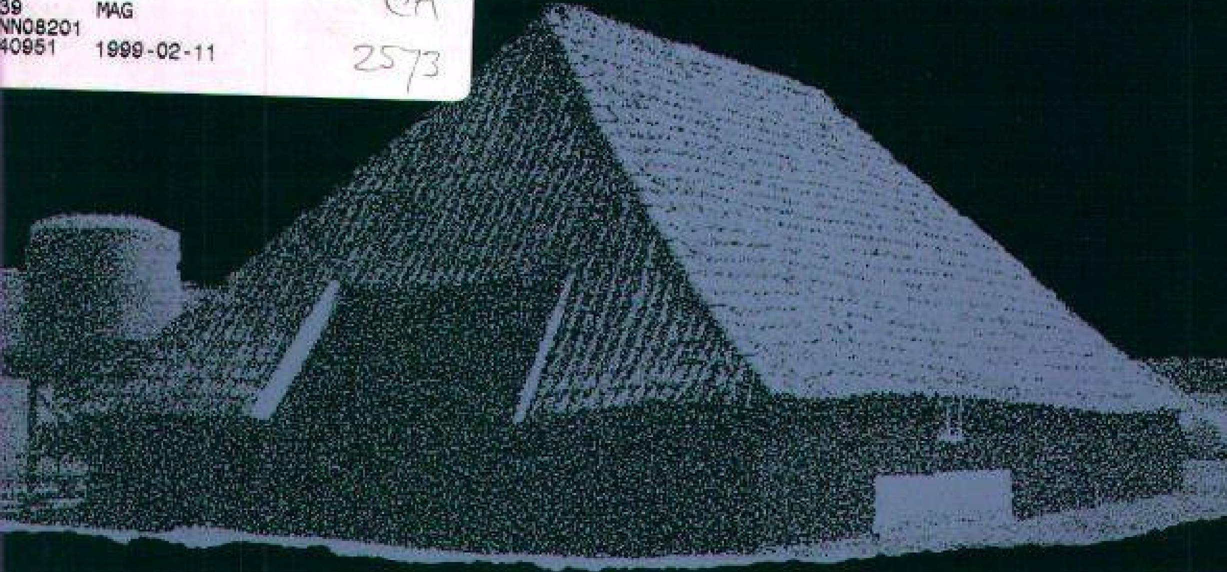

# Economic-environmental modelling of Dutch dairy farms incorporating technical and institutional change

P.B.M. Berentsen

## Stellingen

1. De milieuwetgeving en een mogelijk liberaler markt- en prijsbeleid zullen ertoe leiden dat intensievere melkveebedrijven hun economische voorsprong ten opzichte van extensievere bedrijven verliezen. *(dit proefschrift)*
2. Onderzoek, voorlichting en onderwijs hebben de Nederlandse landbouw sterk gemaakt, nu kunnen ze helpen de landbouw schoner te maken. *(dit proefschrift)*
3. Het milieubeleid zal bijdragen aan een grotere éénvormigheid van de Nederlandse melkveehouderij. *(dit proefschrift)*
4. Een goede modellering van grasproduktie en graslandbeheer is net zo lastig als het realiseren van een hoge grasproduktie en een goed graslandbeheer.
5. Een bepaald nutriëntenoverschot als maat voor de toegestane milieubelasting heeft zijn milieutechnische beperkingen. Een maximale veebezetting als maat voor de toegestane milieubelasting is nog veel beperkter en is daardoor een stap terug.
6. Mensen die pleiten voor een vergaande liberalisering van de landbouw kennen de geschiedenis van de landbouw slecht of zijn weinig begaan met de landbouw.
7. Het is verbazingwekkend hoe gemakkelijk sommige wetenschappers die objectiviteit en verifieerbaarheid hoog in het vaandel voeren deze waarden los lijken te laten als het om geloofszaken gaat.
8. Toename van zinloos geweld, flexibilisering van de arbeidsmarkt en afbraak van sociale voorzieningen zijn allen loten aan dezelfde stam van veramerikanisering van de samenleving.
9. Het is even verbazingwekkend als hoopgevend dat een ex-dictator door een voormalig bondgenoot wordt gearresteerd en mogelijk uitgeleverd om te worden berecht voor zijn wandaden.
10. De verdediging van een proefschrift met stellingen zou een breder beeld van de ontwikkeling van de promovendus geven als meer aandacht werd gewijd aan de stellingen.
11. Goed zingen heeft met veel takken van sport gemeen dat een grote mate van lichaamscontrole en lichamelijke inspanning gecombineerd wordt met uiterste concentratie.
12. Spelen in een loterij is het kopen van een illusie.
13. Geluk vereist noch het nemen van risico noch het volgen van een cursus.

P.B.M. Berentsen
Economic-environmental modelling of Dutch dairy farms incorporating technical and institutional change.
Wageningen, 19 februari 1999

# Economic-environmental modelling of Dutch dairy farms incorporating technical and institutional change

Promotor: dr. ir. J.A. Renkema
Hoogleraar in de Agrarische Bedrijfseconomie

**P.B.M. Berentsen**

# Economic-environmental modelling of Dutch dairy farms incorporating technical and institutional change

Proefschrift

ter verkrijging van de graad van doctor
op gezag van de rector magnificus
van de Landbouwuniversiteit Wageningen,
dr. C.M. Karssen,
in het openbaar te verdedigen
op vrijdag 19 februari 1999
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# Abstract

**Economic-environmental modelling of Dutch dairy farms incorporating technical and institutional change**
Milieu-economische modellering van Nederlandse melkveebedrijven rekening houdend met technische en institutionele veranderingen
Berentsen, P.B.M., 1999

Circumstances in Dutch dairy farming are changing continuously. The general objective in this thesis was to develop and apply a method to enlighten the consequences of these changing circumstances for dairy farms. The research was started with the development of a linear programming model of a dairy farm. The model contains activities for common production processes on dairy farms like grass and silage maize production and milk production. To register nutrient flows nitrogen, phosphate and potassium balances at soil, animal and farm level were included in the model. The model was tested and validated based on average results in practice. Scenario analysis was used to assess consistent scenarios for technical and institutional change. Analysis of historical data taking into account external changes was done to assess future technical change of fodder and milk production. Institutional change included national environmental policy and EU market and price policy. For national environmental policy a moderate and a severe variant of a nutrient balance system with levies on unacceptable surpluses were formulated. For EU market and price policy the two alternatives used were continuation of the current system and a system with decreased milk quota receiving a high price combined with free additional milk production receiving a low price. One forecast for technical change, two for environmental policy and two for market and price policy resulted in four scenarios. Using the farm model the consequences of the scenarios for 2005 were calculated. The results showed that technical change contributes to both farm income and reduction of nutrient surpluses. Environmental policy and the two-price-policy for milk tend to decrease income. Besides, the two-price-policy tends to increase milk production by increasing numbers of animals conflicting with environmental policy. In general consequences of the scenarios are larger for more intensive farms. The final step in this thesis was extension of the model in a spatial and a seasonal dimension in order to realize a more realistic representation of nitrogen flows.

# Voorwoord

Dit proefschrift is de neerslag van zeven jaar milieu-economische modellering. Wat in 1991 begon met het schrijven van enkele papers op basis van berekeningen met een voorloper van het in dit proefschrift beschreven model, leidde vervolgens tot een voorstel voor een promotie-onderzoek en heeft nu geresulteerd in dit proefschrift.

Het uitvoeren van onderzoek naast het verzorgen van onderwijs en andere beheersmatige taken heeft voor- en nadelen. Afwisseling van werkzaamheden houdt de geest levendig en het oog scherp. Daarnaast is een eventuele tegenslag in het onderzoek gemakkelijker te verwerken omdat nog zoveel andere dingen de aandacht opeisen. De keerzijde is dat het onderzoek heel gemakkelijk sluitpost wordt op de tijdbegroting. Zaken die op korte termijn spelen, zoals een student die even vastzit met zijn afstudeervak of een collega met een computerprobleem die dankbaar is voor wat hulp, winnen het vaak van een meer abstract en verder weg liggend onderzoeksdoel. Dit betekent dat het schrijven van dit proefschrift zich over een wat langere periode uitstrekte dan tegenwoordig gebruikelijk is en dat dus een langere adem vereist was. Dit laatste mag voor een zanger en tevens hardloper natuurlijk geen probleem zijn.

Een proefschrift schrijven gaat niet zonder mensen die kritisch over je schouder meekijken. Gerard Giesen en Jan Renkema bedank ik bijzonder voor het helpen uitzetten van de onderzoekslijnen, het becommentariëren van de resultaten en het behoeden voor valkuilen, gedachtenkronkels, etcetera. Daarnaast bedank ik iedereen zowel in familie- en kennissenkring als in mijn werkomgeving voor de belangstelling voor het onderzoek en voor het vertrouwen in het resultaat.

Tenslotte een bijzonder woord van dank voor Sonja voor haar steun en voor de wijze waarop ze zonder te pushen, wat ik waarschijnlijk wel gedaan heb toen zij met haar proefschrift bezig was, regelmatig mijn aandacht wist te richten op dit onderzoek.

Paul Berentsen
Wageningen, december 1998

# Contents

## 1 General introduction

## 2 An environmental-economic model at farm level to analyze institutional and technical change in dairy farming

## 3 Economic and environmental effects of a new protein evaluation system in dairy farming

**7 Introduction of seasonal and spatial elements in grass production and grassland use in a dairy farm model**

**8 General discussion**

# 1. General introduction

## 1.1 Background and scope

Circumstances in modern farming are changing continuously. Changes can be brought about deliberately by governments in order to achieve certain public goals like in environmental policy or they can have a more autonomous character like technical change. In order to stay in business farmers have to adapt farming practices to these changes in the external conditions of the farm. In this study the focus is on changing circumstances in Dutch dairy farming and ways of adaptation to it.

Dairy farming in the Netherlands in the last decades is characterized by a continuous growth of productivity through technical change. Figure 1.1 shows the development of gross productivity at the farm level for bigger dairy farms. Dairy farms are called bigger if their size is bigger than 158 Standard Farm Units (Van Everdingen, 1993). A well managed dairy farm of

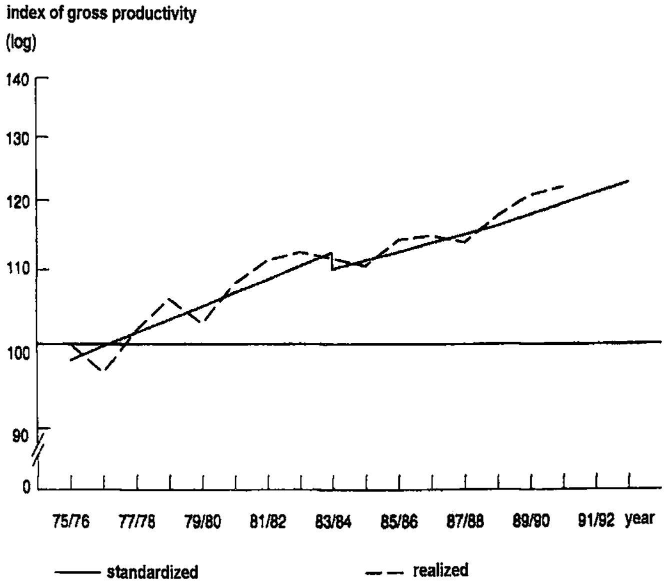

Figure 1.1 Development of the gross productivity at farm level for bigger dairy farms (source: Van Everdingen, 1993).

this size offers employment to about one person. Gross productivity is defined as farm output divided by farm input both measured in constant prices. Before introduction of the quota system in 1984, productivity increased mainly by raising output. This was realized by both raising production per technical production unit (i.e. per cow and per ha) and raising the number of technical production units per farm, so farms became both bigger and more intensive. On the input side substitution took place between labour on the one hand and capital and non-factor inputs like feed stuffs and fertilizer on the other hand (Rutten, 1992). After 1984 when total production was fixed, farm productivity mainly increased by decreasing inputs. This was realized by a further increase of the production per technical production unit followed by a consequential decrease of the number of dairy cows per farm, resulting in a decrease of labour and feed stuff input. Quota transfers partly compensated for the decrease in the numbers of dairy cows per farm.

Both types of production processes on dairy farms (i.e. animal production and fodder production) have brought along their own type of problems and induced governmental policies to overcome these problems. The rapid increase of milk production in the seventies resulted in large production surpluses that could be marketed only with the help of large subsidies. The resulting budgetary difficulties finally lead to the introduction of the milk quota system in the EU. A few years later, high emissions of phosphate and nitrogen to ground and surface waters gave rise to national environmental policy in the Netherlands. Although these losses arise with plant production, it is clear that the high intensity of livestock keeping in the Netherlands, based on substantial feed imports, is a major cause of the environmental problems.

The picture that emerges from these developments is one of continuous adjustments both at the farm level and the agricultural policy level with a strong interaction between these levels. A change of agricultural or environmental policy results in changing external conditions of the farm which can lead to changes in the farm organization. At the other end of the cycle, reactions of farmers on policy adjustments often lead to new policy adjustments.

To understand the relation between policy and agricultural production, insight is required into the possibilities of farmers to adapt farming according to a change of policy and in the goals of farmers. The possibilities to adapt farming require insight into the complex relations at farm level between technical, ecological and economic components. When these insights are combined with possible future developments in the field of technological change and agricultural and environmental policy, the future of Dutch dairy farming can be enlightened. The present study intends to contribute to this enlightenment.

## 1.2 Objective of the research

The study described here aims to contribute to the research on the consequences of changing external conditions for dairy farms. More in particular the objectives are (1) to develop a method including a dairy farm model to examine consequences, and (2) to apply the method in order to offer insight into the possible consequences of changing external conditions. The study focuses on specialized dairy farms on sandy soil. Sandy soil is chosen because environmental problems on that soil type are most severe due to the relatively high animal density and to soil characteristics. About 57% of the specialized dairy farms in the Netherlands are located on sandy soil. The average specialized dairy farm on sandy soil is somewhat smaller but slightly more intensive than the average specialized dairy farm in the Netherlands. The effects at farm level of technical and institutional change are analysed with respect to the farm organization (inputs used and outputs produced), the farm economic results and the environmental load. The insights from this analysis can be used to support farm management decision making and agricultural policy development.

Given the objectives the study covered the following phases:

1. development of a model of a dairy farm containing technical, economical and environmental aspects;
2. exercises with the model including calculation of effects of the use of a new protein evaluation system in dairy farming to examine the usefulness of the system for decreasing nitrogen losses ;
3. validation of the model to make it a good representation of an average dairy farm on sandy soil;
4. assessment of scenarios containing technical and institutional change in dairy farming;
5. application of the scenarios to dairy farms on sandy soil;
6. inclusion of seasonal and spatial elements in the model to make it suitable for analyzing nitrogen flows in detail.

## 1.3 Outline

Chapter 2 describes the dairy farm linear programming model that is used to analyse the effects of technical and institutional change. First the model requirements are derived from the objectives of the study. Next , parts of the model like animal production, feed production and environmental aspects are explained and data sources for these parts are given. The Chapter ends with a model test showing the effects of a levy on nitrogen losses and the effects of technical change (higher milk production versus higher grass and crop production).

In Chapter 3, the model is used to examine the consequences of the change to a new protein evaluation system in dairy farming in the Netherlands. In the beginning of the nineties, problems with nitrogen emission to air and soil brought along the need for a more detailed protein evaluation system for feeding dairy cows that could be used to avoid superfluous protein feeding and consequential nitrogen emission. Special attention is given to a description of the old and the new protein evaluation system.

Chapter 4 is aimed at validation of the dairy farm model and creating a representative basis model. To this end, average results of specialized dairy farms on sandy soils are used. By adjusting fixed assets and production levels and adding restrictions the model simulates reality quite well. Lifting unnecessary restrictions delivers the optimization model for further calculations.

Chapter 5 deals with the development of scenarios concerning technical and institutional change in Dutch dairy farming. The Chapter starts with an overview of the literature on scenario analysis. Next, technical and institutional factors are analysed resulting in (sometimes multiple) forecasts for each factor. Finally, the forecasts are combined into four consistent scenarios.

In Chapter 6 the model derived in Chapter 4 is used to calculate the effects of the scenarios that were derived in Chapter 5 on technical, economic and environmental results. Sensitivity analysis is done with regard to intensity and scale of farming and with regard to the assumed increase of grass production.

In Chapter 7 the focus is turned again to the model. To make the model suitable for analyzing nitrogen flows on dairy farms, seasonal and spatial elements are introduced in the existing model. To determine the effects of the inclusion of seasonal and spatial effects calculations are done with the existing model, the model with three summer periods and the model with three periods and two lots, a homestead lot and a field lot. Additionally, the division of the total area between homestead and field lot is varied to get an idea about the relative importance of the homestead lot.

In the closing chapter some methodological issues are discussed as well as interpretation of the results. The chapter ends with some ideas for further research.

## References

Rutten, H (1992) Productivity growth of Dutch agriculture, 1949-1989. Agricultural Economics Research Institute, Report nr. 470, The Hague.

Van Everdingen, W.H. (1993) Melkvee 1975-1995, bedrijfseconomische beschouwingen. Agricultural Economics Research Institute, Report nr. 6-91, The Hague.

# 2. An environmental-economic model at farm level to analyze institutional and technical change in dairy farming[1]

## Abstract

*A deterministic static LP model of a dairy farm is presented and tested. The objective function of the model maximizes labour income. The model will be used for determining the effects of institutional, technical and price changes on the farm plan, economic results and nutrient losses to the environment. In this paper attention has been paid to the way in which animal production, feed production and environmental aspects were incorporated in the model. Optimizations were made for a typical dairy farm facing a levy on N losses and an increase in milk and plant production. Results are consistent and can be explained from the assumptions made. They show that negative economic effects of environmental legislation can be compensated by positive effects of technical improvement.*

## 2.1 Introduction

Dairy farming in The Netherlands is facing changes that originate from different sources. Changes in the common agricultural policy confront farmers with changing prices for products. Environmental legislation at a national level forces farmers to decrease their nutrient losses to the environment, while at the same time technical change within the sector enable farmers to increase production and efficiency.

To explore the uncertain future in dairy farming, a modelling approach can be useful. If a model representing a dairy farm also had the possibilities of incorporating changes as described above (which can be grouped into scenarios), calculations could elucidate possible future situations in dairy farming.

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[1] Paper by P.B.M. Berentsen and G.W.J. Giesen; published in *Agricultural Systems* 49: (1995) 153-175.

Farmers as well as governmental institutions can benefit from these calculations. Farmers get more insight into the possibilities of reacting to changing policies, and governmental institutions get an impression of possible effects of proposed policies. A comparison between desired effects and calculated effects can lead to more effective policy making. An environmental-economic model of a dairy farm that serves these purposes is presented in this paper. The considerations that led to the specific model and the contents of the model are given. The results of a first test of the model, concerning the incorporation of some institutional and technical changes, are discussed.

## 2.2 Objectives and model requirements

The model presented in this paper was built to serve the purposes of a wider project. The main objective of this project concerns an analysis of possible effects of changing circumstances on Dutch dairy farms. For reasons of analysis, changing circumstances are mostly divided into technical and institutional change. Cochrane (1958) defined technical change as "an increase in output per unit of input resulting from a new organization, or configuration of inputs, where a new and more productive production function is involved". This definition covers the use of new techniques (such as automatic milking) as well as the improvement of existing techniques (such as an increase in milk production per cow by breeding). Following Wossink (1993), the word institution is used as a general indication for policy regulations. Within the context of Dutch dairy farming, policy regulations result from the national government as well as from the European Community (EC). Traditionally, the national government is responsible for social-economic policy, which has its influence on all economic activities. Besides that, the national government looks after specific legislation for firms. A relatively new area in which the influence of the national government is rapidly increasing is that of the natural environment. As most agricultural production is very closely linked to the natural environment by using the soil and other natural resources, governmental interference in this area is increasingly affecting agriculture. The EC interference in agriculture follows from the objectives established in the Treaty of Rome and is indicated as market and price policy and structural policy. This study focuses on environmental and on market and price policy as far as institutional changes are concerned. In modelling at farm level, a third group of factors must be added to the farm circumstances, i.e. the prices of production factors and of products that do not fall under the regime of the EC.

The effects at farm level of technical and institutional change become visible in the farm plan, the farm economic results and in the environment. The farm plan represents the quantities of different outputs produced and of factors used and provides relationships between input and output. The farm economic results follow from the quantities of inputs and outputs and their prices, and give an indication of the profitability of production and of the income of the farm family. Given the increasing emphasis on environmental problems, the effects on the natural environment are also of interest. These effects can be measured by quantification of the substances produced by the farm that cause damage to soil, water and air.

The changes that must be modelled and the desired categories of results require a specific modelling approach. Farmers' reactions to changes can only partly be derived from history. Most of the environmental legislation, for instance, is new and not comparable with other legislation and therefore derivation of empirical relations is impossible. The desired results with respect to the farm plan and environmental consequences require a model in which attention is given to technical relations. Given the necessarily normative approach and the requirement of modelling detailed relations, the use of linear programming offers possibilities. Linear programming presents a collection of relevant technical opportunities offered to the farm by separate activities in a matrix. The rows in this matrix form the constraints that represent the technical relations between the activities. Given the objective function, the solution procedure determines the optimum solution considering all activities and restrictions simultaneously. Marginal product values of the resources are part of the solution and ease interpretation of the results. Linear programming is suitable for the purposes of this study. New production techniques can easily be incorporated by means of adding new activities to the model. Improvement of existing techniques (such as milk production per cow) can be implemented by changing coefficients in the model. Incorporation of environmental legislation can be done by adding new restrictions to the model (as in restricting fertilizer use) or by increasing prices of undesired outputs (e.g., imposing a levy on nitrogen losses). Market and price policies can be integrated by changing existing restrictions (e.g., the amount of milk that is allowed to be produced) or by changing prices in the model. Finally, prices of production factors and products not falling under the EC-regime can easily be altered.

Table 2.1 General structure of the linear programming model

| *Activities*<br>*Constraints* | Feed production for on-farm use | Feed production for sale | Purchase of feed | Animal production | Manure application | Purchase of fertilizer | Other operations: owner's mechanization or contract work | Machinery for owner's mechanization | Nutrient losses | *Right hand side* |
|---|---|---|---|---|---|---|---|---|---|---|
| Land requirements | +1 | +1 | | | | | | | | ≤ Available hectares |
| Milk production | | | | $a_{i,j}$ | | | | | | ≤ Available quota |
| Housing requirements | | | | $a_{i,j}$ | | | | | | ≤ Available cow places |
| Labour requirements | $a_{i,j}$[1] | $a_{i,j}$ | | $a_{i,j}$ | $a_{i,j}$ | $a_{i,j}$ | $a_{i,j}$ | | | ≤ Available labour |
| Feeding requirements | $-a_{i,j}$ | | $-a_{i,j}$ | $a_{i,j}$ | | | | | | ≤ 0 |
| Fertilizing requirements | $a_{i,j}$ | $a_{i,j}$ | | | $-a_{i,j}$ | $-a_{i,j}$ | | | | ≤ 0 |
| Linking animal production and manure application | | | | $-a_{i,j}$ | $a_{i,j}$ | | | | | = 0 |
| Nutrient balances: | | | | | | | | | | |
| - farm level | | $a_{i,j}$ | $-a_{i,j}$ | $a_{i,j}$ | | $-a_{i,j}$ | | | $a_{i,j}$ | = 0 |
| - herd level | $-a_{i,j}$ | | $-a_{i,j}$ | $a_{i,j}$ | $a_{i,j}$ | | | | | = 0 |
| - soil level | $a_{i,j}$ | $a_{i,j}$ | | | $-a_{i,j}$ | $-a_{i,j}$ | | | $a_{i,j}$ | = 0 |
| Linking production activities and operations | $a_{i,j}$ | $a_{i,j}$ | | | | | $-a_{i,j}$ | | | ≤ 0 |
| Linking owner's mechanization and new machinery | | | | | | | $a_{i,j}$ | $-a_{i,j}$ | | ≤ 0 |
| Object function | Costs per ha | Gross margin | Costs per unit | Gross margins | Costs per unit | Costs per unit | Costs per unit | Annual costs | | |

---

[1] $a_{i,j}$ is the technical coefficient that relates activity i to constraint j

## 2.3 Model specification and data used

### 2.3.1 General structure

The general structure of the model is shown in Table 2.1. It has the form of a standard linear programming model:

Maximize $\{\mathbf{Z} = \mathbf{c}'\mathbf{x}\}$
Subject to $\mathbf{A}\mathbf{x} \leq \mathbf{b}$
and $\mathbf{x} \geq 0$

where $\mathbf{x}$ = vector of activities; $\mathbf{c}$ = vector of gross margins or costs per unit of activity; $\mathbf{A}$ = matrix of technical coefficients; and $\mathbf{b}$ = vector of right hand side values.

For easy reference, the activities and constraints are simplified and grouped in Table 2.1. The real LP model consists of some 100 activities and 80 constraints. The groups of activities (**x**) are shown at the top in Table 2.1. Seven groups are distinguished:

- Feed production for on-farm use, with grass production available for grazing and silage making at different levels of nitrogen use, silage maize production and fodder beet production;
- Feed production for sale. A surplus of silage maize can be sold;
- Purchase of feed with a variety of concentrates and roughage that can be bought;
- Animal production including dairy cows with young stock for replacement, beef bulls and suckling cows;
- Manure application consisting of different methods of applying manure on grassland and arable land;
- Purchase and application of different kinds of fertilizer;
- Other operations such as mowing and harvesting grass for silage making which may be done with own mechanization or as contract work;
- New machinery which has to be invested in if operations are carried out with own mechanization.

Each activity has its own specific vector of input and output coefficients. All vectors together form the matrix **A**. The rows of the matrix indicate the type and form of the constraints used:

- The first four constraints link the different activities to the available fixed assets of the farm (e.g., land area, milk quota and cow places) and to labour. The available fixed assets and the available labour are part of the vector of right- hand side values (**b**);

- The feeding requirements match home-produced feed and purchased feed with the animal requirements for energy, protein, etc;
- The fertilizer requirements match the need for nutrients for grassland and arable land with the available nutrients from manure and purchased fertilizer;
- Animal production and manure application are linked to ensure that all manure produced is applied;
- Nutrient balances determine the losses of nitrogen (N), phosphate ($P_2O_5$) and potassium ($K_2O$) to air, soil and ground water;
- Production activities and operations are linked to ensure that necessary operations such as mowing and ensiling of grass take place;
- Operations done with own mechanization are linked with machinery to ensure that the necessary machinery is available.

The last row contains the objective function of the LP model which is to be maximized. In this function the products of the units of activities and the costs or the gross margins per unit of activity are summed up and produce the gross farm result. Consequently, this result includes returns, variable costs and the fixed costs connected with the machinery which are options in the model.

The other part of the fixed costs follows from the fixed assets of the farm, the cost of land, of the barn and of the fixed machinery, and have not been included in the LP model but are calculated separately. The final outcome is the labour income of the farm and is determined by subtracting the other fixed costs from the gross farm result. The labour income is the remuneration for labour and management that is left over after all other costs have been paid.

In the following sections, different parts of the LP model will receive further attention. The initial farm situation is specified by the right-hand side values for land, milk quota, cow places, and labour and by a number of farm specific coefficients (such as the milk production per cow and grass production per hectare).

The software used for optimization is XA-87, developed for solving linear programming problems on a personal computer. The features of XA-87 include reading the LP problem from a LOTUS 123 spreadsheet file and transferring the results to the spreadsheet file. This offers the possibility of using spreadsheet facilities such as cell references, formulas, etcetera. These facilities are used to calculate coefficients with the help of small spreadsheet programs, to use data stored in other spreadsheet files and to present the results in a convenient way. The XA program run on a 80486 personal computer solved the problem presented in a few minutes computational time.

### 2.3.2 Animal production

#### *Dairy cattle*

The central element in the LP model is an average dairy cow with a fixed milk production, calving in February and representing the dairy cattle of the farm. In the model, summer and winter period are distinguished. Feeding requirements are calculated per dairy cow for summer and winter. The bio-economic model of Groen (1988) is used to determine summer and winter milk production, summer and winter energy requirements, and summer and winter dry matter intake capacity. Given the calculated milk production per period, protein requirements are calculated using formulas of the Central Bureau for Livestock Feeding (1991). Furthermore, a requirement concerning the structure of the ration, i.e. the equivalent of effective fibre in long roughage, is included. At least one-third of the dry matter of the ration must consist of structural material (Central Bureau for Livestock Feeding, 1991). Finally, two additional feeding requirements are included in the model. In summer, a minimum of 1 kg of concentrates per cow per day is required to entice the cows to the milking parlour. In winter, a minimum of 2 kg dry matter from grass silage per cow per day is required. This restriction is included to guarantee that grass silage is included in the winter ration, which is common practice in The Netherlands, and to force the model to mow and ensilage grass. Given fluctuations in grass production during summer, mowing grass is necessary for a good grassland management.

In the model it is assumed that per year 1.11 calf is borne per average cow (Groen, 1988) of which 10% die before the age of 10 days (Bloem & Kolkman, 1992). Due to voluntary and involuntary disposal of dairy cows it is assumed that per year 25% of the dairy cows are replaced by heifers raised on the farm.

The amount of manure produced is one of the factors determining the cost of applying manure. Manure production depends on milk production (Bloem & Kolkman, 1992). If cows graze day and night in summer but are milked inside (which is quite common practice in The Netherlands), 10% of the daily manure production is excreted in the barn. If only day grazing occurs, 60% of the manure is excreted in the barn.

The returns per cow amount to Dfl. 5502 and include the returns of milk and culled cows. The returns of calves that are sold are not included because the model offers the possibility of fattening male calves. The costs per cow amount Dfl. 647 and include costs of health care, breeding, energy for milking and interest. Feeding costs are excluded because separate activities for buying roughage and concentrates are used in the model.

### *Other cattle*

In order to be able to replace cows, young stock must be kept on the farm. One activity is used to represent one female breeding calf plus 0.96 yearling. This activity produces 0.883 heifer for replacement of dairy cows. For reasons of selection and disease, 4% of the calves are removed and 8% of the yearlings (Bloem & Kolkman, 1992). Like cows, young stock requires housing capacity. Requirements for energy and protein are calculated for summer and winter using formulas from the Central Bureau for Livestock Feeding (1991). The costs of young stock amount to Dfl. 338 per calf plus 0.96 yearling and include costs of health care, breeding and interest. Feeding costs are not included.

Depending on the housing capacity, beef calves can be fattened on the farm. Beef bulls are kept on a ration of silage maize and a fixed amount of concentrates. Animals are slaughtered when they are 15 months old. With 1992 prices the gross margin per beef bull amounts to Dfl 1350,-. The gross margin includes the returns of the animal, the same costs as given for young stock (Bloem & Kolkman, 1992) and the costs of concentrates. Since the calves are produced by the dairy cattle no costs for the calves are included.

### 2.3.3 Feed production and available other feed

The land of the farm can be used for growing grass, maize, and fodder beets. Grass can be used for grazing and for silage making; maize is used for silage making. Silage maize can be fed in winter and summer. Fodder beets are only fed in winter. In addition to the home-grown feed, concentrates and silage maize can be purchased. All feed supplies net energy, protein and dry matter and uses part of the intake capacity of the animals.

### *Grass*

Dry matter production of grassland per year depends mainly on the available amounts of water and nutrients and on growing conditions; the length of the growing season and the amount of radiation intercepted by the grass are the most important (Van de Ven, 1992). An important factor influencing the amount of radiation is the harvesting frequency. A low harvesting frequency (i.e. mowing grass for silage making at 3000 kgdm/ha) results in a higher dry matter production than a high frequency (i.e. grazing of grass at 1700 kgdm/ha). In general, the total annual dry matter production decreases with increasing harvesting frequency (Sibma & Alberda, 1980). Looking at energy production instead of dry matter production, the difference is much smaller, as grass for grazing has a higher energy content than grass for silage making (Sibma & Ennik, 1988).

At the Experimental Station for Cattle Production (1991), a model was developed to simulate the feeding situation on a dairy farm. The production characteristics in this model are based on experiments and practical results from a number of years. From the results of the model, the energy production per ha can be calculated. It appears that energy production depends mainly on the soil type, on the ground water table and on the level of N use. The mowing percentage, which depends on animal density, and the type of grassland use appear to have little influence. This means that with given soil type and ground water table it is acceptable to use one curve representing the energy production per ha as a function of N-use. The lowest level of N-use that can be simulated with the model of the experimental station is 200 kg/ha. As this may not be low enough under future environmental legislation, extrapolation is necessary. From the literature it appears that a non-orthogonal hyperbola is useful to describe the reaction of plants on nutrient supply (Thornley, 1976; Middelkoop & Aarts, 1991). Figure 2.1 shows the resulting curves for energy production of grassland at different levels of N-use on sandy soil at four different ground water tables varying from ground water table IV (soil with a very good water supply) to ground water table VII (very dry soil).

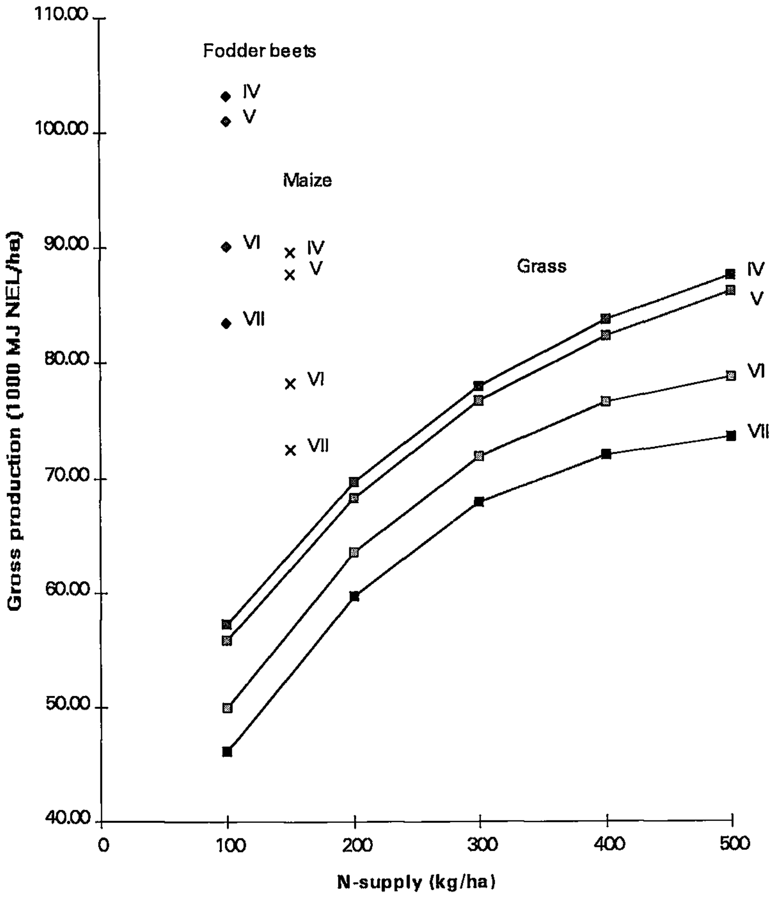

Figure 2.1 Gross energy production at different ground water tables (ranging from good water supply (IV) to very dry (VII) from fodder beets, silage maize and grass at different N levels on sandy soil.

In the model, five levels of N use are distinguished (100, 200, 300, 400 and 500 kg/ha), considering soil type and ground water table. The energy production per ha is taken from the respective curve. Grass produced can be used for grazing and mowing for silage making. Silage and feeding losses (Asijee, 1993) and energy and protein content (Central Bureau for Livestock Feeding, 1991) are used to calculate net energy, protein and dry matter supply per cut.

Each hectare of grassland requires the corresponding amount of mineral N which can be supplied by fertilizer and manure. Requirements for $P_2O_5$ and $K_2O$ are linked with cut activities to take into account the nutrients excreted while grazing.

The costs of grassland include cost of renewing grassland, of fencing, of nutrients other then N, $P_2O_5$ and $K_2O$, of fuel for fertilizing and for tedding and raking grass and of plastics to cover the grass silage. Because grassland has to be renewed more often when it is used more intensive, cost of renewing grassland are higher with higher N-use (Bloem & Kolkman, 1992). Costs of mowing and ensiling are not included. For mowing and ensiling separate activities are used to provide a choice between mowing and ensiling with the owner's labour and machines or as contract work. Mowing and ensiling with the owner's machines requires an investment in a mowing machine and an ensilage wagon with fixed annual costs. Besides that, extra costs for fuel are included per cut. Mowing and ensiling contracted out have a fixed price per hectare.

### *Maize and fodder beets*

Dry matter production of maize and fodder beets are influenced by less factors than dry matter production of grass. Since harvesting takes place at the end of the season, the harvesting frequency and consequently the amount of radiation intercepted by the crops are fixed. Dependency of dry matter production on nutrients differs from that of grass, because nutrients must be available to a minimum level to reach an acceptable production. Nutrients above that level, however, increase production very little. Concerning N on maize, for example, mineral N supplied through fertilizer and manure must be between 20 and 190 kg/ha depending on the N supply of the soil (Aarts & Middelkoop, 1990). Therefore, the nutrient supply for maize and fodder beets advised by the Dutch extension service is used in the model (Roeterdink & Brantjes, 1992). The only variable factor left is the ground water table. As the production dependency of grass, maize and fodder beets on available ground water is similar (Middelkoop & Aarts, 1991), the same proportional differences in dry matter production between ground water tables are used for maize and fodder beets as for grassland. Given average dry matter productions for maize and fodder beets (Bloem & Kolkman, 1992) and average energy content (Central Bureau for Livestock Feeding, 1991), gross energy production per hectare is calculated. In Figure 2.1, gross energy production per hectare of fodder beets (at 100 kg N) and maize (at 150 kg N) for four ground water tables are given. The costs per hectare of maize and fodder beets amount Dfl. 2523 and Dfl. 3904 respectively and include costs of seed bed preparation, sowing, crop care, harvesting and ensiling. It is assumed that all work is contracted out. If fodder beets are fed, an additional investment is required in machinery for feeding, resulting in additional fixed annual costs. If a farm has a surplus of roughage, the model offers the possibility of selling silage maize at a price of Dfl. 2552 per ha (Bloem & Kolkman, 1992). In that case costs of harvesting and ensiling of Dfl. 1190 are for the buyer.

