

Effects of Abolition of Milk Quota:

an Agent Based Modelling Approach

Master Thesis Business Analytics

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Preface

This report is the result of a 12 month internship (50% part-time) at LEI-WUR (Agricultural Economic Institute-Wageningen University and Research Centre). The internship is the completion of the master study Business Analytics.

LEI-WUR performs economic and social research for governments, businesses and organisations. The internship took place at the department of International Trade. This department is involved in several econometric studies to the effect of quota abolition in 2015.

Dairy sector plays a significant role in European agriculture production. In 2006 milk production amounted almost 14% of total agricultural production; for the Netherlands milk production amounts 17% of agricultural production. In 2011 in the Netherlands almost 25% of the farms are specialized dairy farms. In 1984 a quota system for milk was introduced in Europe to prevent overproduction. The quota system limits milk production however it provides the farmers with stable producer prices. This quota system will be abolished in 2015. So far a lot of research has been done to assess the effects of quota abolition using economic and econometric models. We wanted to investigate the same subject by applying an Agent Based Model.

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Abstract

The milk quota system regulates milk production and guarantees a regular milk price creating a stable income since 1984. In 2003 in the Luxembourg Agreement the European Commission decided to abolish the milk quota system from 2015.

As the dairy sector is an important agricultural sector in the European Union (milk production is 14% of total agricultural production; 17% in the Netherlands (Europe, 2009)) a lot of economic research so far has been done to assess possible effects of this abolition on farm structure, milk production, costs and revenues and other key figures. Most of this economic research was carried out by using models at farm level, micro simulation models or general equilibrium models.

Goal of our research is to assess the effects of abolition of the milk quota system for primary Dutch Dairy sector using Agent Based Modeling. Agent Based Modeling is a rather new technique modeling the process bottom up, using agents which are autonomous and can interact with other agents and/or their environment. Agents can be individually and agents can have stochastic properties.

In our research we created an Agent Based Model in NetLogo having farmers as agents which may have the objective to grow to optimal farm scale (130 dairy cows per farm) or quit farming. Actions and interactions of agents are based on historical data from the period 2001-2006 complemented with economic principles and stochastic elements. In the model farmers can quit farming, expand their farm or stay the same size. Shrinkage is not taken into account as the leading economic principle cost minimization does not allow this.

We calibrated the model for 2006 and 2011 and compared the results with data from the Annual Census. Furthermore we performed two types of sensitivity analyses: one-at-a-time and DOE-experiments resulting in meta-models. The results of the sensitivity analysis show that milk price is very important in the effects on farm structure, costs and revenues. Also the radius in which a farm is able to sell his land is a relevant factor. Changes in livestock density are also important but little is known about development in livestock. Therefore we left this factor out of the DOE-experiments. With the DOE-experiment we created meta-models for several output variables like number of farms, number of dairy cows per farm and other. These meta-models perform rather well however they can be improved.

We also performed an uncertainty analysis. Results of the uncertainty analysis show that the uncertainty in outcomes is rather small. When performing 3500 runs for a scenario, minimum values of an outcome differ less than 0.02% from maximum values.

So far quota has never been abolished and therefore we couldn't perform a field validation but only a model-model validation. For this model-model validation we used other research on effects of quota abolition which use economic models at different scale levels. Results of the model validation show the calculated milk production and number of dairy cows are within the range of other model outcomes. On the other hand outcomes of other models were based on different base and reference years having different policies taken into account which hampers comparing results.

The effect of quota abolition, assessed with our model is an increase in milk production and number of dairy cows per farm. The last mentioned results in less costs per unit milk.

Our conclusions about the model are that the model is a start and can be extended with:

- Model the relation between need for fodder and fodder price and uptake this in the cost calculations.
- Include in the above issue an improvement of the current milk market module
- Regional output possibilities which can be relevant in some areas.
- Introducing farm styles at least at national level
- Adding a market mechanism for the price of milk depending on the milk production
- Environmental aspects like emissions and manure surplus.

Before we can apply model extensions it is recommended to change from NetLogo to another modeling language or platform concerning the run-time of the model.

Linkages can be made with other ABM models like SERA and the land market of Valbuena. Finally it would be interesting to explore options of combining the model with the model MAMBO which offers possibilities for environmental studies at regional scale.

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1 Introduction

1.1 Context

The European milk quota system

The milk quota system was established in 1984 to prevent further milk surpluses and to prevent increasing intervention costs (Malak-Rawlikowska, 2006). Each Member State was granted with a national production quota which was distributed over individual farmers. In case of over production in a member state, this country has to pay a levy to Europe (Neville, 2011). This levy is financed by individual farmers who produced more than their individual quota.

According to Chantreuil et al (2008) the system limits the production and therefore can be seen as a scarce production factor. On the other hand, the advantage of the system is that it stabilizes the production price. Furthermore it keeps milk production in less competitive areas.

Quota trade is only allowed between individual farmers in the same member state. Each Member State can define their own trading rules as long as trade only takes place between individual farmers. Member States can even define regions with own quota transfer rules. In the United Kingdom for instance there are specific regions defined where it is not allowed to transfer milk quota out of the region because of social, environmental and political reasons (Neville, 2011). Trade of milk quota can be categorized as lease or permanent transfer.

In 2003 in the Luxembourg Agreement¹ on the Mid-Term-Review (MTR) it was decided to abolish the milk quota system in 2015 (Europe, 2009). In the Health Check of the Common Agricultural Policy (CAP) the European Commission decided to enlarge the quota amount each year with 1% between 2009 and 2013 to make this transition in milk policy smoother. Table 1.1 shows the development of allowed quota and milk production in the Netherlands.

Table 1.1 Development of quota in the Netherlands and paid levy (Wijsman, 2013)

item	unit	2000/'01	2002/'03	2004/'05	2006/'07	2008/'09	2010/'11	2011/'12
national available quota 1)	1 000 ton	10993	10995	11001	11052	11392	11625	11738
distributed to farmers	1 000 ton	10984	10987	10994	11049	11384	11615	11727
delivered milk	1 000 ton	10572	10668	10704	10828	11294	11625	11714
levy to be paid to Europe	mln. euro	-	6.3	23.1	8.8	43.8	38.7	16.4

Source: Productschap voor Zuivel

1) Excl. quota for direct delivery to consumers

Performed research and models for effects quota abolition so far

As the dairy sector is an important agricultural sector in the European Union (milk production is 14% of total agricultural production; 17% in the Netherlands (Europe, 2009)) a lot of economic research so far has been done to possible effects of this abolition on farm structure, milk production, costs and revenues and other key figures. Studies to effects on European Scale and also at Member State level were performed. Most studies are based on economic models using different techniques and are applicable at several levels (farm-level, national level, European level and mixtures). Chantreuil et

¹ See for more explanations section Definitions and further explanations

al. (2008) mention a lot of relevant studies. Some of them are used in our study like Helming and Peerlings (2002) and Lips and Rieder (2005).

There are Agent Based Models like AgriPoliS (Kellerman et al, 2008) and RegMAS (Lobianco and Esposti, 2010) which can be used for analysing policies. However they have not been used for evaluating effects of abolition of milk quota.

1.2 Goal of the study and approach

Goal of the study is to assess the effects of abolition of milk quota for the Dutch dairy sector using Agent Based Modelling.

Effects of quota abolition will be expressed in terms of key-figures representing farm structure. Examples of farm structure key figures are number of dairy cows per farm, number of dairy cows per hectare (ha) land, milk production per cow and cost and revenues per unit milk. We will use 2006 as a base year and predict farm structure for 2011 with and without quota system.

We want to apply Agent Based Modelling (ABM) to fully introduce the effects of quota abolition on individual (dairy) farmers as in economic modelling we have to deal with aggregation of individual results to national results or with national results not reflecting individual behaviour. Question is if we whether can assess the effects of quota abolition using an Agent Based Model (ABM).

In the modelling and scope of the model we limit ourselves to the primary milk production sector being Dutch dairy farmers. Milk processing industry, retail and other are not taken into account.

In our approach we started to describe the domain of dairy farming: what do farm looks like, what are driving factors in decision making and other issues. Then we transformed the domain into an ABM. We calibrated the model and performed a verification and validation. The validation of the model consists of a sensitivity analysis, an uncertainty analysis and a model-model validation. We chose a model-model validation as we wanted to predict results for an event which didn't happen yet.

1.3 Report structure

We start in chapter 2 with an overview of what Agent Based Modelling means, what are agents, what is an agent architecture and some examples platforms with which agent models can be constructed (conceptual modelling). In chapter 3 we describe some examples of applications of Agent Based Modelling to have an idea about the possibilities of the technique. In chapter 4 we focus on evaluations of studies to effects of quota abolition performed with economic models. The domain of Dutch dairy sector will be described in chapter 5. Chapter 6 describes the transformation of the domain of chapter 5 to an ABM. Verification, calibration, uncertainty analysis and sensitivity analysis are described in chapter 7. Chapter 8 reports the results and show the results in context with results of other research (model-model validation). Conclusions are presented in chapter 9. Discussion and recommendations will be reported in chapter 10.

After the References but before the Appendices, there is a list with abbreviations and a section with definitions and explanations of uncommon items

The model code is added as the last appendix (9).

2 Agent Based Modelling

This chapter is the result of a literature study and presents the definition(s) of an agent in Agent Based Modelling. Furthermore Agent architectures are discussed which are a way to describe conceptual agent models.

We will mention some conceptual frameworks with which ABM's can be developed. The results of those conceptual frameworks can be transformed to executable models in an appropriate modelling language or toolkit. This is the last part of this chapter.

2.1 What is an agent and an Agent Based Model

In trying to outline Agent Based Modelling and the contiguous systems it can be applied to, we found a lot of definitions and terms related to ABM. Kremmydas (2012) also refers to this fact just as Wooldridge and Jennings (1995) already did.

In summary we can say ABM is a technique to model systems with certain properties. However this is very basically defined. Ingham (1999) mentions a list of definitions from other work already performed in this field. He also mentions the conflicts of those definitions with other definitions and how this leads to new definitions which will probably be in conflict with other definitions.

“Agents might be many things. Attempts to find one central common denominator of operative or theoretical conceptions of agents in recent publications on the topic... will probably fail” (Krogh ,1996 (as cited in Ingham (1999, p. 1)).

Despite the problem to find a unique definition of an agent we mention here two. The first definition of Macal and North (2010) is not a definition for an agent but mentions the characteristics an agent at least should have:

- Self-contained, modular and unique. The property modular indicates that agents are bounded
- Autonomous; an agent can function independent from other agents and it's environment
- A state which varies over time
- Social; having dynamic interactions with other agents

This enumeration of properties can be found similar or partly similar in other research like Railsback and Grimm (2012).

The second definition is a definition which is common in the field of Artificial Intelligence (AI). Wooldridge and Jennings (1995) distinguish two definitions for agents; a weaker notation and a stronger notation. The stronger notation is particular acceptable for researchers in AI. The weaker definition of Wooldridge and Jennings (1995) is as follows: it is about a hardware or (more usually) software-based computer system that enjoys the following properties:

- **Autonomy:** agents can operate on their own without intervention of other agents. Furthermore they have some control over their actions and internal state.
- **Social ability:** agents interact with other agents by some kind of communication language
- **Reactivity:** agents perceive their environment and respond to changes occurring in the environment.
- **Pro-activeness:** agents do not only act in response to their environment but can take initiative to reach their goal settings.

In the stronger definition of Wooldridge and Jennings agents are seen as

“a computer system that in addition to having properties mentioned in the weak definition is either conceptualized or implemented using concepts that are more usually applied to humans”
(Wooldridge and Jennings, 1995, p. 5).

An example is to characterize agents using mentalist notions like belief, desire and intentions (BDI-agents, see section 2.3).

2.2 Agent and model architectures

Michael et al (2009) define agent architecture as the description of the internal organisation of an agent. There are two main streams within agent architectures: deliberative architectures (or cognitive), reactive architectures and combinations, the so-called hybrid architectures.

Deliberative architecture

Wooldridge and Jennings (1995) define a deliberative architecture as:

“a deliberative architecture contains an explicitly represented, symbolic model of the world and in which decisions are made by logical reasoning, based on pattern matching and symbolic manipulation” (Wooldridge and Jennings, 1995, p. 18).

Michel et al (2009) mention that in a deliberative architecture, agents do have explicit knowledge about the environment and other agents. Agents can reason using this knowledge. This reasoning is described by a symbolic formalism.

There are two main problems by modelling according a deliberative architecture (Wooldridge and Jennings, 1995):

1. Translating the real world into an appropriate symbolic description (transduction problem)
2. Representation of the reasoning of agents. How to translate complex real-world processes and entities into agents reasoning system.

Wooldridge and Jennings (1995) show examples of deliberative architectures: BDI-architectures, IRMA and HOMER. Another one mentioned by Josyula (2006) is TOMAS.

Reactive architectures

According to Wooldridge and Jennings (1995) a reactive architecture is an architecture that does not include any kind of central symbolic world model. Furthermore complex symbolic reasoning is absent.

Michel et al (2009) define a reactive agent as an agent who has no explicit representation of the environment and also not of other agents.

“ Its behaviour is entirely described in terms of stimuli-response loops which represent simple connections between what they perceive and the set of available operations that may be performed”
Michel et al (2009, p. 14).

According to Josyula (2006) reactive architectures were developed as a result of need for error-tolerance and fast reaction in dynamic environments. A disadvantage of reactive architectures is that they cannot make use of plans to optimize an agent's behaviour (Josyula, 2006).

Subsumption architectures belong to the category of reactive architectures.

Hybrid structures

Hybrid structures came into being as researchers argued about the fact both 100% deliberative and 100% reactive agents are not suitable solutions for building agents (Wooldridge and Jennings, 1995).

Combining the two approaches in modules creates flexible agents. A point of concern is the control mechanism as the agents in such a structure consists of modules which deal independently with the reactive and deliberative parts of the agent (Michel et al, 2009)

Procedural Reasoning System (PRS) is an example of a hybrid system (see section 2.3.1). Other examples are TouringMachines, cosy and InteRRaP (Wooldridge and Jennings, 1995; Michael et al, 2009).

2.3 Agent frameworks

2.3.1 BDI/PRS

A Believe-Desire-Intention (BDI) framework is an example of a cognitive architecture (Michel et al, 2009). The agents in the framework are so-called BDI-agents who are rational agents having three mental attitudes: Belief, Desire and Intention (Rao and Georgeff, 1995).

“These mental attitudes determine the systems behaviour” (Rao and Georgeff, 1995, p. 1).

Belief represents the information the agent has about the rest of the world and it self. Desire is what the agent wants to obtain; the objectives of the agents like minimize costs, minimize environmental pressure and so on. Desires can be seen as the representation of the motivational state (Rao and Georgeff, 1995). Intentions are the agents action plans to achieve the goal.

“Intentions of the system capture the deliberative component of the system” (Rao and Georgeff, 1995, p. 4).

The steering and update of beliefs, goals and intentions by a so-called BDE-engine or Interpreter which selects the plans and actions to be performed and goals to be achieved (Rao and Georgeff, 1995).

Messages and perceptions from outside create beliefs of the agent. Furthermore messages influence the agents goals for instance in case of requests from outside. Beliefs and plans together with goals lead to decisions what to do. This initialises intentions: actions to perform to achieve the goals. Decisions also influence the goals to achieve (commitment) (Michel et al, 2009, figure 1.3).

The system is steered by a so-called interpreter (figure 2.1), who starts the process, create and execute the options.

```

BDI-interpreter
initialize-state(),
repeat
    options := option-generator(sensor-input,B,G,I);
    selected-options := deliberate(options,B,G,I);
    execute(I);
    get-new-external-events();
    drop-successful-attitudes(B,G,I);
    drop-impossible-attitudes(B,G,I);
end repeat

```

Source (Pereira, 2005).

Figure 2.1 Concept of a BDI-interpreter

Compared with BDI-architecture one can say

“PRS reduces the abstract notions of desires and intentions to the more concrete concepts of goals and plans” (Pokhar et al, 2003 (as cited in Mousavi et al (2010, p. 558))).

2.3.2 DESIRE

DESIRE is a modelling framework for the design of multi-agent systems at three levels: conceptual design, detailed design and implementation (operational design).

DESIRE stands for framework for Design and Specification of Interacting Reasoning components. The DESIRE framework considers individual agents and the overall system as a compositional architecture (Brazier et al, 1997). One of the goals of the design and development of the DESIRE framework is to provide constructs with which reasoning patterns can be modelled (Brazier et al, 1997). The modelling environment is equipped with tools such as graphical editors. Furthermore DESIRE uses temporal logic as a basis. Therefore specifications and their semantics can be made formal.

Originally DESIRE was designed for formal specification of complex reasoning systems and has been adapted for multi-agent systems (Brazier et al, 1995).

The compositional architecture is based on the task hierarchy obtained by task analysis. In the formal compositional framework for modelling multi-agent tasks the following parts can be distinguished (Brazier et al, 1995):

- Task decomposition: tasks can be classified as composed or primitive tasks. Composed tasks are tasks for which subtasks are defined.
- Information exchange: this is about information exchange between components
- Sequencing of (sub) tasks: this is modelled as task control knowledge. Task control knowledge is about:
 - knowledge which subtask should be activated
 - knowledge about control information related with task activation
- Subtask delegation
- Knowledge structures

In DESIRE agents are approached as composed components.

“A compositional agent is a composed component with a number of subcomponents representing the agents tasks to be performed and additional knowledge of the world and other agents how to interact with them” (Brazier et al, 1995, p. 3).

In the formal specification of agents we find here as well:

- Task hierarchy and task allocation
- Information flow
- Task control: within an agent, between agents and between agents and the environment

DESIRE was applied in several studies as the modelling of an electricity transport network in Spain (Frazier et al, 1995), modelling BDI-agents (Brazier et al, 1997), an elevator design task (Brazier et al, 1996) and other.

2.3.3 COMOMAS

CoMoMAS is conceptual modelling language for developing agent based models or agent architectures. Comomas is an extension of CommonKADS which is a methodology for the development of knowledge-bases systems (KBS).

Agents in CoMoMAS are defined as intelligent and autonomous entities which act on their own using their individual knowledge. Agents have at least four types of competences to be able to act efficiently in a society: reactive, cognitive, cooperative and social (Glaser, 1997). Therefore CoMoMAS can be seen as hybrid architecture.

Agent models are constructed using five analyses steps which create five conceptual models. These conceptual models are used to compose the agent models (table 2.1).

Table 2.1 Analysis steps to define agent models in Comomas

Analysis	Description	Conceptual model
Requirements	Determine design requirements of the MAS	Design model
Functional	Identify tasks to be solved	Task model
Competence	Identify cognitive and reactive competences which the system should provide to solve the tasks	Expertise model
Cooperative	Identify all what has to do with cooperation and conflicts	Cooperation model
Social	Identify organisation and architecture of the MAS	System model

Source: Glaser (1997)

In ComoMAS they use the conceptual modelling language (CML) for a structured and semi-formal description of conceptual model content. This language (used in CommonKADS) has been adapted for use in Comomas adding additional language elements.

A final conceptual model will be translated to an executable architecture or model. In ComoMAS the executable model is implemented in an adapted version of MICE.

According to Glaser (1997) the approach of ComoMAS could be supportive for task-models (like DESIRE) for the functional and cooperative analyses.

2.4 ABM platforms and languages

There are a lot of ABM languages and toolkits. Schut (2007) mentions Swarm, Repast, Netlogo, Newties, Breve, Mason, Starlogo, Framsticks, Ascape, Cormas, MOISE+ and other. Furthermore we

found AnyLogic and SeSAM. All packages have a user interface and ABM-functionalities. However languages like C++, C-Sharp, Java, Matlab and Mathematica and probably other can also be used for ABM.

Macal and North (2010) distinguish three types of platforms or languages depending on how much support the implementation environment provides for the modeller:

- Library-oriented; the agent modelling tool consists of a library of routines organized in an interface (API). Examples are Java archives used by Repast and Mason
- Integrated development environment (IDE); this category can be split up in programs using one file or factored multiple files or combinations. An example of one file is Netlogo.
- Hybrid: here library-oriented and IDE are combined. Examples are Repast Symphony and AnyLogic.

Schut (2007) mentions four issues to take into account when selecting the package in which the model will be implemented:

- Get an idea about the learning curve in relation with the available model time
- Can you achieve what you want with the package
- Play around with some packages to get an idea
- The model simply has to work

Swarm, MASON and RepastS, Repast-Java are discussed in several ABM-software comparing studies. Tobias and Hofmann (2004) compare four free available programs among these Repast and Swarm. They defined several selection criteria and rated the programs according these selection criteria. They distinguished three main selection criteria: General criteria (language independent), Modelling and Experimentation criteria and Modelling Options criteria. Tobias and Hoffman (2004) defined sub-criteria on these main criteria; for instance presence of licence, presence of documentations and presence of support in case of General criteria. Examples of sub-criteria of Modelling Options are level of inter-agent communication and level of generating networks. In all rankings of the three main criteria Repast “beats” Swarm. Both perform in all cases better than the other two programs.

Railsback et al (2007) compare MASON, NetLogo, Repast and Swarm. They therefore also compare the performance of the software packages using the Stupid Model under different conditions like number of objects and number of bugs and the version of the Stupid Model. MASON performs the best followed by Repast and NetLogo. The difference between the performance of MASON and Repast diminish by the increase of the number of objects.

Barryman (2008) compared the toolkits BactoWars, EINSTEIN, MANA, MASON, Netlogo, Repast, Swarm and WISDOM-II using different criteria flexibility, documentation, speed and facilities. His conclusion was that winners on all criteria were MASON and Repast. Despite that he concluded that the final selection depends on the skillset of the person the task is assigned at and the type of task itself.

The SeSAM package is quite unknown in articles and on the web but the program looked quite structured and easy in use when you tried some models out in the system. The problem with SeSAM is the size of the community using the system and also the availability of help or support. Furthermore there was an interruption in the program maintenance due to the fact that the

modelling team (University of Wurzburg) moved to Sweden. This means that from 2009-2010 until recent there has been no support nor development of SeSAm

3 Examples of Agent Based Models

In this chapter we describe some examples of application of agent based modelling. These examples are selected to give researchers in agriculture not familiar with ABM insight in possibilities of the technique. Most examples are related to agriculture showing possibilities of applications of ABM in this sector. To show examples in other fields of research we added two applications of ABM in healthcare. Of these two examples the first one can be seen as application of ABM in Business Optimization and is therefore (with some adaptations) applicable in other firms and other fields of research.

Leykum et al (2012) constructed an ABM model to understand the relation between strategies of medical teams and their improvising talent and the progress of patient's recovery (including mortality). There were two main strategies defined: sense making and improvising. Within each main strategy specific behaviours were distinguished concerning the interaction between the team members and between the team and patient. Model results show that there is difference in patient outcomes depending on the physicians' team.

Paizen et al (2012) created an ABM and combined it with a modified percolation model to characterize the epizootic spread within a poultry intensive livestock production farm. A percolation model is used to model disease spread in plants and animals. In modified versions also mobility is taken into account (animals). A combination of modifying percolation models with ABM improves the modelling of mobility. Characterization of the system took place by focussing on population density, infection longevity, animal mobility and their relative impact. The dependent variable of interest was the agent's mortality or immobility. Paizen et al (2012) refer to the fact that a lot of ABM have been applied in research to spread of diseases between humans (healthcare and epidemiologic research) and refers to Epstein et al (2007), Epstein (2008) and Epstein (2009) (page 110) for for instance research concerning disease spread and vaccination and quarantine policies). Results showed that an ABM in combination with an percolation model (lattice) is a reasonable model to capture dynamics of disease progress in poultry on an intensive livestock farm. There was an interrelation between population density, agent's mobility and longevity on mortality. At high population densities mobility had more influence than longevity and vice versa.

An Agent Based Model was used in a study to climate change and conflict among pastoralists in East Africa (Hailegiorgis et al, 2010). In the model there are herdsman and farmers both using pasture to feed their cattle. Climate affects the growth and use of pasture, especially in drought periods there's a shortage of sufficient growing grass parcels. Conflicts emerge when after a time step two or more agents are on one parcel. The model also measures cooperation. Their conclusions were that with increasing drought the number of conflicts increases and cooperation decreases. Without drought cooperation increases and conflicts emerge at random (not structured). The fewer the population size through drought the less incidents or conflicts arise and cooperation is minimized. Hailegiorgis et al (2010) conclude that although the model is simple (nutritional needs of animals and dynamics between weather and landscape are not taken into account) it's able to capture the non-linear relationship between rainfall and carrying capacity (maximum population size which can sustainable be kept taken food, water and other resources into account).

Millington et al (2008) created an ABM to examine wildfire risk in Mediterranean landscapes. They want to examine the effect of human activity and land-use practices combined with spatial

interaction of vegetation dynamics on wild fire regimes and risks. They refer to the fact that there are already a lot of such studies but in most studies human interaction is not taken into account while according to them humans are the primary cause of wildfire in the Mediterranean Basin. To be able to set behaviour of agents they performed interviews. From these interviews they deduced two types of farmers: commercial minded and traditional minded farmers. They modelled these farmers each with their own behaviour. They concluded that the resulting model is more a heuristic model than a predictive model. Furthermore they concluded that their results highlight the role of spatially-explicit models in understanding the potential consequences of land use/cover change (LUCC). Their model will be included in a larger model for exploring the relation between LUCC and wildfire regimes in central Spain.

Valbuena et al (2010) created an ABM to assess the effects of farmer's decisions on landscape structure in the region "Achterhoek". In this model also biophysical processes were taken into account. One of their main conclusions was that the results show the added value of including diversity of farm decision making in regional LUCC- research. By including individual farm behaviour exogenous processes as well as endogenous processes are taken into account (Valbuena et al, 2010).

Schouten (2013) used an ABM to describe and model the process of resilience. Goal of her research was "to explore how the concept of resilience can be operationalized and implemented into decision-making on the management of rural social-ecological systems" (Schouten, 2013, p. 4). Her model was applied for the region Winterswijk in the East of the Netherlands. Of interest for our research is the land market. The model of Schouten called SERA contains a land market module. Agents (or farmers) interact indirectly by competing on the land market, they interact by an auctioneer. This method is very common, Schouten (2012) refers to a lot of other research with application of this auction mechanism (Parker et al, 2003; Parker and Filatova, 2008; Filatova et al, 2011; Kellerman et al, 2008 ; Magliocca et al, 2011; all cited in Schouten et al, 2012)). The difference with this cited research is that in SERA agents are informed when more than one parcel is offered at the same time and also that agents are informed about several attributes of the parcels like soil quality, size and current land use

We pay special attention to the model AgriPoliS, a model predicting effects of policies on agricultural structure. AgriPoliS stands for Agricultural Policy Simulator. The first version of AgriPoliS was performed by Balmann (1997). AgriPoliS is a spatial and dynamic agent-based model (Happe et al, 2008), with which effects of different policies on structural change in agriculture can be assessed. The purpose of the most recent version of AgriPoliS is

"to understand how the income maximizing behaviour of thousands of individual farm-agents competing for heterogeneous land on a finite landscape affects structural change within a region depending on the agricultural policy" (Brady et al, 2012, p. 3).

