100	100
IF-D14 (8)	100	100	100	100	100	100
IF-GL15 (47)	100	49.36	35.32	25.82	20.07	17.94
IF-GL16 (43)	100	78.3	60.47	47.29	40	32.09
IF-GL17 (140)	100	64.21	48.89	35.62	26.62	24.29
IF-M18 (5)	100	80	80	80	80	80
O-M19 (4)	100	100	100	100	100	100
IF-M20 (3)	100	100	100	100	100	100
IF-M21 (178)	100	3.1	1.85	1.42	0.86	0.64
IF-M22 (225)	100	84.9	76.28	70.36	64.64	62.55
IF-M23 (28)	100	75.12	70.48	67.02	63.93	63.45
Average number of farms	1237	911.23	799.57	690	609.8	563.97

Table 5.13 The decline (in percent) within the different farm types relative to their initial number for period 0,5,10,15,20 and 24 as an average over the 30 different simulations with different landscape characteristics.

The relative decline is of course larger for almost all the farm types in all periods compared to the benchmark simulation. This is not surprising. That certain farm types actually perform better for a number of periods is, however, surprising. Farm type IF-FC5 is more present in period 5 and 10 in the average of the 30 simulations than in the benchmark model (see Table 5.10 and Table 5.13). The same is the case for farm type IF-FC8 in period 5 (see Table 5.10 and Table 5.13). This is in spite of the fact that the landscape characteristics are on average less adapted to these farms' production among the 30 simulations.

There are also farms such as O-FC3 and IF-D12 that seem to perform well independently of the landscape characteristics they possess.

5.5.3 Analysis of the 10 different initial spatial locations of the farmsteads

The results look differently in the case where the real landscape is maintained but the location of the farms within this landscape is changed. To investigate this ten maps were constructed where the spatial location of the farmsteads and their fields have been altered. All other factors are kept unchanged between the ten different simulations. In Table 5.14 the average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 of the 10 simulations is shown.

Period	0	5	10	15	20	24
Average	1237	983.5	929.5	869.7	823.6	796.7
Median	1237	985	920.5	855.5	810	783
Maximum	1237	997	961	931	900	875
Minimum	1237	972	905	846	795	764

Table 5.14 The average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 of the 10 simulations with different farm and field location.

In Table 5.15 the average, median, maximum and minimum values relative to the benchmark –1 are shown in percent of the 10 different farm location simulations.

Period	0	5	10	15	20	24
(Average /Benchmark)-1 (%)	0	-1.35	-2.36	-5.98	-6.3	-7.79
(Median / Benchmark)-1 (%)	0	-1.2	-3.3	-7.51	-7.85	-9.38
(Maximum / Benchmark)-1 (%)	0	0	0.95	0.65	2.39	1.27
(Minimum / Benchmark)-1 (%)	0	-2.5	-4.94	-8.54	-9.56	-11.57

Table 5.15 The average, median, maximum and minimum values of the number of farms relative to the benchmark –1 shown in percent of the 10 different simulations with different farm and field location.

The sensitivity of the different farm locations is as expected much lower than the sensitivity of location of the landscape characteristics. Though the variations between the 10 simulations relative to the benchmark are considerably smaller there are, however, still measurable differences. Considering the large effects on the farms' performance caused by the allocation of landscape characteristics a considerable part of these variations can be caused by the unavoidable small displacements of landscape characteristics between some of the farms. The relatively small variations demonstrate, however, that the displacements must be minor. The change in the individual farm's local competition for land is another likely component for the variation between the simulations of the 10 different farm locations. The effect of the competition is, however, only witnessed indirectly. This claim will therefore first be investigated later. It is useful to investigate the decline of different farm types relative to their initial number for period 0,5,10,15,20 and 24 as an average over the 10 different simulations with different farm locations. This is shown in Table 5.16.

%	0	5	10	15	20	24
O-FC1 (18)	100	100	100	100	100	100
IF-FC2 (15)	100	100	100	98.67	97.33	97.33
O-FC3 (22)	100	100	100	100	100	100
O-FC4 (17)	100	98.82	94.7	46.47	31.18	5.88
IF-FC5 (62)	100	95.8	89.35	82.9	76.45	71.29
O-FC6 (4)	100	100	100	100	100	97.5
IF-FC7 (137)	100	93.65	89.49	83.72	81.39	79.92
IF-FC8 (62)	100	95.48	87.09	81.94	76.61	74.52
IF-FC9 (138)	100	95.58	88.99	83.4	78.19	74.42
IF-FC10 (46)	100	97.6	94.13	92.6	89.13	86.3
IF-D11 (18)	100	100	99.44	93.33	87.78	86.11
IF-D12 (6)	100	100	100	100	100	100
IF-D13 (11)	100	100	100	100	100	100
IF-D14 (8)	100	100	100	100	100	100
IF-GL15 (47)	100	69.57	61.27	48.51	41.91	38.51
IF-GL16 (43)	100	96.28	89.77	81.86	71.4	67.2
IF-GL17 (140)	100	73.14	64.36	55.21	50.36	49.5
IF-M18 (5)	100	80	80	80	80	80
O-M19 (4)	100	95	95	95	95	95
IF-M20 (3)	100	93.33	93.33	93.33	93.33	93.33
IF-M21 (178)	100	4.72	3.7	3.31	2.3	1.74
IF-M22 (225)	100	96.84	94	92.31	89.38	87.82
IF-M23 (28)	100	98.57	97.14	96.79	96.07	95.71
Average number of farms	1237	983.5	929.5	869.7	823.6	796.7

Table 5.16 The decline (in percent) within the different farm types relative to their initial number for period 0,5,10,15,20 and 24 as an average over the 10 different simulations with different farm and field location.

When the development in the number of farms within each farm type for the simulations with the 10 different locations of farms is compared to the results from the 30 simulations with different landscape characteristics the overall impression is that the performance of the first tops the latter. However, also here farm types are surviving in larger numbers under the changing landscape characteristics. Most distinct are the farm types IF-M18 and O-M19 (see Table 5.10 and 5.13).

The development found in the ten simulations is broadly in line with the benchmark simulation. There are of course variations between the values for the individual farm types as also reflected in the number of farms, but none of the farm types witnesses' dramatic changes due to the different farm locations. So though the model is affected by the spatial location of the individual farms and this is reflected in variation of the exact number of farms surviving at a given time period the structure of the regional development is not changing in any notable way. This is, however, when the model is subject to a stable political development that the spatial location of the individual farms only has these minor disturbances. What if the region is subject to some dramatic politically induced changes? Are the findings still of the same nature? If the individual farms in the model are unaffected by their local competition from other farms dramatic changes in the local composition of farms would not affect them.

5.5.4 Analysis of the effect of policy change on the spatial sensitivity

By testing the same ten farm locations against a different and more dramatic policy change the effect of the local competition will better reveal itself. The model should produce similar results as seen with the stable policy scenario if there is no or little effect of the competition.

Instead of maintaining the same political support scheme throughout the simulation is the following simulations subject to a policy scenario where the public support ends. The scenario investigates the effects of the regional development when all subsidies are abolished in an abrupt way.

The number of farms will of course have to reflect the increased competition and the less financial means, but the variation between the 10 different simulations should be similar to what was found in the stable situations. If larger variations are found, it will strongly indicate that their local environment affects the farms. The policy here introduced starts at the same level of support as the previous scenario. In period 4 the support is then abolished and the farms will only be able to make an income through the market.

The result as the average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 of the ten simulations with the different farm locations under this policy scenario is shown in Table 5.17.

Period	0	5	10	15	20	24
Average	1237	863.8	685.1	558.2	439	378.7
Median	1237	943	638	493.5	366	284.5
Maximum	1237	922	826	744	656	627
Minimum	1237	825	610	462	317	237

Table 5.17 The average, mean, maximum and minimum number of farms for period 0,5,10,15,20 and 24 of the ten simulations with the different farm locations under the policy scenario where the public support is abolished after period 4.

Already here the larger variation compared to the 10 simulations under the stable political conditions is obvious (see Table 5.14). Under stable political conditions the span between the maximum and minimum values in period 5 was equal to 25, in period 10 equal to 56, in period 15 equal to 85, in period 20 equal to 105 and in period 24 equal to 111. In the case where the political support is abolished the values for the same periods are: 97, 216, 282, 339 and 390. These significantly larger values indicate that once changes are taking place in the local settings and the farms come under pressure the spatial location of the farms does play a role. This may also help understanding the otherwise peculiar results from the landscape characteristic that some of the farms perform better on average under varying landscape qualities compared with the variation in location. When the local spatial locations of the farms do play a part in the individual farms development particularly in situations with dramatic changes it is also likely that individual farms or types of farms perform better as a result of the changed local environment. In Table 5.18 the sensitivity of the farm types towards changes in the composition of the neighbouring farms is shown during the abolishment of support. The table shows the average decline over the 10 simulations of the different farm types relative to their initial number (in percent) for period 0,5,10,15,20 and 24. This is supplemented with Table 5.19 showing the span between the maximum and minimum number of farms of a given type relative to the initial number of farms of this type (in percent).

%	0	5	10	15	20	24
O-FC1 (18)	100	93.89	87.78	76.67	72.22	68.89
IF-FC2 (15)	100	93.33	91.33	88.67	78	73.33
O-FC3 (22)	100	100	100	100	100	100
O-FC4 (17)	100	86.47	60.59	44.7	27.65	16.47
IF-FC5 (62)	100	85.48	78.38	69.35	55.97	41.93
O-FC6 (4)	100	97.5	97.5	92.5	92.5	82.5
IF-FC7 (137)	100	84.89	77.37	61.31	51.53	45.55
IF-FC8 (62)	100	89.68	77.1	67.42	53.7	46.77
IF-FC9 (138)	100	86.81	77.83	67.68	54.78	49.71
IF-FC10 (46)	100	89.78	67.6	48.91	33.7	27.61
IF-D11 (18)	100	96.67	83.89	74.44	63.33	56.67
IF-D12 (6)	100	100	100	100	100	100
IF-D13 (11)	100	100	100	100	100	100
IF-D14 (8)	100	100	100	100	100	100
IF-GL15 (47)	100	37.66	18.51	15.53	12.77	11.06
IF-GL16 (43)	100	67.2	41.4	24.19	10.47	9.3
IF-GL17 (140)	100	69.43	36	21.43	11.86	9.79
IF-M18 (5)	100	80	80	80	80	80
O-M19 (4)	100	95	95	95	95	95
IF-M20 (3)	100	93.33	93.33	93.33	93.33	93.33
IF-M21 (178)	100	3.26	0.62	0.34	0	0
IF-M22 (225)	100	85.64	64.22	49.33	33.6	24.67
IF-M23 (28)	100	39.29	18.93	17.14	16.07	15.36
Average number of farms	1237	863.8	685.1	558.2	439	378.7

Table 5.18 The decline (in percent) of the different farm types relative to their initial number for period 0,5,10,15,20 and 24 as an average over the 10 different simulations with different farm and field location with the abolishment of public support in period 4.

The Table 5.18 is mainly shown to provide a feel for the magnitude of the changes in the farm structure due to the new political framework conditions. A few farm types are unaffected by the change and single farm types are temporarily doing better in spite of the abandoned support for the sector (that is, however, only the case for farm type O-FC4 in period 24 in the periods shown in the table). More informative for the understanding of the model's spatial sensitivity are the variations between the maximum and minimum number of farms within each farm type relative to the number of farms in the initial period for this farm type (Table 5.19).

%	0	5	10	15	20	24
O-FC1 (18)	0	16.67	33.33	38.89	50	55.56
IF-FC2 (15)	0	26.67	26.67	33.33	46.67	53.33
O-FC3 (22)	0	0	0	0	0	0
O-FC4 (17)	0	23.53	52.94	70.59	64.71	64.71
IF-FC5 (62)	0	8.06	14.52	25.81	37.1	56.45
O-FC6 (4)	0	25	25	25	25	50
IF-FC7 (137)	0	4.38	10.22	27.74	33.58	46.72
IF-FC8 (62)	0	16.13	19.35	32.26	38.71	50
IF-FC9 (138)	0	9.42	11.59	22.46	39.13	44.93
IF-FC10 (46)	0	13.04	43.48	56.52	63.04	69.57
IF-D11 (18)	0	16.67	33.33	33.33	50	44.44
IF-D12 (6)	0	0	0	0	0	0
IF-D13 (11)	0	0	0	0	0	0
IF-D14 (8)	0	0	0	0	0	0
IF-GL15 (47)	0	25.53	31.91	34.04	38.3	38.3
IF-GL16 (43)	0	44.19	44.19	27.91	32.56	27.91
IF-GL17 (140)	0	17.14	47.14	47.86	42.86	37.86
IF-M18 (5)	0	40	40	40	40	40
O-M19 (4)	0	25	25	25	25	25
IF-M20 (3)	0	33.33	33.33	33.33	33.33	33.33
IF-M21 (178)	0	3.93	2.45	1.12	0	0
IF-M22 (225)	0	13.78	30.22	38.67	44.44	50.22
IF-M23 (28)	0	46.43	39.29	39.29	35.71	32.14
Average number of farms	1237	863.8	685.1	558.2	439	378.7

Table 5.19 The variations (in percent) between the maximum and minimum number of farms within each farm type relative to the number of farms in the initial period for this farm type over the 10 different simulations with different farm and field location with the abolishment of public support in period 4.

The very large variation between the maximal and minimal number of farms of a given type is hard to fully ascribe to the small variations in a few landscape characteristics in farms fields. This is therefore strongly suggesting that the spatial locations of the farms do matter in the case of strong sudden changes in the regional farm structure. The interdependency through the land market for the farms means that the composition of the neighbourhood produces variations in the results. Though the variations in percent in Table 5.19 seem to be considerable; it is important to remember that the number of farms ascribed to a given type before making any judgments. The 25% variation seen in farm type O-M19 means only that there is a single farm more in the maximum case of the ten simulations compared to the minimum case. For the majority of farm types the differences are rising with the number of simulation periods, however, as it is the difference between the maximum and minimum this is not always the case as e.g. farm type IF-M21 or IF-GL16 shows.

Considering the combined picture this spatial sensitivity analysis points towards the conclusion that the model is fundamentally stable in its results at the same time as it reacts to changes in the initial conditions. The initial spatial constellation of the farmsteads and their fields seems, however, to play an increasing role when the model is simulating sudden dramatic changes in the structural development. This underlines the importance of recreating a reliable allocation of the farms in space and supports the argument of incorporating the spatial dimension into the model. The visual representations of the simulated outputs may help to understand and communicate the results but more importantly, that the quality of the results increases with the model's ability to reproduce the spatial patterns found in empirical data.

6 Validation of AgriPoliS

6.1 Simulation models and their validation

6.1.1 Introduction

The application of simulation models has increased significantly in recent years. These models are being used in problem solving as well as a support tool for decision-making. Moreover, simulation models have played a very significant role in exploring new grounds in theoretical problems e.g. have simulation models been fundamental for the theoretical understanding of complex systems. Whenever a simulation model is applied, there is a demand for validation and verification of the model.

Verification addresses the model that forms the basis of the simulation and examines its agreement with reality, while validation is testing how well the accordance between the model results is with the studied system.

In this paper the following definition of validation is used "*substantiation that a computerized model within its domain of applicability possesses a satisfactory range of accuracy consistent with the intended application of the model*" (Schlesinger et al. 1979).

In accordance with the above definition, the validation of a simulation model should be an ongoing process, where the intended level of accuracy of the model is specified prior to the development of the model. The validation should include determination of the type of questions, to which the model is developed to give an answer, as the validation has to reflect these questions.

Furthermore, the kind of modelling used in building the model is influencing the types of possible validation methods.

During the development of a simulation model the individual objects of the model should be validated as thoroughly as possible. The so-called "Sargent's circle" shows the simplified version of the modelling process. It is visualising the different steps of the modelling process and their interplay with verification and validation.

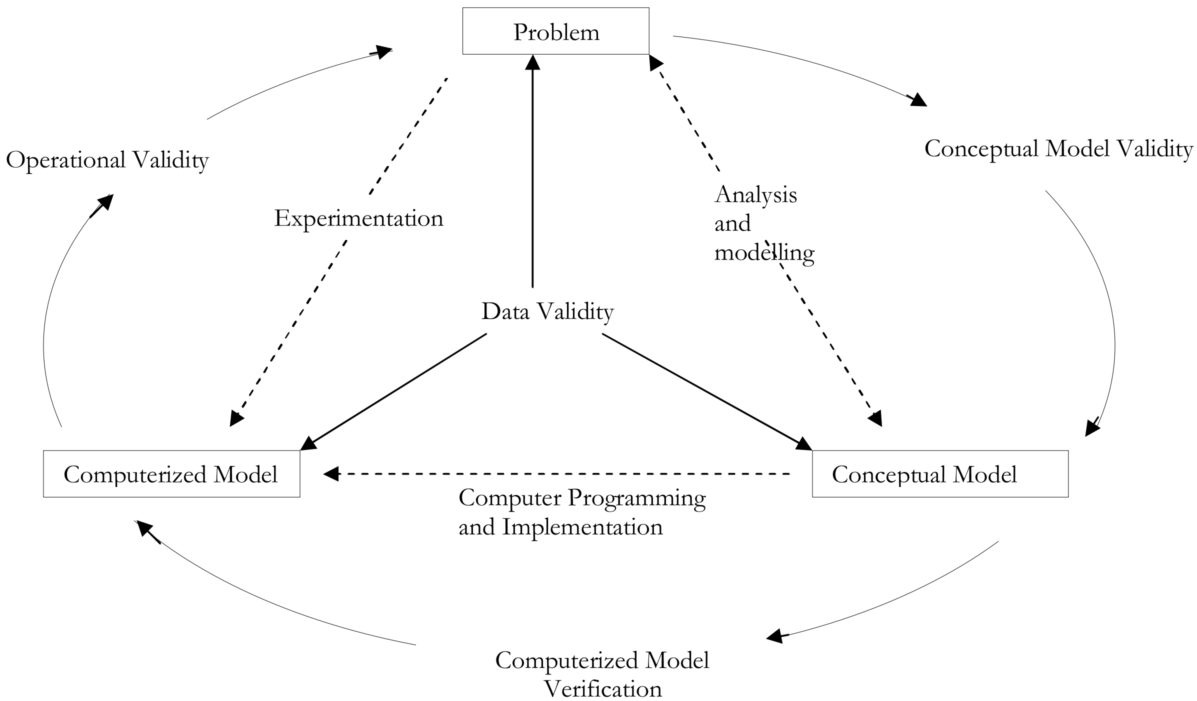


Figure 6.1 Simplified version of the Modeling process, the so-called "Sargent's circle"(Sargent 1996).

The model developers themselves make most of the validation during the development of the model. To avoid their subjectivity validation by external experts is another possibility. In addition it has been attempted to make benchmarks or scoring models to evaluate the findings.

Validation techniques can broadly be classified into three major groups:

- Visual approaches,
- Statistical approaches, and
- Sensitivity analyses.

The three broad groups of classification of validation techniques can of course be specified more.

A list of different validation techniques can be seen below:

•**Animation**: the model's operational behavior is displayed graphically as the model moves through time. •**Comparison to other models**: Various results (e.g. outputs) of the simulation model being validated are compared to results of other (valid) models. •**Degenerate tests**: the degeneracy of the model's behavior is tested by appropriate selection of values of the inputs and internal parameters. •**Event Validity**: The "events" of occurrences of the simulation model are compared to those of the real system to determine if they are similar. •**Extreme Condition tests**: the model structure and output should be plausible for any extreme and unlikely combination of levels of factors in the system. •**Face Validity**:"face validity" is asking people knowledgeable about the system whether the model and/or its behavior are reasonable. •**Fixed Values**: Fixed values (e.g. constants) are used for various model input and internal variables and parameters. This should allow the checking of model results against easily calculated values. •**Historical Data Validation**: if historical data exist (or if data are collected on a system for building or testing the model), part of the data are used to determine (test) whether conducted by driving the simulation model with either distributions or traces •**Historical Methods**: the three historical methods of validation are rationalism, empiricism, and positive economics. Rationalism assumes that everyone knows whether the underlying assumptions of a model are true. Logic deductions are used from these assumptions to develop the correct (valid) model. Empiricism requires every assumption and outcome to be empirically validated. Positive economics requires only that the model be able to predict the future and is not concerned with a model's assumptions or structure.	•**Historical Methods**: the three historical methods of validation are *rationalism*, *empiricism*, and *positive economics*. Rationalism assumes that everyone knows whether the underlying assumptions of a mdel are true. Logic deductions are used from these assumptions to develop the correct (valid) model. Empiricism requires every assumption and outcome to be empirically validated. Positive economics requires only that the model be able to predict the future and is not concerned with a model's assumptions or structure. •**Internal Validity**: Several replications (runs) of a stochastic model are made to determine the amount of (internal) stochastic variability in the model. •**Multistage Validation**: Naylor and Finger (1967) proposed combining the three historical methods into a multistage process of validation. •**Operational Graphics**: Values of various performance measures, are shown graphically as the model moves through time. •**Parameter Variability-Sensitivity analysis**: This technique consists of changing the values of the input and internal parameters of a model to determine the effect upon the model's behavior and output. The same relationships should occur in the model as in the real system. •**Predictive validation**: The model is used to predict the systems behavior, and then comparisons are made between the system's behavior and the model's forecast to determine if they are the same. •**Traces**: The behavior of different types of specific entities in the model are traced through the model to determine if the model's logic is correct and if the necessary accuracy is obtained •**Turing Tests**: People who are knowledgeable about the operations of a system are asked if they can discriminate between system and model outputs.

Table 6.1 List of different validation techniques (Sargent 1998)

The *visual approach* provides a graphical overview of the fit of the simulation results with real-world data. Comparisons are made with regard to the shape of curves, their slopes, inflection points, degree of convergence etc.

The *statistical approach* attempts to quantify the deviation between simulation results and actual data by means of statistical indicators, such as mean squared error or statistical tests.

Sensitivity analyses suggest to implement marginal changes of model variables and to study how stable simulation results are and whether the impact on results is theoretically plausible.

6.2 Validation of AgriPoliS

AgriPoliS has been used as a part of the MEA-Scope modelling approach to simulate the structural development as a result of Common Agricultural Policy (CAP) reform options. The hierarchical modelling approach is a top-down modelling approach where the structural development foreseen by AgriPoliS works as the foundation for the two subsequent models. An investigation of how well results of AgriPoliS are in accordance with the studied system is important for both AgriPoliS as such as well as the combined MEA-Scope model. Of course the reliability of both the MODAM and the FASSET – model is also important for the strength of the statements of the combined model. However, their placement in the modelling structure, their modelling objective as well as their modelling method makes the risk of one of them inducing a major imperfection in the combined model relative small in comparison to AgriPoliS. Both of the models are applied later in the modelling chain, and only MODAM could potentially transfer unreliable data to FASSET for further processing. Moreover both of the models build for a considerable part on processes described within natural sciences and which therefore can be verified with a different degree of precision compared to the predictability of an economic model. The inaccuracies are smaller within natural sciences as a consequence of scientific reductionism and the capability of reproducing experiments. Finally both MODAM and FASSET are only simulating a single production period and therefore not in risk of self-perpetuating processes in the same degree as a dynamic model such as AgriPoliS.

The validation efforts of the MEA-Scope model will therefore concentrate on the reliability of AgriPoliS.

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

Although validation has been an issue in agricultural economics, simulation models from this part of the sciences have still little tradition for validation and the literature conveys often an informal set of procedures to check the validity of models. This is even more pronounced within agent-based modelling of agricultural development.

The ability to replicate empirical evidence is often seen as the only truly decisive criterion for quality of a scientific model. In this view, it is good scientific practice to maximise the empirical testability of a scientific model and the more empirical tests it has resisted without refutation the more it deserves to be called scientific.

However, the essential purpose of any simulation study is the analysis of non-observable scenarios such as the implementation of hypothetical policies or new technologies. By their very nature, there is no real-world data available for these situations. The simulation model needs therefore not only to be empirically valid. Stanislaw (1986) suggested that validation of simulation research should include:

- Theory validity (the validity of the chosen theory relative to the investigated system)
- Model validity (the validity of the model relative to the theory)
- Program validity (the validity of the simulator relative to the model)

The total validity of the model is then the combined validity of the three measurements.

The list can be extended with justification e.g. also include the validity of the behaviour of the agents, validity under extreme conditions and the validity of the structures in the model compared to the investigated system.

This list is of course by no means complete, but it underlines the importance of judging AgriPoliS on more than its ability to reproduce historical real-world data sets. In the case of AgriPoliS, as with most other agent-based models focusing on the agricultural sector, it is, however, the empirical test of the model's validity, which noticeably lacks in the validation of the model. The documentation on the other aspects of the model's validity is not in the form of measurements resulting in a single combined value but in form of reports (Jelínek et al. 2007; Kellermann et al. 2007), background documentation (Happe et al. 2004) and journal articles (Balmann 1993; 1997; Happe et al. 2006; Happe et al. 2006b), where these elements of model validation have been provided to the scientific community. Providing the empirical validation of agent-based models requires, however, that the historical data available for comparison be of a special nature as well as a number of other factors to be in place. In order to clarify the process of empirical validation and some issues connected to the process consider the following hypothetical example:

Empirical validation may take its point of departure in a set of empirically observed data of the generic form (Windrum et al. 2007):

$$(\underline{\mathbf{z}})_{\mathbf{i}} = \{\mathbf{z}_{\mathbf{i,t}}, \mathbf{t} = \mathbf{t}_{\mathbf{0}},....,\mathbf{t}_{\mathbf{1}}\}, \mathbf{i} \in \mathbf{I} \tag{6.1}$$

where the set **I** refers to the observed entity (e.g. farms, firms or households) for which empirical observations for the finite set of time-periods $\{\mathbf{t}_{\mathbf{0}},...,\mathbf{t}_{\mathbf{1}}\}$ in form of *K* variables is contained in the vector $\underline{\mathbf{z}}$. Summarised over the observed entities the data will have the following form (Windrum et al. 2007):

$$\underline{\mathbf{Z}} = \{\mathbf{Z}_{\mathbf{t}}, \mathbf{t} = \mathbf{t}_{\mathbf{0}},....,\mathbf{t}_{\mathbf{1}}\} \tag{6.2}$$

The observed dataset(s) may have a number of characteristics in the form of "stylised facts" or statistical properties, which the model tries to explain.

Both datasets $(\underline{\mathbf{z}})_{\mathbf{i}}$ and $\underline{\mathbf{Z}}$ are the unique outcome of an unknown, real world data-generating process (*rwDGP*). Similarly the model can also be understood as a data-generating process (*mDGP*). The goal for the modeller is that the *mDGP* provides a sufficiently good "approximation" of the *rwDGP* and that this approximation is based on a meaningful explanation of the causal mechanisms generating the observed data.

Empirical validation is therefore the process of comparing and evaluating the ability of the *mDGP* to represent the *rwDGP* (Windrum et al. 2007).

Often when empirical validation of agent-based models is considered the focus is how to compute comparable results as most agent-based models have incorporated some stochastic processes and have some degree of non-linearity in the results.

This is, however, not an issue of similar concern for AgriPoliS. Although the model can make use of some stochastic processes in modelling a number of variables the model is fundamentally deterministic by nature.

However, empirical validation of agent-based models such as AgriPoliS faces other complications, which have to be addressed. The generic description of the empirically observed data is the same whether used for validation of an agent-based model or any other modelling approach. The datasets $(\underline{\mathbf{z}})_{\mathbf{i}}$ and $\underline{\mathbf{Z}}$ from the *rwDGP* may conceal a situation where either of them is fairly easy to predict while the other is very difficult. This depends on the nature of the investigated system as well as elements such as the accuracy or scale by which the *rwDGP* is expressed in the dataset.

The summarized data set $\underline{\mathbf{Z}}$ may e.g. be that the sun shines, modelling details such as how many solar flares will occur within a given time period is a lot harder. Similarly the detailed set $(\underline{\mathbf{z}})_i$ may express a fairly banal element in the investigated system, however, its interdependence with other elements makes the combined system hard to predict.

Analogously for the *mDGP*, either $(\underline{\mathbf{z}})_i$ or $\underline{\mathbf{Z}}$ may be the difficult part of the modelling depending upon the model, however, it is often hard to differentiate between the two. But that being the case the chosen modelling approach will often reveal some insights into its strengths and weaknesses in reproducing the *rwDGP*. Please note that we only consider the ability to reproduce a given set of empirical data and do not consider the reliability of different modelling procedures as such.

An advantage of an agent-based model such as AgriPoliS is the ability to capture in the calibration the heterogeneity found in the empirical data.

It also means, that the number of degrees of freedom that the model has is tremendously larger than traditional top-down modelling approaches where large groups of farms are described as a single entity. Each farm may act individually and constitutes therefore a possible source of error. As the actions of one influence the actions of other farms the empirical validity of the model is depending on the accuracy of each action taken by each individual farm. With the large number of farms included and the large number of possible actions they may take the outcome of the model is reflecting this. Therefore although the large number of farms with their individual actions constitutes a potential source of errors, the size of which may also be to the advantage of the model. If only some of the individual farm's actions overshoot the real choices, while others do the opposite they may cancel out each other and lead to a reasonable aggregated result. However, as the behavioural motivation for the agents often is the same (profit maximization in the case of AgriPoliS) the model will tend to be biased in a given direction. It could be discussed whether the results of models of this nature should be used for predictions (or back castings) or they should be used only to point towards a given direction of the investigated system.

Such an argument implies that the scale and details of the $(\underline{\mathbf{z}})_i$ dataset that an agent-based model uses is too detailed for a real validation of the results. Suggesting one should investigate data on a more aggregated level.

Although this may be true such a statement needs to be tested before one is able to accept it. Agent-based modelling should, however, be judged on a standard acknowledging the particular characteristics of this modelling approach.

The many degrees of freedom which are inherently built into the model make it difficult to produce the same accuracy as seen with standard models; however, the agent-based model offers an abundance of details other modelling approaches are unable to produce. Some might argue that they would rather like a few accurate values than a large number of inaccurate values and in some cases this is true. One should, however, remember that such a direct comparison is seldom possible. Though one model might be better than another to reproduce the right number of farms within a region for a given period of time it does not mean that the composition of the farm types in the region with the less reliable model cannot be of use. Such data might help to give a rough but necessary understanding of how the theory is predicting a given situation and is influencing the individual farms or farm types.

This indicates that rather than understanding modelling as an attempt to predict the development of the investigated system one should understand the model as an idealized optimisation of an approximation of the investigated system. In this light the discrepancy between *rwDGP* and *mDGP* could be understood as the distance between the reality and a local optimum. In many ways this type of analysis would be comparable to other types of deductive understanding of the economic sciences. However, before the discrepancy between *rwDGP* and *mDGP* can be found, it is necessary to understand the foundation on which the analysis has been conducted. The calibration of the model to the investigated area will therefore be presented as well as the empirical data against which the model results will be measured.

6.3 Calibration

The calibration of agent-based models will very often involve some kind of adaptation of one or more empirical samples to the model simply because the details required by agent-based models exceed what is available. Detailed information covering whole regions on a single farm level is seldom accessible. This means that a number of calibration methods have been developed to ensure that the calibration of agent-based models is representing the investigated region in an acceptable way. At the same time the known discrepancies between the real region and its virtual representation in the model represent a source of error that is hard to eliminate from the validation results. Although this study also makes use of empirical samples re-scaled to the site the majority of data is used to characterize the individual farms based on detailed information on a single farm level. The discrepancies between the real region and its virtual representation are thereby reduced to a minimum. This means that the main emphasis of the validation can be placed on the discrepancy between *rwDGP* and *mDGP* rather than accusing the data used for the calibration for the differences.

This underlines the importance of the calibration procedure and therefore an account of the used calibration procedure is given.

AgriPoliS has been calibrated to the Danish river Gudenå watershed region for two years, namely the year 1998 and the year 2002.

In the Danish region we have access to accurate information on: the spatial location of the farms and fields, the number of fields and their soil types as well as the number and types of animals.

This detailed data originates from the national Danish Agricultural Registers, with the Danish acronym GLR/CHR (DMFAF 1999). The GLR/CHR database is a part of the system used to administer EU area and livestock headage support payments (Höll et al. 2002). The machine capacity of the farm is assumed to fit the current production capacity. Based on the current production the machine capacity is therefore calculated and assigned to each individual farm.

First a sub-sample of the FADN-data was made by adjusting the full FADN sample to the regional statistics through minimizing the quadratic deviations between the regional statistics and the sum of farm characteristics times the new extrapolation factors assigned to the farms.

This sub-sample of FADN farms as well as all farms from the region were then classified according to the same farm typology (Kristensen and Kristensen 2004). The typology is developed for Danish farming conditions and contains 31 different farm types. The typology utilizes the detailed information on the farms to classify them using a decision tree technique. The economic values in the FADN farms are then converted into €/ha. The individual farms with the same farm type according to the farm typology are given this value times their ha of land and thereby converting the values back to values fitting their size of production.

This method assumes that the FADN farms have to be representative for the regional farms and that the different production types within farming have to be taken into account when transferring economic quantities. Finally it must implement the size of production. This means that each individual farm in the modelled version of the Danish case study area is unique in all its farm characteristics and that most of the values ascribed to the farms are empirically founded.

The technical coefficients, which represent the entire room of potential production activities present in the location, are the same for the two years assuming that no large technical productivity gains were made on the ordinary farm in the region during the period. So although the sector of course has experienced technical progress within the four years period we are assuming that the technical equipment on the average farm in the region was maintained more or less the same within the period.

The model hereby captures the real heterogeneity of the 2383 farms and 1865 farms present in year 1998 and year 2002 respectively.

An important modification has, however, been introduced on the map of the fields belonging to the farms. Danish legislation demands that the individual farms not only have access to enough land to meet the harmonisation requirements but that the farms in fact possess enough land as owner to meet these requirements. This has; however, the consequence that some of the farms are buying land to meet the harmonisation requirements where the prices are reasonable without considering what is possible to utilise within the production.

Some of the farms within the study area had land on small islands, to which they could not get access within the duration of a workday. As AgriPoliS includes transportation cost between the farmstead and the field such areas would immediately be abandoned in the model. AgriPoliS is considering harmonisation requirements in the form of maximum livestock density, however, not with the special Danish ownership rules specified. The few fields in question have therefore been artificially moved closer to the study area. This has been done so that the relative distance between these plots still indicates the plots that were originally furthest away. In Figure 6.2 the fields for the Danish study area in year 1998 are shown. The fields are marked with black; the red hexagon indicates approximately the border between the fields that have not been moved (inside the hexagon) and fields that have been moved closer (outside the hexagon). Two red arrows point towards examples of moved fields.

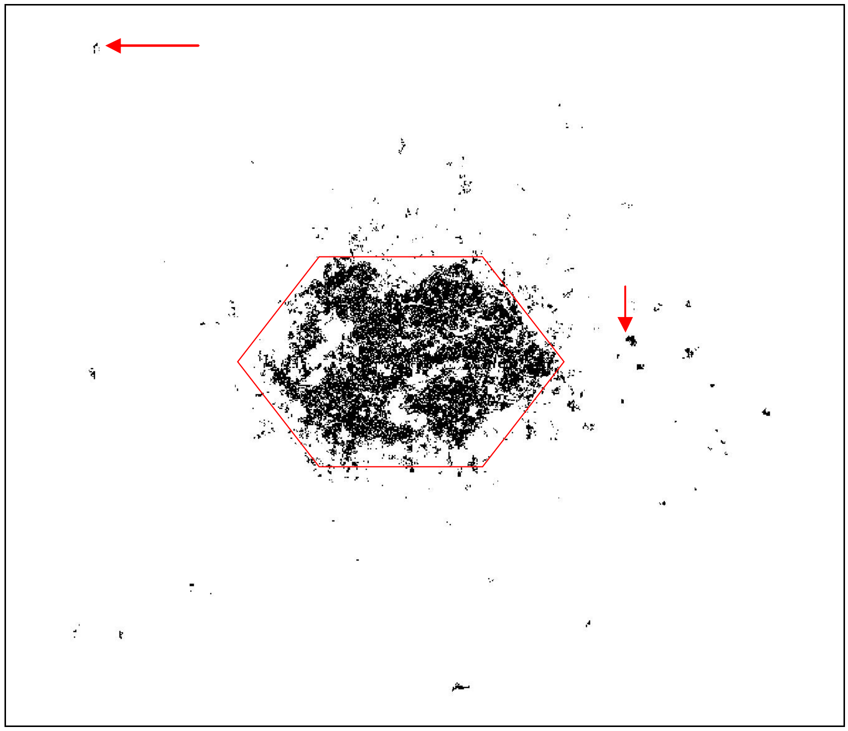


Figure 6.2 The fields of the Danish study area shown in year 1998. The fields are marked with black; the red hexagon indicates approximately the border between the fields that have not been moved (inside the hexagon) and fields that have been moved closer (outside the hexagon). Two red arrows point towards examples of moved fields. Own figure.

The movement of the fields from their real location to the locations indicated in the above map is of course at variance with the empirical data. It is done in order to compensate for a discrepancy between the reality and the model's abilities. The procedure ensures that the farms maintain their real size. There is, however, a drawback with this procedure. It is difficult to ensure that the same fields are moved to the exact same locations in the empirical maps for the different years. Therefore some of these moved fields will not show the same values when spatially analysed. Measures have been taken to reduce this problem to a minimum and the number of fields involved makes it a minor problem. Having said that the issue still exists and should therefore be considered when different results are compared spatially.

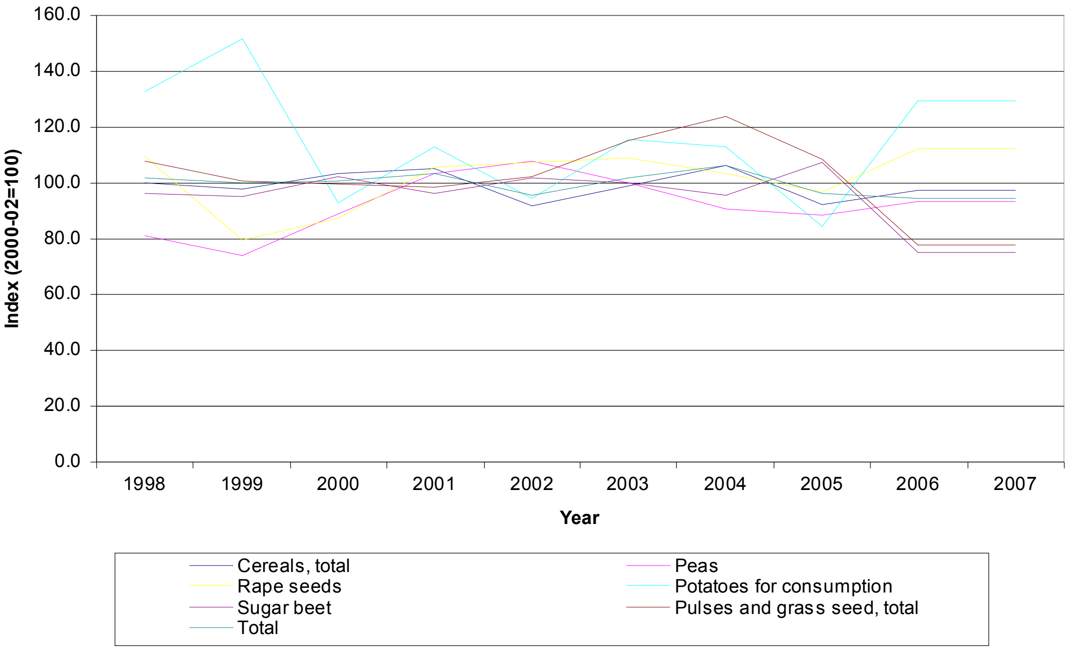


Figure 6.3 The price index for plant products excl. compensation payments. Index (2000-2002=100). (Larsen 2007)

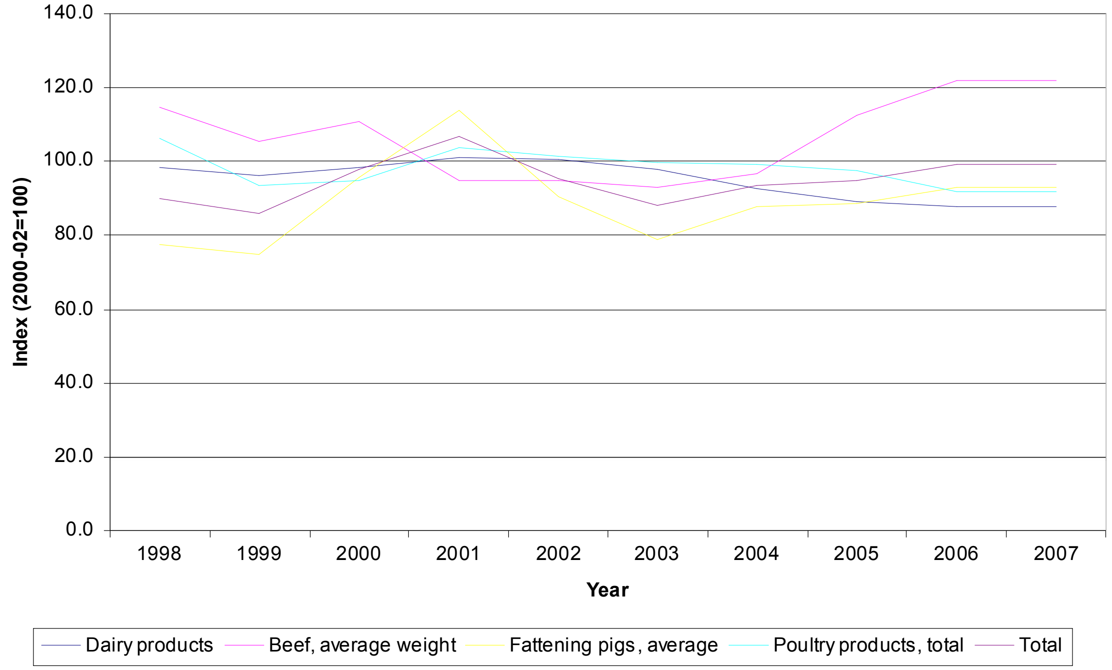


Figure 6.4 The price index for livestock products excl. compensation payments. Index (2000-2002=100). (Larsen 2007)

As the prices for the period 1998-2007 are known the price development of the individual commodities and services within the model is following the real trends. The real price development in the period 1998-2007 can be seen in

Figure 6.3 for plant products and in Figure 6.4 for livestock products. The figures show the developments in a price index based on the period 2000-02.

The real price trends ensure that the farms are optimising each single production period under similar conditions as in the real case.

6.4 Results

6.4.1 Comparison of the farm structure in the river basin Gudenå, Denmark.

Empirical data from the years 1998, 2000, 2002 and 2004 on the exact location of individual plots as well as farm characteristics are used to validate the model by backcasting.

The procedure is as follows. The structure of the individual farms for the year 1998 is read into AgriPoliS. This farm structure along with regional GIS-maps is used to calibrate the model. The model is supplemented with price trends based on the real price development. The result of the simulation is compared to the empirical data.

The analysis will mainly compare the simulated results with the real data from year 2002. This is done in order to eliminate any dramatic shifts in the farm structure due to the effects of the 2003 CAP reform. Although the aim of this model is in part to investigate the effects of CAP-reform options such large external events are in the risk of disturbing the results of a validation in an unbeneficial way. Because the model will immediately react strongly on such sudden changes in the framework conditions for the sector and enter a new stable level of structural development. The real farms will not and cannot react in the same dramatic way shifting the production or closing the production over night.

The structure of the sector will, however, after some time reflect the same economic conditions and therefore the structures found within the model will hopefully reflect the real situation. To validate this behaviour a longer period of time is needed. The year 2004 will therefore not be used as the main year for the comparison. Comparing simulated results for a single year involves always the risk of that particular year being an outlier, and ideally the trend over several years should be used. This has been done when the data enabled it.

The Table 6.2 represents the real number of farms in the region in the years 1998, 2000, 2002 and 2004 compared to the simulated results and an average value for the years 2000, 2002 and 2004 is shown:

Year	Real number of farms	Number of farms in AgriPoliS	The difference between the two	The difference as % of the total numbers of farms
1998	2383	2383	0	0%
2000	2173	2127	-46	2.12%
2002	1871	1980	109	-5.83%
2004	1959	1778	-181	9.24%
Average 2000-2004	2001	1962	-39	-1.95%

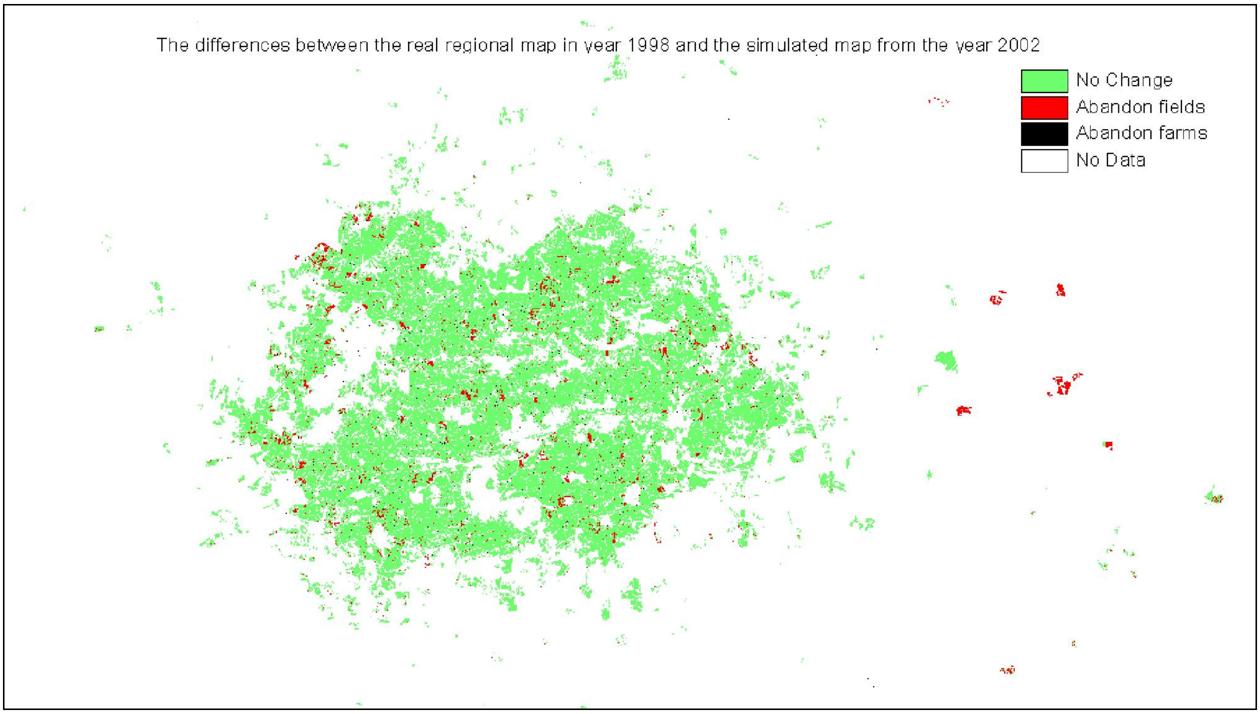
Table 6.2 The real number of farms in the region and in AgriPoliS in the years 1998, 2000, 2002 and 2004. The difference between the two and the difference as percent of the total number of farms for the years 2000, 2002 and 2004

The value of the real number of farms in the region for year 2004 has to be further investigated as the sudden rise in the number of farms seems to contradict a long declining tendency seen in the sector. The sudden rise in the number of farms in year 2004 could give a reasonable suspicion of some kind of changed reporting procedure or agricultural legislation. It could also be due to the 2003 CAP reform.

The difference in the number of farms for this six year period seems acceptable, especially when the nature of agent-based models is taken into account. In particular the difference between the average values for the three years 2000, 2002 and 2004 amounting to only –1.95% gives confirmation to the model. It is, however, a very small sample size and particularly the development in the 2004 numbers help the average value as it equalizes the differences. Moreover, such numbers can conceal differences in the more detailed information such as the individual farm level. Therefore the differences between the actual farms continuing and the farms found in the model have to undergo a more thorough comparison. Their individual characteristics such as type of production, location and size of field and number of animals are thus compared.

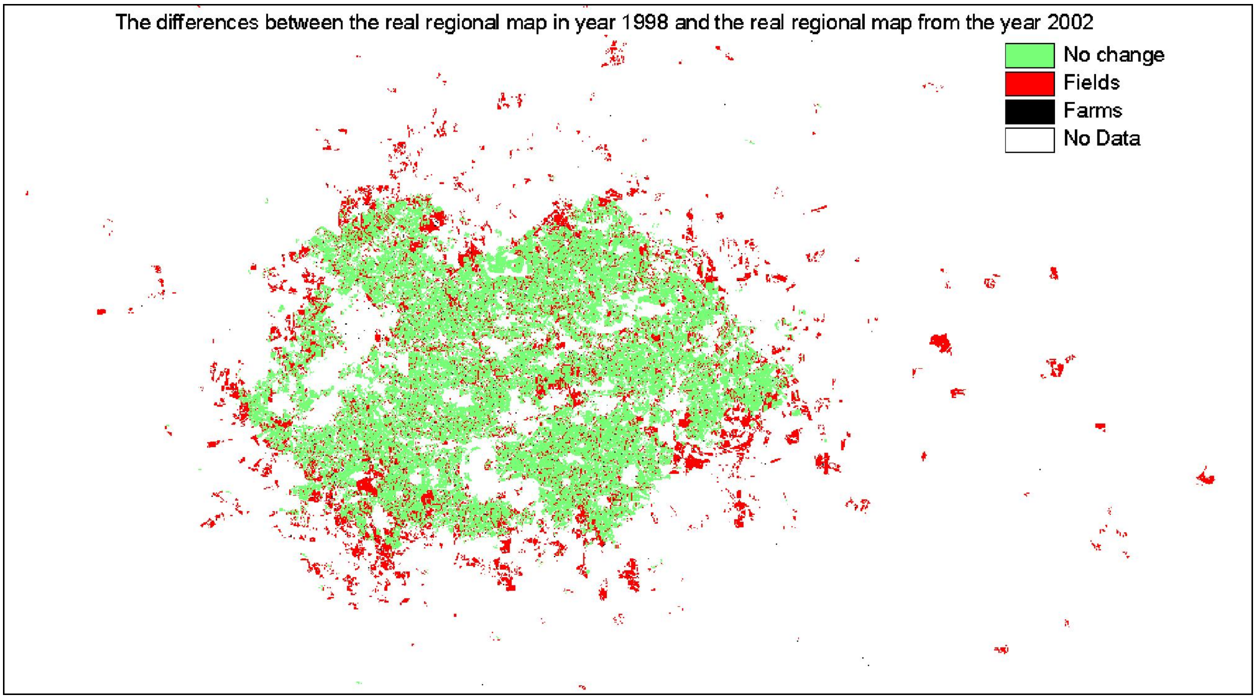
The comparison between the real data and the simulated results will first be investigated with a regional perspective where the model's ability to capture the regional trends such as the area occupied for agricultural production, size of the farms and the type of production can be tested. This is followed by a comparison on the individual farm level.

In Map 6.1 the differences are shown between the real regional map in year 1998 and the simulated map from the year 2002. Hereby the spatial locations of the areas undergoing changes within AgriPoliS can be seen.

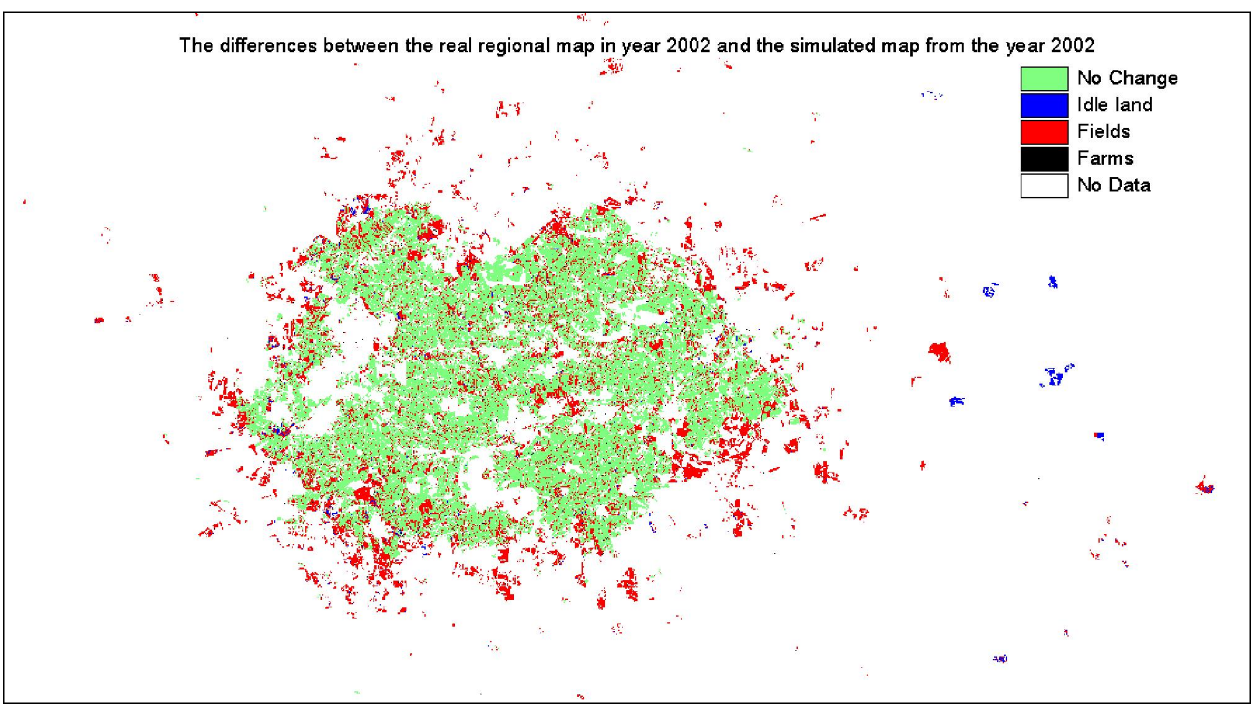


Map 6.1 The differences between the real regional map in year 1998 and the simulated map from the year 2002. The green colour indicates no change, red are abandoned fields and black are abandoned farms. Source: own calculation

In Map 6.2 the differences between the real regional map in year 1998 and the real regional map from the year 2002 are shown. This map illustrates two separate issues though without enabling us to differentiate between the two. The real region has undergone changes in the four years' period and this is in part the area highlighted in red and black. At the same time the difference is illustrating the effect of the moved areas.



Map 6.2 The differences between the real regional map in year 1998 and the real regional map from the year 2002. The green colour indicates no change, red are abandoned fields and black are abandoned farms. Source: own calculation



Map 6.3 The differences between the real regional map in year 2002 and the simulated map from the year 2002. The green colour indicates no change, blue is idle land, red are abandoned fields and black are abandoned farms. Source: own calculation

The clear majority of fields only present in the map for 1998 lies in the outer areas of the region. A number of these fields are here due to the movement of fields from areas farther away of the region as described in the previous section. The further way from the core area of the region the more likely is this explanation for the differences between the maps.