### *Purchased feed*

In addition to home grown feed, concentrates, dried beet pulp and silage maize can be purchased (Table 2.2). The intake capacity needed for concentrates increases more than proportionally with the amount of concentrates eaten by a cow (Jarrige 1988). Therefore, in winter four fill values for concentrates are used in the model. At first, concentrates from the level with the lowest fill value is taken. When more than 3 kg per cow is fed, concentrates from the second level with a somewhat higher fill value is taken, etc. Because in summer only a small

Table 2.2 Feedstuff that can be purchased with their energy content, protein content and price and the availability in summer (S) or winter (W) (Based on Asijee (1993))

| | Price (Dfl/kgds) | Energy content (MJ NEL[1]/kgds) | Protein content (DVE[2]/kgds) | Available |
|---|---|---|---|---|
| Standard concentrates | .41 | 7.2 | 100 | S&W |
| Low protein concentrates | .41 | 7.2 | 89 | S |
| High protein concentrates | .51 | 6.9 | 200 | W |
| Dried beet pulp | .41 | 7.1 | 109 | S |
| Maize silage | .30 | 6.2 | 47 | S&W |

[1] MJ NEL = Megajoule Net Energy for Lactation

[2] DVE = Darm Verteerbaar Eiwit (intestine-digestible protein)

amount of concentrates is fed, the lowest fill value for concentrates is used. Purchased silage maize has the same quality as home-grown maize. The price includes harvesting and ensiling costs.

### 2.3.4 Environmental aspects

The model includes a number of rows that register the losses of N, $P_2O_5$, and $K_2O$ to the environment. Balances at farm level register nutrient input and output and, consequently, total nutrient losses. To gain insight into the efficiency of nutrient use by animals and by crops, also balances at herd level and soil level are used. For N additional rows register the ammonia ($NH_3$) emission and the potential leaching losses to ground water. The actual leaching losses follow after correcting the potential losses for denitrification.

*Nutrient balances at farm, herd and soil level*

Input of nutrients at farm level takes place by the purchase of feed and of fertilizer and for N also by deposition (see Table 2.1). Fertilizers that can be purchased are N, $P_2O_5$, and $K_2O$ with prices per kilogram of Dfl. 1.15, Dfl. 0.94, and Dfl. 0.54 respectively (Bloem & Kolkman, 1992). In The Netherlands, deposition of N by acid rain ranges from 32 to 72 kg/ha depending on the region (Asijee, 1993) resulting in an average of 49 kg/ha. Nutrient output at farm level can occur by delivery of milk, meat (disposed animals), home-grown maize that is sold, and manure that is removed from the farm. Table 2.3 shows the nutrient content of some inputs and outputs. Concentration of nutrients in manure depends on the feed ration of the animals, because the nutrient output in manure is calculated as the input through feed minus the retention in milk and meat. As the feed ration is assessed in the optimization, coefficients describing the nutrient concentrations in manure are unknown in advance. This problem is solved by an estimation of the coefficients before optimizing, a check afterwards (when the feed ration is known) and if necessary by correction of the coefficients followed by a new optimization.

Table 2.3 Inputs and outputs at farm level and their nutrient content (g/kg).

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Input: | | | |
| - standard concentrates | 20.8 | 10.3 | 17.8 |
| - low protein concentrates | 17.6 | 10.3 | 17.8 |
| - high protein concentrates | 56.0 | 25.2 | 24.1 |
| - dried beet pulp | 14.4 | 1.8 | 14.5 |
| - maize silage | 14.6 | 5.0 | 18.1 |
| | | | |
| Output: | | | |
| - milk (3.4% protein) | 5.4 | 2.1 | 1.9 |
| - meat | 25.0 | 8.0 | 9.0 |

[1] Based on Asijee (1993) and Coppoolse (1990)

Balances at herd level focus on the efficiency of nutrient use by animals. Input of nutrients occurs through home-produced and purchased feed, while output takes place by milk, meat and manure.

Balances at soil level focus on the efficiency of nutrient use by crops. Input takes place through fertilizer, manure and for N also through deposition. Together with crops, nutrients are removed from the soil. The remainder is called the nutrient soil surplus. For N this surplus is subject to leaching, denitrification and adding to the pool of organic N in the soil.

### *N losses to the air and soil*

Manure contains organic and mineral N. The concentration of organic N in manure of dairy cattle varies a little with the ration the cattle receives (Valk et al, 1990). In this model, the concentration of organic N is assumed to be fixed. This means that assuming a fixed milk and meat production, every change in the protein content of the ration leads to a change of the mineral N content of manure. Mineral N is mainly found in urine, whereas organic N is mainly found in faeces. If urine comes into contact with the open air, part of the mineral N is emitted as $NH_3$. This means that on a dairy farm, $NH_3$ is emitted from the barn, from manure storage and while applying manure to the land when the cows are kept indoors or from urine patches when cows are grazing.

In a separate module, the coefficients for $NH_3$ emission from manure are calculated, considering the N concentration in fresh manure. As explained above, this concentration is estimated in advance, checked afterwards and if necessary adjusted. Emission from the barn, which has a storage capacity for manure of 2 months underneath the grid floor, is assumed to be 13% of total N (van der Hoek et al, 1989). Emission from either an open or closed manure storage facility, which is optional, increases the total emission from barn and storage to 19% for open storage and to 14% for closed storage (van der Hoek et al, 1989). Mineral N still present after storing will partly be emitted as $NH_3$ while it is applied. Manure can be applied to grassland by surface spreading or by injection. The emission during application amounts to 50% and 1% of the mineral N still present after storing for surface spreading and injection respectively. Manure may be surface spread onto land used for maize, followed by tillage of the land after 24 hours or it may be injected. Emission amounts to 17.5% and 1% respectively. The total $NH_3$ emission calculated is related to the way of manure application. All N from manure not emitted into the air is delivered to the soil balance. Mineral N that is not emitted is taken in by plants that utilize this N with the same efficiency as from fertilizer. This mineral N takes the place of N from fertilizer.

Of mineral N excreted while grazing, 12% is emitted as $NH_3$ and 22% is denitrificated on the soil surface (Goossensen & Van den Ham, 1992). The remaining mineral N can only partly be utilized by grass because of the high N supply in urine patches. This depends on the N level used on the grassland. Mineral N that is not emitted, denitrificated on the soil surface or utilized by grass is a potential leaching loss. The coefficients describing the distribution of N from urine are also estimated in advance, checked afterwards and adjusted if necessary. All N (including organic N) excreted by the cows while grazing that is not emitted or denitrificated on the soil surface is added to the soil balance.

The calculation of potential leaching losses is based on calculation rules given by Goossensen & Van den Ham (1992). Leaching dependent on the use of the land (basis leaching), leaching dependent on the N level and leaching from urine patches are distinguished. Potential leaching from urine patches was described above. Potential basis leaching on sandy soil grassland amounts to 15 kg N/ha. On sandy soil crop land potential basis leaching also depends on the use of manure. Here it amounts to 20 kg N/ha plus 17.5% of N from manure. On grassland, potential leaching dependent on the N level amounts to 0, 4, 21, 60 and 115 kg

N/ha at an N level of 100, 200, 300, 400 and 500 kg/ha respectively. On maize land it amounts to 31 and on beet land 25 kg N/ha.

In the model, real N losses through leaching are calculated by summing up the potential leaching losses and adjusting these for denitrification in the soil. Denitrification in the soil occurs under oxygen-poor circumstances, which means that denitrification is high in wet soils. The actual N leaching amounts to 40, 50, 60 and 75% of potential N leaching in soils with ground water table IV, V, VI and VII respectively (Goossensen & Meeuwissen, 1990). The N that is left after N losses through leaching and denitrification is subtracted from N soil surplus and is assumed to be added to the pool of organic N in the soil.

### *Environmental legislation*

In The Netherlands, environmental legislation has existed for a number of years. Relevant for dairy farming are the $P_2O_5$ limit, the prohibition on applying manure in certain periods and the obligation to inject manure in certain periods.

The $P_2O_5$ limit restricts the application of animal manure on the farm. According to this legislation all animals on the farm are assumed to produce a fixed amount of $P_2O_5$. Moreover, on each hectare only a maximum amount of $P_2O_5$ from animal manure is allowed to be used. If the numbers of animals times the fixed $P_2O_5$ production exceeds the numbers of hectares of different crops times the maximum amounts of $P_2O_5$ allowed, manure has to be removed from the farm. For dairy cows, stock younger than one year and for young stock older than one year, the fixed $P_2O_5$ production amounts to 41, 9 and 18 kg/year respectively. In 1992, the maximum $P_2O_5$ dose from animal manure on grassland, maize land and on land for other crops was 200, 250 and 125 kg $P_2O_5$/ha (Bloem, 1992). By these standards dairy farming is in general not affected by this legislation (Berentsen et al, 1992) but this may change in future as the maximum doses allowed become smaller. In the LP-model, a restriction is used to include the $P_2O_5$ legislation.

To decrease leaching of nitrate, legislation was established that allows farmers to apply animal manure only in the growing season when plants can utilize manure immediately. In 1992, application of animal manure was not allowed from October till February. For maize land September was also included in this period (Bloem, 1992). This means that farmers have to invest in manure storage. In the model, investment in a manure storage is obligatory. There is only a choice between investment in an open or in a closed manure storage.

To decrease $NH_3$ emission, legislation was established that forces farmers to apply manure only by means of injection in certain periods. In 1992, on sandy soil grassland only injection was allowed until June 15. After that, surface spreading was also allowed. On maize land and on land for other crops manure must either be injected or spread, immediately followed by tillage of the ground (Bloem, 1992). Since the LP-model does not work with periods within a year, this legislation is modelled in a different way. In the model, a maximum of one-third of all manure is allowed to be applied by means of spreading on grassland. All other manure must be injected.

### 2.3.5 Other aspects

One of the starting points is that the model can represent the specialized Dutch dairy farms. This implies that labour is supplied by the farmer and his family. It amounts to 3028 hours per year. The demand for labour is split into fixed and variable labour. Fixed labour is labour that has to be done on every dairy farm, irrespective of the number of dairy cows and of specific activities. Calculations based on Pelser (1988) produce 1150 hours of fixed labour per year. The remainder is used as supply of variable labour in the LP-model. In the model, all production activities demand labour.

Most fixed costs are calculated separately from the LP-model. Given input factors such as the size of the farm and the housing capacity of the barn, the land rent and the cost of the barn are calculated. Also the cost of the milking parlour and of basic machinery are calculated outside the LP-model. These investments are not optional, because they are considered necessary to run a dairy farm. Some other investments (e.g. in a mowing machine) are optional and are included in the LP-model.

## 2.4 Model test

Calculations are made for a typical dairy farm on sandy soil. Sandy soil is chosen because environmental problems are most severe with that soil type. Ground water table VI is used.

This rather dry soil is fairly average and makes up 26% of the total sandy soil area (Goossensen & Meeuwissen, 1990). The grazing system used is day and night grazing in summer. The available land of the farm amounts to 24 hectare and the milk quota 12,000 kg/ha. Compared to average figures from the Dutch Farm Accountancy Data Network (Van Dijk et al, 1993) the area and the quota used are quite average. An average milk production per cow of 6500 kg/year is assumed with 3.4% protein and 4.4% fat. The capacity of the barn corresponds to the milk quota and the production per cow and the ratio between dairy cows and young stock.

Four calculations have been made. For the first calculation no additional restrictions are used and the results represent the basis situation. Next, an institutional change is carried out. A levy is placed on N losses above 150 kg/ha. This possible governmental measure to reduce N losses to an acceptable level is in discussion in The Netherlands. From earlier calculations it appeared that a levy of Dfl. 4 will lead to a substantial decrease in N losses (Berentsen & Giesen, 1994). For the last two calculations technical change is introduced in addition to the levy on N losses. First the milk production per cow is increased by 10 % while the milk quota remains unchanged and next grassland and crop production are increased by 10 % while milk production is set to the basis level again. An important difference between these two forms of technical change is that an increase of milk production requires extra energy and protein per cow while an increase of plant production is realized without supply of extra nutrients. Due to plant breeding and better management, plants increase utilization of nutrients.

### 2.4.1 Technical results

In all situations the milk quota is fully used. This means that the number of dairy cows amounts to 44.3 in all situation except for the situation with the higher milk production where it amounts to 40.3. Table 2.4 shows the technical results. In summer fresh grass appears to be an economically attractive feed in all situations while in winter only the minimum amount of grass silage is fed. The costs of mowing and ensiling, which are contracted out, make ensiling of grass relatively unattractive.

In the basis situation the summer ration is completed with 1 kg of concentrate. The winter ration consists of grass silage, of maize silage and of concentrate. A small amount of

Table 2.4 Summer and winter feed ration for dairy cows and land use for four different situations.

| | Basis situation, no additional restrictions | Levy on N losses of Dfl. 4 above 150 kg/ha | Levy plus 10% higher milk production | Levy plus 10% higher grass and crop production |
|---|---|---|---|---|
| Summer ration (kgdm/day per cow) | | | | |
| - Grass | 15.5 | 15.5 | 15.8 | 15.5 |
| - Concentrate standard protein | 1 | 0 | 0 | 0 |
| - Dried beet pulp | 0 | 1.0 | 1.6 | 1.0 |
| | | | | |
| Winter ration (kgdm/day per cow) | | | | |
| - Grass silage | 2 | 2 | 2 | 2 |
| - Maize silage | 5.5 | 6.7 | 6.7 | 6.0 |
| - Concentrate standard | 6.7 | 5.0 | 5.8 | 5.9 |
| - Concentrate high protein | 0.1 | 0.7 | 0.8 | 0.4 |
| | | | | |
| Grassland (ha) | 19.8 | 22.5 | 20.7 | 20.2 |
| N level grassland (kg/ha) | 308 | 200 | 200 | 208 |
| Silage maize (ha) | 4.2 | 1.5 | 3.3 | 3.8 |
| Silage maize purchased (ha) | 1.4 | 4.9 | 2.4 | 1.6 |

high protein concentrate is necessary to meet the protein requirements. From the rations follows the land use. The major part of the land is used for grass with an optimum N level in the basis situation of 308 kg/ha. The remaining land is used for growing silage maize. To fulfil the requirements for feed 1.4 ha of silage maize has to be purchased additionally.

With a levy of Dfl. 4 on N losses the N level on grassland is decreased and concentrate in the summer ration is replaced by dried beet pulp which has a lower N content. Although the amount of grass in the ration remains the same, the N input through grass decreases because of the lower N content of the grass grown at a lower N level. The lower protein content of the grass results in an increase of the amount of high protein concentrate in the winter ration to fulfil the protein requirements. To maintain the same total grass production with a lower N level as in the basis situation, the area of grassland increases. Consequently, the area of silage maize decreases and the area of silage maize purchased increases.

A higher milk production results in higher energy and protein requirements per cow per day and consequently in higher feed intake. On herd level, however, the requirements decrease as less cows are needed to exploit the milk quota. This implies that less energy and protein for maintenance is needed while the requirements for milk production remain the same. In summer the maximum dry matter intake capacity is reached so more than the obliged 1 kg of dried beet pulp is taken up in the ration. In the winter ration more concentrate is taken up. Since the number of cows decreases, total grass production can decrease in spite of the higher grass intake in the summer ration. The area of silage maize increases and the amount of purchased silage maize decreases.

A higher grassland and crop production results in a small increase of the N level on grassland. The summer ration is not influenced. The higher protein content of grass silage due to the higher N level leads to little shifts in the winter ration towards more standard concentrate and less maize silage and protein rich concentrate. The area of grassland can decrease due to the higher production of grassland. Consequently the area of silage maize can increase. The higher plant productivity results in a decreased purchase of silage maize.

### 2.4.2 Economic results

The economic results follow from the technical results (Table 2.5). The gross returns of the farm consist of returns from milk and disposed animals. The returns from milk are the same for all situations. Given fat and protein content, a milk price of Dfl. 794 per ton is calculated. The returns from disposed animals are lower in the situation where the milk production per cow is increased and the number of cows is lower. Consequently gross returns are lower in this situation. The fixed costs are the same for all situations.

In the basis situation returns and costs result in a labour income of Dfl. 30,743. When a levy is imposed on N losses above 150 kg/ha the costs of purchased roughage increase drastically. This is partly compensated by decreasing costs of purchased concentrates (including dried beet pulp), of fertilizer and of maize land. The other costs increase slightly due to injection of the part of the manure that was surface spread in the basis situation. As the N losses remain above 150 kg/ha (Table 6), a levy of Dfl. 4478 has to be paid. All together labour income decreases by Dfl. 5966 (19.4%).

Increasing production per cow is a way to compensate the loss of labour income due to a levy. Compared to the situation with only a levy, a 10% higher milk production decreases

Table 2.5 Economic results for four different situations

| | Basis situation, no additional restrictions | Levy on N losses of Dfl. 4 above 150 kg/ha | Levy plus 10% higher milk production | Levy plus 10% higher grass and crop production |
|---|---|---|---|---|
| Gross returns | 258,168 | 258,168 | 255,464 | 258,168 |
| Variable costs: | | | | |
| - concentrate (incl. dried beet pulp) | 25,015 | 22,133 | 24,989 | 23,634 |
| - purchased roughage | 5326 | 18,984 | 9458 | 6680 |
| - fertilizer | 6637 | 3760 | 3946 | 4177 |
| - grassland costs (excl. fertilizer) | 10,516 | 10,553 | 9662 | 9873 |
| - maize land costs (excl. fertilizer) | 10,519 | 3734 | 8414 | 9642 |
| - other | 37,385 | 37,722 | 34,535 | 37,722 |
| Levy | 0 | 4478 | 3432 | 2524 |
| Fixed costs | 132,027 | 132,027 | 132,027 | 132,027 |
| Total costs (excl. labour) | 227,425 | 233,391 | 226,463 | 226,279 |
| Labour income | 30,743 | 24,777 | 29,000 | 31,889 |

gross returns, costs of purchased roughage, of grassland and other costs. The latter changes with the number of cows. Costs of concentrates, fertilizer and maize land increase. As a result of changing returns and costs and of the decreasing levy that has to be paid, labour income increases considerably. Labour income is still Dfl. 1734 (5.7%) lower than in the basis situation.

With a higher plant production the costs of purchased roughage are more decreased compared to the situation with only a levy. The greater area of maize land leads to an increase in the costs of maize land. The rest of the costs change only slightly and the levy paid decreases. Compared to the basis situation a 10% higher plant production completely offsets the negative economic consequences of the levy. In fact labour income increases by Dfl. 1146 (3.7%).

### 2.4.3 Environmental results

Table 2.6 shows the complete N balance and the losses of $P_2O_5$ and $K_2O$. Nitrogen enters the farm through concentrate, purchased silage maize, fertilizer and deposition and it leaves the farm through milk and meat. In the basis situation input and output of N results in N losses of 264.5 kg/ha. Of these losses ammonia emission and leaching are considered harmful while denitrification is not harmful. N added to the pool of organic N in the soil is not considered harmful on the short term but on the long term it possibly leads to extra leaching. $P_2O_5$ losses are 25.7 kg/ha in the basis situation and $K_2O$ losses are 49.3 kg/ha.

A levy on N losses decreases N input through fertilizer sharply while input through purchased silage maize increases substantially. The change from concentrates to dried beet pulp in the summer ration decreases N input through concentrates (including dried beet pulp). All together N input decreases by 67.9 kg/ha. Obviously, it is more efficient, as far as N use is concerned, to produce grass at a lower N level and purchase extra silage maize. Because N output does not change, the N losses decrease also by 67.9 kg/ha (25.7%). Of the harmful losses especially N leaching decreases substantially. $P_2O_5$ losses decrease mainly due to decreased input through fertilizer and in spite of increased input through purchased roughage. The $K_2O$ losses increase mainly as a result of the high $K_2O$ concentration in purchased silage maize. $K_2O$ input through fertilizer decreases.

A higher milk production per cow decreases the need for purchased roughage and therefor the N input through purchased roughage. N input through concentrates increases. Due to the lower number of dairy cows, N output through meat decreases. N losses decrease to 185.7 kg/ha; a decrease of 29.8% compared to the basis situation. $P_2O_5$ losses remain unchanged compared to the situation with a levy and $K_2O$ losses decrease again to the level of the basis situation.

A higher grass and crop production decreases the need for concentrates and purchased silage maize and by that the N input. Through this, N losses decrease to 176.3 kg/ha; a decrease of 33.3% compared to the basis situation. $P_2O_5$ and $K_2O$ losses undergo only slight changes.

Table 2.6 Environmental results for four different situations (kg/ha)

| | Basis situation, no additional restrictions | Levy on N losses of Dfl. 4 above 150 kg/ha | Levy plus 10% higher milk production | Levy plus 10% higher grass and crop production |
|---|---|---|---|---|
| Nitrogen input: | | | | |
| - concentrates (incl. dried beet pulp) | 59.9 | 56.9 | 62.0 | 57.3 |
| - purchased maize silage | 10.3 | 36.6 | 18.2 | 12.9 |
| - fertilizer | 216.8 | 125.6 | 127.3 | 128.6 |
| - deposition | 49.0 | 49.0 | 49.0 | 49.0 |
| Total | 336.0 | 268.1 | 256.5 | 247.8 |
| | | | | |
| Nitrogen output: | | | | |
| - milk | 63.6 | 63.6 | 63.6 | 63.6 |
| - meat | 7.9 | 7.9 | 7.1 | 7.9 |
| Total | 71.5 | 71.5 | 70.7 | 71.5 |
| | | | | |
| Nitrogen losses: | | | | |
| - ammonia emission | 39.5 | 33.2 | 31.1 | 33.1 |
| - leaching | 53.3 | 29.5 | 31.6 | 34.4 |
| - denitrification | 63.6 | 43.9 | 43.1 | 47.1 |
| - added to organic nitrogen | 108.2 | 90.1 | 79.9 | 61.7 |
| Total | 264.5 | 196.6 | 185.7 | 176.3 |
| | | | | |
| Phosphate losses | 25.7 | 20.8 | 20.6 | 22.2 |
| | | | | |
| Potassium losses | 49.3 | 62.7 | 46.3 | 46.0 |

## 2.5 Discussion

An important part of the data used in the model has a normative character. This counts for most of the costs, for the feeding standards but also for grassland production since grassland production is deduced from results of the Experimental Station for Cattle Production. In general results from experimental stations are above average. Beside normative data, also the method of linear programming gives the results a normative character. Due to various reasons (like imperfect information and risk aversion) farmers often do not succeed to manage the farm according to standards. Consequently the absolute value of the model results does not represent results from practice. Therefore the focus should be more on differences between situations than on the level of results. If the difference between real situations and model calculations is the same for various situations, the calculated changes between situations provide a good estimation of actual results.

The differences in results between situations are quite straightforward and can be explained from the assumptions used in the model. A levy on N losses makes the use of grassland less intensive. Labour income decreases and so do N losses. The negative consequences for labour income can be compensated by an increase of animal and plant productivity. N losses are further decreased by increased animal and plant productivity. This is only the case if increased productivity does not result in an increase of total production by keeping beef bulls for example when empty places are available. In the model calculations the levy on N losses made restocking of empty places with beef bulls economically unattractive.

When a levy on N losses is used, the farm decreases own roughage production and increases purchase of roughage. This means that losses related to the production of roughage are shifted to roughage producing farms. At national level this can lead to a reduction in N losses only if roughage production takes the place of other crops that use N with about the same efficiency as roughage does. An increase in milk production per cow increases the amount of concentrates and decreases the amount of roughage needed. Feedstuffs for concentrates are mainly imported. An increase enlarges manure surplus problems. With on the other hand a decreased need for roughage resulting in land available for other crops, the focus should be, and in practice is, turning to growing crops that can partly replace concentrates. A higher plant productivity contributes positively to environment, at farm level and at national level.

The model developed can be used to examine different questions in the field of institutional and technical change on dairy farms. Moreover, the model offers the possibility to examine questions for dairy farms that differ in intensity and in size.

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# 3. Economic and Environmental Effects of a New Protein Evaluation System in Dairy Farming[1]

## Abstract

*In this paper we quantify possible effects on labour income and N losses on grassland dairy farms situated on sandy soil in the Netherlands when a new protein evaluation system is introduced. The objective function of the linear programming model used maximizes labour income of some typical dairy farms. The model includes various constraints on energy and protein intake in summer and winter as well as different fodders to fulfil the necessary dietary requirements. The N balance of the farm is also included to record N losses.*

*The results show that use of the new protein evaluation system and, in particular, a constraint on the surplus of rumen-degradable protein in summer affects labour income and N losses. When no surplus is allowed in summer and in winter, the labour income on a farm with an average herd density is reduced by Dfl 288/ha (14%), and N losses are reduced by 141 kg/ha (37%). Sensitivity analysis on herd density shows that N losses on farms with a high density can be reduced far more than N losses on farms with a low density, but the income effects do not differ very much.*

## 3.1 Introduction

In the Netherlands a major cause of acidification of the environment and pollution of ground and surface water is ascribable to animal husbandry. In dairy farming the main pollutant is N (Berentsen et al., 1992; Tamminga, 1992). Dairy farming accounts for 56% of the total ammonia emission in the Netherlands compared with 38% from other animal husbandry (Groot Koerkamp et al., 1990). Calculations based on data from Heij and Schneider (1991) indicate that ammonia emission is responsible for 36% of the total acid deposition in the Netherlands; 44% of this

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deposition is emitted abroad. A second problem in dairy farming is N pollution of ground water, caused by high concentrations of manure and fertilizer applied to farmland. In some areas with sandy soil, concentrations of up to 112 mg of N/L were recorded in the ground water (Goossensen and Meeuwissen, 1990). The maximum concentration allowed for drinking water is 11.3 mg of N/L (Anonymous, 1980).

In the "manure action program" of the Dutch government, reduction of the mineral content of fodder and improvement of the utilization of the minerals in fodder are important ways to reduce detrimental nutrient surpluses (Bloem, 1992). To reduce the mineral content of fodder in a reliable way, a system is needed to register the requirement and supply of minerals accurately. As N enters the cow, mainly as protein, a reliable reduction of N losses through diet can only be achieved by use of an adequate protein evaluation system, which was the main reason for developing a new protein evaluation in the Netherlands. Since October 1991, the digestible crude protein system VRE (verteerbaar ruw eiwit) has been replaced by the intestine-digestible protein system DVE (darm verteerbaar eiwit). The very detailed supply and demand accounting of protein in the new system is expected to reduce N losses through better management of diet (Tamminga, 1992).

This paper quantifies possible consequences of the change to the new protein evaluation system on labour income and on N losses on dairy farms situated on sandy soil. A modelling approach is used.

## 3.2 Materials and methods

### 3.2.1 Different Protein Systems

The VRE system, used in the Netherlands since 1930, was replaced by the DVE system in 1991. The DVE system more thoroughly describes the protein utilization taking place inside the ruminant than the former system; therefore, better possibilities exist to balance actual protein requirement and supply. Differences between the two systems are dealt with in the description of the systems.

### *VRE System*

In the laboratory, the crude protein content of a fodder was measured as total N, multiplied by 6.25, the average ratio of protein to N in animal feeds. Except for silages, the NPN compounds were included in this method of calculation. The digestible crude protein content of a fodder was determined through feeding experiments and calculated by subtracting the amount of crude protein excreted in faeces from the crude protein ingested with the feed.

Although the VRE system was simple, it had some disadvantages. The system did not account for the form in which N actually appears in a specific fodder (rumen-degradable or rumen-undegradable). The appearance of N is rather important because rumen-degradable N (RDN) including NPN, can only be utilized by ruminants after conversion to microbial protein, and rumen-undegradable protein can be utilized directly (Van der Honing, 1988). Capture of RDN by rumen microbes depends on the availability of sufficient rumen-degradable energy, which puts limitations on the efficiency of utilization of RDN, including NPN. Because of this limitations, which became particularly apparent at high production levels, it became common practice to advice farmers to supply digestible crude protein up to 20% above allowances. Such a feeding practice resulted in poor utilization and hence big losses of N to the environment.

### *DVE System*

The DVE system contains elements of the French system PDI (protéines digestibles dans l'intestin), the US system absorbed protein (AP) and the Scandinavian system AAT-PBV (amount of amino acids truly absorbed - protein balance in the rumen). The DVE system consists of two parts.

In the first part, requirement and supply of protein are balanced at the small intestine level. The protein supply is calculated very similar to the French PDI system (Verite et al., 1979), except that feed protein values are corrected for intestinal endogenous losses. The protein requirement for milk production is taken from this system. The requirement standards for maintenance, growth and gestation are taken from the US AP system and are adjusted to conditions in the Netherlands. The maintenance requirement includes urinary endogenous N and surface protein losses (NRC, 1989), but not endogenous losses.

The supply of intestine digestible protein (DVE) is the sum of protein that is not degradable in the rumen but is digestible in the intestine (DVBE) plus intestine digestible microbial protein (DVME) minus the protein needed to permit digestion, which consequently is lost through in faeces and urine: the faecal metabolic protein (DVMFE). The DVBE is calculated from the amount of crude protein of a fodder, the rumen degradability of this crude protein, and the intestine digestibility of the undegradable protein. The DVME is calculated from the amount of rumen degradable protein of the fodder and the energy available to form microbial protein out of the rumen degradable protein in the rumen.

The second part of the DVE system consists of a degradable protein balance OEB (onbestendig eiwit balans), which can be used to prevent unnecessary protein losses in the rumen. These losses are undesirable because superfluous protein enters the environment, mainly as urea excreted in urine, which is easily converted in and lost as ammonia. The rumen-degradable protein balance is taken from the Scandinavian AAT-PVB system (Madsen, 1985). The principle is quite simple. For the production of microbial protein in the rumen, rumen-degradable protein and energy are required at a certain ratio. A surplus of rumen-degradable protein leads to unnecessary protein losses, whereas a surplus of energy can give rise to digestibility problems on the long term. The OEB of a fodder is the amount of microbial protein that could be produced given the rumen-degradable protein in the fodder minus the amount of microbial protein that could be produced given the amount of usable energy in the fodder. Thus, a positive OEB value indicates a protein surplus, and a negative OEB value indicates an energy surplus. The OEB value of a ration can be obtained by adding the OEB values of the different fodders in the ration. If the OEB of the ration is close to zero, the diet will be efficient nutritionally and environmentally.

### 3.2.3 Methodology

Analysis is based on three typical dairy farms situated on sandy soil. Although all three farms are characterized by a cultivated area of 24 ha and milk production per cow of 6695 kg/yr, intensity of farming differs. Quotas are: farm 1, 8000 kg/ha; farm 2, 12,000 kg/ha and farm 3, 16,000 kg/ha.

A linear programming model is used to model the dairy farms. The objective function maximizes labour income (i.e., return to labour and management). The basic element in the model is a dairy cow, which is assumed to calve in February. This assumption is made to simplify modelling. Milk production per cow is fixed. A fixed ratio is assumed between the numbers of dairy cows and young stock. The cultivated area can be used for producing grass at different N levels, maize, and fodder beets. For a full description of the model (including values) one is referred to Speelman (1992).

The feeding part of the model is split up into four parts. The dairy cows and the young stock are fed separately, and a division is made between the summer and winter period. For this reason the milk production is divided into summer and winter production also. For dairy cows, constraints are placed on the supply and requirement of energy and protein, for dry matter intake capacity, and for the requirement concerning the proportion of structure, the equivalent of effective fibre in long roughage, in the ration. The summer and winter milk production, the requirement for energy, and the feed intake capacity are determined using formulas of Groen (1988). The formula Groen used for the feed intake capacity is based on that by Jarrige et al. (1986) and by ARC (1980). Given the calculated milk production per period and the lactation stage, protein requirement is calculated using formulas of the Central Bureau for Livestock Feeding (1991). Using the VRE system, the protein requirements are 1.75 kg/d per cow for VRE in summer and 1.53 kg/d per cow for VRE in winter. Using the DVE system, the requirements are 1.26 kg/d per cow for DVE in summer and 1.09 kg/d per cow for DVE in winter. The constraints on structure require that at least one-third of the dry matter of the ration is structural material (Central Bureau for Livestock Feeding, 1991). The fodders that are available in the model together with some feeding characteristics are shown in Table 3.1.

Because dietary requirements of young stock are usually less complicated, constraints are used only for energy and protein. Requirements are calculated using standards of the Central Bureau for Livestock Feeding (1991). A fixed amount of milk powder and of starting concentrate per calf must be used. Available fodders are grass at different N levels and standard concentrate for the summer period and grass silage at different N levels, maize silage, and standard concentrate for the winter period.

The feed ration influences the N content of the manure produced by the cattle. The quantity of N in manure can be calculated by subtracting N output (in milk and meat) from N input (in feed intake). N input can be decreased by changing the feed ration, which decrease N in manure because N output in milk and meat is fixed. The amount of N in manure influences the N lost through ammonia volatilization, leaching, and denitrification. Other important factors that influence ammonia emission are the method and length of storing manure and the manner in which manure is applied to the land. Herein we assumed that manure is stored partly under the

Table 3.1 Different fodders with their protein content according to the old VRE and the new DVE system, OEB values, energy content, the yield of own grown fodders, prices of purchased fodders and the availability of fodders in summer (S) and winter (W) period (figures based on Speelman (1992)).

| Fodder | Protein content | | OEB[3] value | Energy content | Yield | Price | Available |
|---|---|---|---|---|---|---|---|
| | VRE[1] (kg/kg of DM) | DVE[2] (kg/kg of DM) | (kg/kg of DM) | (KVEM[4]/kg of DM) | (KVEM/ha) | (Dfl[5]/KVEM) | |
| Grass 200 N | .142 | .098 | .028 | .974 | 7820 | ... | S |
| Grass 300 N | .159 | .101 | .043 | .985 | 9228 | ... | S |
| Grass 400 N | .178 | .104 | .060 | .995 | 10,160 | ... | S |
| Grass 500 N | .190 | .104 | .077 | 1.005 | 10,780 | ... | S |
| Grass silage 200 N | .104 | .068 | .037 | .850 | 7820 | ... | W |
| Grass silage 300 N | .121 | .071 | .055 | .860 | 9228 | ... | W |
| Grass silage 400 N | .135 | .073 | .071 | .870 | 10,160 | ... | W |
| Grass silage 500 N | .145 | .074 | .084 | .880 | 10,780 | ... | W |
| Fodder beets | .056 | .074 | -.051 | .900 | 14,600 | ... | W |
| Maize silage[6] | .050 | .047 | -.016 | .900 | 12,150 | .39 | S&W |
| Concentrate standard | .133 | .100 | -.011 | 1.044 | ... | .42 | S&W |
| Concentrate low protein | .089 | .089 | -.022 | 1.044 | ... | .42 | S |
| Concentrate high protein | .333 | .200 | .139 | 1.000 | ... | .48 | W |
| Dried beet pulp | .063 | .110 | -.070 | 1.036 | ... | .43 | W |

[1] Digestible Crude Protein.

[2] Intestine Digestible Protein.

[3] Rumen Degradable Protein Balance.

[4] Dutch energy unit for milk production.

[5] Dfl. 1 equals about US $ .60.

[6] Silage maize can be grown on the farm or can be purchased.

slatted floor and partly in a closed manure storage for 6 mo and that two-thirds of the manure are injected into the soil and one-third surface spread. This modelling interpretation of the Dutch manure legislation prescribes, among other requirements, that, in 1992, manure may only be applied on sandy soil during the growing season (February till September) and that surface spreading is allowed only during the last 2.5 mo of the growing season (Bloem, 1992). Other factors than N content of manure that influence leaching and denitrification, are land use and the amount of N applied to grassland. Different forms of land use are available in the model so fodder crops that use nutrients more efficiently can replace less efficient crops. Lowering the N application on grassland decreases the N losses from grass production in spite of a decrease in grass production (Van de Meer, 1986). To record the N losses of the farm, the model contains the N balance.

To examine closely the possibilities offered by the use of the new protein evaluation system, the farm models are optimized with five different (combinations of) protein constraints:

1. The VRE system is used.
2. The DVE system is used without restrictions on OEB.
3. The DVE system is used with the requirement that the OEB of the winter ration of the dairy cattle should be zero.
4. The DVE system is used with the requirement that the OEB of the summer ration of the dairy cattle should be zero.
5. The DVE system is used with the requirement that the OEB of the winter and summer ration of the dairy cattle should be zero.

## 3.3 Results

First, the results for the farm with the average intensity are given, and then the results for the extensive and the intensive farms are discussed.

### 3.3.1 Average Intensity Farm

In all situations, the full milk quota is used, which, with the given milk production per cow, means keeping 43 dairy cows. Table 3.2 shows the land use and the winter and summer feed

Table 3.2 Land use and winter and summer feed ration for dairy cows on the farm with the average density using different protein evaluation systems

| | Protein constraints | | | | |
|---|---|---|---|---|---|
| | VRE System | DVE System without OEB restrictions | DVE System, OEB winter ration of 0 | DVE System, OEB summer ration of 0 | DVE System, OEB winter and summer ration of 0 |
| Grassland, ha | 19.3 | 19.1 | 19.1 | 16.8 | 18.6 |
| N level grassland, kg/ha | 402 | 401 | 401 | 281 | 240 |
| Silage maize, ha | 4.7 | 4.9 | 4.9 | 7.2 | 5.4 |
| Silage maize purchased, ha | 2.3 | .1 | .2 | 0 | 0 |
| | | | | | |
| Winter ration, kg of DM/d per cow | | | | | |
| Grass silage | 2 | 2 | 2 | 2 | 2 |
| Maize silage | 8 | 4.8 | 4.9 | 8.1 | 5.5 |
| Concentrate standard | 3.5 | 7.9 | 7.8 | 3.5 | 7.0 |
| Concentrate high protein | 1.5 | .1 | .1 | 1.4 | .4 |
| OEB[1] Value of this ration, kg | .169 | 0 | 0 | .159 | 0 |
| | | | | | |
| Summer ration, kg of DM/d per cow | | | | | |
| Grass | 15.7 | 15.7 | 15.7 | 11.1 | 11.8 |
| Concentrate low protein | 1 | 1 | 1 | 0 | 0 |
| Dried beet pulp | 0 | 0 | 0 | 5.4 | 4.8 |
| OEB Value of this ration, kg | .924 | .924 | .924 | 0 | 0 |

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[1] Rumen Degradable Protein Balance.

rations for the dairy cows for all five situations. Fodder beets are not grown on the farm because fodder beets require additional investment in machinery, which reduces profit. In Table 3.3, the economic and environmental consequences are given.

### *The VRE System*

When the VRE system is used, land is used for growing grass and maize. The N level of grassland is 402 kg/ha including mineral N from manure. The area of grassland is just enough for grazing the cattle in summer and for producing a minimum amount of grass silage for winter. The winter ration of the dairy cows consists of grass silage, maize silage, and standard and high protein concentrate. The summer ration of the dairy cows consists of grass and a small amount of concentrate, which is used to lure the cows into the milking parlour. Both winter and summer rations have a positive OEB value. The OEB is especially high in the summer compared with the daily protein requirement of 1.75 kg of VRE because of the excessive amount of grass that is fed. To fulfill the dietary requirements of the cattle, fodder consisting of maize silage and concentrate has to be purchased. The labour income of the farm amounts to Dfl. 49673. The N losses per hectare are as high as 380 kg/ha. Of these losses, 54 kg is lost through ammonia emission.