In AgriPoliS the agricultural system is modelled as an agent-based system in which farmers are represented by agents. The decisions a farmer makes are regulated by an individual behaviour model, a mixed-integer programming model (MIP).

A farmer can perform 4 types of actions:

- Standard production activities like breeding animals, crop and meat production
- Auxiliary activities like land rental and production quota's

- Investment activities
- Deciding to stop or continue farming

The decision what to do the next time step is made on their own situation and expectations about prices and policies. Decisions of individual agents are not based on expected and performed behaviour of other agents.

A farmer has to deal with its environment which consists of (Happe et al, 2006):

- its neighbours: farmers in the same region
- landscape or spatial context farmers are located in
- markets for inputs and outputs of the farm (for example feed, fertilizer (inputs) and milk, grain (outputs))

All three mentioned environments are part of a more general technological and political environment.

Landscape is modelled according the principle of Cellular Automata (CA), a set of equally sized cells. These cells have several attributes like soil type, ownership, rented and other. In AgriPoliS farm and land location are not based on real coordinates but landscape is created using a landscape calibration procedure used in the IDEMA project (Kellerman et al, 2008). The so derived landscape is called an abstract or synthetic landscape. According to O'Neill et al (2009) and With (1997) (as cited in Kellerman et al, 2008) the use of such abstract or synthetic landscapes to study landscapes is rather common.

Farmers do not interact directly with each other on markets; interaction on the markets is regulated by market agents.

Recent applications of AgriPoliS can be found in Happe et al (2008), Happe et al (2011) and Bradey et al (2012). Happe et al (2008) used AgriPoliS to assess the effects of two different implementations of decoupled payments. Happe et al (2010) assign a nitrogen surplus model to the outcomes of AgriPoliS. By doing so structural effects of policies can be shown as well as environmental effects. Bradey et al (2012) evaluated the effect of three alternative policy schemes on agricultural structure.

4 Abolition Milk Quota in other Studies

4.1 Introduction

In this chapter we describe some studies which we will use for model validation (see chapter 8) later on. Therefore we focus on research whose outcomes are comparable with our research. For this reason we selected research on effects of abolition of milk quota for the Netherlands and research on effects on groups of countries including the Netherlands.

Studies can be different in (model) technique used, base or reference year and model and policy assumptions

Modelling technique

Helming and Peerlings (2002) mention three types of models with which the effects of abolition of milk quota can be assessed:

- Mathematical programming at farm level
- Micro economic simulation model
- Applied General Equilibrium models (ACE)

Helming and Peerlings (2002) name advantages and disadvantages of use of each of such a model type.

According to Helming and Peerlings (2002) the advantage of the first type of model is they allow a very detailed analysis on farm level but do not take into account effects on sector level.

The second type of models, micro simulation models, has the advantage that they have the ability of calculating policy effects on both farm and sector level. On the other hand these models ignore the effect of policies on input and output prices and other industries.

The third type of models (ACE-models) are good at calculating effects on agricultural industry and other linked industries but they just cannot take into account the diversity of individual farms. This last fact for instance is relevant for the effects of manure surpluses at farm level.

Base year, reference year and policy assumptions

In this report a reference year is defined as the year for which the effect of abolition of milk quota is defined. In case the reference year is lying in the future in most cases a base year is defined. The situation in the base year combined with the expected EU-policy defines the situation in the reference year. In the studies discussed in this chapter we see three kinds of EU-policies each with their own name: Agenda2000, Mid-Term Review and Luxembourg2003. They are further explained in section Definitions and further explanations. Here we restrict us to say that the policies affect trade liberalisation, milk price, intervention price, subsidies and other regulating mechanisms for the coming period.

4.2 Studies on effect of abolition of milk quota for the Netherlands

Helming and Peerlings

Helming and Peerlings (2002) assessed the effect of abolition of milk quota using a mixture of two models. They combined a partial equilibrium mathematical programming model of agricultural supply in the Netherlands (DRAM-model) with an input-output model.

DRAM is a micro economic simulation model. In order to include also the effect of policies on input and output prices and other industries (what is included in ACE-models) they combined DRAM with an Input-Output model.

According to Helming and Peerlings (2002) the advantage of the combination of these two models compared with ACE-models is that the high level of aggregation of commodities and industries are avoided.

Helming and Peerlings defined a reference scenario (for 2008) in which the quota system is still present but with a decrease of the milk price of 30%. This decrease is compensated with a premium per ton of milk which covers half of the income loss (due to the decrease in milk price). They defined several scenarios of which one scenario is the same as the base scenario only now with abolition of milk quota.

Their results show that in case of quota abolition in 2008 number of dairy cows will increase about 35% and milk production increases 38%.

Helming and Van Berkum

Helming and Van Berkum (2008) use the DRAM-model (without linkage with an input-output model) for calculating the effects of abolishing the milk quota system in 2009. They focus on the results per type of dairy cow. In DRAM eight types of dairy cows are distinguished² by grouping dairy cows in the Netherlands by farm size, intensity of farming (dairy cows per utilizable agricultural area (UAA)) and milk production per dairy cow. Helming and Van Berkum performed this distinction for reasons that there might be a difference in the behaviour of farmers on small and large farms as a result of differences in marginal costs. Furthermore cost structures are different between intensive and extensive farms and between different milk production levels.

In their study the reference scenario is defined as the agricultural situation in 2015 where the quota system is still present. Besides the reference scenario they defined another scenario where they predicted the agricultural situation for 2015 as well but now milk quota was assumed to be abolished in 2009.

Their results show that in case of quota abolition in 2009, milk production in 2015 will be 21% higher as the milk production in 2015 when the milk quota system still would be present. The increase in milk production would emerge at large dairy farms (more than 60 dairy cows). On these farms milk production would increase 28%. At small dairy farms with high costs milk production would decline about 13%.

² In DRAM Dutch agriculture is modelled as one farm containing all production activities

Lips and Rieder

In the study of Lips and Rieder (2005) a so called ACE model was used to predict effects of abolition of milk quota in Europe. Lips and Rieder performed the analysis at member state level (15 and Switzerland). The used model is the model of the Global Trade Analysis Project called GTAP-model. The standard version of this model doesn't include the identification of production quotas, therefore the model was modified.

The reference scenario is the agricultural situation in 1997. In the alternative scenario several other agricultural policy changes beside abolition of milk quota were taken into account. These extra agricultural policy options were

- No export subsidies for dairy products
- A direct payment for milk production of 50 € per tonne of quota.
- Liberalization of the common cheese market of Switzerland and the EU

The effect of the alternative scenario with no quota is that producer price of raw milk in Europe (15 member states) decreases 22% just as in the Netherlands. The production of raw milk increases 3% in EU-15 and in the Netherlands up to 14%.

Bouamra-Mechemache, Jongeneel and Réquillart

Bouamra-Mechemache et al (2008) assessed the effects of a gradual increase in milk quotas on the EU dairy sector. Their research is different from research on effects of abolition of milk quota as they combine the effects of three influencing factors on EU dairy sector: enlargement of the EU with new member states, domestic policy reforms and continuing trade liberalisation. They state that so far in research by others only one factor is taken into account. They used a spatial equilibrium model of the European dairy sector including industry from Bouamra-Mechemache et al (2002a) as cited in Bouamra-Mechemache et al (2008).

Most of their results are presented at EU-level but for the three mentioned scenarios they present the relative change in milk production. In the Netherlands milk production would increase with 24% (2015) if milk quota would be abolished (2009) compared to the situation in which the measures of the Luxembourg agreement would hold. This scenario is comparable (policies and years) with Helming and van Berkum (2008) who predicted an increase of 21% in milk production in the Netherlands.

Europe (JRC)

In the study of JRC (Europe, 2009) the effects of abolition milk quota are assessed with the CAPRI-model. The CAPRI-model is a non-linear mathematical programming model which maximizes regional agricultural income taking Common Agricultural Policy (CAP) instruments into account. The CAPRI-model is also an ACE-model.

“The CAPRI-model is an agricultural sector model covering the whole of EU-27, Norway and the Western Balkans at regional level and global agricultural markets at country or country-block level. The CAPRI-model consists of a supply and market module which interact iteratively” (Europe, 2009, p. II)

Four scenarios are defined of which three are used and further discussed here. There are two reference scenarios: one for 2004 (scenario S1: an average of 2003-2005) and one for 2020 (S3). In the reference scenario for 2020 the effect of autonomous policy can be seen when comparing the outcome for agriculture with the reference scenario for 2004. The third scenario (S4) is equal to the reference scenario for 2020 but now also the milk quota system is abolished. The effect of quota abolition can be determined by comparing the outcome of this scenario (S4) with the reference scenario for 2020 (S3). In S3 the full implementation of the Luxembourg Agreement³ is taken into account just as 2% milk quota expansion in 2008. Furthermore the scenario includes reforms on single markets like tobacco and olive oil, reform of the sugar quota and other expected policies.

The study shows an increase in milk supply of 2% between 2004 and 2020 (S3 with quota). Milk production in EU-27 increases with 1%.

The difference between 2020 with and without quota (S3 versus S4) for the Netherlands is an increase in milk production of 21% while Sweden and United Kingdom will face a reduction in milk supply will be reached of about 5%. On average milk supply in EU-27 will increase 5%. The expected producer milk price in the Netherlands will decline 13% while for EU-27 on average the decline will be 10%.

Veenstra en Vessies

Abolition of milk quota might create new challenges in the dairy market. While now (at time of the research of Veenstra and Vessies (2008) quota is linked to land, after abolition this link is disappeared which might lead to an extra increase in farm expansion.

Goal of the research of Veenstra and Vessies (2008) was to assess the relative importance of production factors like capital, land and labour in the process of farm expansion and the determination of optimal farm scale and firm planning. For this purpose they used the linear programming model (at farm scale) of Berentsen and Giessen (1995).

They optimized three situations for two farm types both having 42 Utilizable Agricultural Area (UAA). The farm types they used are an average farm with 517 ton milk quota and a more intensive farm with 756 ton milk quota. The three situations are:

1. An optimization of current situation whereby expansion in stable and land is not possible
2. No quota and stable expansion is allowed
3. No quota and stable expansion and land expansion is allowed

They found that in case of situation 2 (no quota system and stable expansion is allowed) for an average farm, farm expands up to a size (in milk production) where all UAA is used for placing manure and there is no manure surplus present. In case of situation 2 for an intensive farm no stable expansion is used. In case of situation 3 farms expand to a farm size of 180 cows (expansion is restricted by the size of fodder wagon) and 94 ha UAA. In this case the intensive farm is transformed to extensive.

Tonini, Jongeneel and Verhoogh

Tonini et al (2011) applied the methodology of Frahan et al (2011) to assess the effects of quota abolition in the Netherlands using farm data from Dutch Farm Accountancy Data Network (FADN). In summary the methodology of Henry de Frahan et al means that a multi-input multi output cost

³ Relevant in the Luxembourg Agreement for the dairy sector are decoupling of direct payments and a stepwise reduction of intervention prices for butter and skimmed milk powder.

function is estimated for each farm. Per farm this cost function is used in a profit-maximisation programming model with which different responses per farm (income effects, potential supply and other) can be shown. Individual results at farm level can be aggregated to groups with similar features (Frahan et al, 2011).

Tonini et al (2011) calibrated the profit-maximization model at the years 2004, 2005 and 2006 (final results are presented using 2006 as base year). Results were presented at national and local level (Nuts I level⁴).

Besides the scenario with quota abolition, they performed extra scenarios in which they decreased prices (with steps of 10%) up till 50%.

The costs functions are imbedded in the profit-maximisation program and are estimated on the period 1995-2007.

Results of effects of quota abolition are available from the estimated cost functions (elasticity's for input demand and marginal costs, quota rents and other) and from the profit-maximization model (changes in input level, output level, profits, values of quotas and other).

In case of quota abolition Tonini et al (2011) found outcomes (at farm-level):

1. number of farms with 200 ton milk production or more would increase
2. amount of purchased feed would slightly increase
3. number of dairy cows per farm would increase
4. amount of grassland at a farm would hardly be affected

At national level there would be a very small increase in milk supply (< 1%).

4.3 Summary

Table 4.1 shows a summary of the assumptions made in the discussed studies in section 3.2.

The studies are difficult to compare. Results in the mentioned studies are mostly expressed as percentage of change compared to the reference situation. But with the different reference years and policies, these figures cannot directly be compared except in cases were reference year and EU-policies are assumed to be equal (Helming and van Berkum (2008) and Bouamra-Mechemache et al. (2008)).

⁴ See section Definitions

Table 4.1 Differences between research to effects of abolition dairy quota and key-figures in modelling process

Study	Reference year	EU-policy⁵	Change in milk production (%)[*]
Helming and Peerlings (2002)	2008	Agenda2000	38
Helming and van Berkum (2008)	2015 (quota abolished in 2009)	Luxembourg agreement	21
Lips and Reader (2005)	1997	Agenda2000	14
Bouamra-Mechemache et al (2008)	2014	Luxembourg agreement	24
Veenstra and Vessies (2008)	Not relevant	Luxembourg agreement	Only estimates at farm level
EU (2009)	2020	Luxembourg agreement	21
Tonini et al (2011)	2006	Not relevant	No total data for Netherlands

^{*}) change milk production when quota is abolished compared to milk production in reference year with implied EU-policy

⁵ Policies are further explained in section Definitions and further explanations

5 Dairy farming in the Netherland in a nutshell

This chapter is a short introduction in dairy farming in the Netherlands. Where does milk production take place, what's the relation between milk production and milk quota. What are farmer's objectives and which environmental aspects affect dairy farming.

5.1 Size and structure of dairy production

Dairy farming can take place on farms specialized in dairy farming or farms who combine other production activities with dairy farming (table 5.1).

Table 5.1 Distribution of farms and dairy cows over farm-types in 2006

Farm type	Number of farms with dairy cows	Number of dairy cows	Number of farms with 20 dairy cows or more	Number of dairy cows on farms with 20 dairy cows or more
Arable	46	865	19	764
Horticulture	39	1532	27	1479
Permanent crops	**	93	**	92
Grazing animals non-specialized in dairy farming	1357	29156	554	24222
Specialized dairy [*] farming	18862	1294378	18862	1294378
Pigs and poultry	289	9867	197	9069
Combinations	**	1003	**	893
Livestock combinations	1209	59823	1086	58267
Crop/livestock combinations	469	22999	374	22079
Total	22301	1419716	21137	1411243

*) Specialized dairy farming: no distinction in farm size (less and 20 dairy cows or more); **) less than 10 observations or added so other figures are not deductible

Source: Wijsman (2013)

Dairy cows are kept for milk production. Each year a dairy cow produces a calf resulting in a continuous production of milk for about 310 days. The calves are sold or kept and raised for replacement. The increase in value in livestock (in this case dairy cattle) by growing young animals and the selling of surplus animals is called turnover and growth.

Dairy farming is so called land-based farming. Land is needed for production of feed and for manure disposal. Produced feed on dairy farms is mainly grass and maize.

Agricultural structure is a vague term. Zimmerman and Heckelei (2012) used key figures farm size, livestock density⁶ and heterogeneity of dairy farm size as determinants for farm structure. Milk production is defined as an indicator for technology.

⁶ Livestock density is assumed to be a synonym for farm intensity. Both terms are used in this report. Technically we mean number of dairy cows per UAA.

5.2 Farmer's behaviour

Farmers have (un)conscious goals they want to achieve. Despite new upcoming theories like utility maximization by Scitovsky (1943) (as cited in Mansfield, 1988) standard assumption in micro economics for firm goal (and therefore also farm goal) is profit maximization (Mansfield, 1988). Profit is defined as income minus costs. By a constant income profit maximization means cost minimization.

Beside the economic theories it is also known that even when farms do have the same structure, they can develop differently by having different operational management (Lepoutre et al, 2004).

Utility maximization is the optimization of profit maximization and the amount of leisure an entrepreneur enjoys (Scitovsky (1943) as cited in Mansfield, 1988).

Lepoutre et al (2004) described that Hofstee introduced the concept of firm styles in agriculture in 1985. The concept of firm styles in agriculture was further extended by Van der Ploeg. He defined firm style as a decision model shared by more than one firm. Furthermore a decision model is related to strategic opinions how to manage a firm. Firm styles are related to practising agriculture and also to markets and technology

According to Vanclay et al (1988) (as cited in Lepoutre et al, 2004) firm styles are no empirical entities as firm styles are dynamic and therefore cannot empirically be distinguished. Vanclay et al (1988) (as cited in Lepoutre et al, 2004) concluded that farmers cannot easily be classified into firm styles.

Lepoutre et al (2004) conclude that for using farm styles in research methodological improvements will have to be performed.

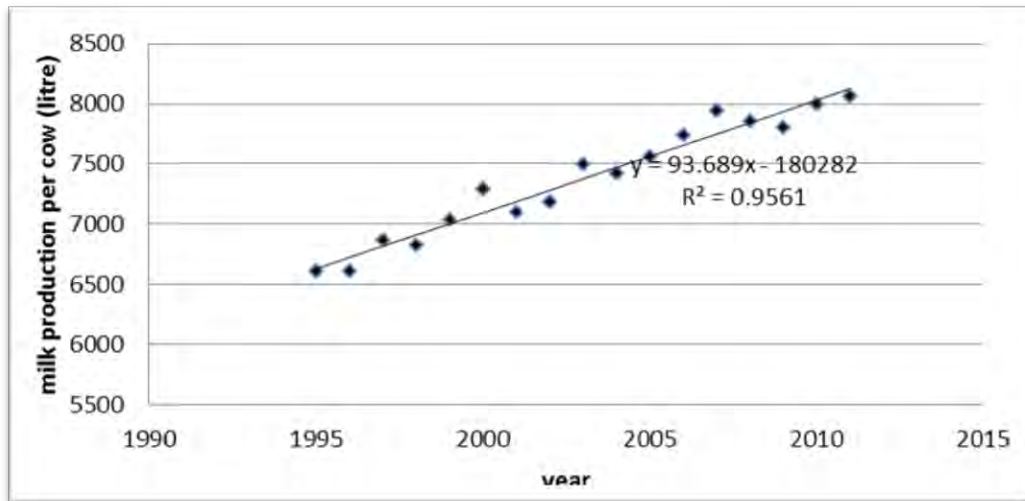
An example of using farm types (firm styles) in Agent Based Modelling is the research of Valbuena et al (2010). Valbuena et al (2010) performed a study to the effects of farmers' decisions on the landscape structure of a Dutch rural region using an ABM. In this model they distinguished five farm types with different behaviour and different goals. Furthermore they described a conceptual framework of how to describe farmer's decisions and of the diversity of decision making. Using this framework they distinguished five farm types based on likelihood, willingness and ability towards certain processes like decrease production and participation in management programs. To apply this typology in simulations a detailed survey was performed under the farmers in the region.

An important process or decision is when to quit farming. We can distinguish two types of farm quitting. Farms will quit farming as their profit is insufficient to continue (costs are higher than their income). Especially when this situation occurs over a longer period quitting farming is a natural choice. The second group of farm quitting are the farms who quit but have sufficient income. Here illness, family problems or other also lead to the decision of farm quitting. Farm quitting was also a process in the farm typology of Valbuena et al (2010).

5.3 Milk production and milk quota

Main income of dairy farmers is the selling of produced milk. In the past it was useful as a farmer to produce as much milk from a dairy cow as could be. Increasing milk production would lead to more income consisting of income from selling milk and of receiving more premiums. Milk production can be increased by breeding plans and also optimizing feed intake.

Between 1995 and 2011 milk production increased 21.9% which means an average increase milk production per cow per year of 1.25% (figure 5.1).

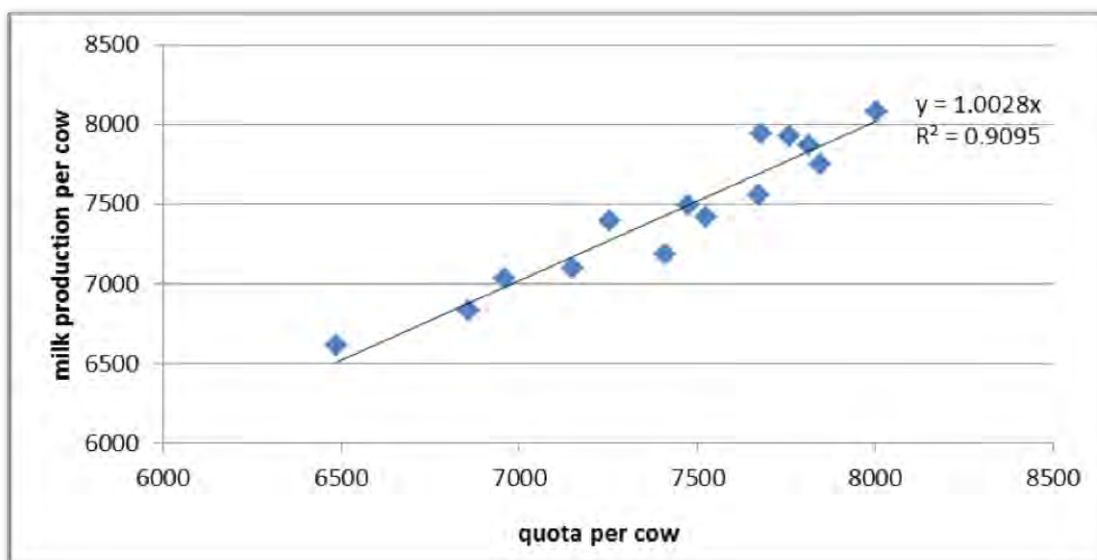


Source: Wijsman (2013)

Figure 5.1 Development in milk production per cow

Milk production is not equal to milk quota. Milk production is what a dairy cow produces; milk quota is the amount of milk a farm is allowed to produce. By management (feed, breeding and other) a farmer can direct milk production of a farm to be equal to milk quota but it's likely that there are differences (figure 5.2). If a farmer produces more milk than the allowed quota a levy will have to be paid.

According to cost minimization the best way to produce the allowed quota is to perform this with a minimum of dairy cows.



Source: Wijsman (2013)

Figure 5.2 Relation between average quota per dairy cow and milk production per dairy cow

5.4 Environment

5.4.1 Nature Conservation areas

In this research we define Nature Conservation Areas (NCA's) as the aggregate of Ecological Main Structure Areas (EMS) and Nature 2000 Areas. EMS areas are designated by Dutch policies. EMS was introduced in 1990 to prevent degeneration of current nature and biodiversity. In the beginning EMS areas should be connected to each other by using so-called connecting areas. Since several years plans have changed and these connecting areas will be replaced by surrounding agricultural areas.

Nature 2000 areas are issued by European policies. Nature2000 areas generate an EU network of nature protection areas established under the EC Habitats Directive (European Commission, 1992) and EC Bird Directive (European Commission, 1979). Goal of Nature 2000 areas is to stop further degeneration of biodiversity (Regie Bureau Natura 2000, 2013).

Farms within the influence of these areas can be hampered in their expansion due to environmental restrictions. EMS and Nature2000 areas can overlap.

Outside the restrictions in the surroundings of NCA's there are additional rules active, influencing the process of farm expansion.

Here we will mention:

1. the Law for Ammonia and Cattle Farming
2. Law for Odour Nuisance and Cattle Farming
3. Assessment Framework Ammonia around Nature 2000 areas (*"Toetsingskader ammoniak rondom Natura 2000 gebieden"*, 2007)

All three rules and legislations offer opportunities for farm expansion under restrictions. But jurisprudence in 2009, lead to a stagnation of authorization of farm expansion (Plan Bureau voor de leefomgeving, 2012). This problem might be solved by new plans (Programmatische Aanpak Stikstof - > PAS) at Province level but they are not active yet.

5.4.2 Manure surplus

In Europe the Nitrate Directive is set to avoid manure surpluses. In the Netherlands derogation is operative meaning that on dairy farms with at least 70% of their UAA covered with grass a manure application of 250 kg N from cattle manure is allowed. All extra manure produced per ha will have to be removed. A farmer has to pay for this removal of manure surplus. Besides the Nitrate Directive with derogation other manure legislation is active in the Netherlands. It consists of additional rules for the application of N, restrictions for the application of phosphate and time related activities such as time of manure application but also the compulsory use of manure application techniques, covering manure storages. Additional stable adaptations to prevent emission of ammonia are mainly part of the Nature Conservation areas.

6 The model

6.1 Purpose and population

Goal of the model is to predict effects of abolition of milk quota on the amount of milk production, on financial characteristics and on farm structure. Farm structure is defined as farm size (dairy cows and UAA per farm) and stock density (dairy cows per UAA).

Scope of the model is the Dutch dairy sector. What do we mean with Dutch dairy sector? In chapter 4 it is mentioned that most dairy cows are kept on specialized dairy farms (91% in 2006) but also on other farm types. For our research we selected all specialized dairy farms and non-specialized dairy farms with at least 20 dairy cows or more. This population covers 99.4% of the number of dairy cows in 2004 (table 4.1). By doing so, we eliminated farmers who keep dairy cows for more or less as a kind of hobby.

6.2 Farmers objective

For our research we selected the economic principle (profit maximization -> cost reduction) as leading principle for farmer's decisions. We took firm styles into consideration but didn't use it as most studies using firm styles gather their data from farm reviews. Furthermore it is known that farm styles are dynamic and also regional bounded and cannot easily be transformed from one to another region. We concluded that having reviews under farmers or construct a farm style typology for the Netherlands would take too much time for our internship and therefore we limited us to the profit maximization. Profit is defined as the difference between revenues and costs.

6.2.1 Optimal farm scale

A cost curve is a relation between output quantity and the average costs per unit output. Cost curves can be classified as short run cost curves and long run costs curves. Both types of cost curves can be used to make decisions for the future of the firm. In a short run cost curve some inputs are fixed but more strictly said:

"in the short run a time period is so brief that the firm cannot vary the quantities of plant and equipment" (Mansfield, 1988, p. 201).

In a long run cost curve all inputs are variable (including capital, plant size, land and other).

As we want to model farm expansion and allow stable expansion and/or expansion of land, we will use the long run average cost curve for calculating costs given the amount of inputs.

Figure 6.1 (the picture at the left side) shows an example of a long run costs curve in which the output (milk production) is replaced by number of dairy cows. Such a curve shows at what firm size total costs per unit milk are at a minimum. The example is theoretical as it is not based on real data but it shows what a complete long run costs curve looks like.

The shape of the long run average cost function represents the economies and diseconomies of scale. According to Mansfield (1988) at a certain firm size the curve moves upward due to the fact that at a certain moment increases in scale results in inefficiencies in management. Examples are more coordination between managers and employees, inflexibility and other.