Map 6.3 illustrates the differences between the real regional map in year 2002 and the simulated map from the year 2002. The Map 6.3 could of course also be extracted by combining the two previous maps. What it shows is an important characteristic of AgriPoliS. The model has a tendency to utilise the whole area with which it was initialised. The few areas that the model has left idle are likely to improve this particular result as the transportation cost ensures that distant areas are abandoned and in this case these areas are likely to be encumbered with errors. The model's economic foundation makes the utilisation of the whole available area more likely. AgriPoliS will therefore be likely to predict an area too large under agricultural production.

The model predicted that 91088[6] ha are in agricultural production in year 2002 where as in reality only 76653 ha were cultivated. The difference between the areas in production in the model and in reality amounts to 14435 ha. This corresponds to 18.9 % of the real cultivated area in year 2002. Having 18.9 % too large an area in production in the relative short prediction period may seem a rough overestimation. The figure is, however, understandable. In the model only 3546 ha (or 3.7%) of the area used in production in year 1998 is abandoned. This should be compared to 19.05% seen in the empirical data for the same year. Though these data may have some potential sources of error such as land bought by farmers with farmsteads located outside the studied region the main differences result from the model itself. In the model, the area is divided into a grid of 1-hectare cells. Potentially each cell can be rented if another farm releases the area. There is no transaction costs associated with buying land in these small bites. This is of course unlike the real situation. Furthermore the other farms are always willing to bid for an additional plot as long as it can be associated with gains regardless how small. These two

[6] The numbers used for this comparison include all fields. Also the areas located far away as the spatial properties of these plots do not influence the calculations.

elements of the model combined mean that only those plots will be abandoned that none of the other farms can utilize for economic gains. This is likely to overestimate the area in production compared to the real situation. This is of course also reflected in the average farm size for the region. Where the average farm size in the model is 46 ha the average farm size of real farms is 41 ha. The agent-based modelling method means, however, that this average difference is unequally distributed among the individual farms.

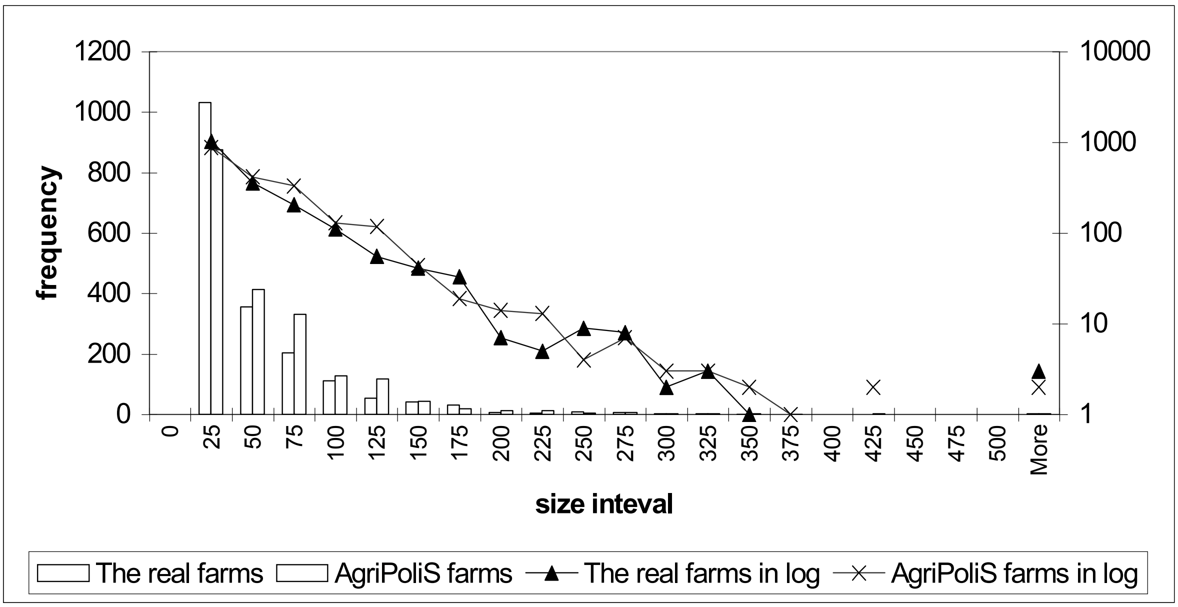


Figure 6.5 The frequency distribution of the farm size in the year 2002 for both the real farms and the farms in AgriPoliS. Bars show normal scale and the curves are logarithmic scale. Own figure

The frequency distribution of the farm size in the year 2002 for both the real farms and the farms in AgriPoliS is shown in Figure 6.5. The frequency distribution is shown both on a normal- as well as on a logarithmic scale. The normal scale is shown as bars and the logarithmic scale as curves.

As Figure 6.5 shows, there is no consistent picture where AgriPoliS is displacing the farms in a clear direction. The largest difference in real numbers can be found in the smallest category for farms between 0-25 ha. Some of these small farms are probably found in the next category. AgriPoliS has a larger number of farms in the middle range (between 25 and 125 ha), however, one has to remember that the model has 109 more farms to display. These 109 farms may constitute a large share of the differences between the two distributions.

The indication of the model to be underestimating the small (hobby) farms is in line with previous results. The model's behavioural foundation is profit maximisation for the individual farm. This means that the model does not capture motives less driven by profit, often seen particularly among hobby (or subsistence) farmers. The farmers falling within this category are therefore often quitting farming faster and in larger numbers in the model as seen in reality.

The type of production that the individual farm in the model undertakes compared to the real region is also important for validating the model's predictive power. The environmental and economic effects of the local production largely depend upon the type of farming taking place. As the empirical data do not hold records on the different crops grown on the individual farms the comparison is focusing on whether the farm is a crop producing farm or runs some animal production and in the latter case which kind of animal production. In Table 6.3 the number of farms within the different types is presented.

	Number of AgriPoliS farms:	Number of empirical farms :	Difference between the two
Dairy	401	275	126
Suckler cows/cows	591	786	-195
Beef/ Cattle	830	852	-22
Sows	310	287	23
Pigs	483	101	382
Only crops	545	787	-242

Table 6.3 The number of farms within different livestock productions or crop production in AgriPoliS and in the real region for the year 2002 and the difference between the two. Own calculations

The accuracy of the model is seen to be low for most of the commodities. In the case of dairy, pigs and crop producing farms there seem to be straightforward explanations. The explanation for the large deviation in number of suckler cows is harder to find.

Dairy farms are over-represented in the model as the economic returns are likely to be relatively good at the same time as the regulative difficulties for farmers in the study area to start a new dairy production are greater than in the model version. Though the model has also incorporated milk quotas the possibility of leasing the needed quotas is always present. For the simulated farms the investment into dairy production is only a matter of the right economic returns and not restricted in the same way as in the real world.

The production of pigs can also be explained following the same line of arguments. Though pig production does not have the same quotas as dairy production it is still a type of production with legislative and practical difficulties in establishing a new production. The environmental concerns related to pig production have drawn political attention to the production and e.g. the smell related to pig production makes it almost impossible to get permission to establish a new production in semi urban areas.

The present model is unable to take these considerations into account when a farm considers starting or expanding a pig production. As the entry barrier and transaction costs associated with pig production are lower in the model the number of pig producing farms is over-represented. The opposite is of course the case for farms only involved in crop production. As the entry barrier for taking up animal production is relative low more farms are utilizing this opportunity. The majority of small part-time farms fall within this category of production. In the model there is standard opportunity cost associated with time as the farmer can choose to work outside the farm. However, in reality the opportunity cost is individually determined. The different valuation of time between part-time farmers and full-time farmers as well as within the two groups will vary considerably. As the model is unable to evaluate the right individual valuation of time it will be more likely to choose to engage in a time costly animal production than a small part-time farm normally would. The under-representation of crop-producing farms therefore appears to be understandable as well. In general the values are not ostentatious if one considers the possibilities for each individual farm and the complexity in describing the behaviour of individual decision makers. But on the other hand the values are not discouraging. The model is clearly not producing completely random values and they do maintain some of the characteristics seen in the empirical data. In order to better understand the accuracy of the simulation results we will now compare individual farms. Numbers covering the whole study area may hide variations as some of the individual farms' actions overshoot the real choices taken while others do the opposite and thereby they may cancel out each other and present a reliable aggregated result. We will investigate whether this is the case by comparing the real farms with their direct virtual representative.

6.4.2 Comparison of individual farms

To compare the individual farm characteristics one must ensure that it really is the same farms that are analysed. Therefore the two maps of the real location of the farmsteads for year 1998 and 2002 are first compared. Besides the 513 farms that have left the sector in the period between 1998 and 2002, there are also a number of other farms that can not be used for an individual farm comparison. The official location of the farmstead is for 237 farms moved within this period of time. Although the majority of these 237 farms presumably could be ascribed to a nearby farmstead on the 1998 map (within a distance of a couple of pixels). Such a procedure would constitute a risk for introducing errors into the analysis. Therefore only the 1633 farms spatially located at the same spot in both years 1998 and 2002 are compared. This comparison builds upon the assumption that the individual farms haven't been subject to acquisitions from other farms, which have taken over this farmstead as their new base. Of the 1633 potential farmsteads in year 2002 AgriPoliS has 1389 correct (corresponding to 85%). The comparison of the individual farm level will therefore be concentrated around these 1389 farms.

The differences in the size among these 1389 individual farms give a good first impression of the model's ability to capture the development of the individual farms. In Table 6.4 the maximum, minimum, average and median deviation in the size between the real farms and the simulated farms in year 2002 is shown in ha:

	ha
Maximum	1252
Minimum	-1036
Average	2.99
Median	3

Table 6.4 Differences in size among the 1389 individual farms identically located in the real region and AgriPoliS for the year 2002 as the maximum, minimum, average and median deviation. Own calculations.

The large deviations of the maximum and minimum difference will catch the eye but are the least surprising results. These two values come from two single outliers among the 1389 farms. They represent the many degrees of freedom that are inherently built into agent based modelling. An individual farm will sometimes develop in one direction within the model while the real farm will develop in another. The fact that they are almost at the same numerical distance from zero means that they cancel out each other more or less. The fact that the average deviation between the sizes of the real farms with the simulated farms in year 2002 is 2.99 ha is more interesting. The same goes for the median on 3 ha. In order to better understand the background for these values the frequency distribution of the deviation between the sizes of the real farms and the simulated farms is shown in Figure 6.6. The majority of farms are in the interval between 0><=10 ha. The interval on the negative side of zero between –10><=0 ha is also fairly well represented. 44 of the farms had the exact same size in both the model and real data (=0). Otherwise the farms are distributed almost symmetrically around zero with a slight overrepresentation of farms larger than the real farms. The large number of farms within the interval between 0><=10 ha as well as the symmetric distribution of the rest of the farms ensure the low average and median deviation. The positive sign of both of these values confirm the same trend previously seen in Figure 6.5 among all of the farms. The model's economic foundation makes the model favour larger farms. However, not in any exaggerated manner.The frequency distribution of the deviation between the sizes of the real farms and the simulated farms are shown in Figure 6.6.

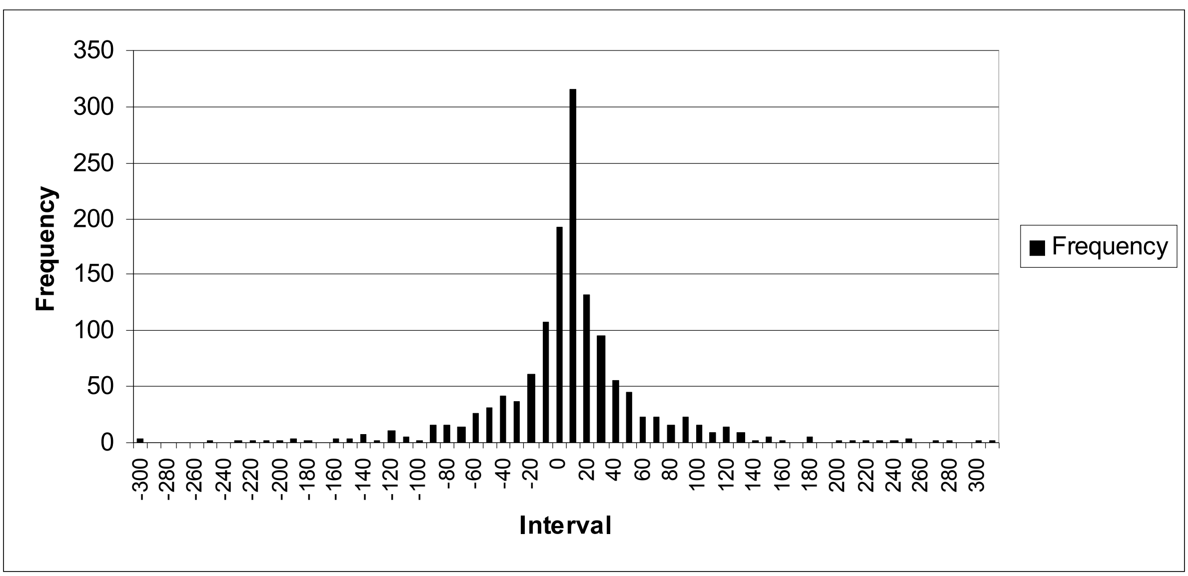


Figure 6.6 The frequency distribution of the deviation between the sizes of the real farms and the simulated farms among the 1389 individual farms identically located year 2002. Own figure

The ability of the model to capture the right type of productions and the size of the production on the individual farms can only be validated with regard to the animal production. The empirical data holds information on the number of animals and their type that each individual farm has. From this it also appears which farms that do not have animal production. The composition of the crops produced is not known and can therefore not be tested. Within the MEA-Scope project the farms' rotation plans and crop mixture are also calculated by the two following models MODAM and FASSET rather than AgriPoliS. Their agreement with empirical data should therefore be investigated to validate this point. In Table 6.5 the number of real farms as well as the simulated farms within AgriPoliS engaged in different types of production are indicated.

	Number of farms in AgriPoliS	Number of farms in the case study	Difference between the two
Dairy cows	296	235	61
Suckler cows/cows	418	628	-210
Beef/ Cattle	581	675	-94
Sows	200	225	-25
Pigs	338	78	260
Only crops	388	540	-152

Table 6.5 The number of farms within different livestock productions or crop production in AgriPoliS and in the real region among the 1389 individual farms identically located for the year 2002 and the difference between the two. Own calculations

Of course the numbers do not sum up to the 1389 farms investigated as some farms are engaged in more than one of these types of productions. The deviation between the real values and the simulated values is considerably relative to the number of farms. In many ways the situation is similar to the case where all the farms in the study area were analysed. Reducing the sample from 1867 to 1389 does not change the major trends (see Table 6.3).

The numbers are within the right order of magnitude with the exception of the pig production. Pig production is of course also the type of production where both in absolute and relative terms the deviation is largest. This is probably not very surprising considering the price development for pig production in 2001 as well as the ease by which the simulated farms can engage in a new type of production compared to the real world. The legislative and practical difficulties in establishing a new pig production are not treated by the simulated farms in a realistic way. Nor are the simulated farms able to consider the long-term trends in the price development in the same way as an experienced farmer. Short-term gains in a given type of production will therefore often result in a too large number of simulated farms investing in this opportunity. The underestimation of the number of farms only engaged in crop production is likely to reflect the same elements as with the pig production. The ease of starting an animal production in the model compared to the real situation as well as the model's focus on economic gains makes it less attractive to maintain a crop production for the simulated farms. The majority of small (hobby) farms fall also into this category and as previously shown it is in this part of the sector that AgriPoliS has difficulties with simulating. Suckler cows are once more sticking out, as it is under-estimated. That the remaining productions options are ranked in the right order indicate that the technical coefficients representing the contribution of the activities to the objective function are fairly accurate. It is of course difficult to completely separately the effect of the technical coefficients from the model's behaviour only by looking at these numbers, but a different ranking would suggest that a given type of production is over- or under evaluated.

The number of animals of a given type on a given farm is of course a very uncertain result. The possibilities for large deviations reflect the fact that the real farms as well as the farms in the model are free to up- or downscale their production as well as to shift production within the investigated period of time. So this part of the validation has to be read with caution. It will, however, still help our understanding of the model and the way it differs from the development in the study area.

By comparing only the farms where one (the real or model farm) or both of them produces a given type of animal, it is possible to find the maximum, minimum, average and median deviation in the number of animals between the real farms and the simulated farms in year 2002. This is shown in Table 6.6:

	Maximum	Minimum	Average	Median
Dairy	171	-215	-1.37	2
Suckler cows/cows	107.79	-392	-17.93	-6
Beef/ Cattle	9621	-1005	153.53	-1
Sows	550	-1080	-27.51	-1
Pigs	7500	-9970	164.47	82

Table 6.6 The maximum, minimum, average and median difference among the 1389 individual farms identically located in the number of livestock for the year 2002. Own calculations

In order to better appreciate the values in Table 6.6, the frequency distribution of the deviation between the numbers of animals of a given type on the farms is shown in Figures 6.7-6.12. The intervals in the different figures are matched to the results shown in each figure and therefore the figures are not directly comparable. The dairy producing farms are having the best average value as well as a small median value. Both numbers cover, however, a different picture that becomes apparent when looking at the frequency distribution of the deviations.

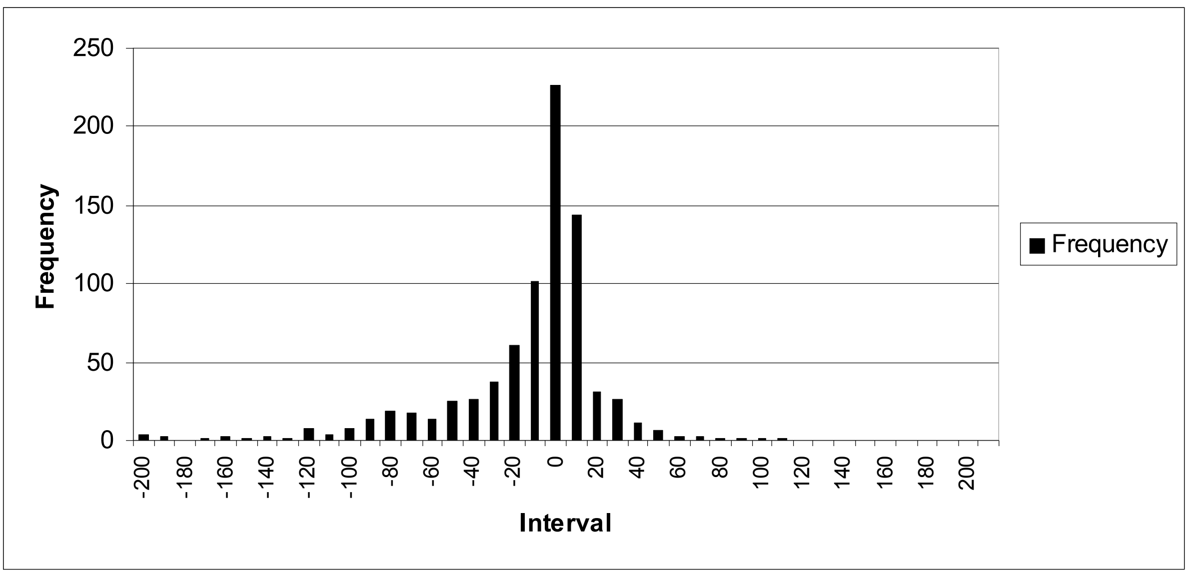


Figure 6.7 The frequency distribution of the deviation between the number of dairy cows on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002. Own figure

The frequency distribution shows a larger variation between the real and simulated farms. The symmetry around the centre ensures the small average and median values, however, the deviation is in reality substantial.

The average and median values of the number of suckler cows could indicate the opposite as the same values did in the dairy case. Though neither the average nor the median values are particularly high the negative trend is clear. The model underestimates the suckler cow production. This is also the case when looking at the frequency distribution of the deviation, but the figure shows also that the estimate of the model is fairly good.

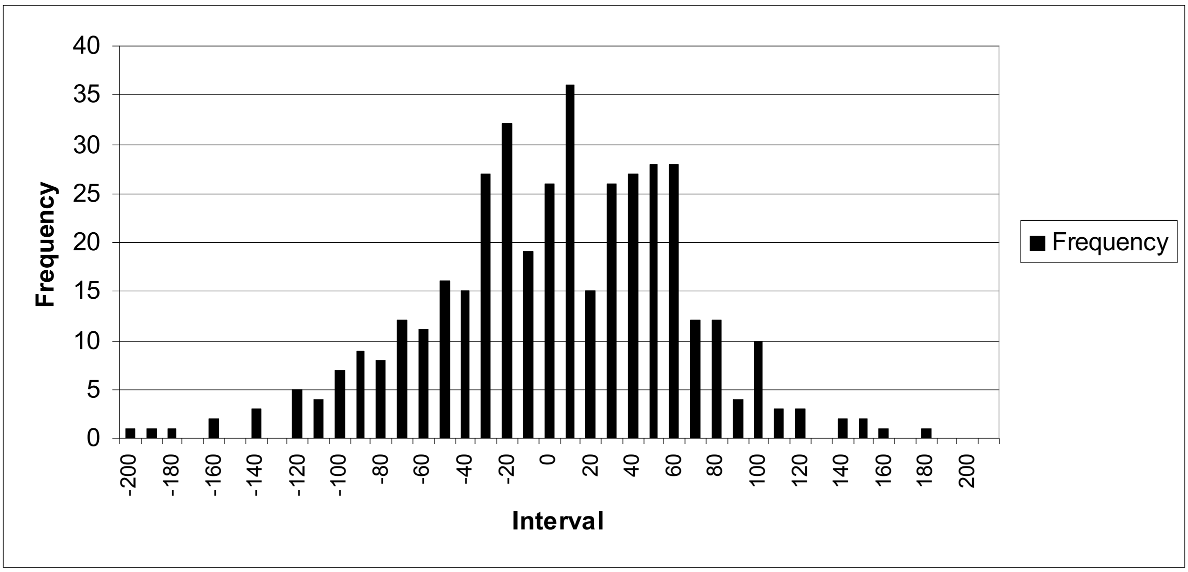


Figure 6.8 The frequency distribution of the deviation between the number of suckler cows on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002. Own figure

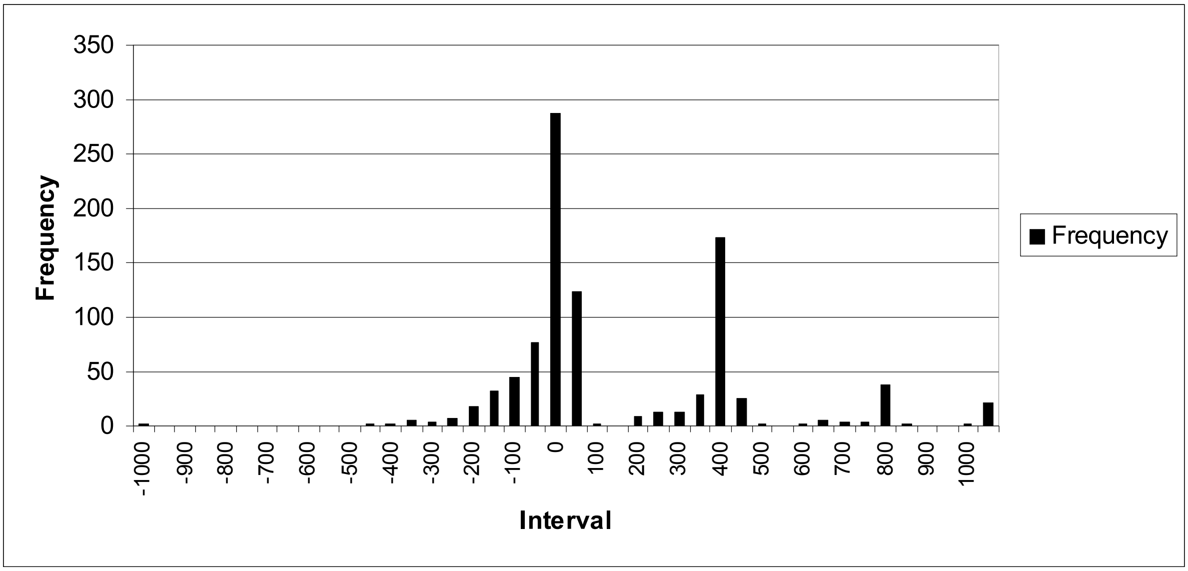


Figure 6.9 The frequency distribution of the deviation between the number of beef cattle on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002. Own figure

Much more difficult to understand are the results for beef production. Both the values in Table 6.6 as well as the Figure 6.9 reveal the same odd results. Though the number of farms with beef production is smaller in the model as shown in Table 6.5 the distribution is displaced towards positive values. Part of the understanding of these results has to be found in the maximum and minimum values for the deviations. The large size of these numbers, particularly the maximum coming from AgriPoliS shows that the variations here are tremendous. The relatively large number of extreme outliers, which also can be seen on the Figure 6.9, means that the average value will be pushed in a strongly positive direction. The two peaks around 400 and 800 animals show that the farms in the model engaging in beef production create relatively large productions.

The simulated sow production looks to be more in line with reality. The large majority of farms lie in the range from –50 to 50.

The average and median values show that the model slightly underestimates the sow production. Not in a dramatic way, however.

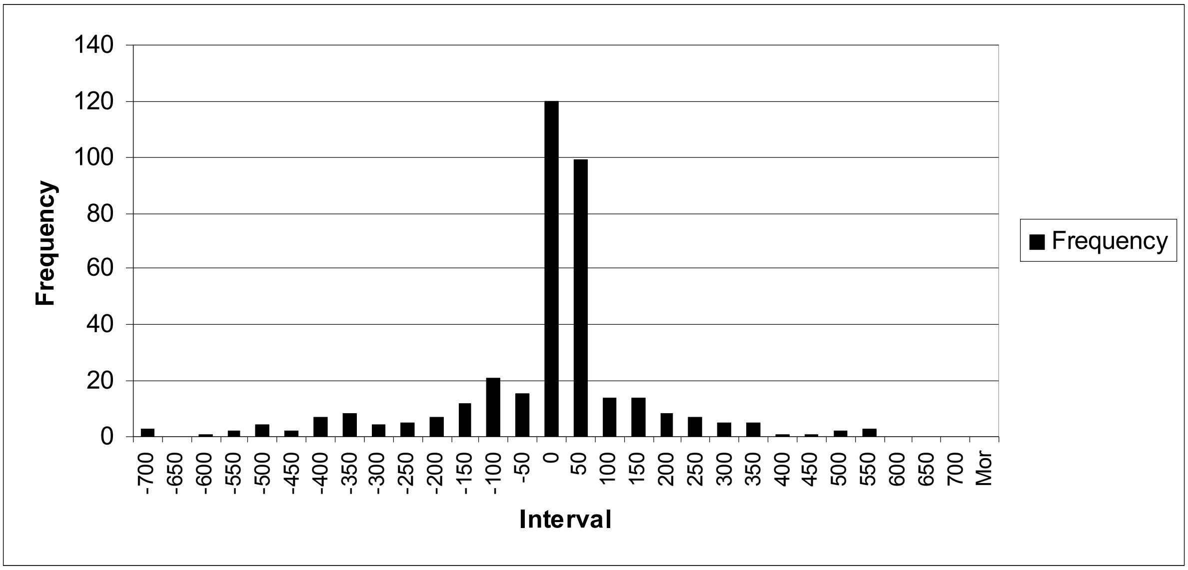


Figure 6.10 The frequency distribution of the deviation between the number of sows on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002. Own figure

Finally Figure 6.11 shows the deviation between the number of pigs on the real farms and the simulated farms. The values in Table 6.6 would suggest that the pig production is where the model has its worst performance. This is maybe not so evident when one also looks at the frequency distribution. The tendency for the model to overestimate the pig production as also previously shown is once more clear. Though a substantial number of farms will be past the scale in both ends of the spectra a reasonable share of the farms is situated close to zero.

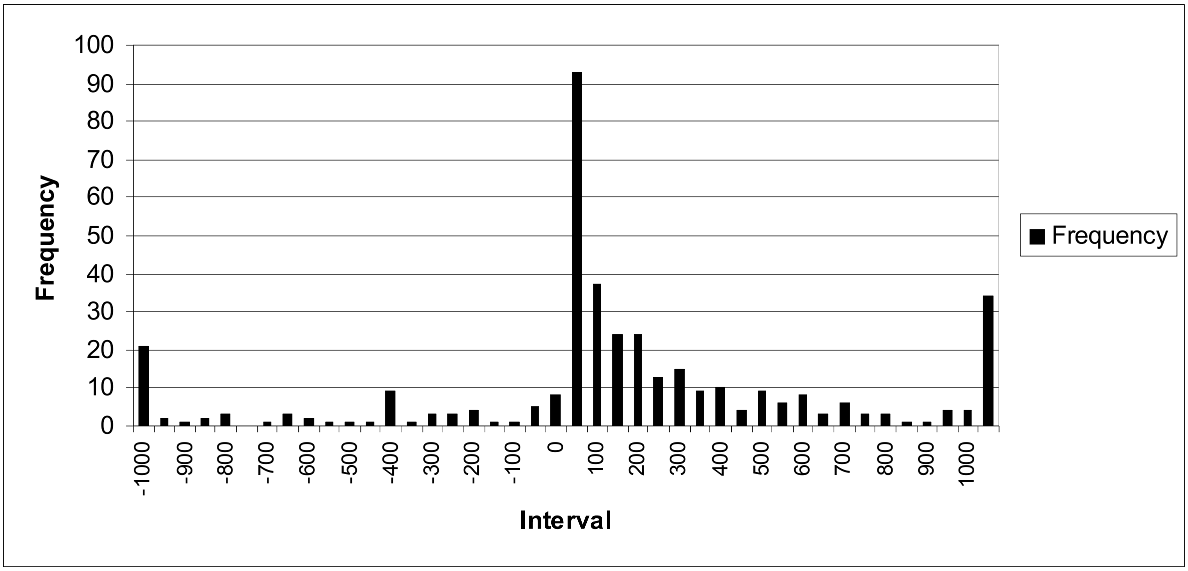


Figure 6.11 The frequency distribution of the deviation between the number of pigs on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002. Own figure

The considerably larger number of farms engaged in pig production relative to the real farms as shown in Table 6.5 makes up for a large share of the result in Figure 6.11. In order to better understand what the contribution of the overrepresentation of farms makes on the frequency distribution the size distribution of the farms with pig production only in AgriPoliS is shown in Figure 6.12. It is clear that the pig farms only represented in AgriPoliS create the pattern of the positive values in Figure 6.11 to a very large degree. Their large number makes it even hard to see the difference between figure 6.12 and the positive side of Figure 6.11 just by looking at the graphs. The interval between 0-50 animals is probably the only place where one can see the difference with the eyes; however, even up to the interval 600-650 animals' farms are simultaneously represented in the model and reality.

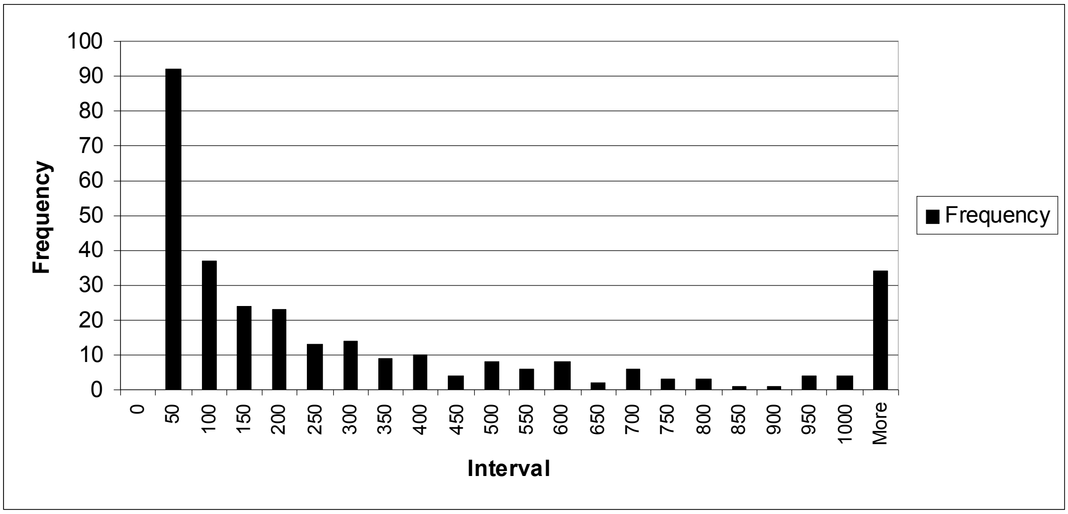


Figure 6.12 The frequency distribution of the deviation between the number of pigs on the real farms and the simulated farms among the 1389 individual farms identically located for the year 2002 where the pig production only takes place in AgriPoliS. Own figure

These findings underline once more the model's tendency to over-represent productions which in reality are subject to restrictions outside the control of the individual farm. The production function of the individual farm may to some extent of course reflect the transaction cost connected to a given production. It is, however, a delicate balance on one hand reflecting the true production function and giving the farms freedom to choose and on the other hand enforcing restrictions upon them without their becoming self-confirming prophecies. The validation of the model helps to demonstrate its characteristics and thereby improves the judgment of the scientific community of the model.

7 Spatial analyses of results from AgriPoliS

7.1 Introduction to the study areas

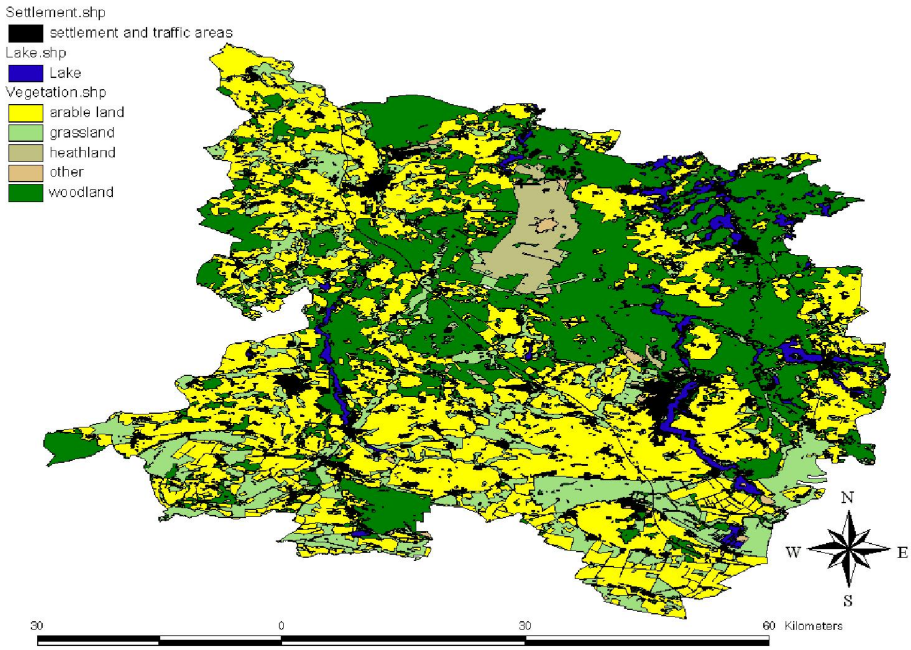
The aim of creating and adapting a model to a given area is of course to be able to better understand the investigated system as well as extrapolating the system into the future in order to better understand the possible effects of choices taken today. The virtual representation of an agricultural region in a model such as AgriPoliS enables one to investigate several different scenarios for potential framework conditions politically induced for the sector's structural development.

In the following the structural development of three of the case study areas from the MEA-Scope project will be analysed. The analyses will mainly study the structural development induced by changes in the economic support for the agricultural sector. The analysis will focus on the spatially detectable effects of different policy changes. The three case study areas chosen for this investigation is the German region Ostprignitz-Ruppin, the Italian region Mugello and the Danish river Gudenå watershed region. The three regions possess each individual property both in relation to the landscape characteristics, farm structure as well as its implementation into AgriPoliS.

The three regions will therefore first be shortly introduced. Followed by a description of the different policy scenarios investigated. The results of the simulations will lastly be presented.

7.2 The study region Ostprignitz-Ruppin (OPR), Germany.

The OPR district is located in the federal state of Brandenburg. OPR covers 2 511 km^2 and is area-wise the third biggest district of Brandenburg. Brandenburg belongs to the North German Lowland, which is a part of the Great European Plain that sweeps across Europe from the Pyrenees in France to the Ural Mountains in Russia. Hills in the lowlands only rarely reach 200 meters in height, and most of the OPR district is well under 100 meters above sea level. The lowlands slope almost imperceptibly towards the sea. A varied nature and culture landscape with numerous avenues, forests, lakes, historical villages and settlement structures shapes the OPR district. Map 7.1 shows where five vegetation types, settlements and waterways are in the region.



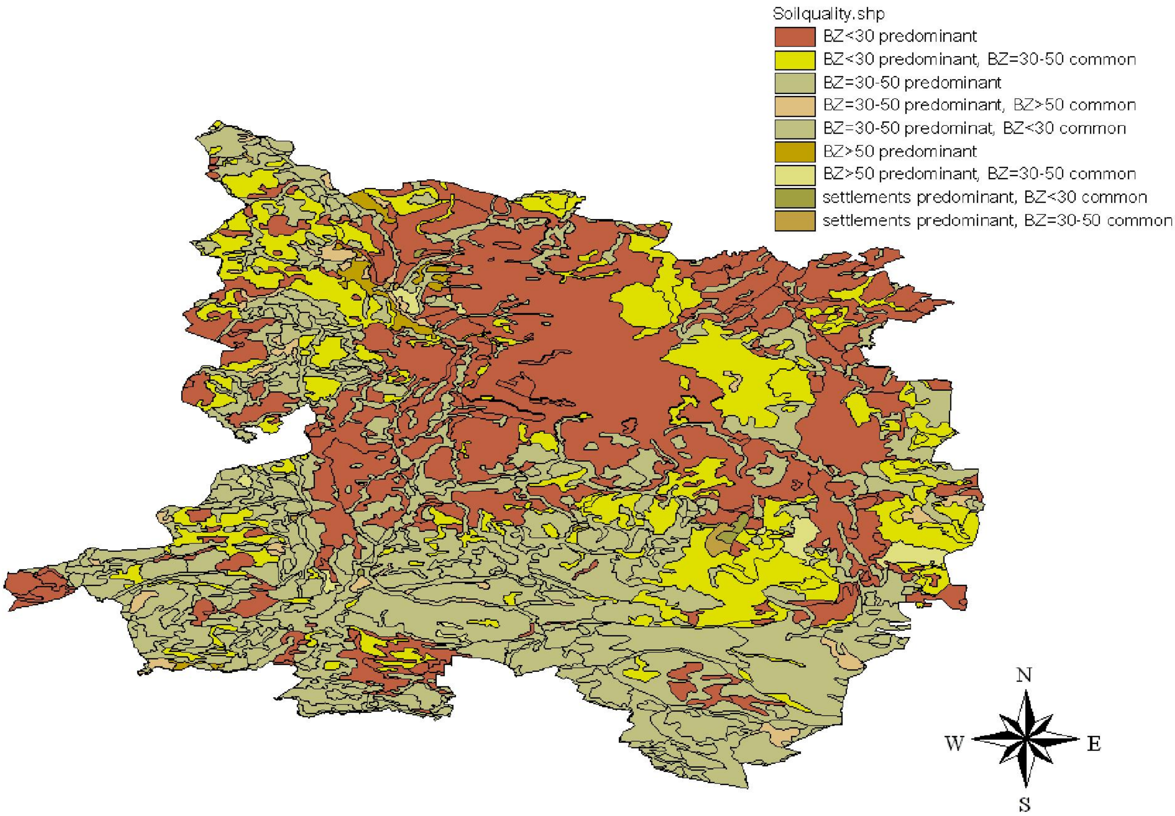
Map 7.1 of five vegetation types, settlements and waterways in the Ostprignitz-Ruppin region. (ZALF, 2003)

The total UAA in 2003 was of more than 126 000 ha, in which 561 farms were performing their activities (Table 7.1).

Products	Unit	
Number of farms	Number	561
Utilized Agricultural Area (UAA)	Ha	126,378
Arable land	Ha	89,566
Grassland	Ha	36,659
Beef cattle[a)]	Heads	27,991
Dairy cows	Heads	15,989
Suckler cows[a)]	Heads	15,969
Pigs for fattening	Heads	4,729
Sows	Heads	9,903

Table 7.1: Agricultural production characteristics in Ostprignitz-Ruppin. Source:(Landesbetrieb_für_Datenverarbeitung_und_Statistik_Land_Brandenburg 2003), except a): (Wirtschafts- und_Landwirtschaftsbericht_für_Ostprignitz-Ruppin 2002).

An average annual precipitation of 520 mm over the past 20 years and quite sandy soils provides rather disadvantageous conditions for crop production. This is illustrated in Map 7.2 showing the regional soil quality classified in the German “Bodenzahlen” (BZ) –system, where good soils are in the range (60< BZ≤100), average soil qualities are in the range (30< BZ≤60) and poor soils range (0< BZ≤30).



Map 7.2 Map of the spatial distribution of soil quality in form of the ”Bodenzahlen” for the Ostprignitz-Ruppin region. (ZALF,2003)

Although 60% of the farms are smaller than 50 ha, the average farm size in the region is well above the German average: the average farm in OPR covers 225 ha, of which 160 ha of arable land and 65 ha of grassland (Landesbetrieb_für_Datenverarbeitung_und_Statistik_Land_Brandenburg 2003). Field crops and grazing livestock farming (according to the FADN classification) are the predominant orientations of the farms in the region, with, for the two farming types, an average farm size slightly above the regional average (Table 7.2).

Farm types	Number of farms	% of the farms of the region	UAA (ha)	% of the regional UAA	Average size (ha per farm of each type)	FADN code
Field crops	227	40.5	61,815	48.9	272	13, 14
Horticulture	3	0.5	153	0.1	53	20
Dairy	65	11.5	1,294	1	20	41
Grazing livestock	234	41.8	58,192	46.1	248	42, 43, 44
Granivore	10	1.7	443	0.4	46	50
Mixed	22	4	4,468	3.5	202	60, 71, 72, 81, 82

Table 7.2: Farms in Ostprignitz-Ruppin by farm type. Source: (Landesbetrieb_für_Datenverarbeitung_und_Statistik_Land_Brandenburg 2003)

7.2.1 Representing the region and farms

By matching the individual capacities of the 259 farms from the FADN database with the regional data of the OPR district, 18 farms have been selected. Each of these 18 farms represents a typical farm for OPR. Among them, 11 are field crop farms (of which nine also keep livestock), 4 raise grazing livestock and the last one is specialised in dairy farming. The last two are mixed farms with field crop farming and livestock. Each typical farm receives a weight (in the range between 1 and 79) so that the specialisation among farms in OPR is respected. The seven family farms of the sample comprise between 15 and 383 ha. The two partnerships, which have been selected, have 65 and 688 ha, respectively. Corporate farms have a size of between 308 and 2850 ha. All livestock in the region are represented: corporate farms own of course the largest herds of animals among the farms selected, but it is balanced by their relatively low weight in the artificial region.

In the representation of the region some discrepancies between the real regional characteristics and the artificial ones were unavoidable. Deviation is mainly due the initial sample from the FADN database in which small and part-time farms are underrepresented.

To represent the internal organisation of typical farms, data on prices, production costs, and technical coefficients were taken from standardised data collections, which are published regularly by various German government agencies and organisations (e.g. KTBL, Brandenburg Ministry of Rural Areas and Agriculture). For AgriPoliS, we considered 23 possible crop and livestock production activities and 39 investment options of various types and sizes. We considered only those activities and investments, which are typical for the region given the specific production conditions. A price trend is attached to each product to simulate the pressure on prices observed in reality.

Finally, some additional parameters necessary for the modelling are listed in the Table 7.3.

Model	Parameter value
Interest rate level	
Long-term borrowed capital	6%
Short-term borrowed capital	8%
Equity capital interest	4%
Plot size	1 ha
Minimum withdrawal per farm household labour unit	15,300 €
Equity finance share	0.5
Milk quota price adjustment	2%
Annual labour hours per labour unit	1,800
Max. permissible stocking density (livestock units per ha) in region	2 LU/ha
Transport costs per year	50 €/km

Table 7.3: Additional model parameters for AgriPoliS (selection) Source: Own calculations based on (Balmann 1995; DEUTSCHE_BUNDESBANK 2003; KTBL various years).

7.3 The study region Mugello, Italy.

The Mugello is a hilly-mountainous region located in the North-Eastern sector of Tuscany, in the province of Florence. The Mugello area (1126.71 km^2, elevation 160-1241 a.s.l.) is situated in the upper middle part of the hydrographical basin of the Sieve River: it is a valley locked up by two main ranges, both part of the principal North Apennine chain.

The Mugello countryside is varied: from the lofty crests of thick woodland, to the chestnut and olive groves; from the fields of wheat and sunflowers on the vast flat terraced lands bordered by cliffs, to the fertile lower valley where the main towns and roads are. The share of the area land cover is by far broad-leaf woodland forest (79%). Permanent non-irrigated arable land takes up 4% of the area and permanent pastures 3%.

The Mugello basin, which lies just below the higher passes of the mountain chain, is often where the cold north wind meets the hot and humid libeccio, sirocco and westerly winds: the result is that the cold winds sweep away the fog produced by the warm winds in winter, and bring in some cool relief to mitigate the hot damp spells that those same winds produce in summer.

About 60 000 people live in the area from which 5% of the working population have occupation in the agricultural sector. There were 1774 farms in the region in the year 2001. In Table 7.4 an overview of the agricultural structure in the Mugello region is given.

As can be seen from the table there are 32111 ha utilized for agricultural production in the region.

Most of the farms are involved in specialist permanent crops. These farms occupy 7753 ha. AgriPoliS does not consider permanent crops and therefore these farms as such are not represented in the model. The part of their production, which involves annual crops, is contained in the model as the statistical data used for the selection of farms from the FADN-sample included their production of annual crops. The elimination of the permanent crops from the production options available to the farms in the region is of course a grave simplification of the model's ability to reproduce the actual agricultural structure in the Mugello region. Without disparaging the effects of not having these types of productions included in the model there are, however, a number of points why the results of a simulation model are still likely to reflect the structural change taking place in the region. The majority of farms within the production of permanent crops are relatively small and often specialised within this area of farming. Some of these farms are part time farms. Due to the time span involved in the production of permanent crops the variations in the size of the area occupied with these types of crops are rather small when analysed on a yearly basis as in AgriPoliS. This part of the agricultural area is therefore almost stable within a substantial amount of time. The ownership of the fields continues traditionally within the family. Therefore the majority of fields are not entering the market for land. This prevents the structural development within the production of permanent crops to have the same vigorous form as seen in other parts of the agricultural sector. The adaptation of AgriPoliS to the Mugello region builds therefore on the assumption that the inertia in the production of permanent crops makes it reasonable to overlook its effects on the structural development in the remaining sector.

Among the remaining farms the largest area utilized for mixed farming are followed by field crop production. The cattle production in the region constitutes more than 72% of the entire production in the province of Florence. The actual recreation of the spatial location of the farms in the region before entering into AgriPoliS is described in section 5.3.2 “The context-dependent analytical approach”.

Mugello, Italy	Value
Number of farms	**1 774**
Utilized agricultural area (UAA; ha)	**32 111**
Number of beef cattle older than 1 year	5 152
Number of dairy cows	2 213
Number of suckle cows	2 457
Number of ewes	10 101
Pigs for fattening of more than 20 kg	3 297
Structural characteristics	
Number of:	1 774
Part time farms	457
Full time farms	1 252
Capitalistic	65
UAA of farms (ha):	32 111
Part time farms	5 460
Full time farms	18 907
Capitalistic	7 744
Area (ha)	31 885
Arable land	15 467
Grassland	12 897
Permanent crops (all except wine)	3 521
Number of farms spezialised in:	1 695
Field crops (FADN farm types: 13,14)	399
Milk (41)	42
Grazing livestocks (42, 43, 44)	237
Mixed (60, 71, 72, 81, 82)	425
Specialist permanent crops (31,32,33,34)	592
UAA of farms spezialised in (ha):	31 975
Field crops	7 305
Milk	2 142
Grazing livestocks	4 216
Mixed (crops and livestock)	10 560
Specialist permanent crops (31,32,33,34)	7 753
Number of farms in different size classes	1 774
1 - 5 ha	869
5 - 10 ha	306
10 - 50 ha	459
50 - 100 ha	80
>100	60
Total number of fattened pigs (heads) of all the farms of the category	3 297
below 50 (heads per farm)	487
50-200	300
1000-2500	2 510
Total number of dairy cows (heads) of all the farms of the category	2 213
below 50 (heads per farm)	1 030
50-150	727
150-250	200
>250	256

Table 7.4 Agricultural structure in the Mugello region. (National_Agricultural_Census 2001)

7.4 The study region river Gudenå watershed, Denmark.

The river Gudenå on the Jutland peninsula is Denmark's longest river. It flows 160 kilometres from Tinnet Krat north west of the town Vejle to it outfall through Randers fiord. It was formed around 15000 years ago during the last Ice Age as the ice glacial streams carved out its bed and the melt water from the stream that eventually became the river. The river and its banks constitute the shelter for many species of animals. It is the watershed for the Gudenå River that makes up the Danish study area.

The valleys of "Nørreå" and "Gudenå" are located in the central part of Jutland between three major cities: Aarhus, Viborg and Randers. The area covers over 76 600 ha and is placed in two NUT 3 counties. The demarcation of the study area by the boundary of watershed determines which farms are included in the study. All farms with their farmstead within the area are included and all fields belonging to them even when located outside the area are still part of the study area. Fields inside the watershed belonging to farms where the farmstead is outside the watershed area is, however, not part of this study.

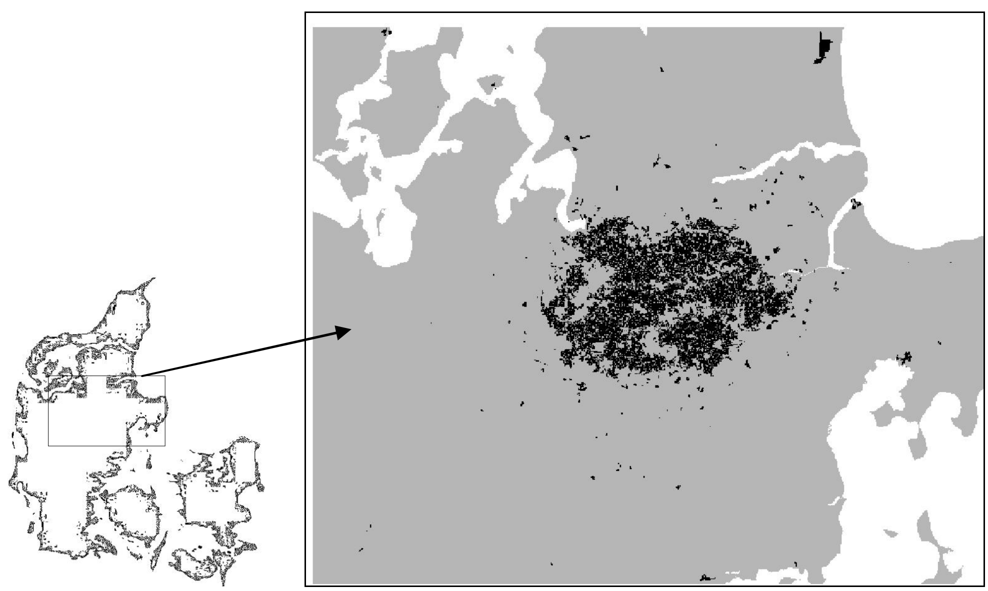


Figure 7.1. Map of the study area. The dark area shows the farms involved and their fields. All fields belonging to farmers in the area are included even if the location of the field is outside the watershed. Note that due to Danish area requirements fields very far from the farmstead can still be favourably owned.

River Gudena, Denmark	Value
Number of farms (>1 ha)	**1 871**
Utilized agricultural area (UAA; ha)[1]	**76 600**
Total number of male cattle (NOT only 1-2 yrs)	10 431
Number of beef cattle (1-2 years old)	237
Number of dairy cows	17 274
Number of suckle cows	6 164
Number of ewes= mother sheep	1 787
Number of other sheep	1 489
Breeding sows of 50 kg or more	36 040
Pigs for fattening of more than 25 kg	234 163

Structural characteristics

Number of:	**1 871**
Individual Farms (>1664 hours)	652
Part time farms (832-1664hours, >1 ha)	913
Housholds= Hobby farms (<832 hours, >1 ha)	306
UAA of farms (ha):	**76 600**
Individual Farms (>1664 hours)[2]	55 412
Part time farms (832-1664hours, >1 ha)[2]	19 384
Housholds= Hobby farms (<832 hours, >1 ha)[2]	1 805
Area (ha)	**77 177**
Arable land (incl. grass in rotation)[1]	72 089
Permanent grassland[1]	5 089
Number of farms spezialised in:	**1 871**
Field crops (FADN farm types: 13,14)	1 157
Milk (41)	214
Grazing livestock (42, 43, 44)	121
Granivores (50)	255
Mixed (60, 71, 72, 81, 82)	124
UAA of farms spezialised in (ha):	**76 600**
Field crops[2]	28 593
Milk[2]	15 316
Grazing livestock[2]	4 033
Granivores[2]	18 945
Mixed[2]	9 712
Number of farms in different size classes	**1 871**
1 - 10 ha	453
10 - 50 ha	933
50 - 100 ha	313
100 - 200 ha	141
above 200 ha	31
Total number of fattened pigs (heads) of all the farms of the category	**234 163**
below 50 (heads per farm)	1 986
50-200	13 193
200-500	28 264
500-1000	52 104
1000-2500	91 436
above 2500	47 180
Total number of sows (heads) of all the farms of the category	**36 040**
below 100 (heads per farm)	3 439
100-200	7 041
200-500	16 885
500-1000	7 595
above 1000	1 080
Total number of dairy cows (heads) of all the farms of the category	**17 274**
below 50 (heads per farm)	3 280
50-150	11 513
150-250	2 154
250-500	327

Table 7.5 Agricultural structure in the study area. 1) UAA in the case study area 2) UAA for farms with address in the area (FJOR 2002)

Inside the watershed 1871 farms are registered. The 1871 farms are on 72089 ha of arable land and 5089 ha of grassland with an average size of 41 ha. In Table 7.5 an overview of the agricultural structure in the study area is given.