### *The DVE System Without OEB Restrictions*

The change from the VRE to the DVE system mainly affects the winter ration. In situation 1, the composition of the winter ration was such that the energy and protein requirements were satisfied, and the maximum feed intake capacity of the cows was reached. Given the changed protein contents, energy contents, and the prices of fodders, an optimal solution of situation 2 is derived in which maize silage and protein-rich concentrate are replaced by standard concentrate. Moreover, the drastic decrease in the protein content of high protein concentrate enables a cheaper ration composition from standard concentrate instead of high protein concentrate and purchased maize silage. This ration has a positive effect on the OEB value of the winter ration, which becomes zero. The summer feed ration of the dairy cows does not change. Small changes in land use have to do with changes in the feeding regimen of the young stock. In the winter, feed ration of the young stock grass silage is replaced to a certain extent by maize silage. The changes are almost

Table 3.3 Economic and environmental effects of using different protein systems on the farm with the average density

| | Protein constraints | | | | |
|---|---|---|---|---|---|
| | VRE System | DVE System without OEB restrictions | DVE System, OEB winter ration of 0 | DVE System, OEB summer ration of 0 | DVE System, OEB winter and summer ration of 0 |
| Economic results, Dfl[1] | | | | | |
| Gross returns | 259,841 | 259,841 | 259,841 | 259,841 | 259,841 |
| Variable costs | | | | | |
| Purchased concentrate | 20,404 | 29,451 | 29,106 | 35,934 | 41,194 |
| Purchased roughage | 9636 | 297 | 644 | 0 | 0 |
| Purchased fertilizer | 9846 | 10,095 | 10,127 | 7018 | 6242 |
| Growing roughage costs (excl. fertilizer) | 23,286 | 23,378 | 23,378 | 26,660 | 22,664 |
| Other | 33,043 | 33,043 | 33,043 | 33,043 | 33,043 |
| Fixed costs | 113,953 | 113,953 | 113,953 | 113,953 | 113,953 |
| Total costs (excl. labour) | 210,168.00 | 210,217.00 | 210,251.00 | 216,608.00 | 217,096.00 |
| Labour income | 49,673.00 | 49,624.00 | 49,590.00 | 43,233.00 | 42,745.00 |
| Nitrogen balance, kg/ha | | | | | |
| N input | | | | | |
| Purchased concentrate | 67.2 | 78.9 | 78.4 | 86.8 | 94.3 |
| Purchased roughage | 16.7 | 0.5 | 1.1 | 0 | 0 |
| Purchased fertilizer | 317.9 | 320 | 319.3 | 209 | 191.5 |
| Deposition | 49 | 49 | 49 | 49 | 49 |
| N output (milk and meat) | 71.2 | 71.2 | 71.2 | 71.2 | 71.2 |
| N losses | 379.60 | 377.20 | 376.60 | 273.60 | 263.60 |
| of which NH3 emission | 53.5 | 52.3 | 52.5 | 44.1 | 43.1 |

[1] Dfl.1 equals about US $ .60.

cost neutral although costs shift from purchased roughage to purchased concentrate. The influence on N losses is only small.

### *The DVE System with zero OEB in the Winter Ration*

The requirement that the winter feed ration of the dairy cows has zero OEB only leads to small changes in the feed ration compared with those of situation 2. As mentioned, the OEB value of the winter feed ration in situation 2 was very close to zero. As a result, the effects on labour income and on N losses are very small.

### *The DVE System with zero OEB in the summer ration*

To reach zero OEB for the summer ration, more changes are necessary. In situation 1, 2, and 3, protein requirements in the summer feed ration were greatly exceeded because grass is the cheapest energy source in summer. In situation 4, the OEB surplus in summer is balanced by decreasing the N level of grassland and by replacing some of the grass and concentrate by dried beet pulp, which has a high negative OEB. This replacement implies that less land has to be used for producing grass; consequently, the area of maize land increases. With more supply of home-grown maize silage (which is cheaper than purchased maize), the winter feed ration changes to almost the same ration as in situation 1. The effects on farm income and on N losses are substantial. The costs of concentrate, including dried beet pulp, increase by almost Dfl. 7000, and the costs of growing roughage increase by more than Dfl. 3000 because of the increased area of maize. Although these increases are partly compensated by a decrease in the costs of purchased fertilizer, mainly due to the lower N level of grassland, the labour income of the farm decreases sharply by Dfl. 6440, which equals Dfl. 268/ha. However, N losses decrease considerably. The N input through concentrate and fertilizer decreases. With a constant N output N losses are reduced about 30% to 273.6 kg/ha. Ammonia emission decreases, mainly as a result of a lower N content of urine that is excreted on the land in summer.

### *The DVE System with an OEB of the Winter and Summer Ration of Zero*

In situation 5, zero OEB is required for both the winter and the summer ration. Compared with situation 4 and according to situation 2 and 3, maize and high protein concentrate are replaced by standard concentrate in the winter ration to achieve an OEB of zero. The winter and the summer ration in situation 5 differ from the rations in all preceding situations because of the lower OEB value of grass (silage) that is produced at a lower N level. The N level is further reduced because the feed restrictions prevent the use of more maize silage and grass on the farm. Growing grass at a higher N level and producing maize silage for sale, which is an option in the model, is not economically viable. Therefore, more dried beet pulp and concentrate must be purchased to meet the OEB requirements in the winter and summer ration (compare the rations in situation 3 and 4). Further changes in the costs of concentrate and of purchased fertilizer and in the other roughage costs decrease labour income compared to situation 4 by a further Dfl. 500. Losses of N are further decreased to 263.6 kg/ha.

### *Labour Income and N Losses at Decreasing OEB Requirements*

To get an impression about the course of labour income and N losses when the OEB requirements were sharpened, some extra calculations were done. The upper bound for the OEB value for the summer as well as for the winter ration was decreased stepwise from 1 to 0 kg/d per cow with steps of .1 kg. The extreme situation (an OEB upper bound of 0) is situation 5. Figure 3.1 shows the consequences for labour income and N losses. Labour income decreases more than proportionally with a decreasing upper bound. This makes sense because the cheapest means of meeting the requirements are used first. When the requirements become more rigid, the solutions become more expensive. The relation between the upper OEB value and N losses is linear to some extent. A more or less linear relation could be expected as the model assumes that all N in manure in the summer period is lost to the environment. Thus, in summer every decrease of the surplus of rumen degradable protein gives a consequential decrease in N losses. At an upper bound of 1 kg the realized OEB value in summer is .924 (see Table 3.2). This means that the upper bound of 1 kg is not limiting, explaining the diverging course at the left part of the line. From an upper bound of .9, the OEB value of the summer ration follows the upper bound. The OEB value of the winter ration remains zero until an upper bound of .4 is reached. Then, as a result of a changed farm plan, the OEB value of the winter ration becomes positive, which indicates that between an upper bound of .4 and .2, part of the N losses in summer are shifted to N losses in winter, explaining the diverging course of the line at these upper bounds.

### 3.3.2 Other Intensities of Farming

On both the extensive and the intensive farm, the full milk quota is used. Given the milk production per cow this means that the extensive farm has 29 cows and the intensive farm has 57 cows. Nitrogen use on grassland is relatively low on the extensive farm but high on the intensive farm. The extensive farm grows maize, which is partly sold. The feed rations on both farms are similar to the farm with the average density (see Table 3.4). Labour income and N losses appear to be strongly related to the animal density on the farm (see Table 3.5).

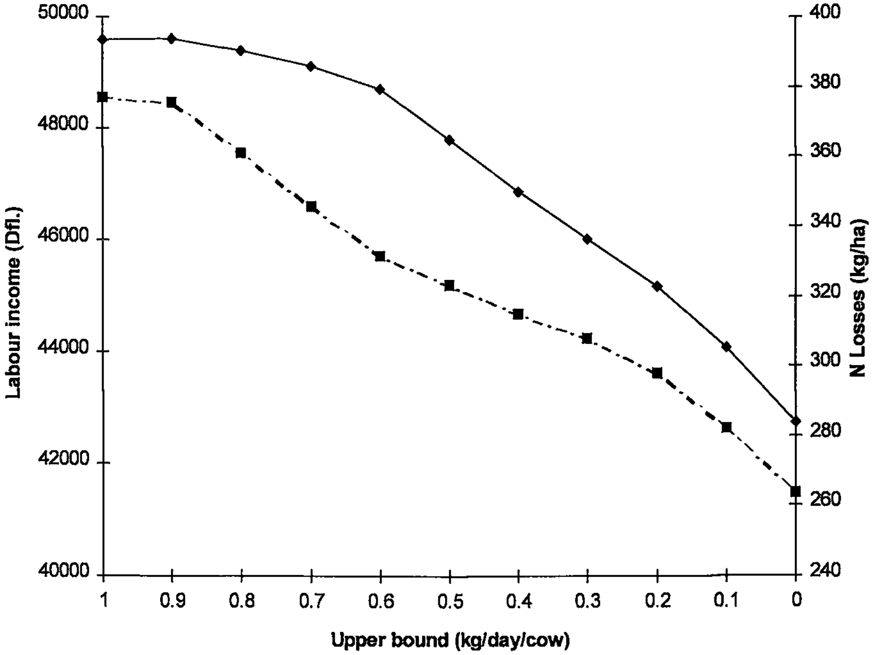

Figure 3.1 Labour income (◆) and N losses (■) at different upper bounds for rumen degradable protein balance (OEB: Onbestendig Eiwit Balans)

Table 3.4 Land use and winter and summer feed ration for dairy cows on a farm with a low and with a high density respectively using the VRE and the DVE protein evaluation system.

| | low density | | | high density | | |
|---|---|---|---|---|---|---|
| | VRE System | DVE System without OEB restrictions | DVE System, OEB winter and summer ration of 0 | VRE System | DVE System without OEB restrictions | DVE System, OEB winter and summer ration of 0 |
| Grassland, ha | 14 | 13.9 | 12.5 | 24 | 24 | 19.5 |
| N level grassland, kg/ha | 311 | 309 | 227 | 500 | 498 | 332 |
| Silage maize own use, ha | 4.7 | 4.8 | 3.6 | 0 | 0 | 4.5 |
| Silage maize (S)old or (P)urchased, ha | $5.3^{S}$ | $5.3^{S}$ | $7.8^{S}$ | $8.4^{P}$ | $6.07^{P}$ | $2.1^{P}$ |
| | | | | | | |
| Winter ration, kg of DM/d per cow | | | | | | |
| Grass silage | 2 | 2 | 2 | 2 | 2 | 2 |
| Maize silage | 8.1 | 8.1 | 5.5 | 8 | 4.81 | 4.9 |
| Concentrate standard | 3.4 | 3.5 | 7 | 3.6 | 7.98 | 7.7 |
| Concentrate high protein | 1.5 | 1.5 | 0.4 | 1.4 | 0 | 0.1 |
| OEB[1] Value of this ration, kg | .170 | .159 | 0 | .182 | .017 | 0 |
| | | | | | | |
| Summer ration, kg of DM/d per cow | | | | | | |
| Grass | 15.9 | 15.9 | 11.8 | 15.3 | 15.5 | 10 |
| Concentrate low protein | 1 | 1 | 0 | 1.2 | 1 | 0 |
| Dried beet pulp | 0 | 0 | 4.8 | 0 | 0 | 6.3 |
| OEB Value of this ration, kg | .667 | .667 | 0 | 1.144 | 1.167 | 0 |

---

[1] Rumen Degradable Protein Balance.

Using the VRE system, the winter feed rations fulfil the energy and protein requirements and include as much roughage as possible. The summer feed rations exist of grass and a small amount of low protein concentrate. As a result of the higher N level of the grassland, the OEB value of the summer feed ration is higher on the intensive farm.

If the DVE system is used without any OEB requirements, only small changes arise. Most significant is the change of the winter feed ration on the farm with the high density. Replacement of maize silage and high protein concentrate by standard concentrate is done similar to the farm with the average density. On the farm with the low density, this replacement does not take place because here home-grown maize silage is fed. The changes of labour income and N losses are small.

Using the DVE system with an OEB of zero for both the winter and the summer feed ration, the summer rations consist of grass and dried beet pulp. For the land use, the required OEB value of zero results in a decrease of the area of grassland and of the N level of the grassland because less protein is required from grass. Consequently, the area of silage maize increases. For the extensive farm, this means that more silage maize is sold, which increases the gross returns of the farm. The intensive farm decreases its amount of purchased roughage. On the extensive farm the costs of purchased concentrate increase substantially. The costs of purchased fertilizer and the other roughage costs decrease. All in all, the labour income on this farm decreases with Dfl. 5465 compared with situation 1. The decrease in labour income amounts to Dfl. 227/ha. On the intensive farm, purchased concentrate is tremendously higher, which is partly compensated by decreases in costs of purchased roughage and of purchased fertilizer. The costs of growing roughage rise due to the increased area of own used silage maize. As a result, the labour income decreases by Dfl. 6608 or Dfl. 275/ha. As sold roughage on the extensive farm increases, so does the N output. Consequently, the changes in N input result in a decrease in N losses of 51 kg/ha. Of this decrease, 5.3 kg is caused by lower ammonia emission. On the intensive farm, N losses decrease by 204.2 kg/ha because of a substantial decrease in N input through purchased roughage and purchased fertilizer. The ammonia emission decrease is 22.8 kg/ha.

Tables 3.2 and 3.4 show little difference in the summer and winter rations between farms with different densities. The main difference lies in the N level of the grassland and, therefore, in the protein and energy content of the grass. On an intensive farm, the optimal N level appears to be higher than on an extensive farm. This makes sense because a lower roughage production on an intensive farm means that more roughage and concentrate would have to be purchased at a certain price. Alternatively, on an extensive farm roughage sold at a lower price is less.

Table 3.5 Economic and environmental consequences of using different protein systems on a farm with a low and with a high density respectively, using the VRE and the DVE protein evaluation system

| | low density | | | | high density | | |
|---|---|---|---|---|---|---|---|
| | VRE System | DVE System without OEB restrictions | DVE System OEB winter and summer ration of 0 | | VRE System | DVE System without OEB restrictions | DVE System OEB winter and summer ration of 0 |
| Economic results, Dfl. | | | | | | | |
| Gross returns | 180,471 | 180,497 | 183,827 | | 346,592 | 346,592 | 346,592 |
| Variable costs: | | | | | | | |
| Purchased concentrate | 13,474 | 13,440 | 27,410 | | 28,411 | 39,260 | 63,952 |
| Purchased roughage | 0 | 0 | 0 | | 39,614 | 28,678 | 9851 |
| Purchased fertilizer | 8820 | 8792 | 7642 | | 13,210 | 13,235 | 7643 |
| Growing roughage costs (excl. fertilizer) | 19,058 | 19,050 | 15,121 | | 16,236 | 15,765 | 22,633 |
| Other | 22,037 | 22,037 | 22,037 | | 44,075 | 44,075 | 44,075 |
| Fixed costs | 103,165 | 103,165 | 103,165 | | 124,816 | 124,816 | 124,816 |
| Total costs (excl. labour) | 166,554 | 166,484 | 175,375 | 0 | 266,362 | 265,829 | 272,970 |
| Labour income | 13,917 | 14,013 | 8,452 | 0 | 80,230 | 80,763 | 73,622 |
| Nitrogen balance (kg/ha): | | | | | | | |
| N input: | | | | | | | |
| Purchased concentrate | 44.5 | 44 | 62.8 | | 91.4 | 104.8 | 138.7 |
| Purchased roughage | 0 | 0 | 0 | | 68.5 | 49.6 | 17 |
| Purchased fertilizer | 221.2 | 220.7 | 171.2 | | 459 | 460 | 259 |
| Deposition | 49 | 49 | 49 | | 49 | 49 | 49 |
| N output (milk, meat and sold roughage) | 88.7 | 88.9 | 108 | | 94.9 | 94.9 | 94.9 |
| N losses | 226 | 225 | 175 | 0 | 573 | 569 | 369 |
| of which NH3 emission | 33.9 | 33.5 | 28.6 | | 80.7 | 79.7 | 57.9 |

Table 3.6 Variables summarizing the economic and environmental effects of going from the VRE protein system to the DVE protein system with OEB values restricted to zero at different herd densities.

| | Low density | Average density | High density |
|---|---|---|---|
| Herd density, dairy cows/ha | 1.2 | 1.8 | 2.4 |
| | | | |
| Decrease of labour income, Dfl[1]/ha | 228 | 288 | 275 |
| Decrease N losses per ha, kg/ha | 51.0 | 116.0 | 204.2 |
| Decrease N losses per cow, kg/cow | 42.7 | 64.7 | 85.4 |
| Decrease of labour income per kg reduction of N losses, Dfl/kg | 4.47 | 2.48 | 1.35 |

[1] Dfl.1 equals about US $ .60.

Table 3.6 summarizes the economic and environmental consequences of switching from the VRE system to the DVE system with OEB values restricted to zero at the different herd densities. This means that the values in the table show how the new protein evaluation system can be used to reduce N losses and how much labour income is affected. The more intensive the animal production, the larger the reduction of N losses/ha and per cow, and the lower the decrease of labour income per kilogram reduction of N losses.

## 3.4 Discussion

The modelling approach used herein is that of an LP model. Labour income is maximized given the restrictions. The restrictions reflect the feeding standards used among other things. One could argue that, in reality, farmers strive to feed according to standards but due to various reasons (i.e. imperfect information, risk aversion, etc.) often do not succeed, making the absolute value of the results questionable. In this paper, however, the focus is more on differences between situations than on the level of results. If the difference between reality and model calculations does not differ between situations, then the calculated changes between situations give a good estimation of what could be achieved in reality.

In the calculations no OEB requirements are used for the rations of the young stock. For the winter period, this is no problem because the OEB value of the ration differs little from zero.

In summer, the ration consists only of grass, which offers possibilities for reducing the N losses even further. In practice, however, young stock usually graze all summer and are not additionally fed because it would involve too much labour. If young stock could be fed according to the OEB requirements, N losses would be reduced further.

To simplify modelling, all dairy cows are assumed to calve in february, which means that about 45% of the milk is produced in the winter period, and the rest is produced in summer. If the cows should calve earlier, the amount of milk produced in winter would increase; therefore the feed intake in winter would increase. From the results , most of the reductions in N losses apparently take place in summer. A shift of the feed intake from summer to winter would therefore reduce the possibilities to decrease N-losses.

The OEB values of different fodders as given in Table 3.1 are averages. Especially for grass, in practice, the OEB value at a given N level can differ greatly, but the DVE value remains almost constant (Wever and Van Vliet, 1991). For concentrate so far there are no stipulated OEB values so, in practice, these values too can differ from the values given in Table 3.1. The OEB value of dried beet pulp depends heavily on the sugar content of the beet pulp. Since the sugar content may vary also the OEB value may differ from the value given in Table 3.1. An optimal use of the new protein evaluation system requires adequate information about the protein contents of fodders that are available for farmers.

The use of the DVE system with OEB values restricted to zero decreases labour income per kilogram reduction of N losses from Dfl 1.35 on the intensive farm to Dfl 4.47 on the extensive farm. Compared to other measures to reduce N losses on dairy farms (Leneman et al., 1992) feeding according to these protein standards is very cost effective. For instance, measures to reduce N losses that require an investment in machinery or in adaptation of buildings have 5 to 25 times higher costs per kilogram reduction of N losses.

## 3.5 Conclusions

The change from the VRE system to the DVE system without OEB requirements only leads to changes in the winter ration of the dairy cows. The economic as well as the environmental effects are small. When OEB restrictions are enforced, particularly on the summer feed ration, considerable changes occur. Land use becomes more extensive (N use is lowered) and the amount of concentrate fed (including dried beet pulp) increases strongly. This results in sharp decreases of both labour income and N losses. The animal density on the farm greatly influences the level of N losses and the possibilities to reduce these. The model calculations support the high expectations of the possibilities the new protein evaluation system offers to reduce N losses. Farmers, however, will have to be persuaded to feed according to severe OEB requirements because labour income decreases. To achieve this, financial stimuli or legal regulations will be necessary.

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# 4. Reality and modelling: Operational validation of an environmental-economic model of a dairy farm[1]

## Abstract

*Operational validation of a linear programming model of a dairy farm is done on the basis of representative results from reality. The model will be used to determine the effects of institutional, technical and price changes on the results of dairy farms. Average results of specialized dairy farms on sandy soil from 1992/93 are presented and representativeness of the year has been checked. Validation of the model was done in a number of steps. In the simulation step many available information from reality has been used in the model. Comparison of the simulated economic and environmental results with those from reality shows that the model is quite capable of simulating reality. In the optimization step a number of behavioral restrictions, which were included in the model in the simulation step, were lifted to give the model back its necessary flexibility. The differences between optimization and simulation results show, among other things, the effects of risk aversion and of lack of information and knowledge. In the optimal situation labour income is 15% higher while N losses and $P_2O_5$ losses are 9% and 41% lower than in the simulated situation.*

## 4.1 Introduction

Modelling can be used as a way to explore an uncertain future. Dairy farming in the Netherlands is facing uncertainties with regard to price and environmental policies and technical changes. To explore possible consequences of these uncertainties an environmental-economic model at farm level was developed (Berentsen and Giesen, 1995). A logical step following model development is model validation.

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[1] Paper by P.B.M. Berentsen, G.W.J. Giesen and J.A. Renkema; published as Wageningen Economic Paper 1996-2.

Model validation can be defined as the process by which it is assured that a model is a description of a selected phenomenon that is adequate for the use it will be put to (Miser, 1993). Three types of validation can be distinguished: technical, operational and dynamic validation (Gass, 1983). Technical validation refers to the use of the right kind of data, of proper assumptions and relations in the model and the use of the correct method. The description of the model and the model test given in Berentsen and Giesen (1995) covered this part of the validation which can also be indicated as internal validation (Taylor, 1983). The results of this technical validation were quite satisfying. Operational validation concerns the assessment of the kind and the importance of errors produced by the model while representing situations from reality. This must lead to conclusions about the practicability of the model to represent reality. Finally, dynamic validation is concerned with determining how the model will be maintained during its life cycle. Operational and dynamic validations are also referred to as external validation (Taylor, 1983).

The main objective of this paper is operational validation of the model. For this, data describing a representative situation from reality are necessary. Assessment of this representative situation is the second objective. Operational validation serves two purposes here. It leads to conclusions about the practicability of the model and it shows the difference between reality and model results.

The paper proceeds as follows. In section 2 the wider context of this research and the consequences for operational validation are given. In section 3 recent results of dairy farms on sandy soil are presented and a representative situation from reality is defined. Section 4 describes methodological aspects of the validation process and of the model that is validated. In section 5 the results of different calculations are given, after which the discussion follows in section 6.

## 4.2 Research objectives and consequences

Assessment of a representative dairy farm and validation of the model based on this dairy farm are done to serve the objectives of a wider project. The main objective of this project concerns an analysis of possible effects of technical and institutional changes on Dutch dairy farms. The results are of interest to policy makers as well as to dairy farmers, as they will show the effects of certain policy changes and also the optimum way to react to these changes. The main interest concerns the economic and environmental results of farms different in size and in animal density.

The research subject is restricted to specialized dairy farms on sandy soil. This soil type presents the most serious environmental problems. A linear programming model developed for this research was presented and tested (Berentsen and Giesen, 1995) and some problems were examined by using the model (see for example Berentsen et al, 1993).

The main objective of the wider project requires the assessment of a situation as representative as possible for which calculations can be made. Representativeness gives the conclusions based on model results a more general legitimacy. The average results of the group of farms under consideration forms the most representative situation as it contains the average size and average levels of production. Validation of the model based on these results is necessary for two reasons. First, the absolute level of the economic results produced by the model is important to gain an impression about economic viability of dairy farming in future. Therefore it is necessary to start with a model that produces a level of economic results comparable with results from reality. Second, it is likely that in coming environmental legislation nutrient losses above a certain level that is considered acceptable will be taxed. Therefore, the absolute level of nutrient losses is important and for a correct representation of reality it is necessary that the model produces a level of nutrient losses comparable to that observed in reality.

To produce sound conclusions about influences of size and animal density on future results, it is important to vary only one of these two aspects at a time. Only then can differences in results be attributed directly to the varied aspect. This makes it impossible to deduce all farming situations from reality since differences in size, intensity and other aspects will be mixed in reality. Therefore, only the situation represented by the average results of all specialized dairy farms is assessed. To get a correct starting situation, the average results from reality must be checked on their representativeness as far as year influences are concerned. This means that especially weather conditions in the year considered should be quite average.

## 3.3 Assessment of a representative dairy farm

For the assessment of a representative dairy farm, data from the Dutch Farm Accountancy Data Network (FADN) were provided by the Agricultural Economics Research Institute. The FADN was set up to provide the national government and the EU with average results of different types of farms in the Netherlands. A secondary goal was to collect data for agricultural economic research. To obtain representative results a stratified sample of all farms between 20 and 500

Dutch size units (dsu) is taken. A 20-dsu farm that is efficiently organized provides employment to about 0.5 full-time equivalent. Stratification is based on economic farm size, acreage, age of the farmer, region and type of farm. Every year some 20% of the farms in the sample are replaced by new farms to keep the stratification correct. The economic accounting of the farm covers the whole farm, which means that all revenues and costs are included. Costs are based on replacement costs of inputs.

For this research project average results of specialized dairy farms on sandy soil obtained from the FADN for 1992/93 are used. Specialized dairy farming means that more than 2/3 of the economic size of the farm is made up of dairy cows. In this sample 210 farms represent about 15,000 farms (Van Dijk et al, 1994). The total number of specialized dairy farms in the Netherlands on all soil types amounts to about 24,000. Besides that, there are about 8500 less-specialized dairy farms. The number of dairy cows kept on specialized dairy farms on sandy soil amounts to 42% of all dairy cows in the Netherlands and milk production to 45% of total milk production in the Netherlands (AERI/CBS, 1993).

Table 4.1 Average farm plan of the specialized dairy farms on sandy soil for 1989/90 to 1992/93 based on FADN-data

| | 1989/90 | 1990/91 | 1991/92 | 1992/93 |
|---|---|---|---|---|
| Land use (ha): | | | | |
| - area of grassland | 22.0 | 22.0 | 22.8 | 21.7 |
| - area of fodder crops | 4.5 | 4.6 | 4.7 | 5.3 |
| - area of cash crops | 0.7 | 0.6 | 0.5 | 0.5 |
| Milk quota (1000 kg) | 320.8 | 323.4 | 327.5 | 330.3 |
| Milk production per cow (kg/year) | 6476 | 6422 | 6507 | 6682 |
| Cattle: | | | | |
| - dairy cows | 50.3 | 50.7 | 50.9 | 49.4 |
| - young stock | 42.8 | 45.1 | 46.3 | 46.5 |
| Economic size (% of total sfu[1]) | | | | |
| - dairy cattle | 66.9 | 67.8 | 68.8 | 68.1 |
| - grassland and fodder crops | 30.1 | 30.2 | 29.4 | 29.0 |
| - pigs and poultry | 2.0 | 2.0 | 1.0 | 2.3 |
| - cash crops | 1.0 | 1.0 | 0.8 | 0.6 |

[1] standard farm unit

Table 4.1 shows the average farm plan of the specialized dairy farms on sandy soil for 1989/90 to 1992/93. The total area of the farm has remained quite constant over the years. Shifts among grassland, fodder crops and cash crops are small. The average milk quota and the average milk production per cow slowly but steadily increase. As a result the numbers of dairy cows and young stock remain fairly constant. The bottom part of the table shows that there is beside dairy cattle and feed production some intensive livestock and cash crop production on these farms. The results of these other branches have to be omitted when validating the model.

Table 4.2 shows average revenues, costs and labour income for the dairy farming part of the farm. The revenues from milk and cattle sold show substantial differences between the years. This is for the greater part due to changes in prices of milk and cattle sold. The average milk price received from the factory, for example, decreased from NLG 83.58 per 100 kg in 1989/90 to NLG 76.92 in 1990/91 and went up again to NLG 80.49 in 1992/93.The other revenues come from roughage and sheep sold, product premiums, renting out milk quota, etcetera.

Table 4.2 Average revenues and costs for specialized dairy farms on sandy soil for 1989/90 to 1992/93 (NLG) based on FADN-data

| | 1989/90 | 1990/91 | 1991/92 | 1992/93 |
|---|---|---|---|---|
| Revenues: | | | | |
| - milk | 267,141 | 245,949 | 256,460 | 261,058 |
| - cattle sold | 57,385 | 45,345 | 45,015 | 50,808 |
| - other | 8477 | 6238 | 6991 | 5190 |
| total | 333,003 | 297,532 | 308,466 | 317,056 |
| | | | | |
| Costs: | | | | |
| - feed purchased | 60,715 | 56,436 | 64,713 | 59,951 |
| - livestock costs | 14,503 | 14,542 | 15,356 | 15,816 |
| - fertilizer | 11,656 | 9889 | 10,202 | 8821 |
| - contract work | 10,931 | 11,099 | 12,118 | 13,243 |
| - machinery and equipment | 46,790 | 50,141 | 50,986 | 47,919 |
| - land and buildings | 49,228 | 51,393 | 55,314 | 55,218 |
| - costs of quota purchased | 9165 | 11297 | 16379 | 19770 |
| - other | 31,995 | 33,906 | 34,991 | 32,921 |
| total | 234,983 | 238,703 | 260,059 | 253,659 |
| | | | | |
| Labour income | 98,021 | 58,830 | 48,408 | 63,396 |

Changes in the costs of feed purchased were caused by changing prices and amounts. A changing amount reflects a difference in home-produced fodder, which may be caused by less-favourable weather conditions. In 1991/92 the dry summer resulted in a lower roughage production, which was compensated by increased purchases of concentrates and roughage. In the same year the price of concentrates went up by 8% (Poppe et al, 1993). As a result the costs of feed purchased increased by almost 15%. In the other three years the amount of feed purchased was fairly constant, so differences in costs were mainly caused by differences in prices. Livestock costs include costs of animal health, breeding, insurance, etcetera. These costs slowly increased as a result of rising prices. Cost of fertilizers is influenced by amount and price. The amount of fertilizer steadily decreased over the years. The price of nitrogen (the main fertilizer) was constant in the first two years. In 1991/92 it increased a little and in 1992/93 it decreased substantially. The cost of contract work increased steadily due to rising prices. Costs of machinery and equipment and of land and buildings are generally rather fixed. The costs of buildings, however, went up as a result of obligatory investments in manure storage (Van Everdingen, 1993). Costs of quota purchased including depreciation and interest increased. Purchase of milk quota is a rather new phenomenon and the average amount of quota purchased increases every year. Other costs are costs that do not belong to any of the preceding entries.

Subtraction of the costs from the revenues results in the labour income of the farm (remuneration for labour and management). In sum, it can be said that from 1989/90 to 1990/91 labour income decreased dramatically, almost entirely due to decreased output prices. From 1990/91 to 1991/92 the price of milk partly recovered but roughage production was lower due to the dry summer. This led to a drastic increase of feed purchased and therefore to a further decrease in labour income. From 1991/92 to 1992/93 output prices recovered further and roughage production was at an average level again, so labour income increased. One thing that has structurally decreased labour income is the increasing costs of manure storage. From the farm plan and the economic results it can be concluded that 1992/93 was quite an average year as far as animal and plant productivity and prices are concerned.

In Table 4.3 the average mineral balances for nitrogen (N), phosphate ($P_2O_5$) and potash ($K_2O$) for 1992/93 are given. These balances have also been corrected for the other branches on the farm. For all three minerals the majority of the input stems from concentrates and fertilizer. For N also atmospheric deposition is substantial. However, this last input cannot be influenced by the farmer. It must be noticed that the figures for roughage purchased, manure supplied and

Table 4.3 Average mineral balances for N, $P_2O_5$ and $K_2O$ for specialized dairy farms on sandy soil for 1992/93 (kg/ha) based on FADN-data

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Nutrient input: | | | |
| - concentrates | 117 | 45 | 70 |
| - roughage purchased | 26 | 8 | 23 |
| - milk powder | 2 | 1 | 1 |
| - fertilizer | 244 | 26 | 13 |
| - manure supplied | 13 | 8 | 9 |
| - deposition | 53 | 2 | 5 |
| - others | 27 | 13 | 25 |
| total | 482 | 103 | 146 |
| | | | |
| Nutrient output: | | | |
| - milk | 67 | 25 | 22 |
| - meat | 14 | 10 | 1 |
| total | 81 | 35 | 23 |
| | | | |
| Nutrient losses | 401 | 68 | 123 |

meat have been adjusted. On average, there is input of minerals through manure supplied and roughage and cattle purchased as well as output through manure removed and roughage and cattle sold. In Table 4.3 only the difference between input and output is given. Other input mainly concerns mainly manure supplied by other livestock branches on the farm. Output of minerals takes place through milk and meat. Subtraction of output from input results in the losses of minerals. The losses of N and $P_2O_5$ are slowly decreasing. For 1983-1986 Aarts et al (1988) calculated average yearly losses of 486 kg/ha for N and 74 kg for $P_2O_5$ on dairy farms on sandy soil.

## 4.4 Method

### 4.4.1 Factors determining farm results

For modelling a practical situation and interpretation of differences between model and practical results it is important to distinguish between different factors that determine the results of a dairy farm. A first group of factors concerns fixed assets such as the area of land, the size of the barn, milk quota and available labour. These factors determine the production capacity of the farm. A second group is made up of the efficiency of production of animals and plants, which follows from the ratios between output and input for plant and animal production. A third group constitutes the prices of inputs and outputs. Lastly, there is a fourth group, which includes behavioral aspects of farmers.

The inputs for plant production consist of mineral N, $P_2O_5$ and $K_2O$, which can stem from fertilizer and animal manure. The output consists of energy and protein. The two major forms of plant production on a dairy farm are grass production and maize production for silage. For production of maize, nutrients have to be available at an optimum level (Aarts and Middelkoop, 1990). For grass production, supply of N determines production, while enough $P_2O_5$ and $K_2O$ must be available to replace the amounts of $P_2O_5$ and $K_2O$ that are removed with grass. Production efficiency of grassland therefore is based on the use of mineral N.

For animal production the inputs consist of energy and protein. The outputs are milk, meat and manure. For dairy cows energy and protein must be available for milk production, maintenance, reproduction and age-dependent growth. The requirements for milk production vary almost linearly with the amount of milk produced, which means that the efficiency for milk production is almost constant. The overall efficiency, however, increases with increasing milk production per cow, since the requirements for maintenance, reproduction and age-dependent growth per cow are constant and hence requirements per kg of milk decrease.

If prices of inputs and outputs and fixed costs are added to the production possibilities and if farmers are economic optimizers, theoretically, this information is sufficient to simulate a dairy farm by an optimization model and to determine farm results. In practice, however, also behavioral aspects play a role. Due to risk aversion, lack of information and lack of knowledge, farmers feed more protein in winter than necessary, purchase more concentrates and less silage maize than optimal and use more $P_2O_5$ and $K_2O$ than required. Due to land division, farmers use more or less land for silage maize than optimal. Due to uncertainty about future environmental regulations, farmers often keep more young stock and beef cattle than economically optimal. In the past the government assigned phosphate quota to farmers based on the numbers of animals present at a certain moment. Should the government decide to use numbers of animals present again in new environmental legislation, then it will be worthwhile to have more animals than economically optimal in the short term. Finally, farmers' goals can differ from maximizing income. Requirement for free time for example can lead to a higher opportunity cost of labour and consequently to a different optimal plan. When simulating reality and interpreting results, all these considerations have to be kept in mind.

### 4.4.2 The model

A linear programming model is used to model the dairy farm. The object function maximizes labour income. Maximization of income appears to be the most general first objective of farmers (Zachariasse, 1972). The basic element in the model is a dairy cow, calving in February with a fixed milk production. Feed requirements are determined, using formulas of Groen (1988). For replacement of dairy cows young stock can be kept. If housing place is available beef bulls can be raised on a ration of silage maize and concentrates. The cultivated area can be used for producing grass, maize and fodder beets. Grass can be grown at a level of 100, 200, 300, 400 or 500 kg of mineral N. In addition to home-produced roughage, silage maize and three kinds of concentrates with different protein contents can be purchased. Nutrients for plant production can be supplied by home-produced manure, by fertilizer and by manure supplied by other farms. The model contains nutrient balances at farm level for N, $P_2O_5$ and $K_2O$ that register nutrient input and output and consequently nutrient losses. In the model labour is supplied by the farmer and the family. All production activities require labour. Activities such as mowing and ensiling of grass and appliance of manure can be done with the farmer's own machinery or can be contracted out. Lastly, investment in land, housing capacity and basic machinery are not optional, therefore costs are calculated separately. For a more detailed description of the model see Berentsen and Giesen (1995).

### 4.4.3 Calculation of unknown parameters

Most of the parameters necessary for simulation of reality with the LP-model are available. The FADN data include the available fixed assets, the level of milk production, the ratio between young stock and dairy cows, land use, etcetera. Parameters, necessary for simulation that are not available are the levels of nutrient use on grassland and silage maize and the levels of energy and protein production of grassland and silage maize. The level of N mineral on grassland, which is the main determinant of production, can be calculated from the data available and assuming a standard level of N mineral on silage maize. For the levels of $P_2O_5$ and $K_2O$ standards are used. Total net energy production from grassland can be calculated assuming that supply and requirement of energy at farm level are equal and assuming a standard silage maize production per hectare. For the level of protein production from grassland a standard is used, describing the ratio between energy and protein production at the N level calculated.

Total mineral N available is the sum of N from fertilizer and mineral N from manure produced by the cattle on the farm, from manure produced by other livestock on the farm and from manure supplied by other farms. N from fertilizer is known. Mineral N from manure produced by cattle on the farm is calculated using standards for manure production and a concentration of mineral N based on model simulations. Mineral N from manure produced by other livestock on the farm and from manure supplied by other farms is calculated by multiplying the corresponding N input into the mineral balance by a standard factor, reflecting the ratio between mineral N and total N in manure from fattening pigs. From the resulting total mineral N available, standard amounts for home-produced silage maize and for other crops (potatoes) are subtracted. Mineral N that remains is used for grassland and division by the area of grassland gives the level of mineral N use on grassland.