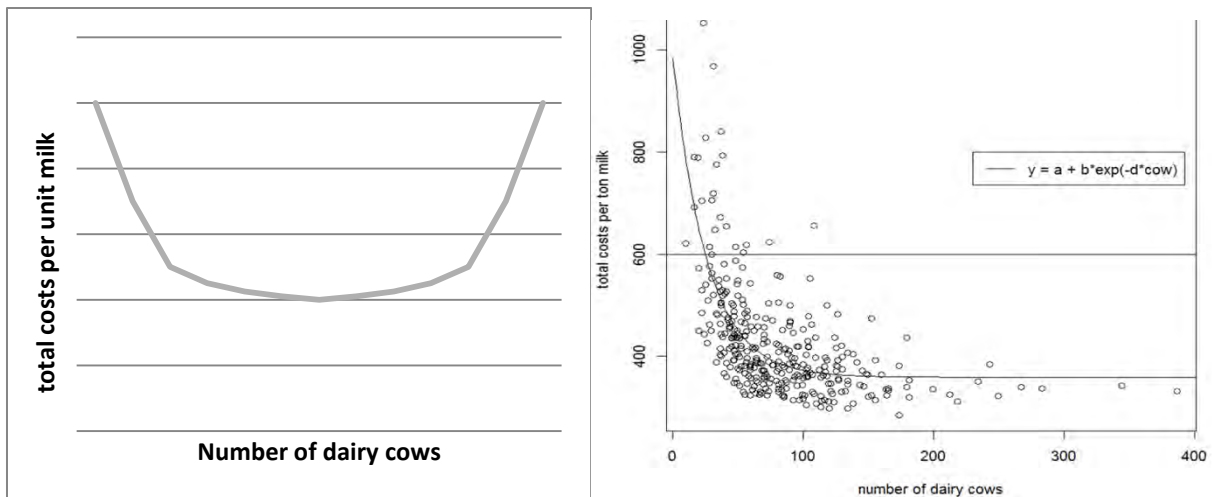


Figure 6.1 Long run average cost-curve based on theoretical assumptions (left) and real data (right)

From a long run average cost-curve we can deduce the farm size at which costs per unit milk are at a minimum. This is the number of dairy cows where the cost-curve is going to run more or less flat. Based on estimations (appendix 1) we found an optimal farm scale of 130 dairy cows. Therefore we translated the goal function of profit maximization into the operational goal function: reach optimal farm scale.

In the model it is assumed that farms with 130 dairy cows or more will not change their farm size. For these farms increasing farm size will not result in lower costs per litre produced milk. It might even be so that very large farms should better reduce their farm size (according to long run average costs curves) as for a certain farm size long run average costs curve increases due to inefficiencies in management. As there is no financial data available about these large farms in the Dutch FADN for 2006 (see figure 6.1 the picture at the right side) and the presence of these large farms in total population is limited (table 6.1), we decided to include them in the model as fixed size farms (they do not grow nor shrink). The only activity they can perform is quit farming.

Table 6.1 Holdings by number of cows-in-milk and cows-in-calf

Year	Number of farms with dairy cows						Total number of farms	Number of dairy cows (x1000)
	1-20	20-50	50-100	100-200	200-500	>= 500		
2006	1891	6391	11135	2700	178	6	22301	1420
2007	1659	5789	10700	2940	217	8	21313	1413
2008	1404	5097	10466	3485	289	5	20746	1466
2009	1187	4627	10360	3769	320	5	20268	1489
2010	1250	4365	9930	3908	346	6	19805	1479

Source: Wijsman (2013)

6.2.2 Revenues and costs

This section reports about the definitions of revenues and costs. An extended overview of definitions of costs and revenues can be found in appendix 2.

Revenues

In our research revenues per farm are defined as the sum of sold milk, turn-over and growth of cattle, EU-premiums and other income like tourists and garaging of caravans and campers (formula

6.1). Sold milk is calculated as the sum of milk produced multiplied with the milk price. Premiums per farm are available for 2009. Turn-over and growth of cattle is assumed to be a fixed amount per dairy cow just as the item “other income”.

$$\text{Revenues} = \text{milkproduction} * \text{milkprice} + \text{number of dairy cows} (a + b) + \text{premiums} \quad (6.1)$$

With:

- a -> turn over and growth per dairy cow
- b -> other income per dairy cow

Costs

Costs per farm in the model are estimated based on total costs from the dataset used in the research of Tonini et al (2011). Costs in this dataset are the sum of all costs excluding costs for family labour⁷. The dataset is based on FADN data and therefore costs are not available for all (dairy) farms in the Netherlands. To apply these costs from FADN data to all farmers we estimated (using multiple regression and neural networks⁸) relations between farm key figures and total costs (excluding labour). The approach and results are extensively described in appendix 3. We present here only the used multiple regression line with all significant independent variables (formula 6.2).

$$\text{Log}(\text{costs}) = 8.46147 + 0.90578 * \log(\text{number of dairy cows}) + 0.21529 * \text{FNSO} + 0.2059 * \text{f_gras} \quad (6.2)$$

With:

- FNSO = 0 in case of specialized dairy farming and FNSO = 1 in case of non-specialized dairy farming with 20 dairy cows or more
- f_grass = grass area / UAA

We could have used the exponential function from appendix 1 however we prefer to use a multiple linear regression function. A multiple linear regression takes into account more attributes per farm which might decrease the error size. Another point against using the exponential function is that it predicts total costs including non-paid labour. In the consideration of farmers for future developments the non-paid labour costs are on average not taken into account. So costs in this appendix are defined a total costs minus calculated costs for non-paid labour.

6.3 Farmers behaviour in the model

This section describes the working of the model using flow diagrams. The section starts with a flow diagram of the whole model. Next sub models are described including further implementation of farmer’s behaviour.

6.3.1 Process overview

The model starts with determining for all farms whether they will quit farming or not (figure 6.1). If a farm continues, the probability on growth or no growth (stable) is assessed. Not all farms can grow;

⁷ Family labour are (or can be) non-paid costs and therefore on average not taken into account within farmers decisions.

⁸ Using linear regression means that there are some restrictions for the used data. In most cases this restrictions cannot be fulfilled. In those cases we also estimated neural networks. However we decided not to use neural networks but the functions from multiple linear regressions. This will improve the acceptance of the Agent Based Model.

a farm might be hampered in his expansion due to environmental restrictions like the presence of a Nature2000 area. Shrinking of farms is not taken into account in the model. As the leading principle is profit maximization farmers will have the ambition to have an optimal farm size. We already mentioned in the previous section that large farms (> 400 dairy cows) should shrink under this theory. As we do not have information about this process and the number of those farms is small we modelled those in such a way that they keep their current farm size.

If a farm wants to grow, the size of farm expansion will be determined (sub model: assess growth potential). A farm cannot grow infinite. For instance a farm might have to lend money to finance the expansion which restricts the size of expansion.

The next sub model is a kind of land market. Here farms who want to sell their land interact with farms who want to expand. The land-market is an exchange market with a small basic financial mechanism. In the final sub model all farms are turned over into their new situation (update farms).

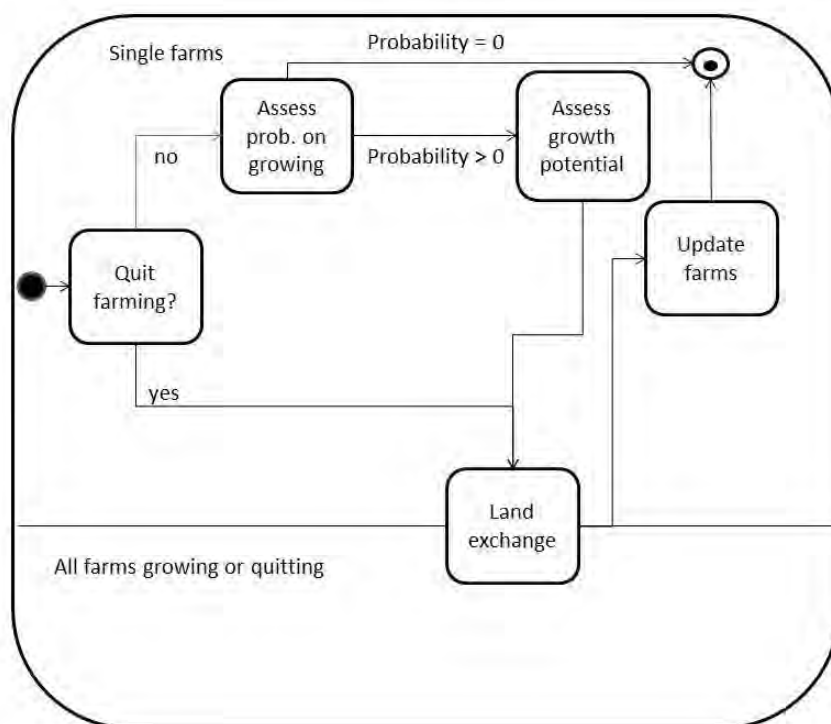


Figure 6.1 Flow diagram of process overview⁹

6.3.2 Sub models

The model is divided in the following sub models (figure 6.1):

1. Quitting farming or not
2. Assessing the probability to expand the farm or not
3. Assessing the farm growth possible
4. Land exchange
5. Updating farms

⁹ Black dot: start of the process, dot with black spot: end of the process

Quitting farming

In section 5.2 we mentioned two types of farm quitting: quitting induced by cost higher than revenues and random quitting (appendix 4) (in other words economic and non-economic driven).

We estimated for both groups' probabilities for farm quitting (table 6.2) using data of the Annual Census of 2001 and 2006. We estimated a long run cost curve for 2001 (appendix 4) as we did for 2006 (appendix 3). For farms present in 2001 we calculated the cost-revenue ratio and determined the age and number of dairy cows. Thereafter we checked the presence of the farms in 2006. For more information about these probabilities see appendix 4.

The age categories are based on research to successors of farmers. When a farm head is 50 years or older he will be asked for the presence of a successor in the Annual Census. If a farmer is 65 or older and there is no successor it is likely that the farmer will reduce his farm. Unfortunately there is no data about successors in 2006.

Table 6.2 Probability of farm quitting

age	Number of dairy cows			
	< 20		≥ 20	
	Cost-revenue ratio ≥ 1		Cost-revenue ratio < 1	
< 50	0.188	0.093	0.163	0.091
50 - 65	0.269	0.126	0.163	0.091
≥ 65	0.287	0.187	0.229	0.139

Figure 6.2 shows the pseudo-code for this sub model

Recipe: Quit farming
Do for all farms
Calculate cost/revenue
Determine probability of farm quitting based on age and farm size
Effectuate farm quitting
enddo

Figure 6.2 Pseudo code sub model "Quit Farming"

It might be surprising that older farmers with a cost-revenue ratio smaller than 1 and less than 20 dairy cows are more likely to quit farming than those farmers with a cost-revenue ratio of 1 or higher. We have to take into account that farmers with less than 20 dairy cows in our population are specialized dairy farmers. Non-specialized dairy farms in our population do have on average a higher costs per unit milk as total costs cannot only be assigned to milk production. On non-specialized dairy farms the main agricultural production is non-dairy. This is a bias in the model. As a result of this bias it is likely that farmers with only 20 dairy cows or less are more in favour of quitting compared to the same population (age) who are likely to have other production branches.

Assessing probability on growth

In this model we relate probability on growth on farmer's age and location near or within NCA's. An older farmer (≥ 65 year) is less willing to increase farm size compared to a young farmer, especially when there is no successor. Unfortunately for 2006 the presence of a successor is not known otherwise we would have taken this into account assessing the probabilities on growth.

Table 6.3 Number of farms and their growth dynamics for 2001-2006

Age	Number of farms			fraction	
	No growth	Growth	Total	No growth	growth
< 50	3523	5664	9187	0.38	0.62
50 – 65	3244	4722	7966	0.41	0.59
>= 65	1128	1371	2499	0.45	0.55
Total	7895	11757	19652	0.40	0.60

We derived probabilities for farm growth depending on age by selecting farms (reference population) that existed in 2001 as well as in 2006 in the Annual Census (Table 6.3). Figure 6.3 shows the pseudo-code for this sub model.

Recipe: probability on growth
Do per existing farm
Calculate age-effect
Calculate location-effect
Probability = age-effect * location effect
enddo

Figure 6.3 Pseudo code sub model “probability on growth”

The location effect refers to the situation that a farm’s probability on growth might be dependent of environmental restrictions (presence of NCA’s, see appendix 5). As far as it can be seen from the data of growth in the period 2001-2006, growth in areas restricted by NCA’s is comparable to growth in areas not restricted by NCA’s. As the years 2001-2006 are not representative for the coming period (developments in Nature2000 areas, further restrictions and jurisprudence, see section 4.4.1) we use this probability as a tuning factor in the calibration of the model.

To get the final probability on farm growth the probabilities on farm growth for age and location are multiplied, assuming independence between age and location. This independence has been tested (appendix 6) and the conclusion is that age and location are independent of each other.

Assessing growth potential

After it is decided that a farm is going to increase in size it has to be determined how much this increase will be. The amount of growth is depending on the UAA on a farm and stock density on the farm.

To be able to transform UAA into a corresponding number of dairy cows and vice versa, we need a relationship between number of dairy cows and UAA. As farm structure of specialized dairy farms is different from the mixture of non-specialized dairy farms we decided to estimate for both categories a relationship. We also decided to categorize different relationships for farms with different livestock densities. Therefore we estimated relationships between UAA and number of dairy cows for two types of farms and three intensity classes (appendix 7). The estimation results used in the model are shown in table 6.4.

Furthermore we introduced an autonomous increase in stock density. This increase was estimated on data of farmers comparable with our population of 2006 (appendix 8). The estimated autonomous

increase in livestock density is normally distributed with an average of 1.06 and a variance of 0.06 ($\sim N(1.06, 0.06)$).

Table 6.4 Estimated coefficients for the relationship number of dairy cows and UAA (log(UAA) as the dependent variable)

Farm type	Intensity (dairy cows per UAA)	Independent variables				R ²
		Log(dairy cow)	Fraction property	Fraction grass	Intercept	
Dairy farms	< 1.5	0.8344	-0.1100	-0.0570	0.5626	0.861
	1.5-1.85	0.9928	-0.0109	0.0095	-0.4711	0.986
	>= 1.85	1.0073		0.0810	-0.8877	0.785
Non-specialized dairy farms	< 1.5	0.8158	-0.2549	-0.2184	1.0554	0.535
	1.5-1.85	1.0074			-0.5351	0.980
	>= 1.85	1.0131		0.0727	-0.9821	0.689

The advantage of increasing livestock density is that less land is needed for increasing milk production. A disadvantage of increasing livestock density is that manure surplus might increase so extra costs for manure disposal will have to be paid. Also at a certain livestock density a farm has to buy extra fodder for his cattle as he cannot produce enough with his current land. Figure 6.4 shows the pseudo-code for this sub model.

Recipe: Growth potential
Do for existing farms who have the potential to grow (farms < 130 dairy cows)
Calculate new farm intensity
Calculate UAA new for 130 dairy cows (based on farm type and intensity)
If new UAA > 120% current UAA
newUAA = current UAA * 1.20
Endif
Calculate number of dairy cows for new UAA (based on farm type and intensity)
enddo

Figure 6.4 Pseudo code sub model "growth potential"

Through change in farm intensity and the relationship between UAA and number of dairy cows for different intensities it can happen that the new calculated number of dairy cows is less than the number of dairy cows present in 2006. As we assume that farms do not decrease their farm size we set the number of dairy cows equal to the number of dairy cows in 2006.

Land exchange

Figure 6.5 shows the flow diagram for this sub model. A "selling" farm (farm is going to quit and offers UAA) searches within a certain radius for a farmer who wants to expand his farm. It's not necessarily a neighbour who will buy the land. It is acceptable although not optimal to have land within 5 – 10 km of the own farm. This land can be used for fodder (mowing) or grazing young and/or meat animals.

Although we could use the land market module of Schouten et al (2012) or Valbuena et al (2010) we decided not to take a real market mechanism into account. First of all the land market of both researches mentioned acted on a regional scale. We wanted to predict effects for national scale and therefore we expected model running problems. Furthermore the price-setting for land on the market is regionally affected by the land market price. To cover the Netherlands taking these regional differences into account, would inhibit the progress of our internship. The option of developing an own comparable market module would take to much time. So we opt for a small market mechanism: we introduced a simple economic principle in the decision-rule to which farmer the land is sold first. In a group of farms the farm with the lowest cost-revenue ratio is the farm is most capable of attracting extern funding for buying land and therefore it should be the farmer who offers the highest price for land.

As land is a kind of saving (value increases over time) costs of land are only rent costs of owned or borrowed capital necessary to finance the buying of land. Costs for land are derived from Wijsman (2013).

In order to meet the environmental restrictions (no increase of deposition on NCA's in case of farm expansion) we implemented the rule that farmers outside the restricted areas may not "sell" land to farmers inside these areas. Farmers inside these areas may exchange land with farmers from both inside and outside NCA's.

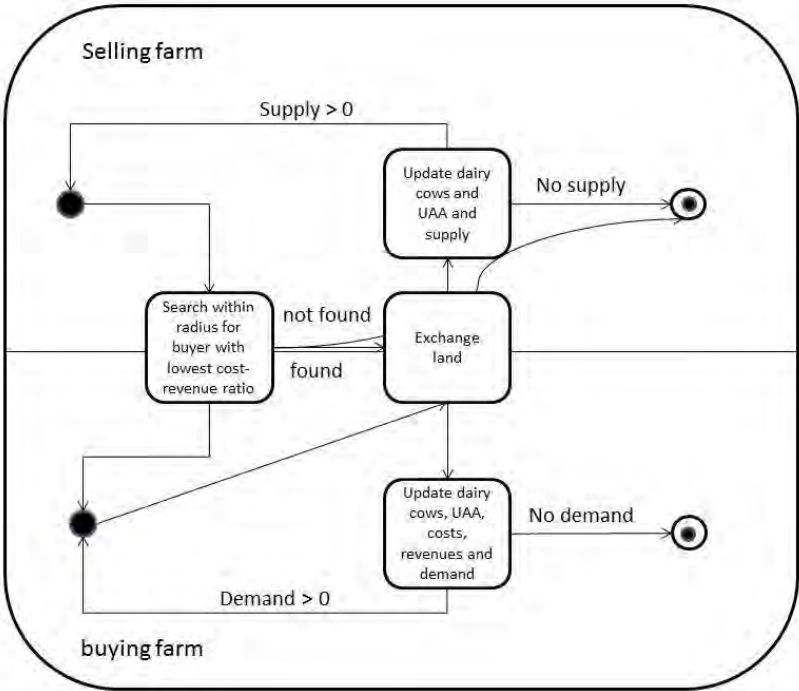


Figure 6.5 Diagram sub model Land Exchange

Update farms

Farms who quit are removed from the system. Farms who continue farming are updated. The number of dairy cows and UAA, milk production including the autonomous milk production growth is recalculated. Also costs and revenues are recalculated based on the new farm structure.

6.4 Model input and output

6.4.1 Input

Model input consists of characteristics or attributes of individual farms (table 6.6) and global data (table 6.7, and 6.8).

For calculating revenues we need one farm attribute: number of dairy cows on a farm (formula 6.1). For cost calculation (formula 6.2) we need besides the number of dairy cows, farm type, grassland and UAA. Location of a farm in relation to the presence with and within NCA's is needed just as (NetLogo) coordinates of the farm. The last ones are needed in order to give sellers of land to look around for potential buyers. Received premiums are available at farm level and are used to calculate revenues. Furthermore we need the agricultural area in which the farm is located to be able to calculate extra costs for land buying and age for assessing probabilities on farm size growth and farm quitting. All these farm attributes are show in table 6.6.

Table 6.6 Farm attributes (source Annual Census 2006, combined with GIS-data and premium data)

Attribute name	Unit	Comments and source
Dairy cows	Number	Annual Census
Utilizable area (UAA)	Ha	Annual Census
Grass	Ha	Annual Census
Age		Annual Census
Farm type	NSO (see section definitions and further explanations)	Annual Census
X coordinate	LAEA projection (base)	Transformed to NetLogo coordinates
Y coordinate	LAEA projection (base)	Transformed to NetLogo coordinates
Received premium	Euro	2009-Support Schemes Service of the Ministry of Economic Affairs.
Agriculture area (14 agricultural areas within the Netherlands)	Not relevant	Indication for land price
Location in relation with NCA's	Number	Indicates location, see appendix 5

Global data is data for each farm equal. One can think about milk price, labour costs and autonomous development in milk production.

Table 6.7 Global input data with default value and reference

Input data	Default value	Used to	Reference
Milk price (€ per ton)	300 euro	Calculate revenues	LEI (2013a)
Optimal farm scale (dairy cows)	130		Appendix 1
Premium (€ per 100 kg milk)	3.30	Is used in case individual farm data is not known.	LEI (2013a)
Manure removal price (€ per m3)	13	Calculate extra costs	Dienst Regelingen (2012)
Manure production (m3 per dairy cow)	26	Calculate manure removal costs	Van Bruggen (2008)
Minimum milk production (litre per dairy cow)	5000	Calculating milk production	Assumption
Land costs per bought UAA (€ per ha)	0	Calculating extra costs	Wijsman (2013)
Fraction of non-paid costs in total costs excluding non-paid costs for family labour	0.2	Used to transform calculated costs of 2006 to the level of 2011	LEI (2013a)
Development of total costs between 2006 and 2011	1.14	Used to transform calculated costs of 2006 to the level of 2011	LEI (2013a)
Number of dairy cows per ha	1.5	Derogation allowed	Section 5.4.2
Global input data used as tuning Parameters	Default value	Used to	Reference
Km radius to search	5 km	Search for potential buyers	Not relevant
Fraction max grow for farms with Cost-revenue ratio > 1	0.20	Limit farm expansion	Not relevant
Fraction max grow for farms with Cost-revenue ratio <= 1	0.20	Limit farm expansion	Not relevant
Milk production growth	0.06	Calculating milk production	Wijsman (2013)
Probability on growth within NCA's	0.59	Assess probability on growth of farms in an NCA	Not relevant
Change in farm intensity	N(1.06,0.06)	Sampling from a ~N-distribution to assess change in farm intensity	Appendix 8

Table 6.8 Global input data being time dependent

Input data	Default value 2006	2011	Used to	reference
Turnover and growth of cattle (€ per dairy cow)	243	260	Calculate income	LEI (2013a)
Extra revenues (€ per dairy cow)	57	212	Calculate income	LEI (2013a)

The last mentioned global input data here are paid rent costs per ha land (table 6.9).

Table 6.9 Used land costs (only interest) in the model

Agricultural area	Price per ha	Interest costs per ha
Bouwhoek en Hogeland	22399	448
Veenkolonien en Oldambt	21213	424
Noordelijk weide gebied	22118	442
Oostelijk veehouderijgebied	29293	585
Centraal veehouderijgebied	38152	763
Ijsselmeerpolders	38216	764
Westelijk Holland	30015	600
Waterland & Droogmakerijen	21737	435
Hollands/Utr. Weidegebied	30203	604
Rivierengebied	37676	754
Zuidwest. Akkerbouwgebied	32072	641
Zuidwest Brabant	34375	688
Zuidelijk veehouderijgebied	35488	710
Zuid Limburg	36331	727

Source: Wijsman (2013)

6.4.2 Output

We wanted to model the effects of quota abolition on farm structure, costs and milk production.

Table 6.10 shows the main outputs from the model. When running multiple runs, variables are written into a csv-file using behaviour space (see section Definitions and explanations). This csv file is input for an R program, producing descriptive statistics, histograms and normality tests.

Table 6.10 Model output per run

Model results
Dairy cows per farm
UAA per farm
Dairy cows Netherlands
Milk production Netherlands
Costs per 100 kg milk
Revenues per 100 kg milk
Net result per 100 kg milk
Number of farms
Number of farms quit
Land exchange

More output is available (farm size classes classified by number of dairy cows and other) or can be made available but output for 3500 runs for the variables presented in table 6.10 already requires the maximum capacity of the R program to process.

For single runs pictures can be made as will be shown in chapter 7.

6.5 Other model issues

Scheduling

The model runs one tick. The time period of a tick is 5 years.

The sub-model “land exchange” stops when there is no further exchange of land between farms possible. This can be the result of the absence suppliers of land, absence of buyers of land or due to restrictions hinder further exchange.

We estimated behaviour of farmers on the period 2001-2006. When simulating we start at 2006 and predict for the next five years. Therefore we can say: the model runs one tick representing 5 years (see section about scales).

Stochasticity

Stochasticity is used at several places in the model:

- Farm quitting
- Probability on farm expansion
- Development in farm intensity

The process of farm quitting and probability on farm expansion are based on uniform distributions. Development in farm intensity is modelled according a normal distribution.

As the model uses stochastic processes, final output is produced by taking the average outcome of 3500 simulation runs.

7 Calibration, verification, sensitivity and uncertainty analyses

In this chapter we describe the process of verification of the model including a sensitivity and uncertainty analysis. As some parameters are not fully known, we first calibrate the model tuning these unknown parameters (see section 7.1). Calibration is according to Cooley and Solano (2011) "the process of tuning a model to fit detailed real data".

Furthermore they define (Cooley and Solano, 2011) verification as checking that a program does what it should do. It does not include the logic of rules to cover the process; it is only about the correctness of the code.

With a sensitivity analysis you explore the sensitivity of model output to small changes in parameter values (Railsback and Grimm, 2012). Roache (1998) and Weiss et al (2005) (both cited in Anderson et al, 2007) state that with a sensitivity analysis one can analyse the effects of altering model inputs on the model predictions to gain a better understanding of the influence of these model inputs. Therefore a sensitivity analysis can be part of verification.

7.1 Calibration

Introduction

In the calibration process we fine-tune the model having model results comparable with real data. At LEI so-called real farm data like structure key figures are available for each year. These data is gathered with the Annual Census (see section Definitions and further explanations). Real data for financial key figures is available in Dutch FADN.

Our model starts with data of 2006 and calculates results for 2011. Therefore we calibrated the model to real values of 2006 and 2011 for some key-figures in dairy production (table 7.1).

We tuned the results of 2011 with quota on three parameters: the probability on farm expansion in Nature Conservation areas (0.59), maximum farm expansion (an increase of 20% of current farm size) and the development of autonomous milk production. The results were tuned in an intuitive cyclic process: first change one or both of the parameters "probability on farm expansion" and "maximum farm expansion" to create the right number of dairy cows and UAA. When an appropriate value was reached, the parameter "Autonomous milk production" was changed until the model output was (almost) equal with the measured milk production (increase of 2.4%).

For calculating the situation of 2011 (with the quota system present) we did not take development in farm intensity into account.

The financial data presented in table 7.1 (under FADN) is based on specialized dairy farms of a farm size of at least 16 so-called "Nederlandse Grootte-eenheden" (nge) while farms in the Annual Census have a farm size of 3 nge's or more. Our modelled population retrieved from the Annual Census is different from the population in the FADN dataset of which we present the financial indicators. First of all our dataset contains more small farms compared to the FADN dataset and second our population contains besides specialized dairy farms also non-specialized dairy farms.

Table 7.1 Measured and calculated values for model output for 2006 and 2011 both with the milk quota system present.