Most of the farms (62%) perform field crop farming. The other farms are then quite equally distributed among dairy farming (11%), grazing livestock farming (6%), granivores (14%) and mixed farming (7%). The biggest average farm size belongs to the mixed farming type with 78 ha. It is to be noted that 234 163 pigs are raised in this case study region, which is by far the highest number among the regions studied in MEA-Scope. Concerning cattle farming, most of the males are slaughtered before they are one year old: it explains why the number of beef cattle between 1 and 2 years old is so low (237 heads).

Farms are mostly distinguished by the number of hours the farmer allocates for farming. Although 72% of the area is occupied by individual farms in which the farmer allocates at least 1 664 hours of work per year, 49% of the farms in the case study area is considered part-time farms (between 832 and 1 664 hours per year). Besides these two dominant types, hobby farming occupies 2% of the UAA; the average size of these farms is no more as 6 ha. The presence of these small farms certainly weight a lot in keeping 74% of the farms in the region below the size of 50 ha.

The actual implementation of the region into AgriPoliS is described in section 5.3.5 “The empirical method”**.**

7.5 Policy settings

The main motive for the construction of the MEA-Scope tool was to investigate the impact of different CAP reform options on the multifunctionality of European agricultural development. Central to the modelling exercise therefore is the possibility of creating policy scenarios that convey elements from both the actual support mechanisms within the different regional settings as well as invented elements to mimic possible new directions for the CAP.

Simulating the actual support mechanisms on its own will not necessarily reveal enough information for one to be able to distinguish the structural effects inflicted on the region through the support mechanisms from the structural development taking place due to the competition among the farms. It is therefore useful to analyse the relative differences between a number of simulations where the framework conditions politically induced change from one simulation to the other while all other factors are kept constant.

The recent reform of the CAP towards decoupled direct payments, modulation, and cross-compliance introduced significant changes for the European agricultural sector. The argument behind these changes is in part to support the provision of certain NCOs for which markets do not exist. But whether the changes in the support also ensure the provision of these NCOs is debatable.

The multifunctionality requires that a large set of externalities related to agricultural production should be taken into account. Finding the right balance between commodity and non-commodity production is a delicate matter simultaneously involving several points of view.

The choice of public support will be reflected in the dynamic development of the farm structure as well as in the production patterns. The reaction to the policy changes of the individual farms will not solely determine the effectiveness of the support.

The complex interrelationships and interdependencies between all the individual farms have to be investigated in a dynamic setting.

The practical realization of the aims of multifunctionality is therefore a central and difficult issue. It is a difficult issue in relation to finding the right support mechanisms as well as the right level of support.

In theory, fully decoupled lump-sum payments based on past levels of support would not generate any price incentive to allocate additional resources in agricultural production. In spite of this, these payments may change both the production patterns at the individual farm as well as being the drivers behind structural changes. The payments can affect farms' resource allocation and thus change their output mix (OECD 2005).

Decisions taken on the individual farms will then again affect their ability to compete and stay in the sector. Some payment schemes may benefit the inefficient producers and thereby slow down the structural change that would otherwise take place. Other schemes could benefit a particular group of farms such as dairy or small farms on the expense of other farms. The decoupled direct payments may therefore significantly affect the response of farms and consequently their production of the different desired non-commodity outputs.

The implementation of a number of such idealized support schemes into a model such as AgiPoliS and investigating the resulting structural development may help us to better understand the likely consequences of implementing something similar into the real region.

In order to be able to analyse the relative changes that the different investigated policy settings inflict on the regional development, a stable scenario is constructed, where no significant changes take place in the simulated region.

The recent CAP reform involves such significant changes and would therefore not be able to act as the stable reference scenario. Instead of this a scenario is constructed mimicking the level of direct payment that the farms received during the Agenda 2000-reform. This level of support is then given throughout the simulated time period.

This scenario is designated "BAS" as the scenario will work as a foundation for the interpretation of the other presented scenarios. In all other scenarios the farms are receiving the same direct payment as in “BAS” in the first three periods in order to simulate the years before the policy change. Whereas “BAS” represents a stable development with regard to the framework conditions politically induced it is not in line with the actual support system in the regions.

None of the presented scenarios attempts to capture the full details of the legislation and programs following the real CAP reform. This is partly due to the fact that each of the simulated regions belongs to different countries, each one with slightly different implementations on the national level. Moreover the aim is not necessarily an attempt to predict the actual development taking place in the regions. Rather to be able to detect and analyse trends imposed on the regions through a conceptualised understanding of the support granted.

So one of the scenarios is more in line with the actual implementation of the recent CAP-reform. It is therefore designated “REF” as to some extent it can work as a point of reference to the development taking place in the real regions. The “REF” scenario is simulating the shift from the Agenda 2000-reform to a decoupled agricultural support program, which is continued throughout the rest of the simulated time periods.

In principle fully decoupled payments should not influence the production decisions of the farmers receiving the payments. That means that neither the shape nor the position of the supply and demand curves should be changed.

Fully decoupled payment is maybe possible in theory; however, it is debatable whether it is also possible to obtain in reality. The practical implementation of decoupled payments still needs to prove its ability to leave the production decisions unaffected. The decoupled payments simulated here do not fulfil these theoretical criteria. Their effect on the structural development is therefore simulated. Like other income transfer mechanisms the actual elaboration of the support mechanisms is important for the unattended effects it may have on the structural development within a given region.

Decoupled payments may take different forms and be granted on different criteria.

The decoupled payment granted in the scenario “REF” is the following: each farm household receives a decoupled single farm payment based on the average direct payment paid to the farm during the three periods prior to the policy change. The direct payment before the policy change is based upon the Agenda 2000 payment. The decoupled payment is bound to the farmer or his or hers legal successors.

The fields will have to be managed in a basic way in order to receive the payment. They will as a minimum have to be cut during the year.

The “REF” scenario includes also the possibility of participating in an Agri-Environmental Measure (AEM). The AEM’s differs in reality between the simulated regions, but in order to ensure comparability between the regional results an identical measure is introduced in all the regions.

The AEM used here is inspired by a real AEM undertaken in the case study area of Ostprignitz-Ruppin, located in the federal state of Brandenburg in Germany. The federal state of Brandenburg has introduced an AEM trying to promote “conversion of land into extensive grassland” in the framework of the Agenda 2000 of CAP. This measure aims not only at maintaining marginal land in a minimum of good condition, meaning that the farmer subscribing to this measure has to mow the grass twice a year, but also at providing pastureland for ruminants. Its implementation on an area of at least 30% of the UAA of the farm delivers to the farmer an Agri-Environmental Payment (AEP) of 130 €/ha of land used as extensive grassland. The possibility of participating in this program will be offered to the farmers as a part of the “REF” scenario.

Three additional scenarios have been constructed. Each of them refers in varying degrees to elements from the “REF” scenario at the same time as it reflects politically interesting possibilities. The three additional scenarios are designated S1, S2 and S3.

The S1 scenario investigates the effect on the structural development, when all the public support is shifted towards the AEM under the 2nd pillar in the CAP. The decoupled payment is abolished and only the support for the AEM is continued with an AEP of 130 €/ha subject to the same conditions as described above.

The S2 scenario could also be designated “end of public support” as the scenario investigates the effects of the regional development when all subsidies are abolished in an abrupt way.

The S3 scenario is very similar to the “REF” scenario. The support is administered in the same way as in the “REF” scenario but a ceiling for the amount a single farm can receive is introduced. The maximum amount of support a single farm may receive will as standard be 300 000€ /year.

In Table 7.6 an overview is given of the scenarios

	1st pillar	2nd pillar (AEP)
BAS	Agenda 2000	AEP
REF	Decoupled payment	AEP
S1	No subsidies	AEP
S2	No subsidies	No AEP
S3	Decoupled payment + ceiling of 300000€/farm	AEP

Table 7.6 Overview of the different scenarios. (Happe 2004; 2006)

All of the scenarios presented here build upon some general assumptions across the different regions.

Space: The smallest spatial unit is always 1 ha. That means that a single pixel is equal to 1 ha of land. Farms with an area smaller than 1 ha are therefore also abolished from the model.

Prices and variable costs: The prices and variable costs are the same for all farmers. In the presented simulations the farmers’ managerial abilities are also the same. The unit cost varies between the different farms as the individual farms livestock production technologies, machinery endowments and the age of the assets will influence the unit cost.

Rental contracts: The farms are allowed to renegotiate their land rental contracts in each period. This means of course that the structural adjustment to new economic conditions goes a lot faster than in the case where the farms operate with fixed lengths of contract. The farm’s ability to react faster means also that the model will react stronger to sudden changes.

The fixed contract lengths give a friction in the region.

Almost all units used in the regional analysis are self-explanatory and will therefore not be presented before use. This is not necessarily the case for an economic indicator such as farm profit. The farm profit is found by first taking the farm revenue (market receipts +direct payments + other receipts) – variable cost = gross margin. The gross margin minus expenses for depreciation, rent expenditure, wages, interest costs, transport costs, overheads, and maintenance costs will then be the farm profit. The farm-household income is then the profit + the off farm income.

7.6 Analysis of the study region Ostprignitz-Ruppin, Germany

The effects the different political support programs have on the regional development can be observed at different levels of the system. The values at the aggregated regional level communicate the general trends for the structural development subject to the different policies.

It is important to have this understanding of the general trends before an in-depth analysis of the regional development is presented. Therefore the aggregated results will be presented first and will hopefully serve as a useful foundation for the spatial analysis of the regional development.

As can be seen from Figure 7.2 there are 585 farms in the region initially. During the time before the policy change takes place the number is decreasing sharply to 412 in year 2004. The decreasing trend continues in all the scenarios, however, with different intensity.

The BAS-scenario continues its downward trend, however, with a declining rate. The number of farms drops below 200 in year 2014 and a steady slow decline is seen in the following years.

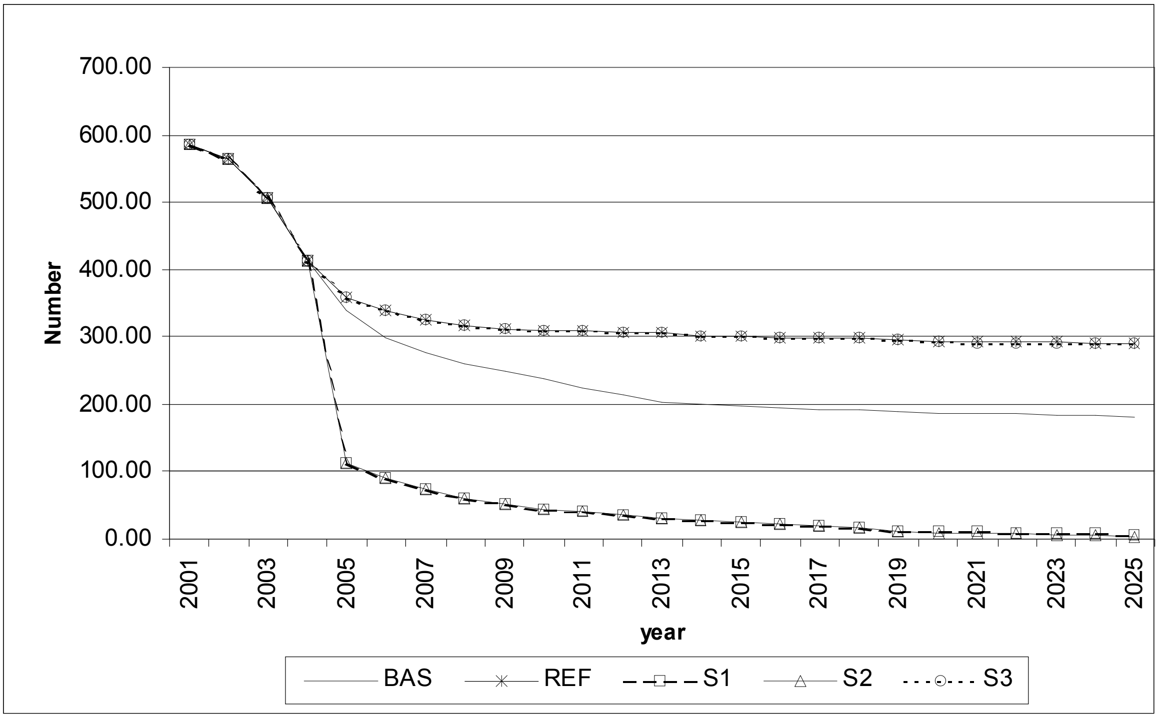


Figure 7.2 Total numbers of farms as a function of time. Source: own calculations

The total number of farms is the same for the scenario REF and S3 throughout most of the simulated period. Not until 2021 and on wards is there a single farm more in the REF scenario compared to S3. This is hardly detectable on the figure.

The total number of farms in the REF and S3 scenario stops its intense decline once the policy is initialised. The number of farms stabilises fast itself around 300 and maintains that level throughout the simulation.

Similarly to the two prior scenarios S1 and S2 are hardly differentiable in the Figure 7.2. The number of farms in the two scenarios separates 3 years earlier than REF and S3. The separation is slightly larger than the prior case, but still hardly visible. The number of farms takes a heavy blow downwards when the policy change sets in. The number of farms is continuously declining throughout the simulation until the sector is almost disappearing from the region.

Similar trends induced through the different policies are seen in the other regions. The intensity and character of the changes might differ; but also a large number of similarities can be seen. The fact that the scenarios REF and S3 as well as S1 and S2 constitute two pairs, which are hard to separate from each other, is also the case in the other regions.

This is hardly surprising when the nature of the different scenarios is considered. In the case of REF and S3 the only difference is that a few large farms are affected by the ceiling for public support. In the case of S1 and S2 the continuation of the AEM-program by allowing the AEP is the only difference. From an economic point of view the funds in the 2nd pillar are relatively small compared to the 1st pillar support and the support is always accompanied with production restrictions. The programs are therefore not necessarily addressing all the farms in the region. For a number of farms the situation within scenario S1 and S2 is therefore identical.

The motive for including all five scenarios in the analysis is due to the political and environmental attention the options within the scenario S1 and S3 have attracted. The option of reducing the cost of the CAP by limiting the maximum amount a single farm can receive has often been debated and so has the option of only supporting environmental initiatives.

The results of all five scenarios will be presented whenever the individual figures allow it without additional space or if there is a need for highlighting differences between the paired scenarios. Otherwise the main focus will be on the BAS, REF and S2 scenarios.

7.6.1 Demonstrating the GIS-based analysis by looking at the dairy production

In order to demonstrate how to understand the GIS-based analysis and to illustrate the advantage of using a GIS-based analysis we will try to take a first look at the dairy production within the study area. The absolute number of dairy cows in the region as a function of time within the different investigated scenarios can be seen in Figure 7.3.

The impact of the different political programs is distinct. Once the different policies are initialised there is a sharp reaction away from the steady decline witnessed in the BAS scenario. The number of dairy cows in the BAS scenario declines throughout the simulation to a point where the dairy production in the region has almost disappeared. In the last simulation periods (which are subject to considerable uncertainty) the numbers of dairy cows in the BAS scenario are below the numbers seen in the S1 and S2 scenarios. These scenarios were on the other hand subject to a sharp decline in the number of animals just after the new policies were introduced. The number of animals decline only slowly from these new low levels and is in periods almost maintained at a constant level. In the case of REF and S3 the number of dairy cows is increasing for a considerable number of periods after the decoupled payments were introduced. Around year 2010 the number of dairy cows very slowly starts to decline again. The two scenarios REF and S3 show here a small deviation as the number of dairy cows in the S3 scenario is slightly higher than REF.

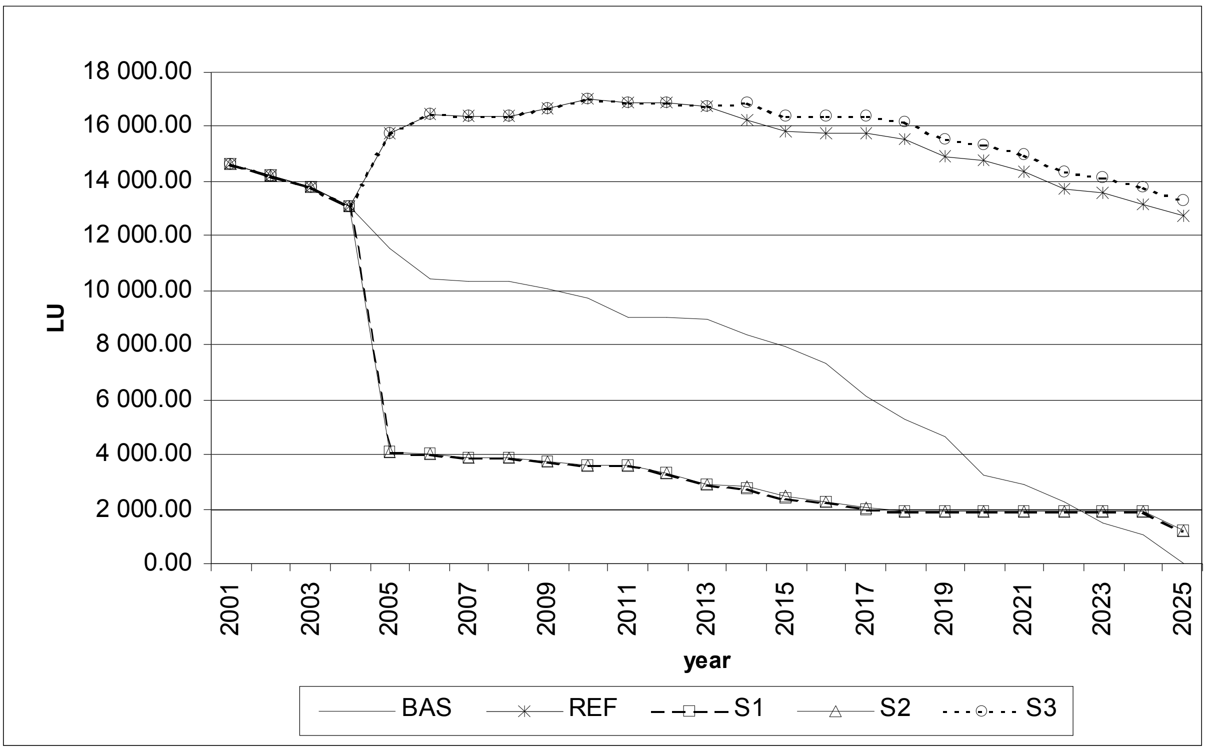


Figure 7.3 The absolute number of dairy cows in the region as a function of time. Source: own calculations

The absolute number of animals in the region gives a limited impression of the intensity of the dairy production taking place. So in order to better understand the character of the production the number of dairy cows per ha is presented in Figure 7.4.

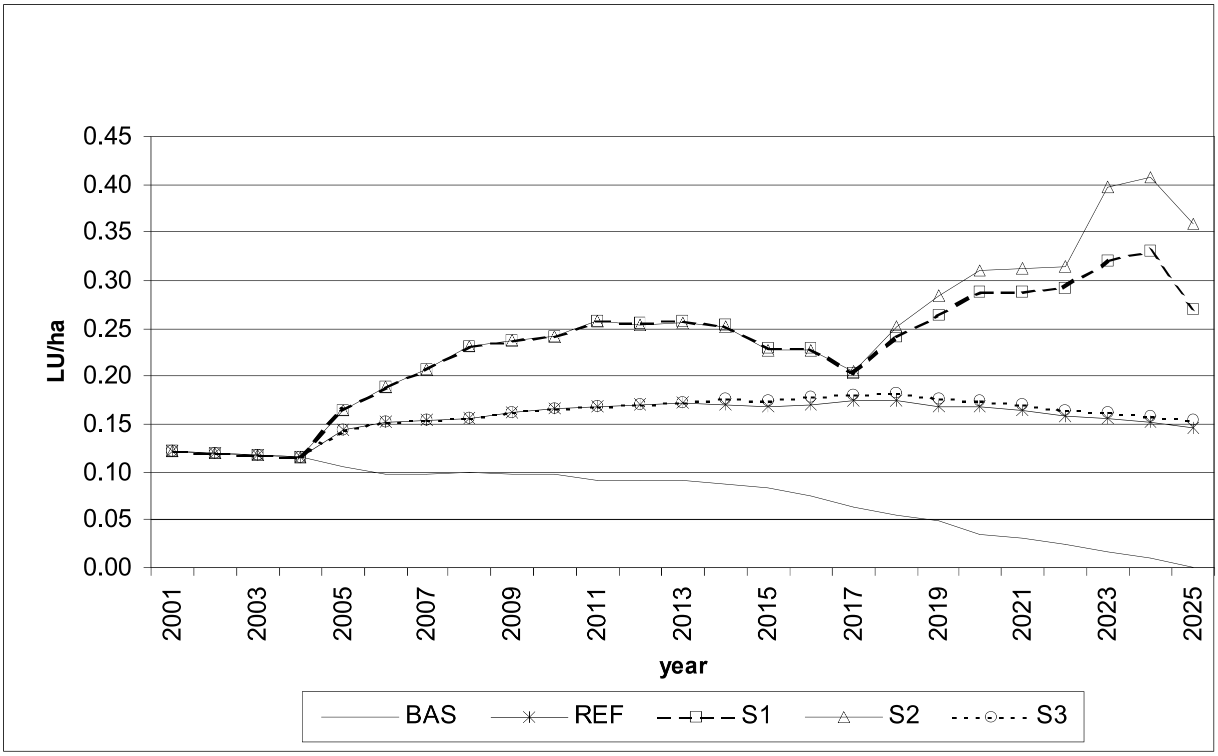


Figure 7.4 Number of dairy cows per ha of all farmland as a function of time. Source: own calculations

The number of dairy cows per ha is also declining in the case of BAS, however, with a considerably smaller gradient relative to the decline in the absolute number of dairy cows. This means that the majority of the decline in number of dairy cows is due to farms quitting their dairy production altogether rather than individual farms downscaling their production.

In the other scenarios the number of dairy cows per ha is increasing. The two decoupling scenarios REF and S3 experience a steady increase in the number of dairy cows throughout the majority of the simulated periods only to have a small decline in the intensity in the last periods. The development in the S1 and S2 scenarios is much more dramatic. The two curves do not follow any clear pattern. In the late part of the simulation the two scenarios clearly separate. Though the curves fluctuate both up and downwards during the simulation the intensity level is at all times above all the other scenarios.

By only looking at Figure 7.3 and 7.4 and their aggregated results it is hard to know what actually is going on. Why are the S1 and S2 curves in Figure 7.4 making such jumps? In order to understand the development it is useful to supplement the analysis with a look at the GIS-maps of the number of dairy cows. Three sets of maps (Map 7.3, 7.4 and 7.5) are presented below.

In order to appreciate the spatial visualisation of the results it is necessary to understand how values are assigned to each point. The model does obviously not “know” precisely where each individual dairy cow is located on a particular farm at a given time. The model “knows” only the value of a given parameter such as the dairy cows that a particular farm has in a particular period. At the same time the area belonging to this farm is known. So each individual piece of land of the given farm is assigned this farms value. That means that if farm X in period 0 has 10 dairy cows all the area belonging to farm X in period 0 will be assigned the value 10 when dairy cows are investigated. That means of course also that the spatial interpretation of the maps has to be understood in this light. It is maybe natural to interpret a marked area on a map as the spatial location such as the specific field where the actual production is taking place. However, AgriPoliS is not operating with such spatial explicitness. The marked area visualises the area belonging to single farms within which the production is taking place. The colour of the area indicates the numerical size of the illustrated parameter. This interpretation of the maps is particularly important to remember when field crops are spatially presented. The marked areas are not the individual fields producing the investigated crop, but the amount of the crop produced on all the farms involved in this crop production.

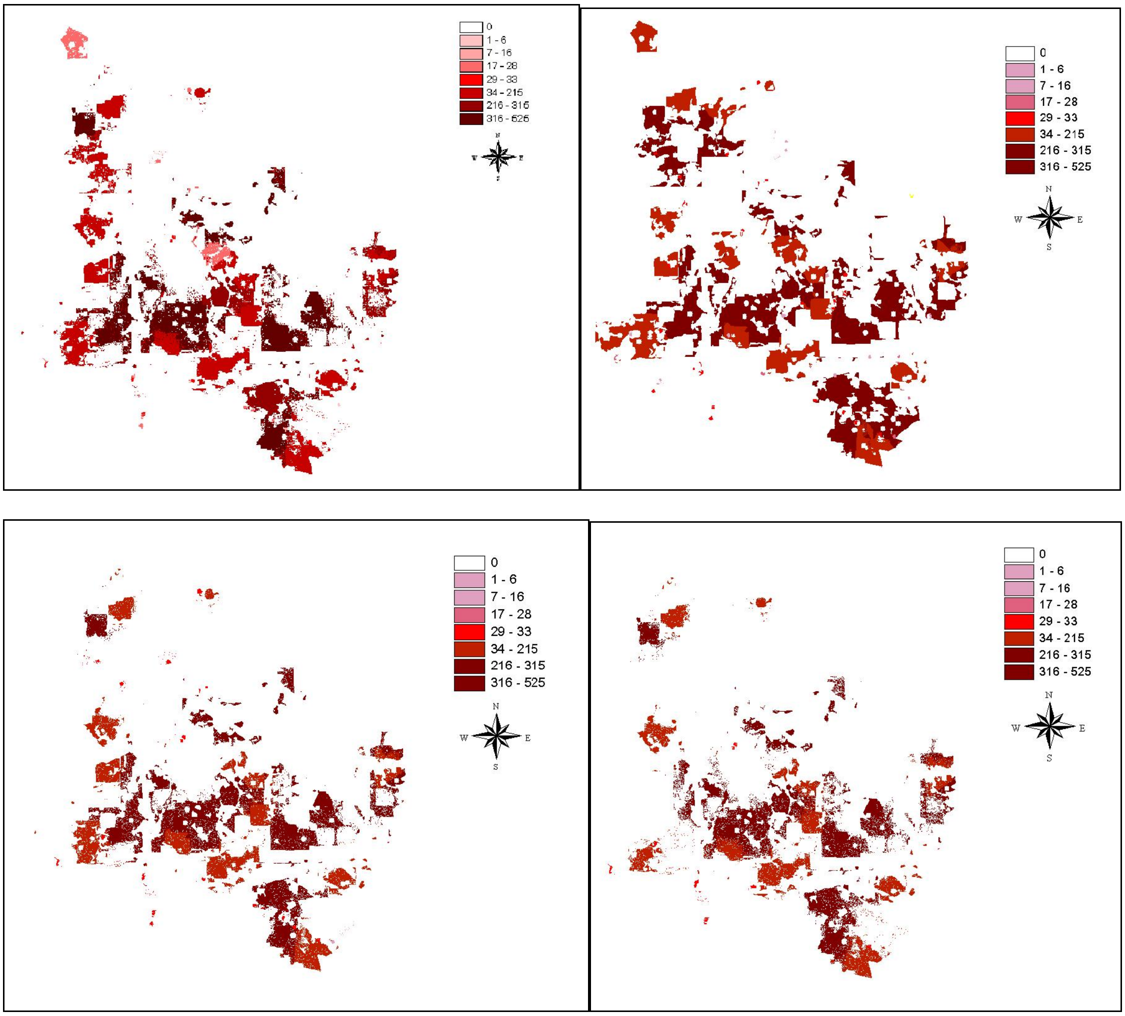
Each of the three map sets (Maps 7.3, 7.4 and 7.5), illustrates the values for a given scenario in the order BAS (Maps 7.3), REF (Maps 7.4) and S2 (Maps 7.5). Each consists of four maps that are organised as follows:

The map in the upper left corner shows the average number of the investigated item (in this case number of dairy cows per farm) in periods 4-10 in space. The value at each individual spatial location is summed up over the 7 periods and divided by the number of involved periods. The starting point in period 4 is chosen, as it is the time step after the initialisation of the different political scenarios. By leaving out the periods before the policy change the effect of the policy change becomes clearer.

The map at the top right shows the number of dairy cows in period 0. As all the scenarios are initialised with the same values this map is the same across the three sets. Hereby the top left map can work as a benchmark both relative to the development during the simulated periods as well as across the different scenarios.

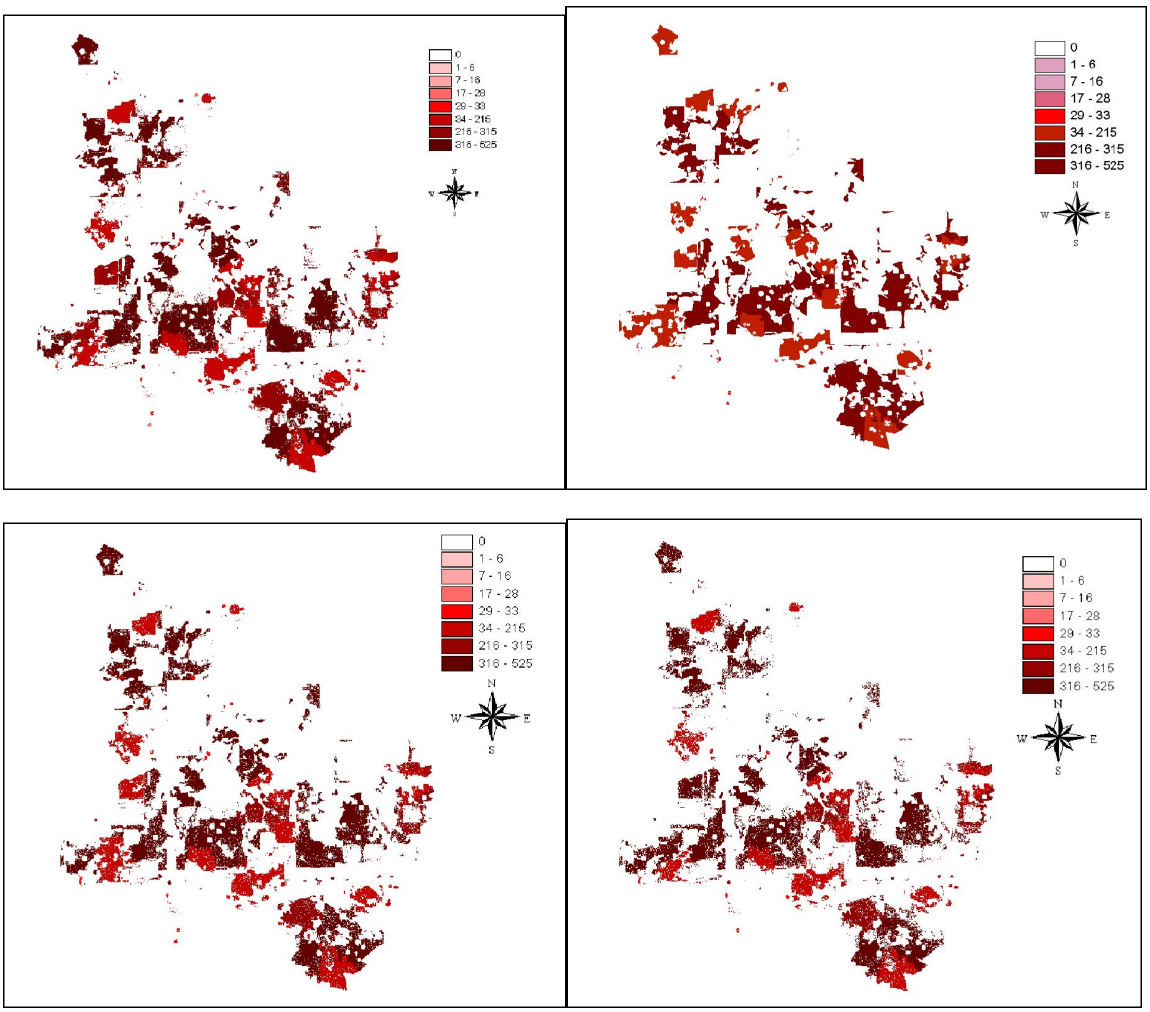
In the map at the bottom left the numbers are shown for period 5. This map shows the effects immediately after the initialisation of the new policies. The map at the bottom right is showing the same in period 10. The map communicates the middle term effects of the policies. As the uncertainty in modelled results increases with the simulated periods the results of later periods are not shown as GIS-maps to avoid over-interpretation of the results.

Let us exemplify the above by reverting to the case of number of dairy cows in the region. In the case of BAS (Maps 7.3) most of the same spatial structures found in period 0 (top right) are detectable in the map of average values (top left), however, in a watered-down version. Some of the areas are not present any longer and most of the rest have lower values. A few of the large farms seem, however, to be able to maintain the intensity in their production. Both the map for period 5 (bottom left) and the map for period 10 (bottom right) reflect the same patterns at the same time, as the decline in the number of dairy cows is evident. The farms involved in dairy cow production have declined between period 5 and 10 as well as some of the farms remaining have changed their size. The maps show hereby that the decline in the total number of dairy cows in Figure 7.3 and the weaker decline in the number of dairy cows per ha comes from a steady decline of the number and size of the farms involved in dairy production.



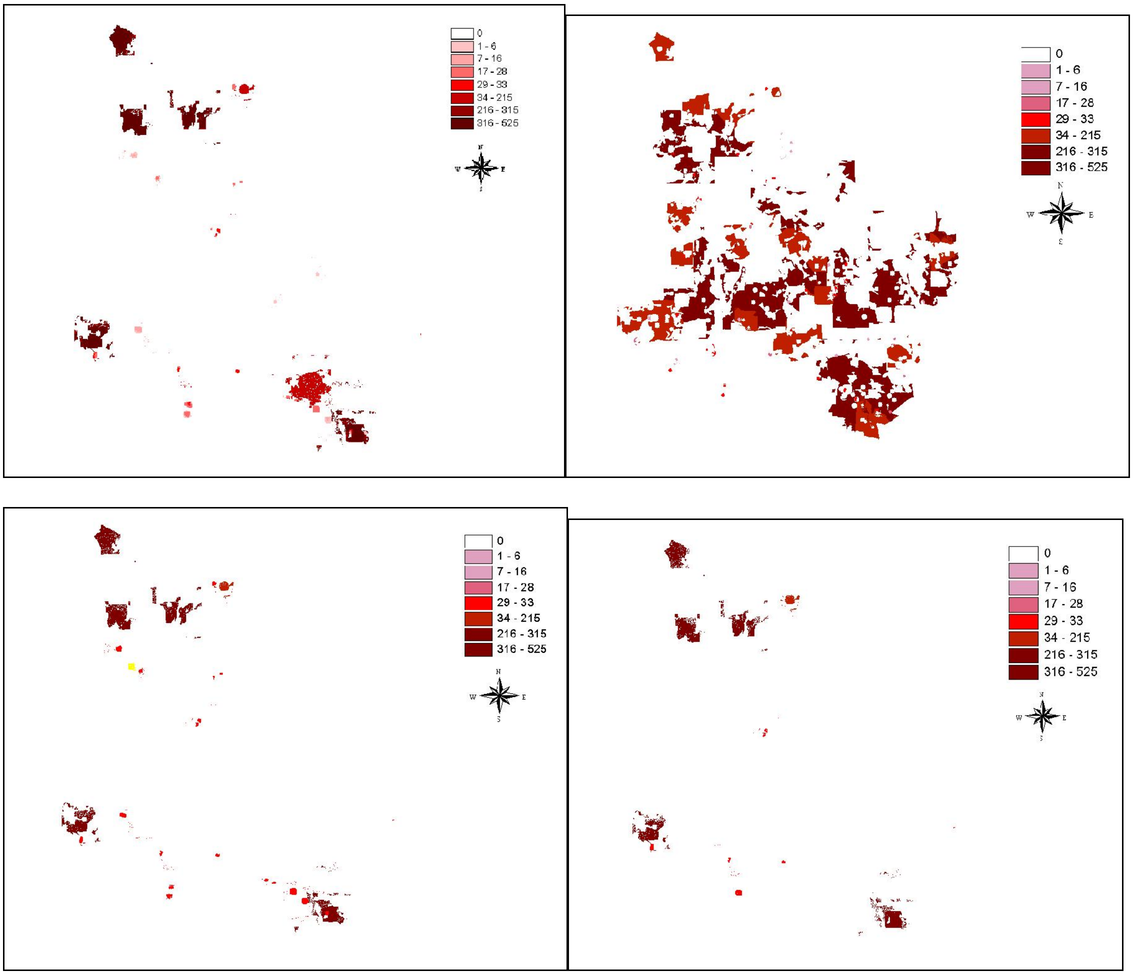
Map 7.3 Results from BAS scenario. Upper left shows the average number of dairy cows per farm in periods 4-10 in space. The value at each individual spatial location is summed up over the 7 periods and divided by the number of involved periods. The map at the top right shows the number of dairy cows in period 0. Bottom left shows the number of dairy cows for period 5. The map at the bottom right shows the number of dairy cows in period 10. Source: own calculations

In the case of the REF scenario shown in the Maps 7.4 the number of dairy cows as well as the area belonging to the dairy producing farms is increased when comparing the average situation after the policy with the point of departure in period 0. This upwards shift is also visible when period 0 is compared to the situation in period 5 and 10. At the same time the slowly starting reduction in the number of animals around year 2011 (period 10) is detectable. The farms have started to dispose of areas particularly around the edges of their fields. The bust in the dairy production that the decoupling of the support gave is slowly declining in period 10.



Map 7.4 Results from REF scenario. Upper left shows the average number of dairy cows in periods 4-10 in space. The value at each individual spatial location is summed up over the 7 periods and divided by the number of involved periods. The map at the top right shows the number of dairy cows in period 0. Bottom left shows the number of dairy cows for period 5. The map at the bottom right shows the number of dairy cows in period 10. Source: own calculations

Far more dramatic are the maps from the S2 scenario shown in Maps 7.5. Without the map for period 0 next to the other maps the region would hardly be recognisable. The three other maps consist solely of a few scattered areas. The averaged development contains a few more areas than seen in the maps for period 5 and 10.



Map 7.5 Results from S2 scenario. Upper left shows the average number of dairy cows in periods 4-10 in space. The value at each individual spatial location is summed up over the 7 periods and divided by the number of involved periods. The map at the top right shows the number of dairy cows in period 0. Bottom left shows the number of dairy cows for period 5. The map at the bottom right shows the number of dairy cows in period 10. Source: own calculations

These areas are indicated as less intensive areas that illustrate that the areas only had dairy cows in part of the investigated time periods rather than showing the average intensity of the production when it was in place.

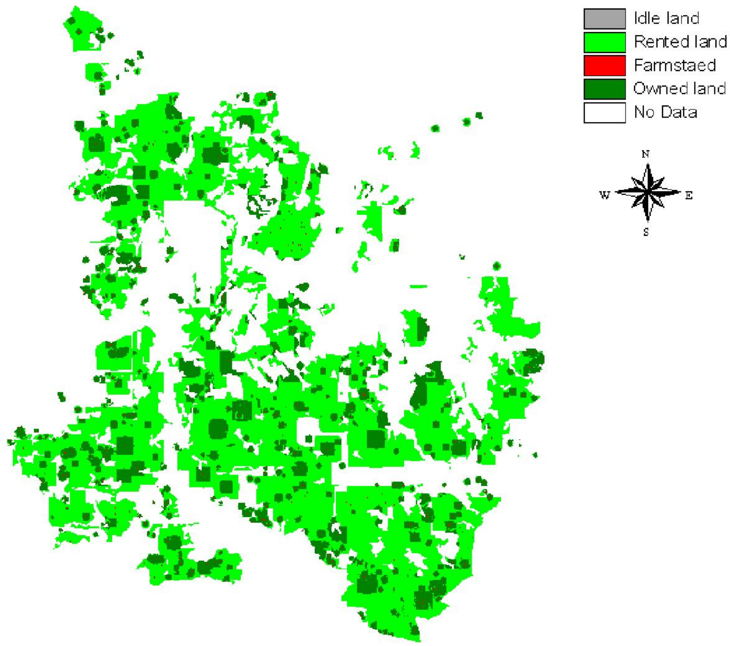
The maps for period 5 and 10 are almost identical with the exception of some of the very small dairy producing farms. The farm structure reveals, however, also the explanation for the large fluctuations in the intensity of the dairy cow production as seen in the Figure 7.4. As the whole dairy production is concentrated around a few very intensive farms even small changes in the number of these farms or the size of their production will result in distinct changes in the average intensity of the production.

The number of dairy cows demonstrates the benefits of spatially analysing the simulated results at the same time as exemplifying the resulting interpretation. Moreover the example could show how large and dramatic effects a shift in the political framework conditions may have on a particular part of the agricultural sector.

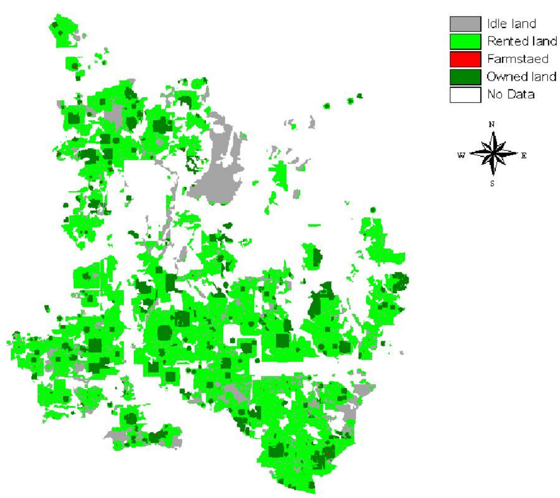
7.6.2 Rented, owned and idle land and farm size

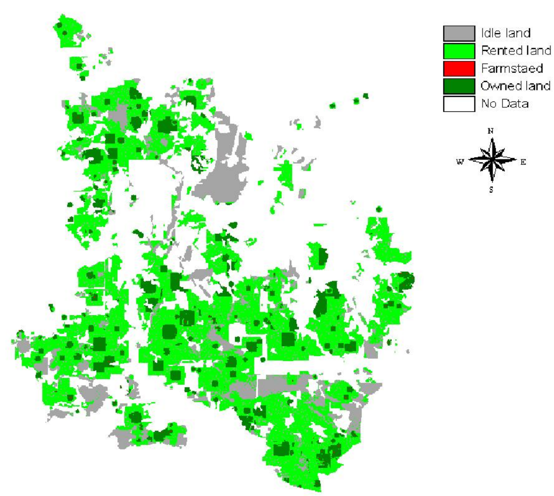
However, in order to be able to extract such information of the maps one needs to be able to hold the development within the dairy production up against the development in the sector as such. As seen in the Figure 7.2 the political framework conditions clearly affect the regional development. In the Maps 7.6-7.8 the areas of rented, owned and idle land as well as the farmsteads are shown for the period 0 (Map 7.6) and for period 5 and 10 in each of the scenarios. Below the maps Table 7.7 is summarising the number within each category. As a single pixel in the maps corresponds to 1ha the values are equal to the hectares of each category.

The amount of idle land is comparable for the BAS and REF scenario as the values in the Table 7.7 shows. The spatial location of the abandoned areas differs, however, for large parts as can be seen from the maps. In the case of BAS the idle areas in period 10 are large coherent lumps of land that are clearly visible. This is not to a similar degree the case for REF in period 10 though the amount of idle land is comparable as Table 7.7 shows. A fair proportion of the abandoned areas are naturally the same in the two scenarios but in the case of REF the idle areas are distributed otherwise in more scattered, smaller parts. The considerably larger number of farms able to continue in the case of REF means that the land left out of production to a lesser degree comes from farms which closed their production altogether but rather from farms that have downscaled their production.



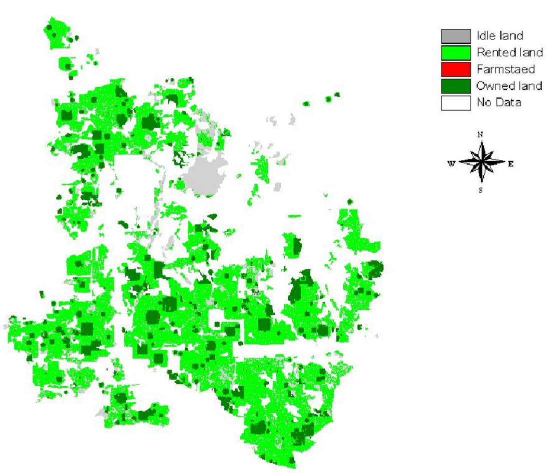
Map 7.7 Areas of rented, owned and idle land for the period 0. Own calculations

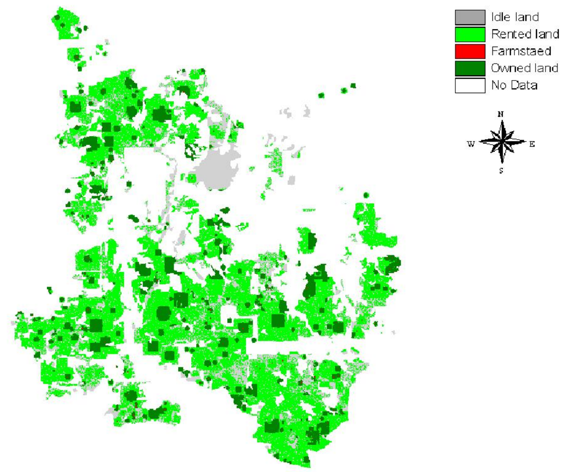




Map 7.8 above left: Areas of rented, owned and idle land for the period 5 in BAS scenario. Own calculations.

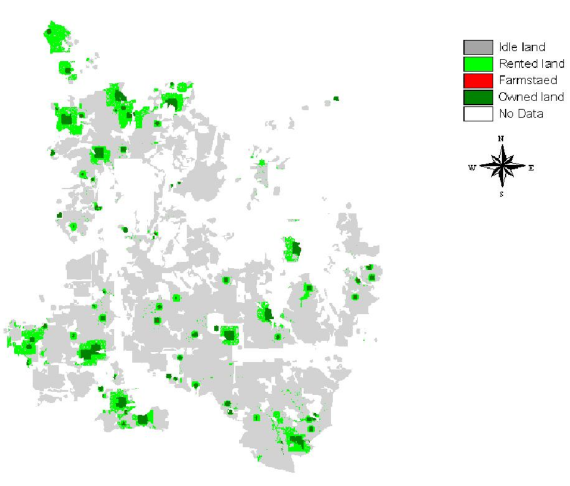
Map 7.9 above right: Areas of rented, owned and idle land for the period 10 in BAS scenario. Own calculations.

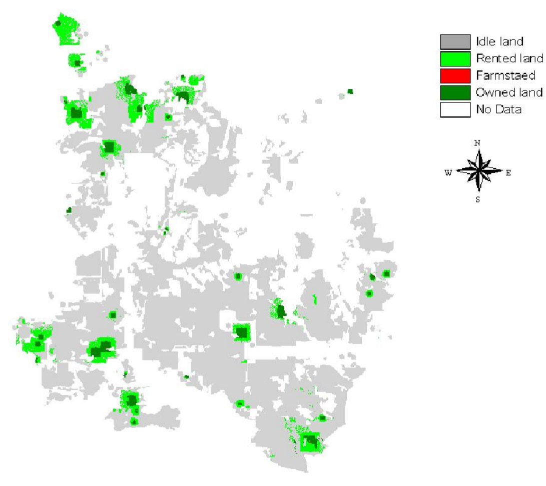




Map 7.10 above left: Areas of rented, owned and idle land for the period 5 in REF scenario. Own calculations.

Map 7.11 above right: Areas of rented, owned and idle land for the period 10 in REF scenario. Own calculations.





Map 7.12 above left: Areas of rented, owned and idle land for the period 5 in REF scenario. Own calculations.

Map 7.13 above right: Areas of rented, owned and idle land for the period 10 in S2 scenario. Own calculations.

The effect of ending the public support, as is the case in the S2 scenario, is clear. For the large majority of farms it is uneconomical to continue farming without public support and only a few intensively producing farms continue. Between period 5 and 10 in the S2 scenario the production is concentrated around a few large farms whereas most of the smaller farms have disappeared.

	Period 0	BAS Period 5	BAS Period 10	REF Period 5	REF Period 10	S2 Period 5	S2 Period 10
Idle land (Ha)	0	21102	28775	19002	27015	102744	108329
Rented land (Ha)	93027	81208	74765	82058	74643	13441	9452
Farms (Number)	585	277	214	325	307	73	35
Owned land (Ha)	27345	18370	17203	19572	18992	4699	3141

Table 7.7. Areas of rented, owned and idle land for the indicated period and scenario. Own calculations

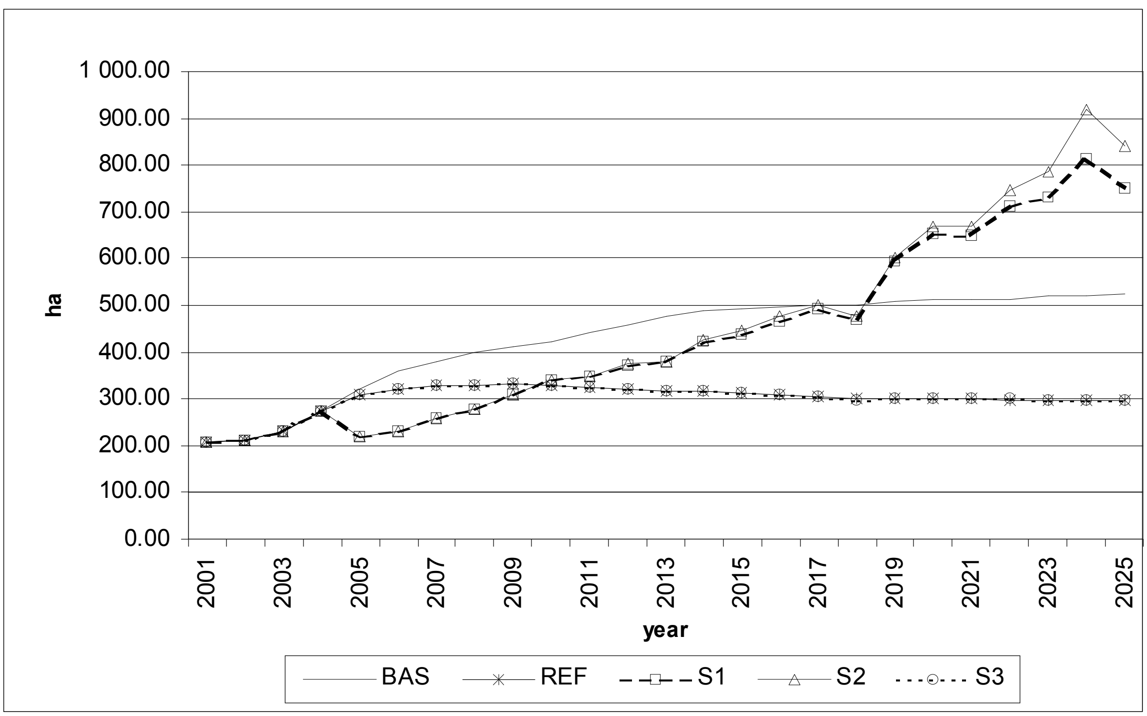


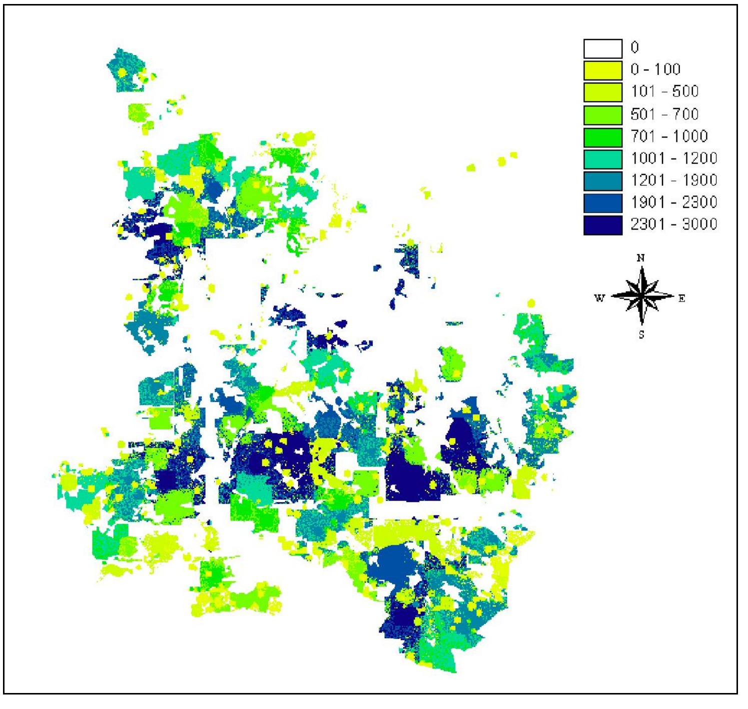
Figure 7.5 Average farm sizes as a function of time. Own calculations

Though the farms in the S2 scenario may seem large as one clearly can distinct most of the individual farms from one another the farms' average size is relative to the other scenarios within the normal range. In Figure 7.5 the development in average farm size over time is shown.

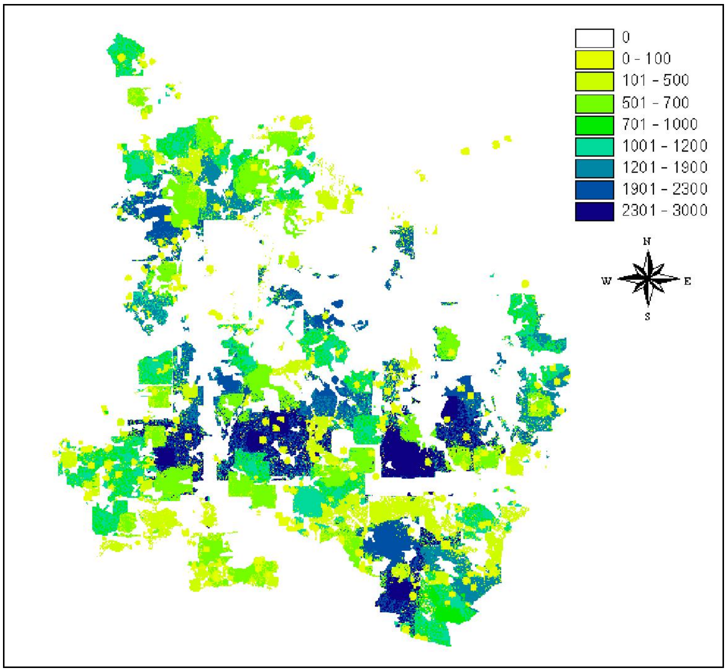
The Figure 7.5 needs to be read with some caution, as among the different scenarios there are large variations in the number of farms that the average farm size is based upon. If a single farm leaves the sector late in the simulation of the S1 or S2 scenario it will likely be reflected in the average farm size value. This is not necessarily the case in the other scenarios as the contribution of most single farms is almost negligible.

To avoid the possible misinterpretation that the Figure 7.5 possibly can lead to, the figure is supplemented with maps of the average size in the period 4-10. The average size is calculated on an individual field basis. A specific field can belong to several farms during the periods. It is the average size of these farms that is used.