For the level of silage maize production a standard is taken based on average silage maize production in 1992/93 on sandy soil (Roeterdink and Haaksma, 1993). Gross energy production amounted to 82,800 MJ NEL/ha. Net energy production from grassland is calculated as the difference between total net energy requirement on the farm and net energy supplied by other sources than grass. Total net energy requirement is calculated by multiplying the numbers of animals in different categories by the energy requirement per animal. Average net energy supplied by concentrates purchased, roughage and milk powder are taken from the FADN data. Net energy supplied by home-grown fodder crops is calculated by multiplying the area of fodder crops by the gross energy production per ha of silage maize and subtracting storing and feeding losses. The resulting net energy from grassland is corrected for average grazing losses and storing and feeding losses and divided by the area of grassland to attain gross energy production per ha of grassland.

### 4.4.4 The validation process

Validation of the model on the basis of the practical results assessed in section 3 is done in four steps.

At the first step, the production capacity and the levels of production in the model are adjusted to results from reality. This means that data for the area of land, available quota, capacity of the barn, available labour and level of milk production realized are taken from the FADN data. From these data, the level of grassland production is calculated as described in section 4.3. Finally, prices of inputs and outputs are set at the level realized in 1992/93. With the resulting model the first calculation is done. This situation is referred to as the situation with the basis model, since no further adaptations in the model have been made.

The second step follows from comparing the results of the first calculation with the results from reality. This indicates that further adaptions have to be made to simulate the results from reality. With the resulting model, which is referred to as the simulation model, the results from reality are simulated as accurately as possible. A comparison of these simulation results and the results from reality leads to conclusions about the practicability of the model to represent reality.

The adaptations made to the model in the simulation phase make the model rather fixed and leave little space for reactions to future changes. Therefore, in the third step those adaptations are critically reviewed and some are cancelled. The resulting model, which is called the optimization model, will be used as the starting model for calculating effects of technical and institutional change. This model is optimized. The differences between optimization and simulation results show the effects of risk aversion, lack of information and of knowledge, etcetera.

The final fourth step is added to examine if the validated model is useful to represent situations from reality that differ in intensity. The group of representative specialized dairy farms on sandy soil is split into three groups, namely a group of farms with a milk quota lower than 11,000 kg/ha, a group with a milk quota between 11,000 and 14,000 kg/ha and a group with a milk quota higher than 14,000 kg/ha. The averages of these groups form representative farms that differ in intensity. Next the extensive and the intensive farm are simulated by using the model that was validated in steps one to three. Lastly, these farm models are optimized. From the results conclusions can be drawn as to whether the model is suitable to be used for other intensities.

## 4.5 Results

The production capacity taken from the FADN data concerns the area of land and the available milk quota. The area of land amounts to 27 ha and the available milk quota to 330,310 kg. The capacity of the barn is based on the numbers of animals present and the space needed per category of animals (Asijee, 1993). Expressed in cow places the capacity amounts to 96. The level of milk production comes down to 6682 kg/cow per year. The level of gross energy production from grassland is calculated as described in section 4.3 and amounts to 73,100 MJ NEL/ha. The corresponding use of mineral N on grassland is 408 kg/ha. Calculations indicate that the average grass production curve used in the model, which was based on results from experiments and reality at the Experimental Station for Cattle Production, overestimated the average energy production from grassland in reality by 3700 MJ NEL (4.8%).

The results of calculations with the basis model and with the further adapted models are given in tables 4.4, 4.5 and 4.6. Table 4.4 shows the farm structure and the technical results, Table 4.5 the economic results and Table 4.6 the environmental results.

### 4.5.1 Results of the basis model

*Technical results*

Given the available milk quota and the milk production per cow in reality, the number of dairy cows in the model calculation equals the number in reality. The number of young stock is minimal, given a minimally required replacement of dairy cows of 25%. The available housing capacity is stocked with beef bulls. Because beef bulls require less space than young stock, 51.4 beef bulls can be kept. Obviously, keeping beef bulls is economically more attractive than keeping young stock, although the model offers the possibility of selling pregnant heifers at the age of two years. Here, a first modelling problem arises. In reality farmers appear to keep more young stock than necessary for replacement and they keep, on average, only a few beef bulls. Keeping beef bulls is obviously not as simple as keeping young stock. A few beef bulls can be kept in a place separate from dairy cows, but the large number resulting from these calculations has to be kept in the cowshed like most of the older young stock. For reasons of quietness in the cowshed farmers do not do this. Besides that, the adaptation of a large number of places for young stock to places for beef bulls will be difficult from an organizational point of view and costly.

Table 4.4 Technical results from reality and from calculations with the basis model, the simulation model and the optimization model of the average dairy farm on sandy soil for 1992/93

| | reality | basis model | simulation model | optimization model |
|---|---|---|---|---|
| Cattle: | | | | |
| - dairy cows | 49.4 | 49.4 | 49.4 | 49.4 |
| - young stock | 48.2 | 27.4 | 48.2 | 46.5 |
| - beef bulls | 5.2 | 51.4 | 5.2 | 5.2 |
| Land use: | | | | |
| - grassland (ha) | 21.7 | 24.2 | 21.7 | 27.0 |
| - N level grassland (kg/ha) | 408 | 319 | 408 | 320 |
| - silage maize (ha) | 5.3 | 2.8 | 5.3 | 0.0000 |
| Feed purchased (1000 MJ NEL): | | | | |
| - concentrates | 718 | 677 | 718 | 406 |
| - roughage | 283 | 945 | 283 | 747 |
| Fertilizer purchased (kg/ha): | | | | |
| - N | 244 | 194 | 244 | 202 |
| - $P_2O_5$ | 26 | 0.0000 | 26 | 0.0000 |
| - $K_2O$ | 13 | 0.0000 | 13 | 0.0000 |
| Manure used ($m^3$): | | | | |
| - from cattle | 742 | 1006 | 742 | 735 |
| - from other livestock | 115 | 0.0000 | 115 | 115 |
| - from other farms | 51 | 0.0000 | 51 | 51 |

All this was not included in the model. A reason for keeping more young stock than necessary is risk aversion. Farmers want to be certain to have enough young stock for replacement in situations that differ from average. Another reason is that keeping more young stock than necessary gives farmers the possibility of selecting their heifers. For these reasons, the maximum number of beef bulls in the simulation model is the same as the number of beef cattle in reality. With the possibility of selling pregnant heifers, the numbers of young stock will probably increase.

Land use differs from reality in that more land is used for growing grass and less for silage maize. Total energy production from grassland differs little because of the lower N level on grassland in the model results. The optimal level of N use on grassland in this situation is around 320 kg/ha. The use of a high N level in reality has certainly to do with advices from the extension services concerning the optimal N level, which changed from 400 kg/ha in the 1980s to 300 kg/ha in the 1990s. In the simulation model the N level is fixed to 408 kg/ha.

One consequence of the lower fodder production and the large number of beef bulls is that more feed has to be purchased, especially roughage although beef bulls also require a substantial amount of concentrates. In reality farmers apparently feed more concentrates and less roughage than optimal. This may have to do with advantages concentrates have like that it is an easier product to feed and that it can be ordered in different compositions. In the simulation model the amount of roughage purchased is set at the amount purchased in reality.

Due to the lower N level on grassland, the average amount of nitrogen purchased per hectare is lower than in reality. The lower N level leads to lower requirements of $P_2O_5$ and $K_2O$. On the other hand, the amount of manure available is higher due to the large number of beef bulls. Consequently, the amounts of $P_2O_5$ and $K_2O$ in manure meets the requirements and no additional $P_2O_5$ and $K_2O$ has to be purchased.

In reality, also manure from other livestock on the farm and from other farms is used. It is assumed that this is manure from feeder pigs. In the simulation model an activity for the supply of extra manure is included and set at the level observed in reality.

### *Economic results*

The economic results are divided into revenues and costs. Using average realized prices (Bloem et al, 1993) the revenues from milk calculated by the model equal those in reality. Due to the large number of beef bulls, the revenues from cattle sold are more than twice as high as in reality. The other revenues in Table 4.5 differ from Table 4.2, because the revenues from roughage sold were left out in Table 4.5. Consequently, the costs of roughage purchased are corrected for with the same amount. The other revenues calculated differ from reality but also their composition is quite different. The model's other revenues consist totally of price premiums from the EU for beef bulls, while the other revenues from reality also come from sheep sold and renting out milk quota.

The costs of concentrates calculated by the model are slightly higher than those in reality although the amount of concentrates is lower. However, the price of concentrates for beef bulls is higher than the price of most of the concentrates for dairy cattle. More in general, a difference

Table 4.5 Economic results from reality and of calculations with the basis model, the simulation model and the optimization model of the average dairy farm on sandy soil for 1992/93

| | reality | basis model | simulation model | optimization model |
|---|---|---|---|---|
| Revenues: | | | | |
| - milk | 261,058 | 261,058 | 261,058 | 261,058 |
| - cattle sold | 50,808 | 108,170 | 50,808 | 49,272 |
| - other | 4085 | 5396 | 567 | 567 |
| total | 315,951 | 374,624 | 312,433 | 310,897 |
| | | | | |
| Costs: | | | | |
| - concentrates | 42,060 | 43,537 | 40,219 | 27,634 |
| - milk powder | 4053 | 7540 | 4053 | 3278 |
| - roughage purchased | 12,734 | 47,946 | 12,288 | 29,713 |
| - fertilizer | 8821 | 6010 | 8203 | 6086 |
| - livestock costs | 15,816 | 19,335 | 15,816 | 15,670 |
| - contract work | 13,243 | 14,988 | 18,394 | 9176 |
| - machinery and equipment | 47,919 | 48,723 | 42,768 | 42,768 |
| - land and buildings | 55,218 | 106,217 | 55,218 | 55,218 |
| - costs of quota purchased | 19,770 | 0.0000 | 19,770 | 19,770 |
| - other | 32,921 | 53,937 | 32,921 | 29,434 |
| total | 252,555 | 348,233 | 249,649 | 238,748 |
| | | | | |
| Labour income | 63,396 | 26,391 | 62,784 | 72,149 |

may arise between the model results and reality in costs of concentrates, even if the same amount of concentrates is used, due to the fact that in reality a large variety of concentrates is fed at a variety of prices. The model uses only three types of concentrates for dairy cows, two types for young stock and one for beef bulls. The costs of milk powder calculated by the model are higher than in reality, due to the number of beef bulls and to the fact that in the model a standard amount of milk powder per animal is taken. In the simulation model the realized amount per animal is taken. The above-mentioned comment on the large variety of concentrates used in reality also applies to roughage purchased. However, in reality the majority of roughage purchased is silage maize. In the model silage maize is the only option. The costs of fertilizer follow from the amount used. The livestock costs calculated by the model are higher than the costs in reality, due to the high number of beef bulls and to the fact that the model uses standards that are higher than the costs per animal in reality. In the simulation model the realized costs per animal are taken. The costs of contract work calculated differ only slightly from those in reality. However, it should be noticed that the area of silage maize calculated is lower than the real area. The costs of contract work of growing silage maize for the farm's own use amount to NLG 1730 per ha. It is quite difficult to compare the costs of machinery and equipment, because the number and type of machines in reality are unknown. This makes it necessary to consider the costs of machinery and equipment always in combination with the costs of contract work. Besides that, in the model the costs of machinery and equipment as well as of buildings are based on standards, which may differ from the costs in the FADN-data which are partly based on standards and partly on reality:

- According to the standards, the depreciation period is 20 years for buildings and 8 years for machinery. This results in average depreciation and interest costs. However, in reality especially buildings are used much longer than 20 years. If buildings and machinery are used beyond the depreciation period, the depreciation costs are zero and the interest costs low. This means that the average depreciation and interest costs are much lower than calculated according to the standards;
- Maintenance costs of buildings and machinery are calculated assuming that maintenance is done by specialists. In reality farmers do a lot of maintenance work themselves, resulting in lower maintenance costs.

In the simulation model the costs of machinery and equipment are adjusted, such that the sum of the costs of contract work and of machinery and equipment is equal to that in the FADN-data. The costs of land and buildings calculated by the model are almost twice as high as in the FADN-data. This is mainly caused by high costs of buildings calculated, due to the factors described above. In the simulation model these costs are set at the level realized in the FADN-data. Costs of quota purchased are a rather new phenomenon. Purchase of quota has not been included in the model so far. In reality depreciation and interest are based on the price paid and a depreciation period of 14 years. In the simulation model the realized costs of quota are included. Finally, the other costs concern a wide range of costs not belonging to the preceding entries. Some of these costs are fixed while others are variable. The high level of other costs calculated has to do with the large number of beef bulls. In the simulation model the other costs are set at the level realized in the FADN-data.

*Environmental results*

Table 4.6 shows the input, the output and the resulting losses of N, $P_2O_5$ and $K_2O$. The nutrient input with roughage purchased calculated by the model is higher than in reality, due to the large number of beef bulls. The input with fertilizer is lower due to the lower N use on grassland. No $P_2O_5$ and $K_2O$ from fertilizer is required. In the basis model no activity is included for manure supplied by other livestock on the farm or by other farms. Consequently, no nutrient input from these sources exists. In the simulation model this activity is added set at the realized level. Also activities for deposition of $P_2O_5$ and $K_2O$ are added. Total N and $P_2O_5$ input calculated by the basis model is considerably lower than in reality, while total $K_2O$ input is higher. This difference can be explained by differences between N, $P_2O_5$ and $K_2O$ in weight of specific inputs related to total nutrient input.

Nutrient output in milk calculated by the basis model is the same as in reality. Nutrient output in meat is much higher than in reality, due to the large number of beef bulls. The nutrient losses follow from subtracting nutrient output from nutrient input. The N and $P_2O_5$ losses in the basis model are lower than in reality, the $K_2O$ losses are higher.

### 4.5.2 Results from the simulation model

To bring the results of the simulation model in accordance with those from reality, some extra adjustments had to be made to the model. To match the number of young stock in the simulation model with the number in reality, it was necessary to force the model to keep the required number

Table 4.6 Environmental results from reality and from calculations with the basis model, the simulation model and the optimization model (kg/ha) of the average dairy farm on sandy soil for 1992/93

| | N | | | | $P_2O_5$ | | | | $K_2O$ | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | reality | basis model | simulation model | optimization model | reality | basis model | simulation model | optimization model | reality | basis model | simulation model | optimization model |
| Nutrient input: | | | | | | | | | | | | |
| - concentrates | 117 | 117 | 117 | 90 | 45 | 51 | 46 | 32 | 70 | 73 | 78 | 54 |
| - roughage purchased | 26 | 82 | 24 | 58 | 8 | 28 | 8 | 20 | 23 | 102 | 29 | 71 |
| - milk powder | 2 | 3 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 |
| - fertilizer | 244 | 194 | 244 | 202 | 26 | 0 | 26 | 0 | 13 | 0 | 13 | 0 |
| - manure supplied | 13 | 0 | 13 | 13 | 8 | 0 | 8 | 8 | 9 | 0 | 9 | 9 |
| - deposition | 53 | 53 | 53 | 53 | 2 | 0 | 2 | 2 | 5 | 0 | 5 | 5 |
| - others | 27 | 0 | 27 | 27 | 13 | 0 | 13 | 13 | 25 | 0 | 25 | 25 |
| total | 482 | 449 | 480 | 444 | 103 | 81 | 104 | 76 | 146 | 177 | 160 | 165 |
| Nutrient output: | | | | | | | | | | | | |
| - milk | 67 | 67 | 67 | 67 | 25 | 25 | 25 | 25 | 22 | 22 | 22 | 22 |
| - meat | 14 | 31 | 16 | 15 | 10 | 23 | 11 | 11 | 1 | 3 | 1 | 1 |
| total | 81 | 98 | 83 | 82 | 35 | 48 | 36 | 36 | 23 | 25 | 23 | 23 |
| Nutrient losses | 401 | 351 | 397 | 362 | 68 | 33 | 68 | 40 | 123 | 152 | 137 | 142 |

of young stock on the farm and to sell part of this young stock as pregnant heifers. Obviously, in the model it is not economically attractive at the given situation to keep more young stock than necessary for replacement. To realize the same areas of grassland and silage maize as in reality, the maximum area of silage maize in the simulation model was set at the area found in reality. The model had to be forced to purchase $P_2O_5$ and $K_2O$ through fertilizer, since $P_2O_5$ and $K_2O$ from animal manure satisfies the requirements of plants.

To match the revenues from cattle sold in the simulation model with those in reality, the replacement rate was increased from 25 to 36%. The FADN data provide no information about the replacement rate but Vink (1993) reports a rate of 36%. This results in lower revenues from heifers sold while the revenues from replaced cattle and calves sold increase. On balance, the revenues decrease. The differences between the simulation results and reality are great as far as other revenues are concerned. The diverse nature of those revenues in reality makes it impossible to include these revenues in the model in a reliable way. Consequently, the simulated total revenues are NLG 3518 lower than in reality.

The simulated costs of concentrates, of roughage purchased and of fertilizer differ from the results in reality, although the amounts (in MJ NEL and in kg) are the same and the prices used were average prices for 1992/93. Differences can arise because the types of concentrates, roughage and fertilizer in reality may differ from those used in the model. In the model only a restricted number of types can be used while in reality a wide variety exists at a variety of prices. On this point the model cannot cover reality totally. The sum of the simulated costs of contract work and of machinery and equipment and all other costs have been made equal to the results in reality.

The simulated input of N almost completely matches with the results from reality. Only the input through roughage purchased differs. This is the result of using only one type of roughage that can be purchased in the model while in reality more types are used. This reason also accounts for differences in $P_2O_5$ input through concentrates and in $K_2O$ input through concentrates and roughage purchased. Total simulated input of N and $P_2O_5$ differs only slightly from total input in reality. For $K_2O$ input the difference is quite considerable. Also differences arise in the output of N and $P_2O_5$ through meat, which cannot be explained by the available data. The simulated losses of N and of $P_2O_5$ differ slightly from the losses in reality, whereas the $K_2O$ losses differ considerably.

### 4.5.3 Results of the optimization model

A number of adaptations made to the model in the simulation phase are cancelled in the optimization model to make the model flexible again. This concerns adaptations based on lack of information and knowledge and risk aversion, such as growing grass at a suboptimal N level, feeding more protein than necessary, feeding concentrates instead of roughage, growing silage maize instead of grass and using $P_2O_5$ and $K_2O$ through fertilizer while it is not required by the crops. For protein feeding a small safety margin of 300 gram protein (200 gram OEB and 100 gram DVE) is used on top of the standard requirements. A safety margin is required because of uncertainty about the exact intake of different roughages and consequently of protein by every individual cow. With an average ration that exactly fulfills the protein standards the risk is high that some cows eat to much protein while, as a consequence, other cows get not enough protein. The replacement rate of 36% is kept the same in the optimization model since it can be argued that this rate is the main determinant of the average age of the dairy cattle and consequently it contributes to the realized milk production. In the optimization model the amount of manure from other animals on the farm and from other farms used in reality is used as a maximum. This includes the assumption that in reality the maximum amount is used, which has a positive effect on grassland and silage maize production.

In the optimal situation the numbers of dairy cows and of beef bulls are the same as in the simulated situation (Table 4.4). The number of young stock is slightly smaller. In this case it is economically not attractive to keep extra young stock that are sold as heifers, because this young stock has to be fed with feed purchased and with grass that can only be grown by raising the N level above 320 kg/ha. The total area is used as grassland to supply enough grass to be able to feed a maximum amount of grass in summer (when it is the cheapest energy source) and a minimally required amount of silage grass in winter. Due to the lower production of home-produced fodder, the amount of feed purchased is higher than in the simulated situation; the amount of concentrates, however, is substantially lower. Part of the concentrates is replaced by silage maize in winter and by grass in summer. The amount of N fertilizer purchased follows from the N level of grassland. Manure produced by cattle on the farm and from other sources satisfies the requirements for $P_2O_5$ and $K_2O$ by silage maize and grass, so no $P_2O_5$ and $K_2O$ through fertilizer is needed.

The small difference in number of young stock causes a small difference in revenues and livestock costs (Table 4.5). The changes in costs of concentrates, milk powder, roughage and fertilizer purchased follow from the changed amounts used. The costs of contract work decrease substantially due to the fact that no silage maize is grown on the farm. The other costs, which are partly related to the numbers of animals and partly to land use, decrease because no silage maize is grown and the number of young stock is lower. On balance, the total costs decrease by NLG 10,901. Consequently, labour income increases by NLG 9365.

Compared with the results of the simulation model the input of nutrients through concentrates and fertilizer decreases substantially (Table 4.6). The input through roughage purchased increases which leads to a decrease for N and $P_2O_5$ in total input. The total input of $K_2O$ increases, due to a different ratio between $K_2O$ content of concentrates and roughage. Nutrient output decreases slightly as a result of the lower number of young stock. Consequently, N losses decrease by 8.8%; $P_2O_5$ losses by 41% and $K_2O$ losses increase by 3.7%.

### 4.5.4 Using the validated model for other intensities

As could be expected fixed assets and grassland and milk production of the average extensive and intensive farm differ from the overall average results that were presented in section 3. On the extensive farm, the area of land is greater and the milk quota smaller than the overall average (Table 4.7). Milk production per cow and grassland production per hectare on the extensive farm are below the overall average. The lower grassland production can only partly be explained by the lower nitrogen level on grassland. The realized grassland production appears to be 6300 MJ NEL/ha (8.3%) lower than the production that could be expected using the overall average production curve and taking into account the nitrogen level on grassland on the average extensive farm. Reasons for this may be grassland management or soil fertility that is worse than average. Finally, labour income and nutrient losses per hectare are lower than the overall average. Concerning all aspects, the intensive farm can be found at the opposite side of the overall average.

When using fixed assets and production levels for model simulation the same kind of adaptations have to be made to the model as described in section 5.2. The model has to be forced to grow grass at a higher nitrogen level, to purchase more concentrates and less roughage, to keep more young stock for replacement and to sell heifers, to grow more silage maize and to purchase more $P_2O_5$ and $K_2O$ fertilizer than optimal. Also the same kind of small differences between

Table 4.7 Fixed assets, levels of production, economic results and nutrient losses for the average extensive farm, the average intensive farm and the overall average on sandy soil based on FADN-data

| | extensive | intensive | overall average |
|---|---|---|---|
| Fixed assets: | | | |
| - area of land (ha) | 28.9 | 23.4 | 26.9 |
| - milk quota (1000 kg) | 259.9 | 385.0 | 330.3 |
| | | | |
| Level of production: | | | |
| - milk production per cow (kg) | 6293 | 6887 | 6682 |
| - grassland production (1000 MJ NEL/ha) | 65.7 | 81.1 | 73.1 |
| - N level grassland (kg/ha) | 386 | 441 | 408 |
| - grassland production minus expected production (1000 MJ NEL/ha) | -9.9 | 3.6 | -3.7 |
| | | | |
| Labour income (NLG) | 50,472 | 66,529 | 63,396 |
| | | | |
| Nutrient losses (kg/ha): | | | |
| - N | 357 | 451 | 401 |
| - $P_2O_5$ | 52 | 82 | 68 |
| - $K_2O$ | 88 | 167 | 123 |

simulation results and results from reality become apparent. They can be attributed to the same causes as described in section 5.2. However, some other deviations come to light. First, in reality the revenues of cattle sold on the extensive farm and the livestock costs are lower than the results simulated by the model. For the intensive farm the opposite is true. It can be assumed that these findings are related to the level of milk production per cow on the farms. The lower level of milk production on the extensive farm may partly be caused by lower breeding costs, which are included in the livestock costs. In turn, the lower level of milk production may cause a lower price of the heifers sold, which results in lower revenues of cattle sold. Second, the sum of the simulated costs of contract work and of machinery and equipment overestimates these costs in reality on the extensive farm, while these costs on the intensive farm are underestimated. From the FADN data it can be concluded that the reason may be a lower than average investment in machinery and equipment on the extensive farm, while this investment is higher than average on the intensive farm. Finally, the costs of quota are much lower than average on the extensive farm, while they are much higher on the intensive farm. Apparently, intensive farms have bought more quota. Together these differences cause an underestimation by the model of labour income on the extensive farm of about NLG 19,000, while labour income on the intensive farm is overestimated by about NLG 11,000.

Going from simulation to optimization, labour income increases by about NLG 6500 on the extensive farm and by NLG 14,000 on the intensive farm. This difference between farms is mainly caused by the assignment of land to grassland and silage maize. On the intensive farm, this division is much further away from the economic optimum than on the extensive farm. Going from simulation to optimization, the N losses decrease by 47 kg/ha on the extensive farm while they increase by 8 kg/ha on the intensive farm. The reason for this difference is again the change in the division of land. Converting land for silage maize to grassland leads to higher N losses per hectare especially if grass is grown at a high N level, which is the case on the intensive farm. On the other hand, N losses go down by a decrease of the N level on grassland and by feeding protein according to the standards plus the safety margin in the winter period. On the intensive farm increase and decrease balance. On all farms, the $P_2O_5$ losses decrease by about 30 kg/ha and the $K_2O$ losses remain more or less the same.

## 4.6 Discussion

The result of the process of operational validation is that the model has become less normative and more empirical. This holds especially for technical data such as the levels of production and the productivity and for levels of different costs. The nutrient balances follow from the technical results. What remains normative are the standards of feeding and of fertilizing with $P_2O_5$ and $K_2O$ and the method of linear programming that is used. The method of linear programming has not so far given cause for reconsiderations. However, it must be noticed that the validation process concerned a static situation. A dynamic validation after some time could lead to the conclusion that linear programming overestimates the flexibility that exists in reality.

A comparison of the results of simulation with the results from reality shows that the model is quite capable of representing a real-life situation. This means that the data, the activities and the restrictions used in the simulation model cover reality quite well.

A comparison of the results of optimization with the results of simulation shows the suboptimality of reality mainly caused by a suboptimal division of land between grassland and silage maize, a suboptimal level of N use on grassland and by suboptimal feeding (especially of protein). The results of optimization show what could be reached economically and environmentally by better management given income maximization as the farmers' main objective.

Simulation of an extensive and intensive farm with the validated model shows that the model underestimates labour income on the extensive farm, while it overestimates labour income on the intensive farm. Since this is caused for the greater part by fixed costs it does not disqualify the model for calculating with different intensities. However, this should be kept in mind when interpreting levels of income. Finally, optimization of farms with different intensities shows that the difference in labour income between optimization and reality increases with increasing intensity. The difference in N losses decreases with increasing intensity.

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# 5. Scenarios of technical and institutional change in Dutch dairy farming[1]

## Abstract

*Scenario analysis is used in this paper to assess consistent sets of future circumstances in Dutch dairy farming. The fields of interest are technical and institutional change. Technical change includes improvement in fodder and milk production. Institutional change includes changes of environmental policy and of market and price policy. All key factors are historically analyzed and forecasts are made for 2005 and are bundled into four scenarios. The scenarios are governed by environmental policy and common agricultural policy. For environmental policy a moderate and a severe variant are distinguished, and for common agricultural policy a price support and a two-price variant.*

## 5.1 Introduction

Dairy farming in the Netherlands faces significant uncertainties in the fields of (1) technical change, (2) environmental policy and (3) market and price policy. Technical change pertains to plant production and animal production which are the two production processes that take place on a dairy farm. The input/output relations that reflect the efficiency of these processes have changed continuously over the past decades. Environmental policy includes all governmental legislation meant to decrease the burden on the environment caused by agriculture. Since the awareness of environmental problems at governmental level is relatively new, this kind of policy is still in a development phase. The market and price policy of the EU strongly influences the prices a dairy farmer receives for his products and to a lesser extent also the prices of production factors. This policy is likely to change as a consequence of GATT negotiations among other things.

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[1] Paper by P.B.M. Berentsen, G.W.J. Giesen and J.A. Renkema; published in *Netherlands Journal of Agricultural Science* 44: (1996) 193-208.

The objective of this paper is to make systematic forecasts for these uncertain factors and to combine them into consistent scenarios representing possible circumstances for the year 2005 for dairy farming in the Netherlands. By doing so the future of Dutch dairy farming becomes more tangible and understandable. The paper starts with a short literature review on scenario analysis ending in the choices that are made in this study.

## 5.2 Scenario analysis

### 5.2.1 Principles of scenario analysis

In literature several definitions of the term scenario can be found. Consensus exists about (1) a scenario, 'not being a prediction of the future' (Zentner, 1982) but 'being an exploration of an alternative future' (Wilson, 1978) (2) the number of scenarios used for a certain subject which must be greater than one (Zentner, 1982) and (3) the number of aspects included in a scenario which must be greater than one since scenarios are multifaceted (Wilson, 1978). Scenarios can be longitudinal or cross-sectional (Schnaars, 1987). Boucher (1985) calls them 'path-through-time' and 'slice-of-time' scenarios. As most of the scenarios proceed in a logical sense at present (Coates, 1985), serious literature mostly deals with longitudinal scenarios. A second distinction is that of scenarios describing some kind of future state versus scenarios describing future circumstances. Firms appear to primarily use scenarios in the latter sense for 'depicting corporate environmental assessments for planning purposes' (Linneman & Klein, 1983, p.100). Interaction between forecasts of individual factors adds the extra dimension to scenarios according to Linneman & Klein (1983) and Zentner (1982). Others do not explicitly state that interdependencies must exist but they write about a scenario being an internally consistent set of forecasts (Millet, 1988).

Scenarios can be used for forecasting if other methods fail. For example, a model can be used for forecasting if the factors influencing a future state or environment are known, if their number is low and if the relationships governing the interactions between factors are well understood (Amara & Lipinski, 1983, p. 43). Good examples of these kinds of situations can be found in physical sciences. A shortcoming that empirical models have in common with trend extrapolation is that both methods are based on historical data, which means that events without a precedent cannot be taken into account (Schnaars, 1987). This leads to the conclusion that scenario analysis can be useful if uncertainty is high and if the number of choice moments and variables are high (Amara & Lipinski, 1983, p. 44). If crucial variables that are hard to predict can be reduced to a few, then scenario analysis is the best method to forecast future environment (Schnaars, 1987).

Literature offers several methods for developing scenarios (see for example Huss, 1988; Von Reibnitz, 1988: Zentner, 1982; Wilson, 1978; Schnaars, 1987). Steps, which all methods have in common, are analysis of historical data, development of forecasts for key factors and selection of scenarios. Different opinions exist on the extent to which development of scenarios can take place in a quantitative way. When scenarios were first used in futures research, development included the use of mathematical methods with a focus on probabilities of events happening in the future and on quantification of interdependencies between events (Helmer, 1977). However, Schnaars (1987) argues that the assignment of probabilities to scenarios implies a precision that is not warranted by either the data that were used to derive them, nor by the phenomenon they purport to predict. Kahn (1968) rejects the notion of quantitative model building, stating that quantitative models focus only on those aspects of a problem that are easily quantified, and, therefore, represent only a partial formulation of the forecasting problem. Selection and assessment of scenarios can be done after the analysis of historical data and the assessment of individual forecasts and of relations between the forecasts, or beforehand, on the basis of some global political or social assumptions (Coates, 1985). The first, inductive, way can be used if the number of influencing factors and the numbers of forecasts per factor are small while the second, deductive, way offers some guidelines for the process of selecting and analysing historical data if the number of factors or the numbers of forecasts per factor are high (Schnaars, 1987). The number of scenarios should not be too high to avoid difficulties for the user in interpreting and managing scenarios (Wilson, 1978). From earlier research, Linneman & Klein (1979) stated that three scenarios were used more than any other number. Wilson (1978) offers four criteria for selecting scenarios, namely relevance, credibility, usefulness and intelligibility. In short this means that a scenario must be relevant, it must seem a possible future, it must be useful for the purpose for which it was created and it must be understandable. The contents of scenarios should be based on some sort of logic according to Coates (1985), such as different values of a range of key variables rather than to produce a "best case", a "worst case" and a "surprise-free case".

### 5.2.2 The use of scenario analysis in this study

In this study scenario analysis is used to compose possible future circumstances for dairy farms. The conditions which lead to scenario analysis as being the best method for future forecasting are almost completely met in dairy farming. Firstly, the subject matter lies in the field of social affairs so timeless laws like in physical sciences are missing. Secondly, the main influencing factors are the state of technology and institutional regulations concerning the market and price policy and the protection of the environment, so the number of crucial variables can be kept low. Finally, the uncertainty, especially in the field of institutional regulations, is high.

An important scientific criterium is that scenarios are verifiable. This requires (1) that scenarios proceed in a logical sense on the present and (2) that scenarios are as quantitative as possible. The longitudinal character of the scenarios is realized by developing forecasts for key factors that currently proceed in a logical sense although this can happen with sudden changes. The quantitative aspect will be restricted to the content of scenarios. A quantitative content also makes the scenarios suitable for modelling purposes. Probabilities will not be attached to scenarios.

The steps that will be taken in the development of scenarios are as follows:

1 The key influencing factors will be assessed in both influencing areas (technology and institutional regulations).

2 Following analysis of historic data on every key influencing factor and based on expected changes, one or more forecasts will be developed.

3 The individual forecasts will be bundled into three or four scenarios, taking into account interdependencies between the factors. The scenarios will be selected based on relevance, credibility, usefulness and intelligibility.

From the above it can be seen that scenarios are assessed after analysis of historic data and assessment of individual forecasts. This inductive way is chosen because the number of influencing factors as well as the number of forecasts per factor is small.

## 5.3 Changing factors in dairy farming

The external changing factors that influence dairy farming are grouped into factors of technical change, factors of institutional change and other factors.

### 5.3.1 Technical change

Cochrane (1958, p.46) defines technical change as "an increase in output per unit of input resulting from a new organization, or configuration, of inputs where a new and more productive production function is involved". A more specific definition is given by Ruttan (1959, p.606). He defines technical change in what he calls a functional sense as "changes in the coefficients of a function relating inputs to outputs resulting from the practical application of innovations in technology and in economic organization".

On a specialized dairy farm two main production processes take place, i.e. plant production and animal production. According to the definitions mentioned above, technical change is expressed by the continuous change of these processes. Plant production on a dairy farm is mainly equivalent with grass and silage maize production. Other roughages are of minor importance. Animal production includes milk production, meat production and reproduction. Milk production is of major importance and meat is considered a by-product.

#### *Grass production*

The average net energy production per hectare of grass in the Netherlands has increased from about 40,000 MJ NEL (megajoule net energy for lactation) in 1971 to about 62,000 MJ NEL in 1983. Since 1985, when milk production was restricted, net energy production has declined (Anonymous, 1993a). From 1974 to 1993 the losses of energy as a result of grazing and forage-making declined on average from about 27% to 22% (Anonymous, 1974, p. 94; Asijee, 1993, p. 182). This decline was the result of better grazing and mowing management and improvements in conserving roughage. Gross energy production (Figure 5.1) can be calculated from the net energy production and the assumption that losses declined by 0.25% per year. Ongoing research on grazing and mowing management and on harvesting and conserving roughage makes it feasible to assume that losses will continue to decline by 0.25% per year till 2005.

An important factor influencing grass production is the supply of mineral nitrogen by fertilizer and manure. Mineral N supply from manure was assumed to be 20 kg per cow per year, as a result N supply from manure per hectare will vary with animal density. From Figure 5.1 it can be seen that N-supply shows a course corresponding to that of energy production with a

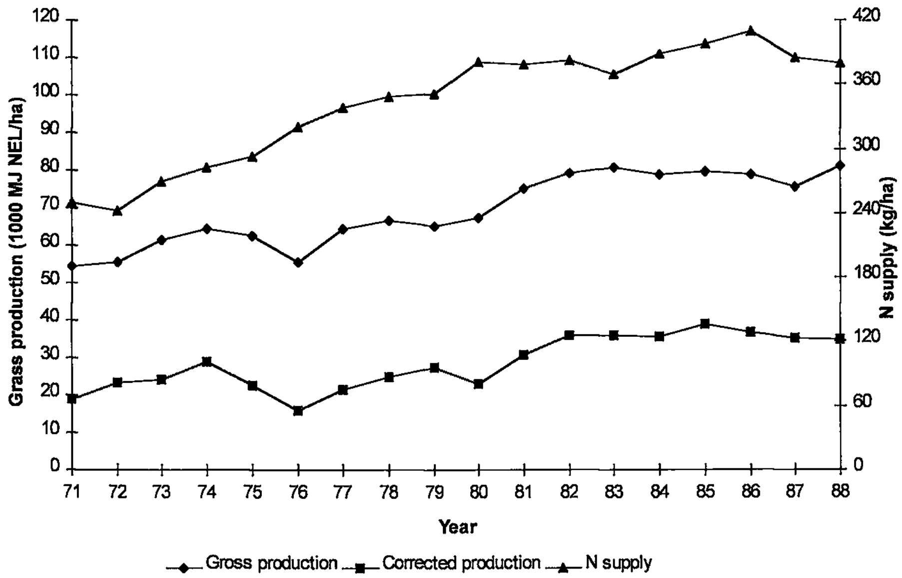

Figure 5.1 Average gross energy production from grassland in the Netherlands from 1970 to 1988, the corresponding average level of N supply and the energy production corrected for weather influences and N supply

minimum in 1972 of about 240 kg/ha and a maximum of about 400 kg/ha in 1986. Other influencing factors are advances in grass breeding and in grassland management (i.e. better grassland care and methods of harvesting grass) improved drainage of wet soils and improved water supply of dry soils. These advances have all increased the ratio between grass yield and N supply (Van der Meer & Van Uum-Van Lohuyzen, 1986, p. 10) which can be regarded as technical change. A final influencing factor is the weather. A well-known example is the dry summer of 1976 which led to a fall in grass production.

Analysis of the data to obtain the yearly increase of grass production at different levels of N supply by means of linear regression did not result in satisfying coefficients. Therefore another way of analysing was used. First, gross energy production has been corrected by using weather indices for grass production (Oskam & Reinhard, 1992) and the effect of N supply known from experimental research (Berentsen & Giesen, 1995). The resulting curve (Figure 5.1) shows a production increase due to technical change. Linear regression on this curve, with time as independent variable resulted in an average yearly increase of gross energy production of 1100

MJ NEL per ha. This average increase belongs to the average N supply of the data which amounts to 343 kg/ha. For other N levels it is assumed that the annual increase as a percentage of total grass production equals the percentage at the average N level of 343 kg/ha. This results in a yearly increase in energy production from grass due to technical change of 743, 929, 1061, 1138, and 1160 MJ NEL per ha at an N supply of 100, 200, 300, 400, and 500 kg/ha respectively. It should be noted that the uncertainty about these calculated increases is higher at low levels of N-supply, since the level of N-supply was higher than 200 kg/ha in the period analysed.

For future, improvements in grass breeding and in grassland management make a comparable increase in production likely (Wilkins, 1987; Wilkins, 1991). Especially the increase of information available and the development of systems that convert this information into practical advise can lead to better and more accurate grassland management.