Source	Parameter	2006		2011	
		Measured	Calculated	Measured	calculated
Annual Census ¹⁰	Number of dairy cows	1409 * 1000	1409 * 1000	1465 * 1000	1475 *1000
	UAA (ha)	926 * 1000	926 * 1000	886 * 1000	902 *1000
	Number of farms	21137	21137	18624	18528
	UAA per farm	43.52	43.52	47.6	48.7
	Dairy cows per farm	66.7	66.7	78.8	79.6
FADN	Costs per 100 kg milk	49.65	52.07	53.42	56/48 ¹¹
	Revenues per 100 kg milk	38.24	37.66	49.51	47.76
Other ¹²	Milk production (kg)	11052 *1000	10928 * 1000	11738 * 1000	11707 *1000

Results

Calculated costs for 2011 are lower compared with Dutch FADN. The point is that we use a cost curve based on a certain population in a certain year. As population changes over time the estimated cost-function doesn't hold anymore. Furthermore prices of inputs like fodder costs can change rapidly between the years. These price changes (like a doubling of the fodder price between 2006 and 2011) are not captured by the used cost curve.

Therefore the question arises whether to predict costs with the model or not. We choose to predict costs but only use it as an indicator for the trend of the effects of measures (input changes).

Appropriate values were defined as a difference between calculated and measured values of 2% and for costs 5% due to the above mentioned difficulties with cost estimations.

We have to be aware that a model that can be calibrated very well is no guarantee for good predictive capabilities.

7.2 Verification

The process of verification can be split up in code verification and calculation verification (Anderson et al, 2007). Code verification is about the fact that the code is an accurate representation of the model. Calculation verification is about the fact that the model represents the mathematical model (Anderson et al, 2007).

We performed code verification during the modelling process. This is in accordance with the American Institute of Aeronautics and Astronautics (1998), Oberkampf et al (2002), Babuska and Oden (2004) an ASME Committee (PT60) on Verification and Validation in Computational Solid

¹⁰ Here data is presented for our specific population (dairy farms of non-specialized dairy farms with 20 dairy cows of more)

¹¹ 56 -> with autonomous costs development, 48 without autonomous cost development

¹² Other: measured is all farms, calculated is for specific population

Mechanics 2006 (all cited in Anderson et al, 2007) who consider code verification as a software development activity.

We performed calculation validation by applying the model (without stochastic elements) to a small area (Terschelling) and checked the results manually. Furthermore after we extend the model to the Netherlands, we checked results by calculating results for a farm by hand. For this we selected at random one or more farms from an output file of one run, recalculated the outputs manually and checked these with the model calculations.

7.3 Sensitivity analysis: one –at-a-time approach

In the sensitivity analysis we change one or more factors at a time. Results are compared with the situation in 2011 without quota. This scenario for 2011 is called the reference scenario and is indicated as B1.

7.3.1 Purpose and planning

We performed a sensitivity analysis changing one parameter at the time, a so called on-at-a-time approach (Manson (2002) and Kleijnen at all (2003) as cited in Happe et al, 2006).

We selected the most uncertain input variables and model assumptions to perform a sensitivity analysis (table 7.2) and assessed the effects on the model outcomes.

Table 7.2 Factors in the sensitivity analysis (only one factor at a time) and the name of the scenario (between ())

Factors	Max-level	Min-level	Default (see chapter 6)
Radius within “sellers” search (km)	10 (G1)	2 (G2)	5
Autonomous milk production (%)	8 (G3)	4 (G4)	6
Land exchange between all collectives	Yes (G5)	No (G6)	no
Restrictions environment on growth probability (fraction)	1.0 (G7)	0.0 (G8)	0.6
Premiums per farm (€)		0 (G10)	
Milk price (€ per ton)	45 (G11)	15 (G12)	30
Number of dairy cows per ha before manure surplus arise		1 (G14)	1.5
Max grow of present UAA on a farm (%)	100 (G15)	50 (G16)	20
Change intensity growth	N(2,0.5) (G17)	N(1,0.05) (G18)	N(1.06,0.06)

7.3.2 Results

Table 7.3 shows the results of the sensitivity analysis per changed (input) parameter. We will discuss per parameter what we could expect and what we get as results.

Change in radius: G1, G2

If we change the radius in which “sellers” can search then the number of potential buyers will change. If the radius increases the “seller” can see more potential buyer and therefore the amount of land exchange might increase. In case a “seller” sees more potential buyers it is also possible for more “buying” farmers to expand their farms. This might cause an increase in total milk production in the Netherlands.

When the radius decreases less land will be changed between sellers and buyers resulting in less farm expansion per farm.

Default in the model (see table 7.2) it is assumed that there is a slight increase in farm intensity. Therefore we might expect an increase in farm intensity when more farms are going to expand their farms. As available land increases also farm intensity increases and the other way around (decreasing).

From table 7.3 we can conclude that what we expected is also happening. We can also see that the increase in radius from 5 to 10 km causes less effect on farm structure than the decrease from 5 to 2 km. This fact indicates that at a certain radius no more farm exchange takes place.

Change in autonomous milk production: G3, G4

Change in autonomous milk production (section 5.2) will affect costs and revenues per unit milk and total milk production. If milk production increases more compared to the reference scenario B1 then (in case of equal costs) costs expressed in euro per unit milk will decrease. The same holds for revenues. This effect is shown in table 7.3.

Land exchange from non-nature conservation areas to nature conservation areas: G5

In the reference scenario B1 there is no land exchange possible from non-NCA's to NCA's (see also chapter 6.3.2). If land exchange would be possible then more land can be exchanged which creates an increase in dairy cows per farm and an increase in total milk production. There will be hardly an effect on costs and revenues.

In this scenario (G5) there might be an effect on farm intensity: in case of more land results in an increase in farm intensity and vice versa. The expected change in farm intensity is visible in the results (table 7.3) although the change is very limited.

Probability on farm expansion in nature conservation areas: G7, G8

For these scenario settings the same reasoning holds for effects structural changes as the scenarios change in radius (G1, G2) and land exchange from non-NCA's to NCA's (G5). An increase in land trade results in a higher stock density and less land exchange results a decrease in stock density compared with the reference scenario B1.

From table 7.3 we can conclude that what we expected is also happening. If the probability on farm expansion is zero (not possible) in NCA's the average number of cows per farm will become decrease. This is of course an average while at regional level (nearby NCA's) the differences can be much more.

No premium: G10

In case no premium(s) will be received, income will decrease and so the cost-revenue ratio will increase leading to more farms quitting farming. It is to be expected that more farms quitting means that more land will be available for land exchange. As more farms quitting implies fewer farms continue, continuing farms can grow further having more dairy cows and UAA per farm.

Total milk production decreases while there are fewer farms with the same milk production per cow.

We have to take into account that for the use of premiums in the model, we combined 2006 with 2009 data. Premiums per farm are available 2009 and we apply these premiums in calculating revenues for 2006. Any development in number of dairy cows per farm between 2006 and 2009 affecting the received premiums is therefore not taken into account.

The effect of no premiums is that revenues decreases resulting in less farms continuing farming. As a result more land is available and continuing farms can expand better resulting in an increase of number of dairy cows and UAA per farm. More dairy cows lead to fewer costs per 100 l milk.

Change in milk price: G11, G12

If milk price increases more farmers will stay farming. This means that less land is supplied for land exchange and furthermore more farms want to expand but the expansion will be less because less UAA is available. The net result will be more farms with less farm development than in the reference scenario leading to more costs per 100 litre milk (costs per unit milk decrease with more intensive farms). On the other hand decrease of milk price will lead to more farmers quitting farming leading to more land available for land exchange, increasing farm size and fewer costs per 100 litre milk. In contradiction with scenario G10 we don't see the expected increase in land exchange in scenario G12. This might have to do with differences in farm structure between the groups of quitting and continuing farms (table 7.4) and the local aspect of farm structure occurrence (see for example figure 7.1 where the province of Friesland has a quit different number of larger farms compared to the Veluwe area).

Change in farm intensity before manure removal costs are taken into account: G14

When derogation doesn't hold any more less dairy cows can be kept on a farm (1 instead of 1.5) before a farmer has to pay for manure removal. In case of no-derogation costs increase and therefore the cost-revenue ratio per farm increases as well contributing to more farmers quitting.

We expect on average an increase in costs of 1.42 euro per litre at the start of the simulation (2006).

It would be plausible to see such an increase in costs for the end of the simulation as well. Table 7.3 shows an increase of 0.04€ per liter. This cannot be explained.

Change in maximum farm land increase: G15, G16

The default value for land increase in case of farm expansion is an increase in UAA with a maximum of 20% of current UAA. If a farm is allowed to increase further, more land can be exchanged. We can see a growth compared with the reference scenario but this growth is larger in case of growth is allowed to 50% of current UAA compared with a growth possibility of 100%.

For some single simulation runs we found that in case of 50% growth allowance 37% of the farmers increased their farm size with 15 ha while in case of 100% growth allowance 30% of the farmers increased farm size with on average 19.5 ha.

Change in intensity growth: G17, G18

If farms are allowed to become more intensive one might expect that number of dairy cows per farm will increase (less costs per production unit). After all more intensive farms can keep more cows on one ha of UAA. On the other hand at a certain point of farm intensity feed production is not enough and costs might increase due to purchasing fodder and increase of manure removal.

In case of more intensive farms less UAA is needed per cow, less land will be exchanged between farms. In this situation we see a strong increase of dairy cows per farm and more dairy cows per farm means less costs per unit milk.

In case intensity growth is less than the default situation (see table 7.2) number of dairy cows per farm is also less compared to the default situation (B1: table 7.3). Fewer dairy cows per farm mean higher costs per 100 litre milk. The increase in revenues is a bit curious. Revenues are sold milk, premiums, turn over and growth of cattle and other income. Premiums are per farm. Fewer cows on a farm means higher premium expressed per cow and therefore higher premiums per 100 l milk (table 7.3).

Table 7.3 Results of sensitivity analyses

Scenario	Structure indicators						revenues (€ per 100 l)
	number of farms	land traded (ha)	milk production (1000 ton)	dairy cow per farm	UAA per farm	costs (€ per 100 l)	
B1	18528	92640	12507	82.2	48.5	46.74	47.35
G1	18528	96531	12604	82.9	48.7	46.64	47.32
G2	18528	76150	12057	79.3	47.6	47.30	47.47
G3	18528	92640	12743	82.2	48.5	45.88	47.18
G4	18527	92635	12270	82.2	48.5	47.64	47.52
G5	18528	94429	12555	82.6	48.6	46.68	47.33
G6							
G7	18526	104487	12836	84.4	49.2	46.27	47.26
G8	18529	62257	11734	77.2	46.9	47.78	47.56
G9							
G10	17581	101618	12109	83.9	49.3	46.33	47.33
G11	19483	69749	12502	78.2	47.1	47.43	47.51
G12	16301	89003	11148	83.3	49.0	46.56	47.33
G13							
G14	18197	88801	12278	82.2	48.4	46.79	47.33
G15	18528	113021	12467	82.0	49.6	46.46	47.36
G16	18529	112286	12606	82.9	49.6	46.33	47.32
G17	18529	69484	14114	92.8	47.3	44.95	46.98
G18	18530	95800	12093	79.5	48.7	47.30	47.46

Table 7.4 Structural characterization of farms quitting for different scenarios

Structure characteristic per farm	Scenarios				
	B1	G10	G11	G12	G14
Number of dairy cows	63.74	79.75	64.48	63.78	66.23
UAA	41.98	50.97	42.3	41.9	43.6
Dairy cows per UAA	1.52	1.56	1.52	1.52	1.52

Overall conclusions which can be drawn are:

- Land exchange from farmers outside Nature Conservation Areas to farmers inside Nature Conservation Areas doesn't seem to be important for model outcomes (compare G5 and B1).
- The probability of a farmer in a NCA to expand farm size looks relevant for farm intensity and milk production. We varied from 0 (farmers are locked) to 100%
- Farm intensity change affects number of dairy cows per farm and therefore also costs. We have to be aware that we took drastic changes in farm intensity change allowing each farm to intensify twice their intensity which is disputable
- Results show that more dairy cows per farm leads to less costs. As this relationship is included in the cost function, we can see that sensitivity and verification are related: what you model is visible in the results.

7.4 Sensitivity analysis by DOE-experiments

7.4.1 Purpose and planning

With a sensitivity analysis of one-at-time one might possibly miss interaction effects between parameters (Happe et al, 2006). Therefore we perform also a DOE-analysis as described in Happe et al (2006). With Design of Experiments (DOE) techniques individual and interactive effects of input parameters, structural assumptions and variables can be assessed (Happe et al, 2006). The input parameters, structural assumptions and variables called factors in a DOE. The factors can have two or more levels (values). The number of experiments in case of x levels and k factors is x^k and in case of 2 levels 2^k .

After performing DOE simulations the results can be analysed by for instance applying regression models (Happe et al, 2006). In the regressions (Meta models) the factors are the independent variables and the response (model outcome) is the dependent variable. From the Meta models we can derive relations between the factors, the responses and interaction effects. Besides regression also other techniques can of course be used to analyse interaction effects of factors like neural networks.

Besides estimating relations and finding what factors are relevant for the output of the model, meta-modelling has the advantage that with those models a lot of scenarios can be run without running the main ABM model. The last one is compared to meta-modelling more time consuming.

“Design of Experiments (DOE) Tutorial “(n.d.) shows an example of interpreting results using Pareto plots. In this Pareto example levels of factors are chosen as a percentage change with respect to the default value of the factor and for all factor changes in level are assumed to be equal. As we can in advance indicate that 1% change in some parameters won't cause any effect we decided to follow Happe et al (2006).

We perform DOE-experiments for the interaction of the five most relevant factors (table 7.5). These five factors with two levels create 32 scenarios. For the analyses we also added some of the results of the sensitivity analysis from section 7.1: G1, G2, G3, G4, G5, G6, G7, G8, G11 and G12.

Table 7.5 Factors in DOE and two levels and the default value

Factors	Max-level	Min-level	default
Radius within “sellers” look (km)	10	2	5
Autonomous milk production (%)	8	4	6
Milk price (€ per ton)	45	15	30
Land exchange between all collectives	yes	no	no
Restrictions environment on growth probability (fraction)	0.8	0.4	0.6

7.4.2 Results

Correlation

We created a correlation matrix between dependent and independent variables (table 7.6).

Table 7.6 correlation matrix between dependent and independent variables

	<i>search radius</i>	<i>auto. milk prod</i>	<i>land-exchange</i>	<i>frac growth within nat. conserv. areas</i>	<i>nr of farms</i>	<i>land traded</i>	<i>milk production</i>	<i>dairy cows per farm</i>	<i>UAA per farm</i>	<i>costs per 100 l milk</i>	<i>revenues p 100 l milk</i>	<i>dairy cows</i>	<i>UAA</i>	<i>costs</i>	<i>revenues</i>
<i>search radius</i>	1.00	0.00	0.03	0.01	-0.01	0.29	0.17	0.27	0.21	-0.20	-0.19	0.18	0.06	0.09	0.16
<i>auto. milk prod</i>	0.00	1.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	-0.80	-0.78	0.00	0.00	0.00	0.23
<i>milk price</i>	0.00	0.00	0.00	0.00	0.99	-0.63	0.80	-0.81	-0.85	0.46	0.48	0.84	0.94	0.92	0.83
<i>land-exchange nat.</i>	0.03	0.00	1.00	0.02	-0.05	-0.07	-0.09	-0.02	-0.02	0.01	0.02	-0.09	-0.07	-0.08	-0.09
<i>conserv. Areas</i>	0.01	0.00	0.02	1.00	-0.01	0.46	0.23	0.38	0.35	-0.24	-0.24	0.24	0.11	0.13	0.21
<i>frac growth within nat. conserv. areas</i>	-0.01	0.00	-0.05	-0.01	1.00	-0.55	0.85	-0.77	-0.81	0.44	0.45	0.89	0.98	0.96	0.89
<i>nr of farms</i>	0.29	0.00	-0.07	0.46	-0.55	1.00	-0.11	0.95	0.93	-0.58	-0.60	-0.12	-0.37	-0.30	-0.15
<i>land traded</i>	0.17	0.28	-0.09	0.23	0.85	-0.11	1.00	-0.38	-0.44	-0.03	-0.03	0.96	0.93	0.94	1.00
<i>milk production</i>	0.27	0.00	-0.02	0.38	-0.77	0.95	-0.38	1.00	1.00	-0.60	-0.62	-0.40	-0.62	-0.56	-0.42
<i>dairy cows per farm</i>	0.21	0.00	-0.02	0.35	-0.81	0.93	-0.44	1.00	1.00	-0.59	-0.61	-0.46	-0.67	-0.62	-0.48
<i>UAA per farm</i>	-0.20	-0.80	0.01	-0.24	0.44	-0.58	-0.03	-0.60	-0.59	1.00	1.00	0.20	0.34	0.31	0.04
<i>costs per 100 l milk</i>	-0.19	-0.78	0.02	-0.24	0.45	-0.60	-0.03	-0.62	-0.61	1.00	1.00	0.20	0.35	0.31	0.04
<i>revenues p 100 l milk</i>	0.18	0.00	-0.09	0.24	0.89	-0.12	0.96	-0.40	-0.46	0.20	0.20	1.00	0.97	0.98	0.97
<i>dairy cows</i>	0.06	0.00	-0.07	0.11	0.98	-0.37	0.93	-0.62	-0.67	0.34	0.35	0.97	1.00	1.00	0.95
<i>UAA</i>	0.09	0.00	-0.08	0.13	0.96	-0.30	0.94	-0.56	-0.62	0.31	0.31	0.98	1.00	1.00	0.96
<i>costs</i>	0.16	0.23	-0.09	0.21	0.89	-0.15	1.00	-0.42	-0.48	0.04	0.04	0.97	0.95	0.96	1.00
<i>revenues</i>															

Metamodelling using regression

Just like Happe et al (2006) we used the DOE-experiments to create a meta-model per model output variable. We estimated per model output variable a multiple linear regression line using the five parameters (which were changed during DOE-experiments (table 7.2)) as independent variables. The output variables were the variables to be predicted in the regressions, the so called dependent variables. Results of the regression are presented in table 7.7.

On average the multiple R^2 is rather high except for the amount of traded land. The factor exchange of land from farmers outside NCA's to farmers inside NCA's is not a relevant factor in the estimated regressions. Milk price, search radius and probability on growth are in this context most relevant factors or variables.

Furthermore we tested for normality of errors (Shapiro test; table 7.7) and heteroscedasticity (Breusch-Pagan test; table 7.7). As we can see the errors of the estimated regression lines are not normally distributed nor heteroscedastic. As is mentioned in section 7.4.1 we also can estimate neural networks as a meta-model but for purposes of understanding we use multiple linear regression.

Table 7.7 Results for estimated multiple linear regression lines

Dependent variable	Independent variables *)						R^2	Test p-value	
	Search radius	Milk prod. Development	Milk price	UA A Exchange	Growth prob.	Inter-cept		Shapiro	Breusch-Pagan
Number of farms			10612.4			14828.3	0.971	< 0.001	0.835
Milk production	32467	111100	4181098		764240	9302580	0.802	< 0.001	0.984
Land traded	1098.1		-65129.4		31182.2	87749.3	0.689	<0.001	0.835
Dairy cows per farm	0.2377		-19.0824		5.7395	81.3842	0.673	0.030	0.673
UAA per farm	0.0617		-6.8118		1.8410	48.5602	0.893	0.020	0.534
Costs per 100 l milk	-0.0535	-0.4443	3.4157		-1.1738	49.7301	0.95	0.050	0.847
Revenues per 100 l milk	-0.0100	-0.0850	0.6902		-0.2263	47.927	0.940	0.022	0.867

*) Only significant contributing independent variables are taken into account

How reliable are the meta-models? For instance what if we predict the number of farms with the meta-model? Table 7.8 shows the reconstruction results for the reference scenario B1.

Some meta-models perform well but the meta-model for traded land is not sufficient for predicting purposes. We conclude that the selected independent factors not fully declare the development of traded land.

Table 7.8 Calculated model results with the original ABM model and with an estimated meta-model

Dependent variable	Calculated with meta model	Calculated with ABM	% difference
Number of farms	17970	18525	-3
Milk production (1000 ton)	11369	12507	-9
Land traded (ha)	55528	89336	-28
Dairy cows per farm	76.9	82.2	-6
UAA per farm	46.85	48.5	-3
Costs per 100 l	47.81	46.74	+2
Revenues per 100 l	47.57	47.4	+0

Summarizing conclusions about the DOE-experiments are:

- Although relevant in one-at-the-time sensitivity analysis the effect of land exchange between non NCA's and NCA's is shaded by the other factors search radius, autonomous milk production, milk price and growth probability within the NCA's.
- Number of farms can rather well be predicted by milk price.
- Costs en revenues per 100 litre milk can well be predicted.
- The amount of exchanged land and number of dairy cows are not completely covered by the five selected factors in the DOE-experiments. For land exchange it might also have to do with the choice of multiple regression instead of another technique.
- Milk price is affecting all model output.

7.5 Uncertainty model outcomes

In the model some choices and parameters are stochastic. As mentioned in section 6.5 stochastic elements in the model are applied when determining farm quitting, probability on farm expansion and development in farm intensity. Farm quitting and probability on farm expansion are sampled from a uniform distribution and development on farm intensity is presumed to be normally distributed.

Each result presented in the previous sections and chapters is an average of 3500 model runs. An interesting question to rise is: what is the range of the outcomes?

To answer this question we examined the spread in results of the reference scenario (table 7.9 and figure 7.1). The spread in results is low. In absolute value the spread (max value minus min value) is the largest for milk production (211809 litres) which is 1.7% of the mean value. The corresponding confidence intervals are also small.

Table 7.9 Statistical key-figures of the model outcomes for the reference scenario

	number of farms	land traded (ha)	milk production (ton)	dairy cows per farm	UAA per farm	costs per 100 l milk	revenues per 100 l milk
min	18351.00	86768.73	12397590.00	81.63	48.24	46.61	47.33
max	18674.00	91360.30	12609400.00	82.80	48.77	46.87	47.37
median	18528.00	89356.10	12507260.00	82.23	48.52	46.74	47.35
mean	18528.00	89336.09	12506850.00	82.23	48.52	46.74	47.35
st.dev	46.92	623.22	30386.27	0.16	0.07	0.03	0.01
95% confidence interval							
min-val	18526.45	89315.44	12505843.30	82.23	48.52	46.74	47.35
max-val	18529.55	89356.74	12507856.70	82.24	48.53	46.74	47.35

We tested whether the distributions of the outcomes are normal distributions. It appeared that the distribution of land traded, milk production, UAA per farm and revenues per 100 litre milk are not normal distributed (Shapiro test: p-value < 0.05). Therefore the 95% confidence interval is not applicable as it assumes normality.

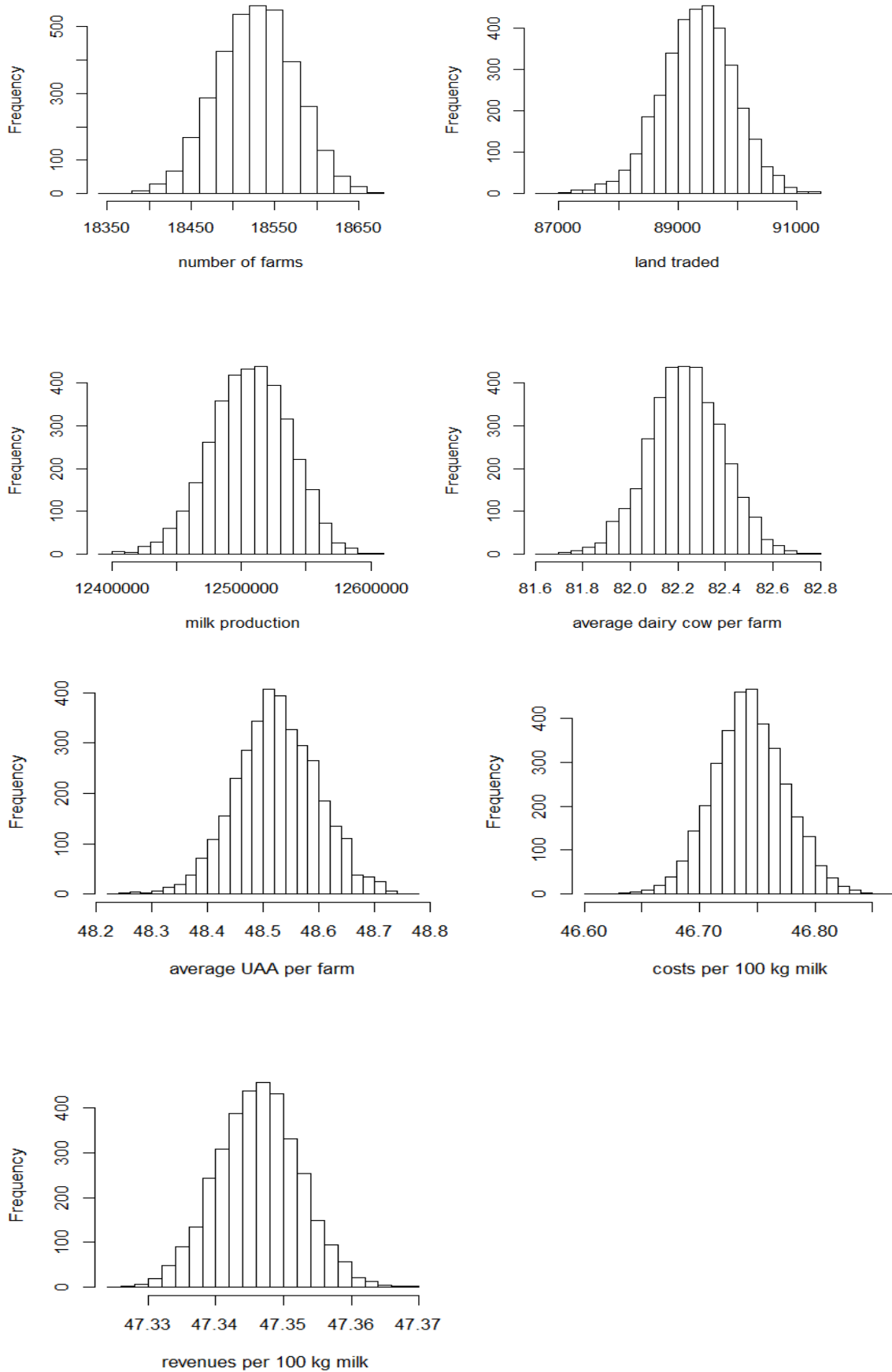


Figure 7.1 Histograms of the model outcomes of the reference scenario

8 Results

This chapter shows the effect of quota abolition for primary Dutch Dairy sector. We also pay attention to graphical outcomes of the model. At last we compared our model results with other research.

8.1 Effects of quota abolition of farm structure

Goal of the study is to assess the effects of abolition of milk quota for the Dutch dairy sector using Agent Based Modelling. Our approach was to take 2006 as base year and calculate the effects for 2011 having the quota system present and not present.