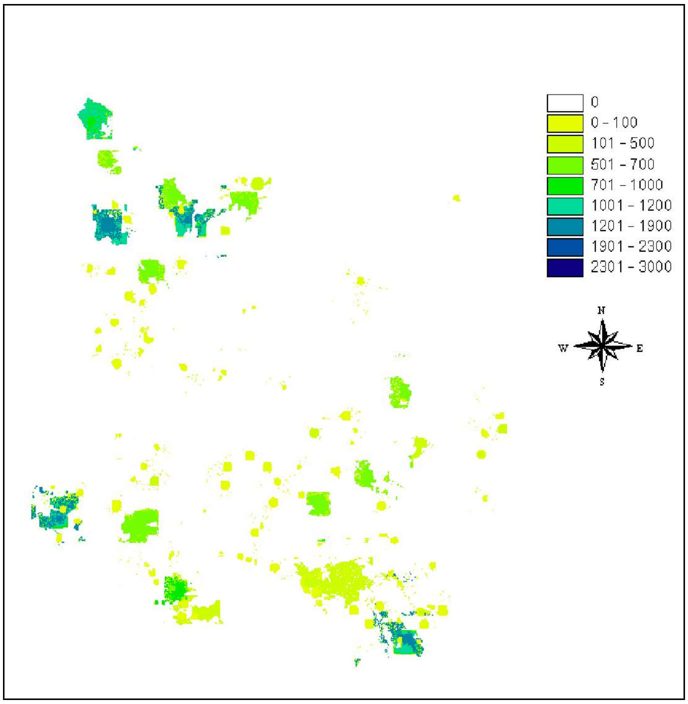
Below the Maps 7.14-7.16 are showing the average size in periods 4-10 in space for the three scenarios BAS, REF and S2.



Map 7.14 Average farm sizes in period 4-10 for BAS scenario. Own calculations



Map 7.15 Average farm sizes in period 4-10 for REF scenario. Own calculations



Map 7.16 Average farm sizes in period 4-10 for S2 scenario. Own calculations

As the colours of size indication in the three maps show the farms in BAS and REF are almost identical. The farms in BAS are slightly larger as the darker colours in the map indicate. The fewer farms in BAS have absorbed land that is divided out on more farms in the case of REF. In contrast to the BAS and REF scenarios the average farm sizes within the period 4-10 for the S2 scenario are not using the full scale of the size range. The few scattered farms still operating in the region are mainly within the size categories from 0-700 ha. Only a few individual farms are in the larger categories. None of them are within the largest categories, otherwise seen in the two other scenarios.

This illustrates why the interpretation of the development in average farm size as seen in Figure 7.5 needs to be supplemented with an elaboration of the size distribution which in this case is indirectly shown via the regional maps.

7.6.3 Farm income and profit

The structural development that the region witnesses through the number of farms and their size tells only indirectly about the economic consequences of the different policies on the individual farms. The economy of the farms is, however, important to understand for a number of reasons.

The economic effects on the individual farms are first of all the driver behind the structural development taking place. The economic consequences will therefore have to be investigated in order to understand the policies. Secondly, the economic costs and consequences associated with different policies are important for the decision makers. Finally the rural economic viability is also a recognized component of a multifunctional analysis of the development in agricultural production.

In Figure 7.6 the average total income per farm including off farm income is shown. The off farm income only parallel displace the curves in Figure 7.6 without changing their course in any of the scenarios. The off farm income plays, however, an important role in the case of S1 and S2 as the average farm income only hereby rises above zero for the first years after the introduction of the new policies. The development in the income per average farm in the case of those two scenarios is increasing from the very low starting point just after the shift in the policies. The small number of farms able to survive the policy change is once more causing the average values for the rest of the simulation to make abrupt jumps. With public support as in the case of S2 or only in form of the simulated AEM as in the case of S1 the farms are experiencing lower average incomes compared to the other scenarios during the whole simulated period.

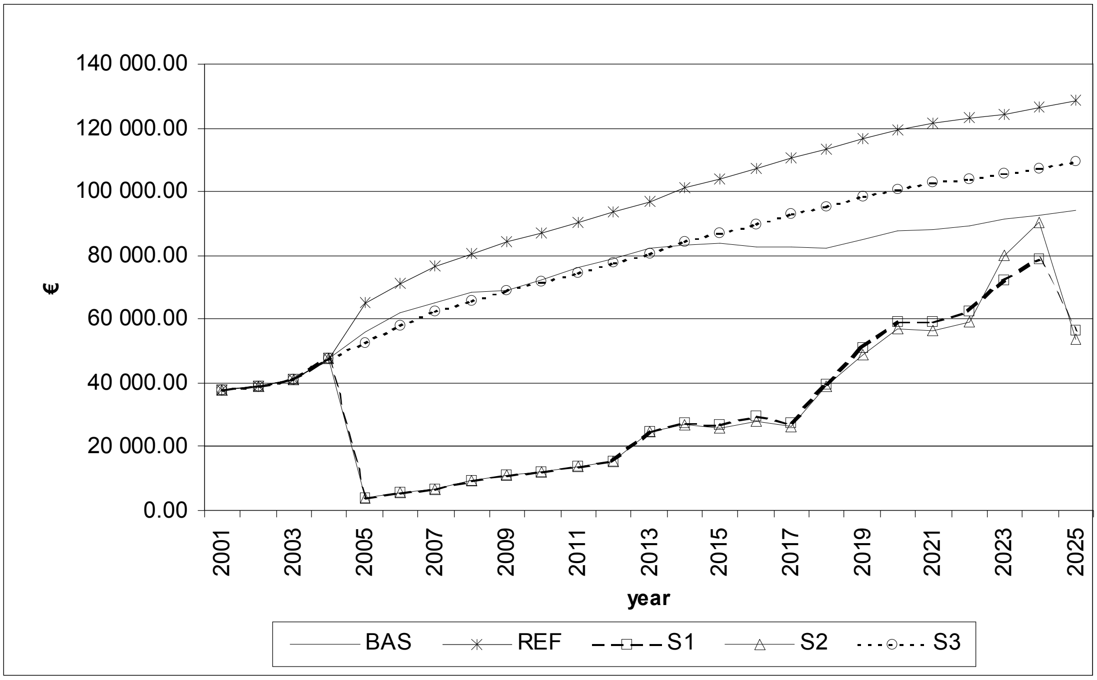


Figure 7.6 Average total income per farm including off farm income as a function of time. Own calculations.

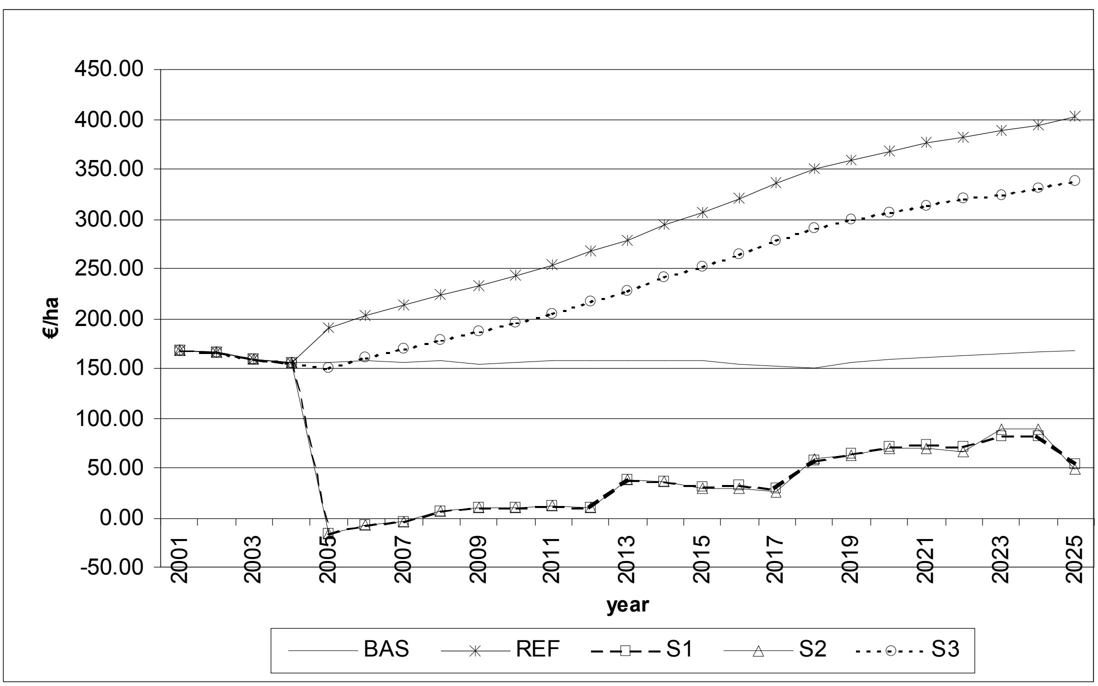


Figure 7.7 Average profit per ha (of area in production) as a function of time. Own calculations

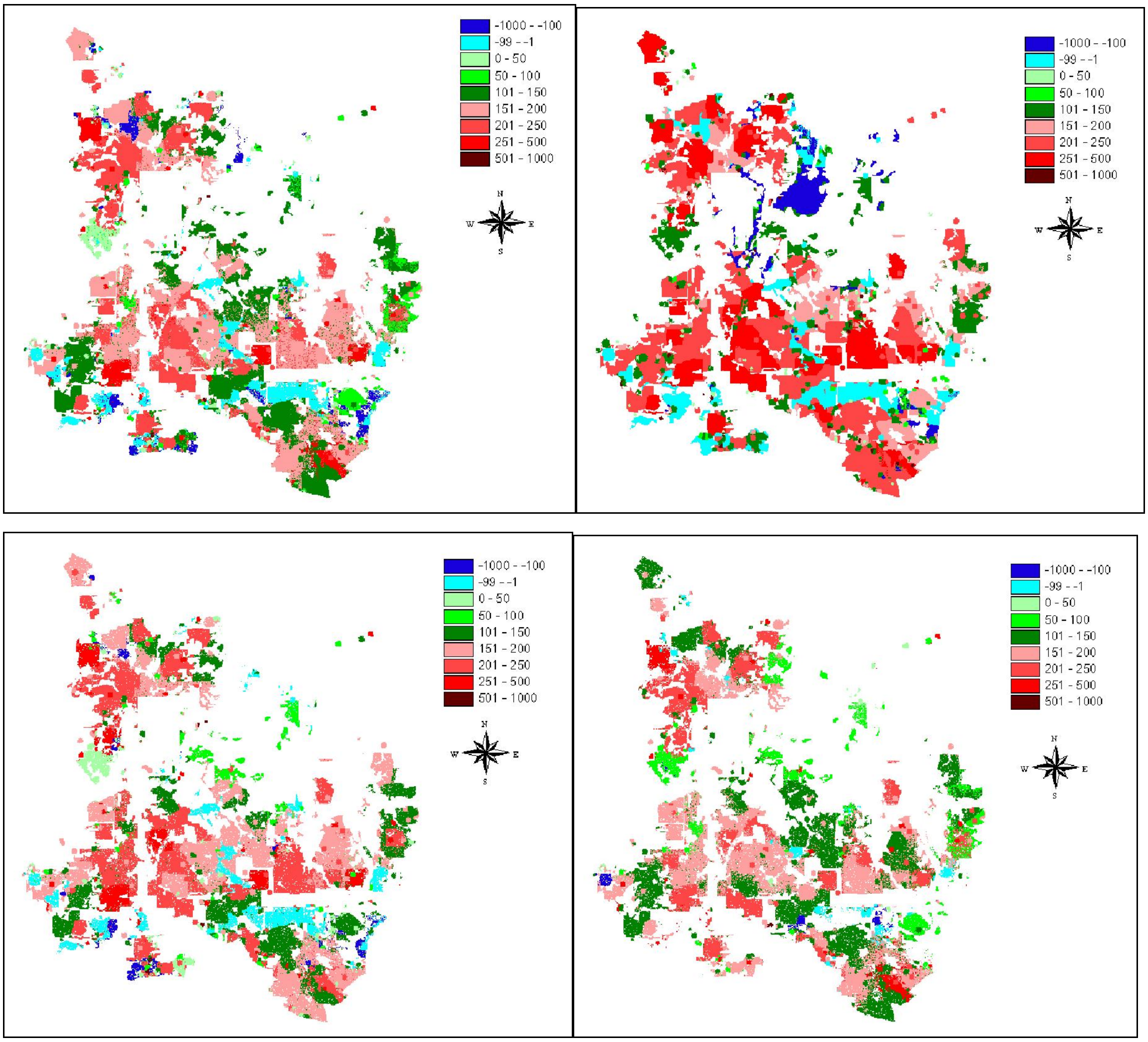
The farms able to stay in the sector during the simulated periods narrow the gap between the average incomes in the S1 and S2 scenarios compared with the other scenarios. The increasing average income in the two scenarios is mainly due to the continued decline in the number of farms rather than efficiency gains in the individual farms. The profit per ha in Figure 7.7 shows that the gradient in the case of S1 and S2 is not comparable to the increase in the farm income. As only the most competitive farms are able to maintain their production the average farm income is growing over time.

In the case of the three other scenarios are the average income is rising during the simulated periods. The level of the average income is similar in all three cases, however, with different variations. In the first years the average income in the case of BAS and S3 is following the same rate of increase, only for BAS to loose pace around year 2013.

The average income in REF and S3 is following the same path with the curve for REF displaced clearly parallel upwards. This is one of the few times where the development in the two scenarios does not follow each other completely and in none of the formerly presented figures have the difference been more persistent and distinct.

In Figure 7.7 showing the profit per ha the same parallel relationship between REF and S3 is found whereas BAS almost maintains at a constant level throughout the simulation. Considering the almost constant number of farms (as seen in Figure 7.2) in the REF and S3 scenario the increase in the profit per ha is particularly striking. The average farm size in REF and S3 is also maintained at a similar level throughout the simulation as Figure 7.5 showed. This means that the increase from 190.4 € per ha to 402 € per ha in the case of REF and from 149.3 € per ha to 336.8 € per ha in case of S3 is mainly due to the farms' ability to adjust to the new political framework conditions. An adjustment process does not take place in the case of BAS as the farms only continue under the same conditions.

Each of the Maps 7.17, 7.18, 7.19 and 7.20 that shows the profit per ha for BAS, REF, S3 and S2 respectively consists of four individual maps in the same structure as previously used. That means that the map in the upper left corner shows the average profit per ha in periods 4-10 in space. The map at the top right shows the profit per ha in period 0. In the map at the bottom left the numbers are shown for period 5. The map at the bottom right is showing the same in period 10. The average profit is calculated on an individual field basis.



Map 7.17 Profit per ha in BAS scenario. Upper left shows the average profit per ha in period 4-10. Top right shows the profit per ha in period 0. Bottom left shows the numbers for period 5. Bottom right shows the average profit per ha in period 10. Own calculations

Though the average value of the profit per ha shown in Figure 7.7 for BAS hardly changes this does not mean that the profit per ha for the individual farm stays the same during the simulation. As the Maps in 7.17 show there are clear changes both relative to the initial period (the top right map) as well as between period 5 and 10 (bottom left and right respectively). The variation in the profit per ha in the initial period is larger than in the two following periods shown. The full range of the scale is in use. As a number of large farms have a high profit per ha in period 0 the first impression of the maps may be that the farmers on average were doing better in period 0 compared to the two other periods shown. By supplementing the maps with the frequency distribution of the profit/ ha for the same intervals as in the maps, as shown in Figure 7.8, the variation in the maps is more comprehensible. The larger number of farms in period 0 makes the frequency of farms within most intervals larger compared to the later periods. By looking at the distribution within period 0 the predominant group of farms falls clearly within the 101-150 €/ha interval. Both in the case of period 5 and 10 the largest groups are in the interval between 151-200 €/ha. The maps for the two periods reveal, however, distinct displacements in the distribution of the profit per ha among the farms. A displacement is hardly detectable in neither the Figure 7.7 nor Figure 7.8.

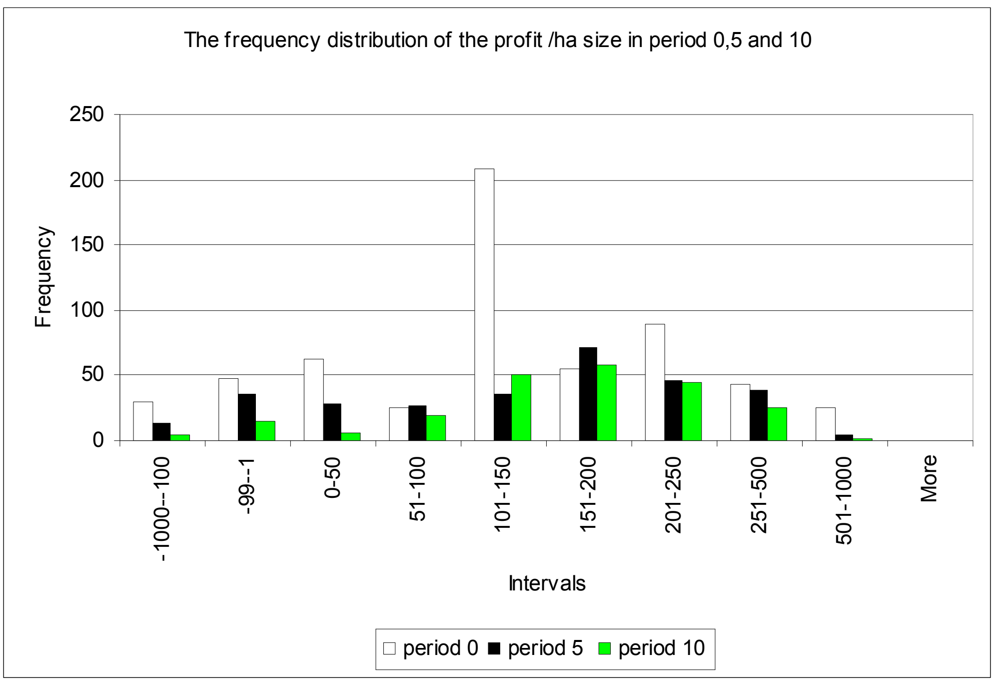
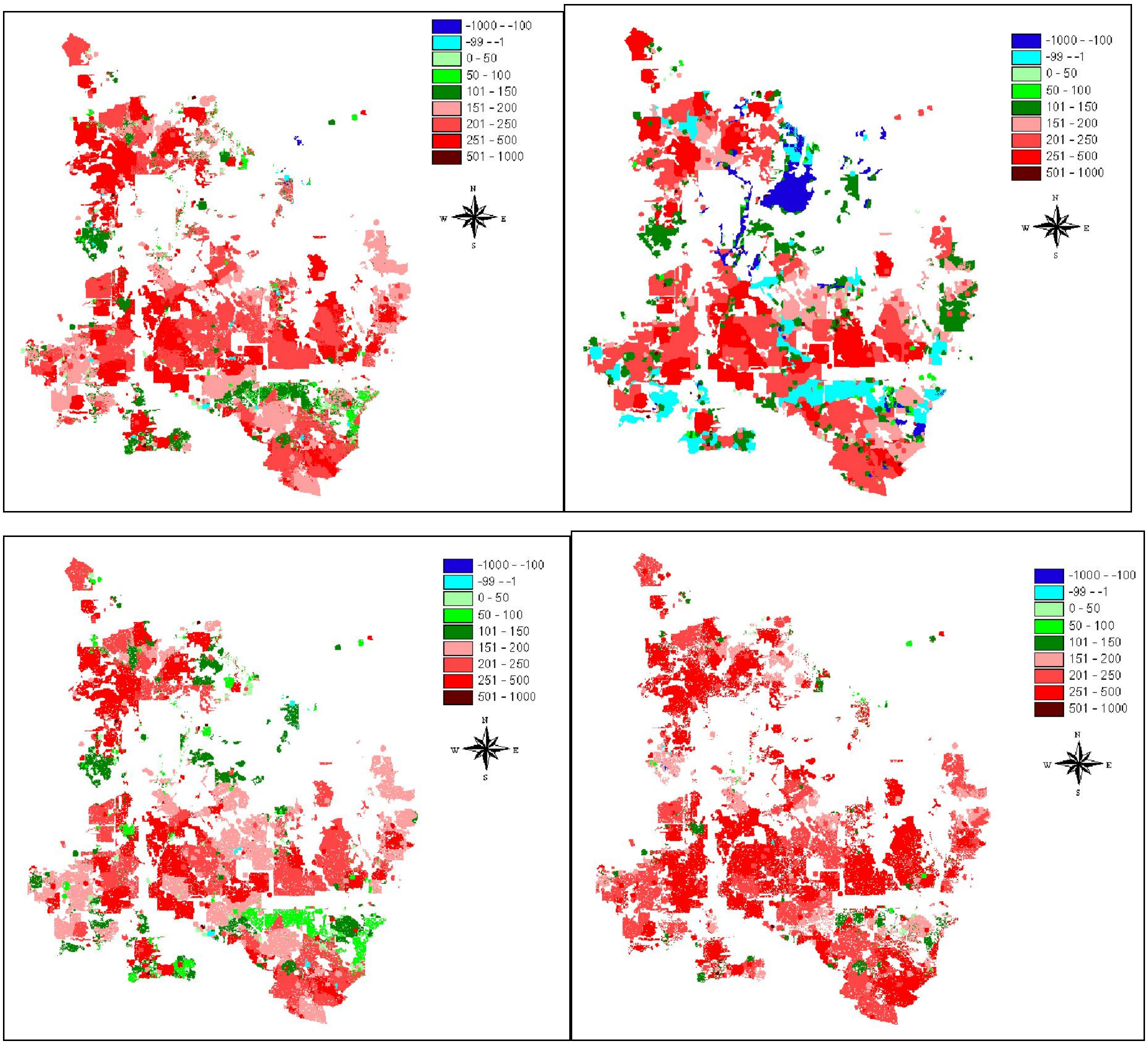


Figure 7.8 Frequency distribution of average profit per ha for period 0, 5 and 10 in BAS scenario. Own calculations.

By looking at the average over period 4-10 and same periods (period 0,5 and 10) for the REF scenario as Maps (7.18) and at the frequency distribution in Figure 7.9 it is clear that the policy change has influenced the profitability in the region compared to the situation in BAS.



Map 7.18 The profit per ha in REF scenario. Upper left shows the average profit per ha in period 4-10. Top right shows the profit per ha in period 0. Bottom left shows the numbers for period 5. Bottom right shows the average profit per ha in period 10. Own calculations.

In the case of the REF scenario the profit per ha is increasing during the simulation so that almost all farms have a positive profit per ha in period 10 and the majority of farms falls into the interval between 251-500 €/ha. The trend towards this high level of profit per ha is also visible in period 5. The farms still in the process of adapting themselves to the new political situation induced, however, are clearly obtaining a high profit per ha.

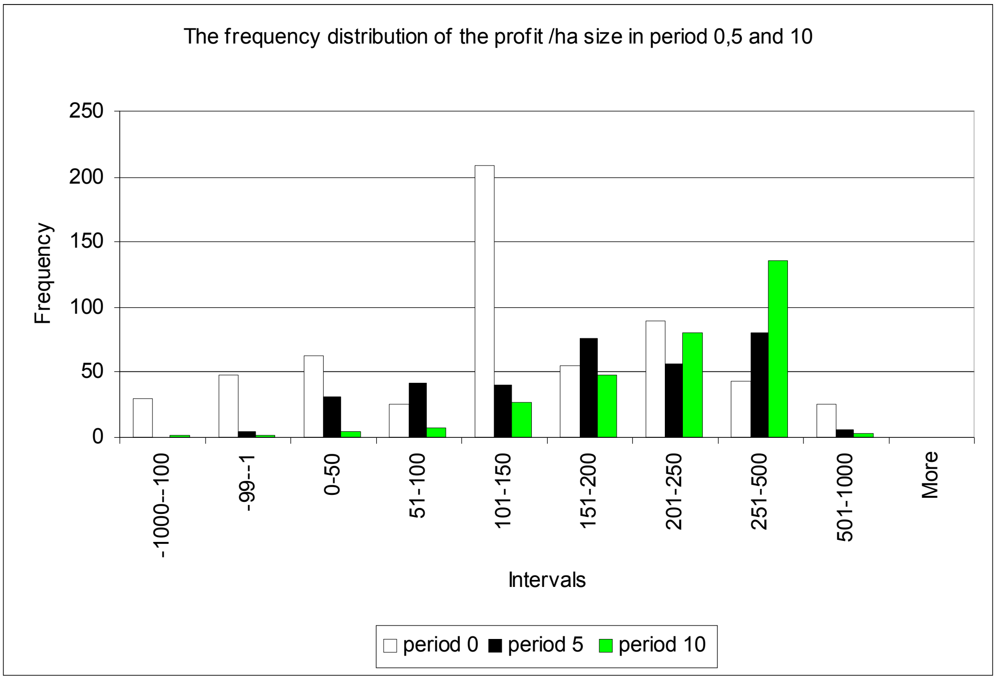
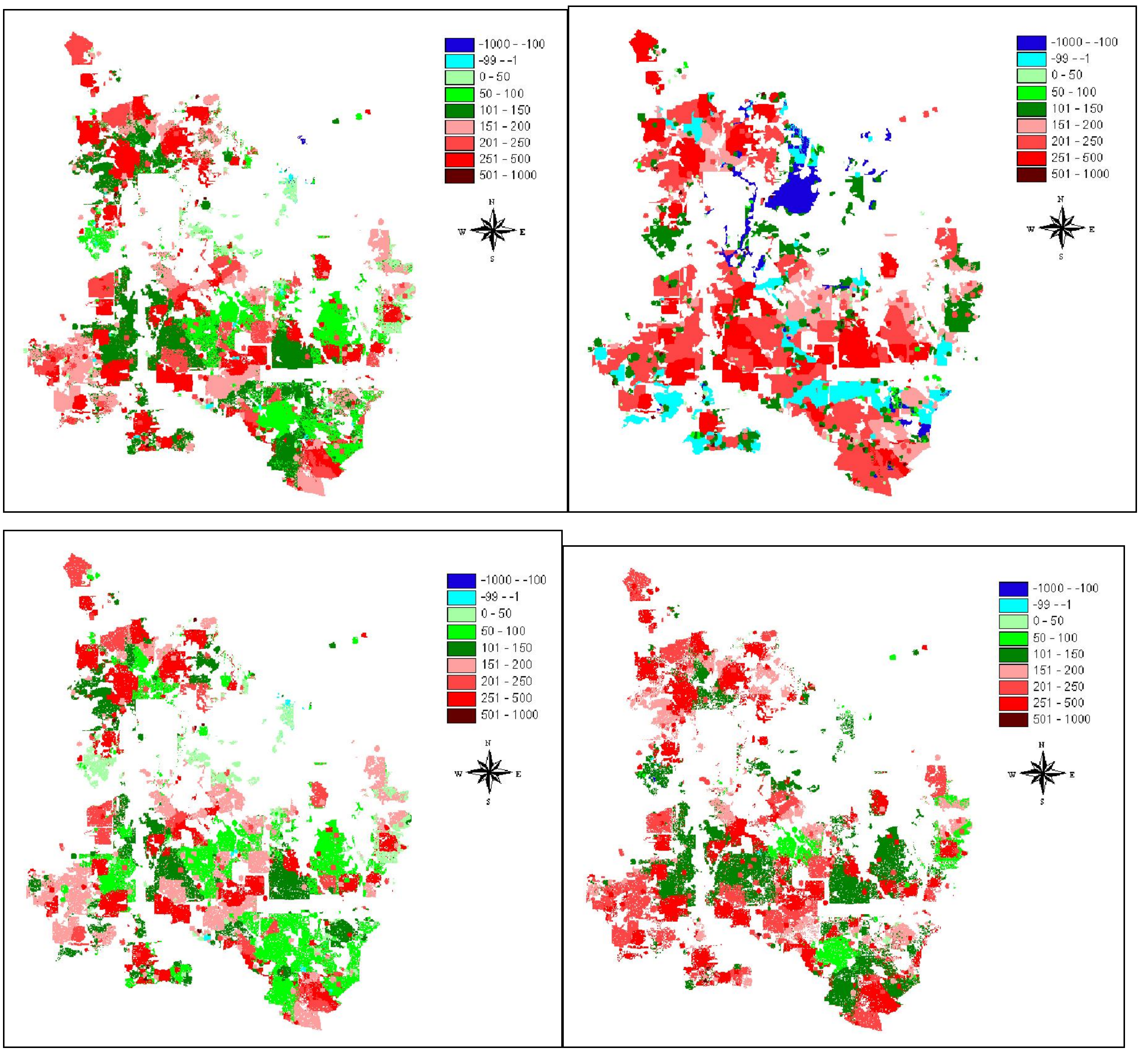


Figure 7.9 Frequency distribution of the average profit per ha for period 0, 5 and 10 in REF scenario. Own calculations.

The development in the profit per ha in the REF scenario needs to be compared with the results from the S3 scenario. As shown in Figure 7.6 and 7.7 there are a differentiation between the average profit per ha in REF and S3 scenario. The two scenarios have otherwise shown a striking similarity in their development. The results for the S3 scenario are shortly presented so a comparison between the two scenarios can be made. A better understanding of the process behind the development in the two scenarios based on this comparison is given.

The area experience an increase in the profit per ha in the scenario S3 as Maps 7.19 show. Almost none of the farms have a negative profit per ha. Both in period 5 and 10 the maps are mainly divided into two large groups of farm profitability per ha. One group of farms in the range of 0-150 €/ha (the green marked areas) and another group with profit per ha above 150 € per ha (the red marked areas). This clear split between the farms in the maps is hardly visible in the Figure 7.10 showing the frequency distribution of the farms profit per ha in period 0,5 and 10. The structure of the frequency distribution for the two periods 5 and 10 may at first glance look identical to the pattern seen in the Figure 7.9 showing the same for the REF scenario. If one compares the frequency distribution of the two scenarios a bit more thoroughly it is possible to detect a small reduction in the interval 251-500 for S3, which again is compensated by small increases in the intervals 100-150 and 151-200. Far more distinct are the differences in the maps from the two scenarios. The small differences between the two frequency distributions propagates in the maps as large areas that have changed from belonging to the high (red) categories in REF and declined to the categories between 0-150 € per ha (green areas).



Map 7.19 The profit per ha in S3 scenario. Upper left shows the average profit per ha in period 4-10. Top right shows the profit per ha in period 0. Bottom left shows the numbers for period 5. Bottom right shows the average profit per ha in period 10. Own calculations.

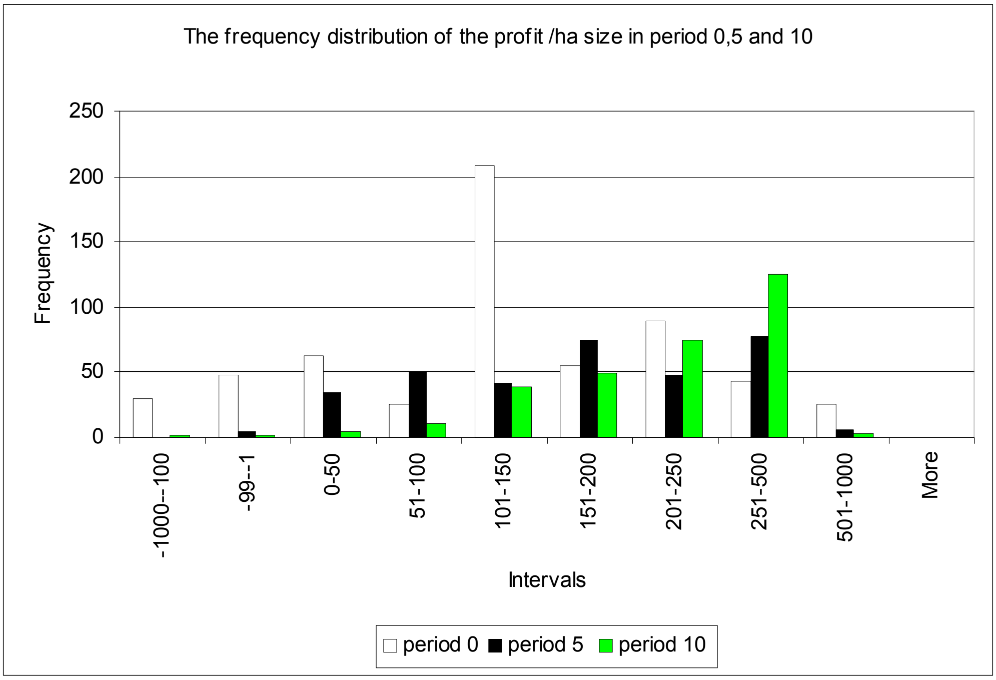
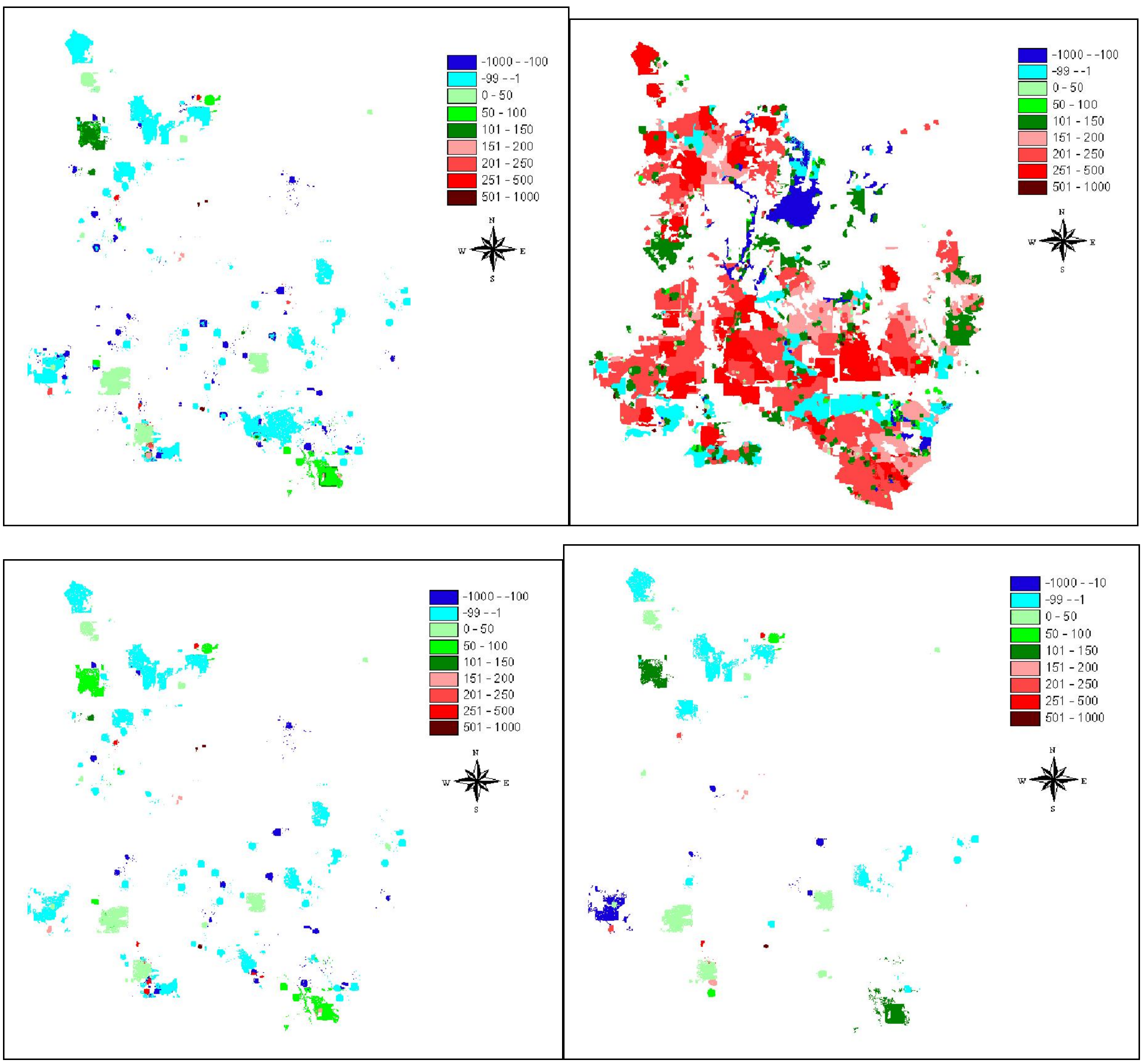


Figure 7.10 Frequency distribution of the average profit per ha for period 0, 5 and 10 in S3 scenario. Own calculations.

What the maps elucidate is the effect of the restriction in the policy settings that differentiate the two scenarios. The majority of farms are unaffected by the limit on the maximum amount of support a single farm may receive of 300 000 € per year. Their development is therefore equal to the development in the REF scenario. The large farms in the region are, however, limited by this restriction and as their fields spatially cover a large part of the fields in the region the maps clearly show the change in their situation. Besides showing how the different types of maps and figures compensate one and another as well as the introduced restriction actually works the reading of the maps and figures can also work as background for the understanding of how the decoupled payment affects the different farms.

As mentioned in the description of the policy settings the decoupled payments are here simulated so that each farm household receives a decoupled single farm payment based on the average direct payment paid to the farm during the three periods prior to the policy change. The direct payment before the policy change is based upon the Agenda 2000 payment. The decoupled payment is bound to the farmer or his or her legal successors. The fields will have to be managed in a basic way in order to receive the payment. As a minimum they will have to be cut during the year. This means that the largest receivers of support at the introduction of the decoupled payments will keep receiving the numerically largest amounts. The largest receivers of support are often the largest farms when the support is coupled. This historically based advantage of the largest farms helps them retain their comparative advantages. The limit on the maximum amount of support that a single farm may receive reduces this historically based advantage.



Map 7.20 The profit per ha in S2 scenario. Upper left shows the average profit per ha in period 4-10. Top right shows the profit per ha in period 0. Bottom left shows the numbers for period 5. Bottom right shows the average profit per ha in period 10. Own calculations.

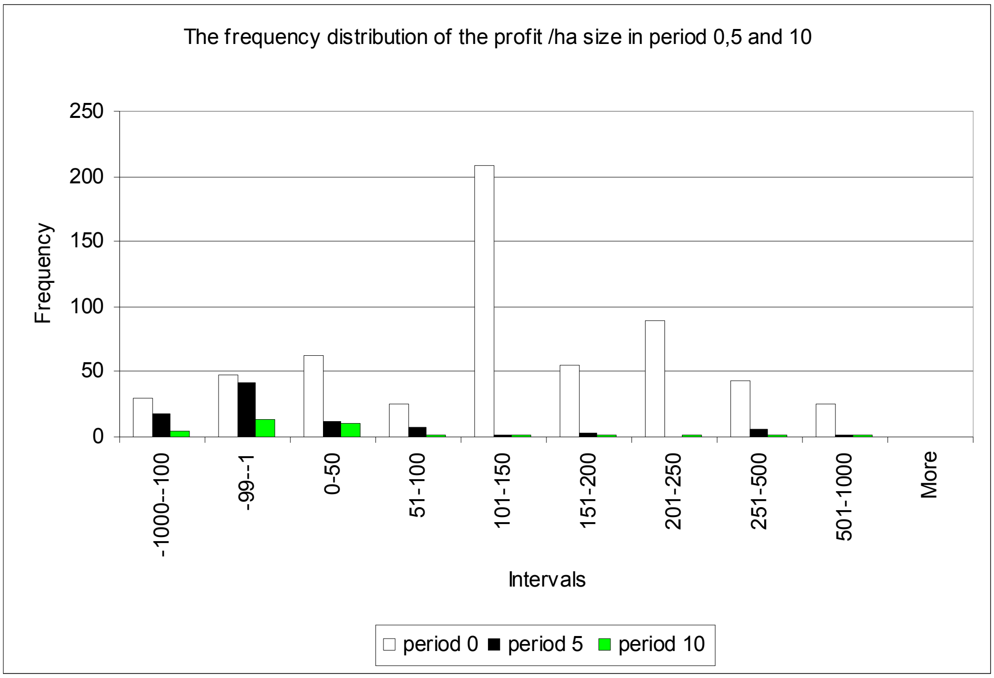


Figure 7.11 Frequency distribution of the average profit/ ha for period 0, 5 and 10 in S2 scenario. Own calculations.

In the case of the S2 scenario the scattered farms are still producing in period 5 and 10 almost all having a negative profit per ha. As can be seen from the Figure 7.6 most of the farms are compensating their income by off-farm earnings. A few farms are able to maintain a positive profit per ha as both can be seen in the map of the average profit per ha for the period 4-10 as well as in Figure 7.11 of the frequency distribution of the profits. A few farms are able to increase their profit per ha from period 5 to period 10 as can be seen from the maps. The main reason for the improvements in the average profit per ha is, however, the reduction in the number of poorly performing farms. One can convince oneself of this by comparing the maps from period 5 and 10.

7.6.4 Public support

The investigated policy scenarios result in large variations in the number and types of farms able to maintain production during the simulated time periods in the German case study area.

The different hypothetical support schemes investigated here may serve as inspiration for decision-makers. For the decision-makers the cost associated with the different support schemes are also an important guideline. Ending all public support as in the S2 scenario is of course not associated with any cost.

The strong effect of ending public support and the dramatic decline in the number of farms seen in the S2 scenario may, however, politically be difficult to implement. Instead of this the two decoupling scenarios REF and S2 both seem to be viable proposals. In Figure 7.12 the collective public cost is associated to the three scenarios: BAS, REF and S3 shown as a function of time.

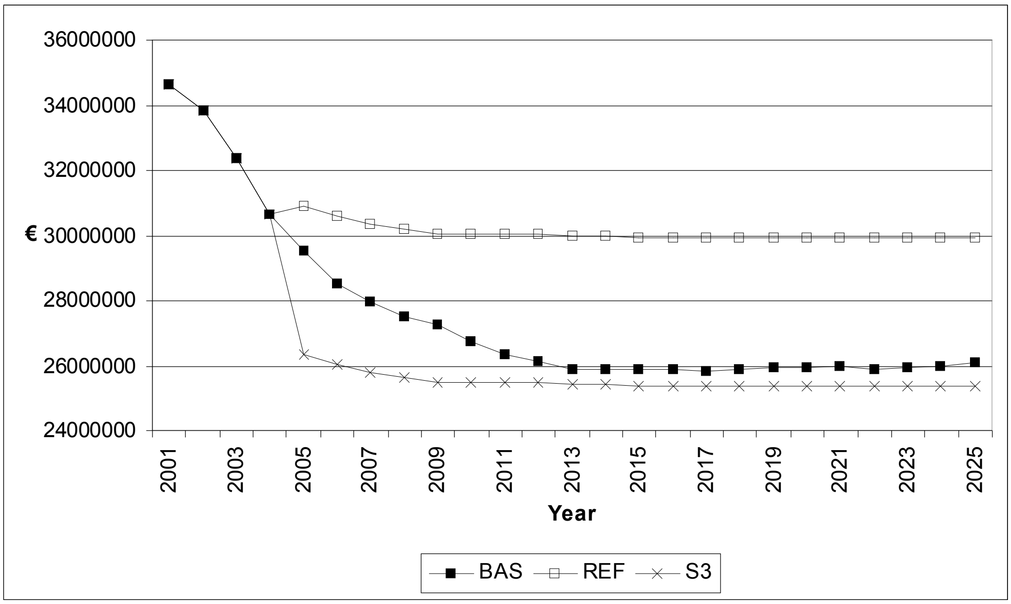


Figure 7.12 Collective public cost associated with the three scenarios: BAS, REF and S3 shown as a function of time. Own calculations.

The public support shown in Figure 7.12 covers only the support granted through the 1st pillar support. The cost associated with AEP is not included as all of the three scenarios operate with the same AEM program. As the number of farms and their types differ in the three scenarios the cost for the 2nd pillar support may also be of a different scale within the three scenarios.

The public support declines in the first years before the policy changes set in. The decline during this period is mainly due to the decline in the number of farms in the region during the same time period. As the different policies are introduced the three curves divide their paths.

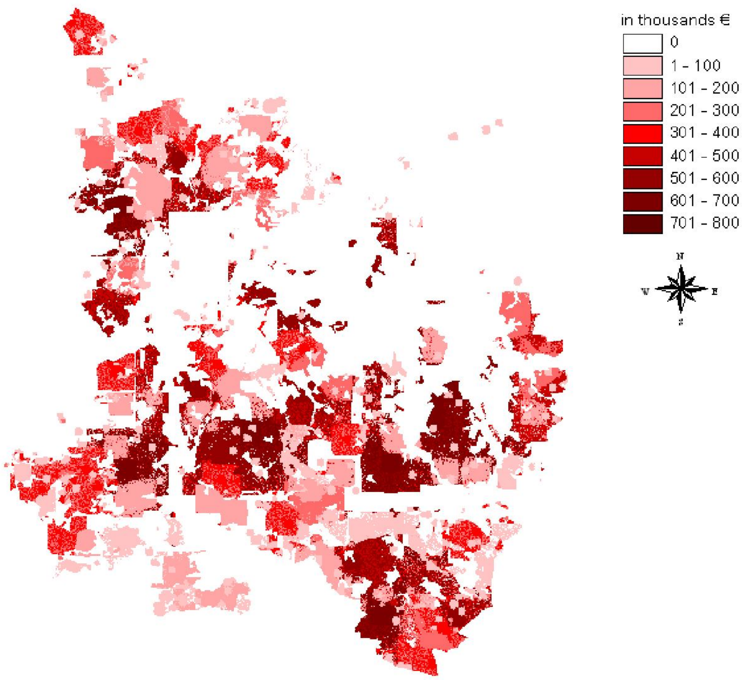
Both the cost for the public support for REF and S3 stays almost at a stable level throughout the simulated periods, however, at two different magnitudes of costs. The cost associated with the REF scenario stays around 30,000,000 €

per year whereas the cost for S2 is in the neighbourhood of 25,500,000 € per year. In the case of BAS the associated cost is steadily declining until it reaches a level of 26,000,000 € per year where it is maintained through out the rest of the simulation. As the support in both REF and S3 is based upon the level of support received by the farms during the years before the initialisation of the new policies the level of support is stable.

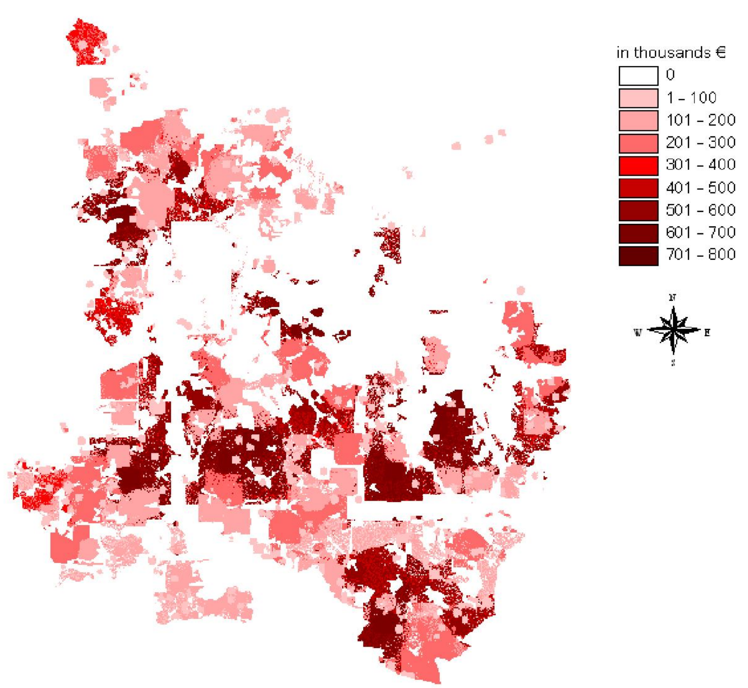
The support granted in both cases is based exclusively upon the number of farms maintained in the sector. The difference of approximately 4,500,000 € per year is due to the maximum level of support that an individual farm may receive. In the case of BAS the amount of public support is determined by the amount and type of commodities that the individual farms produce. The cost of the real support program is therefore likely to experience large variations from one year to the next due to variations in the size of the produced outputs.

The spatial distribution of the support granted through the 1st pillar measurements as an average over the periods 4-10 for the three scenarios BAS, REF and S3 can be seen in the Maps 7.21,7.22 and 7.23, respectively. The amount received through AEM is not included. In both the Maps 7.21 and 7.22 the main receivers of large amounts of support are the larger farms. The cause for the level of support is of course different in the two cases. In the case of BAS the large farms are receiving considerable amounts of support simply because they are able to produce large quantities of the different commodities subsidized. In the case of REF they are maintaining the high level of support due to the large amounts they received prior to the policy change. As the level of support they receive is based on their historical level of support they will maintain the large amount of support. The differences in the amount of subsidies that farms receive in BAS and REF show the individual farms ability to adjust their production over time to the level of support granted.

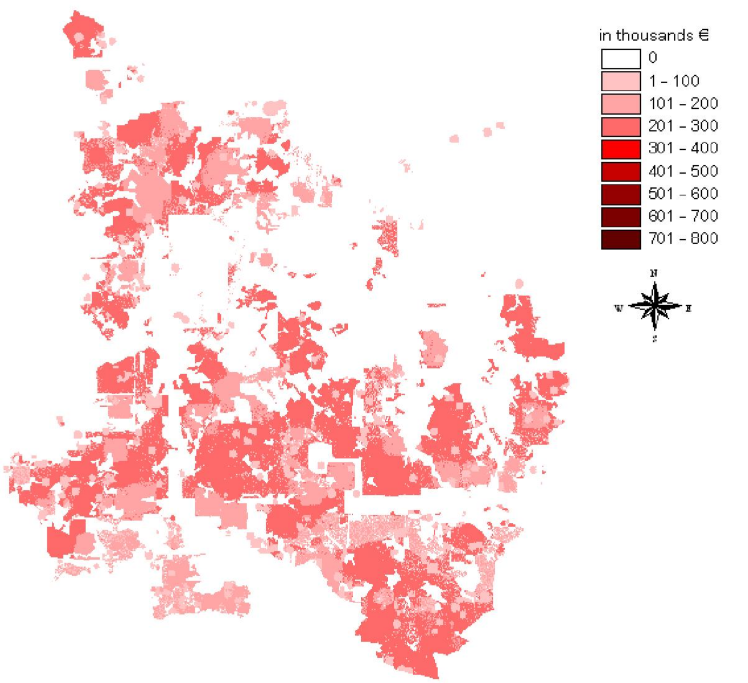
In the case of S3 the level of support received by the different farms is on a more equal scale. The maximum level of support for an individual farm may ensure that the total amounts granted are levelled out. This means of course that the subsidies per ha drop once a farm is above a given size. One can venture into long debates on the fairness of different subsidy schemes, however, rather than moving such a path the simulations REF and S3 are showing a more useful finding. The structural development in the region in the two different scenarios has almost been undetectable until this point. Only when the economic factors of the farms have been investigated a clear distinction between the two scenarios is seen. This means that according to this model the society is able to achieve the same farm structure and types of production at less cost. The level of societal benefits is therefore the same for the two scenarios, however, at a different cost. The lower subsidies to the largest farms in the case of S3 are not affecting the farm production decisions.



Map 7.21 Support granted through the 1st pillar measurements as an average per unit of land over the periods 4-10 in scenario BAS. Own calculations



Map 7.22 Support granted through the 1st pillar measurements as an average per unit of land over the periods 4-10 in scenario REF. Own calculations.



Map 7.23 Support granted through the 1st pillar measurements as an average per unit of land over the periods 4-10 in scenario S3. Own calculations.

7.7 Analysis of the study region Mugello, Italy

7.7.1 Introduction to the general development

The land market is central to the structural development in the real regions as well as in the simulated region in AgriPoliS. So rather than analysing the structural development found in the Italian region Mugello in the different policy scenarios the aim of this chapter will be to investigate the effect of the different policy scenarios on the land prices in the region.

The Italian region is chosen because of the landscape characteristics of the region. The mountainous landscape in the Mugello region means that there is the largest number of landscape characteristics is incorporated into AgriPoliS for this particular region and that the different landscape characteristics is associated with large variation in the agricultural potential of each of the landscape types.

The land market is an essential component of AgriPoliS as structural development in the regions is fuelled by the farms' ability to compete for land. So by understanding the effect that the different policy scenarios have on the land prices in the region it may also help in understanding the underlying processes driving the development as seen in the other regions.

Before we dive into the price development of the land market a short introduction to the general trends for the region subject to the different scenarios is needed. Simply to give a comparable foundation of the regional development for the other case study areas. Each of the regional adaptations of AgriPoliS lead to different responses to the different policies and therefore it is important to have a notion of regional differences before the more in-depth analysis is undertaken.

In Figure 7.13 the total number of farms is shown as a function of time. The same tendency as seen in the German case study area for the scenarios REF and S3 as well as S1 and S2 to follow each other is also seen here. The relative positions of the scenarios are the same as in the German case, in the sense that the S1 and S2 scenarios are having the lowest number of active farms, followed by the BAS scenario somewhere in between the other scenarios and with the highest number of farms found in the REF and S3 scenarios. However, the effects of the different scenarios are far less dramatic in the Italian case. The magnitude of the deviation in the number of farms found in the different scenarios is at a much more moderate level. The different policies still play an important and influential role in the structural development in the region, however, without the same disastrous effect as e.g. the abandonment of the subsidies has on the German case study area.

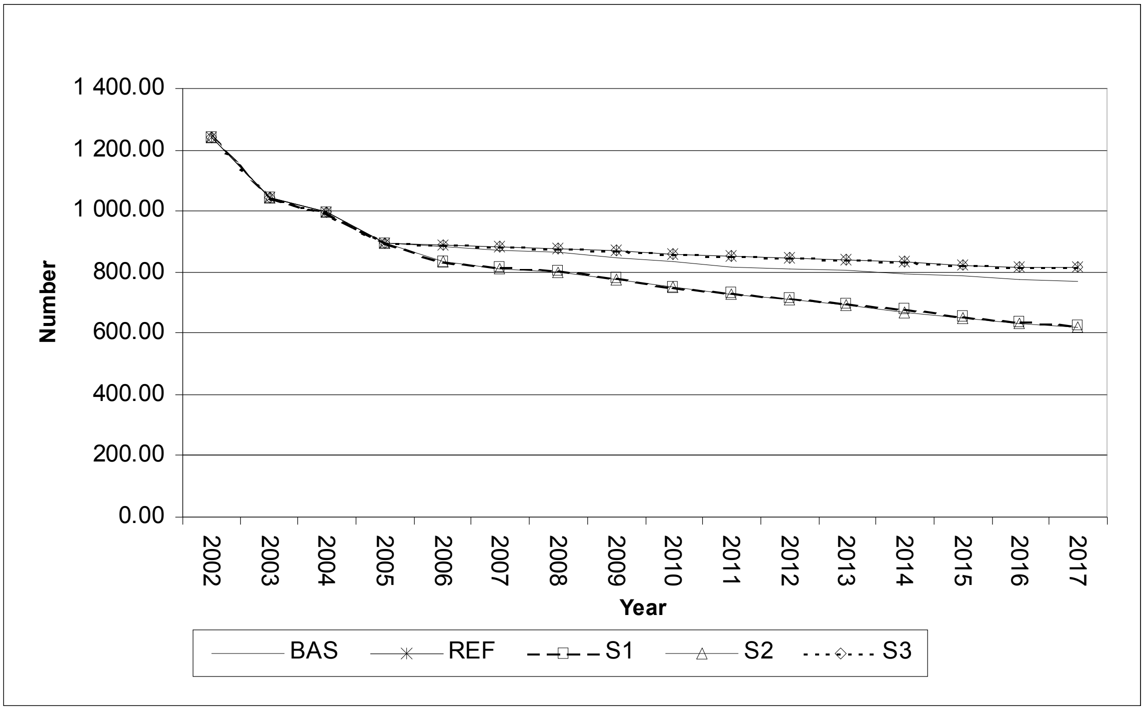


Figure 7.13 Total numbers of farms as a function of time. Own calculations

The average farm size as a function of time is shown in Figure 7.14. As the decline in the number of farms is more moderate in the Italian case than e.g. in the German case the curves are not subject to the same large fluctuations. The deviations in the average farm size between the different scenarios are at a moderate level. The largest difference between the average farm sizes in two scenarios is in the neighbourhood of 5 ha whereas the same difference in the German case approaches 600 ha.