### *Silage maize production*

The acreage of silage maize has grown from 0.4% of the total agricultural area in the Netherlands in 1970 up to 10% in 1990 (Anonymous, 1993a). Reasons for this increase were conversion of mixed farms into specialized farms in which silage maize took the place of grains, increasing slurry output which can be used for growing silage maize very well while grains could not use slurry at all, mechanization of sowing, weed control and harvesting and increasing efforts in breeding silage maize varieties (Te Velde, 1986). Other reasons could be the high energy production per hectare and the high and constant quality of silage maize compared to grass and the good possibility of taking up silage maize in the ration for dairy cows.

Figure 5.2 shows average dry matter production per hectare of silage maize from 1954 to 1993 (Oskam, 1991, Anonymous, 1993a). Linear regression shows an average yearly increase in dry matter production of 125 kg per ha. This increase is the result of breeding and improved crop management. However, fluctuations between years can be quite substantial and can be explained mainly as the result of weather conditions. Night frosts, periods with low temperatures and severe lack of moisture in particular have a negative influence on production (Te Velde, 1984). The results of maize variety trials in the eighties, showing yields up to 17,000 kg dry matter per ha (Te Velde, 1986), give rise to the expectation that the yearly increase can be continued far beyond 2005.

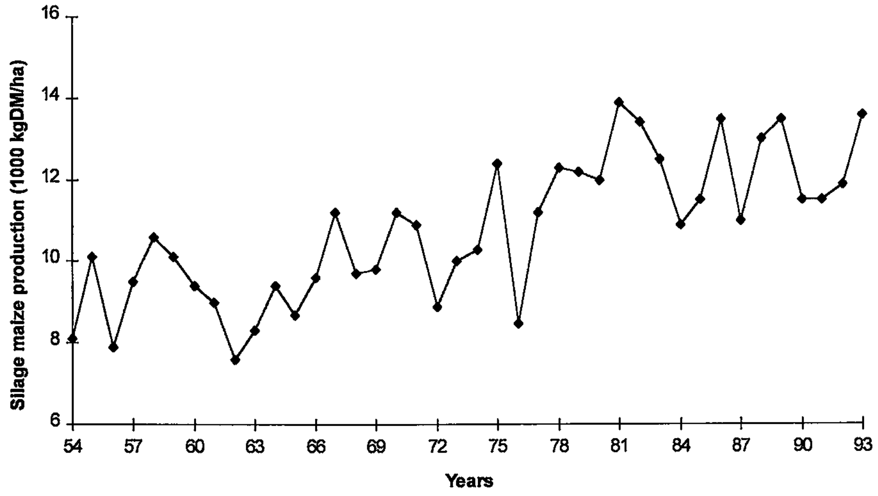

Figure 5.2 Average gross dry matter production from silage maize in the Netherlands from 1954 to 1993.

*Milk production*

Increase in Fat corrected milk production per cow per year in the Netherlands for 1950-1992 exhibits four distinct periods (Figure 5.3). In the first period (1950 to 1975), average increase was 45 kg per cow per year. This period was characterized by low use of artificial insemination and by a considerable growth of the total number of dairy cows. As a result the effect of breeding remained low. Also the effects of improved cow management (including feeding management and health care) on milk production per cow appeared to be low throughout the whole period.

In the second period (1975 to 1984), the yearly increase in milk production was about 100 kg. Increasing use of artificial insemination, development of sophisticated breeding programmes, and introduction of Holsteins into breeding programmes increased the genetic potential for milk production. A better feeding management and a change in the housing and the milking system also contributed to the higher yearly increase.

The third period (1984-1986) was a shock period. It included the years of adaptations of farmers to the introduction of the quota system with sudden deviations in the annual increase of milk production per cow (Burrell, 1989; Dillen, 1989, p.91).

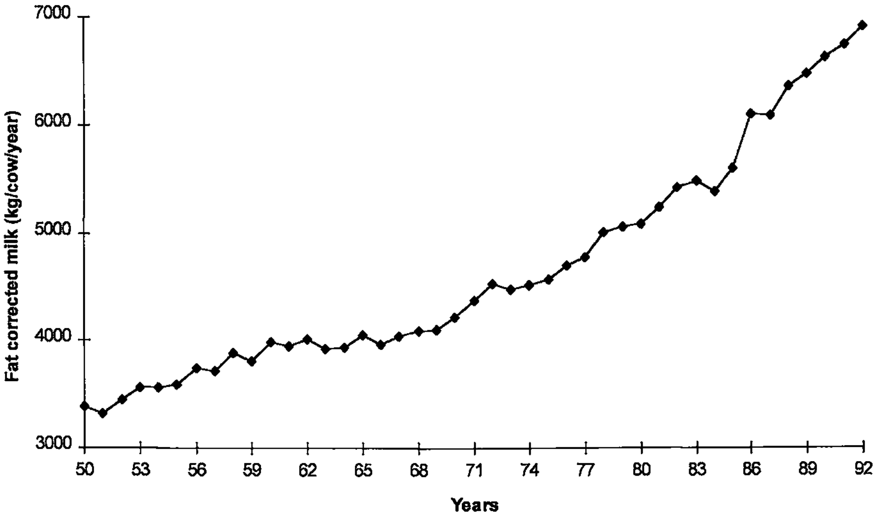

Figure 5.3 Average fat corrected milk production in the Netherlands from 1950 to 1992

In the first three years of the fourth period (1987 to 1992) the milk quota were reduced further by 4% (Krijger, 1991, p.21). The yearly increase in milk production per cow was 145 kg. On top of the factors that previously played a role, the quota system itself became a factor affecting milk production per cow. It gave rise to increased selection at farm level, increased attention to individual cows and more emphasis on increasing milk production per cow (one of the few factors left which could improve income).

If total production remains limited, Fat corrected milk production per cow can be expected to increase at 145 kg per cow because of new breeding techniques and improvements in feeding and health management. Total milk production or numbers of dairy cows may be limited by the quota system but also by environmental regulations. If no production limitations exist, a yearly increase of 100 kg can be assumed.

Increases in milk production caused by automatic milking or by the use of BST are not included in these estimations. Automatic milking is still in a development phase and necessary investments are estimated that high that automatic milking remains economically unattractive for the coming years. The use of BST within the EU is prohibited by legal regulation till 2000 and it is assumed that it will be so till after 2005.

### 5.3.2 Institutional change

By institutions the rules of society or of organizations are meant (Ruttan, 1987, p. 58). Specific rules for agriculture are laid down in policy regulations by the national government and the EU. National policy that applies to dairy farming and that can be expected to change concerns acidification and eutrophication of the environment. EU policy applying to agriculture is laid down in the common agricultural policy (CAP). By far the most important part of the CAP concerns the market and price policy of the EU.

#### *National policy on acidification*

Acidification takes place through deposition of sulphur oxides, nitrogen oxides and ammonia ($NH_3$). Calculations show that Dutch agriculture was responsible for 32% of total acid deposition in the Netherlands in 1990, almost entirely through emission of $NH_3$. Other Dutch sources such as cars, trucks, industries and electricity plants contributed a further 21% while the remaining 47% came from abroad (Anonymous, 1993b, p. 80). Dairy farming contributes substantially to acidification by volatilization of $NH_3$ from manure in the sheds, in storage and on the land.

Legislation to reduce $NH_3$ emission from agriculture was passed in 1991 and basically consisted of (1) manure must be applied with a low emission technique and (2) manure storages must be covered. The obligation to apply manure by means of a low emission technique on sandy soil (and only for a part of the year) became effective in 1992. Beginning in 1995, all manure on all soil types must be applied by means of a low emission technique.

The government target for a maximum $NH_3$ emission at farm level is 20 to 30 kg $NH_3$ per ha in 2015 (Anonymous, 1993b, p.108). To achieve this, the government is developing a system that estimates $NH_3$ emission at farm level and imposes a levy on emission exceeding the accepted level. Since the levy and the effectiveness of the system are still unknown, two policies are assumed for 2005 (Table 5.1). The moderate policy assumes an acceptable emission of 40 kg $NH_3$ per hectare and a levy of NLG 30 per kg emission above the accepted level. The severe policy assumes an acceptable emission of 25 kg/ha and a levy of NLG 60 per kg. The levies are based on extra costs of a low emission cow shed that would be NLG 23 to NLG 55 per kg reduction of $NH_3$ emission (Van der Kamp et al., 1993).

Table 5.1: Two variants of expected environmental policy for 2005 concerning nutrient losses from dairy farming

| | moderate policy | severe policy |
|---|---|---|
| Ammonia emission: | | |
| - acceptable emission level (kg $NH_3$/ha) | 40 | 25 |
| - levy (NLG/kg $NH_3$) | 30 | 60 |
| | | |
| Phosphate losses: | | |
| - acceptable losses (kg $P_2O_5$/ha) | 35 | 20 |
| - levy on first 10 kg exceeding (NLG/kg $P_2O_5$) | 5 | 5 |
| - levy on higher exceeding (NLG/kg $P_2O_5$) | 20 | 20 |
| | | |
| Nitrogen losses: | | |
| - acceptable losses (kg N/ha) | 275 | 180 |
| - levy (NLG/kg N) | 2 | 2 |

*National policy on eutrophication*

Eutrophication of the soil and of ground and surface water are closely related. Eutrophication of the soil takes place by binding phosphate ($P_2O_5$) to soil particles and by accumulation of organic bound N in the soil. When the capacity of the soil to bind $P_2O_5$ is exceeded, $P_2O_5$ is transported by water to surface and ground water. The same counts for organic bound N that is mineralized and not used by plants. Eutrophication of ground water by $P_2O_5$ and N makes it costly to use ground water as drinking water. It is mainly caused by excessive use of animal manure and fertilizer by agriculture. Eutrophication of surface water leads to excessive algal growth that threatens existing eco-systems. It was calculated that in 1990 agriculture was responsible for about 25% of $P_2O_5$ and for about 70% of N in surface water (Anonymous, 1994, p. 97).

Legislation to decrease eutrophication by agriculture was introduced in 1987 and focused on the period during which animal manure can be applied to the land and on the amount of manure that can be applied per hectare. The period during which manure can be applied to the land has been restricted to the growing season when nutrients are utilized by plants. Application outside the growing season in the past has led to excessive leaching of nitrates. The amount of manure that can be applied is measured by its $P_2O_5$ content and based on a normative $P_2O_5$

production per animal and a standard use per hectare depending on the crop that is grown. Although these standards were tightened several times, the $P_2O_5$ legislation so far hardly affected dairy farming (Berentsen et al., 1992). Shortcomings of this legislation concern the exclusion of $P_2O_5$ from chemical fertilizer and the use of a normative $P_2O_5$ production per animal which makes it unattractive to change the actual $P_2O_5$ content of manure by changing feed rations.

In December 1995, the government and the parliament reached agreement on the introduction in 1998 of a system of nutrient balances for $P_2O_5$ and N at farm level (Anonymous, 1995). These balances will register all yearly input and output of nutrients and consequently estimate nutrient losses. A levy will be imposed on losses that exceed an acceptable level of losses. This system will replace the current standards on the maximum use of $P_2O_5$. The acceptable losses will be decreased in a number of steps. The agreed levels of acceptable losses for the different years are provisional. Depending on the results of research, these levels can be changed. Because of this uncertainty, again two policies for 2005 are used here (Table 5.1). The acceptable losses under the moderate policy equal the provisional acceptable losses for 2000. The acceptable losses under the severe policy equal the provisional acceptable losses for 2010 (Anonymous, 1995). The levy on $P_2O_5$ losses increases stepwise with increasing transgression of the acceptable losses.

### *Market and price policy of the CAP*

The main reasons for government intervention in agriculture lie in the special importance for national welfare that governments assign to agriculture and its products and in particular aspects of supply and demand of agricultural products (De Hoogh, 1994). Agriculture's special importance follows from its production of primary necessities of life (i.e. food production) which make agriculture a vital sector. Particular aspects of supply are the influence of weather, which makes the output in the more traditional agricultural sector less controllable, and the existence of long-lasting production cycles that makes it difficult to react rapidly to changing production circumstances and changing consumer demands (Atkin, 1993). Also the organization of agricultural production in many small family farms where labour is a much more fixed input factor than in industrial organizations makes agricultural supply rather insensitive to changing prices (see Helming et al. (1993) and Thijssen (1992) for the case of Dutch dairy farming). The demand of agricultural products is rather inelastic because the amount of food used by consumers is rather independent of the food price and of the income of the consumer. Together, these supply and demand aspects lead to large price fluctuations, often low incomes for farmers and uncertainty in food security (Atkin, 1993). Targets of government intervention are price stabilization, low food prices for urban population or high prices to support agricultural incomes and to stimulate agricultural production (De Hoogh, 1994).

Governmental intervention via the CAP started in 1962 as guaranteed prices for cereals, later followed by guaranteed prices for butter and milk powder. Although at the end of the sixties butter surpluses had already appeared, it was not until 1984 that the introduction of the quota system stopped further increase of milk production within the EU (Fearne, 1991). The next fundamental change in the CAP came in 1992 when the EU member states reached agreement on a derivate of the MacSharry proposals. Pressure from outside the EU to reach an agreement was caused by the Uruguay round of the GATT at which it was agreed to liberalize international trade, including trade in agricultural products.

This agreement, which extends until 2000, only marginally affects the market and price policy for milk. The change concerns a decrease in the intervention price of butter by 5% on the one hand and the abolition of the co-responsibility levy of NLG 1.50 per 100 kg milk on the other hand. As a result, the intervention price for milk decreases by NLG 0.50 per 100 kg compared to the price of 1992. Moreover, the milk quota will be reduced by 2% (Anonymous, 1993c). Other parts of the agreement have affected and will continue to affect dairy farming more strongly. The decrease in the intervention price of grain by 30% will lead to a decrease in the price of concentrates, as fifty per cent of the feedstuffs used for concentrates for dairy cows consist of energy sources like grain and grain substitutes (Dubbeldam, 1993, p. 23). A decrease of the intervention price of grain by 30% means a price reduction of about NLG 12 per 100 kg grain. Calculations point out that prices of grain substitutes that are lower than grain prices, will also have to fall to remain competitive (Lapierre et al., 1993). Prices of concentrates can be assumed to fall by about NLG 4 per 100 kg compared to the price level of 1992. The compensatory payment per hectare of grain of (which applies also to silage maize) decreases the price of purchased silage maize and the costs of own produced silage maize. It can be assumed that the premium of NLG 604 per ha will be passed on to the buyer of silage maize which means that the price of silage maize will decrease by NLG 604 per ha compared to the price of 1992. The 15% decrease in the intervention price of beef will affect prices of cattle. It can be assumed that the prices of culled dairy cows will be reduced by about NLG 200 and of beef bulls by about NLG 300 per animal compared to the price level of 1992. It can be expected that the lower revenues will be partly translated into lower prices of calves. A price reduction of NLG 100 per calf is conceivable. For beef bulls lower prices are partly compensated by raising the EU premium per beef bull from NLG 105 up to NLG 235 .

After 2000, it is possible that the price support for milk will also be reduced. Total abolition of the quota system is less likely, since the system has proved a valuable instrument to control milk supply (Berkhout and Meester, 1994).

For the situation in 2005 two alternatives are assessed. The price support alternative is a continuation of the situation before 2000. The second alternative is a two-price system with a guaranteed high price (the same price as in the price support alternative) for 85% of the available milk quota and a super levy on an unrestricted production of about 50% of the guaranteed price (so that a price of NLG 40 per 100 kg remains). This alternative is based on milk consumption within the EU being about 85% of total EU milk production and on the heavy EU subsidy on export of the remaining 15%, given a world market price of about NLG 30 per 100 kg of milk (Anonymous, 1993d, p. 195). Given the EU budget used for supporting the milk price, lower support per 100 kg milk that is produced over 85% of the available milk quota results in a larger volume of milk that can be supported. This system allows efficient producers to increase their production while less efficient producers will decrease production. Restructuring of milk production can take place to a certain extent and production can become more market-oriented. This option is based on an alternative to the present system presented by Oskam et al. (1988, p. 74).

### 5.3.3 Other changes

One remaining important factor that affects dairy farming and one that can be expected to change is the number of dairy farms and consequently the distribution of land and milk quota over the farms. The number of dairy farmers who stop farming depends on factors like age, whether they have a successor, and the economic circumstances within and outside the agricultural sector. The economic circumstances outside the agricultural sector are particularly hard to predict. Here it is assumed that the yearly growth of the average dairy farm in the future, which depends on the number and the size of the dairy farms that will stop, will be the same as it was in the period 1985-1992. From Dutch Milk Marketing Board data and from the Farm Accounting Data

Network it can be concluded that the milk quota of the average dairy farm increased yearly by about 4000 kg while the area of land increased by about 0.4 ha per year.

## 5.4 Combining changes to scenarios

In the process of developing forecasts one interdependency arose. The yearly increase in milk production per cow appeared to be higher in case total milk production is restricted. Since the two options for the market and price policy differ with respect to restricting total milk production, the high increase in milk production should be combined with the price support option while the low increase in milk production should be combined with the two-price system. However, there are two reasons to assume that the increase of total milk production under the two-price system will be small. First, the price of the extra milk that is produced is so low that increase of total milk production will certainly be restricted by the availability of fixed assets like the capacity of the stable. Second, environmental legislation will probably also restrict increase of total milk production. Therefore, it is assumed that the high increase in milk production will prevail in all situations. Given the unique forecasts for increases in fodder production, this means that there is one unique forecast for technical change.

Technical change and the change of farm size form the decor against which the institutional changes take place. There are two alternatives for both national environmental policy and market and price policy. Consequently the number of scenarios that can be constructed amounts to four (Figure 5.4). Four scenarios is a number that can be handled, so the number itself gives no reason for further selection. However, a check for relevance, credibility, usefulness and intelligibility is useful.

Relevance means that the factors that make up the scenarios all critically affect the subject. The subject here is the future of Dutch dairy farming. All factors were selected based on their influence on the future of Dutch dairy farming. This means that they are relevant by definition.

Credibility means that the scenarios must be acceptable for people interested in the future of Dutch dairy farming. Acceptable not meaning desirable but imaginable for people who are well aware of the situation in dairy farming. Although this means that the judgement should be made by others, it is possible to say something about the credibility of the underlying factors. There will be little discussion on the existence of technical change. The rate of technical change in the future is based on historical developments, thereby assuming that the same mechanisms will also work in the future. The future of environmental legislation in the Netherlands is becoming clearer and clearer. The system with mineral balances, will certainly going to be used in the future. By choosing two variants for uncertain factors in this system, that are both based on governmental policy proposals, the range of possibilities is covered quite well. The future of the market and price policy of the CAP is certainly the hardest factor to forecast. The two alternatives that were chosen represent continuation of the existing situation and a closer connection with the market. A closer connection with the market can go as far as leaving dairy farming completely to the open market. However, if the market and price policy is headed towards an open market after 2000, it will take a transition period. A two price policy, which includes both protection and a closer link with the market, is chosen because it could very well be used as a transition system.

The usefulness of scenarios depends on the accuracy of the description of the scenarios. Moreover, if scenarios of future circumstances are to be used in modelling, they must necessarily be quantitative. As forecasts of all underlying factors are quantitative, all scenarios are quantitative and as a result they are equally useful.

The intelligibility of scenarios depends on the complexity of the scenarios. The complexity follows from the numbers of factors that make up the scenarios and from the

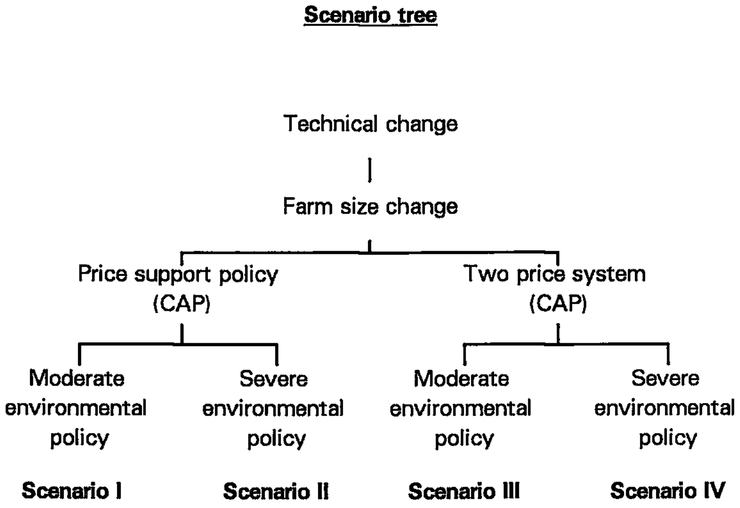

Figure 5.4 Construction of the different scenarios

interdependencies between the forecasts of individual factors. The numbers of factors underlying the scenarios are equal for all scenarios and moreover, they are relatively low. Together with the absence of interdependencies between individual forecasts, this makes the scenarios easy to understand.

## 5.5 Discussion

The data that were used to determine technical change all relate to dairy farming in the Netherlands in general. This means that the forecasts generated from these data are average forecasts. It is conceivable that factors like soil type with regard to fodder production and cattle breed with regard to milk production have an influence on yearly increase that differs from average. This should be borne in mind when individual forecasts or the scenarios are used for a specific situation.

Technical change can be underestimated by the scenarios if unforeseen innovations become important before 2005. However, there are not many examples of such innovations in the past. Most major innovations take a long time before they are ready to be used in practice and to be adopted by a substantial number of farmers.

In the section on the market and price policy of the CAP, price changes are given that will follow from the agreement of the MacSharry proposals. These price changes necessarily refer to 1992, the year of the agreement. General price developments for important inputs and outputs are not given. Data on nominal prices of milk, beef and concentrates since the introduction of the quota system show no clear trend in terms of increasing or decreasing prices. The only clear conclusion that can be drawn is that prices fluctuate.

In general, the scenarios but also the forecasts for individual factors can form a basis for exploring the future of dairy farming in the Netherlands both from a policy and a farm management point of view. In subsequent research, the scenarios will be used as input for a dairy farm model (Berentsen and Giesen, 1995) to asses the consequences for representative dairy farms on sandy soils.

## Acknowledgements

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# 6. Economic and environmental consequences of technical and institutional change in Dutch dairy farming[1]

## Abstract

*A linear programming model of a dairy farm is used to explore the future for different types of Dutch dairy farms under different scenarios. The scenarios are consistent sets of changing factors that are considered external at farm level. The factors are either technical, like efficiency of milk production and feed production, or institutional, like national environmental legislation and EU market and price policy. Income and nutrient losses for farms differing in intensity and size are generated for the base year 1992 and for 2005. The results show that technical change up to 2005 has a positive influence on labour income as well as on nutrient losses. The increase of labour income is higher for farms with a higher total milk production in the basis situation. The influence of environmental policy on labour income and environmental results is bigger for farms with a higher intensity, as these farms have to take more measures to comply with governmental policy. Replacement of the price support policy for milk by a two-price system with a high price for a restricted amount of milk and a low price for an unrestricted amount of milk has negative consequences for labour income, especially for intensive farms.*

## 6.1 Introduction

Future possibilities for dairy farming depend strongly on technical and institutional change which can be considered external at farm level. On a dairy farm the state of technology is expressed by the efficiency of fodder production and animal production. Institutions strongly influence prices of inputs and outputs in dairy farming (European Union) and environmental restrictions that dairy farmers have to fulfil (national government).

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[1] Paper by P.B.M. Berentsen, G.W.J. Giesen and J.A. Renkema; published in *Netherlands Journal of Agricultural Science 45 (1997): 361-379.*

Several studies have been conducted to forecast the future of Dutch agriculture in general and dairy farming in particular. Studies of Muller et al. (1993) De Groot et al. (1994) and Kolkman et al. (1993) include technical and institutional change in the scenarios applied. However, verification of these scenarios and the consequential results is difficult as the development of the scenarios is rather vague and the results are described in global non quantitative way. Other studies focus on the effects of only one changing factor. An example of this are studies that try to asses the effects of a future environmental policy (Van de Ven, 1996; Berentsen et al., 1992).

The objective of this paper is to determine economic and environmental consequences of a number of scenarios including technical and institutional change up to 2005 for different dairy farms on sandy soil in the Netherlands. The dairy farms differ with respect to intensity and size, which are two aspects with a substantial impact on farm results. Sandy soil is chosen because in the Netherlands this soil type has the severest environmental problems.

A linear programming model of a specialized dairy farm has been developed to simulate the different situations (Berentsen & Giesen, 1995). This model was validated based on the average results of a representative sample of dairy farms on sandy soil in the Netherlands in 1992

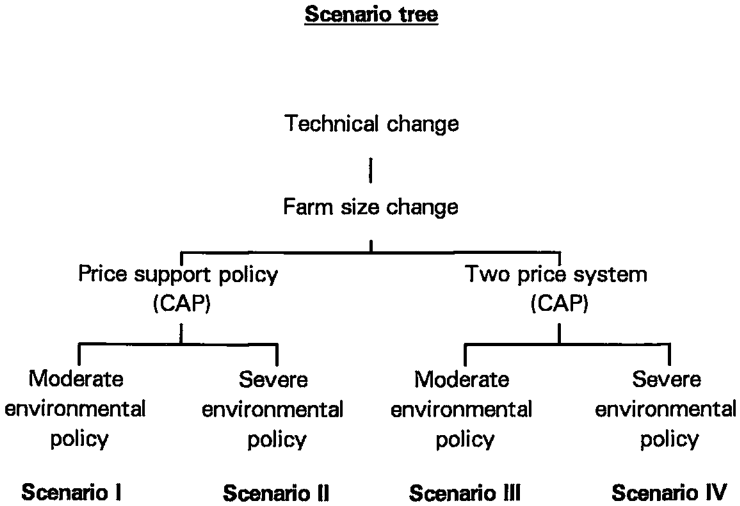


Figure 6.1 Scenarios of technical and institutional change in Dutch dairy farming.

(Berentsen et al., 1996b). The consequences of the scenarios are determined by comparing the results for 2005 with those of 1992.

## 6.2 Scenarios of technical and institutional change

The overview of the scenarios (Figure 6.1) shows that there is one forecast for technical change; one for farm size; there are two forecasts for national environmental policy and two for the market and price policy of the EU. This results in four scenarios (see also Berentsen et al., 1996a).

Technical change in fodder production and milk production are the result of breeding activities and of management improvement. For fodder production in general, improvement of management includes drainage of wet soils, water supply to dry soils, improvement of soil fertility and soil structure and improvement of crop care. For grass production in particular, improved management includes also better timing of grazing and harvesting and better methods of harvesting and ensiling grass. Improvement of management in milk production is characterized by better feeding management and health care and, since the introduction of the milk quota system, by increased selection of cattle. Table 6.1 shows the production levels of specialized Dutch dairy farms on sandy soil in 1992 and a forecast for the production levels in 2005 based on the levels of 1992 and on analysis of historic production data (Berentsen et al., 1996a).

Environmental problems related to dairy farming are acidification and eutrophication. Calculations show that Dutch agriculture was responsible for 32% of total acid deposition in the Netherlands in 1990, almost entirely through volatilization of $NH_3$ from manure in sheds, in storage and on the land (Anonymous, 1993, p. 80). Eutrophication of ground water by $P_2O_5$ and $NO_3$ is mainly caused by excessive use of animal manure and fertilizer by agriculture. It threatens the use of ground water as drinking water. National environmental legislation so far focussed on methods of storing and applying manure to decrease $NH_3$ volatilization, and on the period during which manure can be applied and on the amount of manure that can be applied per hectare to decrease $P_2O_5$ and $NO_3$ leaching. For the future the government is going to introduce a system of nutrient balances for N and $P_2O_5$ at farm level with a levy that will be imposed on losses that exceed an acceptable level. For $NH_3$ emission the government is studying a system that estimates $NH_3$ emission at farm level and imposes a levy on emission exceeding an acceptable level. Here it is assumed that in 2005 a system with acceptable emissions and levies will be used for both $NH_3$ emission and N and $P_2O_5$ losses (Table 6.2). Because of uncertainty about the $NH_3$ system

Table 6.1 Expected technical change for specialized Dutch dairy farms on sandy soil.

| | Year | |
|---|---|---|
| | 1992 | 2005 |
| Grass production: | | |
| - yearly gross energy production (1000 MJ NEL/ha) at: | | |
| * 100 kg N/ha | 46.3 | 56.0 |
| * 200 kg N/ha | 59.8 | 71.9 |
| * 300 kg N/ha | 68.1 | 81.9 |
| * 400 kg N/ha | 72.9 | 87.7 |
| * 500 kg N/ha | 75.2 | 90.2 |
| - loss of energy by grazing (%) | 22.0 | 18.8 |
| - loss of energy by mowing and ensiling (%) | 20.0 | 16.8 |
| Gross energy production silage maize (1000 MJ NEL/ha) | 82.8 | 92.9 |
| Gross energy production fodder beet (1000 MJ NEL/ha) | 100.7 | 109.7 |
| Milk production per cow (kg/year) | 6682 | 8445 |

and about the exact path through time of the nutrient balances system two alternative policies are assumed.

For the influence of the EU market and price policy on dairy farming the years 1992 and 2000 are important. In 1992 the EU members reached an agreement, which extends to 2000, on a derivate of the MacSharry proposals with a number of consequences for dairy farming. The decrease in the intervention price of grain by 30% will lead to a decrease in the price of concentrates, as the prices of grain substitutes are linked to the prices of grain. The compensatory payment per hectare of grain (which applies also to silage maize) decreases the price of purchased silage maize and the costs of own produced silage maize. As a result of a decrease in the intervention price of beef by 15%, prices of removed cattle and young stock will decrease. The intervention price for milk will decrease by NLG 0.50 per 100 kg, as a result of a decrease in the intervention price of butter by 5% on the one hand and the abolition of the co-responsibility levy of NLG 1.50 per 100 kg milk on the other hand. Moreover, the milk quota will be reduced by 2%. Table 6.3 shows the consequential prices for 1992 and 2005. In 2000, EU member states will

Table 6.2. Two variants of expected environmental policy for 2005 concerning nutrient losses from dairy farming.

| | Policy | |
|---|---|---|
| | Moderate | Severe |
| Ammonia emission: | | |
| - acceptable emission level (kg $NH_3$/ha) | 40 | 25 |
| - levy (NLG/kg $NH_3$) | 30 | 60 |
| Phosphate losses[1]: | | |
| - acceptable losses (kg $P_2O_5$/ha) | 35 | 20 |
| - levy on first 10 kg exceeding (NLG/kg $P_2O_5$) | 5 | 5 |
| - levy on higher exceeding (NLG/kg $P_2O_5$) | 20 | 20 |
| Nitrogen losses[1]: | | |
| - acceptable losses (kg N/ha)[2] | 275 | 180 |
| - levy (NLG/kg N) | 2 | 2 |

[1] Source: Anonymous (1995a)

[2] N losses through atmospheric deposition are not included

have to reach agreement on policy after 2000. As milk is one of the products left with a substantial price support, it is possible that this price support and the quota system will be changed. For the situation in 2005 two alternatives are assessed. The price support alternative is a continuation of the situation before 2000. The second alternative is a two-price system with a guaranteed high price (the same price as in the price support alternative) for 85% of the available milk quota and a super levy on the unrestricted production of about 50% of the guaranteed price (so that a price of NLG 40 per 100 kg remains).

Due to exit of some dairy farms the average size of dairy farms measured in available land and milk quota is continuously growing. Based on historical data it is assumed that the average size yearly increases by 4000 kg milk quota and by 0.4 ha per year.

Table 6.3. Prices (in NLG[1]) of inputs and outputs in 1992 and 2005.

| | Year | |
|---|---|---|
| | 1992 | 2005 |
| Inputs: | | |
| - standard concentrate (NLG/100 kg) | 34.60 | 30.60 |
| - purchased silage maize (NLG/ha) | 3300 | 2696 |
| Outputs: | | |
| - male calf (NLG/animal) | 370 | 270 |
| - replaced dairy cow (NLG/animal) | 1363 | 1163 |
| - milk (NLG/100 kg) | 79.00 | 78.50 |
| Premium silage maize (NLG/ha) | - | 604 |

[1] NLG 1 equals about 0.6 US$

## 6.3 Methodology

### 6.3.1 The farm model

A linear programming model is used to model the dairy farm. The objective function maximizes labour income (i.e. return to labour and management) as maximization of income appears to be the most general first objective of farmers (Zachariasse, 1974). The basic element in the model is a dairy cow, calving in February and producing a fixed amount of milk. Feed requirements are determined using formulas of Groen (1988). For protein feeding, a safety margin of 300 gram per cow per day (200 gram OEB and 100 gram DVE) is included in the requirements to reflect uncertainty about exact feed intake in reality (Berentsen et al., 1996b). In order to be able to replace cows, young stock is kept on the farm. An eventual surplus of pregnant heifers can be sold.

The land of the farm can be used for growing grass, maize, and fodder beet. Grass can be grown at different levels of N supply and it can be used for grazing and for silage making. Maize can be grown for silage making, and can be fed in winter and summer. Fodder beet can be grown for feeding in winter. In addition to home-grown feed, different types of concentrate (with different protein content), dried beet pulp and silage maize can be purchased. All feed supplies energy, protein and dry matter and uses part of the intake capacity of the animals.

Nutrients for plant production can be supplied by home-produced manure, by fertilizer, and (to a certain extent) by manure supplied by other farms. The model contains nutrient balances at the farm level for N, $P_2O_5$ and $K_2O$ that register nutrient input and output and consequently nutrient losses. $NH_3$ emission is estimated separately and is affected by housing, type of manure storage and application, and by extent of grazing. To make realization of the ammonia emission targets possible, adaptation of the stable is included in the model. Emission reduction percentages and costs are based on Van der Kamp et al. (1993). Calculation of N leaching is based on calculation rules of Goossensen & Van Den Ham (1992). Given soil type and ground water table, leaching depends on the use of the land (i.e. grass, maize of fodder beet production), on the N level on grassland and on the intensity of grazing (number of urine patches).

In the model, labour is supplied by the farmer and the family. Activities such as mowing and ensiling of grass and application of manure can be done with the farmer's own machinery or can be contracted out. Investment in land, housing capacity and basic machinery are not optional, therefore these costs are calculated separately from the LP model. For a more detailed description of the model see Berentsen & Giesen (1995).

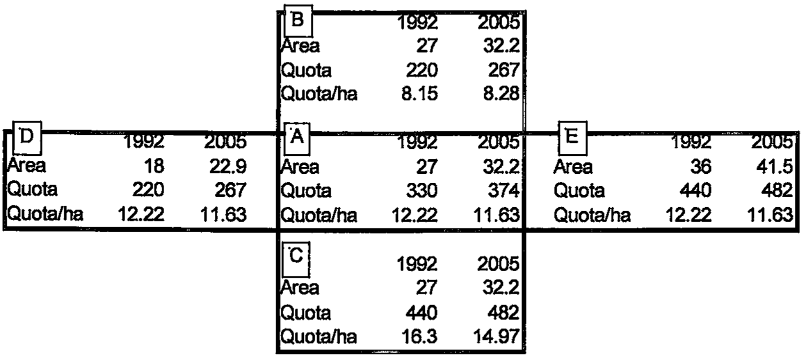
### 6.3.2 Organization of the analysis

The average area of specialized dairy farms on sandy soil in 1992 was about 27 ha and the average quota was about 330.000 kg. The capacity of the stable is calculated from the numbers of animals on the farm and it appears to be capacity for 55 dairy cows plus young stock (Berentsen et al., 1996b). On the average farm, 166 $m^3$ of pig manure is used besides manure produced by the own cattle. Growth of area and milk quota according to the scenarios suggests an area of 32.2 ha in 2005 and a milk quota of about 374,000 kg. The first step of the analysis concerns optimization of this farm for the situations of 1992 and those of 2005 according to the four scenarios. This step includes a detailed comparison of the technical, economic and environmental results.

Next, intensity (by a change of milk quota) and scale (by a change of milk quota and of area) are varied to asses the effects of intensity and scale on economic and environmental results. Intensity and scale are varied separately in order to examine their distinct impact on results.

Figure 6.2 gives an overview of the area, quota and intensity for 1992 and 2005 of the basis farm (indicated as farm A) and all alternative situations. The horizontal dimension in this figure is the scale, expressed in hectares and milk quota. The vertical dimension is the intensity, expressed in quota/ha. To ease interpretation of the results, differences in intensity and scale are chosen such that farm B and D on the one hand and farm C and E on the other hand have the same total quota. Comparison of farm B with D and of farm C with E shows the effects of intensity because of different areas. The quota for 2005 used in Figure 6.2 represents the price support policy (scenario I and II). For the two-price system (scenario III and IV) the quota is 15% lower. The intensity of farming for these scenarios results from the calculations.

Sensitivity analysis is carried out for the average farm, with special attention to the increase of grass production. In Berentsen et al. (1996a), it is noted that the increase of grass production, especially at low levels of N supply, is hard to forecast. The general shape of the grass production curve shows a decreasing marginal production at increasing N supply which means that grass production per kg N supply is higher at low levels of N supply. A consequence could be that the possibilities to increase grass production at low N supply are relatively smaller than at high N supply. To examine the consequences of such an assumption, calculations are made with energy production from grass at an N supply of 500, 400, 300, 200 and 100 kg/ha that is based on a yearly increase that amounts to 100, 85, 70, 55 and 40% of the initial increase respectively.



| B | 1992 | 2005 |
|---|---|---|
| Area | 27 | 32.2 |
| Quota | 220 | 267 |
| Quota/ha | 8.15 | 8.28 |

| D | 1992 | 2005 |
|---|---|---|
| Area | 18 | 22.9 |
| Quota | 220 | 267 |
| Quota/ha | 12.22 | 11.63 |

| A | 1992 | 2005 |
|---|---|---|
| Area | 27 | 32.2 |
| Quota | 330 | 374 |
| Quota/ha | 12.22 | 11.63 |

| E | 1992 | 2005 |
|---|---|---|
| Area | 36 | 41.5 |
| Quota | 440 | 482 |
| Quota/ha | 12.22 | 11.63 |

| C | 1992 | 2005 |
|---|---|---|
| Area | 27 | 32.2 |
| Quota | 440 | 482 |
| Quota/ha | 16.3 | 14.97 |

Figure 6.2. Area (ha), quota (x1000 kg) and intensity (1000 kg/ha) for 1992 and 2005 of the average specialized dairy farm(A) and four alternative farming situations

## 6.4 Results

### 6.4.1 The average farm

Table 6.4, 6.5 and 6.6 show the technical, the economic and the environmental results. The optimized situation for 1992 is the basis on which the situations resulting from the scenarios are compared.