We calculated the situation for 2011 with the quota system still present and for 2011 without the quota system (table 8.1). Hereby we used the input parameters of table 6.8 for both situations in 2011 except two parameter values. For 2011 with the quota system present we assumed no significant change in farm intensity and as described in the calibration section 7.1, autonomous milk production per dairy cow was assumed to be 2.4% instead of 6% (section 5.1).

As results we see an increase in number of dairy cows for the Netherlands as a whole and in the number of dairy cows per farm. The increase in dairy cows and the increase in autonomous milk production development per dairy cow induce a total milk production increase as well.

As costs per unit of milk decreases with an increase of number of dairy cows we also see a decrease in costs per unit milk.

Farmers receive premiums as a lump sum per farm. The consequence is that when milk production increases on the farm the amount of income from premiums will be less per unit of milk.

Table 8.1 Effects of quota abolition on farm structure and other indicators for 2011

Source	Parameter	Quota system present		Quota system abolished
		Measured	calculated	calculated
Annual Census	Number of dairy cows	1465 * 1000	1475 *1000	1523*1000
	UAA (ha)	886 * 1000	902 *1000	899 *1000
	Number of farms	18624	18528	18528
	UAA per farm	47.6	48.7	48.5
	Dairy cows per farm	78.8	79.6	82.2
FADN	Costs per 100 kg milk	53.4	56/48 ¹³	46.7
	Revenues per 100 kg milk	49.5	47.8	47.4
Other	Milk production (kg)	11738 * 1000	11707 *1000	12507 *1000

Point for improvement is the assumed change in farm intensity. Although it's very likely that farmers will intensify after quota abolition and thereby reduce their costs, there are oppositely-acting forces (see section 6.3.2) as change in fodder costs and manure removal costs. These factors are here not

¹³ 56 -> with autonomous costs development, 48 without autonomous cost development

taken into account moreover the assumed change in farm intensity is based on data of 2001-2006. In this period there was no concrete view on quota abolition so the behaviour in that period doesn't reflect the presumable change in farm intensity.

8.2 Graphical results

Next two pages show some graphical results of some model outcomes and scenarios. The figures present the average farm size per grid of 4 km². Yellow-green means an average farm size of less than 80 dairy cows per grid and blue means an average farm size of 80 dairy cows and more.

Table 7.1 shows an increase in average farm size from 66.7 in 2006 to almost 80 in 2011 having the milk quota system present. Figure 8.1 shows this difference as well when comparing 2006 with 2011 with quota system present (upper part of the picture). The difference between 2011 with and without quota system is presented in the under part of figure 8.1. In 2011 without the quota system average farm size is 82 dairy cows. This is a small difference which can hardly be seen except in the area west of the Veluwe. Here in 2011 without quota we can see some more blue dots compared with 2011 with quota.

Figure 8.2 shows the effects of no farm expansion in NCA's and for increase of stock density. The effects of no farm expansion in the NCA's can best be seen in the middle of the Netherlands (Utrecht, Gelderland) and the South (Brabant and Limburg).

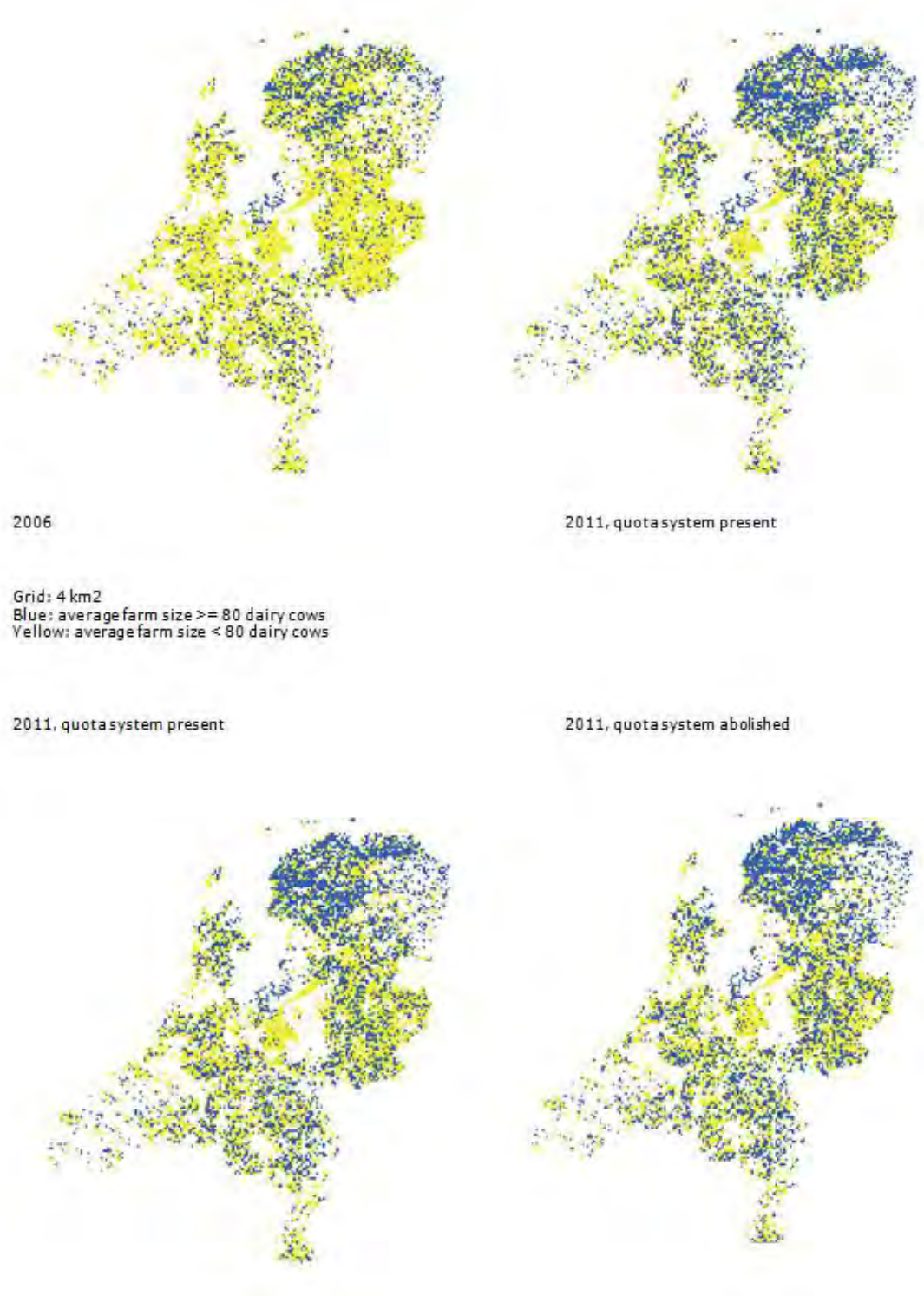


Figure 8.1 Average farm size per grid (4 km²) in different situations



Figure 8.2 Average farm size per grid (4 km²) in different situations in 2011 without quota

8.3 Validation

8.3.1 Introduction

“Validation processes attempt to demonstrate whether the simulation is a good model of the target phenomena. A model that can be relied on to reflect the behaviour of the phenomena is valid” (Cooley and Solano, 2011, p. 128).

As in our research we want to predict phenomena which never happened before, validation of our model will be difficult. This problem of validating such non-observable systems is also addressed by Sargent (2007). He defines operational validity as

“Operational validation is determining whether the simulations model’s output behaviour has the accuracy required for the model’s intended purpose over the domain of the model’s intended applicability” (Sargent, 2007, p. 130).

He classifies the testing of operational validity into four categories depending on whether the model functions in an observable or non-observable system and whether the approach of validation will be subjective or objective. As our model predicts for an event in the future (abolishing milk quota) we have to do with a non-observable system. We would prefer an objective approach but according to Sargent then we would have to compare with other models using statistical tests. Moreover, as our model works on a different level compared with the models we compare with (those models produce results at national average level) we cannot perform statistical tests.

Having evaluated the above arguments we restrict ourselves to an operational validation of a non-observable system using a subjective approach. Sargent (2007) mentions for this category: explore model behaviour and comparing results with other models. According to Sargent for this category of systems (not-observable) it is not possible to obtain a high degree of confidence in the model. In the previous chapter we already described a sensitivity analysis (one at a time and DOE) and uncertainty analysis which can be seen as elements in exploring the model behaviour (Sargent, 2007). In this section we will describe comparing model outcome with other models as described in chapter 3.

8.3.2 Validation Results

First we compared the results for 2011 with and without quota system (table 8.2).

Table 8.2 Model results for 2011 with and without quota

Source	Parameter	2011: with quota		2011: without quota
		Measured	calculated	calculated
Annual Census	Number of dairy cows	1465 * 1000	1475 *1000	1525 * 1000
	UAA	886 * 1000	902 *1000	899 * 1000
	Number of farms	18624	18528	18527
	UAA per farm	47.6	48.7	48.5
	Dairy cows per farm	78.8	79.6	82.3
	Cow per UAA	1.65	1.64	1.69
FADN	Costs per 100 kg milk	53.42	56/48	46
	Revenues per 100 kg milk	49.51	47.76	47.30
Other	Milk production	11738 * 1000	11707 *1000	12530 * 1000

The model predicts an increase in milk production in 2011 of 7% when the quota system will be abolished.

Then we compared results with other research (table 8.3) about effects of abolishing the quota system. In chapter 4 we already presented for research used in the validation the percentage change

in milk production when the quota system would be abolished, compared to situation with the quota system present. In table 8.3 we recalculated this percentage change to absolute values of milk production and also present change in absolute values of number dairy cows. We have to take into account that the difference in absolute amount is valid for the specific year research is applied to. While these years are different between the studies we chose, comparing of the data is difficult.

Although our results show the lowest development in milk production and dairy cows they are not unrealistic if we take into account that in our model we implemented the most recent insight about effect of NCA's on farm expansion probabilities.

Table 8.3 Estimated numbers of dairy cows and milk production in case milk quota has been abolished according to several studies

Source	Absolute values		Index (our research = 100)	
	Milk production (1000 litre)	Number of dairy cows (in 1000)	Milk production	Number of dairy cows
Helming and Peerlings (2002)	16051	1850	128	121
Helming and van Berkum (2008)	13229	1430	106	94
Lips and Reader (2005)	12573		100	
EU (2009)	13471	1639	108	108
Our research	12530	1525	100	100

Veenstra and Vessies (2008) calculated effects per farm (table 8.4). They estimated the farm structure two farm types (average farm and intensive farm) and for two cases with and without quota. In the situation of presence of the quota system, neither stable expansion nor extra rent of land was allowed. Without the quota system stable expansion was allowed with rent of land and without rent of land. Table 8.2 shows the results for an average farm without the quota system present as we produce with our model the average farm. Furthermore we didn't compare with the system with the quota system present as the model of Veenstra and Vessies is static. Which means that the results with and without quota are based on the same year. This year is not deductible from the report of them.

Table 8.4 Results of the study of Veenstra and Vessies (2008) and our research for an average farm

Indicator per farm	No quota		Our research
	Stable expansion/ no rent of land	Stable expansion and rent of land	Stable expansion and land expansion
Number of dairy cows	80	180	82
UAA	42	94	48.5
Stable capacity	126	282	
Quota per farm (1000 litre)	619	1386	676
Milk per cow	7738	7738	8244
Milk per ha	14735	14735	13938

Here (table 8.4) our model results show a bit higher milk production per cow compared to Veenstra and Vessels as we took into account development in milk production through the years while Veenstra en Vessels kept milk production fixed.

Tonini et al (2011) performed results per farm and region. For the Netherlands hardly any change in production could be seen after abolishing of milk quota (increase with 0.7% compared with 2006) but per farm size there were differences. They found that after quota abolition milk production increased on small dairy farms while in large farms milk production stayed the same.

We simulated the growth of milk production on farms using one single run which has comparable output with the average of 3500 simulations.

The results of our model also indicate a stronger increase in milk production in terms of percentage than larger farms (up to 130 dairy cows) (figure 8.3). We also added a linear regression line in the figure (8.3) (fraction increase = $0.47 - 2.27 \text{ E-}5 * \text{quota}$).

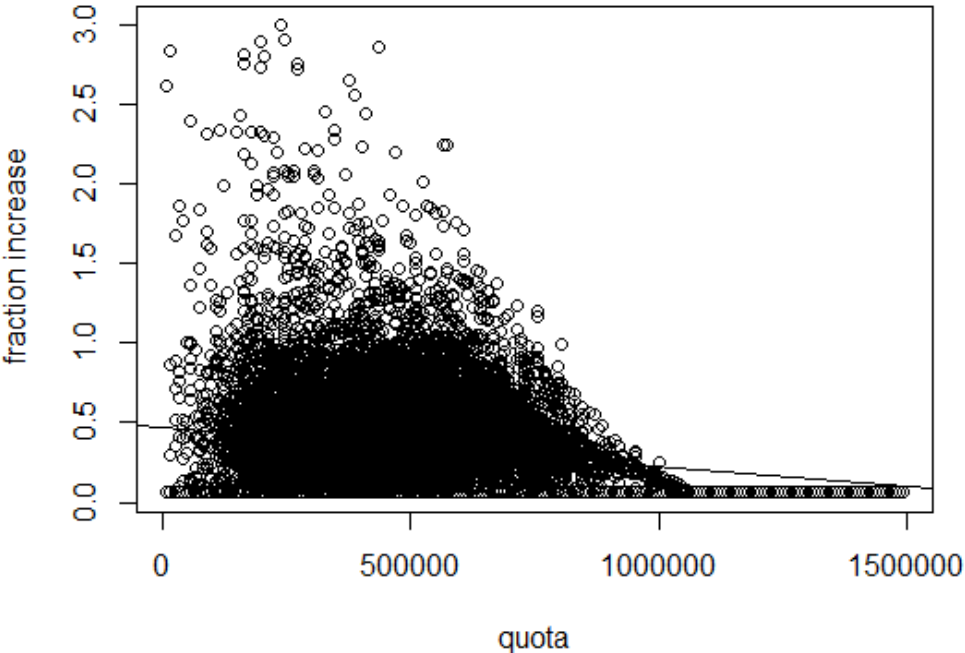


Figure 8.3 Increase in milk production per farm (in terms of percentage) related to farm size measured in quota.

When we look at the changes in absolute values then larger farms increase most. Summarizing we can say that the model-model validation shows that the effects of quota abolition on milk production, number of dairy cows and other are not divergent from other studies although the effects assessed with our model show the smallest effects. This can be explained by the modelling of farm expansion probabilities in NCA's. These expansion possibilities are limited and not included in the calculations of the other models discussed here.

9 Conclusions

With the developed model we can assess the effects of abolition of milk quota for the Dutch dairy sector expressed in changes of farm structure, milk production and costs and revenues. Our results show effects on national level and on average farm level.

When we compare our research with other studies about effects of quota abolition, our model results are within the range of other models (milk production and number of dairy cows at national level). Having model results in line with other model results is not an exclusively reason for the predictive quality of the model. We compared our results with models having a different reference year, acting under different policies and with other technical assumptions like development in milk production. Furthermore our model takes into account the location of the farm in relation with NCA's affecting expansion possibilities which was not done in the other models.

The uncertainty range in the model results is very small (minimum value is less than 0.02% from maximum value).

In case of further use of the model more attention should be paid to the issue of change in farm intensity.

Sensitivity analysis shows that milk price and development in livestock density are the most important factors in the development of farm structure. The problem with change in livestock density is that the used development parameters (including the distribution) are pure hypothetical. Therefore we didn't take livestock density as a factor in the DOE-experiments.

Search radius is a non-linear factor and appeared to be relevant in predicting almost all selected output parameters. If we double the search radius the number of dairy cows per farm increases with less than 1%. Otherwise if we decrease search radius with 60% (3 km) number of dairy cows per farm reduces with 3.5%.

With the results of the DOE-experiments it is possible to make meta-models for output parameters like milk production, number of dairy farms and so on using four input factors: search radius, milk price, milk development per cow and expansion probabilities in the NCA's. Before doing so it is advisable to expand the DOE-experiments with more observations (then 43 observations are not much) and estimated meta-models can be based on coincidence.

10 Discussion and recommendations

With the developed model we can access the effects of abolition of milk quota for the Dutch dairy sector expressed in changes of farm structure, milk production and costs and revenues.

As abolition of milk quota never happened before it is difficult to validate the model. We compared results (milk production and number of dairy cows at national level) with other studies about effects of quota abolition for validation. Our model results are within the range of other models although having model results in line with other model results is not an exclusively reason for the predictive quality of the model. The models we compared our results with, were validated in other research using ex-post validation. Hence these models can neither validate their model outcomes in case of quota abolition as we can.

We see our model as a start or prototype with possibilities for model extensions.

To make those model extensions possible workable we first of all would advise to convert the model from Netlogo to Repast-Java or another comparable language. Depending on the search radius the time to run 3500 simulations varies from 1 hour and 15 minutes to 2.5 hour using an Apple notebook with an SSD drive and eight processors. We also used a standard LEI-computer with a HDD drive and four processors for some runs. Here a simulation of 1 hour and 15 minutes at an Apple took 3.5 hours.

Extensions we think of are:

- Model the relation between need for fodder and fodder price and uptake this in the cost calculations. Adapt the model in such a way that the system of land exchange stops when there's equilibrium between costs, farm intensity and fodder demand.
- Include in the above system a market module for milk at national level. When milk production increases and consumption of milk stays at the same level, prices would decline. Applying this relationships means that you can calculate equilibrium in supply and demand. As start consumption could be set exogenously.
- Regional output: Results of the model are aggregates at national level but these changes might not occur on farm level as in some regions farms can less expand as a result of presence of NCA's.
- Introducing farm styles for national level and later on when data is available for regional level.
- Applying a market module for land at regional level like Valbuena et al (2010) or Schouten (2012). Another option would be to implement our milk production rules and effects on structure and costs and revenues into their model
- Environmental indicators can be linked such as emissions and manure surplus. It's also an option to link the model with the model MAMBO from LEI. MAMBO is a farm based model covering all farms from the Annual Census and is used for estimating environmental effects of policies.

Abbreviations

ABM	Agent Based Modelling
ACE	Applied General Equilibrium models
AI	Artificial Intelligence
AWU	Annual Working Unit
BDI	Belief, Desire and Intentions (used for indicating agent type)
CA	Cellular Automata
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regionalized Impact
CBS	Centraal Bureau voor de Statistiek
CML	Conceptual Modelling Language
DOE	Design of Experiments
DRAM	Dutch Regionalised Agricultural Model
EMS	Ecological Main Structure areas
EU-15	European countries at 1th of January 1995 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom)
EU-27	European countries at 1th of January 2007 (EU-15 +Poland, Czech Republic, Cyprus, Latvia, Lithuania, Slovenia, Estonia, Slovakia, Hungary, Malta, Bulgaria and Romania)
FADN	Farm Accountancy Data Network
GTAP	Global Trade Analysis Project
KBS	Knowledge Based Systems
LAEA	Lambert Azimuthal Equal Area projection
LEI	Landbouw Economisch Instituut or Agricultural Economic Research Institute
LUCC	Land Use/Cover Change
MIP	Mixed Integer Programming
MTR	Mid-Term Review
NCA	Nature Conservation Area

Nge	Nederlandse Grootte-eenheid
NSO	Dutch variant on European Standard Output types
ODD	Overview, Design concepts and Details
PRS	Procedural Reasoning System
UAA	Utilizable agricultural area
WUR	Wageningen University and Research Centre

Definitions and further explanations

Agenda2000

“Agenda 2000 explicitly established economic, social, and environmental goals within a new reformulated set of objectives for the CAP consistent with the requirements of the Amsterdam Treaty.

This had the aim of giving concrete form to a European Model of Agriculture and preserving the diversity of farming systems spread throughout Europe, including regions with specific problems, in the years ahead” (EC, 2012)

Agenda2000 implies for the dairy sector that intervention prices will decrease from 2005 each year with steps of 5% and that dairy farmers will partly be compensated for this loss by direct payments per kg milk. Furthermore the quota system will be maintained for at least 6 years (Helming and Peerlings, 2002)

Annual Census: each farm in the Netherlands of a relevant size has to fill in each year the composition of his farm like number of animals per type, crop area per crop type, age, location, number of employees and so on. In some years additional data is required like parcelling, allotment, presence of a successor. No financial data is asked for. Data is gathered and further processed by CBS and LEI. Aggregated data can be entered by Statline from CBS (n.d.) or Wijsman (2013).

Behaviour Space: a software tool integrated in NetLogo with which you can perform multiple experiments and also vary at the same time parameter values. More information about Netlogo and the functionality Behaviour Space can be found on <http://ccl.northwestern.edu/netlogo/docs/behaviorspace.html>.

Binternet

Binternet is a user friendly interface with which predefined tables from Dutch FADN can be retrieved (LEI, 2013a);

Decoupled payments

In earlier year farmers were supported with payments coupled to production. The more a farmer produced the more payments he or she would receive. Since 2003 the EU is changing the system of payments to a system of decoupled payments where payments are no longer related to production.

Derogation

“A derogation is a provision in an EU legislative measure which allows for all or part of the legal measure to be applied differently, or not at all, to individuals, groups or organizations” (Eurofound, 2007).

In the context of this research we talk about derogation of the Nitrate directive. According to the Nitrate Directive the maximum application of animal manure on a farm is not allowed to exceed 170 kg N per ha. In the Netherlands derogation is obtained. Farms having at least 70% of their UAA used as grass are allowed to apply 250 kg N from animal manure (only cattle).

FADN: Farm Accountancy Data Network. *“FADN is a micro economic database containing information on agricultural holdings in EU member states” (Happe et al, 2006).* Information consists

of agricultural structural data (as in the Annual Census but more extended) and financial data like production costs, factor input and subsidies. More information can be found at European Commission (n.d.).

Luxemburg agreement 2003

"A formal decision on further "CAP reform - a long-term perspective for sustainable agriculture" was taken by the EU Council of farm ministers meeting in Luxembourg on 26 June 2003. The reform includes far-reaching amendments of current policies, including further reductions in support prices, partly offset by direct payments and a further decoupling of most direct payments, such as the new single farm payment from current production. The different elements of the reform will enter into force in 2004 and 2005. A single farm payment will enter into force in 2005. If a member state needs a transitional period due to its specific agricultural conditions it may apply the single farm payment from 2007 at the latest" (OECD, 2005).

NSO farm type

NSO farm type is a farm type classification based on the European Standard Output type and adapted to the Dutch agricultural situation. The NSO classification exists of 9 main categories and 38 subcategories. We use in our research NSO 4500 for specialized dairy farms. More information about this farm type can be found at LEI (2013b).

Nuts-regions

The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU for the purpose of:

- The collection, development and harmonisation of EU regional statistics.
- Socio-economic analyses of the regions.

There are three layers:

- NUTS 1: major socio-economic regions
- NUTS 2: basic regions for the application of regional policies
- NUTS 3: small regions for specific diagnoses

Nuts1 regions are countries or EU-members. In the Netherlands Nuts2-regions are Provinces and Nuts3 regions are Corop-areas.

See Eurostat (2012) for more information.

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Appendices

1 Optimal farm scale

In this appendix we describe the estimation of the optimal farm scale for specialized dairy farms.

1.1 Material

We used costs and number of dairy cows data of 2006 from the research of Tonini et al (2011) to estimate the relationship between number of dairy cows and total costs (paid and non-paid costs) per litre milk.

We eliminated one observation of total costs of 3646 euro per ton milk. This observation could very well be an error for costs were extremely high where milk production was low. Other data of this farm indicated that the cows produced around 1800 litre milk per cow which is very odd.

1.2 Results

We estimated an exponential relationship (figure A1.1) as

$$\text{Total costs per ton milk} = 359.436 + 622.7703e^{-0.0385 \cdot \text{cow}}$$

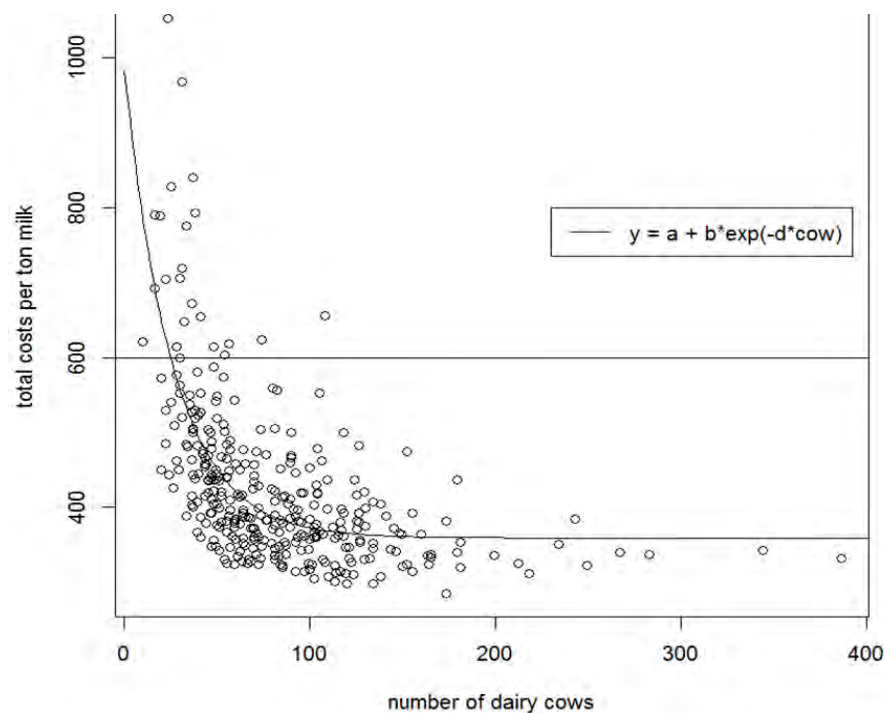


Figure A1.1 Relationship between number of dairy cows and total costs per ton milk.

Based on the relationship above we calculated for a farmsize of 130 dairy cows and up that an increase of one cow results in an increase of less than 1% of total costs per ton milk. .

Therefore we consider 130 dairy cows as the optimal farm scale. Farmers can grow more however this growth will have no scale effect. At a certain farm size (> 400 dairy cows or more) costs will even increase. Those farms could better decrease their number of cows or invest in new technologies (see Mansfield (1988)).

2 Costs and revenues

In this appendix we present some definitions of costs, revenues and other (financial) indicators. We join the definitions of those in the Dutch FADN and as they are presented at LEI (2013a).

Costs

Costs can be divided into paid and non-paid costs. Paid costs can be divided into attributed costs and non-attributed costs. Non-paid costs consist of calculated costs for labour of entrepreneurs, spouses, other family labours and other volunteers and of calculated costs for capital like land (figure A2.1).

Total costs	Paid costs	Attributable	
		Non-attributable	
	Non paid costs/ calculated costs	Costs non-paid labour	
		costs capital	Land
			Other tangible assets
Organic assets			
Monetary assets			
Costs as it is in cost-ratio	Paid costs		
	Non paid costs for capital		

Figure A2.1 Composition different costs (van der Veen et al, 2006)

In the decision making on a long term farmers do not take labour of themselves and of direct family into account. Costs in the cost-revenue ratio are regarded as costs without calculated costs for labour.