The large difference between the sizes of the deviation in two areas comes, however, not only from the impact that the policies have of the structural developments in the two regions.

The farms in the Italian case are far more homogeneous and smaller from the beginning of the simulation compared to the farms found in the German case study area. Therefore the same kind of variations in the average size is simply not an option in the Italian region. The smaller decline in the number of farms means also that the size of the sample helps averaging out the impact that the policy changes may have on individual farms. The opposite is of course clearly the case in the S2 scenario for the German area.

The average farm size is almost the same in the case of the BAS, REF and S3 scenarios and the average farm is only slightly larger in the case of the S1 and S2 scenarios. The average farm size of the S1 scenario separates itself from its normal pair with the development in the S2 scenario and achieves the largest average farm size.

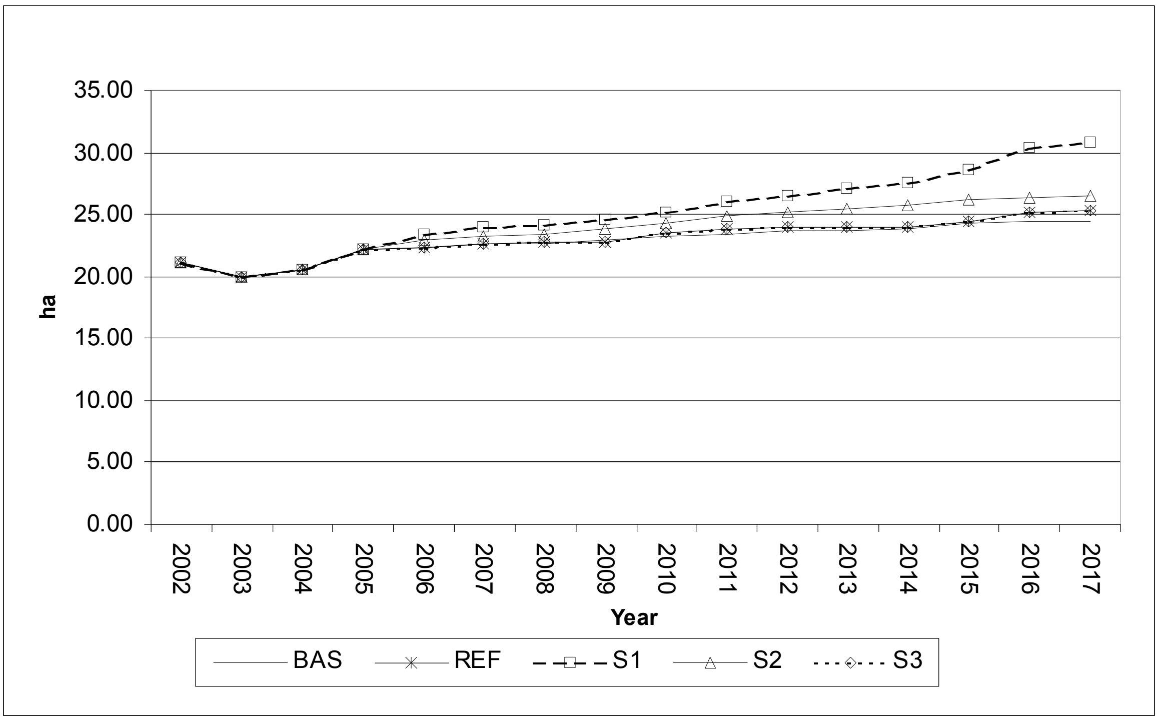


Figure 7.14 The average farm size per ha as a function of time. Source: own calculations

In Figure 7.15 the profit per ha is shown as a function of time. The pattern found here shows that the same effects found earlier for the different policy scenarios are taking place in the Italian case. The abandonment of the subsidies in S1 and S2 leads to the drop in the profit per ha right after the initialisation of the policies. The slight separation between the curves of the S1 and S2 scenarios is of course different compared to the development in the German case. Though it may look fairly interesting and seems to call for further investigation the focus will be maintained on the overall development of the region subject to the different policies.

Looking at the general trends in the profit per ha the developments in the different scenarios are comparable to the development seen in the German case study area. The profit per ha is highest in the two decoupled scenarios, REF and S3 and lowest in the two scenarios where the first-pillar support is abolished.

The coupled payment scenario BAS is in between the four other scenarios at a level similar to the two decoupled scenarios.

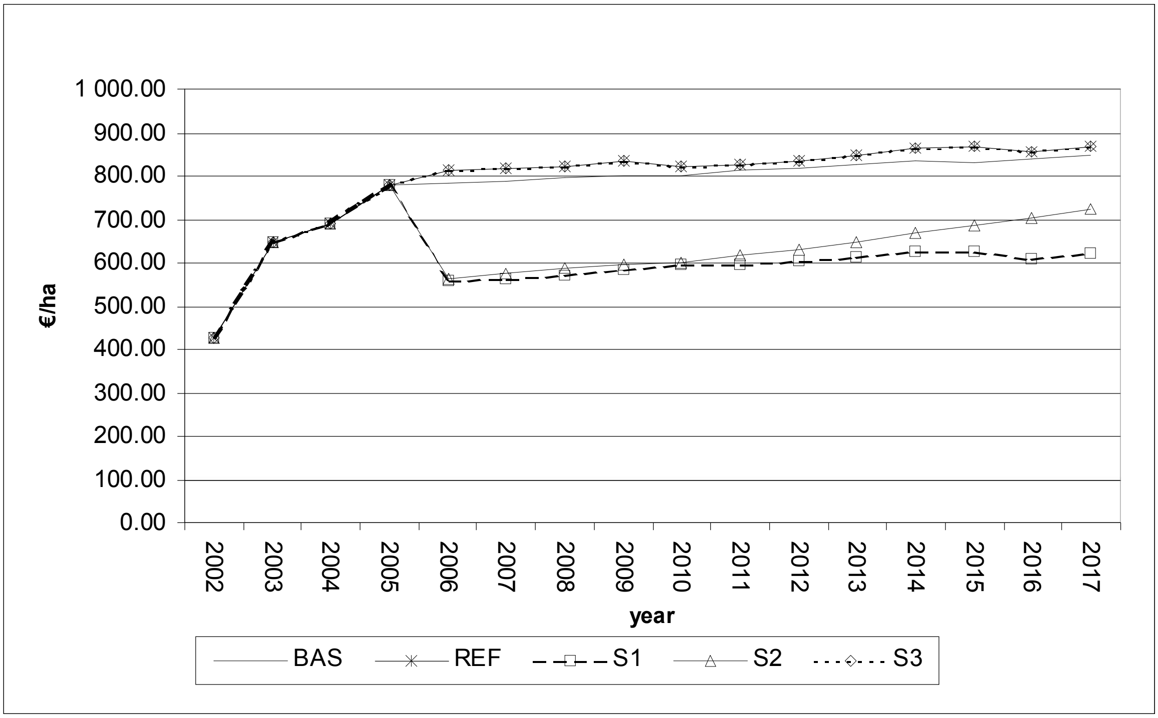


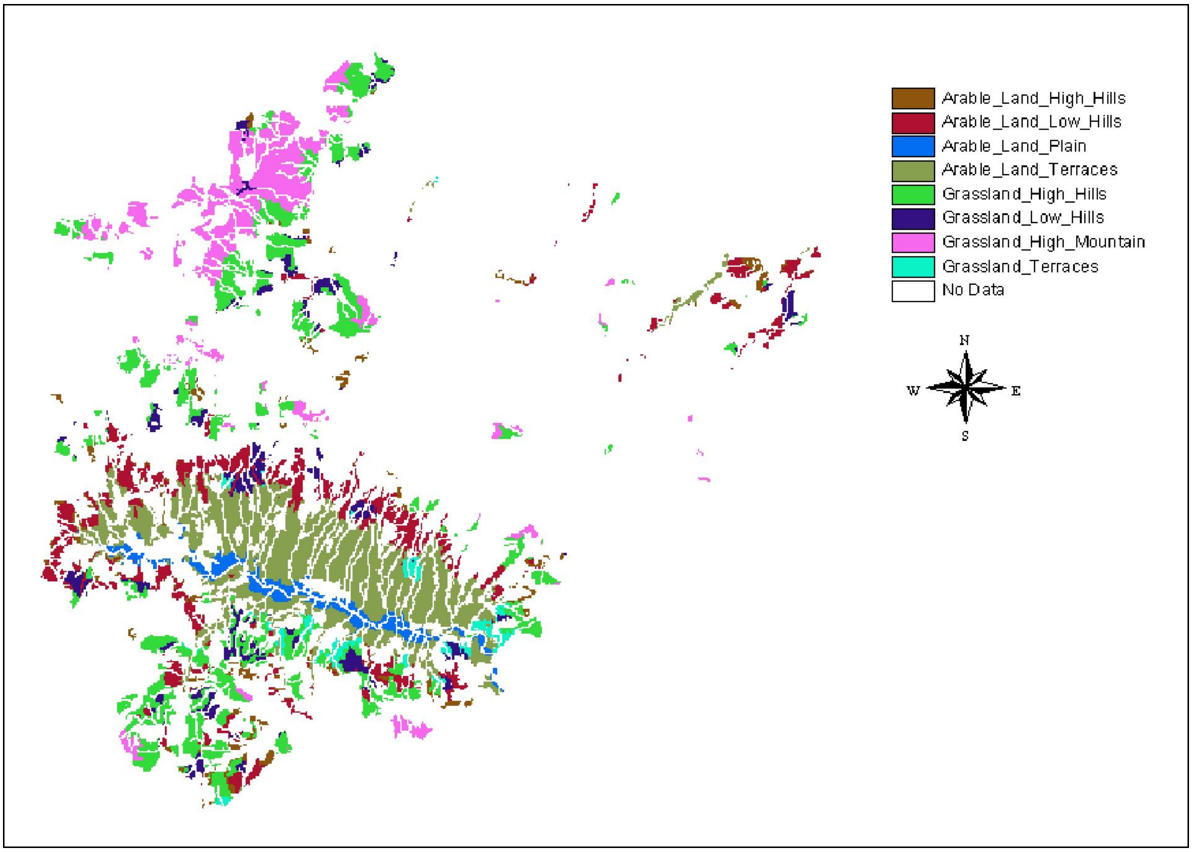
Figure 7.15 Average profit per ha as a function of time. Source: own calculations

7.7.2 The land market

This short overview of the overall effects of the agricultural structure in the Mugello region paves the way for the main focus of this analysis namely the land market. In AgriPoliS the land market is simulated as an auction. Each individual farm calculates its shadow price for a single additional plot of a given quality as well as the shadow price for a number of additional plots of an equal quality (eight plots in this case) to ensure that the possible economic benefits of a size expansion is included in the farms' bid of land. Each farm compares the two shadow prices. The number of adjacent farm plots and the distance-dependent transport costs between the farmstead and the plot are calculated and based on all of this information the farm decides its bid for an additional plot. The bids are collected and compared and the farm with highest bid receives the plot wanted at the price of the second highest bid. It is all taking place in a 2-dimentional space where each individual plot represents a standardised spatial entity of a specific size. In AgriPoliS, the land market is the central interaction institution between agents.

Due to the mountainous landscape in the Mugello region eight different landscape characteristics are constructed for the region. Each landscape characteristics have a different production potential for the farms. Each individual farm has a different potential for utilising the different production potential that the fields offer.

The spatial distribution of the different landscape characteristics in the simulated region can be seen on Map 7.24.



Map 7.24: The spatial distribution of the different landscape characteristics in the simulated region. (Ungaro et al. 2006)

A large share of the plots in the Italian region is owned by the farms and will only be traded on the land market if the farm that owns them is stopping farming and therefore sells all its land. This means that it will be difficult visually to relocate the same landscape structures found in the Map 7.24 in the maps of the traded plots of the different landscape characteristics as most of the plots are not in these maps.

To some extent the maps will visually look like a number of more or less scattered points. The information told by these points is, however, what is important. Rather than investigating the price development for each of the eight landscape characteristics the focus will be on the arable_land_terraces and the grassland_high_hills. Each of the two landscape characteristics is chosen as a representative of the two major classes of the landscape characteristics namely: The arable and grassland type of landscape. Their spatial extent made them the natural choice of the two landscape types.

In Figure 7.16 and 7.17 the average rental price per ha for the two landscape characteristics in each of the five different scenarios is presented as a function of time.

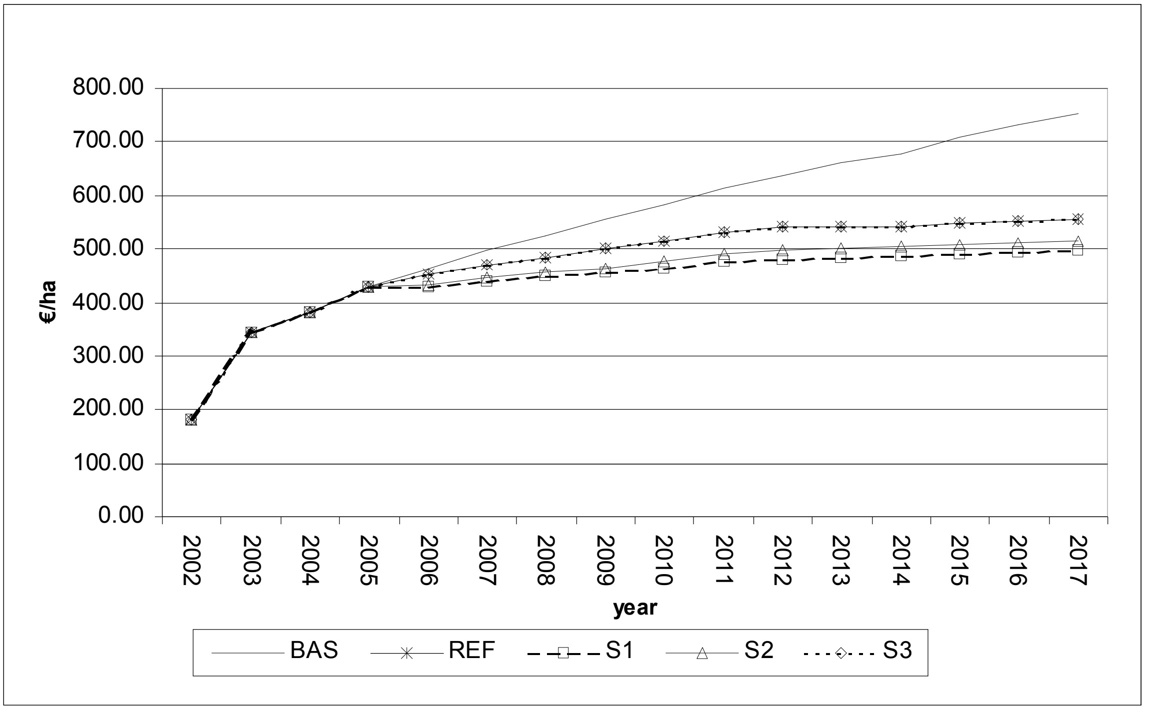


Figure 7.16 Average rental price per ha of arable land terraces in each of the five different scenarios as a function of time. Own calculations

As can be seen from Figure 7.16 showing the average rental price per ha for arable_land_terraces the average rental price is persistently rising until the effects of the different scenarios kick in. The average rental price per ha continues ascending by the same pace in the case of the BAS scenario, however, the average rental price for the other breaks off and increases by a smaller gradient. The average rental price follows each other in the case of the REF and S3 scenario and lies above the level found in the S1 and S2 scenarios. There is a small difference between the average rental price in the S1 and S2 scenarios, with the S2 scenario constantly experiencing slightly higher prices.

In the case of the average rental price per ha for the grassland_high_hills landscape characteristic in Figure 7.17 the picture is less clear. The average rental prices are kept within a small range compared to the case of arable_land_terraces landscape characteristic. The narrower range in the price development means that the variation within the different scenarios overlaps each other. The lowest price level is constantly found in the S2 scenario and the BAS scenario tends to constitute the upper boundary for the price variations.

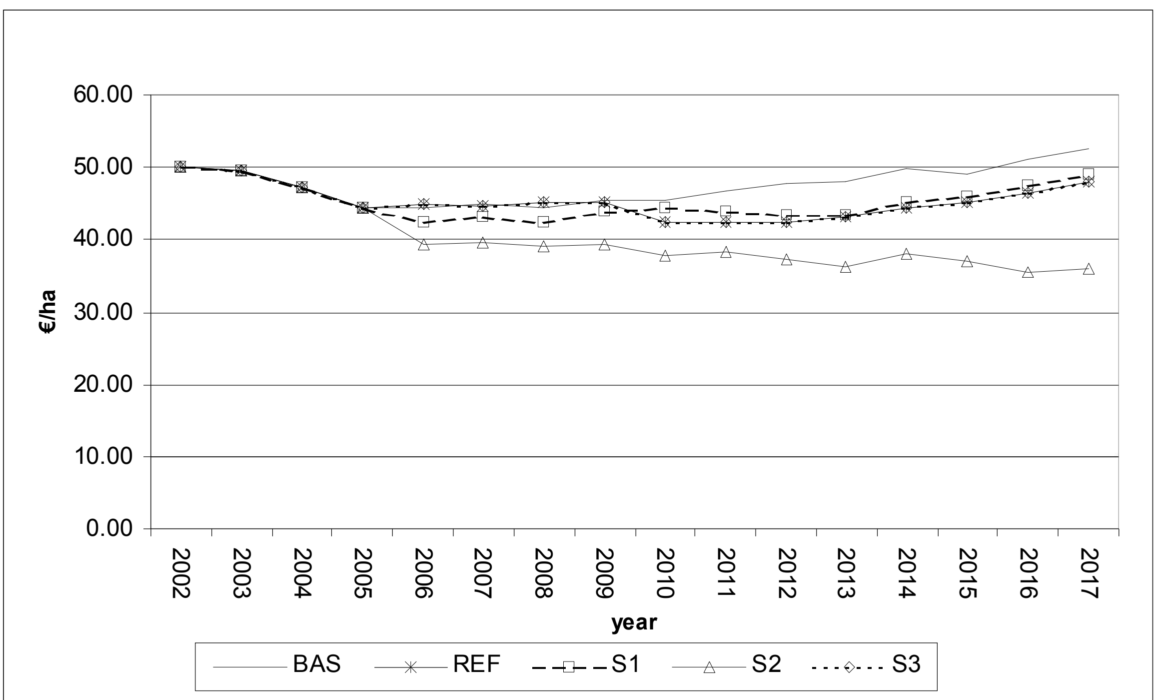
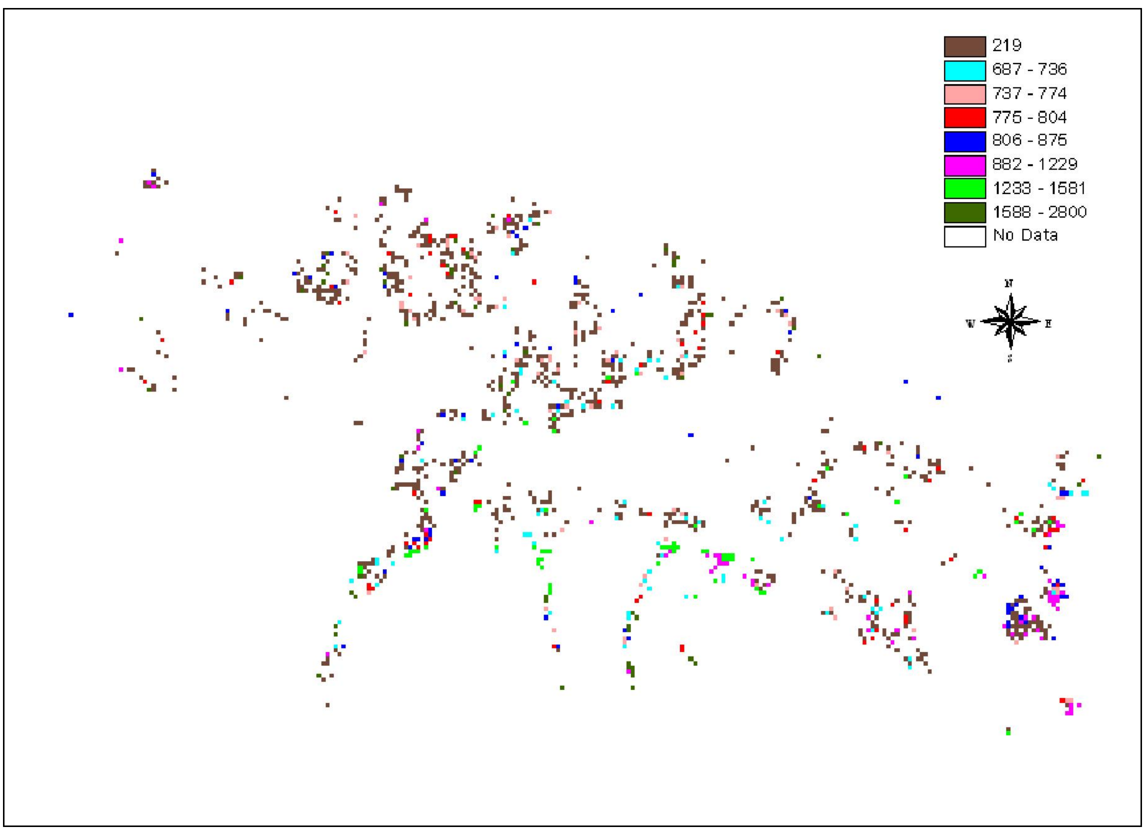


Figure 7.17 Average rental price per ha of grassland high hills in each of the five different scenarios as a function of time. Own calculations

The rental price developments shown in Figure 7.16 and 7.17 are, however, only the average rental price found in the region and that conceals a far larger range of individual rental prices. As the individual farms base their bids upon their individual shadow price, transportation cost as well as the other mentioned elements the variation within the bids is rather large.

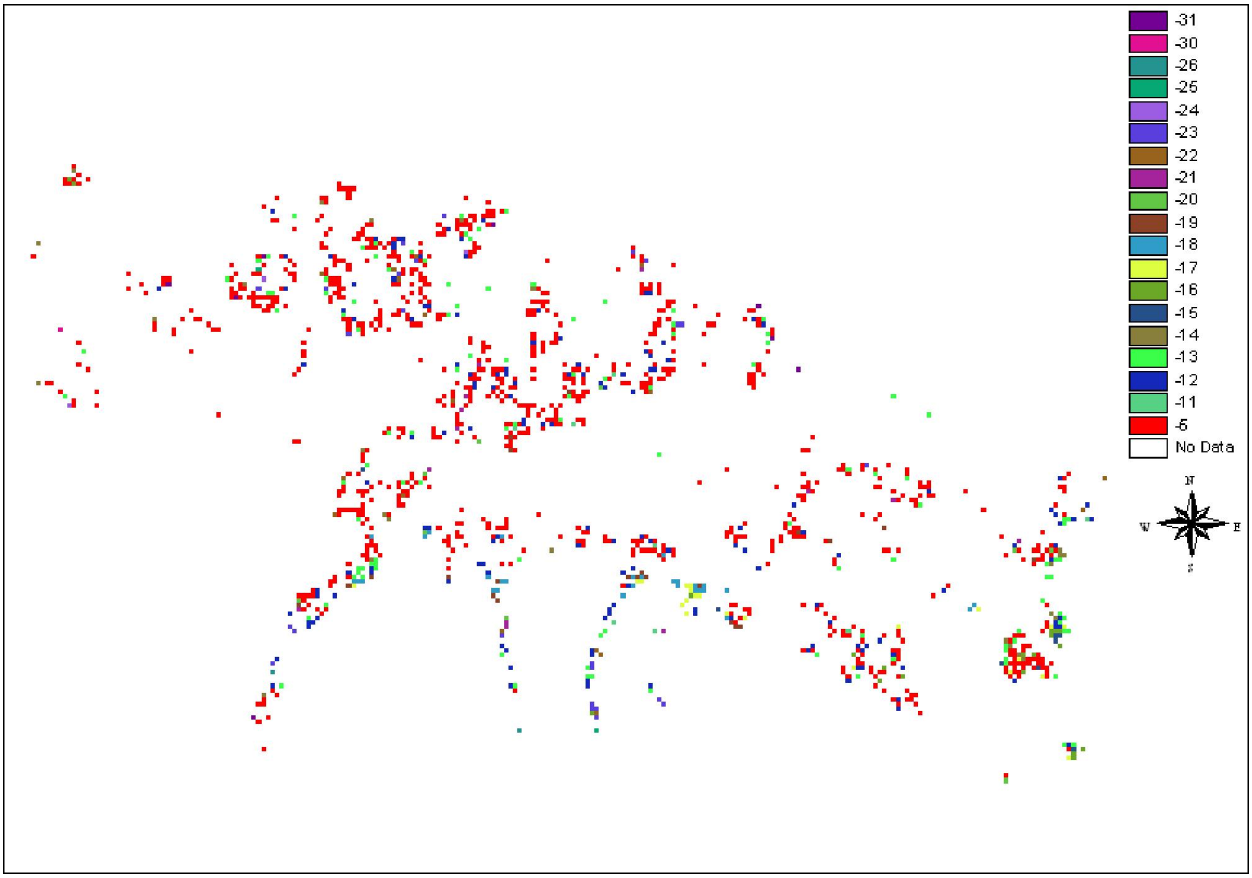
In Map 7.25 the average rental price of the periods 4-10, is shown for the individual plots in the BAS scenario. Far the largest numbers of plots are rented at a price equal to 219 € per ha. This price is a level above the initial price of 180 € per ha and seems to constitute a price below which all farms in the area are able to make a profit. The large majority of rental prices are at this level (830 of 1318 possible). The most remarkable issue is the jump made by the scale to the next prices and particularly the range that the scale has to have to cover all prices. Though the highest category is hardly used there is a number of fields that falls into the next range from 1233 to 1581 € per ha.



Map 7.25 Average rental prices for the individual plots of the type arable_land_terraces for the BAS scenario in the period 4 –10. Own calculations

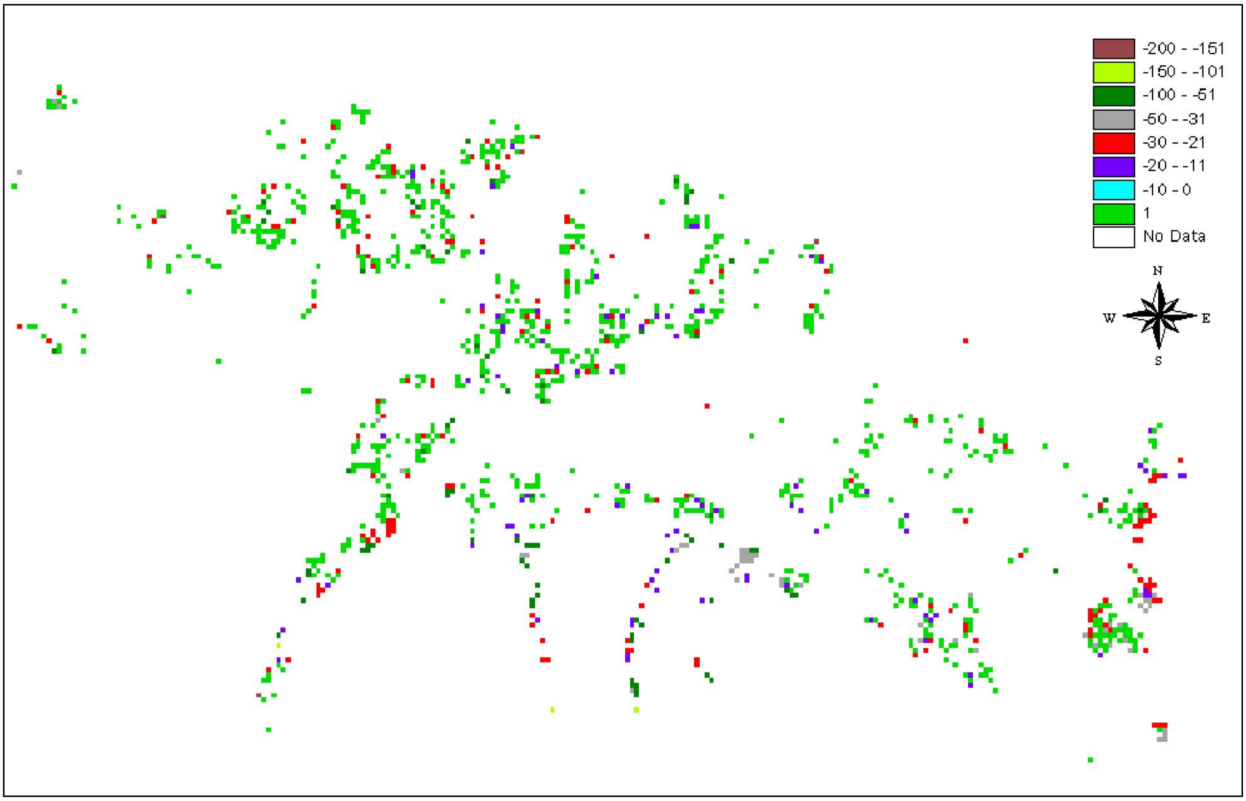
The face value seen here is of course very unrealistic. No farmer in the area would ever pay 1000 € more than the normal price in the region. Even though the prices seem very far away from anything informative the bold statement here is that the values reflect something interesting in the understanding of the regional development as well as the inner working of the model.

To appreciate the individual rental prices we need to turn to the other scenarios. We are only investigating the case of the REF scenario and the S2 scenario due to the similarities between REF and S3 as well as between S1 and S2 scenarios. Instead of looking at the spatial average rental price pattern of the two additional scenarios directly the same average rental prices for the periods 4-10 are found for the two scenarios and the differences of the values in the case of the BAS scenario are found. That means that in the case where a given field is rented both during the REF and BAS scenario the values are subtracted from each other (in that order: REF-BAS). The spatial results can be seen in Map 7.26. What the map shows is that the fields in the BAS scenario having an average rental price of 219 € per ha is in the case of the REF scenario five € per ha less (also in REF 830 fields are involved). The subtraction of the average rental prices for the remaining fields gives a larger variation, however, not something which by any means reflect the outrageous values seen in the Map 7.25. The farms are bidding almost the same rental prices as in the case of the BAS scenario. This shows that 213 € per ha constitutes the price below which all farms in the area are able to make a profit during the REF scenario and more importantly, the farms are making bids for the other fields at a similar level as seen in the BAS scenario. Even the very expensive fields are also in the case of the REF experiencing average rental prices at almost the same level. This proves first of all that the farms' bids by no means are random numbers; something that the high prices could otherwise lead one to believe. The high rental prices are in reality reflecting the true value that the field constitutes for the farm better than a lower and thereby more realistic rental price would do. The spatial distribution of fields shows also that the high average rental prices tend to cluster around certain areas. This underlines once more the non-random nature of the numbers. Farms within the area have faced some prospective lucrative opportunities if only the farm was able to expand its production. Therefore the size of the bids is so high. The difference between the average rental prices in the BAS and REF scenarios reflects the differences in the shadow price experienced by the farms under the two different policies. As the decoupled support makes the farms less dependent of their actual production the value of land is also slightly lower in the case of the REF scenario.



Map 7.26 Difference in average rental price value for the individual plots of the type arable_land_terraces (REF-BAS) scenario in the period 4 –10. Own calculations

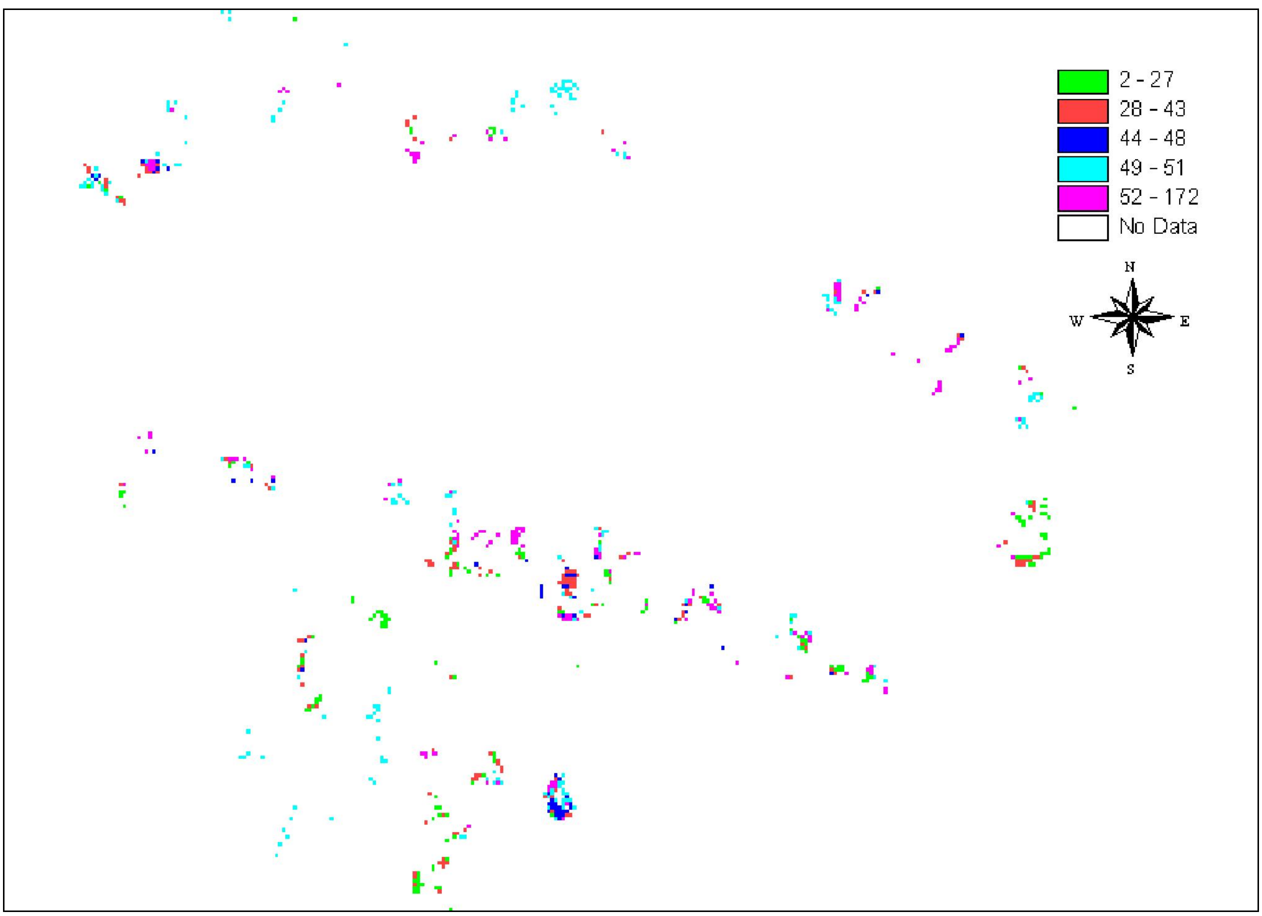
The rental prices in the BAS and REF scenario are likely to reflect the actions of almost the same farms. The decoupled payments help preserving a few more farms than in the case of coupled payments, however, in the case of the Mugello region the difference in the number of farms is low. The structural effect of the policies is larger in the case of the S2 scenario. The Map 7.27 shows the spatial results of the differences between the average rental prices in the periods 4-10 in the S2 and BAS scenario, a case where a given field is rented out in both scenarios (in the order: S2-BAS). The Map 7.27 shows a number of interesting points. First of all the lowest rental price in the area is 1 € higher than in the BAS scenario. The price of 220 € per ha constitutes the lowest price in the S2 scenario. This is an interesting result and is likely to reflect the farms' need to expand in order to maintain active during the S2 scenario. The fields with the higher level of average rental prices are in most cases between –11 to –30 € per ha lower in the S2 scenario than in the BAS scenario. These fields are having a difference in rental prices similar to what was found between the REF and the BAS scenario. However, as seen in the Map 7.27 there are single fields with a very large difference in the rental prices in the S2 and BAS scenario. This is likely to be fields that could be utilized in a different way in the case of BAS than in the S2 scenario. The most likely cause for these differences is that the farm making the bids during the BAS scenario is changed or stopped in the S2 scenario.



Map 7.27 Difference in average rental price value for the individual plots of the type arable_land_terraces (S2-BAS) scenario in the period 4 –10. Own calculations

The average rental price for the whole region in the different scenarios as seen in Figure 7.16 and 7.17 shows that in the case of arable_land_terraces there were clear differences between the scenarios. In the case of the grassland_high_hills landscape characteristics the differences are smaller and the patterns therefore also less clear. This is also the case when the individual fields with grassland_high_hills are submitted to the same investigation as just performed on the area of the arable_land_terraces.

In the Map 7.28 the average rental prices for the individual plots for the BAS scenario in the period 4 –10 are shown. The widespread area that the grassland_high_hills landscape characteristic are scattered around makes it hard both to include all fields of this type in the map and at the same time making it possible to see the difference clearly. The Map 7.28 is therefore including most of the rented fields of the grassland_high_hills quality, however, not all. The remaining fields show similar characteristics as the fields in the map. The same goes also for other maps of the rental prices for the grassland_high_hills landscape characteristics.



Map 7.28 Average rental prices for the individual plots for the BAS scenario of the type grassland_high_hills in the period 4 –10. Own calculations

The average rental prices within the period 4-10 for the grassland_high_hills type in the BAS scenario show a very diversified pricing. The spatial location of the individual fields plays clearly a strong role for the average rental price. The most common single price is 49 € per ha which is a single euro below the initial rental price of 50 € per ha. Most fields have a price below 49 € per ha with a large group between 30 and 20 € per ha.

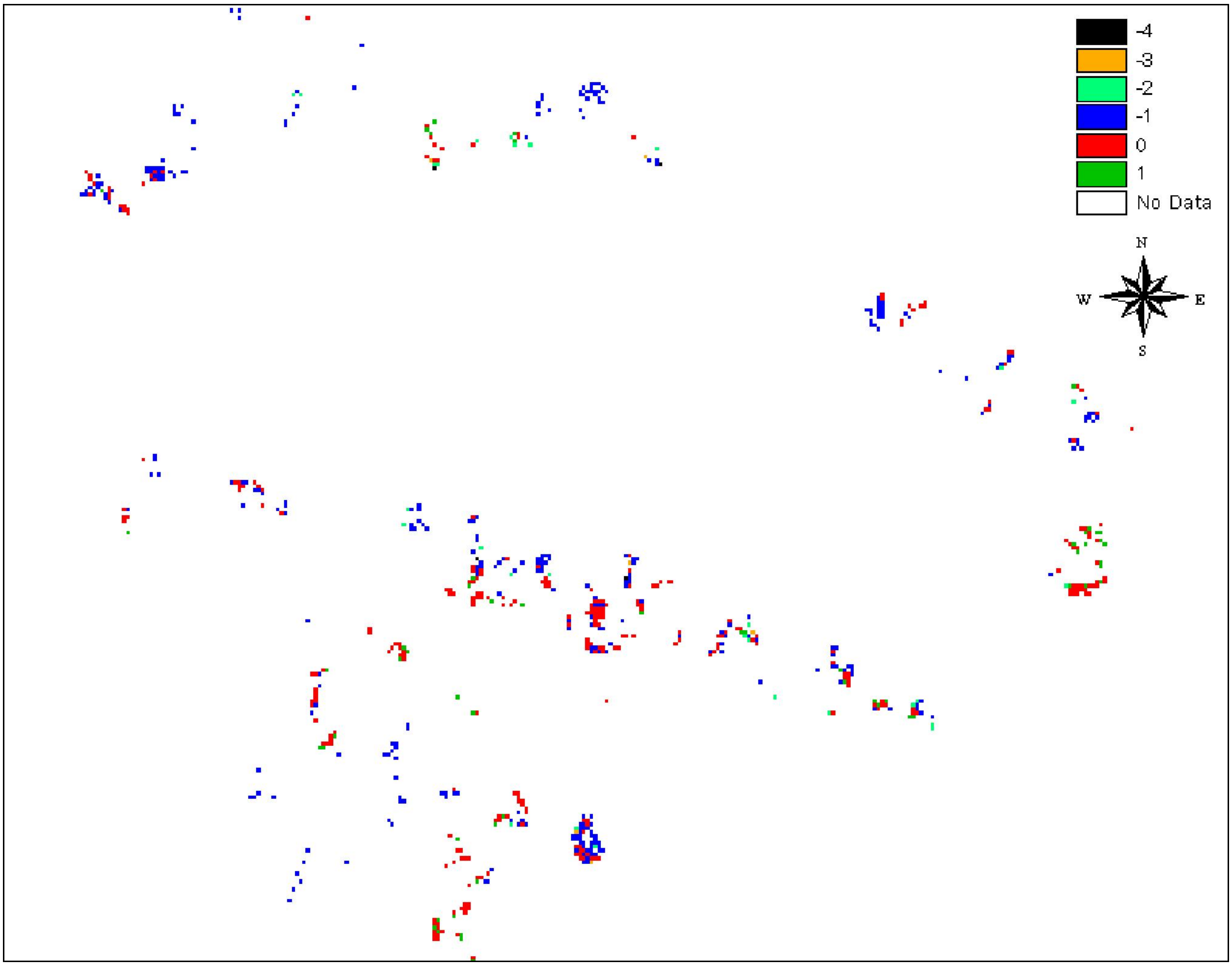
As can be seen from the Map 7.28 also a number of fields with average rental prices above 49 € per ha are there.

In Map 7.29 the spatial result of the differences between the average rental prices in the periods 4-10 in the REF and BAS scenario is shown, a case where a given field is rented out in both scenarios (in the order: REF-BAS) for grassland_high_hills. The variation of the rental prices for the fields is very small between the two scenarios. There are 60 fields where the rental price in the REF scenario is 1 € higher than in the BAS scenario. For 327 fields the average rental price is the same in the two scenarios. For 365 the rental price is 1 € lower in the REF scenario, the rental price is 2 € lower for 33, for 6 the rental price is 3 € lower and finally 4 fields have a rental price 4 € lower in the REF scenario compared to the BAS scenario.

Also in the case of the grassland_high_hills landscape characteristic there is a general agreement between the individual fields' rental prices in the BAS and REF scenario. The results in the Map 7.29 confirm the findings from the arable_land_terraces area.

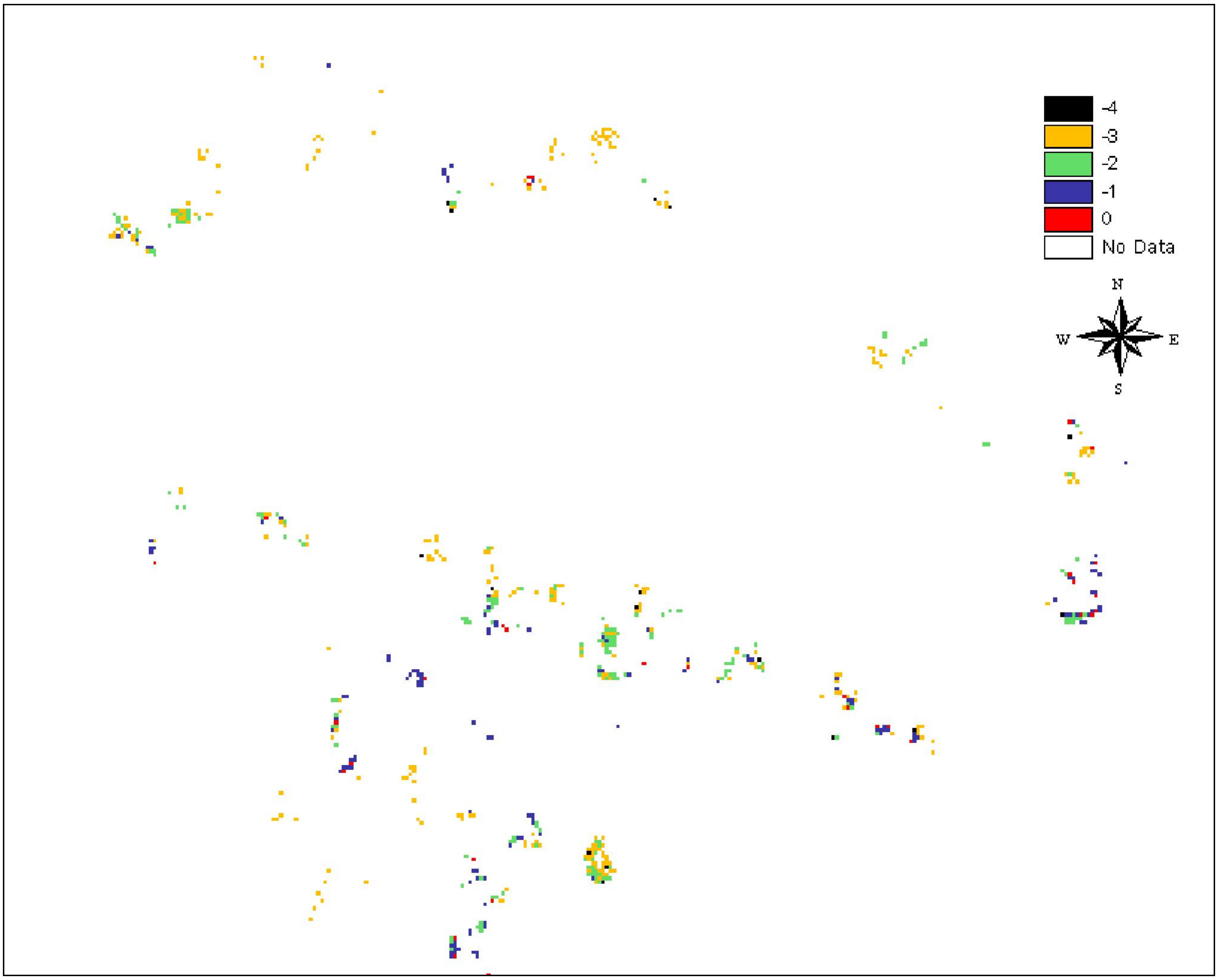
In the case of the S2 scenario a very similar rental price level is found. In Map 7.30 the result of the same small exercise is presented. The spatial results of the differences between the average rental prices in the periods 4-10 for the S2 and BAS scenario are shown in the case where a given field is rented out in both scenarios (in the order: S2-BAS) for grassland_high_hills.

The variation in the rental prices for the fields is once more very small between the two scenarios. Here 34 fields are with the same average rental price as in the BAS scenario. For 142 the rental price is 1 € lower in the S2 scenario, the rental price is 2 € lower for 193, for 309 the rental price is 3 € lower and finally 17 fields have a rental price 4 € lower in the S2 scenario compared to the BAS scenario.



Map 7.29 Spatial results of the differences between the average rental prices in the periods 4-10 in the REF and BAS scenario, a case where a given field is rented out in both scenarios (in the order: REF-BAS) for grassland_high_hills. Own calculations

None of the fields has a higher average rental price in the S2 scenario compared to the BAS scenario and the scale is similar to the one found in the comparison of the BAS and REF scenario. Though the range is the same there is, however, an appreciable displacement in the results from the S2-BAS comparison. Where the majority of fields in the REF-BAS comparison had either the same value as in the two scenarios or a rental price 1 € lower in the REF scenario the rental price is around 3 € lower in the case of the S2 scenario. The abolishment of the subsidies in the S2 scenario reduces the rental price level for grassland_high_hills slightly. The value of the utilisation of the area is, however, not changed in a way that bears comparison with the dramatic change one could expect as a result of the abandonment of agricultural support.



Map 7.30 Spatial results of the differences between the average rental prices in the periods 4-10 in the S2 and BAS scenario, a case where a given field is rented out in both scenarios (in the order: S2-BAS) for grassland_high_hills. Own calculations

The spatial analysis of the rental prices for the two landscape characteristics in the Mugello region has given an insight into the dynamics driving the structural change in AgriPoliS by elucidating the farms' bidding behaviour on the land market.

The prices of the individual plots offered by the farms seem alarming at first sight as the variation in the price level does not correspond to what one would expect. The reason for the deviations between the simulated land market and the real land market is likely to lie in the simulated farms' willingness to reveal their true shadow price on the market independently of the normal market price. The prices found for the individual plots in the model are therefore expressing a slightly different element of economic system than the real land market prices reveal. Better knowledge of the nature of the farm actions on the land market in AgriPoliS hopefully also helps to better understand the results of the different policy scenarios with respect to the structural development that the policies induce.

7.8 Analysis of the study region river Gudenå watershed, Denmark

7.8.1 Introduction to the general development

The model of the Danish case study area: River Gudenå watershed is particularly interesting due to the large amount of accurate empirical data that the model is based upon. The individual farms in the case study area are described with an unprecedented number of details and an unprecedented degree of precision for the AgriPoliS.

The actual spatial location of all the farms and their fields, the number of fields and their soil types as well as the number and types of animals are all factors known to the model. The machine capacity of the farm is assumed to fit the current production capacity. So a machine capacity based on the current production is calculated and assigned each individual farm.

This information enables the description of each individual farm within the AgriPoliS to be in direct accordance with a corresponding real farm. The accuracy of the empirical data used in a model is often one of the limiting factors in developing empirically founded large scale agent-based models. The possibility to investigate the AgriPoliS-model's ability to simulate the regional development under such ideal conditions is in itself of interest. At the same time this policy analysis of the region will demonstrate the structural development for the region that AgriPoliS predicts.

The accuracy of the empirical input data implies that the model is close to reality. This realism in the model means that the analysis of the results has to be treated with more care. As the model farms have their corresponding real farms, it would be inappropriate to describe the development of individual farms. So although the presented results are only reflecting the projected development of the farms within AgriPoliS, a negative projection of an individual farm might create a bad business climate around this particular farm. Individual farms will therefore not be picked out for further analysis.

Instead, the farms are analysed on a regional scale as well as with respect to farm types.

The diversity in the description of the individual farms as well as the size of the simulated region means that some kind of sub-grouping of the farms is necessary in order to communicate the regional development.

The Danish case study area has been submitted to the same policy scenarios as described in the section: Policy settings. For the majority of parameters the scenarios REF and S3 as well as the scenarios S1 and S2 develop in a similar manner also here; that is the results are for the two pairs in most cases almost identical. This is for example the case for the total number of farms in the region as a function of time as can be seen in the Figure 7.18.

The total number of farms in the region is steadily declining in all scenarios.

The S1 and S2 scenarios differentiate themselves from the other scenarios with a sudden decline in the number of farms once the policies are initialised. After the sharp drop in the number of farms around the time of the beginning of the new policies the number of farms in the region is declining with a slope almost identical to the other scenarios. The most striking thing is, however, that the development in the number of farms in the case of BAS, REF and S3 is almost the same. In the German case study area OPR the effect of the REF and S3 was that the number of farms in the region was maintained on a higher level compared to BAS. It is, however, not the case in the Danish region. Though differences are detectable they are of a smaller magnitude.

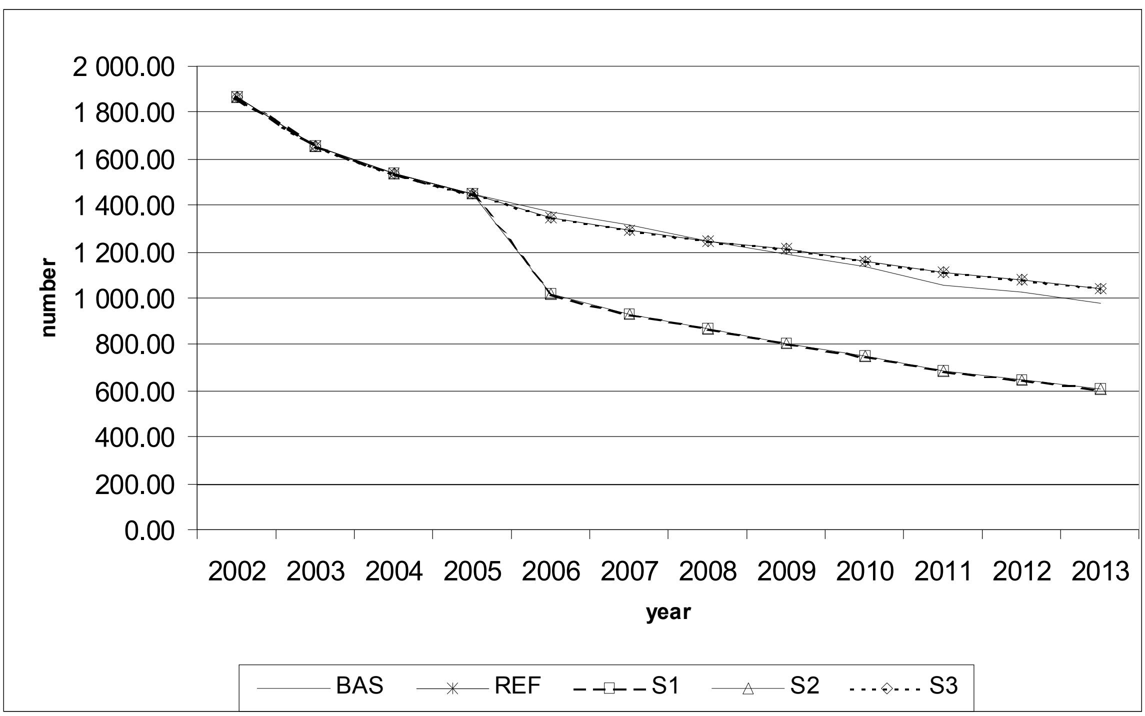


Figure 7.18 Total numbers of farms in the region as a function of time. Own calculations

A different picture is seen when considering the average farm size shown in Figure 7.19. Here the scenarios REF and S3 are clearly separated from the rest.

In all the investigated scenarios the average farm size is steadily increasing by such a rate that in the case of BAS the average farm size almost doubles within the investigated period.

The fewer farms in S1 and S2 are experiencing similar growth rates in size as the farms in BAS.