In the basis situation, the available milk quota and the milk production per cow result in 49.4 dairy cows (Table 6.4). The number of young stock is restricted by the available grass. As the total area is used for grassland, producing additional grass to raise more young stock can only be realized by using a higher N level. This appears to be economically unattractive. To meet the feeding requirements, silage maize and concentrates are purchased. The farm plan results in a labour income of NLG 70,834 (Table 6.5). Table 6.6 shows the balances of N and $P_2O_5$ at the farm level. Input of nutrients takes place by purchase of concentrates, roughage and fertilizer, by the use of animal manure from farms with pigs (which is common practice on sandy soil in the Netherlands). Output takes place through milk and meat. Harmful N losses consist of $NH_3$ emission and of N leaching. $NH_3$ emission is expressed in kg $NH_3$/ha to make the value comparable with the standards for 2005.

In 2005, the total area and the milk production per cow have increased. Under scenario I and II, the milk quota has also increased. From Table 6.6 it appears that all nutrient losses under scenario I are lower than the acceptable losses, meaning that the moderate environmental policy has no impact on the farm plan under scenario I. The increase in milk production per cow and the increased milk quota results in 44.3 dairy cows (Table 6.4). The number of young stock is maximal given the number of female calves that are born per year. The lower number of cattle and the higher production per hectare of grassland results in a lower area of grassland (23.9 ha) and a lower N level on grassland (200 kg/ha). The rest of the area is used for growing silage maize, part of which is sold. Since higher producing cows need more concentrates, purchase of concentrates increases. Total revenues increase because of higher milk production, silage maize sales, and the EU compensatory payment for silage maize (Table 6.5). The feed costs are lower because of lower prices and because no silage maize is purchased. The other variable costs are higher as a result of the larger total area and the larger area of silage maize. The costs of contract work of a hectare of silage maize are much higher than of a hectare of grassland which is mainly

Table 6.4. Technical results of the average specialized dairy farm on sandy soil for 1992 and for 2005 using four scenarios.

| | 1992 | 2005 | | | |
|---|---|---|---|---|---|
| | | Price support policy | | Two price system | |
| | Basis | Mod. env. policy | Sev. env. policy | Mod. env. policy | Sev. env. policy |
| Milk quota (1000 kg) | 330 | 374 | 374 | 318 | 318 |
| Milk production above quota (1000 kg) | - | - | - | 150 | 66 |
| Cattle: | | | | | |
| - dairy cows | 49.4 | 44.3 | 44.3 | 55.4 | 45.5 |
| - young stock | 46.9 | 45.8 | 35.4 | 44.3 | 36.3 |
| Land use: | | | | | |
| - total area (ha) | 27 | 32.2 | 32.2 | 32.2 | 32.2 |
| - grassland (ha) | 27 | 23.9 | 24.8 | 28.1 | 25.7 |
| - N level grassland (kg/ha) | 320 | 200 | 157 | 200 | 153 |
| - silage maize for on farm use (ha) | - | 6.9 | 6.4 | 4.1 | 6.5 |
| - silage maize for sale (ha) | - | 1.4 | 1.1 | - | - |
| Feed purchased: | | | | | |
| - silage maize (ha) | 8.0 | - | - | 3.9 | - |
| - concentrates (1000 kg) | 70.1 | 92.3 | 92.1 | 114.6 | 94.7 |

grazed. Costs of land and buildings increase because of the larger area and because of the obligation to close the manure storage. The growth of the milk quota is realized by purchase of quota, which increases the cost. Changes in revenues and costs result in a labour income that is some 25% higher than in 1992. The input of N per hectare has decreased considerably because of the absence of roughage purchased and a lower overall fertilization level (Table 6.6). N output increases particularly because of silage maize that is sold. The net result is a tremendous decrease in N losses of 184 kg/ha. The lower number of cattle, coverage of manure storage and the larger area lead to a decrease in $NH_3$ emission of 29 kg $NH_3$/ha. N leaching is decreased by 20 kg/ha due to lower N use on grassland. $P_2O_5$ input is decreased mainly because no roughage is purchased. The lower $P_2O_5$ output through culled cows is compensated by higher output through silage maize sold.

Table 6.5. Economic results (NLG) of the average specialized dairy farm on sandy soil for 1992 and for 2005 using four scenarios.

| | 1992 | 2005 | | | |
|---|---|---|---|---|---|
| | | Price support policy | | Two price system | |
| | Basis | Mod. env. policy | Sev. env. policy | Mod. env. policy | Sev. env. policy |
| Revenues: | | | | | |
| - milk | 260,812 | 293,682 | 293,682 | 309,852 | 276,139 |
| - cattle sold | 41,610 | 34,118 | 25,691 | 32,150 | 26,373 |
| - silage maize sold | | 2320 | 1856 | | |
| - EU compensation silage maize | | 5024 | 4510 | 2484 | 3947 |
| total | 302,422 | 335,144 | 325,740 | 344,485 | 306,458 |
| Costs: | | | | | |
| - feed purchased | 55,232 | 32,117 | 31,269 | 51,104 | 32,137 |
| - fertilizer | 6206 | 3322 | 2195 | 2566 | 1890 |
| - other variable costs | 46,304 | 61,106 | 56,783 | 60,036 | 56,877 |
| - land and buildings | 55,269 | 63,203 | 74,041 | 63,203 | 74,041 |
| - quota purchased | 19,770 | 37,970 | 37,970 | 37,970 | 37,970 |
| - other fixed costs | 48,807 | 48,807 | 48,807 | 48,807 | 48,807 |
| - levy | | | 248 | 1163 | 1282 |
| total | 231,588 | 246,525 | 251,313 | 264,849 | 253,004 |
| Labour income | 70,834 | 88,619 | 74,427 | 79,636 | 53,454 |

A comparison of the acceptable losses with the realized losses in Table 6.6 shows that the farm plan under scenario II is governed by the acceptable $NH_3$ emission. Total N losses are much lower than the acceptable losses, while $P_2O_5$ losses are slightly higher than the acceptable losses. Table 6.4 shows that the number of young stock is minimal given the replacement rate. The N level on grassland is decreased to a level that makes it possible to meet the acceptable $NH_3$ emission while still producing enough grass. To reduce $NH_3$ emission, part of the concentrates consists of dried beet pulp, which has a low protein content. Compared to scenario I, the revenues are lower because of the lower number of young stock and because less silage maize is sold (Table 6.5). The lower N level on grassland leads to lower fertilizer costs. The other variable costs are lower than under scenario I because of the lower number of young stock and the smaller area of silage maize. The levy on $NH_3$ emission requires investment in adaptation of the stable to

Table 6.6. Environmental results of the average specialized dairy farm on sandy soil for 1992 and for 2005 using four scenarios. Between brackets the acceptable losses.

| | 1992 | 2005 | | | |
|---|---|---|---|---|---|
| | | Price support policy | | Two price system | |
| | Basis | Mod. env. policy | Sev. env. policy | Mod. env. policy | Sev. env. policy |
| Nitrogen[1] (kg N/ha): | | | | | |
| - input | 436 | 255 | 223 | 286 | 220 |
| - output | 80 | 83 | 79 | 90 | 74 |
| - losses | 356 | 172 (328) | 144 (233) | 196 (328) | 146 (233) |
| - of which $NH_3$ emission (kg $NH_3$/ha) | 65 | 36 (40) | 25 (25) | 41 (40) | 26 (25) |
| - of which N leaching (kg N/ha) | 55 | 35 | 28 | 33 | 26 |
| Phosphate (kg $P_2O_5$/ha): | | | | | |
| - input | 72 | 63 | 54 | 61 | 52 |
| - output | 35 | 35 | 33 | 38 | 31 |
| - losses | 36 | 29 (35) | 21 (20) | 23 (35) | 21 (20) |

[1] Included in this table is N input through deposition which amounts 53 kg/ha for N. Consequently, acceptable N losses are 53 kg/ha higher than in Table 6.2.

decrease emission. This raises the costs of land and buildings. Summarizing, labour income returns to a level only slightly higher than in the basis situation, which means that replacement of the moderate by the severe environmental policy costs the farm about NLG 14,000. Compared to scenario I, the input of N has decreased because of lower fertilizer input (Table 6.6). N output has decreased, mainly as a result of selling less silage maize. Consequently, total N losses are 28 kg/ha lower than under scenario I. This decrease to far below the acceptable level is caused by the $NH_3$ emission policy. A low N level on grassland, for example, results in a relatively low N content of grass, a low N content of manure and as a result in lower $NH_3$ emission and lower N leaching. $P_2O_5$ input decreases mainly because of the use of dried beet pulp, which has a low $P_2O_5$ content. The output of $P_2O_5$ decreases because of the smaller amount of silage maize that is sold.

Under scenario III, the milk quota is decreased by 15%, but milk production at a price of NLG 40 per 100 kg is not restricted. Total production is limited by the available stable places. Building extra places is not an option in the model. The shadow price of stall places, which amounts NLG 340, indicates that building extra places would not be economically attractive. Under scenario III, milk production at the low price is beneficially. All the available places are filled with dairy cows while the number of young stock is minimized (Table 6.4). In this situation, total milk production is raised to 468,000 kg, some 25% higher than under scenario I and II. The moderate environmental policy allows grass production at an N level of 200 kg/ha. The higher number of animals requires extra purchase of silage maize and concentrates. In spite of the 25% increase in milk production, total revenues are only 3% higher than under scenario I (Table 6.5). This is caused by the lower quota with the guaranteed price and by the lower price for unrestricted production. The higher number of animals than under scenario I leads to higher costs of feed purchased. Comparing labour income under scenario III and I, it appears that at the moderate environmental policy, the replacement of the price policy system by the two-price system leads to a decrease in income of about NLG 9,000. The higher intensity of the farm leads to a higher N input than under scenario I, mainly through more purchased feed (Table 6.6). N output is higher than under scenario I because more milk is produced and more cows are culled. N losses are higher than under scenario I, but still far below the acceptable losses. Since $NH_3$ emission is strongly related to the numbers of animals, it is higher than under scenario I and notably above the acceptable level of 40 kg/ha, so levy has to be paid. N leaching is lower than under scenario I due to the lower area of silage maize. Compared to grassland fertilized at a moderate N level, silage maize causes more N leaching. This is the result of the absence of a crop on maize land in the winter period when organic N that mineralizes is subject to leaching. $P_2O_5$ input is lower than under scenario I because the area of grassland is higher and grass fertilized at a low level requires less $P_2O_5$ than silage maize. The output is in line with the production of milk and meat. Consequently the losses are lower than under scenario I and far below the acceptable level.

Scenario IV combines the two-price system with the severe environmental policy. Given a minimal number of young stock and an investment in stable adaptation to decrease $NH_3$ emission, the number of dairy cows and the N level on grassland are adjusted such that protein requirements for the stable period (both OEB and DVE) are exactly fulfilled, while $NH_3$ emission above the acceptable level is minimized. The result is a total milk production that is only slightly higher than under scenario I and II (Table 6.4). To satisfy the feeding requirements, only concentrates have to be purchased. The low price for part of the milk production results in total revenues that are about 6% lower than under scenario II (Table 6.5), the scenario which is comparable as far as environmental policy is concerned. At the severe environmental policy, the two-price system results in a reduction in labour income by some NLG 20,000 compared to scenario II. Input, output and losses of nutrients are practically identical with those under scenario II (Table 6.6).

In summary, comparison of the results of scenario I with the basis situation shows that assumed technical change contributes substantially to a higher income and to lower - environmental losses. Hence, the moderate environmental policy has no influence on the results. Introduction of the severe environmental policy almost completely offsets the income increase caused by technical change. The combination of moderate environmental policy and the two-price system leads to a considerable increase in total milk production, but only to a moderate increase in income because of the lower milk price. Scenario IV, the combination of the severe environmental policy and the two-price system, is a worst case scenario as far as labour income is concerned.

### 6.4.2 Differences in intensity because of different milk quota (farm B and C)

In the basis situation the extensive farm (B) has a lower number of dairy cattle (which follows from the lower quota), a lower N level on grassland, a smaller area used for grassland, it sells roughage in stead of purchasing, and it purchases a lower amount of concentrates compared to the average farm (A). Consequently, labour income is lower. The opposite holds for the intensive farm (Figure 6.3).

Going from the basis situation to the situation under scenario I, all farms react in nearly the same way. Numbers of dairy cattle are decreased and the N level on grassland is decreased. The area of grassland is decreased, except for the intensive farm that has a shortage of grassland in the basis situation. Comparison of the labour income under scenario I with that in the basis situation indicates that the increase of labour income is strongly related to the labour income in the basis situation (Figure 6.3). Obviously, production possibilities for the future follow from present production. The environmental results show that only the intensive farm has a $NH_3$ emission that is slightly higher than acceptable. The resulting levy levels out the income differences to some extent. The $P_2O_5$ losses of the intensive farm are lower then of the other farms because of the partial replacement of concentrates with a high $P_2O_5$ content by dried beet pulp with a lower $P_2O_5$ content. Dried beet pulp, which has also low protein content, is used to decrease $NH_3$ emission.

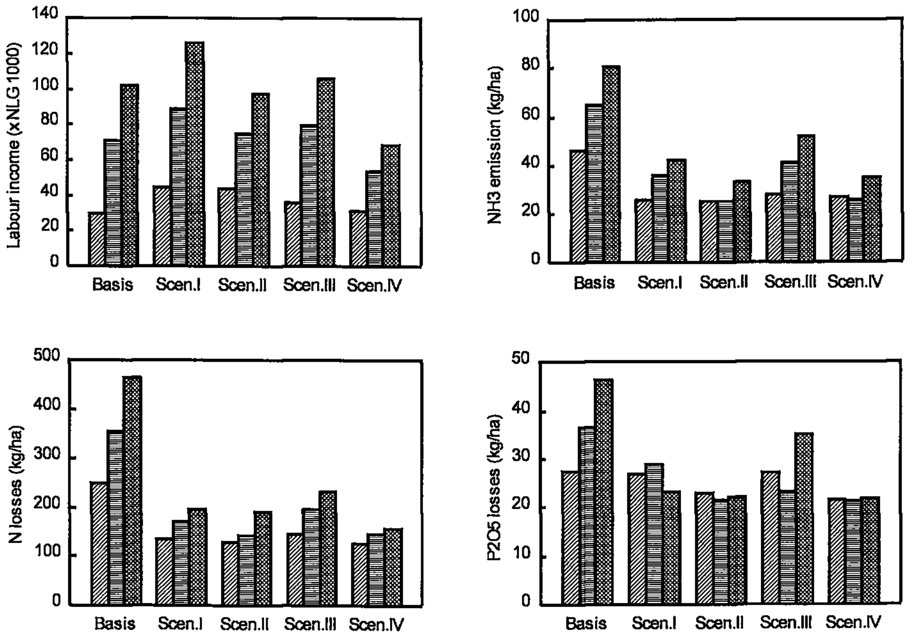


Figure 6.3. Labour income and nutrient losses for the extensive (▨), the average (▤) and the intensive (▩) farm in the basis situation and under four scenarios.

When the severe environmental policy is introduced (scenario II), the differences in intensity lead to sharply different results. The extensive farm can meet the acceptable losses with only some decrease in the N level on grassland and small changes in the feed ration. Consequently, income remains almost the same as under scenario I. The average and the intensive farm also have to invest in adaptation of the stable to decrease $NH_3$ emission. For the intensive farm, unacceptable $NH_3$ emission remains and a substantial levy has to be paid. The result is a fall of the income to a level lower than that in the basis situation.

Under scenario III, which combines the two-price policy with moderate environmental policy, all farms produce the maximum amount of milk given the available cow places in the stable. This results in a total milk production of 312,000 kg for the extensive farm and 614,000 kg for the intensive farm. The result is a labour income of about the same level as in the basis situation. For the average and the intensive farm, the levy for exceeding the acceptable $NH_3$

emission, which is a consequence of the high number of animals, levels out the income differences to some extent. The levy paid is not high enough to require adaptation of the stable.

The combination of the severe environmental policy and the two-price policy results in a total milk production on the intensive farm of 409,000 kg, which is the amount that has a guaranteed price. The extensive farm is less hindered by environmental legislation and produces the same total milk production as under scenario III. The extensive farm has to make some changes in the farm plan and in the rations to meet the acceptable level of $P_2O_5$ losses. This results in a small decrease in income compared to scenario III. For the intensive farm, the decrease of returns and the substantial levy on $NH_3$ emission decreases income to almost half of the income under the favourable scenario I.

### 6.4.3 Differences in scale (farm D and E)

Farm D and E in Figure 6.2 have the same intensity as farm A, but they differ in scale. Having the same intensity means that not only the market and price policy, but also the environmental policy leads in a relative sense to exactly the same results for all three farms. This could be expected as far as the use of variable production factors is concerned. However, this holds also for the use of fixed production factors, showing that the differences in economies of scale between the farms are not big enough to justify differences in investments. Consequently, a more detailed comparison of the results of the small and the large farm with the average farm adds nothing to the results that were presented in section 6.4.1.

### 6.4.4 Differences in intensity because of different areas

Comparison of the extensive farm (B) with the small farm (D) and of the intensive farm (C) with the large farm (E) shows effects of intensity because of differences in area, at a lower and a higher intensity level. Here, the focus is on income. Comparison of environmental results would be a repetition of the comparison of the farms A, B, and C, since environmental results are presented on a hectare basis.

The extensive and the small farm have the same quota, but the area of the small farm is only two-thirds of that of the extensive farm. In spite of the extra area of the extensive farm, the labour income of both farms in the basis situation is almost the same (Figure 6.4). This means that the returns of the extra area are completely cancelled by the costs. The extra area of the extensive farm is used for keeping extra young stock, for producing grass at a lower N level and for producing and selling a small area of silage maize. Under scenario I and scenario III, in which the environmental policy has little influence, the extra area of the extensive farm leads to an income lower than that of the small farm. This is due to technical change that decreases the need for land to produce roughage for own use. The extensive farm has an advantage when the farms are confronted with the severe environmental policy. Labour incomes differ by NLG 8,000 to 11,000 under scenario II and IV respectively.

The intensive and the large farm have the same quota, but the area of the intensive farm is only three-quarters that of the large farm in the basis situation. The extra area of the large farm is used for keeping more young stock, for growing grass at a lower N level and for producing silage maize which decreases the amount of silage maize that has to be purchased. This results in a labour income that is about NLG 10,000 higher than the labour income on the intensive farm. The difference in labour income decreases slightly under scenario I, but it increases under the scenarios II to IV. Under scenario IV it nearly reaches NLG 19,000.

Comparing these results, it appears that in an intensive situation (farm C) an increase of the area leads to higher income while no increase of income is realized when the area is increased in a less intensive situation (D). Mainly responsible for this difference is the shortage of grass in the summer ration of the dairy cows in the intensive situation. To minimize this shortage, grass is grown at a high N level while roughage and concentrates are purchased to make up the ration.

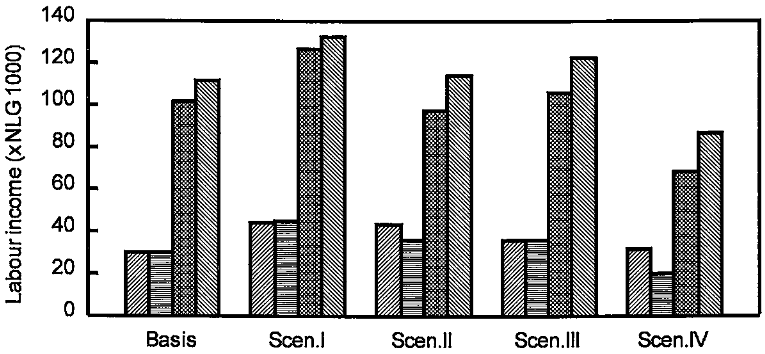


Figure 6.4. Labour income for the extensive (▨), the small (▤), the intensive (▩) and the large (▧) farm in the basis situation and under four scenarios.

All of these are expensive measures. Apparently, there exists an optimal farming intensity given an available milk quota beyond which further extensification has no positive effect on farm income. Shadow prices of land indicate that this intensity lies between the intensity of farm D and that of farm B. Technical change tends to increase this optimal intensity while severe environmental legislation tends to decrease it.

### 6.4.5 Sensitivity analysis

Here it is assumed that the increase in grass production at an N-supply of 500, 400, 300, 200 and 100 kg/ha is 100, 85, 70, 55 and 40% respectively of the yearly used in the previous situations. Table 6.7 shows some of the differences for the average farm. Under scenario I, lower grass production is for the most part compensated by an area of grassland that is 1.9 ha larger. Instead of selling 1.4 ha of silage maize, now 0.6 ha has to be purchased, which makes a total difference of 2.0 ha. Labour income is NLG 2,253 lower. Of the environmental losses, only N losses are substantially higher, which is the case for all scenarios. N leaching differs with the area of silage maize and the N level on grassland. All other differences are small. Under scenario II, lower grass production is compensated for by a higher N level on grassland and by a larger area of grassland. Due particularly to the higher N level, $NH_3$ emission is higher and levies have to be paid. As a consequence, labour income is NLG 2,677 lower. The greatest difference in labour income arises when total milk production is raised to a high level (i.e. under scenario III). In that case, lower production of grass is compensated fully by higher roughage purchases. Under scenario IV, the difference in labour income is NLG 3,325. To balance feed requirements and feed supply, the number of dairy cows is 1.7 lower, the area of grassland is slightly larger and the N level on grassland is higher.

From these results, it can be concluded that differences in income are bigger when pressure from environmental legislation is higher (scenario II) or when production becomes more intensive (scenario III). Hence, intensive farms loose more than extensive farms when technical change is lower than expected.

Table 6.7. Differences in results for the average farm due to a lower increase in grass production.

| | 2005 | | | |
|---|---|---|---|---|
| | Price support policy | | Two price system | |
| | Mod. env. policy | Sev. env. policy | Mod. env. policy | Sev. env. policy |
| Technical results: | | | | |
| - area of grassland (ha) | +1.9 | + 1.2 | + 2.3 | + 0.4 |
| - N level on grassland (kg/ha) | 0 | +15 | 0 | +14 |
| - area of silage maize purchased (sold)[1] | + 2.0 | + 1.1 | +2.1 | 0 |
| Labour income (NLG) | - 2253 | - 2677 | - 3388 | - 3325 |
| Environmental results: | | | | |
| - N losses (kg N/ha) | + 15.2 | + 20.8 | + 17.7 | + 16.4 |
| - $NH_3$ emission (kg $NH_3$/ha) | 0 | + 0.4 | - 0.2 | - 0.6 |
| - N leaching (kg N/ha) | - 1.6 | + 0.6 | - 2.4 | + 1.3 |
| - $P_2O_5$ losses (kg $P_2O_5$/ha) | - 0.9 | - 1.0 | + 4.8 | - 1.0 |

[1] A positive value means that more silage maize is purchased or that less silage maize is sold

## 6.5 Discussion

### 6.5.1 Assumptions

The analysis is conducted using 1992 base prices and assuming all prices will not be affected by inflation. An overview of the prices of the last fifteen years for the main output (i.e. milk) and for the main inputs (i.e. concentrates and fertilizer) shows that existing inflation did not structurally affect these prices (Anonymous, 1995b). The assumption that also in the future prices will not be affected by inflation means that calculated labour income for 2005 can be considered nominal income. When comparing income for 1992 and 2005 the effect of inflation should be kept in mind. Any inflation in the period 1992-2005 leads to a lower real value of the calculated labour incomes for 2005.

Technical change as it is used in the scenarios includes increase of production without quality changes. Especially in roughage production, quality changes are hard to asses. In roughage production quality is defined by the amount of energy per kg dry matter. If dry matter intake capacity of the dairy cow is limiting dry matter intake from roughage, then increase of quality results in a higher proportion of roughage in the ration and consequently in lower concentrate costs. However, from the results it appears that dry matter intake capacity only has a small influence on the summer rations. Quality of milk is defined by the fat and protein content of milk. With a milk quota that is partly based on fat content of the milk and with a price for milk based on fat and protein content it is attractive to decrease the fat/protein ratio in the milk. An increase of the protein content of milk at a given fat content results in a higher milk price and in higher feeding costs. On balance, labour income will increase. However, the room for such a change is small, as fat and protein content of milk are positively correlated (Wilmink, 1987).

From a comparison of the results under the different scenarios with those in the basis situation it appears that in general the average fertilizing level per hectare decreases. This lower fertilizer use per hectare results in a substantial decrease in demand of fertilizer at national level. Given normal market reactions, this could lead to a decrease in the price of fertilizer, which would have a positive effect on labour income of all farms. However, since fertilizer is a commodity that has a relatively open market and considering the small Dutch share in total demand for fertilizer (Heijbroek & De Kater, 1993), the price reductions due to a decreased Dutch demand for fertilizer will be small. Furthermore, it appears that purchase of concentrates per farm increases. At the national level, the increase in the amount of concentrates purchased at the farm level is partly compensated by the lower number of dairy farms. Nevertheless, higher milk production per cow requires a higher proportion of concentrates in the ration. With a given national milk quota, this leads to higher use of concentrates in dairy farming at the national level. It is possible that this will lead to higher prices of concentrates. In the eighties, a substantial reduction in the use of concentrates caused by introduction of the quota system led to a fall in prices of concentrates. Higher prices of concentrates obviously have a negative effect on farm income. This effect will be bigger under scenario III if total milk production is raised to a high level and it will be higher on intensive and larger farms that rely more on the use of concentrates. Finally, it appears that on an intensive farm purchase of roughage decreases while on an extensive farm, that has little opportunities to utilize its surplus area, supply of roughage increases. It can be expected that this will have a price depressing influence. However, this influence could very well be tempered by arable farmers that exchange production of silage maize for production of grains. For intensive farms, a lower price for roughage means an increase in labour income while for extensive farms it decreases labour income. Taken together, intensive farms can compensate a higher price for concentrates by a lower price for roughage purchased. The negative consequences for extensive farms could be eased by growing crops that have the same fodder characteristics as concentrates. However, the costs of these concentrate-replacing crops must not be too high. Fodder beet, for example, which has feeding characteristics similar to concentrates is not taken up in the farm plan because of the high costs of harvesting.

The price of milk is a main determinant of the revenues and consequently of the labour income of the farm. In addition to the EU price support, the milk price depends on a number of uncertain factors like the US dollar exchange rate, demand and supply of milk and milk products on the EU market and the world market price. The price used in the scenarios (NLG 78.50 per 100 kg) is based on the 1992/93 price. Since 1992/93, the price has declined. For the results, a decrease of the high milk price by NLG 1 per 100 kg would mean a decrease of income by NLG 2270 for the extensive and the small farm under scenario III and IV, up to a decrease of NLG 4820 for the intensive and the large farm under scenario I and II. For the average farm a price decrease of NLG 4.70 would completely offset the positive income effects due to technical change. In all these cases the milk price does not influence the optimal plan of the farm, as producing milk is by far the most profitable production possibility of the farm.

The replacement rate of dairy cows in the model is based on the actual average replacement rate in 1992 of 36% (Berentsen et al., 1996b). This rate is used for 2005 also because it is assumed that the yearly increase in milk production is partly caused by this high replacement rate. Decreasing the amount of young stock on the farm is often advocated as a means to decrease nutrient losses (Aarts et al., 1992). Under a severe environmental policy and for intensive farms, a decrease in the number of young stock without a decrease in milk production per cow would have a positive influence on labour income, on nutrient losses in general, and on $NH_3$ emission in particular. When using the two-price system a decrease in the replacement rate would be beneficial for all farms, since a greater part of the stable capacity can be used for dairy cows and total milk production can be raised to a higher level.

### 6.5.2 Results

The results show that dairy farms can at least maintain their income at the level of 1992 under most of the scenarios. The only exception counts for more intensive farms in case of the scenario that combines the severe environmental policy with liberalization of milk production.

Comparison of the consequences of the complete scenarios with the results of the scenario studies that were mentioned in the introduction shows that in all studies technical change has an increasing effect on income whereas environmental legislation has a decreasing effect on income.

Concerning the aspect of intensity, comparison with the findings of other studies is possible. From the results of this study it appears that income differences between intensive and extensive farms tend to increase as a result of technical change. However, environmental policy and liberalization of milk production have a stronger decreasing effect on income differences. As far as environmental policy is concerned this is in line with findings of Van de Ven (1996). Based on model calculations she reports a decrease in the optimal animal density in dairy farming as a consequence of the introduction of environmental legislation. This means that in terms of income, intensive farms suffer more from environmental legislation than extensive farms. That the stronger position of intensive dairy farms decreases in case milk production is liberalized is also reported by Oskam (1996). He concludes that, although the initial situation for extensive dairy farms is weaker than for intensive farms as far as income is concerned, the perspectives for extensive farms get closer to the perspectives for intensive farms when the quota system is relaxed.

## 6.6 Conclusion

Technical change up to 2005 has a positive influence on labour income as well as on nutrient losses. The increase of labour income is higher for farms with a higher total milk production in the basis situation. A severe environmental policy has a negative effect on labour income. This effect is bigger for farms with a higher intensity, as these farms have to take more measures to comply with governmental policy. Replacement of the price support policy for milk by a two-price system with a high price for a restricted amount of milk and a low price for an unrestricted amount of milk has negative consequences for labour income. Also in this case intensive farms loose more income than extensive farms.

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# 7. Introduction of seasonal and spatial elements in grass production and grassland use in a dairy farm model[1]

## Abstract

*The research presented in this paper is part of a project focused on modelling the relation between management practices and nitrate leaching on a dairy farm. Nitrate leaching on a dairy farm is closely linked with grass production and grassland use which includes fertilization. The starting point in this paper is a linear programming model of a dairy farm in which grass production and grassland use is modelled using one growing period and one lot. This means that the model does not allow for seasonal and spatial variation. To include seasonal and spatial elements, the model was extended first to three periods in the growing season and then to two lots. The resulting three models were used to make calculations for an average dairy farm in a situation without and with proposed environmental policy. From the results it can be concluded that the inclusion of seasonal and spatial elements increases the insight in the use of grassland during the growing season. Seasonal specification does not have a great influence on farm plan, income, and nutrient surpluses. The impact of spatial specification, however, with the restriction that one of the two lots cannot be grazed by dairy cattle is greater.*

## 7.1 Introduction

The starting point in this paper is a linear programming model of a dairy farm that has been developed to analyse possible effects of changing circumstances on Dutch dairy farms (Berentsen & Giesen, 1995). Now, the focus is on nitrate leaching as a particular consequence of dairy farming. Nitrate leaching on a dairy farm occurs while growing forage, therefor detailed modelling of forage production is important. This particularly applies to grass

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[1] Paper by P.B.M. Berentsen, G.W.J. Giesen and J.A. Renkema; submitted to Grass and Forage Science

production, as the options to use grassland are much more numerous than that of a feed crop like silage maize. Two important aspects that were ignored in the basis model were seasonal and spatial variation in grass production and grassland use. Seasonal variation includes: (1) differences in the growing capacity of grass during the growing season; and (2) variation in fertilization and the use of the grass for grazing and mowing during the growing season. Spatial variation includes the use of more lots and restricting the use of a particular lot. An example of the latter is the existence of a field lot that is too far away from the cowshed to be used for grazing by the dairy cows. Seasonal and spatial elements allow a more accurate representation of grass production and grassland use, and a better understanding of the relation between management practices and nitrate leaching.

Much work has been done in modelling grass production and grassland use (e.g. Sheehy *et al*, 1996; Overman *et al*, 1994; Van de Ven, 1992; Kristensen & Sorensen, 1989; Innis, 1978). Several researchers have iincluded some kind of seasonal production pattern in their grass production models (e.g. Kanneganti *et al*, 1997; Johnson & Parsons, 1985; Smith *et al*, 1985; Torssell & Kornher, 1983; Pendleton *et al*, 1983). In the Netherlands, much modelling work including seasonal variation has been done at the Experimental Station for Cattle Production (1991).

This paper examines the impact on farm plan, revenues and costs and on nutrient surpluses of the inclusion of seasonal and spatial elements in grass production and grassland use in the dairy farm model. A description is given of the basis model and of the inclusion of seasonal and spatial variation in this model. Calculations were made using the three resulting models for different circumstances. Determination of nutrient surpluses, and of nitrogen surpluses in particular is the first step towards the determination of nitrate leaching. The relation between management practices at a given time and place and nitrate leaching, is still the missing link and the subject of field studies.

## 7.2 Method

### 7.2.1 The basis model

The basis model is a standard linear programming model. The farm is restricted by available fixed assets (e.g. land area, milk quota and cow places in the stable) and available labour. The land in the model is one lot that can be used for all land use activities. Other important input is the level of milk production per cow and of plant production per hectare. The objective function maximizes labour income (return to labour and management).

The central element in the model is a dairy cow, which is assumed to calve in February. A minimal ratio is required between the number of young stock and the number of dairy cows to guarantee replacement of dairy cows. Surplus pregnant heifers can be sold. The feeding part of the model is split up into four parts. The dairy cows and the young stock are fed separately, and a division is made between summer, when cows and young stock can graze, and winter. For dairy cows, feeding constraints concern the demand and supply of energy and protein, the dry matter intake capacity, and the demand for structure in the ration. Milk production, energy requirements and feed intake capacity in the summer and winter period are determined using formulas of Groen (1988). Protein requirements are calculated using formulas of the Central Bureau for Livestock Feeding (1995). Because dietary requirements of young stock are usually less complicated, constraints only pertain to energy and protein. Fodder for dairy cows and young stock is the roughage produced on the farm, three types of purchased concentrates that differ in protein content, and purchased maize silage.

The land can be used in the model for growing grass, silage maize and fodder beet. Grass can be produced in the model at five different levels of nitrogen fertilization (100, 200, 300, 400 and 500 kg/ha). A maximum of two adjacent levels can be chosen in the optimization process. Gross energy production per year at each N level (Figure 7.1) is based on the Experimental Station for Cattle Production (1991) and on validation of the model for specialized Dutch dairy farms on sandy soil (Berentsen *et al.*; 1996). Grass can be used for grazing and mowing cuts for dairy cows and for young stock. A grazing cut (1700 kgdm/ha) is used for feeding in summer, while a mowing cut (3500 kgdm/ha) is used for feeding in winter. Since the summer is considered as one period there is no time dimension in grass production. This means that the model ignores differences in grass production and feeding requirements during the growing season. To force the model to mow grass, a minimum amount of grass silage in the winter ration is required.

Compared to grass production, modelling of maize and fodder beet production is easier. Above an optimal nutrient level, production dependency on nutrients is low (Aarts and Middelkoop, 1990), so only one level of nutrient supply for each crop is used. Silage maize can be grown as feed for dairy cows in winter and in summer, and for young stock in winter. Fodder beet can only be fed to dairy cows in winter.

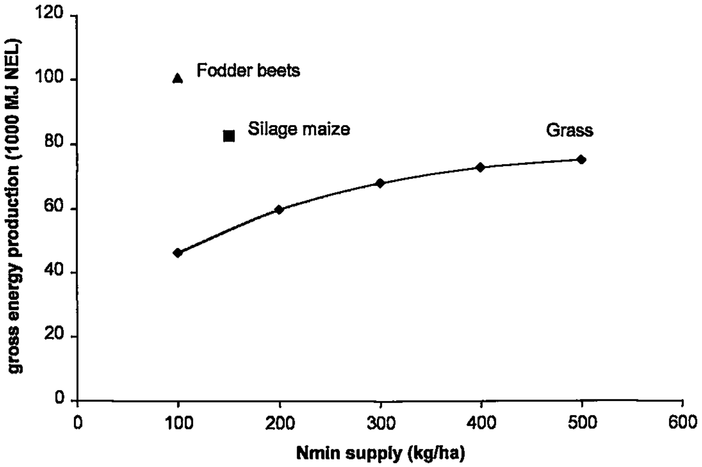

Figure 7.1 Gross energy production from grass, silage maize and fodder beets

Nutrients for plant production can be supplied by fertilizer and by manure, part of which can come from other farms. This is usual in the Netherlands, where pig and poultry producers generally have a small area of land, and consequently a manure surplus. They supply manure for free to surrounding dairy farms. In the model this amount is set at a maximum that equals the perceived average amount in 1992/93. The model contains nutrient balances for N, $P_2O_5$ and $K_2O$ at farm, herd and soil level that record nutrient input and output and consequently nutrient surpluses. $NH_3$ emission is assessed separately and is affected by type of housing, type of manure storage and application and by extent of grazing.

In the model, labour is supplied by the farmer and the family. Activities such as mowing and ensiling of grass and application of manure can be done with the farmers own machinery or can be contracted out. Investments in land, housing capacity and basic machinery are considered to be basic for every dairy farm. Therefore these fixed costs are calculated separately from the LP model. For a more detailed description of the model see Berentsen and Giesen (1995).

### 7.2.2 Inclusion of seasonal and spatial elements

To include seasonal elements in the model, the summer period is divided into three periods: May-June, July-August, and September-October. Consequently, milk production, feeding requirements and grass production are assessed per period. Milk production and feeding requirements per period can easily be calculated according to Groen (1988) and the Central Bureau for Livestock Feeding (1995).

Potential grass production per hectare is given by the number of growing days per period. Each time grass is cut by either grazing or mowing cut it will require a particular number of growing days depending on: (1) the use for grazing (at 1700 kgdm/ha) or for mowing (at 3000 kgdm/ha); (2) the N level of the particular cut (10, 30, 50, 70, 90, or 110 kg N/ha); and (3) the period in which cutting takes place. The number of days per cut and the number of days per period result in the number of cuts per period (Figure 7.2). Cutting at higher levels of N supply in the first and second period results in part of the N supplied being available for the following cut. Obviously the effect will be higher after a grazing cut, where a lower amount of N is taken up by the grass. In the model this effect is taken into account by transferring part of the N supply for a particular cut to the following periods (Table 7.1). For example, a gift of 90 kg N for a grazing cut in the first period results in 30 kg available N in

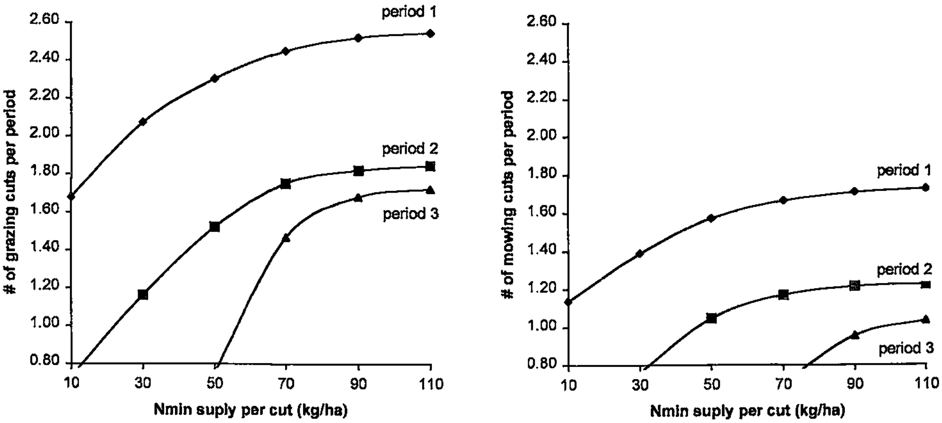

Figure 7.2 Number of grazing and mowing cuts per period in three summer periods at various levels of N supply.