In the model we use costs and prices of 2006 for decision making and costs and prices of 2011 for presenting the model output. Final costs are multiplied with costs development between 2006 and 2011 to cover also land increase and other developments.

Revenues

Revenues are calculated as the sum of Turnover and growth of cattle, EU-payments, milk and other income.

Turnover and growth of cattle is based on FADN-data for 2006 (LEI, 2013a).

EU-payments are taken from a dataset of Support schemes service of the Ministry of Economic Affairs. This dataset contains payments in 2009 to all farmers in the Netherlands. If farms taken from the Annual Census couldn't be traced in premium dataset, a premium of 3.30 euro per 100 litre milk is used (LEI (2013a)).

Revenues from milk are the product of number of dairy cows, milk production per dairy cow and milk price.

Other income (like day tourism, garaging caravans and other) is set to 56 euro per cow based on FADN-data for 2006.

Cost-revenue ratio

Cost-revenue ratio is the quotient of costs (excluding non-paid labour) and revenues.

Other financial indicators

The model output also contains the variable Net result. Net result is defined as the difference between revenues and costs. Net result per 100 l milk is the quotient of Net result and milk production (in 100 l).

3 Estimating costs for farms

Long run average costs are estimated with farm inputs. Inputs are derived from Dutch FADN data and costs are derived from the research of Tonini et al (2011) for the year 2006.

3.1 Multiple linear regression

We used two methods to estimate costs for each farm: multiple linear regression and neural networks. We applied multiple linear regressions in the model as this will improve the acceptance of the Agent Based Model.

Multiple linear regression:

The model final is defined as:

$$\text{Log(costs)} = a + b * \text{log(dairy cows)} + c * \text{FNSO} + d * \text{f_grass}$$

With:

- FNSO = 0 in case of a dairy farm (NSO = 4500) and FNSO = 1 in case of non-specialized dairy farms with 20 dairy cows or more
- f_grass = grass area / UAA

Other variables used in the first model are age, non-paid family labour, fraction land property and UAA. These variables were removed using backward elimination.

We used weighted linear regression with the farm FADN weight factor. The regression results are presented in Table A3.1

Table A3.1 Estimated regression coefficients with dependent variable log(costs)

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	8.46147	0.12009	70.46	< 2.00E-16
log(COW)	0.90578	0.02662	34.028	< 2.00E-16
f_grass	-0.2059	0.04106	-5.016	8.62E-07
factor(FNSO)1	0.21529	0.05659	3.805	0.000169

Residual standard error: 1.963 on 331 degrees of freedom

Multiple R-squared: 0.8015, Adjusted R-squared 0.7997

F-statistic: 445.6 on 3 and 331 DF, p-value: < 2.2e-16

Errors

The plots to check the errors look quite nice for normality and constancy of variance (figure A3.1)

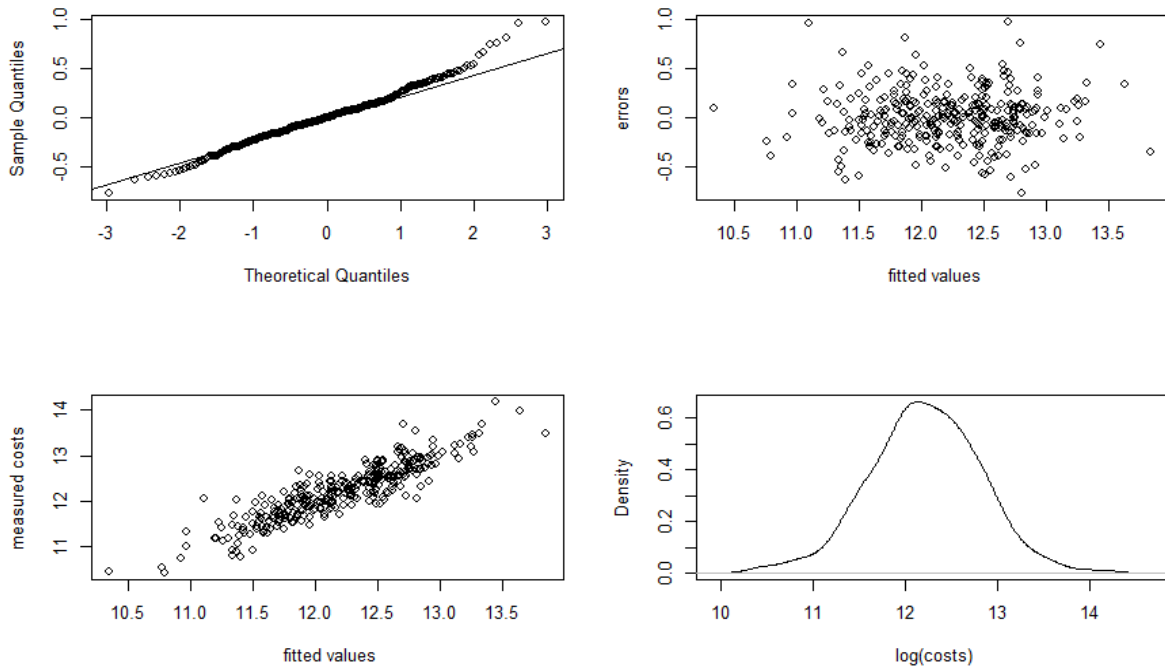


Figure A3.1 Plots to check errors on normality and constancy of variance

Tests for normality and constancy of variance show that the errors do not meet the restrictions (using significance level (α) of 0.05) belonging to the use of multiple regression. The p-value for the normality test (Shapiro-Wilk) was 0.003 and the p-value for the Breusch-Pagan test was 0.004 (homoscedasticity).

Therefore we conclude that errors are not normally distributed, nor the restriction of constant errors for the estimated multiple regressions are fulfilled. We decided to estimate also a neural network as an alternative.

3.2 Neural network

The weights of the attributes in the estimated network are presented in Table A3.2.

Correlation between predicted and measured costs is 0.88.

Table A3.2 Attribute weights in the estimated neural network

	weight
Node 1 (Sigmoid)	

logMelkkoe:	-3.176
FNSO:	-0.36
f_eigendom:	0.482
Bias:	-2.707
Node 2 (Sigmoid)	

logMelkkoe:	-1.794
FNSO:	0.25
f_eigendom:	-0.446
Bias:	-2.292
Node 3 (Sigmoid)	

logMelkkoe:	3.941
FNSO:	0.561
f_eigendom:	0.18
Bias:	-1.819
Output	
=====	
Regression	(Linear)

Node 1:	-0.892
Node 2:	-1.068
Node 3:	1.183
Threshold:	-0.096

4 Farm quitting

Farm quitting can be classified as cost quitting and random quitting. Farmers quit because production costs of milk are (constantly) higher than revenues. Random quitting is the process that farmers quit due to illness, urban extension, no successor and other. In this appendix we estimate probabilities on farm quitting for both quitting types. The probabilities on farm quitting for 2006-2011 are based on quitting probabilities for 2001-2006.

4.1 Approach

Cost quitting

We estimated a cost-function (multiple regressions) for 2001 from the (FADN-) dataset of Tonini et al (2011) completed with Annual Census data. This cost function can be applied together with revenue calculation to farms of the Annual Census of 2001. We distinguished two groups of farms: specialized dairy farms (NSO = 4500) and non-specialized dairy farms (NSO <> 4500 and 20 or more dairy cows). We checked the presence of the farms in 2006 and applied the estimated cost-function to these farms. We used this information to estimate probabilities for farm quitting per age-class and farm size.

Estimated model

The estimated model is:

$$\text{Log}(\text{Costs}) = a + b * \log(\text{dairy cows}) + c * f_{\text{grass}} + d * \text{factor}(\text{FNSO})$$

The estimated coefficients are presented in table A4.1

Table A4.1 Estimated coefficients of linear model predicting costs

	Estimate	Std. Error	t value	Pr(> t)
(Intercept)	8.44765	0.17311	48.798	< 2e-16
b	0.96061	0.03484	27.573	< 2e-16
c	0.25968	0.05788	4.487	1.23E-05
d	-0.50652	0.094	-5.389	2.00E-07

Check on the errors

The errors are normally distributed. We tested this with Shapiro-Wilk normality test (significance level α 0.05). Error-plots are presented in figure A4.1.

data: errors1

W = 0.9906, p-value = 0.2153

We tested with ncvTest on non-constant error variance.

Non-constant Variance Score Test

Variance formula: ~ fitted.values

Chi square = 1.441428 Df = 1 p = 0.2299084

We accept H0, the errors do have a constant error variance.

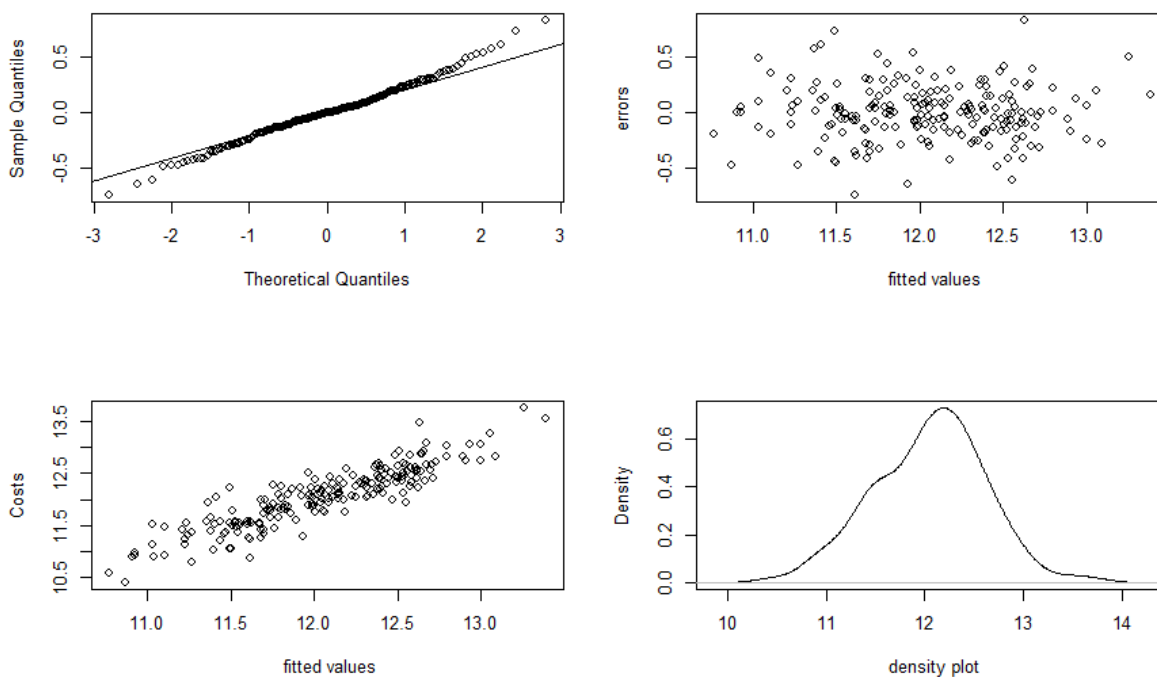


Figure A4.1 Error plots to check normality and homoscedasticity.

4.2 Probabilities

We found that not all farms with a cost-revenue ratio 1 or higher quit farming (table A4.1)

Table A4.2 Continuing farms between 2001-2006, related to cost-revenue ratio, farm size and age (number of farms)

age	cost-revenue ratio ≥ 1				cost-revenue ratio < 1			
	quit		continued		quit		continued	
	< 20	≥ 20	< 20	≥ 20	< 20	≥ 20	< 20	≥ 20
< 50	33	287	143	2786	14	715	72	7113
50 -65	89	338	242	2348	38	1012	128	6255
≥ 65	94	205	234	887	54	531	79	2118
Total	216	830	619	6021	106	2258	216	15486

We derived the probabilities of quitting from Table A4.2. For instance there are 176 farmers in 2001 with an age younger than 50, less than 20 dairy cows and a cost-revenue ratio 1 or higher. From this group 33 farmers stopped farming, which is 18.8%.

Table A4.3 probability of farm quitting

age	cost-revenue ratio ≥ 1		cost-revenue ratio < 1	
	< 20	≥ 20	< 20	≥ 20
< 50	0.188	0.093	0.163	0.091
50 -65	0.269	0.126	0.229	0.139
≥ 65	0.287	0.187	0.406	0.200

The probabilities for farms with a cost-revenue ratio < 1 are used to express random farm quitting.

It might be surprising that older farmers with a cost-revenue ratio smaller than 1 and less than 20 dairy cows are more likely to quit farming than those farmers with a cost-revenue ratio of 1 or higher. We have to take into account that farmers with less than 20 dairy cows in our population are specialized dairy farmers as we excluded non-specialized dairy farmers with less than 20 dairy cows. Non-specialized dairy farms in our population do have on average a higher costs per unit milk as total costs cannot only be assigned to milk production. On non-specialized dairy farms the main agricultural production is non-dairy. This is a bias in the model. True this bias it is likely that farmers with only 20 dairy cows or less are more in favour of quitting compared to the same population (age) who are likely to have other production branches. Farmers with only 20 dairy cows or less are more in favour of quitting compared to the same population (age) who are likely to have other production branches.

5 Nature conservation areas

In this appendix we describe the location of farms from our selected population (specialized dairy farms and non-specialized dairy farms with at least 20 dairy cows) in relation with the position of EMS and Nature2000 areas. Furthermore the development of these farms between 2001 and 2006 has been calculated from Annual Census data.

5.1 Situation 2006

We have information about the location of farms relative to position of EMS and Nature 2000 areas for 2006. We defined three situations per landscape type (EMS, Nature2000): within 500 meter of an area type, within the area type and outside the influence of the area type. Combining these three situations for two landscape types, results in 9 possible location types (Table A5.1).

Table A5.1 Definition of location types

	Within 500 m of Nature 2000	In Nature 2000	No Nature 2000 restrictions
Within 500 m EHS	1	2	3
In EHS	4	5	6
No EHS restriction	7	8	9

About 50% of the farm population in the model is not influenced by NCA's (table A5.2).

Table A5.2 Number of farms per location type

Indicator	EMS	Nature 2000 area		
		Within 500 m of Nature 2000	In Nature 2000	No Nature 2000 restrictions
<i>Number of farms</i>	Within 500 m EMS	1278	54	7169
	In EMS	235	202	1411
	No EMS restriction	33	7	10748
<i>Number of dairy cows</i>	Within 500 m EMS	81656	3401	469042
	In EMS	14605	11919	88409
	No EMS restriction	2111	670	739430
<i>UAA size</i>	Within 500 m EMS	57189	2545	296267
	In EMS	11493	9686	59574
	No EMS restriction	1453	507	481216

These 50.8% of farms cover 52% of the number of dairy cows and 52% of UAA. For almost all locations farms are on average representing less cows and more UAA according to the group that is not hampered by the presence of nature conservation areas. This means that those farms are already (a bit) less extensive than the group without influence of Nature Conservation areas. There is an exception: location 8 covers 7 farmers. Those farmers are younger, have on average 95 dairy cows and 72 UAA against 67 dairy cows and 44 UAA on average farms (whole group). This deviation is the result of two large farms and is not structural.

5.2 Development 2001-2006

We also looked at farm development between 2001 and 2006 in relation with location (development measured in change of number of dairy) and found no significant differences between the groups. This has also been tested with an analysis of variance. Most divergent locations do have relative few observations and therefore no significant difference between locations in farm development could be found (table A5.3).

Table A5.3 Number of farms increasing their number of dairy cows between 2001 and 2006

Location	% farms		Number of dairy cows	
	Growth	No growth	Growth	No growth
1	53	47	10.6	-7.1
2	67	33	10.2	-7.6
3	53	47	11.6	-7.5
4	45	55	10.6	-5.2
5	50	50	11.8	-6.9
6	54	46	10.6	-6.9
7	48	52	14.7	-11.8
8	83	17	14.7	-7.0
9	55	45	10.8	-7.3
total	54	46	11.7	-7.3

After the period 2001-2006 more Nature2000 areas have been indicated. Also rules for (farm) expansion have become more powerful. So we think that the difference in development between farms cannot be measured by looking at the history. Therefore we decided to use one probability for farms in location 1 to 8 and tune this with the calibration with 2011 (will be 0.59). For location 9 we use growth potential probability 1.

6 Probabilities on farm expansion

In the model we assume probabilities on farm expansion to be related to age and location. Expansion is measured in crop area (UAA).

6.1 Age

We derived probabilities for farm growth depending on age by selecting farms (reference population) that existed in 2001 as well as in 2006 in the Annual Census (Table A6.1).

Table A6.1 Number of farms and their growth dynamics

Age	Number of farms			fraction	
	No growth	Growth	Total	No growth	growth
< 50	3523	5664	9187	0.38	0.62
50 – 65	3244	4722	7966	0.41	0.59
>= 65	1128	1371	2499	0.45	0.55
Total	7895	11757	19652	0.40	0.60

Furthermore (however we don't take this into account in the model) growth on growing farms, is on average 10 ha. This varies from 9.5 ha for farmers of 65 years or older and 10.6 ha for farmers younger than 50 years.

We used fraction growth as probability for growth per age category (table A6.1).

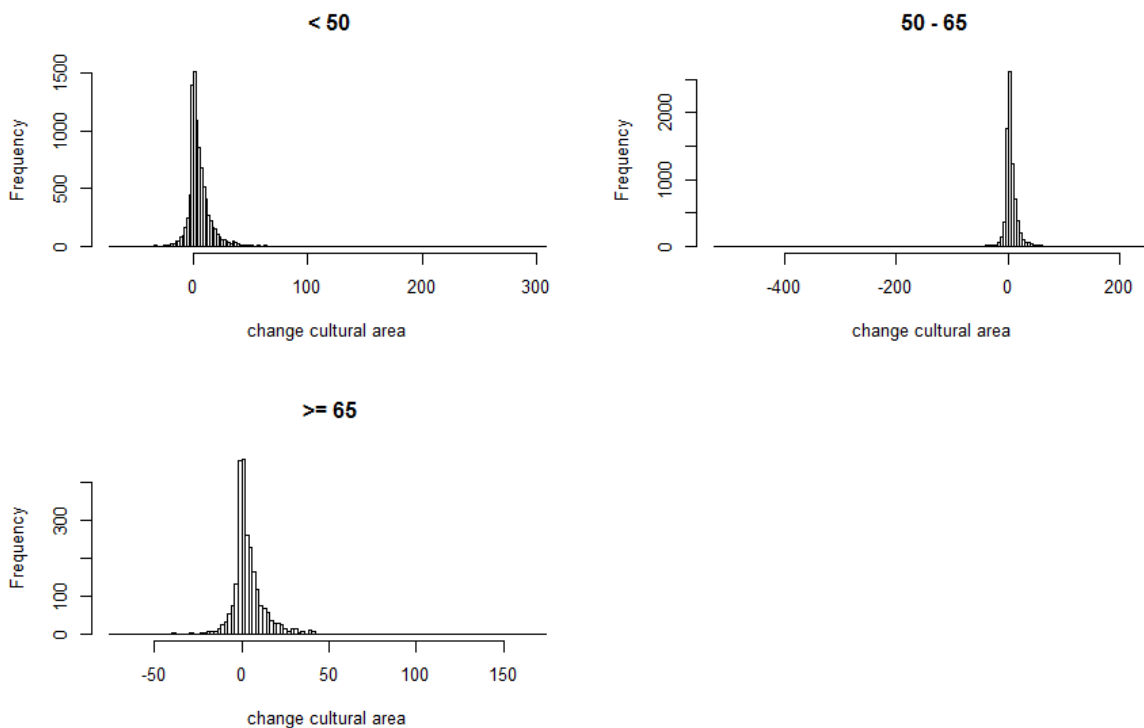


Figure A6.1 Histograms for change in UAA per age category.

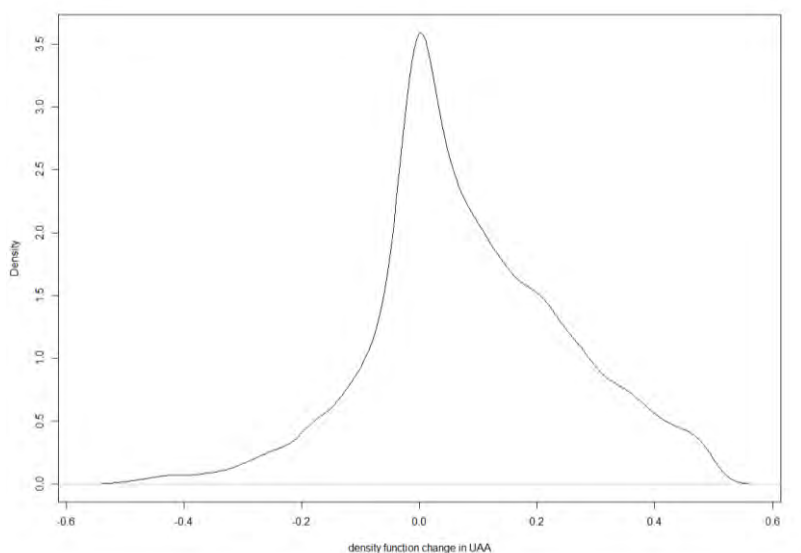


Figure A6.2 density function for farmers younger than 50 and with change in UAA in between – and + 50%.

We also made histograms and density plots and checked for normality and Laplace distributions (figure A6.1).

None of the above mentioned two distributions were applicable to the current dataset. Otherwise we could have sampled from these distributions instead of using a normal distribution. The problem is the presence of some outliers in the dataset (tails in figure A6.2) were we see increases in UAA up to 300 ha and decreases in UAA up to 500 ha.

Part of these particular farm expansions and reductions are results of farm splitting up and farm joining's. When we adjust the dataset for extremities the distribution will not improve. Figure B5.2 shows the distribution for farmers younger than 50 whose change in UAA is in between – 50% and + 50%.

6.2 Location

The effect of location on the expansion probabilities is described in appendix 5. Here we focus on the question whether it is correct to multiply age and location effect or not. In other words: are age and location independent?

Table A6.2 average age per location

	Nature 2000 influence		
	Within 500m Nature 2000	In Nature 2000	Out of Nature 2000 influence
EMS influence			
Within 500 m EMS	50.5	50.9	50.3
In EMS	51.4	51.4	50.8
Out of EMS influence	48.7	48.1	50.5

The average age of the whole population is 50.5 (table A6.2). Is there a relation between age and location? It looks as if some locations have younger farmers like farmers outside the influence of EMS

but under influence of Nature 2000 areas. However, looking at the number of farms in location 7 and 8 we decided to neglect this effect.

We checked this by applying an analysis of variance on the data.

Analysis of Variance Table

Response: age

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
factor (locatie)	8	710	88.809	0.7669	0.6321
Residuals	21128	2446703	115.804		

Our conclusion is that there is no significant relation between location and age. Hence we can multiply age and location effect to determine the final expansion possibilities.

7 Relation between number of dairy cows and UAA

To be able to transform UAA into a corresponding number of dairy cows and vice versa, we need a relationship between number of dairy cows and UAA. As farm structure of specialized dairy farms is different from the mixture of non-specialized dairy farms we decided to estimate for both categories a relationship. Furthermore we also decided to categorize different relationships for different farm intensities.

7.1 Material

The relationship(s) between dairy cows and UAA are estimated based upon Dutch Annual Census Data from 2006.

7.2 Multiple regression

The results of the multiple regressions are shown in table A7.1. Only the significant variables in the multiple regressions are shown.

Table A7.1 Estimated coefficients for the relationship number of dairy cows and UAA (log(UAA) as the dependent variable)

Farm type	Intensity (dairy cows per UAA)	Independent variables				R ²
		Log(dairy cow)	Fraction property	Fraction grass	Intercept	
<i>Dairy farms</i>	< 1.5	0.8344	-0.1100	-0.0570	0.5626	0.861
	1.5-1.85	0.9928	-0.0109	0.0095	-0.4711	0.986
	>= 1.85	1.0073		0.0810	-0.8877	0.785
<i>Non-specialized dairy farms</i>	< 1.5	0.8158	-0.2549	-0.2184	1.0554	0.535
	1.5-1.85	1.0074			-0.5351	0.980
	>= 1.85	1.0131		0.0727	-0.9821	0.689

We checked errors of all six regressions. Plots of the errors for the linear model for dairy farms with intensity < 1.5 dairy cow per UAA are shown in figure A7.1. From the plots and also from tests for normality (Shapiro-Will or Kolmogorov-Smirnoff) and heteroscedasticity (Breusch Pagan) we conclude that errors were not normally distributed, nor the restriction of constant errors could be fulfilled for all six estimated multiple regressions. We decided to estimate also six neural networks as an alternative (section 7.3)

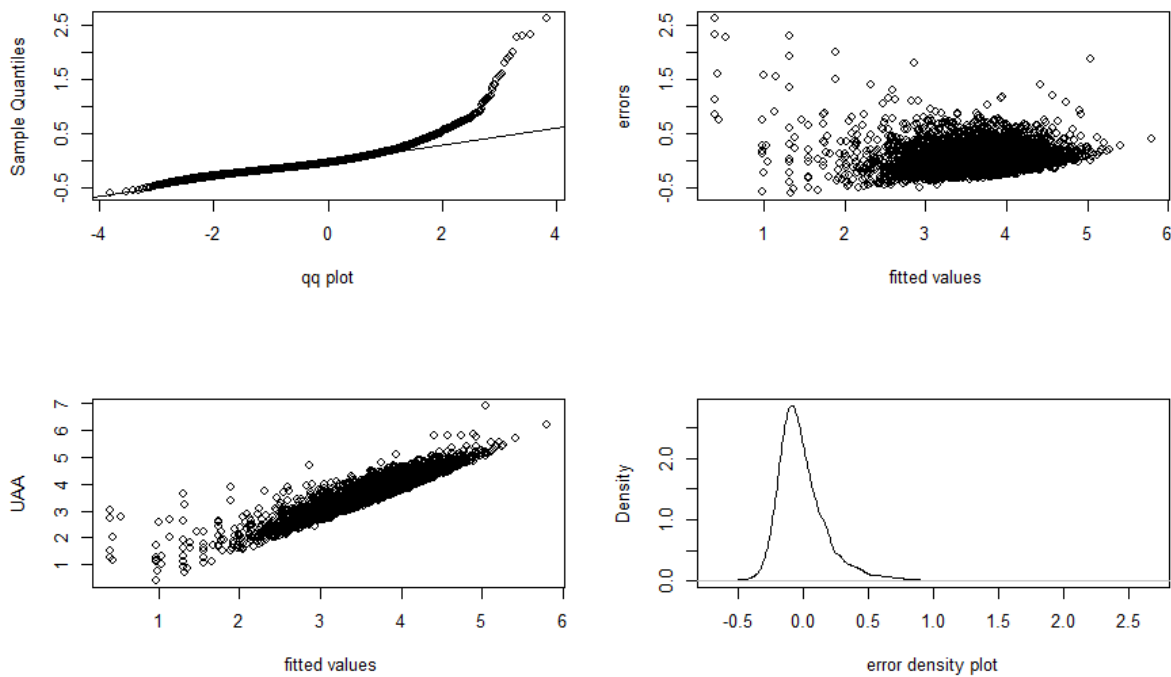


Figure A7.1 Error plots for fairy farms with intensity less than 1.5 dairy cows per UAA

7.3 Neural networks

In the estimated neural networks (table A7.3) we don't find variable fraction grassland. We selected the variables with Forward Selection method implemented in Rapid Miner.