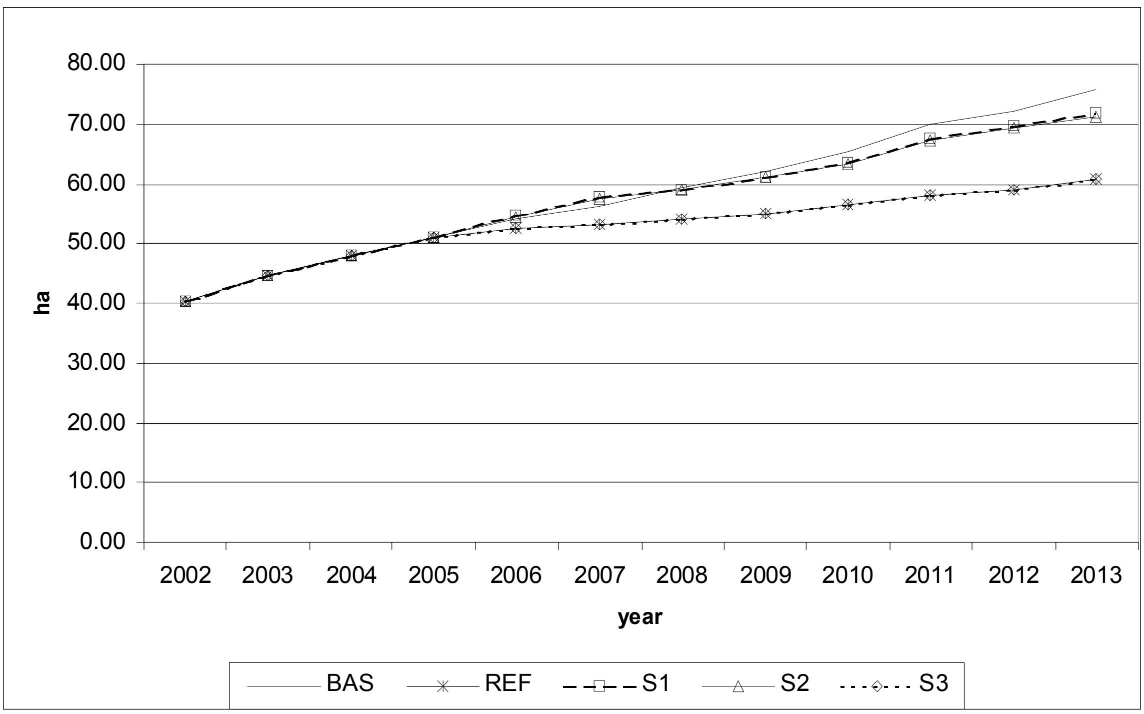


Figure 7.19 Average farm sizes as a function of time. Own calculations

In Figure 7.20 showing the average livestock per ha the first thing to notice is the strong increase in the average livestock per ha from year 2002 to year 2003. This increase results from the LP-procedure. The increase shows how the empirical data on the individual farms' stable capacity and their FADN-based capital are subject to an optimisation under the input-output coefficients found as Leontief production functions is adjusting itself to each other. In the ideal case such adjustments should not take place, as the farms empirically founded should be the correct and optimal constellation. However, this is obviously not the case here. Partly as the different empirical data do not fit precisely to each other, e.g. the Leontief production functions are based on average values for given set of inputs and therefore not individually adjusted to each individual farm. Partly because the economic data from the FADN-farms are an approximation of the real values, as they are not known. Finally the strict profit maximisation that is describing the individual farms' decision-making, is resulting in a different behaviour than the one observed in the real region.

Once all the different causes for the observed jump in the first period are identified, it is also important to notice that this jump is not seen in all figures nor is the quantity of a dramatic size. So even though the shift in the average livestock per ha in this first period is a cause of concern, the size of the jump is to some extent also confirming the quality of the model as well as indicating that profit optimisation might after all be a good behavioural approximation. The deviation would most likely be of a larger magnitude if this were not the case. Once the average livestock per ha has achieved its new higher level a steady decline is seen in the values for all the scenarios.

The average livestock per ha is most steadily declining in the case of the BAS scenario. The other scenarios are breaking off from this continuous trend. In the case of REF and S3 they are breaking off right after the initialisation of the policies and they are dropping from 0.41 LU per ha in year 2005 to 0.31 LU per ha in the following year. In the case of REF and S3 the LU per ha is also continuously declining, however, with a slower rate than BAS is. The difference between BAS on one hand and REF and S3 on the other is therefore decreasing during the displayed periods in Figure 7.20. When the difference is largest in year 2006 there is 0.08 LU per ha more in the BAS scenario compared to REF and S3. In year 2013 there is 0.04 LU per ha more in the BAS scenario. The average LU per ha in the S1 and S2 is slightly below BAS just after the policy change. For a couple of years the three scenarios are at the same level later S1and S2 exceed BAS.

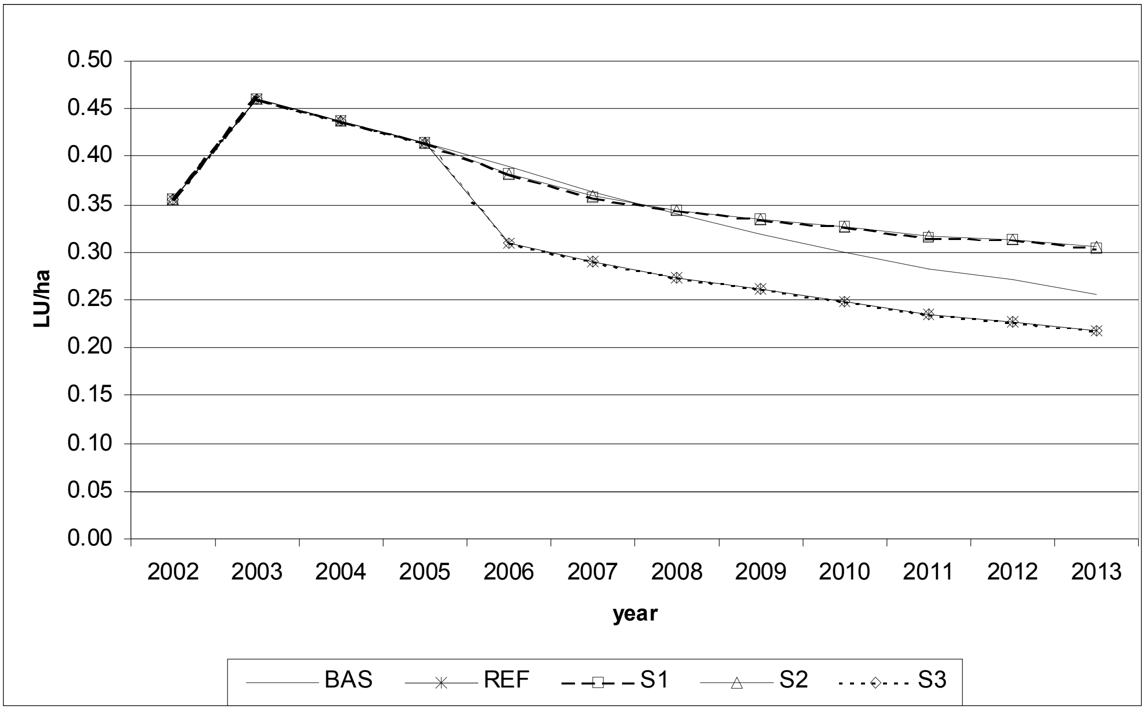


Figure 7.20 Average livestock per ha as a function of time. Own calculations

7.8.2 Farm income and profit

The development in the average total farm income as a function of time is shown in Figure 7.21 and the average profit per ha is also shown as a function of time in Figure 7.22.

As the subtle differences in the figures are hard to see each of the two figures is supplemented by a table (Table 7.8 and 7.9 respectively) showing the percentage deviation in the values relative to the BAS scenario. This means that the BAS scenario value for a given year is index 100.

In Table 7.8 the index values corresponding to Figure 7.21 for the average total farm income is given and Table 7.9 is linked to Figure 7.22 displaying the percentage deviation in the average profit per ha relative to the BAS scenario. In the tables only the years after the introduction of different policies are shown. The total average farm income for the different scenarios (Figure 7.21 and Table 7.8) indicates that the total income is relatively alike for all the scenarios, particularly when compared to the variation in the total income that the different scenarios caused in the German case study area (see e.g. Figure 7.6). The average total farm income is rising considerably in all scenarios during the investigated periods with a single exception for the S1 and S2 scenarios in the period where the policies are coming into force.

In these two cases there are small drops in the total income per farm in this period. In the case of REF and S3 as well as S1 and S2 one can see small variations in their values by comparing the values in the Table 7.8. This confirms the finding from the German study area that the main difference between the two paired scenarios has to be found within the farms' economic variables. The magnitude of the effect is, however, also here considerably smaller relative to the changes in the German case. The framework conditions politically induced are in general having a considerably smaller impact on the structural development in the Danish case study area compared to the German region. The relative importance of the commodity related incomes versus the subsidies are clearly different between the two regions. The model result suggests that the Danish region is more able to maintain an income without the subsidies. Having said this, one has still to remember that the values presented in Figure 7.22 and Table 7.8 are only based on the farms able to stay in the sector. The main consequences for the sector of the policies are that a large number of farms are eliminated from the sector and they are not included in the figure and table shown here. The fewer farms left in both scenario S1 and S2 are rather surprisingly able to end up having a higher total income per farm than in the other scenarios. The more intense economic selection process taking place in the liberalized scenarios means that the farms remaining in production are only the most efficient ones.

The average income per farm is therefore in these scenarios exceeding the average values from the other scenarios. The opposite is to some degree taking place in the REF and S3 scenario. Though the number of farms able to stay active due to the policies is a little larger than the number of farms in the BAS scenario (see Figure 7.18), REF and S3 are still the two scenarios with the largest number of active farms in the investigated periods. The above-mentioned selection process has therefore had the least impact on the composition of farms compared to the other scenarios. A higher share of the least competitive farms is therefore able to continue farming and is thereby reducing the average income per farm.

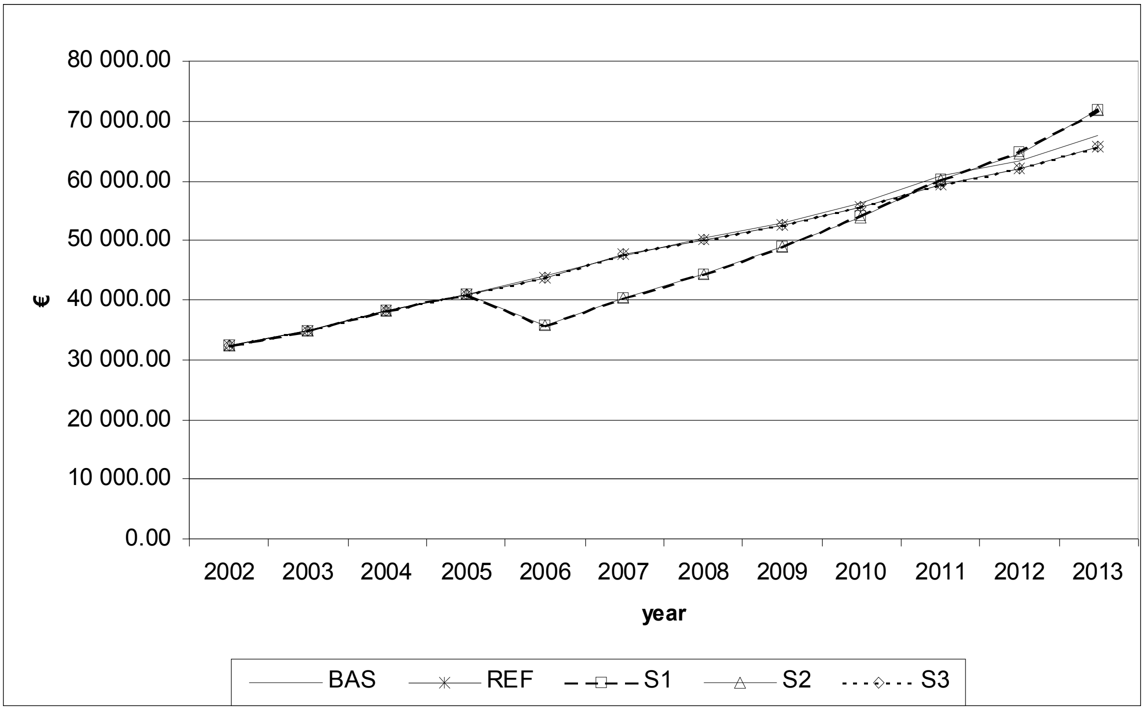


Figure 7.21 Average total farm income in euros (profit + off farm incomes) as a function of time. Own calculations

Year	2006	2007	2008	2009	2010	2011	2012	2013
BAS	100	100	100	100	100	100	100	100
REF	99.19	100.63	99.42	99.31	98.9	97.29	97.84	97.56
S1	81.11	85.21	88.03	92.49	96.15	98.96	102.19	106.76
S2	80.95	85.19	87.75	92.2	95.84	98.94	101.80	106.38
S3	99.10	100.54	99.33	99.22	98.8	97.20	97.75	97.48

Table 7.8 Average total farm income relative to the BAS scenario in percent as a function of time. Own calculations

The development in the profit per ha for the different scenarios as a function of time shown in Figure 7.22 and Table 7.9 is the picture similar to the patterns found for the total farm income in many respects. There are, however, also some distinctions to be made. In contrast to the total income per farm the REF and S3 scenario are obtaining higher values in the years from 2007 and onwards and the values for S1 and S2 surpass BAS already in 2011, one year earlier than before. The differences between the values in the scenarios are also larger in the case of profit per ha. The fact that the REF and S3 scenario obtains higher values relative to BAS in the case of profit per ha, whereas the opposite was the case for the farm income, tells indirectly something about the underlying farm structure. The farms in the BAS scenario tend to be larger and thereby able to create a larger income even though the profit per ha is lower.

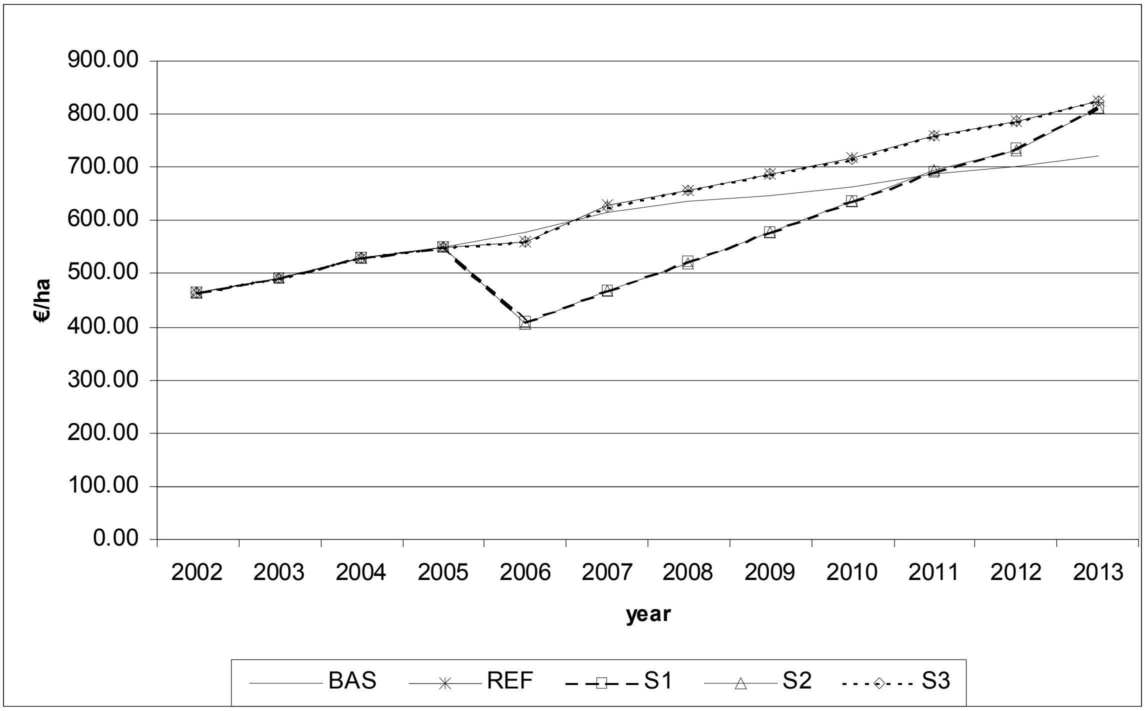


Figure 7.22 Average profit per ha (of land in production) as a function of time. Own calculations

Year	2006	2007	2008	2009	2010	2011	2012	2013
BAS	100	100	100	100	100	100	100	100
REF	97.17	102.08	103.72	106.48	108.26	110.26	112.58	114.42
S1	70.59	76.00	82.28	89.32	96.00	100.50	104.76	112.46
S2	70.41	76.12	81.99	89.18	95.88	101.01	104.71	112.73
S3	97.02	101.95	103.58	106.35	108.12	110.13	112.45	114.29

Table 7.9 Average profit per ha (of land in production) relative to the BAS scenario in percent as a function of time. Own calculations

7.8.3 Farm types

As previously shown the different average values from the scenarios are often covering quite diverse structural characteristics in the simulated regions. Therefore it is useful to investigate the regional development in a more detailed way.

The farms are therefore divided into four types. The four types are:

Specialised granivore

Grazing livestock

Specialised field crops

Mixed farms

A farm will fall into one of the first three types if more than 50% of the total gross margin comes from production activities characterising the type.

In cases where neither specialised granivore, grazing livestock nor specialised field crops accounts for more than 50% of the total gross margin the farm falls into the mixed farm type.

There are a number of reasons for investigating the structural development in the region through changes in the composition of farm types. One of them is that though the policy changes affect all farms the ability to adapt to the novel situation and benefit from the new conditions that the policies are offering is different among the main farm types.

So a way of understanding the effects of the different policies and the structural characteristics induced by the policies is to follow the changes in shares of the different farm types. This is a result of the fact that the effects that agricultural production has on its proximities is largely dependent on the main production activities of the farms. So the farm types also suggest the type of externalities that the farms inflict on the surroundings.

The effects that agricultural production has on its proximities are of course important to know when evaluating the different policy options. In Table 7.10-7.12 the shares of the four farm types within period 0, 5 and 10 as well as the average for period 4 to 10 are shown as numbers for the scenario BAS, REF and S2, respectively.

The shares in the three periods (0,5 and 10) are illustrated in a Figure 7.23-7.25 below each table. In both the Tables 7.10-7.12 and the Figures 7.23-7.25

all the values are calculated as the percentage relative to the number of farms in the region in that particular period.

This means that the number of a given farm type may drop from one period to the next at the same time as its percentage is rising. The other farm types have only to decrease in larger numbers during the same period of time.

Farm type (BAS)	**Period 0**	**Period 5**	**Period 10**	**Average for period 4 to 10**
Specialised granivore	11.14%	4.26%	1.57%	3.35%
Grazing livestock	14.14%	22.26%	21.23%	21.82%
Specialised field crops	62.35%	52.36%	60.86%	55.40%
Mixed farms	12.37%	21.12%	16.34%	19.44%

Table 7.10 Shares of the four farm types in the three periods 0, 5 and 10 and the average for period 4 to 10 for the BAS scenario. Own calculations

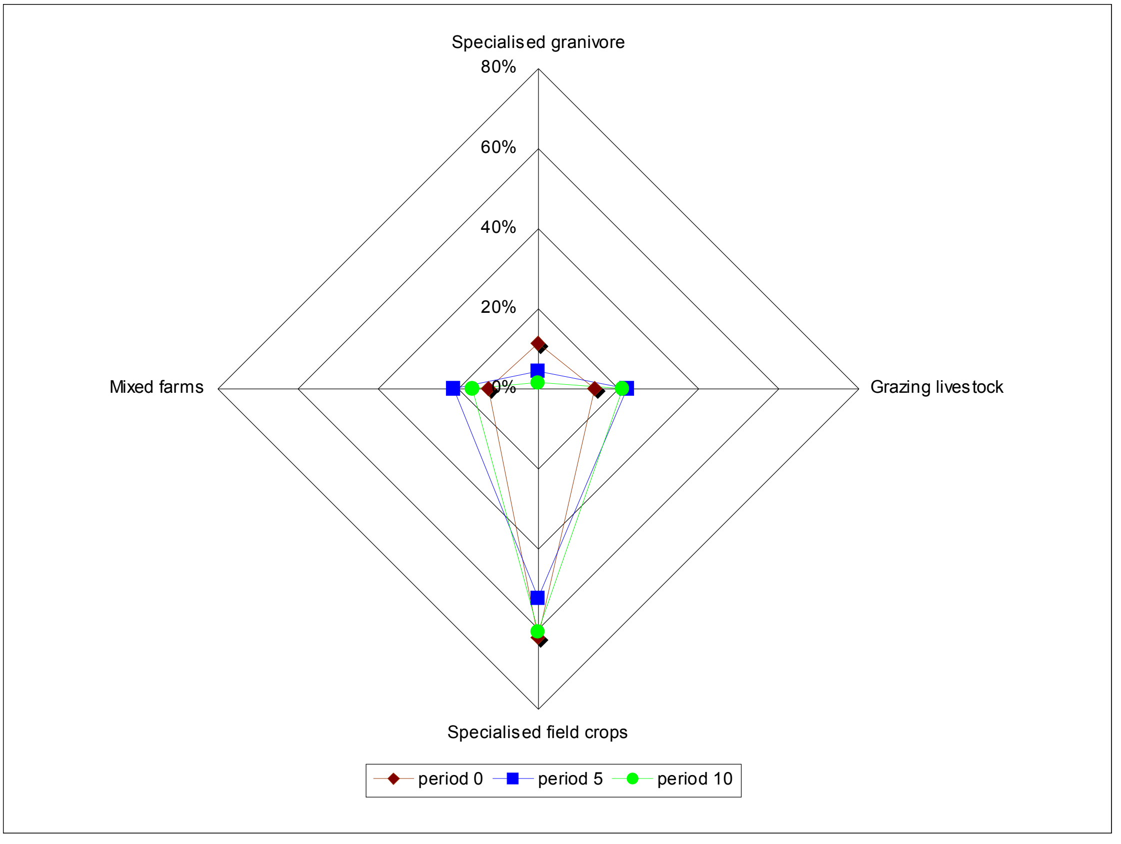


Figure 7.23 Shares of the four farm types in the three periods 0, 5 and 10 for the BAS scenario. Own calculations

As can be seen from Figure 7.23 and Table 7.10 the share of specialised granivore farms is sharply declining in the investigated time span for the BAS scenario. In return the grazing livestock production is expanding its share by an almost similar part. Both the specialised field crop farms and mixed farms are moving approximately 10% away from their original value in period 5. There is a decline in the number of specialised field crop farms and an increase of the mixed farms. In period 10 the specialised field crop farms are almost back at their original level, whereas mixed farms are at a level somewhere between their original share and their share in period 5. From the average values it appears that the mixed farms predominately have had the high share around 20% in the investigated periods. The grazing livestock farms appear to have been stable around the 22%. The average value for the specialised granivore farms seems to confirm the continuous decline in their share and the 55% for the specialised field crop farms indicates movement within its share during the investigated periods.

In the case of REF in Table 7.11 and Figure 7.24 there are fewer changes in the different farm types' shares within the investigated periods compared to BAS. The share of specialised granivore farms is also here declining, however, in a more moderated way. The share of the grazing livestock farms hardly changes during the periods and opposite BAS the specialised field crop farms are increasing their share and the mixed farms decreasing in their share during the REF scenario. The changes in their shares are, however, within a smaller span compared to BAS.

The REF scenario preserves better the original farm structure even though BAS is the stable continuation of the initial policy scheme. The decoupling of the subsidy in REF reduces the competitive pressure among the farms as a basic level of income is ensured.

Farm type (REF)	Period 0	Period 5	Period 10	Average for period 4 to 10
Specialised granivore	11.14%	7.15%	5.53%	6.68%
Grazing livestock	14.14%	15.18%	14.62%	14.88%
Specialised field crops	62.35%	67.13%	72.10%	68.89%
Mixed farms	12.37%	10.54%	7.75%	9.55%

Table 7.11 Shares of the four farm types in the three periods 0, 5 and 10 and the average for period 4 to 10 for the REF scenario. Own calculations

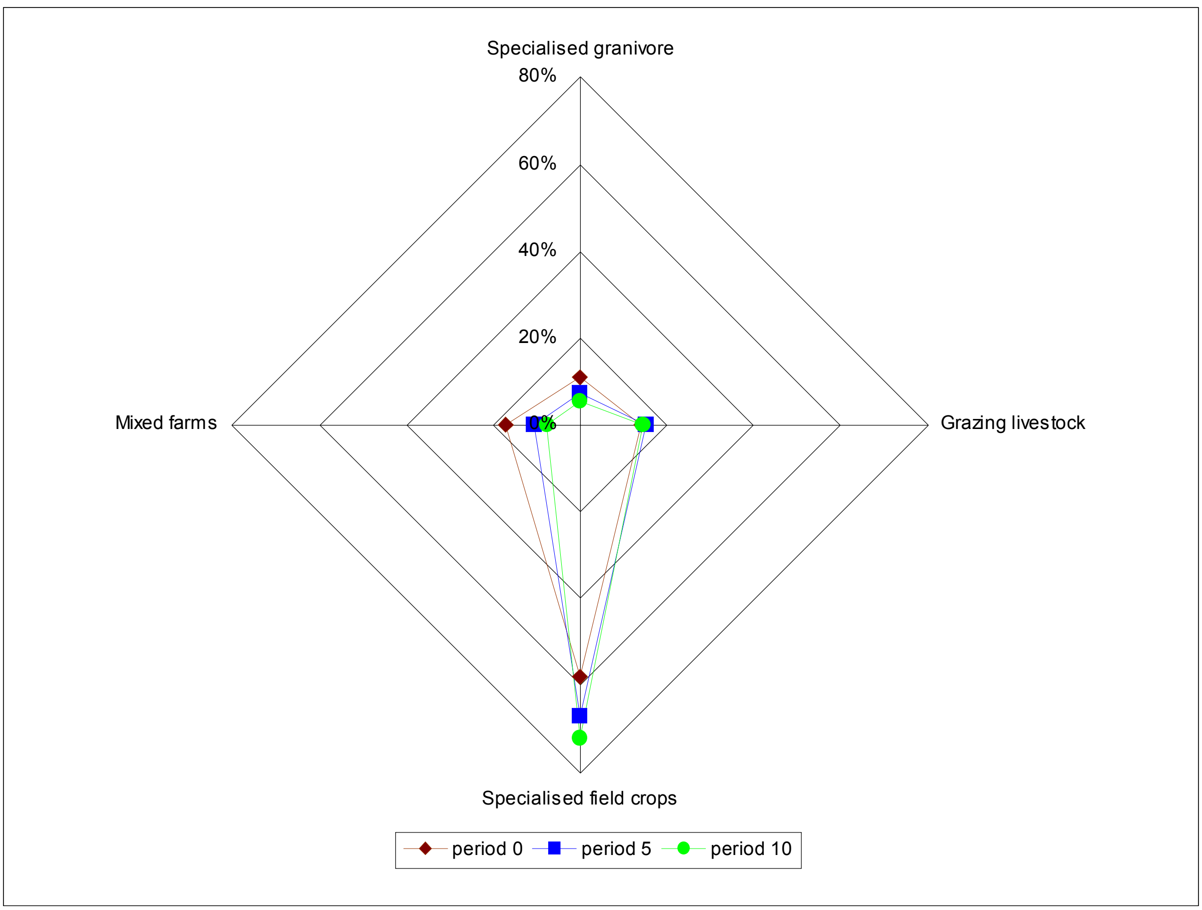


Figure 7.24 Shares of the four farm types in the three periods 0, 5 and 10 for the REF scenario. Own calculations

When looking at the shares of the different farm types shown in Table 7.12 and Figure 7.25 for the S2 scenario it is important to recall that the number of farms within the periods after the policy change are considerably reduced. As Figure 7.18 for the Danish case and Figure 7.2 for the German case study area showed, the reduction in the number of farms is on the other hand not as dramatic as the same policy change was in the German case study area. Among the farms staying active the farm types shifting in slightly different directions are compared to the two scenarios previously presented.

The share of specialised granivore farms is, however, also here declining and at a rate comparable to the REF scenario. In period 5 the grazing livestock farms are expanding their share to a similar degree as seen in the BAS scenario. In period 10, however, the grazing livestock farms in REF scenario continue to expand rather than decline its share as seen in BAS for the same period, though at a more moderate pace.

The specialised field crops farms are the types particularly hard hit due to the liberalization in the S2 scenario. The decline in their share in period 5 is maybe comparable to the decline in BAS, but in contrast to the BAS scenario this decline continues at a similar rate.

The mixed farms increase their share in period 5 to a similar level as seen in BAS but are continually increasing their share within the investigated periods in the S2 scenario. The S2 scenario is the one of the three scenarios, which experiences not only the largest shifts in the number of farms but also the largest changes in the composition of the farm types.

Farm type (S2)	Period 0	Period 5	Period 10	Average for period 4 to 10
Specialised granivore	11.14%	7.53%	4.78%	6.46%
Grazing livestock	14.14%	21.72%	24.23%	22.51%
Specialised field crops	62.35%	50.65%	42.75%	47.98%
Mixed farms	12.37%	20.11%	28.24%	23.05%

Table 7.12 Shares of the four farm types in the three periods 0, 5 and 10 and the average for period 4 to 10 for the S2 scenario. Own calculations

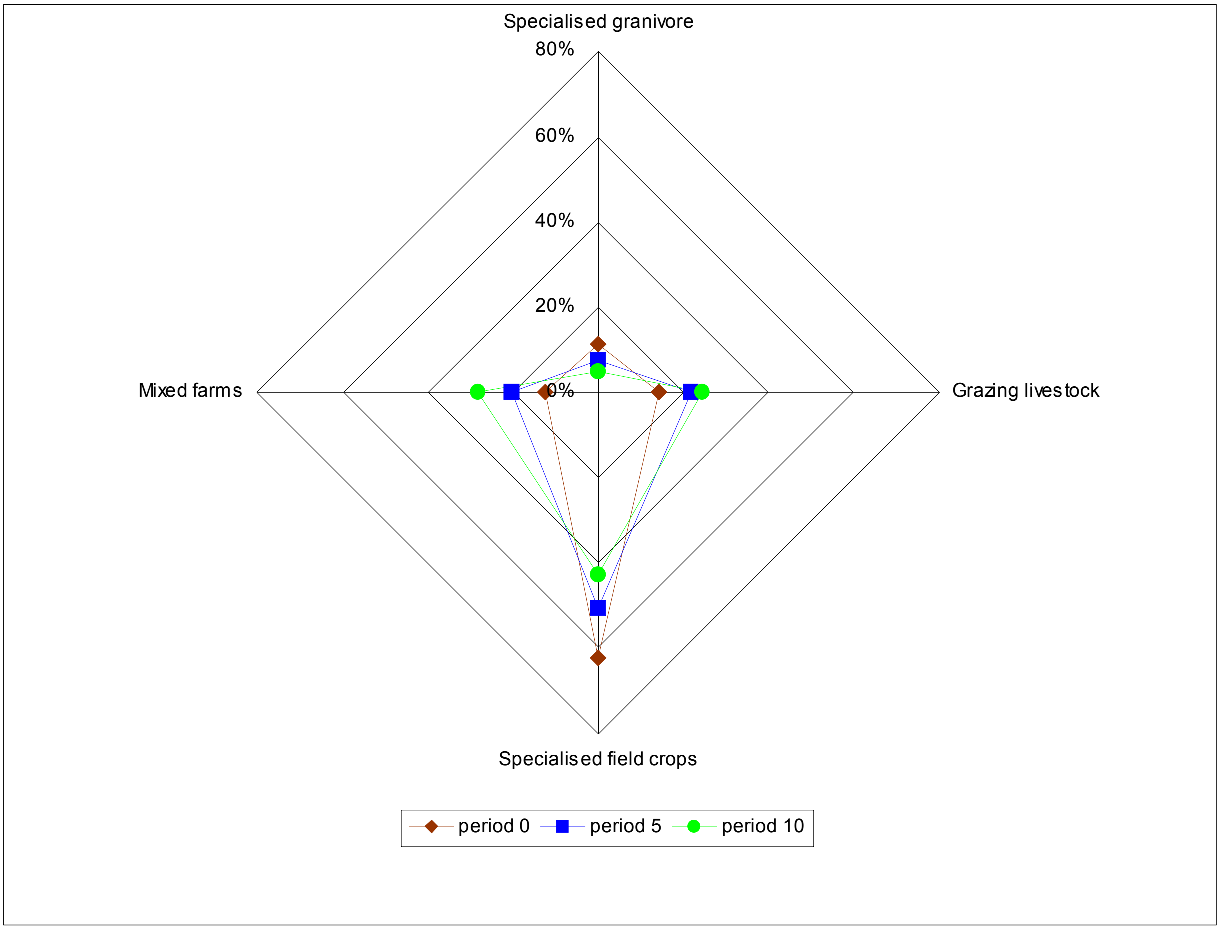


Figure 7.25 Shares of the four farm types in the three periods 0, 5 and 10 for the S2 scenario. Own calculations

7.8.4 The locations of the farm types in the landscape

The share of the different farm types compares the number of farms within each type with the total number of farms in that particular period. This does not necessarily correspond to the farm types present in the region and their influence on the regional landscape, as the size of the farms isn't the same.

If the majority of a particular farm type tends to be small farms and the opposite is true for another farm type the latter will tend to influence the local environment to a larger extent than the numerical value might suggest.

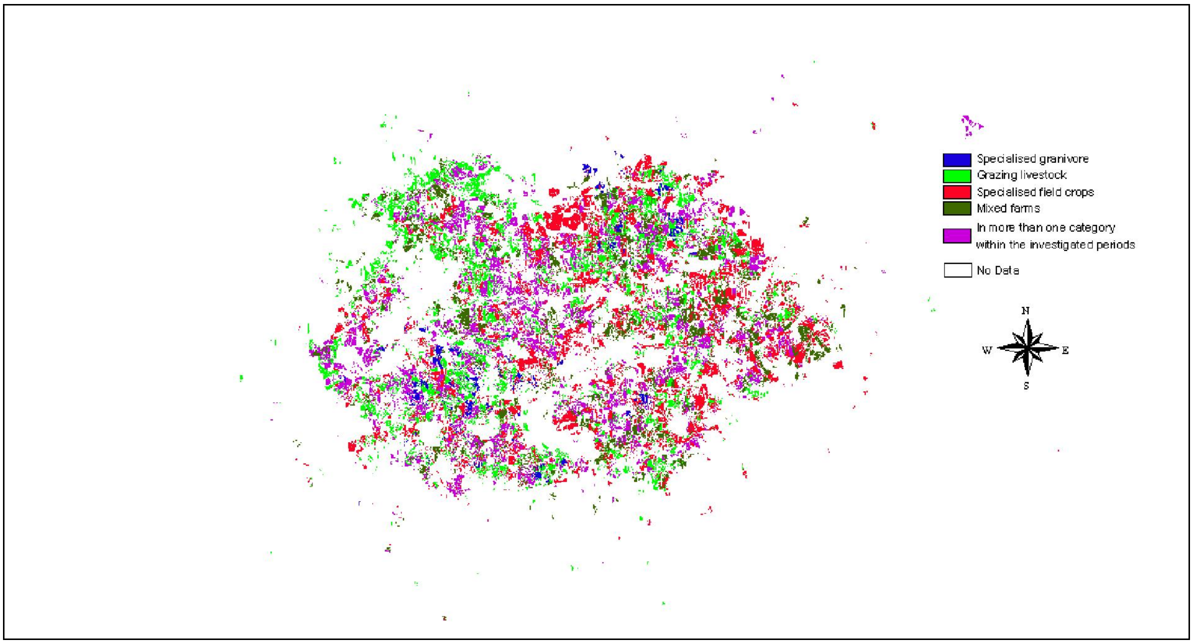
Three maps have therefore been made (Map 7.31-7.33) in order to communicate the spatial distribution of the different farm types in the region. Each map is presented with a corresponding table (Table 7.13-7.15). The maps show the farm type presence in each location in the periods 4 to 10 for the three scenarios BAS, REF and S2.

If a given area has been utilised by more farm types during the investigated period either because the farm using the field has changed type or because the field has been sold from one farm to another farm of a different type this area will fall into the category “in more than one category within the investigated time periods”. This means also that these areas may have changed farm type status one or more times during the simulated periods. Neither the times that the areas have changed status nor from which and to which type the areas have been changed will appear on the maps. The maps provide the visual impression of the regional development are, however, hard to quantify. Each of the maps is therefore supplemented by a table in which the number of pixels in the map within each category is given. As a pixel in the maps corresponds to 1 ha these values give a clear impression of the extent of the different farm types.

As can be seen from the Map 7.31 and the corresponding Table 7.13 25 % of the area is utilised within the investigated periods under the BAS scenario by shifting farm type. Thus the majority 75% of the utilised area is remaining in production subject to the same kind of farming. The 75% of the area utilised by the same farm type does not necessarily mean that the same farm has managed the area during the investigated period; however, if the area has changed ownership it has been attached to a farm of the same type as it previously belonged to. So the distinction between the areas “in more than one category within the investigated period” and the other areas is expressing the stability in landscape characteristics.

The direct and indirect effects of agricultural production is of course strongly linked to the actual management of the individual fields and can therefore only poorly be captured by a rough farm grouping as in this investigation, however, it may still communicate to which extent the induced policies give rise to dramatic landscape changes.

Of the area used by a single farm type 4.3% is devoted to the specialised granivore production, while grazing livestock amounts to 33.6% and 41% is on the hands of specialised field crop farms and the fields of mixed farms amounts to 21.1%. With some caution these values can be compared to the average share that the different farm types have as shown in Figure 7.23 and Table 7.10 within the same period. Cause for caution is of course that 25 % of the area is utilised by farms of varying types and this area is prevented from entering into the comparison.



Map 7.31 Farm type presences in each location in the periods 4 to 10 for the BAS scenario. Own calculations.

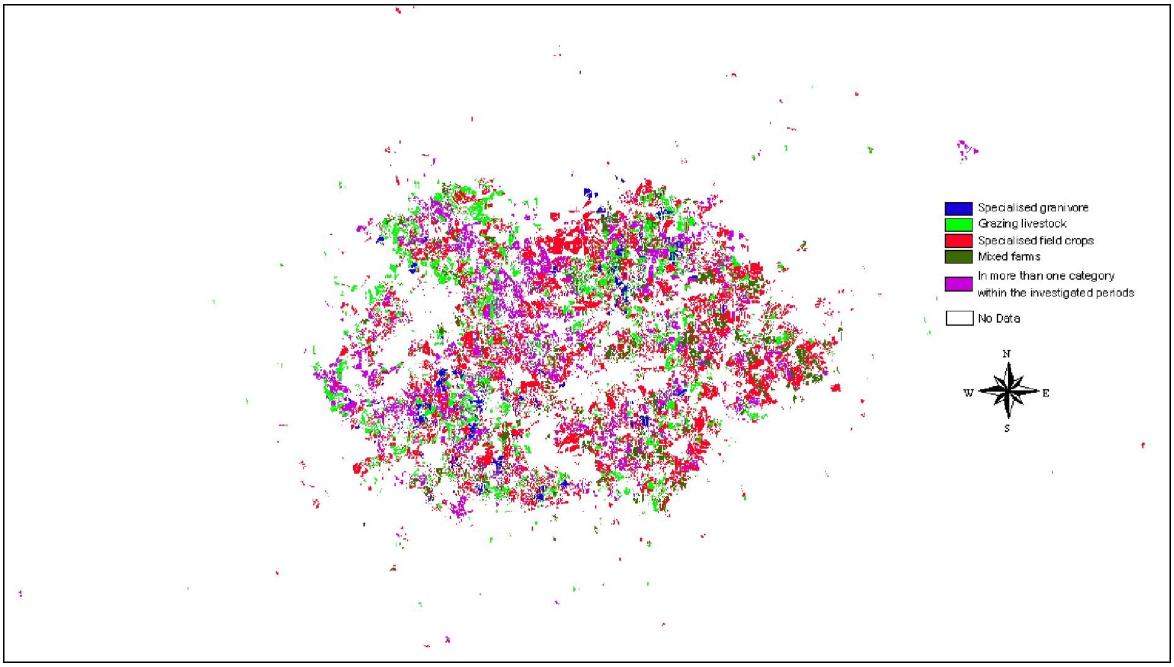
Type	Number of pixels (=size in ha)
Specialised granivore	1747
Grazing livestock	13587
Specialised field crops	16582
Mixed farms	8532
In more than one category within the investigated periods	13551
Sum	53999

Table 7.13 Area covered by each farm type in the periods 4 to 10 for the BAS scenario. Own calculations.

The direct comparison shows, however, that the area occupied by specialised granivore and grazing livestock exceeds their average number of farms while specialised field crops farms and mixed farms utilised less than their average number of farms in the region would suggest for the different farm types utilised the same average area used. Particularly grazing livestock farms and specialised field crop farms differ considerably. Whether the cause is the differences in size, differences in their activities on the land market and thereby included in the 25% of the area not accounted for, or other reasons need further investigation to be clarified.

The area maintained in production in the REF scenario during the investigated periods is 1567 ha larger than in the BAS scenario. The share of the area that falls into the category “In more than one category within the investigated periods” is 22.65% of the total area.

The larger number of farms maintaining production means that less land comes to the market and is traded. For the area utilised by a single farm type 5.53% is used by the specialised granivore production, 25.1% used for grazing livestock production, 55.93% specialised field crops fields and 13.41% is fields of mixed farms. The same cautious comparison with the shares of the average number in the region from Figure 7.24 and Table 7.11 tells us that the specialised granivore production utilises less area than the share of their numbers indicate, grazing livestock production has a higher share of land, while both specialised field crops and mixed farms have a smaller share of the area. Though the numbers contain the same elements of uncertainty as mentioned in the comparison of the results from the BAS scenario, the different percentages of the area that are utilised by a single farm type can give us some kind of yardstick to compare the landscape characteristics that the different scenarios produce. The slightly smaller area maintained in agricultural production in the BAS scenario compared to the REF scenario is to a large degree utilised for grazing livestock production and mixed farms whereas specialised field crop farms and specialised granivore farms account for a larger share in the REF scenario compared to the BAS scenario. The impact of the policies on the characteristics of the landscapes differs and could therefore potentially be investigated as input into decision-making processes.



Map: 7.32 Farm type presences in each location in the periods 4 to 10 for the REF scenario. Own Calculations.

Type	Number of pixels (=size in ha)
Specialised granivore	2377
Grazing livestock	10798
Specialised field crops	24037
Mixed farms	5763
In more than one category within the investigated periods	12591
Sum	55566

Table 7.14 Area covered by each farm type in the periods 4 to 10 for the REF scenario. Own calculations

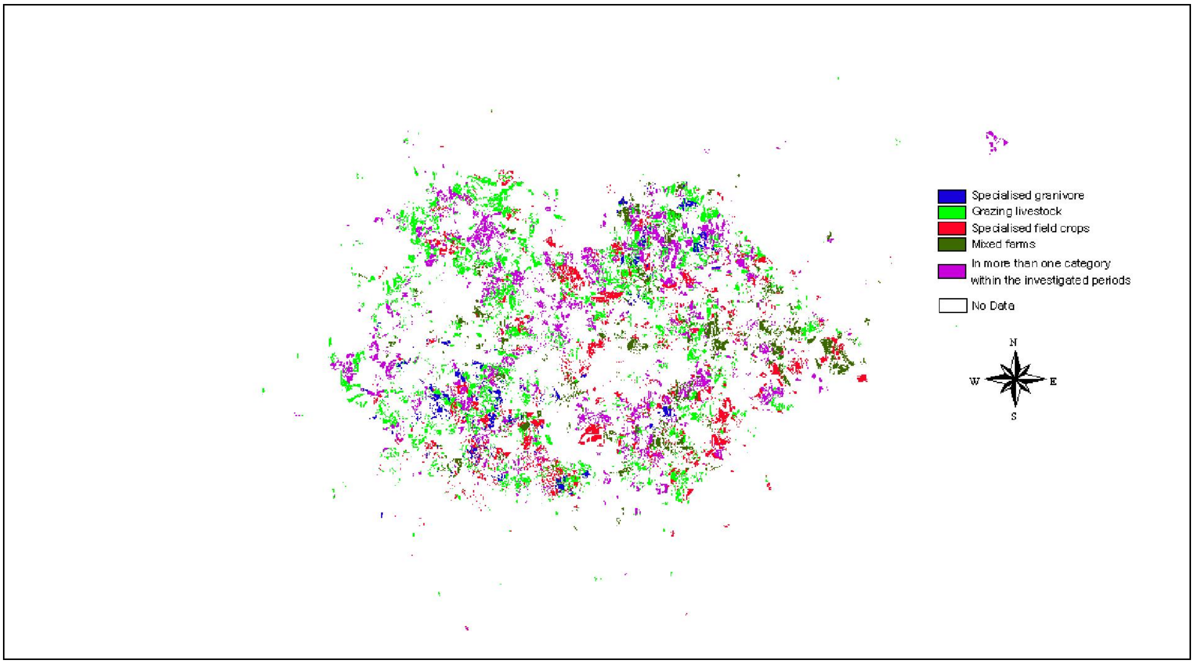
Another political option is of course to abolish the support for the agricultural sector. The main effect is a sudden drop in the number of farms in the region. The area utilised for agricultural production is also declining. The area is reduced by 20580 ha compared to the BAS scenario. In other words, only 61.8% of the area utilised for production in the BAS scenario is also cultivated in the S2 scenario. This is of course the main impact on the landscape characteristics in the region rather than the relative shifts in the shares of fields used by the different farm types. The positive or negative effects of abandoning land on the local environment are a separate issue not investigated here. It is, however, important to mention that the abandonment of land in a multifunctional analysis of a given region can neither be brushed aside as a purely positive nor purely negative development for the investigated area. Under certain conditions the abandonment of land may reduce more negative externalities than positive effects of agricultural production while the opposite may also be the case.

The spatial location of the abandoned individual fields influences the sum of the functions with which the area further on contributes. As an example areas close to sensitive nature areas will contribute in a different respect than areas located closely to urban areas. It means, however, that the main effect of the S2 scenario in a multifunctional analysis of the case study area falls outside the scope of this work and will therefore have to be noticed, when the combined picture of the effects of the different scenarios has to be drawn.

The area that is used by more than one farm type constitutes 26.8% of the area remaining after period 10. That implies a larger activity on the land market or larger adjustments by the individual farms both in size and type to the current market situation compared to the two prior scenarios.

In the case of fields utilised by a single farm type during the investigated periods 7.03% are used by the specialised granivore production, 48.15% used for grazing livestock production, 26.68% specialised field crops fields and 18.13% fields of mixed farms.

If the different shares of the area utilised are compared to the same shares in the case of the BAS scenario the shares of specialised granivore farms and grazing livestock farms are higher whereas specialised field crops farms and mixed farms are lower. Particularly the share of specialised field crops farms has dropped significantly. A direct comparison between the two scenarios is, however, difficult as the size of the region in the two scenarios differs heavily.



Map 7.33 Farm type presences in each location in the periods 4 to 10 for the S2 scenario. Own calculations

Type	**Number of pixels (=size in ha)**
Specialised granivore	1719
Grazing livestock	11778
Specialised field crops	6526
Mixed farms	4436
In more than one category within the investigated periods	8960
Sum	33419

Table 7.15 Area covered by each farm type in the periods 4 to 10 for the S2 scenario. Own calculations.

7.8.5 The farm types and profit

The spatial extent of the different farm types reveals not necessarily much about the profitability of the different areas of specialisation that the farm types cover.

A simple average value even when supplemented with values for the spread among the profits would normally provide foundation for evaluating the economic viability of the different farm types. In this case it is possible to combine the spatial representation of the different farm types with an indication of each individual farm's profit.

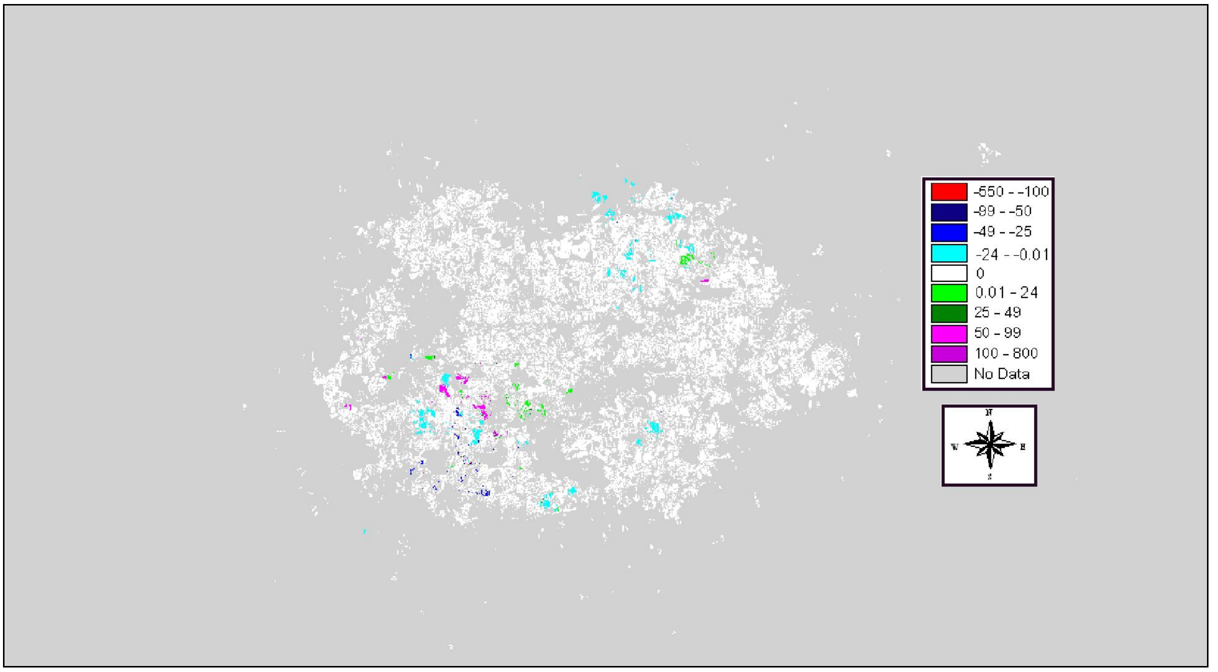
The focus on the profitability of the different farm types is chosen in recognition of the importance for the farms to be economically sound. The profit of a farm provides of course not sufficient information to truly be able to judge the economic soundness of given farm. It can, however, with some justification work as a basic indicator for the economic viability for the farms. Furthermore the profits of these specialised farms may at the same time provide insights to the profitability of their dominant production practice.

For each of the three investigated scenarios BAS, REF and S2 five maps are made. Four of these maps show the profitability of the farms type specialised granivore, grazing livestock, specialised field crops and mixed farms. The fifth map shows the profitability of the farms within the category "In more than one category within the investigated periods". All maps are average values from the periods 4-10.

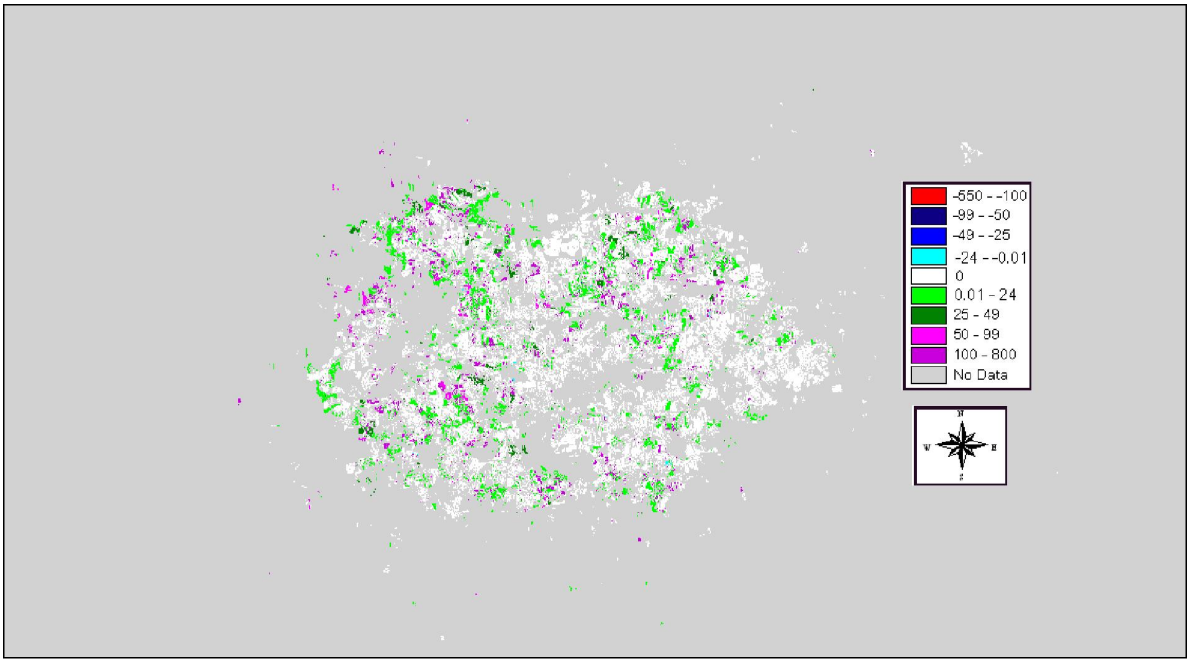
The profitability in the maps is shown with a commonly used scale in all maps. The scale needs, however, a small explanation. Note that the scale is not made with equal intervals. They show the profit in hundreds of euros.

For better visualization of the region in the maps the "No-data" is given a grey colour. All farms of a different farm type are given the profit 0 in the maps so that their area is also visual. The value 0 is chosen as none of the farms has an (average) profit equal to zero. As there are large variations in the profitability of the farms within each farm type category as well as the difficulties with quantifying the results displayed in the maps it proved useful to supplement the maps with two tables for each scenario. In the first table the number of farms from each of the five categories within each of different profitability classes is used as scale in the maps. The last column shows the total number within each of the five categories. The second table shows the same count of farms, however, as the percentage of the total number of farms within the particular category. The second table provides hopefully hereby a better overview than the exact values in the first table.