Table 7.1 Effect of N supply in periods 1 and 2 on available N in periods 2 and 3

| | N supply per cut | | | | | |
|---|---|---|---|---|---|---|
| | 10 | 30 | 50 | 70 | 90 | 110 |
| Grazing cut: | | | | | | |
| • effect of N supply in period 1 on available N in period 2 | - | - | 10 | 20 | 30 | 40 |
| • effect of N supply in period 1 on available N in period 3 | - | - | 5 | 10 | 15 | 20 |
| • effect of N supply in period 2 on available N in period 3 | - | - | 10 | 20 | 30 | 40 |
| Mowing cut: | | | | | | |
| • effect of N supply in period 1 on available N in period 2 | - | - | - | 10 | 20 | 30 |
| • effect of N supply in period 1 on available N in period 3 | - | - | - | 5 | 10 | 15 |
| • effect of N supply in period 2 on available N in period 3 | - | - | - | 10 | 20 | 30 |

period 2, and 15 kg available N in period 3. The same cut in period 2 supplies 30 kg N in period 3. The required number of growing days for each cut and the N supply to subsequent periods again are based on figures from the Experimental Station for Cattle Production (1991) and validation has taken place according to Berentsen *et al.* (1996).

The spatial element is included in the model by dividing the total area of land into two lots. This makes the model more suitable to represent real situations as the land on many dairy farms in the Netherlands is spread over a number of lots. Whether or not a lot can be used for grazing of the dairy cattle is an important distinguishing aspect. Among other things, this would depend on the distance between the stable and the lot and the existence of roads that cannot be crossed by dairy cattle. The distance between the lot and the stable affects costs and labour. In the model, a farmstead lot (accessible for dairy cattle) and a field lot (not accessible for dairy cattle) are distinguished. The size of the two lots and the distance of the field lot can be adjusted in the model to make it possible to calculate for different situations.

### 7.2.3 Organization of the calculations

To show effects of the inclusion of time and space, calculations have been done with the basis model, with the model with three time periods and one lot and with the model with three time

Table 7.2 Proposed policy for 2005 concerning acceptable surpluses and levies for N and $P_2O_5$.

| | N | $P_2O_5$ |
|---|---|---|
| Acceptable surplus on grassland (kg/ha) | 200 | 25 |
| Acceptable surplus on arable land (kg/ha) | 110 | 25 |
| Levy on surpluses above acceptable (NLG/kg) | 1.50 | 5.00 |

periods and two lots. Starting point is the average specialized dairy farm on sandy soil in 1992/93 (Berentsen *et al.*, 1996). The farm is characterized by an area of 27 ha, a milk quota of 330,000 kg and a production per cow of 6682 kg per year. Calculations have been done for a situation without an environmental policy and for one with an environmental policy. The environmental policy used is the latest version of the governmental proposals for 2005 (Anonymous, 1997). It is based on mineral balances that register nutrient input and output and consequently nutrient surpluses. Table 7.2 shows the surpluses for N and $P_2O_5$ that are considered acceptable and the levies on the surpluses that exceed the acceptable level.

## 7.3 Results

### 7.3.1 Situation without an environmental policy

The technical results in the situation without an environmental policy are shown in Tables 7.3 and 7.4. The model is mainly driven by animal production. This means that land use is mainly determined by the feeding requirements of the dairy cattle. The economic and environmental consequences of the farm plan are shown in Tables 7.5 and 7.6, respectively. In all the models, the number of dairy cows is the maximum, given the milk quota and the milk production per cow. The number of beef bulls is also the maximum, given the capacity of the stable for beef bulls.

Using the basis model, the number of young stock amounts to 46.5 (Table 7.3). Most of this young stock is used for fixed yearly replacement of 36% of the dairy cows. The rest is sold as pregnant heifers. A balance is kept between the number of young stock is balanced and the availability of grass for grazing and ensiling for feeding young stock at the optimal N level. The summer ration of the dairy cows consists of grass and concentrates. It is restricted

Table 7.3 Numbers of animals and dairy cattle feeding rations from the three models without environmental policy

| | basis model | model with three time periods | model with time periods and two lots |
|---|---|---|---|
| Cattle: | | | |
| - dairy cows | 49.4 | 49.4 | 49.4 |
| - young stock | 46.5 | 48.2 | 48.2 |
| - beef bulls | 5.4 | 5.4 | 5.4 |
| | | | |
| Ration per dairy cow (kgdm/cow/day): | | | |
| - summer over all/period 1 | | | |
| • grass | 15.8 | 18.2 | 18.1 |
| • silage maize | 0 | 0 | 0 |
| • standard concentrate | 1.0 | 1.0 | 1.0 |
| • restricted by[1] | E, D | E | E |
| - summer period 2 | | | |
| • grass | - | 16.8 | 13.4 |
| • silage maize | - | 0.4 | 3.2 |
| • standard concentrate | - | 1.1 | 1.9 |
| • restricted by | - | E, D | E, D |
| - summer period 3 | | | |
| • grass | - | 11.3 | 11.3 |
| • silage maize | - | 0 | 0 |
| • standard concentrate | - | 1.1 | 1.1 |
| • restricted by | - | E, D | E, D |
| - winter period | | | |
| • silage grass | 2.0 | 2.1 | 1.9 |
| • silage maize | 6.7 | 6.6 | 6.7 |
| • protein rich concentrate | 5.9 | 5.9 | 6.0 |
| • restricted by | E, P | E, P | E, P |

[1] The ration can be restricted by energy (E), protein (P) and dry matter intake capacity (D).

by the energy requirement and by the dry matter intake capacity of the cow. To satisfy the dry matter intake capacity restriction, part of the grass for grazing is grown at an N level of 400 kg/ha resulting in a higher energy content of the grass. The winter ration consists of a

Table 7.4 Use of the land and feed purchased from the three models without environmental policy

| | basis model | model with three time periods | model with time periods and two lots | |
|---|---|---|---|---|
| | | | farmstead lot | field lot |
| Land use: | | | | |
| - grassland (ha) | 27 | 27 | 16.2 | 9.4 |
| - silage maize (ha) | 0 | 0 | 0 | 1.4 |
| | | | | |
| Grassland use: | | | | |
| - N level cuts period 1 (kg/ha) | - | 76 | 85 | 86 |
| - N level cuts period 2 (kg/ha) | - | 90 | 90 | 52 |
| - N level cuts period 3 (kg/ha) | - | 70 | 80 | 70 |
| - N gift period 1 (kg/ha) | - | 176 | 215 | 180 |
| - N gift period 2 (kg/ha) | - | 120 | 100 | 30 |
| - N gift period 3 (kg/ha) | - | 23 | 37 | 65 |
| - total N gift grassland (kg/ha) | 320 | 319 | 352 | 275 |
| - number of grazing cuts (ha) | 143.1 | 142.1 | 97.3 | 37.1 |
| - number of mowing cuts (ha) | 9.2 | 11.1 | 0 | 10.5 |
| | | | | |
| Feed purchased: | | | | |
| - silage maize (ha) | 8.7 | 8.8 | 8.2 | |
| - concentrates (1000 kg) | 75.7 | 76.1 | 79.3 | |

minimum required amount of silage grass that is grown at 400 kg N/ha, silage maize and protein rich concentrates, all of which exactly meets the energy and protein requirements. The land is used only for growing grass with an average N gift of 320 kg/ha (Table 7.4). The total number of grazing cuts and mowing cuts show that most of the grass is used for grazing. Silage maize and concentrates need to be purchased to satisfy the feeding requirements. The total revenues is derived largely from sold milk and to a lesser extent from animals sold (Table 7.5). Major farm costs constitute the costs of purchased feed and the fixed costs comprising the cost of housing and machinery. Total revenues and costs result in a labour income of the farm of NLG 72,150. The nutrient balances at farm level (Table 7.6) show input of N and $P_2O_5$ through purchased feed, fertilizer, manure supplied by other farms and deposition, output through milk and meat and consequential surpluses. When no environmental policy is involved all models use the maximum amount of manure from

Table 7.5 Economic results (NLG) from the three models without environmental policy

| | basis model | model with three time periods | model with time periods and two lots |
|---|---|---|---|
| Total revenues | 310,897 | 312,459 | 312,459 |
| | | | |
| Costs: | | | |
| - grass and maize production | 9708 | 10,707 | 14,262 |
| - feed purchased | 60,625 | 61,874 | 60,870 |
| - fertilizer | 6086 | 6205 | 6110 |
| - other variable costs | 38,533 | 38,790 | 38866 |
| - fixed costs | 123,795 | 123,795 | 123,795 |
| total | 238,747 | 241,371 | 243,903 |
| | | | |
| Labour income | 72,150 | 71,088 | 68,556 |

outside the farm. However, as the ratio of nutrients in manure does not correspond with the requirements of the crops, this leads to overfertilization of $P_2O_5$.

When using the model with three time periods, the number of young stock is increased to its maximum given the available stable capacity. In period 1 the ration of the dairy cows is restricted only by the energy requirement (Table 7.3). Concentrate is taken up at the minimal required level. Due to shortage of grass at the economically optimal N level of 90 kg/cut, the ration of dairy cows in period 2 consists partly of silage maize besides grass and concentrate. Both in periods 2 and 3 more concentrate is fed than the minimal required level. This is the result of the dry matter intake capacity that is restricting the rations. In the winter period the ration is restricted by energy and protein requirements. The uptake of silage grass in the winter ration shows that the division of grass growth in three periods automatically results in ensiling grass. Ensiling grass takes place in period 1 when enough grass is available. The availability of grass in period 1 also explains the higher number of young stock, as young stock and dairy cows do not compete for fresh grass in this period. Grass is grown at an average N level of 76 and 70 kg/cut in the first and third period respectively (Table 7.4). In the second period when there is a shortage of grass for grazing the N level rises to 90 kg/cut. Mowing of grass only takes place in period 1. The N level on mowing cuts in this period is

Table 7.6 Nutrient balances at farm level (kg/ha) from the three models without environmental policy

| | basis model | | model with three time periods | | model with time periods and two lots | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | N | $P_2O_5$ | N | $P_2O_5$ |
| Input: | | | | | | |
| - feed purchased | 149 | 53 | 152 | 54 | 149 | 53 |
| - fertilizer | 202 | 0 | 205 | 0 | 202 | 0 |
| - manure supplied | 40 | 21 | 40 | 21 | 40 | 21 |
| total | 391 | 74 | 397 | 75 | 391 | 74 |
| Output | 82 | 36 | 83 | 37 | 83 | 37 |
| Surplus | 309 | 38 | 314 | 38 | 309 | 37 |

some 30 kg higher than on grazing cuts. The protein and energy requirements in winter make it attractive to use more N as grass grown on a higher N level has a higher protein and energy content. The N gift per period is based on the N level per cut and the number of cuts. The N gift for period 2 and 3 is adjusted for the transfer of part of the N supplied in period 1 and 2 (see Table 7.1). The resulting total N gift of 319 kg/ha is almost the same as in the situation with the basis model. The number of grazing cuts and mowing cuts and the amount of feed purchased differ only slightly from the results from the basis model. The overview of revenues and costs in Table 7.5 shows that total revenues are slightly higher than in the basis model owing to the higher number of young stock. This is also the reason for the higher costs of grass production and of purchased feed. It appears taking together revenues and costs, that labour income is some NLG 1100 lower than calculated using the basis model. The nutrient balances differ only slightly from the basis model (Table 7.6). Input through feed and output are slightly higher as well as the N surplus.

Two lots are used in the third model. The farmstead lot and the field lot cover 60% and 40%, respectively, of the total farming area. The change in use follows from the fact that dairy cows can only graze on the farmstead lot. The inclusion of two lots does not affect the numbers of animals when compared to the model with only three periods (Table 7.3). As grass from the farmstead lot in period 1 is fertilized at a higher N level, resulting in higher energy and protein content, the dairy cow ration in period 1 contains a little less grass. In the second period the ration contains more silage maize and concentrate as the shortage of grass for grazing dairy cows becomes more evident. The winter ration contains a little less silage grass compensated by more silage maize and concentrates. The farmstead lot covers 16.2 ha of grassland (Table 7.4). All the grass produced on this lot is used for grazing the dairy cows. To keep the grass tasty, the residue is mown immediately after every second grazing cut. The N level per cut is adjusted to the need for grass in each period with a maximum of 90 kg in period 2. The result is a total N gift of 352 kg/ha. The field lot is split up into an area for grassland and silage maize. The area of grassland is proportionate to the amount of grass needed for grazing young stock. Given grass production per period and feeding requirements of young stock it appears that period 3 and an N level of 70 kg/cut are decisive. Mowing of grass for winter feeding mainly takes place in period 1. The higher number of mowing cuts and the lower N level of the cuts in periods 2 and 3 result in a substantially lower N gift on grassland of the field lot than on the farmstead lot. The rest of the field lot is used for producing silage maize. Total feed production on the farm is somewhat higher than in the previous model. This is mainly due to the higher energy production per hectare of silage maize. Consequently the amount of feed purchased is lower. On the other hand the costs of silage maize are relatively high, raising the costs of grass and maize production (Table 7.5). On balance, total costs increase by almost NLG 2500 compared to the previous model. As revenues remain unchanged it appears that the distinction between the two lots decreases labour income by almost NLG 2500. Production of silage maize on the farm and a higher amount of silage maize in the summer ration have a positive influence on the nutrient balances (Table 7.6). It decreases the input of nutrients through purchased feed and for N also through fertilizer. As a result surpluses of N and $P_2O_5$ are almost the same as that of the basis model. However, there are substantial differences between the lots. The nutrient surpluses for the farmstead lot and the field lot respectively are 386 kg/ha and 194 kg/ha for N and 46 kg/ha and 25 kg/ha for $P_2O_5$. The reason for these large differences is that most of the animal manure excreted in the stable is applied on the farmstead lot. Besides, during grazing more animal manure per hectare is excreted on the farmstead lot than on the field lot. The animal manure applied on the field lot is just enough to satisfy the $P_2O_5$ and $K_2O$ requirements. On the farmstead lot this results in a high N surplus as N from manure is utilized less efficiently than N from fertilizer and in overfertilization with $P_2O_5$.

Summing up, it can be said that the effects of detailing grass production during the growing season on farm plan and economic and environmental results are small. However, it increases the insight into how grassland is used during the summer period. Splitting up land use in a spatial sense has greater impact on farm plan, economic results and the nutrient surpluses per lot.

### 7.3.2 Inclusion of environmental policy

The results of the calculations for the situation with environmental policy are summarized in Tables 7.7 and 7.8. All three models produce the same numbers of dairy cows and of beef bulls as in the situation without environmental policy. The numbers of animals and the dairy cow rations can easily be understood from Table 7.3, so no extra table is used for this. A general point concerning the summer rations is the change of standard concentrate by protein poor concentrate, which decreases N input at farm level. Finally, the requirements that restrict the rations are all the same as in the previous situation.

In the basis model, environmental policy causes minimization of the number of young stock. Only young stock for replacement is kept. Except for the protein content of concentrate, the summer ration remains unchanged. The winter ration of the dairy cows changes slightly towards more concentrate due to lower energy and protein content of grass grown at a lower N level. The N gift on grassland decreases to 278 kg/ha (Table 7.7). The amounts of purchased silage maize and concentrates both decrease. This shows that the decrease in feed production due to the lower N level is less than the decrease in feed requirement due to the lower number of young stock. Labour income decreases by some NLG 3000, NLG 1000 of which is attributable to lower revenues and lower costs. The rest consists of levy on N surpluses above the acceptable level. Table 7.8 shows a substantial decrease of N input through fertilizer and manure supplied from outside the farm. As N output decreases only slightly, the N surplus falls by some 60 kg/ha. The surplus of $P_2O_5$ is slightly lower than the acceptable limit. This is achieved by decreasing the supply of P2O5 through manure from outside the farm by 67% in order to meet the $P_2O_5$ requirements of grass.

In the model with three periods the number of young stock remains at its maximum, so total feeding requirements remain the same. Like the situation without environmental policy, the explanation is that only part of the summer a shortage of grass for grazing exists. The levy on N and $P_2O_5$ surpluses decreases the N level per cut in period 1 and 2. In period 1, this only affects the amount of grass for ensiling and not the ration in this period. As a result

Table 7.7 Number of young stock, use of the land, feed purchased and labour income from the three models with environmental policy

| | basis model | model with three time periods | model with time periods and two lots | |
|---|---|---|---|---|
| | | | farmstead lot | field lot |
| Number of young stock | 39.4 | 48.2 | 48.2 | |
| Land use: | | | | |
| - grassland (ha) | 27 | 27 | 16.2 | 10.6 |
| - silage maize (ha) | 0 | 0 | 0 | 0.2 |
| Grassland use: | | | | |
| - N level cuts period 1 (kg/ha) | - | 69 | 85 | 42 |
| - N level cuts period 2 (kg/ha) | - | 70 | 70 | 48 |
| - N level cuts period 3 (kg/ha) | - | 70 | 70 | 67 |
| - N gift period 1 (kg/ha) | - | 156 | 215 | 71 |
| - N gift period 2 (kg/ha) | - | 84 | 58 | 50 |
| - N gift period 3 (kg/ha) | - | 45 | 34 | 68 |
| - total N gift grassland (kg/ha) | 278 | 285 | 306 | 190 |
| - number of grazing cuts (ha) | 138.2 | 140.4 | 94.5 | 37.6 |
| - number of mowing cuts (ha) | 8.8 | 9.1 | 0 | 9.1 |
| Feed purchased: | | | | |
| - silage maize (ha) | 8.2 | 9.3 | 9.9 | |
| - concentrates (1000 kg) | 75.3 | 79.3 | 82.1 | |
| Labour income (NLG) | 69,048 | 67,804 | 65,184 | |

of the lower amount of grass ensiled the winter ration changes towards lesser silage grass and more silage maize and protein rich concentrate. In period 2, the ration of the dairy cows contains less grass and more silage maize and protein poor concentrate. In period 3, the N level per cut and the ration remain unchanged. The total N gift on grassland decreases by 34 kg/ha. The lower production per hectare is expressed by a lower number of grazing and mowing cuts and is compensated by higher feed purchases. Labour income decreases by some NLG 3200, NLG 900 of which comprises higher costs and NLG 2300 the levy on N surpluses. Revenues remain unchanged. From the nutrient balances it can be seen that the

Table 7.8 Nutrient balances at farm level (kg/ha) from the three models with environmental policy

| | basis model | | model with three time periods | | model with time periods and two lots | |
|---|---|---|---|---|---|---|
| | N | $P_2O_5$ | N | $P_2O_5$ | N | $P_2O_5$ |
| Input: | | | | | | |
| - feed purchased | 145 | 51 | 156 | 55 | 161 | 54 |
| - fertilizer | 168 | 0 | 172 | 0 | 153 | 0 |
| - manure supplied | 16 | 9 | 13 | 7 | 15 | 8 |
| total | 329 | 60 | 341 | 62 | 329 | 62 |
| Output | 81 | 35 | 83 | 37 | 83 | 37 |
| Surplus | 248 | 24.5 | 258 | 25.0 | 246 | 25.0 |

amount of manure supplied from outside the farm is adjusted again to meet the requirements for $P_2O_5$. N input is also decreased by this and by a decreased amount of fertilizer. Input of N and P2O5 through feed purchased increases. As output remains unchanged, the N surplus falls by 56 kg/ha and the P2O5 surplus falls by 13 kg/ha.

In the model with two lots, the number of young stock also remains at its maximum. The N level on the farmstead lot in period 1 ensures that there is enough grass to achieve the same ration of the dairy cows as in the situation without environmental policy. In periods 2 and 3 the N level is decreased to 70 kg/cut leading to lesser grass and more silage maize and concentrates in the ration. The relatively high total N gift on the farmstead lot illustrates how valuable grass is for grazing dairy cows. The use of the field lot is determined by the efficiency of N use by grass and silage maize, the grass requirement of young stock and the winter ration of the dairy cows. As the efficiency of N use by grass increases at decreasing N levels, and as silage maize has a higher efficiency of N use than grass, the levy on N surplus restricts both the N level on grassland and the area of grassland. However, a minimal amount of grass is required for both feeding the young stock and for exactly balancing the protein and energy requirement and supply in the dairy cows' winter ration. The result is that the major part of the field lot is used for growing grass at a total N gift of 190 kg/ha. A small part is used for growing silage maize. The lower feed production leads to higher feed purchases.

Here too, the environmental policy decreases labour income by some NLG 3400, half of which is creditable to the higher costs and the other half to the levy on N surplus. The nutrient balances show a substantial decrease of N input by fertilizing, fine tuning of P2O5 supply through decreasing the amount of manure from outside the farm, increased input of nutrients through purchased feed and a fall of 63 kg/ha for N surplus and 12 kg/ha for P2O5 surplus. The nutrient surpluses for the farmstead lot and the field lot are 300 kg/ha and 165 kg/ha for N and 27 kg/ha and 23 kg/ha for $P_2O_5$ respectively. Compared to the situation without environmental policy, the differences between the surpluses on the farmstead and the field lot are very much less. This is totally due to the decrease of the amount of manure from outside the farm.

Inclusion of environmental policy in the models leads to more or less the same effects on the economic and environmental results. However, a more detailed model gives better insight into the way the surpluses are reduced. From the three period models it appears that N surpluses are mainly curbed by decreasing the N level on cuts in the first and second period. Division in two lots shows that the difference in the level of grass production between the two lots is increased by environmental policy.

### 7.3.3 A stepwise increase of the size of the field lot

To show the effects of the size of the field lot on labour income and nitrogen losses, calculations were made in which the percentage field lot was increased stepwise by steps of 10%. The initial grazing system for dairy cows is day and night grazing. As the farmstead lot decreases, so does the amount of fresh grass for dairy cows and silage maize enters the ration. If more than 20% of dry matter in the ration in a period consists of silage maize, the grazing system for that period is changed manually to day time grazing only. This is more or less in line with practice. The switch to only day grazing takes place in period 2 at a field lot of 50%, and in period 1 and 3 at a field lot of 60%.

The top graph of Figure 7.3 shows labour income with and without environmental policy as a consequence of the percentage field lot. If the percentage field lot is higher than 20%, labour income decreases in both situations for a number of reasons:

1. Grass for ensiling is mown at the field lot which leads to extra transportation costs;

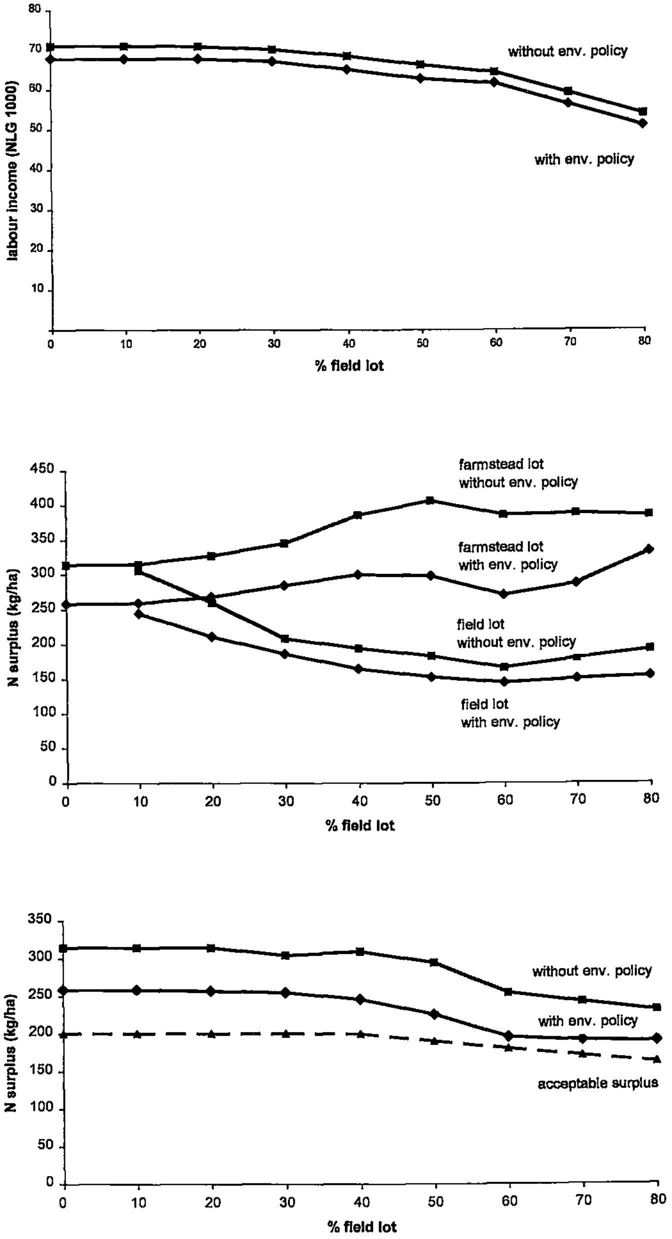

Figure 7.3 Labour income, N surpluses per lot and over all N surpluses without and with environmental policy for various divisions of the total area.

2. Part of the manure excreted in the stable must be transported over a longer distance to the field lot, and a change of the grazing system results in more manure being excreted in the stable. Both causes lead to higher costs of applying manure;
3. At a higher percentage the amount of fresh grass grown at the initial N level is not longer sufficient to supply enough energy for the dairy cows in summer. Silage maize enters the rations and the N level of grass on the farmstead lot increases;
4. Finally, the amount of fresh grass is that low and the amount of silage maize is that high that protein rich concentrate enters the dairy cows' summer ration to supplement the protein requirement.

The second graph shows the N surplus for the farmstead and the field lot for both situations. On the farmstead lot the N surplus initially increases. This is because: (1) animal manure is used as much as possible on the farmstead lot because of the lower transportation costs, and (2) the N level on the farmstead lot is increased to produce enough fresh grass. The introduction of silage maize in the summer ration has an adverse effect on N surplus on the farmstead lot as it contains little protein. This leads to a lower N content of faeces and urine excreted while grazing. The switch from day and night grazing to only daytime grazing decreases the N surplus on the farmstead lot. It results in less faeces and urine being excreted while grazing. The most important difference between the situation without and with environmental policy has to do with the substantial increase of the N level on grassland in the situation with environmental policy when protein supply for dairy cows finally becomes a problem. In the situation without environmental policy, the increase of the N level on the farmstead lot takes place together with the increase of silage maize in the summer ration. The N surpluses on the field lot decrease in both situations as a result of a decrease of the N level on grassland and of the introduction of silage maize on the field lot. The final graph shows the resulting N surpluses at farm level and the acceptable N surplus. Comparing this graph with the previous one clearly shows that an increase of the field lot decreases the average N surplus, while it increases the difference between the lots.

## 7.4 Discussion

The level of detail in modelling the seasonal elements depends mainly on available data that can be used for modelling. Diversion of the growing season for grass in three periods is quite common in Dutch modelling and extension with respect to grass production. Consequently, data on production and on energy, protein and nutrient content of grass are available for these three periods. The level of detail in the spatial sense concerns the number of lots used. The most important difference between lots is determined by whether or not a lot can be used for grazing dairy cows. As this results in two possibilities, inclusion of two lots in the model is the logical consequence.

From the results it can be concluded that inclusion of seasonal elements in the model gives a better insight into how grassland is used during the growing season. It does not result in great differences in farm plan, income and N and $P_2O_5$ surpluses. Inclusion of the spatial element means an important restriction on the use of part of the land. It results in differences in land use between the farmstead and the field lot and in substantially lower income. The value of fresh grass as a cheap energy and protein source for dairy cows is expressed by a high N level of grass on the farmstead lot. The consequences of inclusion of the seasonal and spatial elements in the situation with and without environmental policy do not differ much.

The main effects of environmental policy are a decrease of the N use on grassland and a decrease of the amount of manure brought in from outside the farm. While this leads to moderate decreases of income, it does not result in realization of the acceptable surpluses as far as N is concerned. Apparently, the levy of NLG 1.50 per kg extra surplus is not high enough. This is in line with the findings of earlier research where a levy of at least NLG 3 was required to realize a more substantial reduction (Berentsen & Giesen, 1994). On the other hand the acceptable surpluses used her are intended for the year 2005. Advancing technical development can help solve the problem. Since the introduction of the quota system, technical change took on more and more the form of decreasing inputs at a given output level, including a more efficient use of nutrients for plant and dairy production.

A substantial field lot results in a more balanced summer ration of the dairy cows as silage maize partly replaces fresh grass in the ration. This decreases the average N surplus and it brings the farm closer to governmental targets for the average N surplus. However, the different options of using the two lots can lead to a high N surplus on the farmstead lot. Although this is compensated by a low surplus on the field lot it can be judged negatively especially since N leaching is a local environmental problem. This illustrates that a governmental policy based on average surpluses is not in all cases sufficient to avoid environmental damage. Additional calculations with separate acceptable surpluses and levies for the farmstead (60%) and the field lot (40%) point out that with almost no extra costs the N surplus on the farmstead lot is decreased by 4.5%. Contrastingly, the N surplus as well as production on the field lot increases.

Time and space were chosen as the elements for further specification of a grassland based dairy farm model. This has resulted in better understanding of grassland use through the year and it has shown the importance of good parcellation both from an economic and environmental point of view. The next step in this research project will be the establishment of the relationship between the use of grassland and nitrate leaching. Results of recent experimental research, such as research into the relation between the moment of formation of urine patches and nitrate leaching (Van der Putten & Vellinga, 1996) will be the basis for further modelling.

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# 8. General discussion

In this final chapter the method used and the results obtained will be discussed. The discussion is guided by the general aim of the study which was contributing to the research on the consequences of changing external conditions in dairy farming. The study has resulted in (a) a linear programming model of a dairy farm and (b) insight into possible consequences of changing external conditions.

At the end of each chapter of this thesis main points have been discussed. This chapter will therefore be devoted to matters with a more general character. In section 1 methodological issues will be discussed like the use of a linear programming model, the approach at farm level and the use of scenarios. Section 2 contains the discussion about interpretation of results. Major attention is paid to explaining differences between results in reality and model results. In section 3 ideas for further research are presented.

## 8.1 Methodological issues

### 8.1.1 The use of an LP model

There are basically two approaches to economic analysis of production: econometric modelling and mathematical programming. An econometric model is based on statistical analysis of historical data. As this automatically includes behaviour, econometric modelling is a suitable method for analysing the past. Using econometric modelling for forecasting the future is likely to be successful if the influencing factors are more or less the same as in the past. If, however, circumstances are changing in an unprecedented way, econometric modelling is a less valid method for forecasting. In Dutch dairy farming this is the case. Especially environmental policy is a new factor in the period concerned in this study and farmers reactions to it cannot be derived from historical data. Mathematical programming uses knowledge about farmers objectives and detailed information about the production process to model a dairy farm. In linear programming this is done by formulating an objective function, a number of activities representing the farmers production possibilities and restrictions that (1) represent the technical relations between the different production possibilities, (2) link the different activities to the available fixed assets of the farm, and (3) represent external conditions. Mathematical programming is called normative as it is based on a general but limited concept of farmers objectives and because many relations are based on standards and not on perceived results in reality. Linear programming is quite suitable for exploring the future of Dutch dairy farms as it can incorporate (1) new production techniques by adding new activities, (2) improvement of existing production techniques by changing technical coefficients, (3) environmental legislation by adding new restrictions to the model or by putting prices on undesired outputs, and (4) market and price policies by changing restrictions or prices. The objection of a normative model that does not necessarily represent farmers behaviour in reality is partly lifted by validating important technical relations in the model on the basis of average results in reality (see Chapter 4). The aspect of the normative objective function remains. This will receive further attention when discussing the results.

Mathematical programming includes other types of linear programming beside basic linear programming (LP) which is used in this study. Especially Interactive Multiple Goal Linear Programming (IMGLP) is often used in explorative land use studies (De Wit et al., 1988). The essential difference between the two techniques is that in LP there is only one objective which is optimized, whereas in IMGLP there are several objectives to be optimized. However, the different objectives in IMGLP are not optimized simultaneously but step by step. In every step one objective is optimized while the other objectives function as a restriction with acceptable goal values that must be realized. By tightening the goal restrictions in successive iteration cycles, the feasible solution area is reduced, until a situation is reached where it is impossible to improve any of the goals without sacrificing one or more of the others. IMGLP is especially interesting when different parties with conflicting goals are involved in a decision making process. For dairy farming in the Netherlands this approach is used by Van de Ven (1996). Different goals used in that study are maximization of income and of milk production and minimization of different nutrient surpluses, of nutrient losses and of labour. The results nicely shows the trade-offs between the different goals. In the study here, the focus is on the effects of possible circumstantial changes for farms. So the viewpoint is more that of a farmer. This means that for example governmental environmental goals when translated into policy become restrictions for farmers, albeit soft restrictions with a weight on violation of the restriction. Used in that sense LP is quite a suitable method

Linear programming includes the use of only linear relations. In reality, however, some relations are non linear. An important example in dairy farming is the relation between the application of mineral nitrogen on grassland and grass production. The results of many experiments show that marginal grass production decreases at increasing N application. In linear programming, modelling non linear relations is solved by using a number of activities, each representing a particular N application level with a corresponding grass production. By doing so, a non linear relation is represented by a number of linear relations, each valid for a short trajectory. In the model described in chapter 2 five N application rates on grassland were used. The inclusion of seasonal elements in this model (chapter 7) led to a much greater variety of possible N application rates. Comparison of the results from both models shows that the optimal N level at a given animal density was almost the same. This indicates that the choice for five N application rates in the initial model was quite good. The number of non linear relations on a dairy farm is not so high. In the model, beside N application on grassland, the only other non linear relation is that between the amount of concentrate used and the fill value of concentrate. Also this is satisfactorily solved by using a number of concentrate feeding levels.

The required level of detail in the model depends on the aim the model is used for and on the effects of non linearity in aggregated activities. An example of the former is concerned with the environmental results. The environmental policy used in the scenarios applies to ammonia emission and nitrogen and phosphate surpluses per hectare. For adequate modelling this implies that the model must contain an ammonia emission restriction and nitrogen and phosphate balances at farm level. Greater level of detail is not necessary for determining the effects of the scenarios. In Chapter 7 where the focus is turned explicitly to nitrogen losses to air and soil greater detail in modelling nitrogen streams is required. Non linearity in aggregated activities can be caused by the representation of a number of similar activities by one average activity. An example of this is the use in the model of one average dairy cow to represent all dairy cows in combination with feeding. In reality the dairy cattle consists of dairy cows of different ages, with different genetic potential to produce milk, and in different stages of lactation. Milk production can easily be averaged. Dry matter intake capacity and energy and protein requirements can be determined by using the average milk production. This itself does not lead to aggregation errors since dry matter intake capacity and feeding requirements vary linearly with milk production. The problem arises from the combined use of dry matter intake capacity and feeding requirements and more in particular from the fact that the relative increase of dry matter intake capacity is smaller than that of energy and protein requirements at a given increase of milk production (Groen, 1988). This means that dry matter intake capacity can restrict the ration of a high producing cow while it does not restrict the ration of an average or low producing cow. If that is the case, the ration of the average producing cow is not the same as the average ration of the low and high producing cow. Calculations with the model with a number of representative cows based on energy requirement and comparison of the results with the results of calculations with one representative cow showed that this effect exists (Hin, 1994). However, at an average milk production of 7500 kg the effect on farm plan, labour income and nutrient surpluses is only very small. The effects increase with an increase of milk production.

### 8.1.2 Approach at farm level

Modelling changes in agriculture is done either on farm level or on a higher level like a region (e.g. Van de Ven, 1996) or an agricultural sector of an economy (e.g. Oskam, 1988). Historically, farm level modelling is the domain of farm economists and of other scientists with a strong technical interest. The method applied is mainly a programming method that leaves room for many technical specifications. The higher level is historically the domain of general agricultural economists with econometric modelling based on behaviour in the past as the general method. More recently, the combination of the modelling level and the method applied has become less unambiguous as programming methods are used also at higher aggregation levels (e.g. Rabbinge & Van Latestein, 1992) and econometric modelling is used at farm level (e.g. Thijssen, 1992).

The level where the decisions which products, how much and in which way to produce are taken is the farm level. Modelling at farm level enables simultaneous consideration of production, price and policy information just like a farmer does. This makes the modelling results more easy to understand and accept especially by people who are not familiar with the modelling technique. Modelling at farm level also enables calculating for farms that differ in size and in intensity. This makes it possible to show distributional effects of policies which is important especially for farmers who are interested firstly in consequences for their own type of farm. A major drawback for modelling at farm level compared to the sector level is the lack of a mechanism that controls demand and supply of inputs and outputs. At farm level prices of inputs and outputs generally do not depend on amounts purchased or produced. However, a similar reaction of a great number of farmers concerning amounts of inputs or outputs often results in price changes to balance demand and supply. As far as modelling of dairy farming at farm level is concerned, the existence of milk quota solves the main problems of market reactions at the output side. The main inputs in dairy farming are fertilizer, concentrate and for intensive farms also roughage. At the end of Chapter 6 it is discussed that (1) changes in the demand for fertilizer will probably not lead to great price changes because the Netherlands is only a small party on the international fertilizer market, (2) an increase in the demand for concentrate due to a higher milk production per cow can have a price increasing and consequently an income decreasing effect and (3) an increase in the production of silage maize combined with a decrease of demand will not lead to great price changes because of arable farmers who can easily exchange production of silage maize for production of grains.

### 8.1.3 The use of scenarios

Scenarios are used in this study to compose possible future circumstances for Dutch dairy farms. The use of scenarios and the absence of probabilities attached to the scenarios illustrates the uncertainty about future developments. It must be emphasized that consequently the results of the calculations based on the scenarios are not a prediction of the future but an exploration of possible futures. However, these futures are quite conceivable as the forecasts that form the scenarios all proceed in a logical sense at the present. The scenarios contain forecasts for technical change, for Common Agricultural Policy, for environmental policy, and for increase in the size of farms. For technical change and for increase in the size of farms only one quite obvious forecast is used. For both Common Agricultural Policy and environmental policy two forecasts are used. For Common Agricultural Policy future developments are highly uncertain, so the two forecasts are just two possible outcomes. Reality can be quite different. The future of environmental policy is more clear. It is quite obvious that acceptable nutrient surpluses and levies will be used as policy instruments. The exact level of acceptable losses, however, is subject of discussion. Therefore two forecasts for environmental policy are used, a moderate and a severe policy. The combination of two forecasts for Common Agricultural Policy and two for environmental policy results in four scenarios.