Some performance indicators of the networks are presented in table A7.2. Correlation means correlation between predicted and measured values. Correlation measured is quite high.

We also estimated a regression lines between predicted and measured values. The best fit is if measured is equal to predicted ($y = x$).

Table A7.2 Performance indicators of the estimated neural networks

Performance	Specialized dairy farms			Non-specialized dairy farms, 20 or more dairy cows		
	< 1.5	1.5-1.85	>= 1.85	< 1.5	1.5-1.85	>= 1.85
root_mean_squared_error	0.141 +/- 0.029	0.067 +/- 0.010	0.275 +/- 0.040	0.421 +/- 0.042	0.070 +/- 0.008	0.330 +/- 0.116
normalized_absolute_error	0.054 +/- 0.029	0.155 +/- 0.018	0.387 +/- 0.045	0.694 +/- 0.050	0.166 +/- 0.026	0.539 +/- 0.083
correlation	0.998 +/- 0.000	0.993 +/- 0.000	0.885 +/- 0.026	0.723 +/- 0.058	0.990 +/- 0.002	0.842 +/- 0.078

For non-specialized dairy farms with low intensity (< 1.5 dairy cow per UAA) we plotted predicted and measured values (figure A7.2). For this farm type correlation of the estimated network is the lowest of all six networks. The predicted values are on average 2% lower than the measured values.

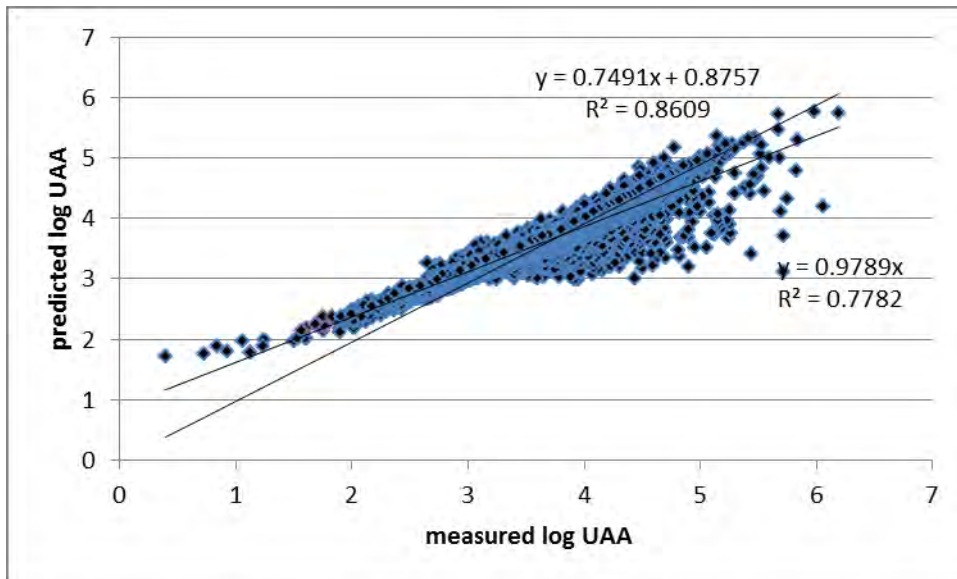


Figure A7.2 Measured and predicted logarithms of UAA on non-specialized dairy farms with less than 1.5 dairy cow per ha.

Table A7.2 Estimated neural networks for the relationship between UAA and number of dairy cows for two farm types and three intensity classes.

	specialized dairy farms			non-specialized dairy farms, 20 or more dairy cows		
	< 1.5	1.5-1.85	>= 1.85	< 1.5	1.5-1.85	>= 1.85
Node 1 (Sigmoid)						
age	-5.1	-0.006	0.433	-0.291	0.504	0.592
fraction property	-0.48	0.011	-0.059	0.228	-0.322	-0.099
log(dairy cow)	-1.627	-2.573	1.154	-2.233	-1.567	0.694
Bias	-7.149	-1.465	-3.25	-4.782	-1.864	-2.508
Node 2 (Sigmoid)						
age	1.649	-0.003	-0.121	0.428	-0.313	-0.349
fraction property	-0.062	0.052	0.053	-0.35	0.206	-0.028
log(dairy cow)	-2.164	2.82	2.146	2.861	-2.052	1.94
Bias	-4.509	-1.722	0.34	-1.003	-1.872	0.338
Node 3 (Sigmoid)						
age	-0.031	-0.05	0.506	-0.278	0.02	0.559
fraction property	0.141	-0.151	-0.077	0.231	-0.062	-0.096
log(dairy cow)	-2.423	1.137	1.311	-2.252	2.058	0.698
Bias	0.854	-2.597	-3.266	-4.833	-1.393	-2.507
Output						
=====						
Regression (Linear)						
Node 1	-1.006	-1.299	0.852	-2.047	-0.855	0.96
Node 2	-1.196	0.991	1.094	1.495	-1.11	1.083
Node 3	-1.379	0.735	0.903	-2.115	1.63	0.956
Threshold	0.875	0.055	-0.301	-0.456	-0.058	-0.234

8 Change in farm intensity

To be able to say something about change in farm intensity we studied the dynamics of farm intensity between 2001 and 2006 (Table A8.1)

Table A8.1 Indicators for farm structure for farms continuing between 2001 and 2006

Indicator	2001			2006		
	Average	Min	Max	Average	Min	Max
Dairy cows	68.7	2	1056	76.2	1	1178
UAA	44.7	0.7	1003	46.8	1.16	1334
Dairy cows per UAA	1.54	0.07	26.92	1.62	0.0045	43.15
Intensity index (2001=1)				1.08	0	18.2

On average livestock density increased with 8% between 2001 and 2006. However the range is quite broad. The change is between a decrease of 100% and an increase of 1720%. From the data it is not clear whether or not it can happen in reality.

We tried to define a distribution for (relative) change in intensity and with help of a plot of this indicator (figure A8.1). Due to outliers defining a distribution is not direct possible.

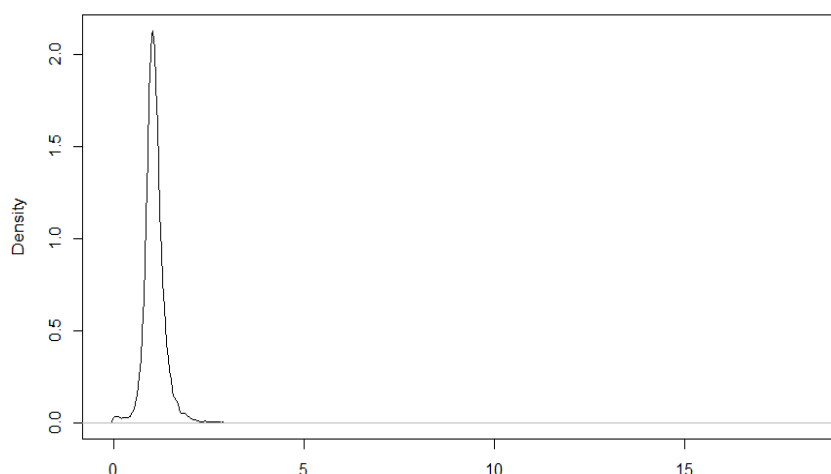


Figure A8.1 Density plot for intensity index (change according to intensity 2001).

When we limit the dataset to farms that change intensity with a maximum of -100 and + 100% we get a kind of distribution which we might interpret as “normal” distribution (figure A8.2). Doing this what part of dynamics do we capture? It appears that by limiting the dataset we miss about 1% of the number of dairy cows and almost 1% of UAA (table A8.2).

We also conclude from the data (table A8.3) that the farmers who intensified more than two times their intensity of 2001 were less intensive in 2001 (on average) than those who intensified less.

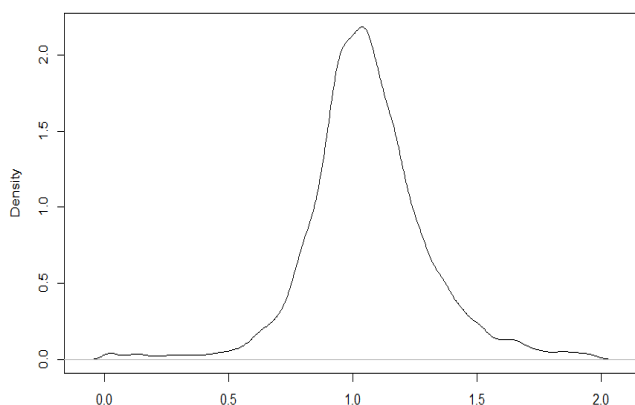


Figure A8.2 Density plot of fraction change in farm intensity (dairy cows per ha).

Table A8.2 Groups of intensity change and their contribution in farm structure in 2006

Fraction change intensity	Number of farms	Number of dairy cows 2006	Ha UAA 2006	Absolute change in intensity between 2001 and 2006	Average number of dairy cows per farm 2006	Average UAA per farm 2006
=< -2 or >=2	142	14269	6015	345	100.5	42.3
> -2 and < 2	14194	1078603	664910	1024	76.0	46.8
All	14336	1092872	670925	1369	76.2	46.8

Table A8.3 Groups of intensity change and their contribution in farm structure in 2001

Fraction change intensity	Number of farms	Average number of dairy cows per farm 2001	Average UAA per farm 2001
=< -2 or >=2	142	63.5	63.9
> -2 and < 2	14194	68.8	44.5
All	14336	68.7	44.7

We tested the fraction change in farm intensity as shown in figure A8.2 on normality. It appeared not to be normally distributed. Despite all these counter-arguments we decided to implement in the model a slight change in farm intensity, using the data of figure 8.2. Farms change in intensity and we wanted to take that fact into account in the model. We assumed a normal distribution using the mean and standard deviation of the distribution of fraction change in farm intensity ($\sim N(1.06, 0.06)$).

Before a farm is linked to farm type and farm intensity, in the model farm intensity is changed by sampling from the above mentioned distributions and multiplies this fraction change with the current farm intensity.

9 Model code (Netlogo)

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;; version 13 mei.
;; This version is equal to the version of Mai 8th maar nu met minder patches
;; met patchsize 4 ipv 1 en mogelijkheid tot het maken van plaatjes
;;
;; This version is not suitable for scenarios with milk price changes
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

;;*****
;;*
;;* Initialization of patches, turtles, globals and other issues
;;*
;;*****
;;* wake up gis

extensions [ gis]

globals
  [ ;; gis-related variables
    bedrijven                ;; farms and their locations
    Nederland                ;; shape file of the Netherlands

    ;; input variables
    amount_per_hour_2006    ;; amount paid for one hour of family labor
    amount_per_hour_2011    ;; amount paid for one hour of family labor
    cow_max                  ;; optimal farm scale
    hours_per_aje           ;; number of hours represented by an aje
    km_max                   ;; search radius, maximum distance between buyer and seller
    milkprice_2006          ;; milkprice per ton milk in 2006 !!
    milkprice_2011          ;; milkprice per ton milk in 2006 !!
    extra_revenue_p_cow_2006 ;; extra revenue per cow besides milk, omzet en aanwas, premiums
    extra_revenue_p_cow_2011 ;; extra revenue per cow besides milk, omzet en aanwas, premiums
    max_grow                ;; maximum limit on growing (=max_grow_1 or max_grow_2)
    max_grow_1              ;; maximum limit on growing with costrevenues < 1
    max_grow_2              ;; maximum limit on growing with costrevenues >= 1
    omzetaanwas_2006        ;; turnover and growth 2006 (euro per dairy cow)
    omzetaanwas_2011        ;; turnover and growth 2011 (euro per dairy cow)
    manure_price_2006       ;; manure removal price 2006 (euro per m3)
    manure_price_2011       ;; manure removal price 2011 (euro per m3)
    mest_cow_per_ha         ;; number of dairy cows per ha before cost for manure removal are taken into account
    land_price              ;; land price in euro per ha (only rent costs)
    manure_volume           ;; manure production (m3) per dairy cow
    f_auto_milkprod_grow    ;; fraction autonomous growth in milk production
    min_milkprod_p_cow      ;; minimal milk production per dairy cow (liter)
    premium_per_100kg       ;; premium per 100 liter a farmer receives if no individual data is known
    f1                      ;; parameters of the (normal) distribution changing in farm size

    ;; OUTPUT VARIABLES NOT FOR TESTING PURPOSE

```

```

;; globals for output of the base situation (= 2006)
b_total_farms                ;; number of farms
b_total_dairy_farms          ;; count farms with [FNSO = 0]
b_total_dcows                ;; number of dairy cows on farms
b_total_dcows_dfarms        ;; number of dairy cows on dairy farms
b_Revenues                   ;; Revenues per farm at start
b_revenues_per_100kg         ;; revenues per 100 l milk at start
b_Costs_per_Liter            ;; costs per l milk at start
b_Netresult                  ;; average Netresult at farms at start (revenues - costs)
b_netresult_per_100kg        ;; average Netresult per 100 l milk per farm at start
b_Costs                       ;; total costs at start
b_cow_p_farm                 ;; number of dairy cows per farm at start
b_cult_p_farm                ;; UAA per farm at start
b_total_paid_labor           ;; total amount virtually paid for family labor
b_costs_per_100kg           ;; total costs per 100 l milk including virtually paid family labor
b_av_milkprod                ;; average milk production per farm
b_av_paid_labor              ;; average paid labor per farm

b_total_milkprod             ;;sum [milkprod] of farms
b_total_grass                ;;sum [grass] of farms , IS UAA !!
b_nr_class_1_20              ;;count farms with [dcows > 0 and dcows < 20 ]
b_nr_class_20_50             ;;count farms with [dcows >= 20 and dcows < 50 ]
b_nr_class_50_75            ;;count farms with [dcows >= 50 and dcows < 75 ]
b_nr_class_75_100           ;;count farms with [dcows >= 75 and dcows < 100]
b_nr_class_100_150          ;;count farms with [dcows >= 100 and dcows < 150]
b_nr_class_150_200          ;;count farms with [dcows >= 150 and dcows < 200]
b_nr_class_gr_200           ;;count farms with [dcows >= 200 ]
b_cow_class_1_20            ;;sum [dcows] of farms with [dcows > 0 and dcows < 20 ]
b_cow_class_20_50           ;;sum [dcows] of farms with [dcows >= 20 and dcows < 50 ]
b_cow_class_50_75           ;;sum [dcows] of farms with [dcows >= 50 and dcows < 75 ]
b_cow_class_75_100          ;;sum [dcows] of farms with [dcows >= 75 and dcows < 100 ]
b_cow_class_100_150         ;;sum [dcows] of farms with [dcows >= 100 and dcows < 150 ]
b_cow_class_150_200         ;;sum [dcows] of farms with [dcows >= 150 and dcows < 200 ]
b_cow_class_gr_200          ;;sum [dcows] of farms with [dcows >= 200 ]

;; globals for output at the end situation

total_farms                  ;; total number of farms
total_cultgrond              ;; total UAA
total_labor_paid             ;; total amount of virtual paid family labor
total_dcows_dfarms          ;; total number of dairy cows on dairy farms
total_farms_quit             ;; number of dairy farms quit
total_milkprod               ;; total milk supply
average_deltaCosts           ;; average change in total costs
average_deltacow             ;; average change in number of dairy cows
average_farm_size1           ;; average nnumber of dairycows per farm
average_farm_size2           ;; average area per farm (UAA)
dfarms_total_milkprod        ;;
nr_class_1_20                ;; number of farms with [dcow > 0 and dcow < 20]
nr_class_20_50               ;; number of farms with [dcow >= 20 and dcow < 50]

```



```

nr_class_50_75          ;; number of farms withh [dcow >= 50 and dcow < 75]
nr_class_75_100         ;; number of farms with [dcow >= 75 and dcow < 100]
nr_class_100_150        ;; number of farms with [dcow >= 100 and dcow < 150]
nr_class_150_200        ;; number of farms with [dcow >= 150 and dcow < 200]
nr_class_gr_200         ;; number of farms with [dcow >= 200]
cow_class_1_20          ;; number of dairy cows on farms with [dcow > 0 and dcow < 20]
cow_class_20_50         ;; number of dairy cows on farms with [dcow >= 20 and dcow < 50]
cow_class_50_75         ;; number of dairy cows on farms with [dcow >= 50 and dcow < 75]
cow_class_75_100        ;; number of dairy cows on farms with [dcow >= 75 and dcow < 100]
cow_class_100_150       ;; number of dairy cows on farms with [dcow >= 100 and dcow < 150]
cow_class_150_200       ;; number of dairy cows on farms with [dcow >= 150 and dcow < 200]
cow_class_gr_200        ;; number of dairy cows on farms with [dcow >= 200 ]

av_costs                ;; average costs per farm including virtually paid family labor
av_Revenues             ;; average Revenues per farm
av_Costs_per_Liter      ;; average costs per liter milk finally
av_Netresult            ;; average Netresult at farm after simulation
av_cow_p_farm           ;; average number of dairy cows per farm
av_cult_p_farm          ;; average UAA per farm
av_costs_per_100kg      ;; average costs per 100 l milk (including family labor)
av_revenues_per_100kg   ;; average revenues per 100 l milk
av_netresult_per_100kg  ;; average net result per 100 l milk
av_total_milkprod        ;; average total milk production
av_total_labor_paid     ;; average virtually paid family labor per

nr_qfarms               ;; number of quitting farms

;; output variables for testing
dairyfarms              ;; number of dairy farms in final population
total_deltacow          ;; variable for testing -> sum of deltacow
groupsize               ;; number of farms with cost-revenue ratio < 1 in base situation 2006
total_supply1           ;;
total_supply2           ;;
total_demand            ;;
total_dcows             ;; total number of dairy cows after simulation
total_grass             ;; total amount of UAA(!) after simulation

milkprod_free           ;; milkproduction on quitting farms
cows_free               ;; nr of cows on quitting farms
cult_free               ;; UAA of quitting farms
land_supply             ;; sum of area of quitting farms
prop_supply             ;; sum of property of quitting farms
cow_supply              ;; sum of dairy cows on quitting farms
land_demand             ;; potential land demand based on cow demand
cow_demand              ;; potential cow_expansion
final_cow_growth        ;; revealed growth in dairy cows on continuing farms
final_traded_area       ;; revealed grow in area of traded area.

```

```

;; helping variables
rr                ;; global for random sampling
rgrow             ;; global for random sampling
random_quit      ;; random quitting probability (in 1000)
cost_quit        ;; cost quitting probability (in 1000)
yyy              ;; helping var to create space in outputfile
ht1              ;; helping globals (distribution of land) in distribute EHS
ht2              ;; helping globals (distribution of land) in distribute EHS
ht3              ;; helping globals (distribution of land) in distribute EHS
ht4              ;; helping globals (distribution of land) in distribute EHS
dhulp            ;; helping variable in distribute EHS
]

breed [ farms farm]

farms-own [ ;; state variables
farm_id          ;; so called bdlkey ; only used in setup-gis
dcows            ;; number of dairy cows per farm
lbgeb           ;; number of agricultural area
FNSO             ;; factor used in calculating total costs including labor family;if 1 the non-dairy, if 0 dairy farming
property         ;; land property of the owner
cultgrond       ;; amount of grass (ha)
aje             ;; available aje at the farm
age             ;; farmers age
Loc             ;; location number, depending on presence of NCA's
premie          ;; total premium received
gras            ;; ha gras

;; calculated (helping) variables

grass_pot1       ;; UAA potentially on the market by random quitting farms
grass_pot2       ;; UAA potentially on the market by cost quitting farms
grass_pot        ;; sum of grasspot1 and grasspot2 ; grass_pot is used in the land exchange part
farm_quit_random ;; if 1 farm is random quitting through unknown factors
farm_quit_costs  ;; if 1 farm is quitting due to cost-revenue ratio
labor_paid       ;; value of family labor including the owner
prop_free        ;; amount of property on the market
farms_die        ;; is 1 in case of a quited farm
fcow_max         ;; max potential cows for an individual farm depending on location effects
fgrow_prob_loc   ;; change that fcow_max will be realized due to location
fgrow_prob_age   ;; probability fcow_max will be realized due to age
cult_need        ;; potential need for land based on cow expansion
cow_expansion    ;; potential cow expansion
final_cult_need  ;; revealed growth in land
final_cow_expansion ;; revealed growth in dairy cows
cultgrond_start  ;; starting value amount of land [ha]
dcow_start       ;; starting value number of dairy cows
costs_start      ;; costs at start
CostRevenues     ;; proportion costs - Revenues

```

```

f_property          ;; fraction land in property
cow_p_ha           ;; number of dairy cows per ha
h_UAA              ;; helping var
f_gras             ;; fraction grassland grass / UAA
hcow              ;; helping var
help_cow_p_ha     ;; helping var
cow_p_ha_org       ;; number of dairy cows in before
manure_surplus    ;; m3 manure surplus at farm level

;; output variables for aggregation in final output

bf_CostRevenues    ;; CostRevenue ratio at start
bf_Costs           ;; costs per farm at start including virtually paid family labor
bf_Revenues        ;; Revenues per farm at start
bf_Netresult       ;; Netresult (Revenues - costs) per farm at start
milkprod           ;; milkproduction per farm
costs              ;; total costs
Revenues           ;; total Revenues (milk and premiums)
grass_need1        ;; UAA needed for farm expansion
extra_costs        ;; extra costs a farm has to pay due to farm expansion
manure_costs       ;; manure costs a farm has to pay extra due to farm expansion
land_costs         ;; costs for land buying (only rental costs)

;; helping variables but not for use
dmilkprod          ;; interim milk production
grass_need         ;; interim for extra grass needed for expansion
grass_pot_new      ;; interim for UAA supply on the marker
delta_cow          ;; interim for potential grow in dairy cows
deltaCosts         ;; interim for deltaCosts
dCosts            ;; interim for costs

]

patches-own
[
  pnr_farms        ;; number of farms on a patch
  koe              ;; number of dairy cows on a patch
  gem_koe         ;; average number of dairy cows on a patch
]

```

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; SET-UP used in the beginning to construct files with
; Netlogo x- and y-coordinates
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

```

to setup-gis

```

clear-all ;; don't loose datasets

set bedrijven gis:load-dataset "e:/1_VU/Stage/NetLogoModellen/DCM_Nl/data/lok06_hv_LAEa_join.shp"
set Nederland gis:load-dataset "e:/1_VU/Stage/NetLogoModellen/DCM_Nl/data/prov2012LAEA.shp"

gis:set-world-envelope (gis:envelope-union-of (gis:envelope-of bedrijven)
                                              (gis:envelope-of Nederland))

set yyy " "
file-open "NetLogo_gis.txt"
foreach sort farms [ask ? [file-write farm_id file-write xcor file-write yyy file-print ycor]]
file-close

reset-ticks
end

;;;;;;;;;;;;;
; ALTERNATIVE SET-UP; speeds up in case of multiple runs UNDER CONSTRUCTION ;
;;;;;;;;;;;;;

to setup-scenarios
clear-all

; resize-world 0 350 0 200

create-farms 21137

reset-ticks
end

;;;;;;;;;;;;;
;GO: RUN THE MODEL
;;;;;;;;;;;;;

to go

read-data

if(ticks = 1) [stop]

initialize-globals

calc-data

update-globals

create-output

stop

```

```

end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; READ DATA AND ASSIGN TO FARMS ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to read-data

  file-open "InputData_June2013.txt"

  ask farms
  [
    set xcor file-read set ycor file-read set aje file-read set cultgrond file-read set age file-read set FNSO file-read set dcows file-read set
    property file-read set loc file-read set premie file-read set gras file-read set lbgeb file-read
  ]
  file-close

end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; CALCULATION MODULE ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to calc-data

  ; INITIALIZE
  initialize-farm-attributes
  initialize-base-situation
; make-plot

  ; effects on grow expansions due to age and location
  location-effect
  age-effect

  ; POTENTIAL EXPANDING OR SHRINKING
  calc-expanding

  ; FINAL EXCHANGE OF LAND
  distribute-area

end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; INITIALIZE GLOBALS;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to initialize-globals

  set hours_per_aje          2000

```

```

set amount_per_hour_2006          22
set amount_per_hour_2011          24
set milkprice_2006                 296      ; euro per ton
set milkprice_2011                 384
set cow_max                        130
set km_max                         5
set premium_per_100kg              3.30
set random_quit                    0
set omzetaanwas_2006               246
set omzetaanwas_2011               260
set manure_price_2006              13
set manure_price_2011              13
; set land_price                   2500
set land_price                     0
set manure_volume                  26
set max_grow_1                     0.2      ; maximum grow as a fraction of current UAA
set max_grow_2                     0.2      ; maximum grow for farms with CostRevenues > 1
set min_milkprod_p_cow              5000
set f_auto_milkprod_grow            0.06
set extra_revenue_p_cow_2006       57
set extra_revenue_p_cow_2011       212
set mest_cow_per_ha                 1.5

```

end

```

;;;;;;;;;;;;;
; CALCULATE FARM STRUCTURE AT START ;
;;;;;;;;;;;;;
to initialize-base-situation

```

```

set b_total_farms                  count farms
set b_total_dcows                  sum [dcows] of farms
set groupsize                      count farms with [bf_CostRevenues <= 1]

set b_total_milkprod               sum [milkprod] of farms
set b_av_milkprod                  b_total_milkprod / b_total_farms
set b_total_grass                  sum [cultgrond_start] of farms
set b_total_paid_labor             sum [labor_paid] of farms
set b_av_paid_labor                b_total_paid_labor / b_total_farms
set b_costs                        sum [bf_Costs] of farms + b_total_paid_labor
set b_cow_p_farm                   b_total_dcows / b_total_farms
set b_cult_p_farm                  b_total_grass / b_total_farms
set b_Revenues                     sum [bf_Revenues] of farms
set b_revenues_per_100kg           b_Revenues / (b_total_milkprod * 10)
set b_Costs_per_Liter              b_costs / (b_total_milkprod * 1000)
set b_costs_per_100kg              b_costs / (b_total_milkprod * 10)
set b_Netresult                    b_Revenues - b_costs
set b_Netresult_per_100kg          b_revenues_per_100kg - b_costs_per_100kg