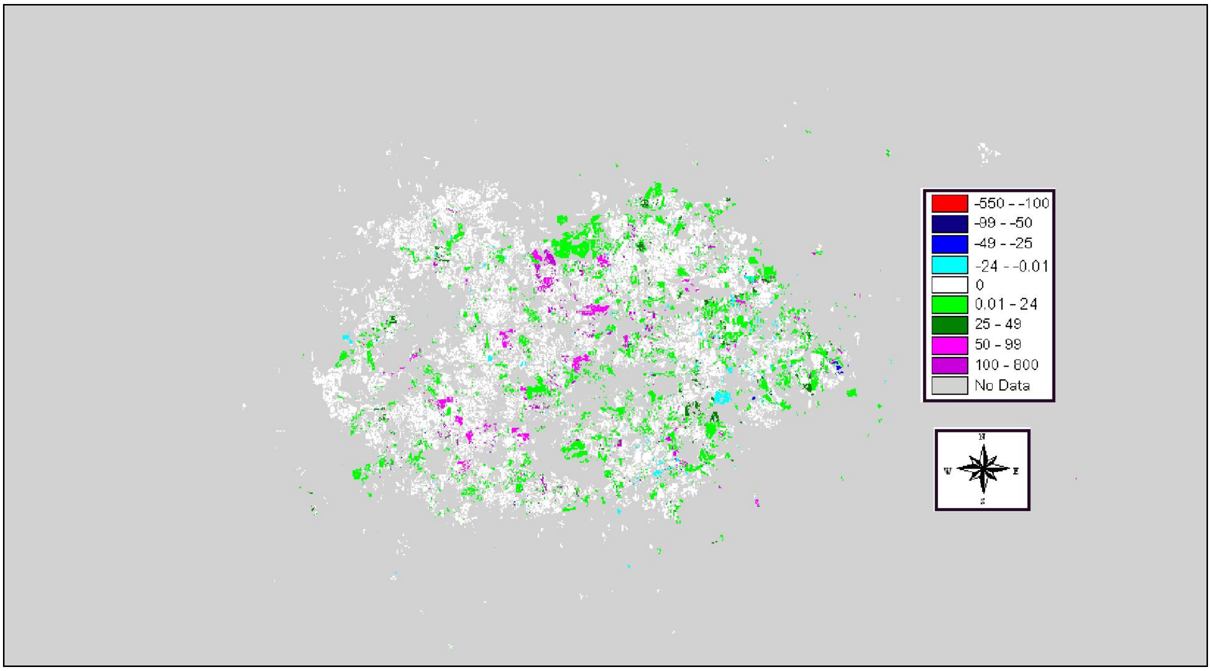
The Maps 7.34-7.38 show the average profits for the period 4-10 for the five categories starting with specialised granivore (Map 7.34), grazing livestock (Map 7.35), specialised field crops (Map 7.36), mixed farms (Map 7.37) and "In more than one category within the investigated periods" (Map 7.38) for the scenario BAS. The information in Table 7.16 and 7.17 is corresponding to the mentioned maps and therefore also for the scenario BAS. The average profit is calculated on an individual field basis.



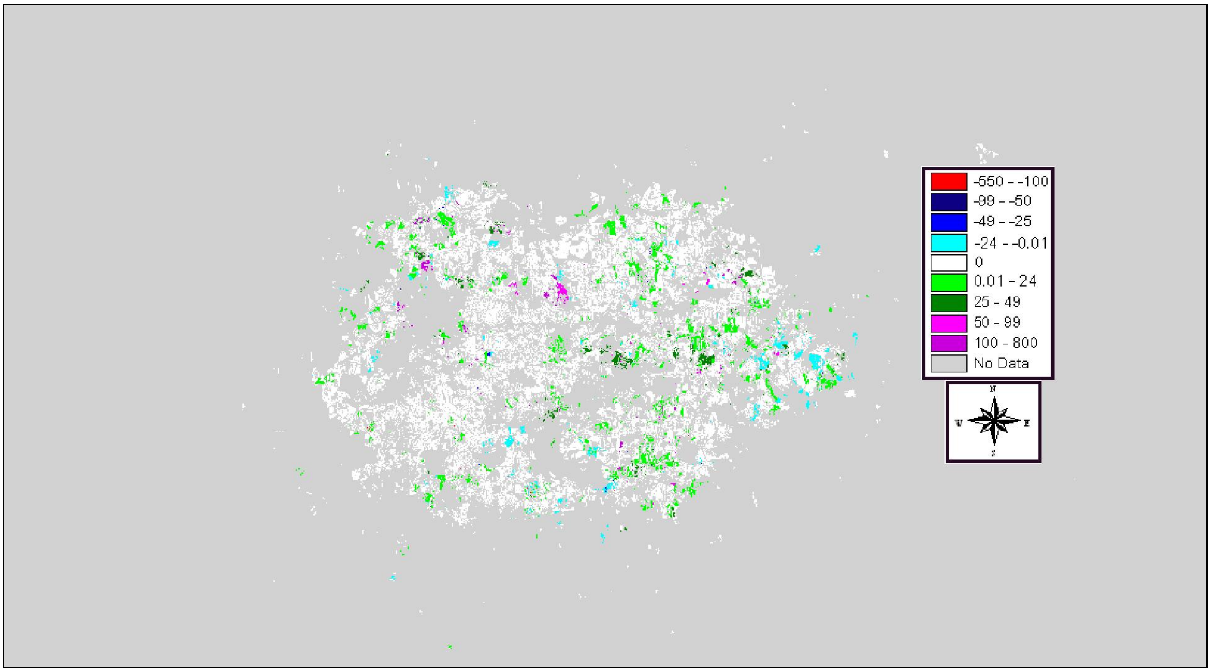
Map 7.34 Average profits in the BAS scenario for the periods 4 to 10 in the farm type: Specialised granivore. Source: Own calculations



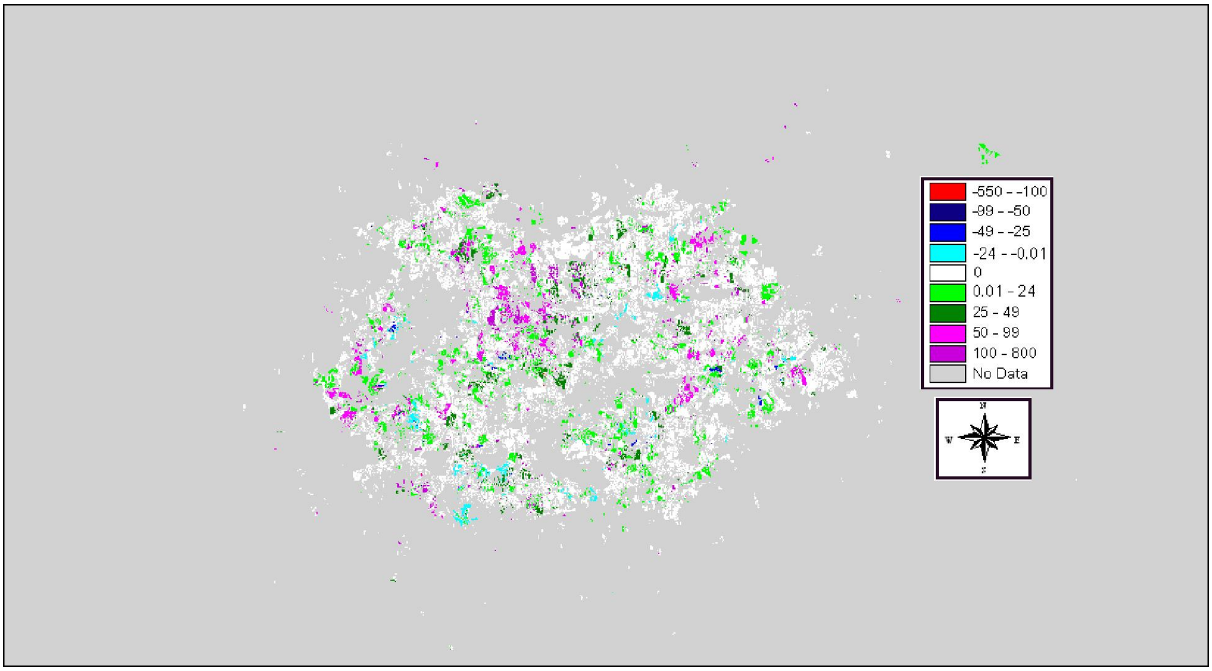
Map 7.35 Average profits in the BAS scenario for the periods 4 to 10 in the farm type: Grazing livestock. Source: Own calculations



Map 7.36 Average profits in the BAS scenario for the periods 4 to 10 in the farm type: Specialised field crops. Source: Own calculations



Map 7.37 Average profits in the BAS scenario for the periods 4 to 10 in the farm type: Mixed farms. Source: Own calculations



Map 7.38 Average profits in the BAS scenario for the periods 4 to 10 in the farm type: In more than one category within the investigated periods. Source: Own calculations

Type	-550 - -100	-99 - -50	-49 - -25	-24 - -0.01	0	0.01-24	25-49	50-99	100-800	Total
Specialised granivore	0	2	2	8	0	0	2	0	2	16
Grazing livestock	0	0	0	1	0	46	44	41	79	211
Specialised field crops	0	0	2	5	0	325	63	31	38	463
Mixed farms	1	5	2	12	0	55	19	15	15	124
In more than one category within the investigated periods	1	2	2	5	0	45	33	40	80	206

Table 7.16 Number of farms with an average profit in the indicated range (BAS scenario periods 4 to 10) in each farm type. Source: Own calculations

Type (%)	-550- -100	-99- -50	-49- -25	-24 – -0.01	0	0.01 -24	25-49	50-99	100 - 800	Total (number)
Specialised granivore	0	12.5	12.5	50	0	0	12.5	0	12.5	16
Grazing livestock	0	0	0	0.47	0	21.8	20.85	19.43	37.44	211
Specialised field crops	0	0	0.43	1.07	0	70.04	13.58	6.68	8.19	463
Mixed farms	0.81	4.03	1.61	9.68	0	44.35	15.32	12.1	12.1	124
In more than one category within the investigated periods	0.48	0.96	0.96	2.4	0	21.63	15.87	19.23	38.46	206

Table 7.17 Number of farms in percent with an average profit in the indicated range (BAS scenario periods 4 to 10) in each farm type. Source: Own calculations

As it appears both from the maps and tables the number of farms typed as specialised granivore is rather limited, a total of 16 to be precise. The majority of these farms have negative average profits within the investigated period. Half of the farms fall into the lowest negative profit grouping, where the profits range from –24 to –0.01. Four of the remaining eight farms are also having negative profits, however, within the categories –99- –50 and –49- –25. The last four farms are having positive profits. Within the two categories 25-49 and 100-800. Especially the latter highly profitable category is interesting. As it shows the ability of the farms specialised with granivore productions to produce a profit.

Both the pig and sow productions that are part of the specialised granivore farm type are productions that are hard to model for a number of reasons. The legislative difficulties connected to the expansion of a production or launch of a new production is probably not captured very well by the model, as the transaction costs associated are not well integrated in the model. This was shown in the validation of the model.

Another problem associated to these types of production, which more likely is the root of the matter here, is the relatively large fluctuations in price and production capacity seen within these productions. This means that particularly within these areas of productions there may be particularly large discrepancies between the linearly decreasing prices used by AgriPoliS and the real price fluctuations. The initially chosen price for the price development within the model can therefore be of importance. In this case the prices from the year 2002 are chosen and if looking at the price development within the period 1998-2007 the 2002 price for fatting pigs is almost an average price (see Figure 6.3 and 6.4). Though the initial price itself may be within a reasonable range the volatile nature of this branch of production calls upon caution in the interpretation of this part of the model results.

The case of farms where more than 50% of the total gross margin comes from grazing livestock in the BAS scenario, as can be seen on Map 7.35, gives a far more positive impression. Contrary to the farms specialised in granivore production, almost all farms are creating a profit. There is a single farm that on average has a negative profit, however, the rest of the farms with grazing livestock production is generating a positive average profit. Most of the farms are even within the top category.

A parameter such as profit can of course be said to give a somewhat distorted picture, as the larger farms tend to produce larger profits simply due to their size. As the Map 7.35 shows the size of the profit is, however, not necessarily directly related to the size of the farms. To some extent the map could indicate that the opposite might be the case as a number of large coherent areas falls into the lowest positive profit category. Here it is, however, important to be cautious about the interpretation. A single coherent area may in reality consist of several individual farms spatially located near each other. It is therefore difficult to ensure that the visual impression also reflects the actual structure without further investigation. A small isolated area will, however, often represent a single farm and though some of the farms do have fields located in several spatially separated locations a number of the small coherent areas is also representing individual farms, when further investigated.

The farm type grazing livestock is the best performing farm type of the farm types where no changes have taken place during the investigated period. The category ”In more than one category within the investigated periods” is performing similarly well.

As previously seen in Figure 7.23 and Table 7.10 (the shares of the four farm types within period 0, 5 and 10 as well as the average for period 4 to 10) the share of farms within grazing livestock has increased within the simulated periods relative to the initial situation. That means that the profitability of grazing livestock production has tempted other farms to engage into the production. The share is, however, still moderate compared to the corner-solutions that one sometimes experiences in LP-based models. More interesting is it that the share is slightly decreasing within the investigated period at the same time as other farm types increase their share. This shows that only those farms that have the potential to engage into grazing livestock production will do it rather than the majority of farms due to high gross margins.

The distribution between the profit groups is fairly similar for the specialised field crop farms and the mixed farms. In both cases a few of the farms are unable to generate positive profits. Most of the farms with negative profits are in the profit range from -24 to –0.01. The majority of farms within the two farm type groups are able to generate positive profits. In both cases the farms with positive profits are distributed so that the majority of farms fall into the low profit category (with 70.04% and 44.35% of the farms in the case of specialised field crops farms and the mixed farms respectively). The number of farms able to create higher profits is smaller and is in the range of 10 % for each of the following profit categories. The spatial distribution of the farms and their spatial characteristics in the Maps 7.36 and 7.37 do not reveal any distinct characteristics of the farms.

The farm category ”In more than one category within the investigated periods” is particularly interesting in a number of ways. The ability of the farms to change their type of production is one of the strengths of AgriPoliS in the investigation of the structural development in the areas and therefore this category is interesting to highlight. More importantly is, however, what the farms in the category can tell us about the regional development.

In this farm category you will find all farms that in the interval from period 4 to 10 have at least one time changed their farm type as 50% of their total gross margin comes from different activities.

Some of the farms may have been balancing between two categories so that a small shift in composition of products can result in a different farm type. Other farms may have been actively investing in new production capabilities and thereby changed their predominant source of gross margins.

That means that the farms in this category have to be understood as a very diverse group of farms. There is, however, a general character trait for these farms and that is their flexibility. They have all proven their ability to change in accordance with the market demand. Not all farms in the model are in a position where they have the possibility to utilise different parts of the market. Changing the predominant production on a farm in the model involves often a combination of capital for new investments and a composition of the farm’s capacities that are combinable with the new area of production. Not all farms are in a position to meet these requirements.

The value of being able to change focus in the production is reflected in the distribution of the farms within this category into the different profit-groups. As previously mentioned are the two farm categories with the best performing farms “grazing livestock” and this category. If one looks at the distribution of the numbers it could lead somebody to believe that the profits simply reflect that the farms in this category are all farms that have changed their production into “grazing livestock” production and therefore will experience similar profits.

Though this undoubtedly is the case for a number of the farms it is certainly not the full explanation. There are two main arguments justifying this. The first reason is that the profits are the average profits for the farms in the investigated period. That means that the profit the farm had prior to the farm’s change also plays a part in the profit it is reported to have. Therefore one would expect that the farm’s profit at least has to be slightly lower as the lower profits from the period(s) prior to change may also influence the result. The rough division of the profits into categories could of course cover small variations in the profits if that was the case, however, not if combined with the following argument. As the share of farms specialised in “grazing livestock” actually is slightly declining during the investigated periods at the same time as the share of specialised field crops farms increases (seen in Figure 7.23 and Table 7.10). This means that not all of the farms in the category ”In more than one category within the investigated periods” can have changed into grazing livestock production.

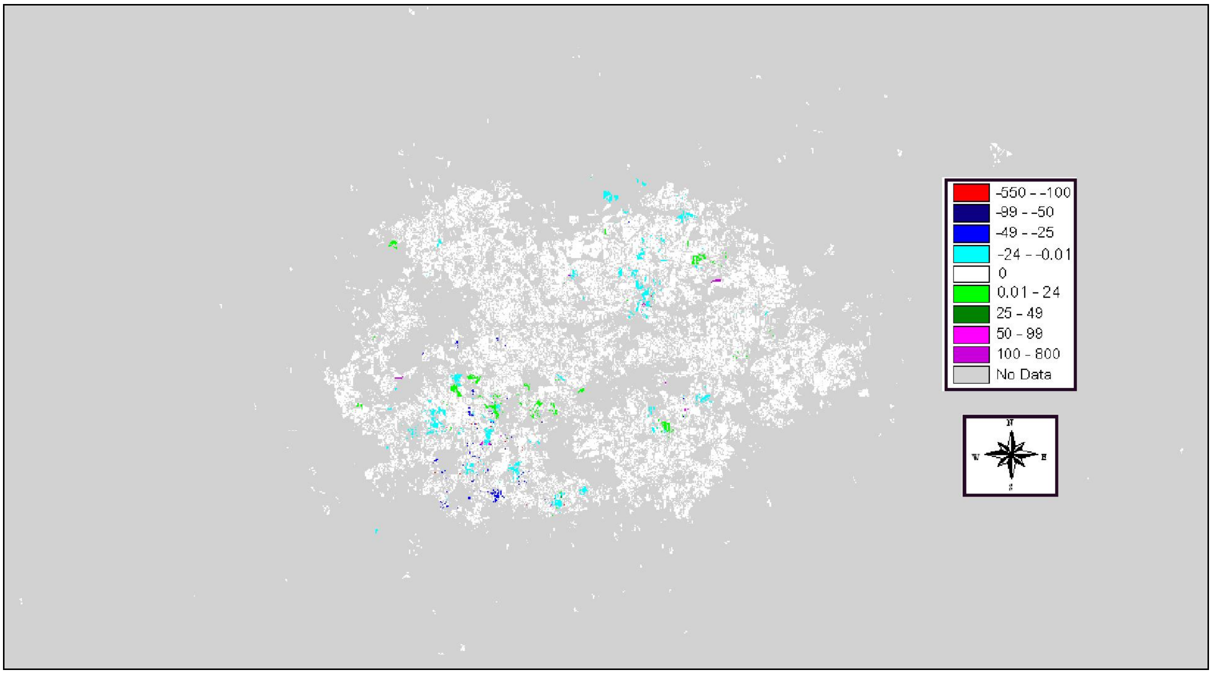
The large numbers of farms within this group that are generating positive profits are also interesting from a risk perspective. The change from one category and into another normally involves investments or disinvestments on the farm. This means that by necessity the farms are subsequently having a lower liquidity relative to the case, where they didn’t make the investment. Lack of liquidity could of course impose a risk for these farms in the following periods. The distribution in the farms’ profits indicates, however, that the farms are not leaving the sector earlier due to this risk. The farms’ investment strategies seem to be sensible which of course to some extent also reflects the risk that the farms are taking by investing. In the case of all three scenarios the investigated period is a stable period.

Though the farms can only forecast the price and support development a single period ahead, the development in the period is stable as no abrupt changes are taking place. Once the new policies have been introduced, the main trends in the price developments are maintained for the following periods. The economic soundness of an investment in the first part of the investigated periods would therefore be likely to have maintained its marginal advantage for this particular farm even though the price has numerically declined in the intervening period.

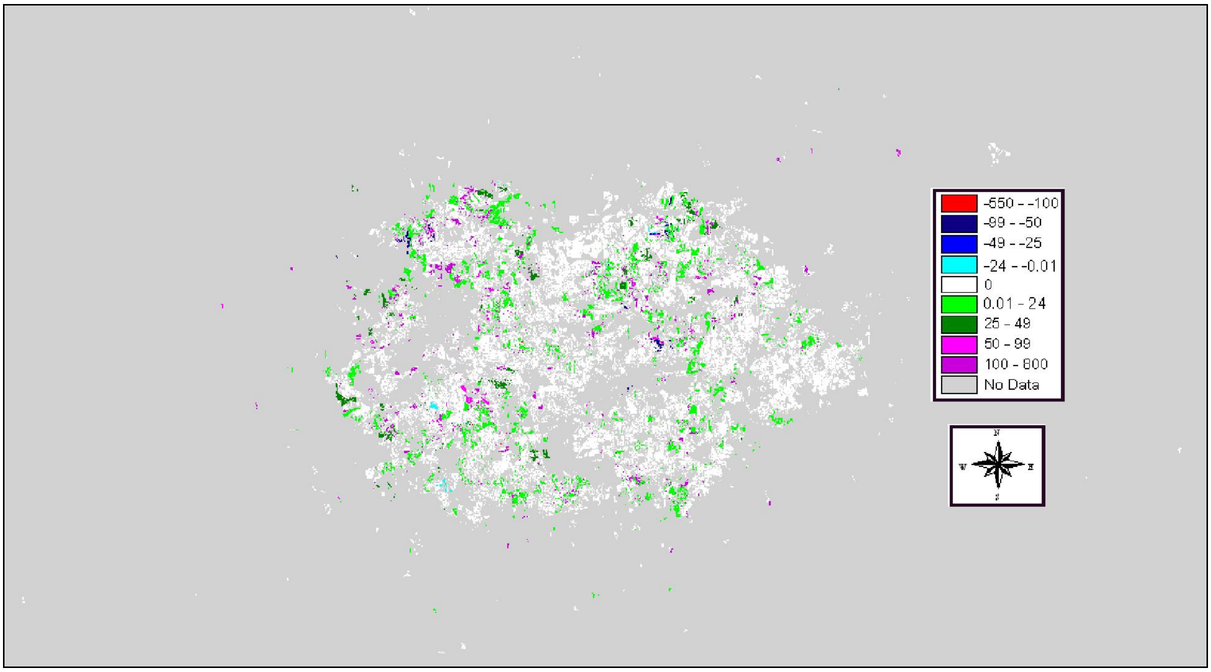
In the case of the BAS scenario the farms are not even exposed to any sudden changes in the support schemes. The motivation for changing the specialisation is likely to be induced from changes in the size of the farm or its liquidity. For some farms the marginal returns of one production type will change in comparison with the other produces in such a way that it will lead to a shift in the farms' composition of produces.

The fairly large number of farms falling into this category even during a stable scenario such as BAS reflects, however, also one of the unrealistic characteristics of AgriPoliS. The average real farmers would probably be reluctant to make such a fundamental change in their production as a change in the farm type reflects. Many would neither have the willingness nor the ability to shift their specialisation. In the case of the model the shift is, however, only a question of the profitability of the different productions. The transaction cost connected to such a shift is likely to be underestimated by the model as it is mainly imagined to be reflected in the investment costs. The model's ability to change the farm type rather free of charge means, however, that the results better reflect the optimal structural development for the region within the different political scenarios.

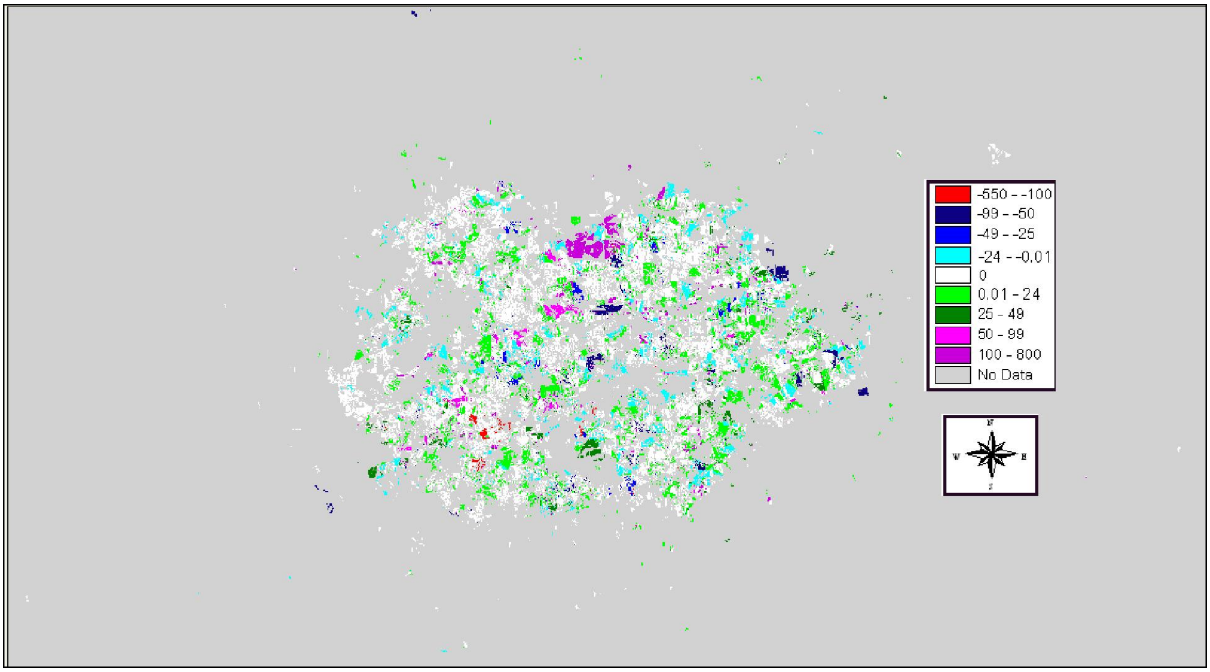
In the case of the REF scenario the Maps (7.39-7.43) are showing the average profits for the period 4-10 for the five categories in the order of specialised granivore (Map 7.39), grazing livestock (Map 7.40), specialised field crops (Map 7.41), mixed farms (Map 7.42) and "In more than one category within the investigated periods" (Map 7.43). The information in Table 7.18 and 7.19 is corresponding to the mentioned maps and therefore also for the scenario REF. The average profit is calculated on an individual field basis.



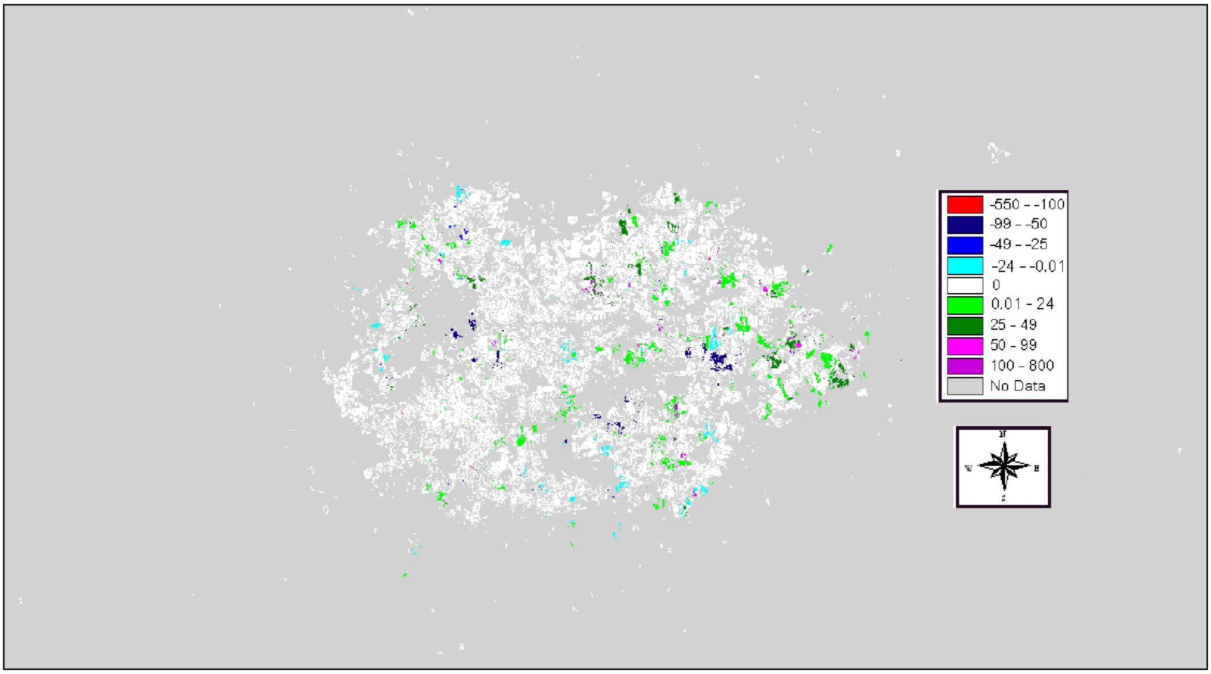
Map 7.39 Average profits in the REF scenario for the period 4 to 10 in the farm type: Specialised granivore. Source: Own calculations



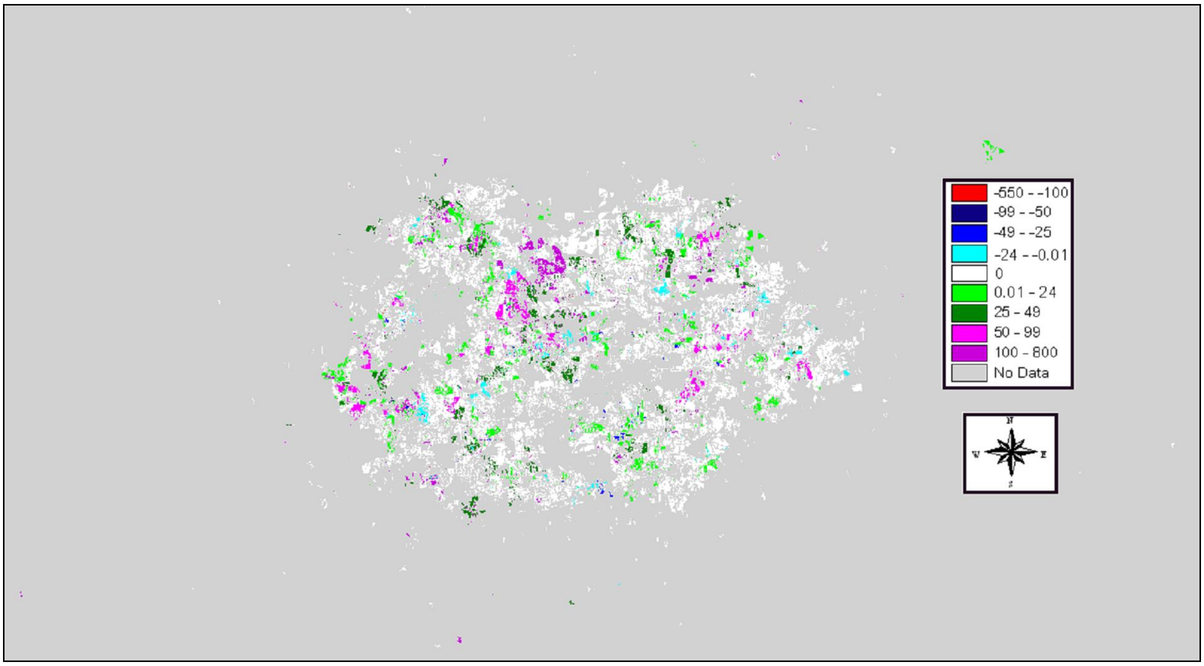
Map 7.40 Average profits in the REF scenario for the period 4 to 10 in the farm type: Grazing livestock. Source: Own calculations.



Map 7.41 Average profits in the REF scenario for the period 4 to 10 in the farm type: Specialised field crops. Source: Own calculations



Map 7.42 Average profits in the REF scenario for the period 4 to 10 in the farm type: Mixed farms. Source: Own calculations.



Map 7.43 Average profits in the REF scenario for the period 4 to 10 in the farm type: In more than one category within the investigated periods. Source: Own calculations.

Type	-550- -100	-99- -50	-49- -25	-24- -0.01	0	0.01- 24	25- 49	50- 99	100- 800	Total
Specialised granivore	0	5	7	10	0	7	0	3	1	33
Grazing livestock	3	0	0	5	0	36	27	33	55	159
Specialised field crops	26	25	27	66	0	445	27	21	49	686
Mixed farms	4	2	6	10	0	21	3	6	16	68
In more than one category within the investigated periods	1	3	5	18	0	31	15	24	79	176

Table 7.18 Number of farms with an average profit in the indicated range (REF scenario period 4 to 10) in each farm type. Source: Own calculations.

Type (%)	-550- -100	-99- -50	-49- -25	-24 - -0.01	0	0.01-24	25-49	50-99	100-800	Total (num -ber)
Specialised granivore	0	15.15	21.2 1	30.3	0	21.21	0	9.1	3.03	33
Grazing livestock	1.89	0	0	3.14	0	22.64	16.98	20.75	34.59	159
Specialised field crops	3.79	3.6	3.94	9.62	0	64.87	3.93	3.06	7.14	686
Mixed farms	5.88	2.94	8.82	14.7	0	30.88	4.41	8.82	23.52	68
In more than one category within the investigated periods	0.57	1.7	2.84	10.23	0	17.61	8.52	13.63	44.88	176

Table 7.19 Number of farms in percent with an average profit in the indicated range (REF scenario period 4 to 10) in each farm type. Source: Own calculations.

In case of the specialised granivore farms in the REF scenario compared to the same farms in the BAS scenario the first thing to notice is the larger number of farms still active. Though the specialised granivore farms in both cases constitute a small part of the regional production the relative difference between the two scenarios is considerable. The profitability of the specialised granivore farms is, however, still generally low. This could indicate that more fundamental difficulties in modelling this production type remain an issue for consideration.

The generally low profitability of the specialised granivore farms is also distinct in the case of the REF scenario as there are twice as many farms having a negative profit as farms having a positive average profit. The spread of the 2/3 of the farms that experience negative profits is the same as in the BAS scenario, but the shares of the total farms falling into each category differ. The 1/3 of the farms having positive profits are in the same way making use of the full range of profit categories as in the BAS scenario.

Similar to the BAS scenario are the majority of farms is found within the lowest negative profit grouping, where the profits range from -24 to –0.01. The share of the total number of active farms within this grouping is; however, considerably lower in the REF scenario compared to the BAS scenario. The nominal number of farms in the category is ascended by 2 in the case of the REF scenario, however, as the total number of active farms in REF are doubled compared to the BAS scenario the farms are constituting a small share of the total number of farms within this farm type. An almost as large number of farms have been able to make it into the lowest positive profit category, ranging from 0.01-24.

Only a single farm is found in the highest profitability class in the REF scenario compared to the two farms in the case of the BAS scenario. Accordingly a few farms are in the next profitability class in the range from 55-99 whereas farms in the BAS scenario only were able to make it into the 23-49 range. The rather subtle displacement between the different profit classes is, however, not the most distinct effect of the different policies induced in the region. The doubling of the number of active farms within specialised granivore is the major outcome of the decoupled support.

The number of farms typed as grazing livestock farms is smaller in the case of REF scenario compared to the BAS scenario. The 25% less farms in the case of REF may indicate that the grazing livestock farms are having slightly more difficulties under the decoupled scenario as in the case of the coupled support corresponding to the agenda 2000 in the BAS scenario. The distributions in the different profit classes of the remaining active farms are very similar in the two scenarios. The majority of farms within this farm type are able to generate large positive average profits. Looking at the share of the farms within the different profit classes the grazing livestock farms are once more the most profitable farm type category among the farms not changing main production during the investigated period. However, relative to the grazing livestock farms in the BAS scenario the farms which are subject to the decoupled payments in the REF scenario doing are slightly worse. An explanation for this is likely to be found in the way the subsidies are divided among the farms in the coupled and decoupled case as in BAS and REF. The explanation will also offer an argument for the larger number of specialised granivore farms in the case of the REF scenario. In the case of the coupled support scheme, as in BAS, the subsidies are given to farms based on the quantity of a number of individual commodities, which they may produce. Dairy production is an example of a production that received subsidies, while pig production did not receive any coupled payment. The decoupled payment on the other hand is based on the previously received levels of support. After the introduction of the decoupled payment the market prices of the different commodities are playing a more direct role as to the farms' choice of production. But at the same time almost all farms are guaranteed a steady income independently of their type of production. The continuation of the farm is the only demand for receiving the support. The farms are therefore willing to continue farming to receive the public support for a longer time than when the payment was linked to a single commodity. The threshold for quitting farming is raised for all farm types by means of the method of public payment. The farm types that did receive the large contributions, as they were involved in production of commodities receiving large subsidies are to some extent worst off as the amount of payments is now divided on a large number of farms. Therefore it seems reasonable that the number of specialised granivore farms is largest in the REF scenario and that grazing livestock farms thrive better in the BAS scenario.

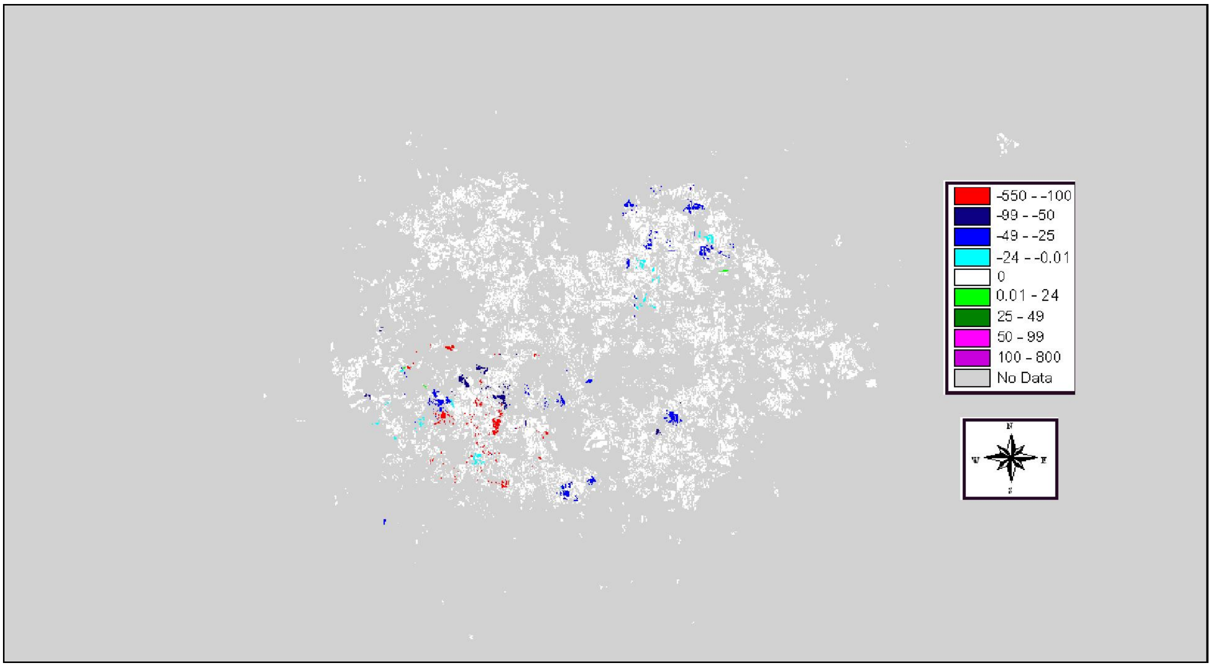
A considerably larger number of specialised field crops farms stay active in the REF scenario compared to the BAS scenario, however, their profitability is more varied and tend to be generally lower. The cause seems likely here to come from the connexions between the form of subsidies granted in the two scenarios and its influence on the farms' threshold of quitting farming.

Mixed farms do not experience the same large displacements in their ability to create a profit between the two scenarios. There are of course also changes in the number of farms in total as well as in the different profit categories. The displacements are simply of a smaller magnitude in the case of mixed farms compared to e.g. grazing livestock farms. The mixed farms are likely to be able to change in the proportions of their different types of production, so that the composition of commodities is well adjusted to the current market. The public support is of course playing an important role for the market signals to which the farms may adjust.

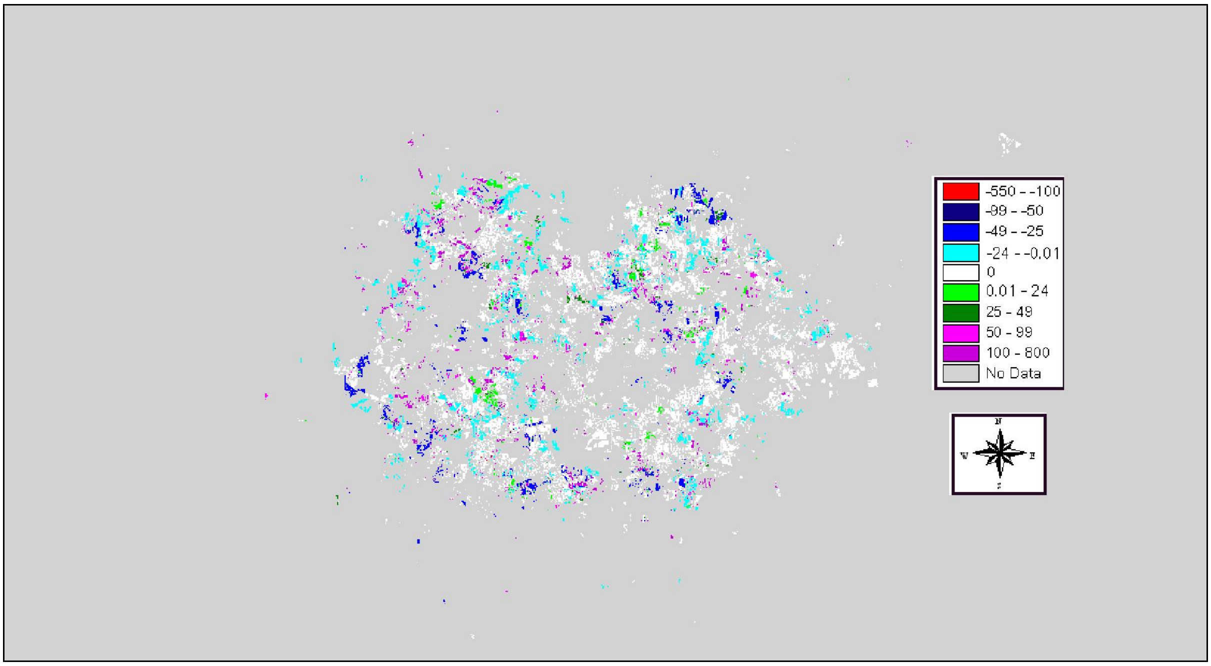
The advantage of being able to adjust to a new situation is also seen, when considering the last category: "In more than one category within the investigated periods". The highest share of farms within the most profitable group is found here. Even though the number of farms within this category only constitutes 15.5 % of all farms the highest nominal number of farms within the most profitable group is also found here. There are also a number of farms within this category unable to produce an average profit, however, they are a minority. There are slightly less farms within this category in the REF scenario compared to the BAS scenario, and though there is a larger share of farms in the top profit group in the REF scenario it is hard to judge the scenario in which this category of farms are doing best.

The same cautiousness as previously mentioned in connexion to the BAS scenario has to be taken when evaluating the cause for the performance of these farms. However, a likely explanation seems still to be these farms' ability to switch production to the type most profitable at a given time.

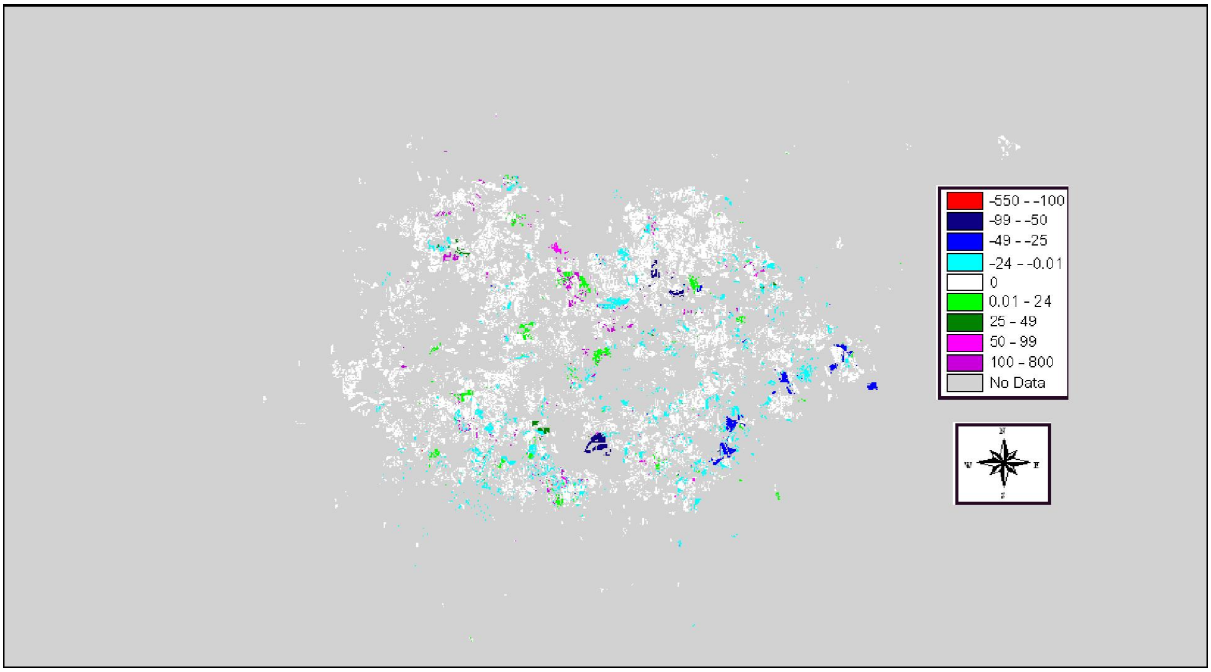
Similarly to the two prior scenarios investigated the maps of the average profits for the period 4-10 for the five categories are shown (Map 7.44-7.48) for the S2 scenario. Once more the order of the maps is: specialised granivore (Map 7.44), grazing livestock (Map 7.45), specialised field crops (Map 7.46), mixed farms (Map 7.47) and "In more than one category within the investigated periods" (Map 7.48). The information in Table 7.20 and 7.21 is corresponding to the mentioned maps. The average profit is calculated on an individual field basis.



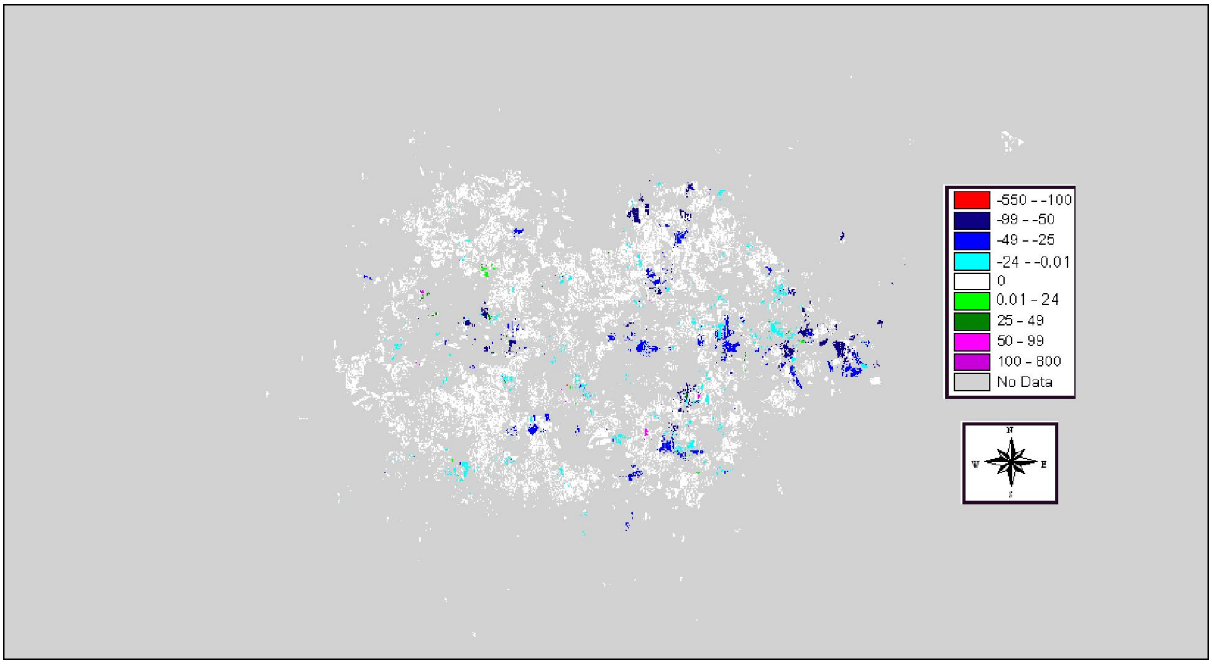
Map 7.44 Average profits in the S2 scenario for the period 4 to 10 in the farm type: Grazing livestock. Source: Own calculations.



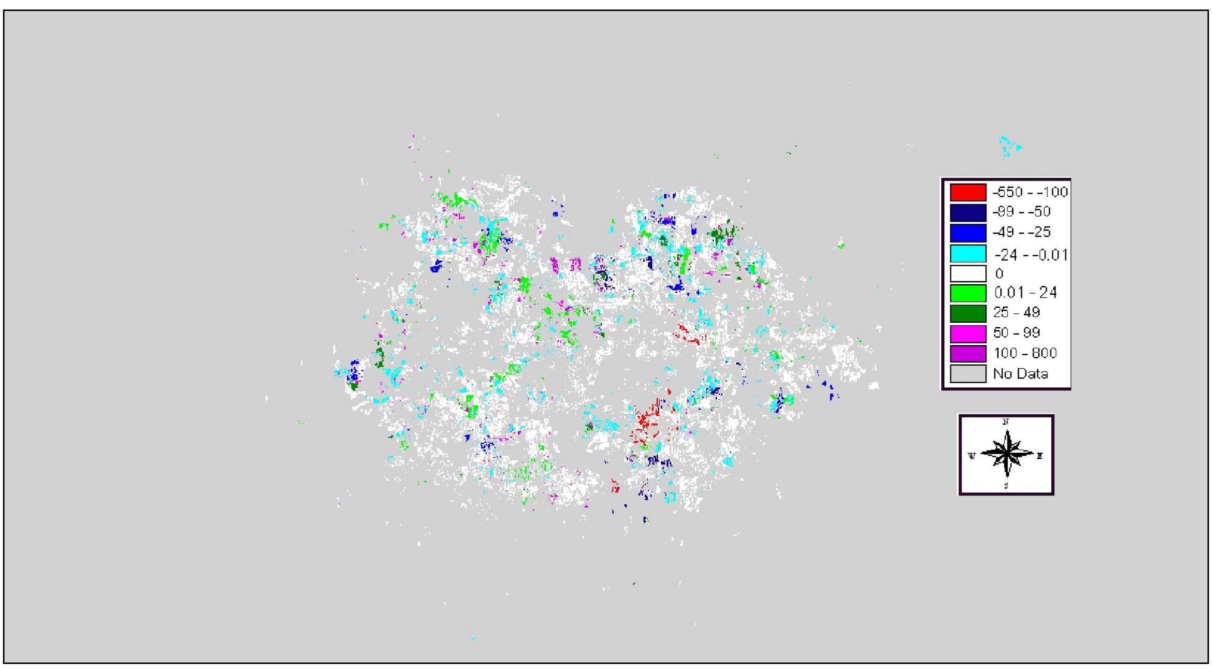
Map 7.45 Average profits in the S2 scenario for the period 4 to 10 in the farm type: Grazing livestock. Source: Own calculations.



Map 7.46 Average profits in the S2 scenario for the period 4 to 10 in the farm type: Specialised field crops. Source: Own calculations



Map 7.47 Average profits in the S2 scenario for the period 4 to 10 in the farm type: Mixed farms. Source: Own calculations.



Map 7.48 Average profits in the S2 scenario for the period 4 to 10 in the farm type: In more than one category within the investigated periods.

Type	-550- -100	-99- -50	-49- -25	-24- -0.01	0	0.01-24	25-49	50-99	100-800	Total
Specialised granivore	16	1	2	0	0	0	0	0	0	19
Grazing livestock	90	29	10	8	0	8	3	6	0	154
Specialised field crops	22	45	56	62	0	5	2	4	9	205
Mixed farms	30	10	16	23	0	1	0	0	1	81
In more than one category within the investigated periods	37	42	32	44	0	6	5	6	18	190

Table 7.20 Number of farms with an average profit in the indicated range (S2 scenario period 4 to 10) in each farm type. Source: Own calculations.

Type (%)	-550- -100	-99- -50	-49- -25	-24- -0.01	0	0.01-24	25-49	50-99	100-800	Total (number)
Specialised granivore	84.21	5.26	10.53	0	0	0	0	0	0	19
Grazing livestock	58.44	18.83	6.49	5.19	0	5.19	1.95	3.9	0	154
Specialised field crops	10.73	21.95	27.32	30.24	0	2.44	0.98	1.95	4.39	205
Mixed farms	37.04	12.34	19.75	28.4	0	1.23	0	0	1.23	81
In more than one category within the investigated periods	19.47	22.1	16.84	23.16	0	3.16	2.63	3.16	9.47	190

Table 7.21 Number of farms in percent with an average profit in the indicated range (S2 scenario period 4 to 10) in each farm type. Source: Own calculations.

The first thing to notice from the maps of S2 is of course the general decline in the size of the investigated area. The effect of the tremendous change in the farming conditions due to the elimination of the public support has already made its main inroads into the number of farms still active in the region. So the number of investigated farms is considerably smaller compared to the two prior scenarios. The impact of the policy change is, however, also reflected in the profits that the remaining farms are able to create.

The farms able to remain active during the S2 scenario show which farms are able to stay competitive on a free market with prices in the neighbourhood of the 2002 price level. The abandonment of public support for agricultural production and the drop in active farms will of course be reflected in the commodity prices as a rising trend. A smaller supply along with a steady demand is likely to push the prices upwards. As the model is unable to simulate such macro-economic price developments one of the assumptions is that these results build upon an unlikely linear negative price trend based upon the initial 2002 price level. This is particularly important when the profits of the different farms are investigated. The profits of the farms are likely to be lower in the case of this simulation compared to a real situation with prices able to surpass the level in the model. Such assumptions will create more dramatic results than the reality is likely to develop. The result tells, however, more than just a possible path that the structural development in this region will undergo in the agricultural sector due to the abandonment of subsidies. The scenario is also a test of the different farms' ability to cope under economic pressure. Therefore the results of this scenario are also interesting in this light.

Also in the case of the S2 scenario specialised granivore farms are the least profitable undertakings. The average profits for specialised granivore farms are all negative. Of the small number of farms within this category most of the farms are having considerable losses. Almost all of the farms are in the lowest category with a negative profit between –550 to –100.

Though the majority of farms in the S2 scenario are having negative profits the specialised granivore farms are the only types where none of the farms have been able to create a profit.

In the case of grazing livestock farms more than half of them are also in the lowest possible category. However, even though the price level and the abandonment of subsidies make it difficult for the majority of grazing livestock farms to make profits, a few farms are able to create a positive average profit. Within the different profit groups the distribution of the grazing livestock farms is strongly inclined towards the lowest categories. These farms have developed in to a strongly regulated and subsidised sub-sector and therefore are adapted to the conditions politically induced. Milk quotas and similar regulative measurements have reduced these farms' possibilities to adjust their size and production to the most efficient level. At the same time there is stretched out a kind of safety net under the farms as the coupled subsidies ensure some level of income. But when the subsidies abruptly are taken away as in the simulated case of the S2 scenario the farms are thrown into a situation that they are hardly adapted to and therefore all of them are unable to make profits on their production. Neither the grazing livestock farms nor the specialised granivore farms experience a dramatic decline in their number of farms compared to the two other scenarios. The large decline in the number of farms is mainly seen among the specialised field crops farms.