## 8.2 Results

Comparison of reality with results from calculations with an optimization model often suggests that farms are in a suboptimal position (e.g. Chapter 4; Van Deurzen et al., 1996) . Partly, this is a matter of validation by using correct levels of production and correct prices for inputs and outputs. For another part it has to do with the impossibility of a model to cover reality completely. An example is the allotment of land on a farm that was not included in the model up to Chapter 7. Inclusion of allotment in Chapter 7 showed that allotment influences the use of the land and the fertilization level on grassland. A third reason for supposed suboptimality follows from the fact that optimization is based on information about the realized results of farms. This means that model decisions are based on full information while in reality a farmer has to make decisions based only on expectations about the weather, about animal production, etc. A farmer must for example plan in early spring how to divide his land between grassland and land for silage maize. During the growing season the weather can be such that the yield from grassland tuns out to be higher than expected, while the yield from silage maize falls short. Optimization afterwards based on these results would probably result in a plan with more grassland suggesting that the plan in reality is suboptimal. Farmers, who are aware of these kind of uncertainties, often take little risk by choosing for example for growing more silage maize than optimal because it has less weather risks or by feeding more concentrate than optimal because it is a feed with a guaranteed quality and it uses little of the intake capacity of the cow. The element of risk turns the focus to farmers objectives. Differences between farmers objectives and the objective used in the model can be another reason for suggested suboptimality. Farmers possess numerous goals. The importance an individual attaches to one goal compared to another depends on that persons current financial situation, current and future financial needs and set of values (Boehlje & Eidman, 1984). From research in 1993 and 1995 it appeared that dairy farmers in the Netherlands, beside to income maximization, also gave high priority to good technical results and to paying attention to livestock while leisure time and the use of environmentally sound practices received much lower priority (Huirne et al., 1996). As all objectives play a role in the decision process in reality it is obvious that it can lead to results that differ from a modelling approach with only one economic objective. The high priority for good technical results can for example explain the higher concentrate use in practice. Finally, part of the suggested suboptimality can be real suboptimality due to lack of knowledge or lack of information or lack of confidence in the supplied information. An example is given by the use of mineral nitrogen on grassland. For a number of years the generally advised mineral nitrogen gift on sandy soils amounted to 400 kg/ha in the Netherlands. In the beginning of the nineties insights changed and the economically optimal advised gift was decreased to 300 kg/ha. However, due to farmers who did not pick up or did not trust the information, the average mineral nitrogen gift on grassland on sandy soils is still much higher than 300 kg/ha.

The reasons mentioned above cause differences between reality and model results. Labour income according to the model is higher than in reality while the surpluses of N and $P_2O_5$ are lower than in reality (see Chapter 4). The viewpoint that the focus should be on differences between model situations rather than on differences between model results and reality is not valid as far as nutrient surpluses and environmental policy is concerned. Targets for nutrient surpluses that are used in environmental policies refer to absolute surplus levels. So if the model underestimates nutrient surpluses the effects of environmental policies especially on income are underestimated by the model. However, a policy with a levy on nutrient surpluses can cause farmers to gain more information and to reconsider safety margins in production, thereby bringing results in reality closer to the model results in the end situation.

Overlooking the results it can be stated that dairy farmers can benefit a lot if they succeed in making full use of technical improvement. As intensive farms generally have higher marginal costs they can benefit even more from technical change than extensive farms. This relative advantage of intensive farms disappears however if a severe environmental policy is applied or if farms get the possibility to extend milk production. Extensive farms can easily comply with the environmental standards. Beside that they have 'environmental space' to extend production if production would be more liberalised. With this knowledge intensive farms can anticipate on future circumstances by putting more emphasis on increasing the area of land in stead of or combined with increasing milk quota. For policy makers it is interesting to know that technical change contributes substantially to lower nutrient losses. Therefore it is of interest for the whole society that the government not only sets the standards for acceptable surpluses, but also helps farmers to realize these standards by supporting research in this area and by making the results of research available for practical farmers. Research, education and extension remain of major importance for farmers as well as for the government. In the past it has helped to make Dutch agriculture strong, now it can help to make Dutch agriculture clean.

## 8.3 Further research

Up to Chapter 7 the focus was on effects of changing circumstances on Dutch dairy farms. One of these changing circumstances concerned environmental policy. Environmental policy concerns nitrogen and phosphate surpluses and ammonia emission. Nitrogen surplus is an imperfect indicator of environmental damage as it is comprises harmful and non harmful nitrogen losses and storage of organically bound nitrogen in the soil in a ratio that is not constant. Chapter 7 is the first step towards modelling at farm level of nitrate leaching being one of the harmful nitrogen losses. The inclusion of time and space in grass production and grassland use in the model is necessary as nitrate leaching depends on management practices at a given time and place. A substantial amount of technically oriented research is carried out to assess the relation between management practices and nitrate leaching at given soil characteristics. This type of research mainly takes place on plot level. In coming research the results of this plot level research will be integrated in the dairy farm model and thereby be aggregated to the farm level. Calculations with the adapted model will show (1) how nitrate leaching can be minimized, (2) what the associated costs are and (3) what the relation at farm level is between nitrate leaching and the nitrogen surplus.

The environmental policy introduced in 1998 has brought with it a renewed interest of farmers how to comply to governmental standards applied in the policy. In a general sense use of the model can contribute to insights required by carrying out proper calculations and publishing the findings. Both policy makers and farmers can use these insights while evaluating policies and farm management. However, farmers are more and more interested in the consequences and costs of measures they can take in their own particular circumstances. This raises the question if the model could be made suitable for decision support at farm level. A number of issues have to be dealt with to realize this. First of all a farmer has to have insight in characteristics of his own farm like the fixed assets and input-output relations. Especially the last point is complicated. Animal output in terms of milk produced and animals sold is information every farmer can supply. This is often not the case with input at animal level like roughage intake. Amounts of roughage produced on the farm are hardly measured. Moreover, if a farmer would want to measure roughage production, he runs into the problem that it is almost impossible to measure grass for grazing. This means that part of the animal input, which is at the same time output of plant production, is unknown to a certain extent. Input for plant production is difficult as far as the use of animal manure and nitrogen supply of the soil is concerned. However, the use of samples can give information about this. Taken together, the assessment of input output relations is not easy. Obviously, it is always possible to use standards when farm specific information is missing, but this makes the results less farm specific. A second point concerns the inclusion of risk elements in the model. This brings the model closer to reality as was argued in the previous section. Moreover, it can result in a possible range of outcomes thereby illustrating the effect of influences with a random character like the weather. Finally, more attention could be paid to the farmers objectives. This does not necessarily lead to some kind of multiple goal programming. New objectives can get the form of additional restrictions with a minimal required value. All these adaptations can make the model results more acceptable and usable for farmers. However, the complexity of the use of an LP-model for decision support should not be underestimated. Also, correct interpretation of model results is not always obvious and it often requires a lot of knowledge about the model. Concluding it can be said that there is a long way to go before the model can be used for extension at farm level. For the time being farmers can be supported by presenting results of calculations for different situations in which farmers can recognise their own situation and by explaining the underlying mechanisms.

Finally, it can be stated that the model developed is a useful tool to examine numerous other issues concerning dairy farming. Mostly this requires only slight model alterations or additions. However, it should be noted that a correct use of the model requires a continuous revise and update of the model. This counts in the first place for prices of inputs and outputs that can change quite rapidly. Beside that, also changes in technical relations that follow from scientific research should be taken into account. Lastly, there should be an open mind for new production techniques.

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# Summary

Circumstances in Dutch dairy farming are changing continuously. The two types of changes that were distinguished in this study are technical and institutional change. Technical change is understood as a change in production technique. In this research this mainly applies to improvement of existing techniques, resulting in increases of milk production per cow and of plant production per hectare. Institutional changes are changes brought about by some kind of government in order to achieve certain targets. An example is the national environmental policy. For farmers it is important to recognise these changes in time so they can be incorporated in farm management in order to guarantee continuation of the farm in the future. For the government it is important to identify possible consequences for farms of certain governmental policies in combination with technical change. This cleares questions like (1) does a governmental policy lead to the desired result and (2) are there no unacceptable side effects as a result of a policy.

This study aims to contribute to the research on the consequences of changing external conditions for dairy farms. More in particular the research objectives were:

1. development of a method including a model of a dairy farm to assess consequences of changing external conditions;
2. application of the method developed to provide insight into the possible consequences of changing external conditions.

The outline in this thesis is formed by development of the dairy farm model, application of the model to some simple questions as a kind of model test, assessment of a representative farm and validation of the model based on this farm, development of scenarios for changing circumstances and model calculations to assess the consequences of the scenarios for different types of farms. Finally, attention has been paid to further specification both in time and space of grass growth and grassland use in the model. This was done to facilitate the analysis of nitrogen flows on a dairy farm.

## The farm model

The model developed is a static, deterministic, linear programming model of a dairy farm. The objective function maximizes labour income. The central element in the model is a dairy cow, calving in February with a fixed milk production. Young stock is kept for replacement of the dairy cows. Animal production and feeding in the model are distinguished for the summer and winter period. Fodders that can be produced on the farm are grass (at a nitrogen level ranging from 100 to 500 kg/hectare), silage maize and fodder beet. Purchased feed can exist of a number of concentrate types (with different protein content) and maize silage. Feeding is modelled based on energy and protein requirements and dry matter intake capacity. Besides, a certain amount of structural material in the ration is required.

Manure from the animals on the farm, fertilizer and manure from other farms supply nitrogen, phosphate and potassium to grow the fodder crops. The model contains balances for nitrogen, phosphate and potassium on farm level, on soil level and on animal level for both the summer and winter period. Total ammonia emission is recorded by a separate counting constraint.

In the model labour is supplied by the farmer and the family. Each production activity requires labour. To fulfil activities like mowing and ensiling of grass and application of manure the model can choose between own mechanisation and contract work. Therefor, investment in machinery for these tasks is an option in the model. Like ground and the stable, all other machines are considered basic equipment of a dairy farm so these are not options in the linear programming model.

With the model developed some simple questions were examined. One of these concerned the DVE-OEB-protein evaluation system. The question was what the possible consequences for labour income and nitrogen surplus could be of the use of this new system compared to the use of the old system. From model calculations with the old and the new system it appeared that the change to the new system itself hardly influenced nitrogen surplus and labour income. On the other hand, the OEB (rumen degradable protein balance) in the new system appeared to be a good means to decrease the nitrogen surplus. Restriction of the amount of rumen degradable protein that could be lost in the rumen (the OEB) led to a more extensive grassland use and to dried beet pulp that was included in the summer ration. The result was a substantial decrease of the nitrogen surplus, but also of the labour income.

## Model validation

To be sure that future forecasting by means of model calculation has a certain representativity it is necessary that (1) the situations for which calculations are made are representative and (2) the model is a good representation of reality and differences between practice and model results can be explained. The characteristics of the basic farm situation were based on average results of specialized dairy farms on sandy soil for 1992/93. The study focuses on sandy soil because environmental problems on sandy soil are most severe and consequently the biggest effects of environmental policy can be expected on this soil type. Data to describe the farm situation are the farm size, measured in available area (27 ha), in milk quota (330.000 kg), and in stable capacity (96 cow places for housing dairy cows and young stock) and the level of production (the state of the art), measured in milk production per cow (6682 kg/year) and in grass and crop production per hectare.

Validation was done in a number of steps. In the simulation step apart from the structural data mentioned above a lot of other information from the real farm results was used like purchased amounts of feed and fertilizer. Comparison of the model results with the results from reality showed that the model was capable to simulate reality. In the optimization step behavioural restrictions used for simulation were lifted. The difference in results between simulation and optimization (higher labour income and lower nitrogen and phosphate surpluses) showed the effect of differences in goals between model and reality (like risk aversion) and of lack of information or knowledge.

## Scenarios for changing circumstances

Scenario analysis has been used to assess consistent sets of future circumstances. This was done in three steps:

1. defining key factors in technology and in institutional regulations;
2. development of one or more forecasts for key factors based on analysis of historical data;
3. combining individual forecasts for key factors to four scenarios based on relevance, credibility, usefulness and intelligibility.

Defined key factors in technology on a dairy farm were grass and crop production per hectare and milk production per cow. Choosing these factors means choosing a certain aggregation level. Underlying factors such as breeding, grassland management, drainage, and water supply where it concerns grass production were not considered as independent key factors but were used for historical analysis. Institutional key factors were the national environmental policy and the market and price policy of the EU. Both concerned regulations specifically developed for dairy farming.

Developments in grass and crop production per hectare and milk production per cow were analysed on the basis of historical data. From 1971 to 1988 grass production per hectare in the Netherlands increased by 1100 MJ NEL at an average N supply of 343 kg/ha. This increase was related to the possible levels of N supply in the model and extrapolated to 2005. This resulted in a gross energy production from grassland in 2005 of 55960, 71900, 81835, 87630 and 90135 MJ NEL/ha at an N supply of 100, 200, 300, 400 and 500 kg/ha respectively. Apart from that it was assumed that losses from grazing and forage making can decline further till 19% and 17% respectively of the gross energy production by improving grassland management and forage making. From 1954 till 1993 silage maize production per hectare increased yearly by 125 kgdm/ha on average mainly as a result of breeding. Also this trend was extrapolated, resulting in a production in 2005 of 92875 ML NEL/ha. Extrapolation of trends for the increase of grass and silage maize production was done based on the idea that sudden changes were not observed in the past and are therefor not expected for the future. The development of fat corrected milk production per cow per year from 1954 till 1993 exhibited four different periods. Before introduction of the quota system yearly increase amounted to 45 kg/cow till 1975 and 100 kg/cow from 1975 till 1984. Introduction of the quota system resulted in a shock period with sudden deviations in the increase in milk production per cow. From 19986 till 1993 yearly increase amounted to 145 kg/cow. This final trend was extrapolated till 2005 under the assumption that total milk production will be restricted either by continuation of the quota system or by environmental legislation.

The long term national environmental policy concerning dairy farming is uncertain. To prevent further eutrophication of surface and ground water an acceptable surplus per hectare for N and $P_2O_5$ will be used with a levy on any surplus exceeding the acceptable surplus. Future policy concerning acidification is less clear. Here it was assumed that for 2005 an acceptable ammonia emission level per hectare will be used with a levy on emission above the acceptable level. For this total package of environmental policy a moderate and a severe variant was formulated. Differences concerned the height of the acceptable surpluses and the acceptable emission respectively. The market and price policy of the EU influences dairy farms in different ways. Decrease of the price support for grain will result in lower prices for grain and grain substitutes which was assumed to result in a price decrease of concentrates of NLG 4 per 100 kg compared to the price level of 1992. The compensatory payment per hectare of grain (which applies also to silage maize) was assumed to result in an estimated decrease of the silage maize price of NLG 604 per hectare. Decrease of beef intervention results in an estimated decrease of cattle prices by 15%. The market and price policy for milk for 2005 is highly unpredictable. Therefor, two alternatives for 2005 were assessed. The first alternative includes continuation of the current policy with a slight decrease of the milk price. The second alternative assumes a 15% decrease of the milk quota and free production of additional milk at a price of NLG 40 per 100 kg.

Finally, exogenous growth of the farm size was included in the scenarios. Based on perceived growth in reality from 1985-1992 it was assumed that farms grow with 0.4 hectare and 4000 kg milk quota per year.

The combination of all developments resulted in four scenarios. The distinction between the scenarios is formed by the moderate versus the severe variant of the environmental policy and by the existing price support policy for milk versus the two price system.

## Consequences of scenarios for dairy farms

The LP model was used to assess the economic and environmental consequences of the scenarios for dairy farms. It is conceivable that the farm structure will affect the results. An intensive farm can be expected to be influenced more by environmental policy than an extensive farm. For this reason calculations were made for a number of farms that differ in intensity and in size.

Analysis of the results showed that expected technical change contributes substantially to raising labour income and decreasing environmental losses. The scenario that combines the price support policy with the moderate variant of environmental policy therefor resulted in a substantially higher income for all types of farms compared to the basis situation. Changing the moderate variant of environmental policy for the severe variant negates most of the previous positive income effects. As was expected this was especially the case for the intensive farm. The combination of the moderate environmental policy and the two price system increased total milk production. The stable capacity was the limiting factor. Compared to the price support policy the increase of income was considerably lower due to (1) the smaller amount of milk receiving the high milk price, and (2) the low price for the rest of the milk production. The final scenario that combines the two price system with severe environmental policy was really a worst case scenario. Especially the intensive and the average farm loosed a substantial amount of income compared to the basis situation. The extensive farm was the only farm that realized a higher income under all scenarios. This was mainly due to the small effect of environmental policy on this farm.

## Inclusion of seasonal and spatial elements in modelling grass production and grassland use

In the model used for this research a summer and winter period were distinguished. Besides, one lot was assumed. In reality grass production and grassland use varies through the growing season. In spring grass production is high and consequently most of the grass silage for winter is produced in spring. Also division of the land in more than one lot is common practice. Whether or not a lot can be used for grazing the dairy cattle is the most important distinguishing aspect. A field lot often has a different use (growing silage maize, grazing young stock) than a farmstead lot (grazing dairy cattle). Space and time variation were included in the model by using three summer periods and two lots. This was done to get a better representation of reality by the model and to get a better monitoring of nitrogen flows inside the farm.

Three types of calculations were made to determine the influence of the level of detail in the model on the results: a calculation with the original model, a calculation with the model with three periods, and a calculation wit the model with three periods and two lots. Calculations were made for a situation without and with environmental policy.

Comparison of the results from the three period model with the results from the original model showed only small differences. However, insight in the results increased using a three period model. From the results of the three period model it appeared for example that the third summer period is a bottleneck as far as available grass for grazing is concerned. This became even more clear when environmental policy was included. As a result of the environmental policy N supply in the first and second period decreased while N supply in the third period increased to compensate for lower transfer of N supply from previous periods. Division of the land in a farmstead lot and a field lot restricts the using possibilities for part of the land and it had therefor a bigger effect on farm income. Besides, the less intensive use of the field lot resulted in much lower N surpluses on the field lot than on the farmstead lot.

Introduction of seasonal and spatial elements in the model was a first step in trying to relate nitrate leaching to management measures. The N surplus is a limited criterion for harmful N losses because N surplus includes also non harmful losses and N storage in the soil. To determine nitrate leaching seasonal and spatial specification is necessary because level, moment, and type of N supply affect nitrate leaching.

# Samenvatting

De omstandigheden in de Nederlandse melkveehouderij veranderen voortdurend. Twee typen veranderingen die in deze studie worden onderscheiden zijn technische en institutionele veranderingen. Technische veranderingen zijn veranderingen in de produktietechniek. In deze studie wordt daaronder voornamelijk verstaan de verbetering van een bestaande techniek, resulterend in een verhoging van de melkproduktie per koe en van de gewasproduktie per hectare. Institutionele veranderingen zijn veranderingen die door een overheid teweeg worden gebracht om een bepaald doel te realiseren. Het nationale milieubeleid is daar een voorbeeld van. Voor boeren is het van belang deze veranderingen tijdig te signaleren en er met het bedrijfsbeleid op in te spelen zodat het voortbestaan van het bedrijf beter gewaarborgd is. Voor de overheid is het van belang tijdig te onderkennen wat de mogelijke consequenties voor agrarische bedrijven zijn van bepaalde beleidsvoornemens in combinatie met technische veranderingen om te kunnen bepalen (1) of het beleid tot de gewenste doelen leidt en (2) of er geen onaanvaardbare neveneffecten ontstaan.

De onderhavige studie heeft tot doel bij te dragen aan het onderzoek naar de gevolgen van veranderende omstandigheden voor melkveebedrijven. Concreet gaat het om de volgende twee doelstellingen:

1. het ontwikkelen van een methode met inbegrip van een model van een melkveebedrijf om gevolgen van veranderende omstandigheden te kunnen vaststellen;
2. het toepassen van de ontwikkelde methode om inzicht te verschaffen in de mogelijke gevolgen van veranderende omstandigheden.

De lijn in het proefschrift wordt gevormd door het ontwikkelen van het model, het toepassen van het model op eenvoudige vraagstellingen als een soort modeltest, het vaststellen van een representatief bedrijf en het valideren van het model aan de hand van dat bedrijf, het ontwikkelen van scenario's voor veranderende omstandigheden en het doorrekenen van de gevolgen van die scenario's voor verschillende soorten bedrijven. Tenslotte is aandacht gewijd aan het verder detailleren naar ruimte en tijd van grasgroei en graslandgebruik in het model teneinde een betere analyse van stikstofstromen op een melkveebedrijf mogelijk te maken.

## Het bedrijfsmodel

Het ontwikkelde model is een statisch, deterministisch, lineair programmeringsmodel van een melkveebedrijf. In de doelfunctie wordt de arbeidsopbrengst gemaximaliseerd. Het centrale element in het model is een in februari afkalvende melkkoe met een vaste melkproduktie. Voor vervanging wordt jongvee aangehouden. Produktie en voeding in het model zijn onderscheiden voor een weide- en een stalperiode. De soorten voer die verbouwd kunnen worden zijn gras (op een stikstofniveau variërend van 100 tot 500 kg/ha), snijmais en voederbieten. Aangekocht voer kan bestaan uit enkele soorten krachtvoer (met een verschillende eiwitinhoud) en snijmais. De voeding is gemodelleerd op basis van KVEM- en DVE-behoefte en drogestofopnamecapaciteit. Daarnaast wordt een structuureis aan de rantsoenen gesteld.

In de behoefte aan stikstof, fosfaat en kalium van de gewassen wordt voorzien door het gebruik van mest van het bedrijf, van kunstmest en eventueel van mest van andere bedrijven. Het model bevat balansen voor stikstof, fosfaat en kalium op bedrijfsniveau, op bodemniveau en op dierniveau voor de stal- en weideperiode. Een telregel bepaalt daarnaast de totale ammoniakuitstoot.

Arbeid wordt in het model geleverd door de ondernemer en het gezin. Elke produktieactiviteit vraagt arbeid. Voor activiteiten als het maaien en inkuilen van gras en het aanwenden van mest is in het model een keuzemogelijkheid aanwezig tussen loonwerk en eigen mechanisatie. Een investering in de daarvoor noodzakelijke machines is daarom een optie in het model. Alle overige machines horen net als de stal en de grond tot de basisuitrusting van het bedrijf en staan dientengevolge niet ter keuze.

Met het ontwikkelde model zijn enkele eenvoudige vraagstellingen onderzocht. Eén daarvan betrof het DVE-OEB-eiwitwaarderingssysteem. De vraag was wat de mogelijke gevolgen voor arbeidsopbrengst en stikstofverlies waren van het overstappen op en gebruik maken van dit nieuwe systeem. Uit de resultaten van modelberekeningen met het oude VRE-systeem en het nieuwe systeem bleek dat de overstap op het nieuwe systeem op zich nauwelijks gevolgen had voor stikstofverliezen en arbeidsopbrengst. Wel bleek de OEB in het nieuwe systeem een goed aangrijpingspunt om N-overschotten te beperken. Werden namelijk beperkingen gesteld aan de hoeveelheid onbestendig eiwit die in de pens verloren mag gaan (de OEB) dan werd het graslandgebruik extensiever en werd gedroogde bietenpulp opgenomen in het weiderantsoen. Het gevolg is een substantieel lager stikstofverlies, maar ook een daling van de arbeidsopbrengst.

## Modelvalidatie

Om aan toekomstverkenningen door middel van modelberekeningen een zekere mate van representativiteit toe te kunnen kennen is het noodzakelijk dat (1) de situaties waarvoor gerekend wordt representatief zijn en (2) het model de praktijkresultaten goed kan weergeven c.q. dat verschillen tussen praktijk- en modelresultaten verklaarbaar zijn. De karakteristieken van het uitgangsbedrijf zijn vastgesteld op basis van de gemiddelde gegevens van LEI-boekhoudingen van gespecialiseerde melkveebedrijven op zandgrond in Nederland voor het boekjaar 1992/93. De studie is toegespitst op zandgrond omdat op die grondsoort de milieuproblemen het grootst zijn en dus het meeste effect verwacht mag worden van milieubeleid. De gegevens die input vormen voor het model zijn de bedrijfsgrootte, gemeten in oppervlakte grond (27 ha), in melkquotum (330.000 kg) en in stalcapaciteit (96 koeplaatsen voor de huisvesting van melkkoeien en jongvee) en het produktieniveau (de stand van de techniek), gemeten in melkproduktie per koe (6682 kg/jaar) en in gewasprodukties per hectare.

De validatie is uitgevoerd in enkele stappen. In de simulatiestap is naast de bovengenoemde gegevens veel andere informatie uit de bedrijfsgegevens gebruikt zoals informatie over aangekochte hoeveelheden voer en kunstmest. Vergelijking van de modelresultaten met de werkelijke resultaten liet zien dat het model goed in staat was de werkelijkheid te simuleren. In de optimalisatiestap werden de extra gedragsbeperkingen voor de simulatie losgelaten. Het verschil in resultaten tussen optimalisatie en simulatie (een hogere arbeidsopbrengst en lagere stikstof- en fosfaatoverschotten) geeft weer wat het effect is van verschillen in doelstellingen tussen model en werkelijkheid (zoals risico-aversie) en van gebrek aan informatie of kennis.

## Scenario's voor veranderende omstandigheden

Scenario-analyse is gebruikt om de veranderende omstandigheden logisch te bundelen en ze weer te geven in scenario's. Dit is gedaan in drie stappen:

1. het vaststellen van sleutelfactoren in technologie en in institutionele regelingen;
2. het maken van één of meer voorspellingen ten aanzien van sleutelfactoren op basis van analyse van historische data;
3. het bundelen van voorspellingen ten aanzien van sleutelfactoren tot vier scenario's op basis van relevantie, geloofwaardigheid, bruikbaarheid en begrijpelijkheid.

De vastgestelde sleutelfactoren in de technologie op een melkveebedrijf zijn de gewasprodukties per hectare en de melkproduktie per koe. De keuze voor deze factoren is de keuze voor een bepaald aggregatieniveau. Onderliggende factoren zoals bijvoorbeeld veredeling, graslandmanagement, ontwatering en watervoorziening als het gaat om de grasproduktie per hectare zijn niet aangemerkt als zelfstandige sleutelfactoren, maar gebruikt in de historische analyse. De institutionele sleutelfactoren zijn het nationale milieubeleid en het markt- en prijsbeleid van de EU. In beide gevallen gaat het om regelgeving die specifiek betrekking heeft op de melkveehouderij.

De ontwikkelingen in gewasprodukties per hectare en melkproduktie per koe zijn geanalyseerd op basis van historische data. De grasproduktie per hectare in Nederland bleek in de periode 1971-1988 met gemiddeld 160 KVEM/jaar te zijn gestegen bij een gemiddelde stikstofgift van 343 kg/ha. Deze stijging is gerelateerd aan de mogelijke stikstofgiften in het model en doorgetrokken tot 2005. Dit resulteert in een bruto KVEM-opbrengst van grasland in 2005 van respectievelijk 8110, 10.420, 11.860, 12.700 en 13.070 KVEM/ha bij een N-gift van 100, 200, 300, 400 en 500 kg/ha. Daarnaast is verondersteld dat door beter management en betere voederwinningsmethoden de beweidings- en voederwinningsverliezen verder kunnen dalen tot 19% respectievelijk 17% van de bruto KVEM-produktie. De snijmaisproduktie per hectare bleek in de periode 1954-1993 met gemiddeld 125 kgdm/ha per jaar gestegen te zijn voornamelijk ten gevolge van veredeling. Ook deze trend is doorgetrokken hetgeen resulteert in een produktie in 2005 van 13.460 KVEM/ha. De achterliggende gedachte bij het doortrekken van de trend voor de stijging van gras- en snijmaisproduktie is dat schoksgewijze veranderingen in het verleden niet te onderkennen waren en dat dergelijke veranderingen voor de toekomst niet voorzien worden. In de ontwikkeling van de vet-gecorrigeerde melkproduktie/koe per jaar van 10054 tot 1993 zijn vier verschillende periodes te onderscheiden. Voor de invoering van de melkquotering bedroeg de jaarlijkse toename per melkkoe tot 1975 45 kg en van 1975 tot 1984 100 kg. De invoering van de melkquotering leidde tot een schokperiode met een grote jaarlijkse toename van de melkproduktie per koe. Van 1986 tot 1993 bedroeg de toename 145 kg per koe. Deze laatste jaarlijkse stijging is gehandhaafd voor de periode tot 2005 onder de veronderstelling dat mogelijkheden voor uitbreiding van de produktie beperkt zijn hetzij door handhaving van de quotering, hetzij door milieuwetgeving.

Het nationale milieubeleid met betrekking tot de melkveehouderij op de langere termijn is een onzekere factor. Duidelijk is dat ter voorkoming van verdere eutrofiering van oppervlakte- en grondwater een beleid gevoerd zal worden met voor de nutriënten N en $P_2O_5$ de vaststelling van een acceptabel overschot per oppervlakte-eenheid en een heffing op hogere overschotten. Het toekomstig beleid ten aanzien van verzuring is minder duidelijk. In deze studie is hiervoor aangenomen dat voor 2005 een acceptabele ammoniakemissie per hectare met een heffing op emissie boven het acceptabele niveau zal gelden. Van het aldus samengestelde pakket is een gematigde en een strenge variant geformuleerd. De verschillen betreffen de hoogtes van de acceptabele overschotten respectievelijk van de acceptabele emissie. Het markt- en prijsbeleid van de EU heeft op meerdere manieren invloed op het melkveebedrijf. Afbouw van de steun voor graan leidt tot lagere prijzen voor graan en graansubstituten hetgeen resulteert in een veronderstelde daling van de krachtvoerprijs van *f* 4,- per 100 kg. De hectaretoeslag voor het verbouwen van graan en snijmais leidt tot een veronderstelde daling van de snijmaisprijs met *f* 604,- per hectare. Afbouw van de interventie van rundvlees leidt tot een veronderstelde daling van de prijzen van rundvee met 15%. De inhoud van het markt- en prijsbeleid voor melk in 2005 is hoogst onvoorspelbaar. Om deze reden is gekozen voor het opnemen van twee varianten. De eerste variant is voortzetting van het huidige beleid waarbij een lichte daling van de melkprijs is verondersteld. In de tweede variant wordt verondersteld dat het melkquotum, waarvoor dezelfde iets lagere melkprijs geldt, teruggebracht wordt tot 85% van het huidige quotum gebaseerd op de melkconsumptie in de EU. Voor alle overige vrij te produceren melk is een prijs van *f* 40,- per 100 kg verondersteld.

Tenslotte is als ontwikkeling in de scenario's opgenomen de toename van de bedrijfsgrootte. De veronderstelde ontwikkeling is gebaseerd op de werkelijke ontwikkeling van 1985-1992. De gemiddelde jaarlijkse toename van de bedrijfsgrootte bedroeg 0,4 hectare en 4000 kg melkquotum.

Het combineren van alle genoemde ontwikkelingen levert vier scenario's op waarbij het onderscheid gevormd wordt door enerzijds de gematigde versus de strenge variant van het milieubeleid en anderzijds het bestaande markt- en prijsbeleid versus de tweeprijzen-variant.

## Gevolgen van de scenario's voor verschillende melkveebedrijven

De scenario's zijn met behulp van het ontwikkelde model doorgerekend teneinde een beeld te krijgen van de economische en milieutechnische gevolgen voor melkveebedrijven. Verwacht mag worden dat de bedrijfsopzet van invloed is op de gevolgen. Zo zal een intensief bedrijf meer invloed ondervinden van milieubeleid dan een extensief bedrijf. Om deze reden zijn de scenario's voor een aantal bedrijfsopzetten doorgerekend waarbij verschil is gemaakt in intensiteit uitgedrukt in melkquotum per hectare en in bedrijfsgrootte uitgedrukt in hectare bedrijfsoppervlakte.

Uit analyse van de resultaten blijkt dat de veronderstelde technische ontwikkeling een substantiële bijdrage levert aan verhoging van de arbeidsopbrengst en aan verlaging van de milieuverliezen. Het scenario dat het bestaande markt- en prijsbeleid combineert met het gematigde milieubeleid leidt daardoor tot een substantieel hogere arbeidsopbrengst voor alle bedrijven vergeleken met de basissituatie. Verwisseling van het gematigde milieubeleid voor het strenge milieubeleid doet de positieve inkomenseffecten voor een deel teniet. Zoals kon worden verwacht wordt hierdoor het intensieve bedrijf het zwaarst getroffen. De combinatie van een gematigd milieubeleid en het tweeprijzen-systeem leidt tot een sterke toename van de totale produktie. De grens wordt hierbij gevormd door de beschikbare stalcapaciteit. De toename in arbeidsopbrengst ten opzichte van de basissituatie is duidelijk minder dan bij voortzetting van het bestaande markt- en prijsbeleid vanwege (1) de kleinere hoeveelheid melk waarvoor de garantieprijs geldt en (2) de veel lagere prijs voor de overige melkproduktie. Bovendien ondervindt met name het intensieve bedrijf onder dit scenario negatieve gevolgen voor de arbeidsopbrengst van het gematigde milieubeleid. Het laatste scenario, de combinatie van het tweeprijzen-systeem met streng milieubeleid is duidelijk een 'worst case' scenario. Met name het gemiddelde en het intensieve bedrijf verliezen veel arbeidsopbrengst ten opzichte van de beginsituatie. Het extensieve bedrijf is het enige bedrijf dat onder alle scenario's een hogere arbeidsopbrengst realiseert dan in de basissituatie.

## Detaillering van grasgroei en graslandgebruik in tijd en ruimte

In het model voor dit onderzoek is uitgegaan van twee periodes binnen het jaar, namelijk een stal- en een weideperiode. Daarnaast is uitgegaan van één aaneengesloten oppervlakte grond. In de praktijk blijkt de groei van gras en het gebruik van grasland nogal te variëren gedurende het groeiseizoen. Zo is bijvoorbeeld de grasgroei in het voorjaar het grootst en wordt dientengevolge in het voorjaar het meeste gras gemaaid voor wintervoer. Wat de verdeling van de grond betreft blijken er in de praktijk vaak meerdere kavels te zijn waarbij het belangrijkste onderscheid tussen de kavels gevormd wordt door de bereikbaarheid van de kavels voor melkkoeien. Een veldkavel wordt vaak op een andere manier gebruikt (verbouwen van snijmais, beweiding door jongvee) dan een huiskavel (beweiding door melkvee). Om deze variatie in de tijd en in de ruimte weer te kunnen geven is het model uitgebreid van één naar drie weideperiodes en van één naar twee kavels (een huis- en een veldkavel). Het doel hiervan is, naast een betere weergave van de praktijk door het model, om stikstofstromen en –overschotten binnen het bedrijf beter te kunnen bepalen.

Om te kunnen bepalen of de mate van detaillering invloed heeft op de resultaten en of het inzicht verbetert zijn drie soorten berekeningen gemaakt: één met het basis model; één met het model met drie perioden en één met het model met drie perioden en twee kavels (60% huiskavel en 40% veldkavel). Dit is gedaan voor een situatie zonder en één met milieubeleid.

Uit vergelijking van de resultaten blijkt dat de economische en milieutechnische resultaten tussen het model zonder en dat met drie perioden weinig te verschillen. Wel neemt het inzicht toe als een drie-perioden model wordt gebruikt. Zo blijkt dat de laatste weideperiode een knelpunt is wat betreft de beschikbaarheid van gras. Dit wordt met name duidelijk als het milieubeleid opgenomen wordt in het model. Door het milieubeleid daalt in de eerste en tweede periode het stikstofgebruik op grasland terwijl in de derde periode het stikstofgebruik stijgt om de lagere nalevering van stikstof uit de voorgaande periodes te compenseren. Het splitsen van de oppervlakte grond in een huis- en een veldkavel beperkt de gebruiksmogelijkheden van een deel van de grond en heeft daardoor een groter effect op de arbeidsopbrengst. Daarnaast is te zien dat het stikstofoverschot op de veldkavel door het minder intensieve gebruik veel lager ligt dan op de huiskavel.

De detaillering van het model is een eerste stap in een vervolgonderzoek waarin getracht wordt verband te leggen tussen managementmaatregelen en stikstofuitspoeling. Het stikstofoverschot is slechts een beperkte maatstaf voor schadelijke stikstofverliezen omdat het de som van schadelijke verliezen, niet schadelijke verliezen en bodemophoping is. Voor het bepalen van stikstofuitspoeling is detaillering in ruimte en tijd noodzakelijk omdat niveau en moment van stikstoftoediening van invloed zijn op de stikstofuitspoeling.

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# Curriculum Vitae

Paulus Bernardus Maria Berentsen werd geboren op 15 december 1957 te Lievelde. In 1974 behaalde hij het diploma MAVO aan de Sint Franciscusschool voor MAVO te Lichtenvoorde. In 1977 volgde het MTS-diploma Werktuigbouwkunde aan de RK MTS te Doetinchem en in 1981 het HTS-diploma Werktuigbouwkunde aan de HTS te Enschede. In 1982 werd, na een schriftelijke cursus en een toelatingsexamen scheikunde, een aanvang gemaakt met de studie Agrarische Economie aan de toenmalige Landbouwhogeschool. In januari 1988 werd deze studie afgesloten met als afstudeervakken Agrarische Bedrijfseconomie, Algemene Agrarische Economie en Staathuishoudkunde. Na het afstuderen volgde een aantal tijdelijke projecten bij de toenmalige vakgroep Agrarische Bedrijfseconomie. Deze hadden ondermeer betrekking op het ontwerpen en bouwen van een computerprogramma waarmee in het onderwijs studenten een bedrijfsevaluatie kunnen uitvoeren en op een onderzoek naar de economische gevolgen van mond- en klauwzeeruitbraken in Nederland. Met dit laatste onderzoek, waarin voor het eerst ook de gevolgen van exportbelemmeringen op een modelmatige manier opgenomen werden, werd ondersteuning geleverd ten behoeve van het Nederlandse standpunt inzake het afschaffen van de jaarlijkse MKZ-vaccinaties bij rundvee. In 1990 volgde een tijdelijke aanstelling als universitair docent bij de toenmalige vakgroep Agrarische Bedrijfseconomie met een onderwijs- en een onderzoekstaak. De onderzoekstaak betrof het leveren van ondersteuning in het lopende onderzoek naar de effecten van technologische en institutionele veranderingen in de Nederlandse melkveehouderij. In de loop van 1991 en 1992 werd enkele malen een deel van de aanstelling omgezet van tijdelijk naar vast. Dit bood de mogelijkheid het onderzoek op te zetten als een promotie-onderzoek hetgeen resulteerde in dit proefschrift.