```

```

set b_nr_class_1_20          count farms with [dcows > 0 and dcows < 20 ]
set b_nr_class_20_50        count farms with [dcows >= 20 and dcows < 50 ]
set b_nr_class_50_75        count farms with [dcows >= 50 and dcows < 75 ]
set b_nr_class_75_100       count farms with [dcows >= 75 and dcows < 100 ]
set b_nr_class_100_150      count farms with [dcows >= 100 and dcows < 150 ]
set b_nr_class_150_200      count farms with [dcows >= 150 and dcows < 200 ]
set b_nr_class_gr_200       count farms with [dcows >= 200]
set b_cow_class_1_20        sum [dcows] of farms with [dcows > 0 and dcows < 20 ]
set b_cow_class_20_50       sum [dcows] of farms with [dcows >= 20 and dcows < 50 ]
set b_cow_class_50_75       sum [dcows] of farms with [dcows >= 50 and dcows < 75 ]
set b_cow_class_75_100      sum [dcows] of farms with [dcows >= 75 and dcows < 100 ]
set b_cow_class_100_150     sum [dcows] of farms with [dcows >= 100 and dcows < 150 ]
set b_cow_class_150_200     sum [dcows] of farms with [dcows >= 150 and dcows < 200 ]
set b_cow_class_gr_200      sum [dcows] of farms with [dcows >= 200 ]

```

end

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; INITIALIZE EXTRA FARM ATTRIBUTES ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

```

to initialize-farm-attributes

```

ask farms
[
  set labor_paid      aje * hours_per_aje * amount_per_hour_2006

  ;; some times property is more than cultgrond (94 of the 21137 cases)

  if(property > cultgrond) [set cultgrond property]

  set cultgrond_start  cultgrond

  ifelse(cultgrond > 0)
  [ set f_property  property / cultgrond
    set cow_p_ha    dcows / cultgrond
    set f_gras      gras / cultgrond
  ]
  [ set f_property 0
    set cow_p_ha 0
    set f_gras 0
  ]

; the first time extra costs are 0
set extra_costs      0

update-CostRevenues

set bf_CostRevenues  CostRevenues

```

```

        set bf_Revenues      Revenues
        set bf_Costs        costs
        set bf_Netresult    bf_Revenues - bf_Costs

        set costs_start    costs
        set dcow_start     dcows
    ]
; export-world "beginning_basis.csv"

end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; calculate farms possibilities for potential growth or shrink ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to calc-expanding

ask farms
[
    execute_cost_quit

    ; farms with less than 1 ha, quit as well
    if(cultgrond < 1)
        [set farms_die 1
         set farm_quit_costs 1
         ]

    if (farm_quit_costs != 1)
        [ execute_random_quit
        ]

    if(farm_quit_costs != 1 and farm_quit_random != 1)
        [
            if dcows > 0    ;; farm didn't quit for costs reasons and didn't quit for random
            [

                if(bf_CostRevenues < 1 or (bf_CostRevenues >= 1)); and stop_grow > pstop_grow))

                [set rgrow random(100) / 100
                 set fgrow_prob_age 1
                 set fgrow_prob_loc 1
                ;
                 ifelse (rgrow < (fgrow_prob_loc * fgrow_prob_age))

                    [
                        set delta_cow fcow_max - dcows
                        if (delta_cow < 0) [set delta_cow 0]
                        ;
                        set grass_need (7.190 + 0.547 * fcow_max - cultgrond)
                    ]
                ]
            ]
        ]
    ]

```



```

        if (delta_cow > 0) [calc_grass_need]
            set grass_need1 grass_need

        if (grass_need < 0) [set grass_need 0] ;; check further
    ]
    [ set delta_cow 0
      set grass_need 0
    ]
  ]
]
set grass_pot grass_pot1 + grass_pot2
]

end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; EXECUTE COST QUIT
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to execute_cost_quit

  set cost_quit 0

  if(CostRevenues > 1 and dcows > 0)
  [
    ifelse(age < 50)
    [
      ifelse(dcows < 20)
      [ set cost_quit 188]
      [ set cost_quit 93]
    ]
    [ifelse(age >= 50 and age < 65)
    [
      ifelse(dcows < 20)
      [ set cost_quit 269]
      [ set cost_quit 126]
    ]
    [if(age >= 65)
    [
      ifelse(dcows < 20)
      [ set cost_quit 287]
      [ set cost_quit 188]
    ]
    ]
  ]
]

set rr random(1000)
if rr < cost_quit

```

```

    [
      set grass_pot2 cultgrond
      set farm_quit_costs 1

      set farms_die 1
    ]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; EXECUTE RANDOM QUIT
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to execute_random_quit

set random_quit 0

if(CostRevenues <= 1 and dcows > 0) ; don't take potential quitters into account
[
  ifelse(age < 50)
  [
    ifelse(dcows < 20)
    [ set random_quit 163]
    [ set random_quit 91]
  ]
  [ifelse(age >= 50 and age < 65)
  [
    ifelse(dcows < 20)
    [ set random_quit 229]
    [ set random_quit 139]
  ]
  [if(age >= 65)
  [
    ifelse(dcows < 20)
    [ set random_quit 406]
    [ set random_quit 200]
  ]
  ]
  ]
]

set rr random(1000)
if rr < random_quit
[
  set grass_pot1 cultgrond
  set farm_quit_random 1

  set farms_die 1
]
]
end

```

```

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; calculates the effect of location on farms possibillities for potential growth or shrink ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to location-effect

  ask farms
  [
    set fcow_max cow_max
    ifelse (loc != 9)
    [ set fgrow_prob_loc 0.59]
    [ set fgrow_prob_loc 1 ]
  ]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; make a plot of results or input
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to make-plot
  ask patches

  [
    set koe 0
    set pcolor 9.9
    ask farms-here
    [
      set koe koe + dcows
      set color 9.9
      set size 0.1
    ]

    set pnr_farms (count farms-here)

    if(count farms-here > 0) [set gem_koe koe / count farms-here]

    ifelse(gem_koe > 0 and gem_koe < 80 )
    [set pcolor 45]
    [ifelse (gem_koe >= 80)
      [set pcolor 105]
      [set pcolor 9.9]
    ]
  ]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; calculates the effect of age on farms possibillities for potential growth or shrink ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to age-effect

```

```

ask farms
[
  ifelse (age < 50)
  [set fgrow_prob_age 0.7]
  [ifelse (age >= 50 and age < 65)
    [
      set fgrow_prob_age 0.4
    ]
    [
      set fgrow_prob_age 0.1
    ]
  ]
]

end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; final distribution of land ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to distribute-area

; if a farm (supplier) is in location 2, 4, 5, 6 or 8, it supplies to all farms
; above is possible because growing farms in location 2, 4,5, 6 or 8 can only grow when they are supplied by farms in the same location
; if a farm (supplier) is in location 1,3,7 or 9 the supplier can only supply to farms in the same type of area

ask farms
[ if grass_pot > 0
  [
    ifelse ((loc = 2 or loc = 4 or loc = 5 or loc = 6 or loc = 8))
    [
      distribute_EHS
    ]
    [
      distribute_free ; no
;      distribute_EHS ; yes
    ]
  ]
]

end

; distribute if the selling farm lies within an area with restrictions

to distribute_EHS

  set grass_pot_new 0

```

```

while [grass_pot_new != grass_pot]
[
  let neighbor-farms farms in-radius km_max with [grass_need > 0]
  let farm-closest-buyer min-one-of neighbor-farms [CostRevenues]
;
  let farm-closest-buyer min-one-of farms in-radius km_max with [grass_need > 0] [distance myself]

ifelse farm-closest-buyer != nobody
[
; MORE SUPPLY THAN DEMAND
ask farm-closest-buyer
[
  ifelse grass_need < [grass_pot] of myself
  [ set cultgrond cultgrond + grass_need
    set dhulp 0
    set dhulp grass_need
    set grass_need 0
    set dcows delta_cow + dcows
    set ht1 1
    calc-extra-costs
    update-CostRevenues
  ] ;; end first command

; MORE DEMAND THEN SUPPLY
  [ set cultgrond cultgrond + [grass_pot] of myself
    set dcows dcows + delta_cow * ([grass_pot] of myself / grass_need)
    set grass_need grass_need - [grass_pot] of myself
    set ht2 1
    calc-extra-costs
    update-CostRevenues
  ] ;; end second command
] ;; end of land exchange

if(ht1 = 1) ; more supply then demand and there is still available
[
  set grass_pot_new grass_pot
  set grass_pot grass_pot - dhulp
  set ht1 0
]
if(ht2 = 1) ; more demand then supply but the single supplier had nothing left
[
  set grass_pot_new 0
  set grass_pot 0
  set farms_die 1
  set ht2 0
]
]

;; there are no dairy farms to exchange land with

```

```

    [
      set grass_pot_new 0
      set grass_pot 0
      set farms_die 1
    ] ;; bedrijf kan niet verhandelen en wordt opgeheven
  ]
end

; DISTRIBUTE IF THE SELLING FARM LIES IN AN AREA WITHOUT RESTRICTIONS

to distribute_free

  set grass_pot_new 0
  while [grass_pot_new != grass_pot]
  [
    let neighbor-farms farms in-radius km_max with [grass_need > 0 and (loc = 1 or loc = 3 or loc = 7 or loc = 9)]
    let farm-closest-buyer min-one-of neighbor-farms [CostRevenues]
;    let farm-closest-buyer min-one-of farms in-radius km_max with [grass_need > 0 and (loc = 1 or loc = 3 or loc = 7 or loc = 9)] [distance
myself]

    ifelse farm-closest-buyer != nobody
    [
; MORE SUPPLY THAN DEMAND
      ask farm-closest-buyer
      [
        ifelse grass_need < [grass_pot] of myself
        [ set cultgrond cultgrond + grass_need
          set dhulp 0
          set dhulp grass_need
          set grass_need 0
          set dcows delta_cow + dcows
          set ht3 1
          calc-extra-costs
          update-CostRevenues
        ] ;; end first command

; MORE DEMAND THEN SUPPLY
        [ set cultgrond cultgrond + [grass_pot] of myself
          set dcows dcows + delta_cow * ([grass_pot] of myself / grass_need)
          set grass_need grass_need - [grass_pot] of myself
          set ht4 1
          calc-extra-costs
          update-CostRevenues
        ] ;; end second command
      ] ;; end of land exchange

    if(ht3 = 1) ; more supply than demand and there is still available
    [
      set grass_pot_new grass_pot
    ]
  ]
end

```

```

        set grass_pot      grass_pot - dhulp
        set ht3 0
    ]
    if(ht4 = 1) ; more demand than supply but the single supplier had nothing left
    [
        set grass_pot_new 0
        set grass_pot      0
        set farms_die      1
        set ht4 0
    ]
]

;; there are no dairy farms to exchange land with
[
    set grass_pot_new 0
    set grass_pot      0
    set farms_die      1
] ;; bedrijf kan niet verhandelen en wordt opgeheven
]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; calc grass need and change in dairy cows
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to calc_grass_need

    calc-intensity
    set hcow dcows + delta_cow
    UAA_dcow_relation
    ;h_UAA total area needed

    ; max grow is 20% of current area

    ifelse(CostRevenues < 1)
    [set max_grow max_grow_1]
    [set max_grow max_grow_2]

    if(h_UAA > cultgrond * (1 + max_grow)) [set h_UAA (1 + max_grow) * cultgrond]
    if(h_UAA >= cultgrond) [ set grass_need h_UAA - cultgrond]

    ; calc new delta cows based on new area
    reset_delta_cows
    ifelse(hcow > dcows)
    [set delta_cow hcow - dcows]
    [set delta_cow 0]
end

to calc-intensity
    set f1 random-normal 1.06 0.06

```

```

set cow_p_ha_org cow_p_ha
set cow_p_ha cow_p_ha_org * fl

end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; intensity and relation UAA and number of dairy cows
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to UAA_dcow_relation

;; calculate intensity class and grass need for delta_cow

ifelse(FNSO = 0)
[
  ifelse (cow_p_ha < 1.5)
    [FNSO1Small]
    [
      ifelse(cow_p_ha >= 1.5 and cow_p_ha < 1.85)
        [FNSO1Medium]
        [FNSO1Big]
      ]
    ]
  [
    ifelse (cow_p_ha < 1.5)
      [FNSO2Small]
      [
        ifelse(cow_p_ha >= 1.5 and cow_p_ha < 1.85)
          [FNSO2Medium]
          [FNSO2Big]
        ]
      ]
  ]
]

end

to FNSO1Small
set h_UAA exp(0.5626 + 0.8344 * ln(hcow) - 0.110 * f_property - 0.0570 * f_gras)
end

to FNSO1Medium
set h_UAA exp(-0.47711 + 0.9928 * ln(hcow) - 0.109 * f_property + 0.0095 * f_gras)
end

to FNSO1Big
set h_UAA exp(-0.8877 + 1.0073 * ln(hcow) - 0.081 * f_gras)
end

to FNSO2Small
set h_UAA exp(1.0554 + 0.8158 * ln(hcow) - 0.2549 * f_property - 0.2184 * f_gras)

```



```

end

to FNSO2Medium
  set h_UAA exp(-0.5351 + 1.0074 * ln(hcow))
end

to FNSO2Big
  set h_UAA 0.6164 + 0.3989 * hcow + 1.3182 * f_gras
end

;;;;;;;;;;;;;
; reset delta_cows
;;;;;;;;;;;;;

to reset_delta_cows

  ;; calculate intensity class and grass need for delta_cow

  ifelse(FNSO = 0)
  [
    ifelse (cow_p_ha < 1.5)
      [revFNSO1Small]
      [
        ifelse(cow_p_ha >= 1.5 and cow_p_ha < 1.85)
          [revFNSO1Medium]
          [revFNSO1Big]
        ]
      ]
  ]
  [
    ifelse (cow_p_ha < 1.5)
      [revFNSO2Small]
      [
        ifelse(cow_p_ha >= 1.5 and cow_p_ha < 1.85)
          [revFNSO2Medium]
          [revFNSO2Big]
        ]
      ]
  ]

; if(hcow / h_UAA > 3.5) [set hcow h_UAA * 3.5]

end

to revFNSO1Small
  set hcow exp((-0.5626 + ln(h_UAA) + 0.110 * f_property + 0.0570 * f_gras) / 0.8344)
; if(hcow / h_UAA > 1.5) [set hcow h_UAA * 1.5]
end

to revFNSO1Medium
  set hcow exp((0.47711 + ln(h_UAA) + 0.109 * f_property - 0.0095 * f_gras) / 0.9928)

```

```

;   if(hcow / h_UAA > 1.85) [set hcow h_UAA * 1.85]
end

to revFNSO1Big
  set hcow exp((0.8877 + 1.0073 * ln(h_UAA) + 0.081 * f_gras)/ 1.0073 )
;   if(hcow / h_UAA > 3.5) [set hcow h_UAA * 3.5]
end

to revFNSO2Small
  set hcow exp((-1.0554 + ln(h_UAA) + 0.2549 * f_property + 0.2184 * f_gras) / 0.8158)
;   if(hcow / h_UAA > 1.5) [set hcow h_UAA * 1.5]
end

to revFNSO2Medium
  set hcow exp((0.5351 + ln(h_UAA)) / 1.0074)
;   if(hcow / h_UAA > 1.85) [set hcow h_UAA * 1.85]
end

to revFNSO2Big
  set hcow (-0.6164 + h_UAA - 1.3182 * f_gras)/ 0.3989
;   if(hcow / h_UAA > 3.5) [set hcow h_UAA * 3.5]
end
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;; Recalculate cost/Revenues after a increase of land
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to update-CostRevenues

  calc-milkprod

; sometimes premium is 0, but that's unlikely

  if(premie = 0)      [set premie premium_per_100kg * 10 * milkprod]

; set premie 0

  set CostRevenues    0
  set costs           exp(0.90578 * ln(dccows) + FNSO * 0.21529 + 8.46147 - 0.20595 * f_gras ) + extra_costs
; set costs           exp(0.6164 * ln(dccows) + FNSO * 0.16308 + 9.74103 - 0.16024 * f_gras + 0.15077 * aje) + extra_costs

  set Revenues        milkprice_2006 * milkprod + premie + dccows * omzetaanwas_2006 + dccows * extra_revenue_p_cow_2006

  ifelse Revenues != 0
  [ set CostRevenues costs / Revenues]
  [ set CostRevenues costs]

end

to calc-extra-costs

```

```

set extra_costs 0

if(cultgrond > 0) [set help_cow_p_ha dcows / cultgrond]

calc_landcosts

ifelse(help_cow_p_ha > mest_cow_per_ha)
  [set manure_surplus (help_cow_p_ha - mest_cow_per_ha) * cultgrond * manure_volume
   set manure_costs manure_surplus * manure_price_2006
  ]
[set manure_costs 0]

set extra_costs land_costs + manure_costs

end

to calc_landcosts

if(lbgeb = 1) [set land_costs (cultgrond - cultgrond_start) * 448]
if(lbgeb = 2) [set land_costs (cultgrond - cultgrond_start) * 424]
if(lbgeb = 3) [set land_costs (cultgrond - cultgrond_start) * 442]
if(lbgeb = 4) [set land_costs (cultgrond - cultgrond_start) * 585]
if(lbgeb = 5) [set land_costs (cultgrond - cultgrond_start) * 763]
if(lbgeb = 6) [set land_costs (cultgrond - cultgrond_start) * 764]
if(lbgeb = 7) [set land_costs (cultgrond - cultgrond_start) * 600]
if(lbgeb = 8) [set land_costs (cultgrond - cultgrond_start) * 434]
if(lbgeb = 9) [set land_costs (cultgrond - cultgrond_start) * 604]
if(lbgeb = 10) [set land_costs (cultgrond - cultgrond_start) * 753]
if(lbgeb = 11) [set land_costs (cultgrond - cultgrond_start) * 641]
if(lbgeb = 12) [set land_costs (cultgrond - cultgrond_start) * 688]
if(lbgeb = 13) [set land_costs (cultgrond - cultgrond_start) * 710]
if(lbgeb = 14) [set land_costs (cultgrond - cultgrond_start) * 727]

end

to calc-milkprod

set milkprod 7.744 * dcows

if(milkprod * 1000 / dcows < min_milkprod_p_cow) [set milkprod min_milkprod_p_cow * dcows / 1000]

;set milkprod 8.008 * dcows - 19.295
;if(milkprod / dcows < min_milkprod_p_cow / 1000) [set milkprod min_milkprod_p_cow * dcows / 1000]

end

to calc-dmilkprod

set dmilkprod 7.744 * dcows * (1 + f_auto_milkprod_grow)

```

```

    if(dmilkprod * 1000 / dcows < min_milkprod_p_cow) [set dmilkprod min_milkprod_p_cow * dcows / 1000]
;set dmilkprod (8.008 * dcows - 19.295) * (1 + f_auto_milkprod_grow)
;if(dmilkprod / dcows < min_milkprod_p_cow / 1000) [set dmilkprod min_milkprod_p_cow * dcows / 1000]

end

;;;;;;;;;;;;;;
; create output ;
;;;;;;;;;;;;;;

to create-output

; TEST OUTPUT
update-globals

; FARM output
update-farms

; FINAL OUTPUT
update-results
print-results      ;; per run on screen
; write-results    ;; per run in a file: do not use for multiple runs

end

;;;;;;;;;;;;;;
;;      UPDATE FARMS
;;;;;;;;;;;;;;

to update-farms

update-quiting-farms
update-continuing-farms

end

;;;;;;;;;;;;;;
;;      UPDATE CONTINUING FARMS
;;;;;;;;;;;;;;

to update-continuing-farms

ask farms with [farms_die != 1]
[
  calc-dmilkprod

```

```

set dCosts                exp(0.90578 * ln(dcows) + FNSO * 0.21529 + 8.46147 - 0.20595 * f_gras )

set costs                 dcosts
set deltaCosts           dCosts - costs_start
set cult_need            grass_need
set Cow_expansion        delta_cow
set final_cult_need      cultgrond - cultgrond_start
set final_cow_expansion  dcows - dcow_start
set revenues             dmilkprod * milkprice_2011 + premie + dcows * omzetaanwas_2011 + dcows * extra_revenue_p_cow_2011
]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
;;          UPDATE QUITTING FARMS
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;

to update-quitting-farms

ask farms with [farms_die = 1]
[
  set nr_qfarms          1 + nr_qfarms
  set cows_free          dcows + cows_free

  calc-dmilkprod

  set milkprod_free      dmilkprod + milkprod_free
  set cult_free          cultgrond + cult_free
  set prop_free          property + prop_free
  die
;   set dmilkprod 0
]
end

;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
; finalize output results ;
;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;;
to update-results

; make-plot
; export-world "test.csv"

set total_farms_quit     nr_qfarms

set total_farms          count farms
set dairyfarms           count farms with [FNSO = 0]
set total_labor_paid     sum [labor_paid] of farms
set total_dcows          sum [dcows] of farms

```

```

set total_cultgrond      sum [cultgrond] of farms
set total_milkprod      sum [dmilkprod] of farms
set av_total_milkprod   total_milkprod / total_farms
set av_total_labor_paid total_labor_paid / total_farms
set av_cow_p_farm      total_dcows / total_farms
set av_cult_p_farm     total_cultgrond / total_farms
set average_deltaCosts (sum [deltaCosts] of farms) / total_farms
set average_deltaCow   (sum [delta_cow] of farms) / total_farms
set land_supply        cult_free
set av_costs           (sum [costs] of farms + total_labor_paid) / total_farms
set cow_supply         cows_free
set cow_demand         sum [delta_cow] of farms
set land_demand        sum [grass_need1] of farms
set final_cow_growth   sum [final_cow_expansion] of farms
set final_traded_area  sum [final_cult_need] of farms
set av_costs_per_100kg (sum [costs] of farms + total_labor_paid * (24 / 22)) / (total_milkprod * 10)
set av_Revenues        sum [Revenues] of farms / total_farms
set av_revenues_per_100kg sum [Revenues] of farms / (total_milkprod * 10)
set av_Netresult       av_Revenues - av_costs
set av_netresult_per_100kg av_Netresult / (av_total_milkprod * 10)

set nr_class_1_20      count farms with [dcows > 0 and dcows < 20 ]
set nr_class_20_50     count farms with [dcows >= 20 and dcows < 50 ]
set nr_class_50_75     count farms with [dcows >= 50 and dcows < 75 ]
set nr_class_75_100    count farms with [dcows >= 75 and dcows < 100 ]
set nr_class_100_150   count farms with [dcows >= 100 and dcows < 150 ]
set nr_class_150_200   count farms with [dcows >= 150 and dcows < 200 ]
set nr_class_gr_200    count farms with [dcows >= 200 ]
set cow_class_1_20     sum [dcows] of farms with [dcows > 0 and dcows < 20 ]
set cow_class_20_50   sum [dcows] of farms with [dcows >= 20 and dcows < 50 ]
set cow_class_50_75   sum [dcows] of farms with [dcows >= 50 and dcows < 75 ]
set cow_class_75_100  sum [dcows] of farms with [dcows >= 75 and dcows < 100 ]
set cow_class_100_150 sum [dcows] of farms with [dcows >= 100 and dcows < 150 ]
set cow_class_150_200 sum [dcows] of farms with [dcows >= 150 and dcows < 200 ]
set cow_class_gr_200  sum [dcows] of farms with [dcows >= 200 ]

end

to print-results

output-write " new results "
output-print " "
output-write "land supply "
output-print land_supply
output-write "cow supply "
output-print cow_supply
output-write "final_cow_growth"
output-print final_cow_growth
output-write "final_traded_area"
output-print final_traded_area

```

```

output-write " cow_demand"
output-print cow_demand
output-write " land demand "
output-print land_demand

output-write "Total cultgrond "
output-print Total_cultgrond
output-write " total_farms      "
output-print total_farms
output-write " total_dcows      "
output-print total_dcows
output-write "NSO 4500"
output-print dairyfarms
output-write " total_farms_quit  "
output-print total_farms_quit
output-write " b_total_dcows     "
output-print b_total_dcows
output-write " b_total_grass"
output-print b_total_grass
output-write " total number of dairy cows after simulation"
output-print total_dcows
output-write "total amount of ha in use after simulation"
output-print total_cultgrond
output-write " average Revenues per 100 kg"
output-print av_revenues_per_100kg
output-write " average costs per 100 kg"
output-print av_costs_per_100kg
output-write "average Netresult per 100 kg"
output-print av_netresult_per_100kg
output-write " average Revenues per 100 kg milk at star "
output-print b_Revenues_per_100kg
output-write "average costs per 100 kg milk at start"
output-print b_Costs_per_100kg
output-write "average Netresult per 100 kg milk at start"
output-print b_Netresult_per_100kg
output-print b_cow_p_farm
output-print b_cult_p_farm
output-print av_cow_p_farm
output-print av_cult_p_farm
output-print b_av_milkprod
output-print b_av_paid_labor
output-print av_total_milkprod
output-print av_total_labor_paid
output-print total_milkprod
output-print groupsize
end

to write-results

file-open "results.txt"

```

```

file-write "name " file-write "base situation " file-print "scenario results "
file-write "total milkproduction " file-write b_total_milkprod file-print yyy
file-write "total grass area " file-write b_total_grass file-print yyy
file-write "dfarms 1-20 " file-write b_nr_class_1_20 file-print nr_class_1_20
file-write "dfarms 20-50 " file-write b_nr_class_20_50 file-print nr_class_20_50
file-write "dfarms 50-75 " file-write b_nr_class_50_75 file-print nr_class_50_75
file-write "dfarms 75-100 " file-write b_nr_class_75_100 file-print nr_class_75_100
file-write "dfarms 100-150 " file-write b_nr_class_100_150 file-print nr_class_100_150
file-write "dfarms 150-200 " file-write b_nr_class_150_200 file-print nr_class_150_200
file-write "dfarms >= 200 " file-write b_nr_class_gr_200 file-print nr_class_gr_200
file-write "cows on dfarms 1-20 " file-write b_cow_class_1_20 file-print cow_class_1_20
file-write "cows on dfarms 20-50 " file-write b_cow_class_20_50 file-print cow_class_20_50
file-write "cows on dfarms 50-75 " file-write b_cow_class_50_75 file-print cow_class_50_75
file-write "cows on dfarms 75-100 " file-write b_cow_class_75_100 file-print cow_class_75_100
file-write "cows on dfarms 100-150 " file-write b_cow_class_100_150 file-print cow_class_100_150
file-write "cows on dfarms 150-200 " file-write b_cow_class_150_200 file-print cow_class_150_200
file-write "cows on dfarms >= 200 " file-write b_cow_class_gr_200 file-print cow_class_gr_200
file-write "nr of quitted farms" file-print nr_qfarms
file-write "increase in dcows" file-print cows_Free
file-write "change in total costs per liter" file-print average_deltaCosts

file-close

end

;; ----- Create Output on monitors ---
to update-globals
  set Total_demand sum [grass_need] of farms
  set Total_supply1 sum [grass_pot1] of farms
  set Total_supply2 sum [grass_pot2] of farms
  set Total_deltaCow sum [delta_cow] of farms
  set Total_grass sum [cultgrond] of farms
end

;; ----- One-Liners -----

to clear-all-but-globals
  reset-ticks ct cp cd clear-links clear-all-plots clear-output
end

```