As with all farm types the majority of specialised field crops farms also are having negative profits. However, the farms are scattered fairly evenly among the groups and with a small tendency towards the part of the negative scale closer to zero. So although the farms clearly are struggling to make a profit the distribution among the profit groups would not necessarily point towards a massive decline in the number of farms as have been seen.

The likely cause for the steep drop in the number of specialised field crops farms cannot be read out of the numbers for the average profits among the remaining farms. The sharp decline in the number of farms came right after the initialisation of the abandonment of the subsidies as Figure 7.18 shows. Before the policy change the specialised field crop farms are a diverse group also including a number of small to medium sized farms. Though these farms not necessarily constitute a large share of the agricultural area nor contribute to the regional output with a significant share of the production, they are many numerically. The abandonment of subsidies makes it uneconomical to continue farming for many of the small to medium sized specialised field crop farms.

Next to the specialised granivore farms mixed farms are the worst performing farm type. The ability to utilise and serve different parts of the market simultaneously as well as to adjust their production to small displacements in the market prices is not the same advantage during the S2 scenario as in the two previous scenarios. The farms in the S2 scenario need to be highly efficient in order to be able to stay in business and the main possibility to become efficient in the model is through economies of scale. Therefore there is a tendency that larger and more specialized farms are performing better during the S2 scenario and the mixed farms are not performing as well as during the other scenarios. The need for being a large and specialized farm in order to perform well in the S2 scenario could seem contradicted by the farms in the "in more than one category within the investigated periods" category.

The difficult market conditions are once more showing up in the number of farms within the different profit-groups as the majority is having negative profits. However, relative to the other farm types the farms within this category are performing well. The reason for the farms in this category to perform relative well compared to the mixed farms is that the farms here have shown a different kind of flexibility than the mixed farms. The farms here have selected the most profitable production for their farm and then changed the whole farm into this area of production. The farms are thereby specializing into the new production type with the same intensity as other farms in that particular line of work. The farms able to make such a transition need access to capital in order to make the investments needed. The larger farms are more likely to have the needed capital and therefore it is reasonable to suspect the farms in this category to have a larger average size than the average farm size for all the farms. The profit distribution of the farms in this category is therefore confirming the picture that large specialised farms are the ones mainly able to operate under the conditions offered during the S2 scenario.

8. Conclusion/ summary:

The recent reform of the CAP towards decoupled direct payments, modulation, and cross-compliance introduced significant changes for the European agricultural sector. Not only has the nature of the payment schemes changed, the justification behind the payment have also been modified. The former coupled payment system supported the farms primary production of food and fibres without the same degree of recognition to the effect agricultural production has on the proximities directly and indirectly. The recent reform reflects the changed view on this issue.

The management of the man-made landscapes should preferably incorporate and promote the largest number of desired functions with which the land can serve us. In the densely populated industrialized countries of Europe this need for management is elucidated through the concept of multifunctionality.

The multifunctionality and its political recognition gave the positive as well as negative externalities of land use a collective notion. At the same time and maybe more importantly the idea of multifunctional land use marks a shift away from the dominant strategy of segregating land uses.

Neither land use management nor the multiple uses of land are new to man, however, for centuries segregation and specialisation have been the cornerstones in the land use development.

Multifunctional land use recognizes the societies' collective interests in the landscape and attempts to promote responsible production patterns reflecting these demands. Specialisation within agricultural production systems (as well as other uses of the land) will definitely take place in the years to come. However, the framework conditions for the production set by the society are likely to reflect the diversified interest in the land resource.

The implications of the change in the framework conditions politically induced on the structure of farms in the European landscape have been the epicentre from which the research presented in this thesis originates.

Here particularly with a focus on the spatial and temporal results of different CAP reform options.

Not only are the spatial characteristics and site conditions determining the farms' production potential and its influence on the surrounding environment but also the multifunctional agricultural analysis requires to be considered in a given spatial and temporal framework.

Therefore the incorporation of Geographic Information System into AgriPoliS constitutes a major part of the further development of the model made within this study. The ability to simulate the regional development based on site characteristics no longer restricted to arable and grassland, but defined according to regional needs enables the model to be constructed with an unprecedented degree of empirical detail.

The calibration of a model with this kind of spatial accuracy opens up a new set of challenges and promises. The spatial precision must of course not be used at the expense of the accuracy of the calibration of the remaining variables. In the case of an agent-based model such as AgriPoliS the location of the farms into the spatially explicit regions is of particular concern.

Each individual farm simulated within AgriPoliS builds upon accountancy data from real individual farms from the simulated regions. The sensitive nature of these data means that the accountancy data come with no information about the spatial location of the farm providing them. Recreating the spatial location of the farms included in the model will pose an issue for the calibration of the model. Therefore four methods: The arable / grassland method, the context-dependent analytical approach, the field map method and the empirical method have been developed and applied to different landscapes.

The different methods supplement each other as the number of empirical data needed rises with each of the methods. The four methods may serve as inspiration for the construction of other spatially explicit models. Neither the presented methods nor any other method will ever be able to recreate a hundred percent accurate location of the farms in a region as long as "representative" farms from the FADN sample are used. The challenge is to find the most reliable method. Each methodology has its strengths and weaknesses. The question is, however, whether the method increases accuracy and offers insights to a larger degree than a random location procedure.

In this line of thought a variation to the four methods is presented and investigated. An attempt is made to determine the minimum sample size of farm locations required to ensure the ability to reproduce a reliable map of a given region.

Both the variability of an individual farm's spatial relationship as well as the average values of farm categories found in the FADN sample was investigated with regard to variation in sample size and composition.

Though the findings of the particular case of the River Gudenå watershed, Denmark are specific to that area the ability to find values through supplementing field studies to help the location of farms is demonstrated.

This work also points towards a supplementing approach for validating the accuracy of different farm location methods rather than only relying on indirect statistics.

Incorporating the more explicit landscape characteristics into AgriPoliS is also associated with the risk of overfitting the model. It is therefore important to investigate the influence that added empirical details have on the model results. AgriPoliS was therefore tested for its sensitivity to the initial spatial location of the farmsteads and their fields.

The spatial sensitivity analysis showed, that the model is stable in its results at the same time as it reacts to changes in the initial conditions.

On the other hand the sensitivity towards the initial spatial location of the farms and their fields do not necessarily reveal the accuracy in the model's ability to produce reliable results. This was investigated through a validation of AgriPoliS by backcasting.

AgriPoliS was calibrated to the Danish river Gudenå watershed region for two years, namely the year 1998 and the year 2002. The accuracy by which the model was calibrated is vital to the reliability of the validation. Each individual farm of the 2383 farms and 1865 farms present in year 1998 and year 2002 respectively was recreated in AgriPoliS. For each of the farms the spatial location of the farm and its fields, the number of fields and their soil types as well as the number and types of animals are known. The machine capacity of the farm is assumed to fit the current production capacity. Based on the current production the machine capacity is therefore calculated and also assigned to each individual farm. The real price development of the different commodities as well as other economic factors such as the interest rate is also known and incorporated into the model. Farms from the FADN-samples for the two years are used to calibrate the individual farms economic status. First a sub-sample of the FADN-data was made by adjusting the full FADN sample to the regional statistics through minimizing the quadratic deviations between the regional statistics and the sum of farm characteristics times the new extrapolation factors assigned to the farms.

This sub-sample of FADN farms as well as all the farms from the region was then classified according to the same farm typology.

The typology utilizes the detailed information on the farms to classify them using a decision tree technique. The economic values in the FADN farms are then converted into €/ha. The individual farms with the same farm type according to the farm typology are given this value times their ha of land and thereby converting the values back to values fitting their size of production.

This method assumes that the FADN–farms have to be representative of the regional farms and that the different production types within farming have to be taken into account when transferring economic quantities.

The precision in the calibration means that the main emphasis of the validation can be placed on the discrepancy between the real farm structure in the region in the later periods and the farm structure predicted by AgriPoliS rather than blaming the data used for the calibration. The difference between the number of farms in the years 2000, 2002 and 2004 in the model and the real region was at an acceptable level. A direct comparison between the individual farms spatially situated at the same location both in the real region as well as in the simulated version for the year 2002 was made and showed a slight tendency to overestimate the farm size.

Having presented an opportunity to evaluate the reliability of AgriPoliS the foundation is laid for investigating the effects different CAP-reform options have on the structural development in three European regions.

The three regions are Ostprignitz-Ruppin, Germany, Mugello, Italy and the River Gudenå watershed, Denmark. Each of these regions possesses characteristics, which make them particularly interesting to investigate. The investigation of the three regions enables at the same time one to see how the same CAP reform options propagate differently within the different European regions.

The effect of the different CAP-reform options has its most distinct impact in the German region. In the case of the abandonment of the subsidies almost all farms within the region are disappearing. The large majority stops right after the introduction of the new policy. These results can in part be ascribed to local characteristics and in part to model specifics.

The simulated decoupling scheme has in general an almost preserving effect upon the farm structure. The number of farms in BAS scenario, which is a continuation of the agenda 2000 support scheme, lies in between.

The relative distribution among the scenarios of the farms able to stay active is the same within all three cases. However, the magnitude differs between the three regions. Both in the Danish and Italian region the effects of the different policy schemes are less pronounced.

To a large degree the average profit per ha in all three regions is following the same relative distribution among the scenarios.

The profit per ha tends to be highest in the case of the decoupled policy scenarios and lowest in the case where the first pillar support is abandoned.

The agenda 2000 support scheme tends to produce profits per ha in between the two. However, regional differences as well as changes over the investigated periods occur.

The average farm size within the three regions does not follow a uniform pattern among the scenarios. This is in part due to the large regional structural differences and in part due to differences in the sample size from which the average values are found. In the case of the average profit per ha as well as the average farm size the average values conceal a more diverse structural development taking place within the investigated regions.

The spatial analysis of the structural change taking place within the regions enables a far more accurate understanding of the extent and effects that the induced policy changes have on the regions. The dramatic effect on the landscape caused by the reduction in the number of farms in the German case study area is truly comprehensible once the large reduction of cultivated areas are visualised on maps.

The character of the AgriPoliS models land auction is better understood when the individual bids for the same plots are compared across the scenarios.

The spatial prevalence of different farm types within the Danish landscape helps in fully understanding the structural change taking place due to the policies.

The structural effects on the landscape level as well as the nature of the model are better communicated through the spatial and temporal analysis of the model's results.

Most importantly the multifunctional effects of the different CAP-reform options are truly illuminated when the effects which agricultural production has on the proximities are analysed in a temporal and spatial context.

This thesis hopefully constitutes a useful contribution in this direction.

Zusammenfassung

In der letzten Zeit erfuhr der europäische Agrarsektor deutliche Veränderungen aufgrund der Reform der GAP mit der Entkoppelung der Direktzahlungen, Modulation und Cross-Compliance. Aber nicht nur das Subventionssystem für die Landwirtschaft hat sich verändert, auch die Rechtfertigung, die hinter den Zahlungen stand wurde modifiziert. Das vorhergehende gekoppelte Subventionssystem unterstützte ausschließlich die betriebliche Agrarerzeugung ohne hiermit verbundene Effekte der landwirtschaftlichen Tätigkeit direkt oder auch nur indirekt zu berücksichtigen. Die letzte Reform zeigte eine deutlich andere Sichtweise auf dieses Thema. Alle gewünschten bzw. positiven anthropogenen Effekte der Landnutzung auf die Landschaft sollen soweit als möglich im agrarischen Subventionssystem berücksichtigt werden. Die betriebliche agrarische Landnutzung soll in den dicht besiedelten Industriestaaten der EU soweit als möglich das Prinzip der Multifunktionalität der Landnutzung berücksichtigen. Multifunktionalität und die damit verbundene politische Berücksichtigung geben den positiven, wie negativen externen Effekten der Landnutzung eine gesellschaftliche Dimension. Im selben Zug und vielleicht sogar noch wichtiger zeigt die Idee von Multifunktionalität eine Abkehr der bis dahin dominierenden Strategie der isolierten Berücksichtigung verschiedener Landnutzungsverfahren.

Zwar sind weder Landnutzungsmanagement noch die verschiedenen Arten der Landnutzung neu für die Menschheit, aber dennoch war für Jahrhunderte die Abgrenzung und die Spezialisierung ein Grundpfeiler in der Entwicklung der Landnutzung. Die multifunktionale Landnutzung erkennt die verschiedenen gesellschaftlichen Interessen an und versucht die Produktionsverfahren zu fördern, die diese Interessen widerspiegeln. Ohne Frage wird eine Spezialisierung (wie auch die anderen Arten der Landnutzung) innerhalb der landwirtschaftlichen Produktionssysteme auch in Zukunft weiterbetrieben werden. Dennoch werden die Rahmenbedingungen der Produktion, die von der Gesellschaft vorgegeben sind, die verschiedenen Interessen in der Nutzung von Ressourcen widerspiegeln. Der Ausgangspunkt von dem die hier vorliegende Studie ausgeht, sind die Auswirkungen der politisch induzierten Veränderungen der Rahmenbedingungen bzw. die Erweiterung der zu berücksichtigenden Interessen in der agrarischen Landnutzung, die weit über das rein betriebswirtschaftliche hinausgehen, auf die Struktur landwirtschaftlicher Betriebe in der EU.

Der Fokus dieser Studie liegt auf den räumlichen und zeitlichen Auswirkungen unterschiedlicher Maßnahmen der GAP-Reform. Da die räumlichen Eigenschaften und Gegebenheiten einer Landschaft das Produktionspotenzial eines Betriebes und dadurch wiederum die Auswirkungen des Betriebes auf seine Umwelt beeinflussen, ist es für eine Analyse der Multifunktionalität der Agrarproduktion notwendig, diese in einem räumlichen und zeitlichen Rahmen zu berücksichtigen. Aus diesem Grund ist die Integration eines geographischen Informationssystems in AgriPoliS ein wesentlicher Beitrag zur Weiterentwicklung des Modells innerhalb der vorliegenden Arbeit. Die Fähigkeit regionale Entwicklungen basierend auf Landschaftseigenschaften, die nicht auf lediglich zwei Bodentypen (Acker- und Grünland) beschränkt, sondern entsprechend der regionalen Erfordernissen definiert sind, zu simulieren, ermöglicht ein Modell mit beispielloser empirischer Detailliertheit. Die Kalibrierung des Modells in einer solchen räumlichen Detailschärfe bringt schwierige Herausforderungen mit sich. So darf die räumliche Exaktheit nicht auf Kosten der Kalibrierung der verbleibenden Variablen geschehen. Für den Fall agentenbasierter Modelle wie AgriPoliS ist dabei die Anordnung der Betriebsstätten in einer räumlich explizit abgebildeten Region von besonderer Bedeutung.

Jeder einzelne Betrieb in AgriPoliS beruht auf Buchführungsdaten von tatsächlich vorhandenen Betrieben in der Region. Dass die Buchführungsdaten anonymisiert vorliegen, bedeutet, dass keine Informationen über die räumliche Anordnung der Betriebe vorhanden sind. Die erneute, räumliche Anordnung der Betriebe wirft Fragen zur Kalibrierung des Modells auf. Hierfür werden vier Ansätze vorgeschlagen: Die „Acker-/Grünlandmethode“, ein kontextabhängiger analytischer Ansatz, die „Feldkartenmethode“ und ein empirischer Ansatz wurden entwickelt und auf unterschiedliche Regionen angewendet. Die vier vorgeschlagenen Methoden ergänzen sich insofern, als dass der benötigte Umfang an empirischen Daten in der genannten Reihenfolge der Methoden ansteigt.

Die Ansätze mögen dabei als Anleitung für die Erstellung weiterer, räumlich expliziter, Modelle dienen. Denn weder die vorgeschlagenen Ansätze, noch weitere denkbare, sind in der Lage die räumliche Anordnung eines Betriebes exakt abzubilden so lange nur „repräsentative“ Betriebe aus FADN-Daten verwendet werden. Die Herausforderung besteht darin, die vertrauenswürdigste Methode zu bestimmen. Jeder Ansatz hat seine Schwächen und Stärken. Die Frage ist mit welchem Ansatz der Fehler in der Anordnung im Vergleich zu einer zufälligen Anordnung bestmöglich reduziert werden kann.

Hinsichtlich der Fragestellungen werden die vier Methoden anhand der Gudenå Region[7], für die die Lage der Betriebe bekannt ist, untersucht. Es wird versucht die minimale Stichprobengröße bezüglich der Betriebsstandorte zu bestimmen. Dies soll gewährleisten, dass eine verlässliche Reproduktion der Karte einer gegebenen Region möglich ist. Sowohl die Variabilität des räumlichen Bezuges auf Betriebsebene als auch der Durchschnittswerte über die Betriebsklassen aus dem FADN-Sample wurde hinsichtlich der Streuung von Stichprobengröße und Zusammensetzung untersucht. Auch wenn die Ergebnisse spezifisch für die Gudenå Region sind, konnte demonstriert werden, wie es mit Hilfe von Daten aus zusätzlichen Feldstudien möglich ist, die Lage von Betrieben im Raum korrekt zu bestimmen. Somit wird in dieser Arbeit ein ergänzender Ansatz zur Bewertung der Genauigkeit verschiedener Methoden zur Modellierung von Betriebsstandorten entwickelt, statt sich nur auf indirekte Statistik zu stützen.

Die detailliertere Modellierung der Landschaft in AgriPoliS birgt jedoch auch das Risiko das Modell mit Informationen zu überfrachten. Es ist daher wichtig zu untersuchen, welchen Einfluss empirische Details auf das Modell haben. Aus diesem Grund wurde AgriPoliS auf die Sensitivität hinsichtlich der Initialisierung der Standorte von Betrieben und der räumlichen Verteilung der unterschiedlichen Bodenqualitäten getestet.

Die räumliche Sensitivitätsanalyse zeigt, dass die Variation der Betriebsstandorte geringen Einfluss auf die Ergebnisse hat. Dagegen ist die explizite Abbildung der Landschaft von erheblicher Bedeutung. Die Tatsache, dass AgriPoliS auf unterschiedliche Initialisierung reagiert, sagt andererseits nicht notwendigerweise etwas über die Verlässlichkeit der Simulationsergebnisse aus. Dazu wurden die Simulationsergebnisse mit Hilfe von Backcasting validiert.

Das Modell wurde anhand der dänischen Gudenå Region für die Jahre 1998 und 2002 kalibriert. Die Genauigkeit der Anpassung ist entscheidend für die Verlässlichkeit der Validierung. Jeder einzelne der 2383 bzw. 1865 landwirtschaftlichen Betriebe aus den Jahren 1998 und 2002 wurde in AgriPoliS nachgebildet. Für jeden Betrieb sind dabei der Standort, die Lage der Flächen, die Flächenausstattung und Bodentypen sowie die Art und der Umfang der Tierhaltung bekannt. Die Maschinenausstattung wird so kalkuliert, dass diese annahmegemäß den aktuellen Produktionskapazitäten angepasst ist und sich so ebenfalls den einzelnen Betrieben zuordnen ließ. Die reale Preisentwicklung für die verschiedenen Güter sowie andere ökonomische

[7] Wassereinzugsgebiet des Flusses Gudena in Dänemark

Indikatoren wie der Zinssatz waren ebenso bekannt und wurden im Model berücksichtigt. Da für die obengenannten Betriebe keine ökonomischen Kennzahlen verfügbar waren, wurden ihnen Werte von entsprechenden FADN-Betrieben zugewiesen. Dafür wurde zuerst ein Subsample aus allen dänischen FADN-Betrieben durch Minimierung der quadratischen Abweichungen zwischen Regionalstatistik und der Summe der Betriebseigenschaften multipliziert mit den Betrieben zugewiesenen Hochrechnungsfaktoren gebildet.

Dann wurde das Sub-Sample von FADN-Betrieben und sämtliche Betriebe der Region an Hand detaillierter Daten mit Hilfe eines Entscheidungsbaumes klassifiziert. Die ökonomischen Daten der FADN-Betriebe wurden in Euro pro Hektar umgerechnet. Jedem der 2,383 bzw. 1,865 Betriebe wurden daraufhin die ihrem Typ entsprechenden ökonomischen Daten zugewiesen.

Dieser Vorgehensweise liegt die Annahme zugrunde, dass die ausgewählten FADN-Betriebe repräsentativ für die Betriebe in der Region Gudenå sind. Gleichzeitig berücksichtigt diese Methode die unterschiedlichen Produktionsrichtungen der Betriebe bei der Zuweisung der ökonomischen Daten.

Auf Grund der Genauigkeit der Kalibrierung kann davon ausgegangen werden, dass die Unterschiede zwischen der tatsächlichen Agrarstruktur in späteren Jahren und der von AgriPoliS vorhergesagten Agrarstruktur modellendogen sind und weniger auf Ungenauigkeiten in den Ausgangsdaten beruhen.

Der Unterschied zwischen der tatsächlichen Anzahl an Betrieben in den Jahren 2000, 2002 und 2004 und der Anzahl der Betriebe im Model ist dabei akzeptabel. Ein direkter Vergleich zwischen Betrieben, die sich sowohl in der tatsächlichen Region als auch in der simulierten Version von 2002 am gleichen Ort befinden, zeigt eine geringe Tendenz zur Überschätzung der Betriebsgröße.

Nachdem eine Möglichkeit zur Beurteilung der Verlässlichkeit von AgriPoliS präsentiert wurde, wird diese als Grundlage für die Untersuchung der Auswirkungen unterschiedlicher Szenarien zur Umsetzung der GAP-Reform von 2003 auf den Strukturwandel in drei europäischen Regionen angewendet.

Untersucht werden die Regionen Ostprignitz-Ruppin in Deutschland, Mugello in Italien und Gudenå in Dänemark. Jede dieser Regionen weist Besonderheiten auf, welche sie besonders interessant für Untersuchungen macht. Die Untersuchung dieser drei Regionen zeigt gleichzeitig zu welchen unterschiedlichen Entwicklungen die gleichen Politikszenarien in verschiedenen europäischen Regionen führen. Die Auswirkungen der unterschiedlichen Politikszenarien sind in der deutschen Region am stärksten ausgeprägt. Im Falle einer vollständigen Kürzung der Prämien würden beinahe alle Betriebe aufhören. Die große Mehrheit der Betriebe hört gleich nach der Politikänderung auf.

Auf der anderen Seite wirkt sich das Entkopplungsszenario beinahe strukturkonservierend aus. Die Anzahl der Betriebe im Szenario BAS, welches die Fortführung der Agenda 2000 Politik darstellt, liegt zwischen diesen beiden Extremszenarien.

Die Auswirkungen der unterschiedlichen Politikszenarien auf den Strukturwandel sind relativ gesehen in allen Regionen gleich. Allerdings ist die Stärke des Strukturwandels in den Regionen unterschiedlich. Sowohl in der dänischen als auch in der italienischen Region sind die Auswirkungen der unterschiedlichen Politikszenarien weniger ausgeprägt. Ebenso ist die Relation des Gewinns pro Hektar zwischen den Politikszenarien in allen drei Regionen ähnlich.

Der Gewinn pro Hektar ist bei Politikszenarien mit Entkoppelung am höchsten und wenn die Unterstützung über die erste Säule wegfällt am niedrigsten. Unterstützungsmaßnahmen im Rahmen der Agenda 2000 führen zu Gewinnen pro Hektar zwischen den beiden erstgenannten Extremen. Dennoch darf nicht übersehen werden, dass sowohl regionale Differenzen als auch Veränderungen über den Zeitablauf festzustellen sind.

Die durchschnittliche Betriebsgröße der drei Regionen entwickelt sich bei verschiedenen Szenarios nicht nach einem einheitlichen Muster. Dies ist zum Teil auf große regionale Differenzen in der Agrarstruktur aber auch auf unterschiedlich große Samples zurückzuführen, die den Durchschnittswerten zugrunde liegen. Sowohl beim durchschnittlichen Gewinn pro Hektar als auch bei der durchschnittlichen Betriebsgröße verdecken die Mittelwerte doch eher die recht unterschiedlichen strukturellen Entwicklungen, die sich in den Untersuchungsregionen vollzogen.

Die räumliche Analyse des strukturellen Wandels in den Regionen erlaubt ein deutlich vertiefteres Verständnis der Effekte und des Ausmaßes der Veränderungen, die die Politikveränderungen auf die Regionen hatten. Die dramatischen Effekte auf die Landschaft, die in der deutschen Fallstudie die Abnahme der Betriebszahl hervorruft, werden erst verständlich, wenn der starke Rückgang der Anbaufläche auf der Landkarte visualisiert wird.

Die Eigenschaften der Landauktion im Modell AgriPoliS lassen sich besser verstehen, wenn die individuellen Gebote für ein Stück Land zwischen den verschiedenen Szenarios verglichen werden.

Die räumliche Konzentration unterschiedlicher Betriebsformen in der dänischen Landschaft verbessert das Verständnis eines politikinduzierten Strukturwandels.

Sowohl die strukturellen Effekte auf die Landschaft als auch die Natur des Modells lassen sich transparenter machen durch die räumliche und zeitliche Analyse der Modellergebnisse. Am wichtigsten ist dabei, dass die multifunktionalen Effekte unterschiedlicher Optionen der CAP-Reform erst wirklich sichtbar werden, wenn die Effekte der landwirtschaftlichen Erzeugung auf die Umgebung in einem räumlichen und zeitlichen Kontext analysiert werden.

Diese Doktorarbeit möchte einen Beitrag in diese Richtung leisten.

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Appendix

A. 1: The use of the AgriPoliS landscape generator

In this small note an impression of the use of the AgriPoliS landscape generator will be presented. In the input file three numbers will be given for each soil type:

Name	Range
Share of plots to the north	1-100
Share of plots to the west	1-100
Variation	1-100

The "share of plots to the north" and "share of plots to the west" is an attempt to let the user define where most plots of this type should be located the on north-south and the west-east axis. The range states the percentage of the whole axis where the location is. The "variation" is a scale of how large the spread should be. The designation "variation" is chosen purposely to mark the difference from the normal use of the notion spread. The variation is used in the first phase of the location procedure. The procedure finds the location defined by the user. Then a randomly chosen spot is found and the variation demarks the weight the two locations are given. The scale goes from 1, which means no variation (=only the user defined location is given a weight) to 100 as maximum variation (= only the random location is given a weight).

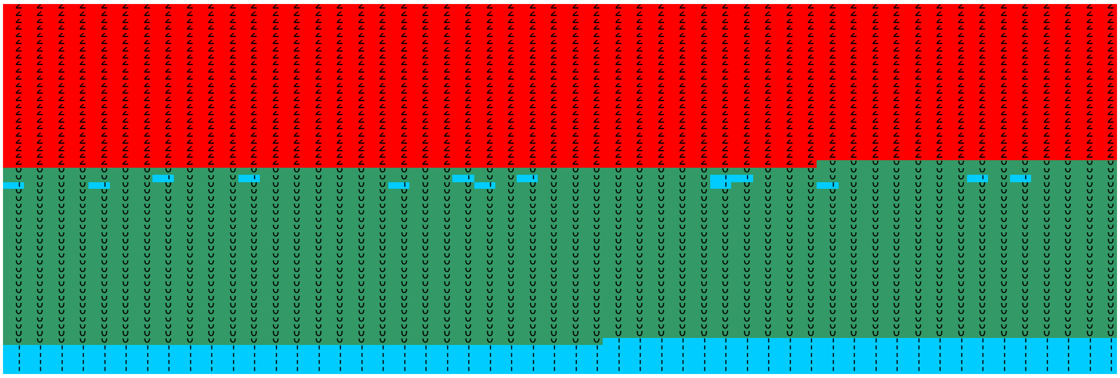
Once the weighted location between the two original spots is found the procedure will go to the next phase. A Gaussian distributed variable is multiplied to the location in order to add some fuzziness to the location and if the location is preoccupied the neighbouring cells will be tried. The routine will be repeated if these plots are also taken, until a free spot is found.

Looking at some examples may make it more understandable. In the examples studied some common properties have to be explained firstly. In all cases three different soil types are used (more can be added when needed). Each soil type is given a colour (green, blue or red) and the ascribed values are listed in a table before each soil map.

First we will look at the importance of the variation. In the first soil map the soils are intentionally divided into three separate regions. Note the lonely blue soils close to the red soils. Only when the location of the soils is given in such a way that the soils don't compete over the locations they will have it all to themselves. For the location the competition is keener around the blue area than close to the red area and therefore some of the last blue soils are located here.

SOIL MAP

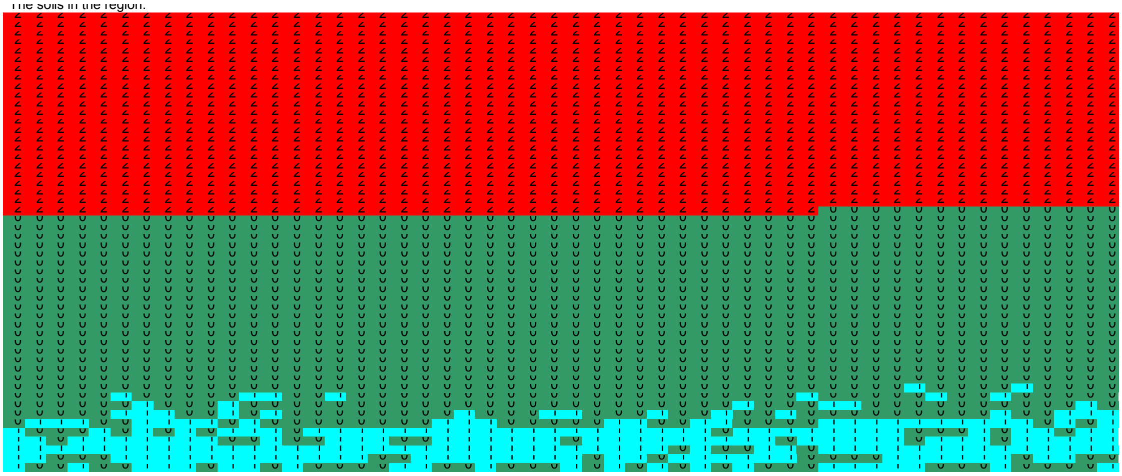
	Green	Blue	Red
Share of plots to the north	70	1	100
Share of plots to the west	70	100	1
Variation	1	1	1



Once a little variation in the location is introduced the effect of the competition is even clearer. The green and blue soils are fighting for the same space while the areas of the red soils' are out of reach.

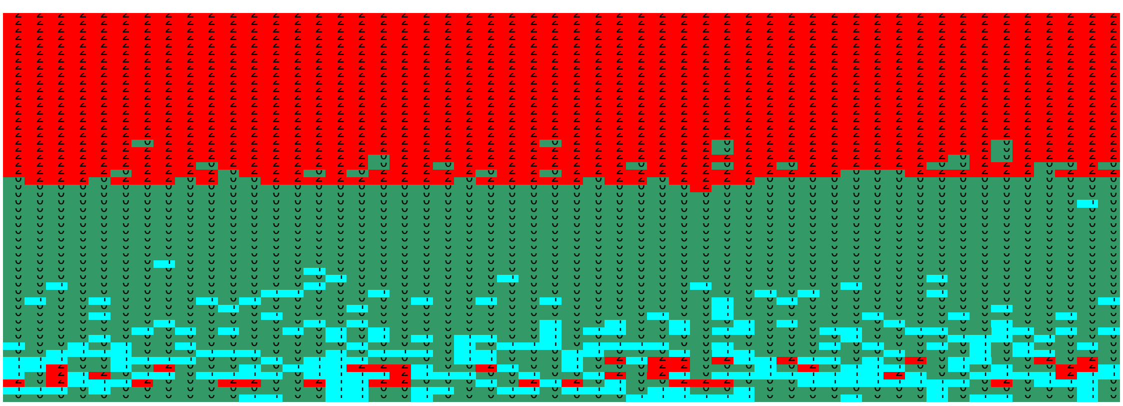
	Green	Blue	Red
Share of plots to the north	70	1	100
Share of plots to the west	70	100	1
Variation	5	5	5

The soils in the region.



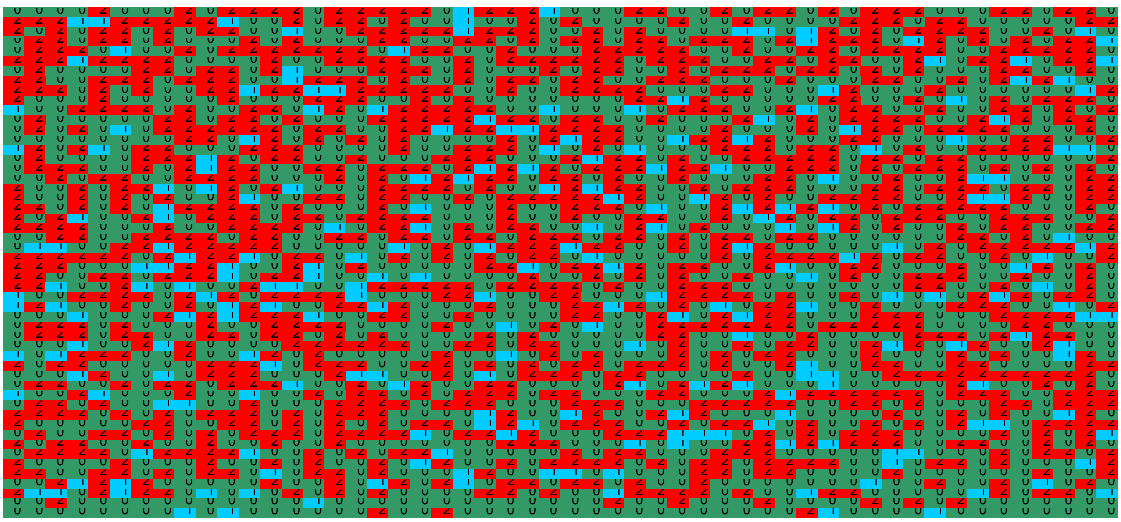
With some additional variation red area is also affected. The location of the lonely red soils could, however, indicate some structure in the order of who is choosing the next location (and that blue was the last one). By having a random order of the next soil type to be placed into the region this is avoided.

	Green	Blue	Red
Share of plots to the north	70	1	100
Share of plots to the west	70	100	1
Variation	10	10	10



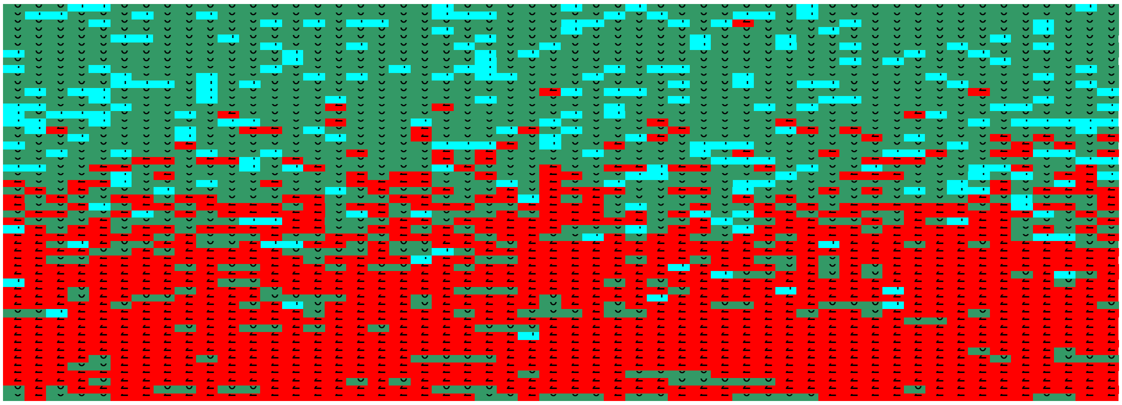
Once the variation raises the soil will be randomly located.

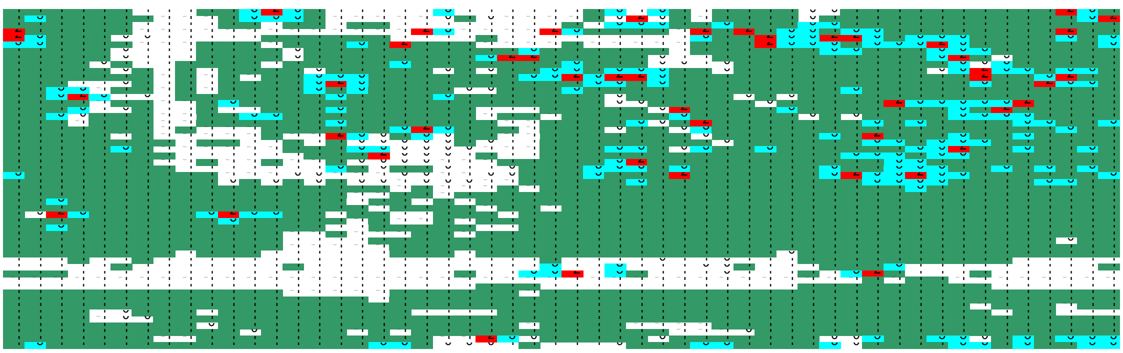
	Green	Blue	Red
Share of plots to the north	70	1	100
Share of plots to the west	70	100	1
Variation	50	50	50



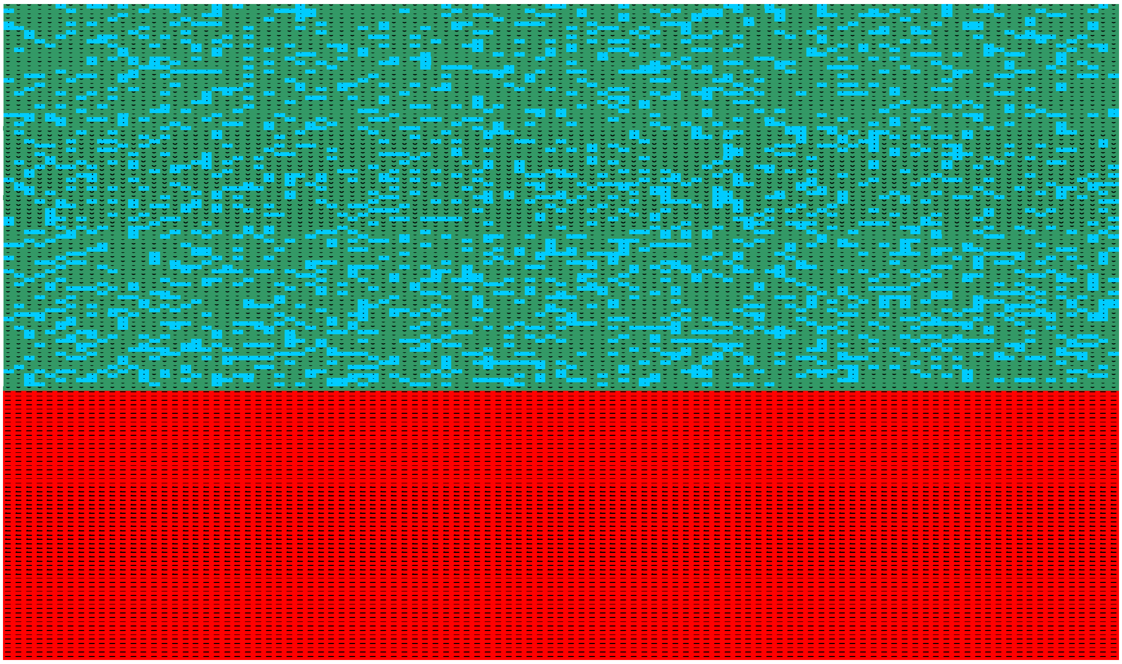
With the three parameters it will be possible to create regions with all kinds of soil distributions such as the two ones below. For both of them the state map for the first period is included (the map with the white area). Here green is rented land, red is farms and blue is owned land. The white areas are either dead plots or unused land.

	Green	Blue	Red
Share of plots to the north	50	75	10
Share of plots to the west	5	1	100
Variation	20	20	20

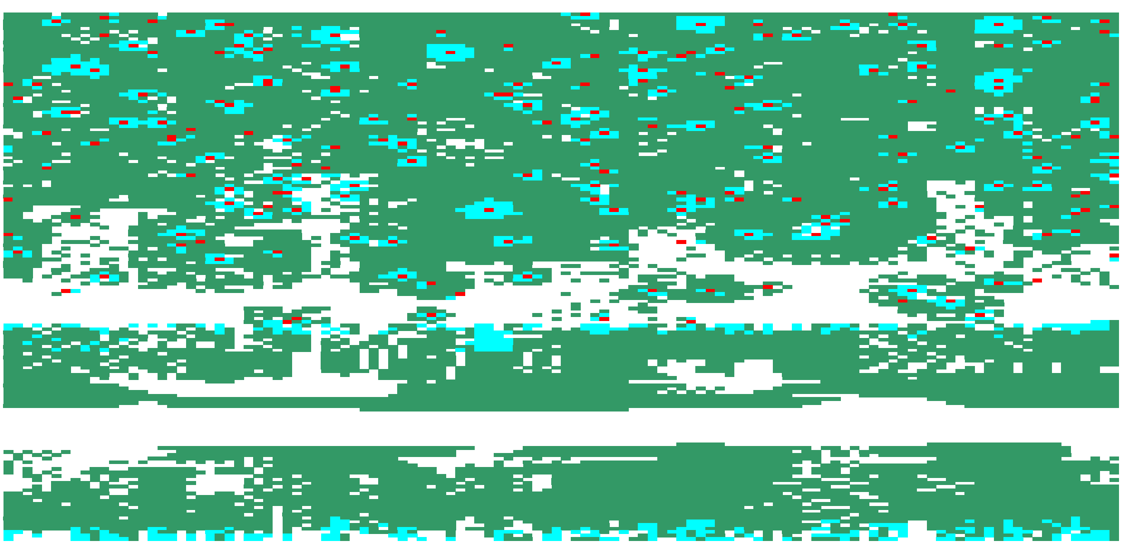




	Green	Blue	Red
Share of plots to the north	20	40	1
Share of plots to the west	5	1	100
Variation	10	10	1



STATE MAP



A. 2 Mathematical terms of minimization of the squared deviation between goal and FADN farms

The selection procedure for finding and assigning weights to typical farms based on regional statistics and FADN-sample for regional modelling with the agent-based model AgriPoliS.

Please note that the following is a quotation from Kellermann, Happe et al. (2007).

Let $\mathbf{b}^k \in \Re^m$ be the vector of *m* farms in region *k* and let $\mathbf{y}^k \in \Re^n$ be the vector of weights for *n* statistical goal criteria in the region. Furthermore, let $v_{i,j}$ be the contribution *j* of farm *i*, and $V \in \Re^{m \cdot n}$ the matrix of contributions of all farms. From this, we derive the vector of all goal criteria $\hat{\mathbf{y}}^k$ for the virtual region *k*

$$\hat{\mathbf{y}}^k = \mathbf{b^k V}$$

Now we can construct a normalised matrix $\mathbf{X^k} \in \Re^{m \cdot n}$ with

$$\mathbf{X^k} = \left[a_j^k \frac{v_{i,j}}{y_j^k} \right]_{\substack{i=1,\dots,m \\ j=1,\dots,n}}$$

and a_j^k as the priority level of criterion *j* in region *k*, or $\mathbf{a}^k \in \Re^m$ as the vector of weights of all criteria in region *k*. The vector of weights $\mathbf{b}^k$ then results from the minimisation problem

$$\min_{\mathbf{b^k}} \{(\mathbf{X^k b^k} - \mathbf{a^k})^T (\mathbf{X^k b^k} - \mathbf{a^k})\} \qquad \text{with } \mathbf{b}^k \geq 0$$

This problem can be solved with a quadratic programming algorithm. All farms with $\mathbf{b}_i^k > \mathbf{0}$ are then considered as being representative of the region. All other farms are no longer considered and are removed from the sample.

A.3 Results from Recreating location from non-spatial data –sample size requirements to reproduce the locations of farms in the European Farm Accountancy Data Network.

For the category "All Farms" as well as the five field size categories the relative difference between the maximum and minimum values are presented for the sample size 20, 100, 400 and 1000.

	All farms			
Summary:	20	100	400	1000
All FARMS	50.57%	12.53%	3.38%	2.25%
0-20ha farms	50.34%	12.72%	3.54%	2.30%
21-50ha farms	50.46%	12.07%	3.98%	2.38%
51-100ha farms	51.07%	12.03%	3.20%	2.04%
101-200ha farms	51.03%	14.23%	2.44%	1.90%
more than 200ha farm	50.56%	14.08%	4.01%	2.53%
plant_production farm	50.69%	13.83%	3.00%	2.17%
1-50 animal unities	50.46%	12.06%	3.70%	2.30%
more than 50 animal u	50.47%	11.57%	3.78%	2.28%
pock	50.56%	12.42%	3.93%	2.41%
dairy	50.49%	11.58%	3.78%	2.23%

	0-20ha farms			
Summary:	20	100	400	1000
All FARMS	33.32%	7.55%	4.18%	2.21%
0-20ha farms	34.33%	7.66%	4.16%	2.21%
21-50ha farms	34.94%	6.80%	4.44%	2.22%
51-100ha farms	29.12%	7.08%	4.60%	2.18%
101-200ha farms	29.34%	11.01%	5.03%	2.22%
more than 200ha farm	40.49%	9.82%	5.16%	2.69%
plant_production farm	32.40%	9.93%	4.39%	2.23%
1-50 animal unities	34.04%	6.98%	4.27%	2.20%
more than 50 animal u	34.31%	6.32%	4.51%	2.21%
pock	36.01%	7.56%	4.56%	2.32%
dairy	33.42%	6.01%	4.52%	2.15%

	21-50ha farms			
Summary:	20	100	400	1000
All FARMS	24.97%	10.89%	7.06%	2.44%
0-20ha farms	26.72%	11.25%	6.59%	2.32%
21-50ha farms	25.13%	10.39%	6.66%	2.10%
51-100ha farms	20.97%	10.98%	8.77%	2.87%
101-200ha farms	28.92%	14.62%	7.79%	3.35%
more than 200ha farm	35.98%	14.67%	7.57%	2.56%
plant_production farm	28.74%	13.36%	6.84%	2.69%
1-50 animal unities	23.56%	10.10%	7.06%	2.28%
more than 50 animal u	21.47%	9.47%	7.90%	2.32%
pock	26.96%	11.05%	6.75%	2.19%
dairy	20.51%	9.37%	8.12%	2.38%

51-100ha farms

Summary:	20	100	400	1000
All FARMS	304.90%	76.24%	62.59%	18.08%
0-20ha farms	305.09%	76.24%	62.65%	18.04%
21-50ha farms	299.00%	76.07%	62.82%	18.01%
51-100ha farms	305.41%	76.22%	62.35%	18.23%
101-200ha farms	322.47%	77.18%	61.93%	18.28%
more than 200ha farm	313.54%	76.87%	62.88%	18.28%
plant_production farm	314.12%	76.83%	62.27%	18.09%
1-50 animal unities	301.14%	75.95%	62.69%	18.05%
more than 50 animal u	297.67%	75.85%	62.87%	18.15%
pock	301.58%	76.05%	62.90%	18.07%
dairy	297.17%	75.69%	62.72%	18.13%

101-200ha farms

Summary:	20	100	400	1000
All FARMS	132.39%	87.32%	97.66%	45.47%
0-20ha farms	132.21%	86.80%	97.75%	45.21%
21-50ha farms	133.25%	87.21%	97.77%	45.55%
51-100ha farms	132.51%	88.68%	97.09%	46.39%
101-200ha farms	129.74%	87.42%	97.80%	45.12%
more than 200ha farm	134.77%	86.60%	99.28%	45.11%
plant_production farm	129.64%	86.60%	97.57%	44.54%
1-50 animal unities	133.27%	87.41%	97.64%	45.67%
more than 50 animal u	134.95%	88.28%	97.89%	46.58%
pock	133.08%	86.84%	98.09%	45.56%
dairy	135.11%	88.61%	97.54%	46.58%

	more than 200ha farms			
Summary:	20	100	400	1000
All FARMS	466.76%	281.75%	91.46%	50.22%
0-20ha farms	468.18%	283.22%	91.94%	50.19%
21-50ha farms	482.32%	282.26%	92.78%	49.96%
51-100ha farms	459.67%	276.07%	88.91%	50.16%
101-200ha farms	419.13%	282.50%	88.99%	51.50%
more than 200ha farm	486.57%	283.89%	94.94%	50.56%
plant_production farm	439.52%	284.31%	90.62%	50.88%
1-50 animal unities	477.63%	281.32%	92.09%	50.05%
more than 50 animal u	488.82%	278.57%	91.62%	49.51%
pock	481.55%	282.93%	92.82%	49.82%
dairy	486.15%	277.33%	91.33%	49.75%

Selbstsändigkeitserklärung

Eidesstattliche Erklärung

Ich erkläre hiermit an Eides statt, dass ich die vorliegende Dissertation selbständig und nur unter Verwendung der angegebenen Literatur und Hilfsmittel angefertigt habe. Mit dieser wissenschaftlichen Arbeit wurden noch keine vergeblichen Promotionsversuche unternommen.

Des Weiteren erkläre ich, dass keine Strafverfahren gegen mich anhängig sind.

Kopenhagen, 9/12-2009	Martin Damgaard
Ort, Datum	Unterschrift

Curriculum Vitae

Personal data:

Name:	Martin Damgaard
Date of Birth:	The 19th of May 1970
Mailing Address:	Møllevænget 11, Strø 3320 Skævinge Denmark
Phone:	+45 35852260
Email:	Damgaard@foi.dk

Education:

2003-2008	Doctoral degree (Ph.d.) at Halle university, Germany
1997 - 2002	Master in agricultural economics/ land use in developing countries at The Royal Veterinary and Agricultural University of Denmark. Specializing in development economics with emphasis on natural resource economics and project management.
1998 - 1999	SLUSE diploma, an interdisciplinary education in tropical land use management, funded by DANCED, the Danish Environmental Protection Agency, and organized by the Royal Veterinary and Agricultural University of Denmark, Copenhagen University and Roskilde University Centre in collaboration.
1995 - 1996	"Læreanstalternes fælles formidlingskursus", interdisciplinary course on communication.
1992 - 1997	Bachelor in agricultural economics at The Royal Veterinary and Agricultural University of Denmark.

International experience

Nov. 2003- 2007	Employed at IAMO, Germany
May. - Sep. 2000	Fieldwork for master thesis in Bungoma Kenya
October 1998	Field course in Sarawak, Malaysia

On a more personal basis I have travelled eight month in West Africa (Ghana, Burkina Faso, Togo, Benin, Niger, Chad and Cameroon) and nine month in Southeast Asia (Nepal, Thailand, Vietnam, Laos, Malaysia and Indonesia).

Employment

2009-	Economist at ATP group, Denmark
2007- 2009	Research assistant at the Institute of Food and Resource Economics at the University of Copenhagen, Division of Production and Technology.
2003-2007	Scientific employee at IAMO, Germany.
2003	Consultant work for Bacess / BioVentiC.
2000 - 2001	Web programmer at Kultunaut.dk

Language Proficiency

Danish: Native speaker
English: Fluent.
German: Good knowledge.
French: Minimum knowledge.
Swedish and Norwegian: Good knowledge.

Interest

Professional
To me the most promising new conquest lies imbedded in the intersection between theoretical physics, computer sciences and economic reality. It covers the study of non-linear complex systems, cellular automata models, swarm behaviour and optimisation, experimental economics, self-organized criticality and Bak-Sneppen models. My economical background gives me a stronger focus on the practical consequences and uses embedded in these studies.
A driving force in my study of economics has been a reflection over the nature of this field.

I have had a growing scepticism towards a fundamentalist understanding of the narrative skills of mainstream economic theory.

Kopenhagen, 9/12-2009	Martin Damgaard
Ort, Datum	Unterschrift

Abstract

The recent reform of the Common Agricultural Policy (CAP) towards decoupled direct payments, modulation, and cross-compliance introduced significant changes for the European agricultural sector.

The implications of the change on the structure of farms in the European landscape have been the epicentre from which the research presented in this thesis originates.

Here particularly with a focus on the spatial and temporal results of different CAP reform options.

Therefore the incorporation of Geographic Information System into the applied agent-based model AgriPoliS has been a part of the present study.

Furthermore an extensive analysis of the spatial sensitivity of the model has been performed showing the model to be stable in its results. Having presented an opportunity to evaluate the reliability of AgriPoliS the foundation is laid for investigating the effects different CAP-reform options have on the structural development in three European regions. The three regions are Ostprignitz-Ruppin, Germany, Mugello, Italy and the River Gudenå watershed, Denmark. The investigation of the three regions enables at the same time one to see how the same CAP reform options propagate differently within the different European regions.

Keywords: Agent-based modelling, GIS, Structural Change, Multifunctional Agriculture, CAP-reform

Abstract

In der letzten Zeit erfuhr der europäische Agrarsektor deutliche Veränderungen aufgrund der Reform der GAP mit der Entkoppelung der Direktzahlungen, Modulation und Cross-Compliance.

Der Ausgangspunkt von dem die hier vorliegende Studie ausgeht, sind die Auswirkungen der politisch induzierten Veränderungen der Rahmenbedingungen bzw. die Erweiterung der zu berücksichtigenden Interessen in der agrarischen Landnutzung, die weit über das rein betriebswirtschaftliche hinausgehen, auf die Struktur landwirtschaftlicher Betriebe in der EU.

Der Fokus dieser Studie liegt auf den räumlichen und zeitlichen Auswirkungen unterschiedlicher Maßnahmen der GAP-Reform. Aus diesem Grund ist die Integration eines geographischen Informationssystems in AgriPoliS ein wesentlicher Beitrag zur Weiterentwicklung des Modells innerhalb der vorliegenden Arbeit.

Weiterhin wurde AgriPoliS auf die Sensitivität hinsichtlich der Initialisierung der Standorte von Betrieben und der räumlichen Verteilung der unterschiedlichen Bodenqualitäten getestet. Nachdem eine Möglichkeit zur Beurteilung der Verlässlichkeit von AgriPoliS präsentiert wurde, wird diese als Grundlage für die Untersuchung der Auswirkungen unterschiedlicher Szenarien zur Umsetzung der GAP-Reform von 2003 auf den Strukturwandel in drei europäischen Regionen angewendet.

Untersucht werden die Regionen Ostprignitz-Ruppin in Deutschland, Mugello in Italien und Gudenå in Dänemark. Die Untersuchung dieser drei Regionen zeigt gleichzeitig zu welchen unterschiedlichen Entwicklungen die gleichen Politikszenarien in verschiedenen europäischen Regionen führen.

Schlüsselwörter: Agentenbasierte Modellierung, GIS, Strukturwandel, GAP-Reform, Multifunktionale Landwirtschaft