Nutrient management strategies on Dutch dairy farms: An empirical analysis

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Abstract

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Agricultural nutrients are a possible pollutant of (ground)water bodies. For prevention and control purposes, the European Nitrate Directive (91/676/EC) was issued, which was implemented in The Netherlands by means of the Mineral Accounting System (MINAS). MINAS tracks nutrient flows on farms and taxes farmers with high nutrient surpluses. The taxes are such, that MINAS can pose a threat to the financial viability of individual farms. In order to prevent taxation, farmers will have to alter nutrient management on their farm in an economically sound manner. To assess the (financial) feasibility of the MINAS-surplus standards a project called ‘Farm Data in Practice’ (Project Praktijkcijfers in Dutch) was initiated by the Dutch government in co-operation with farm organisations. The research presented in this thesis describes an empirical analysis of the relationship between farm and farmer characteristics, the way nutrients are managed on the farm, and the financial consequences, based on the bookkeeping and survey data of specialised dairy farms collected by the FDP-project. The nutrient management changes that were implemented over the course of 1997-1999 and the nutrient management plans of 2000 to meet the nutrient surplus standards set in MINAS for 2003 were evaluated using statistical methods (e.g. LISREL and (tobit-) regression) Data Envelopment Analysis, and case-study research. The results of this thesis show that farm management is a more important factor in the improvement of nutrient efficiency and reduction of nutrient surpluses than farm structure. An improvement of nutrient management (either through efficiency or technology improvements) proved to be financially beneficial as well. Furthermore, farmer characteristics like education and perceived environmental uncertainty, and farm strategy (growth, diversification, and process-control) direct the course of change in nutrient management (both farm structure and farm management). Result-oriented policy measures like MINAS appear to be more effective than measure-oriented policies like the Nitrate Directive because the former allow farmers to find a fit between external en internal farm characteristics and give them the responsibility to find a solution for the environmental problem on their farm.

Key Words: MINAS; nitrogen surplus; phosphate surplus; nutrient efficiency; nutrient productivity; financial consequences; strategic management; perceived environmental uncertainty; nutrient management planning; dairy farming; The Netherlands.

Woord vooraf

Het kan raar lopen. Het ene moment ben je bezig met het organiseren van postdoctoraal onderwijs en het doen van onderzoek naar de motivatie van deelnemers aan Project Praktijkcijfers en denk je bij jezelf dat het nu toch echt hoog tijd wordt Wageningen eens te verlaten. Het volgende moment heb je 'ja' gezegd tegen een promotieonderzoek naar datzelfde Project Praktijkcijfers in datzelfde Wageningen. De belangrijkste reden om aan dit onderzoek te beginnen was dat het om 'echte' boeren ging die (meestal) met veel inzet bezig waren milieuvriendelijker te leren werken. Het beetje twijfel dat ik nog had werd door het enthousiasme en de overtuigingskracht van destijds nog dr.ir., tegenwoordig prof.dr.ir. Ruud Huirne de wereld uit geholpen. Ruud, bedankt voor de vrijheid die ik heb gekregen in het inrichten en uitvoeren van het promotieonderzoek en het gemak waarmee je 'resources' organiseerde en mobiliseerde.

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Christien Oudersteijn, 2002

Contents

I General Introduction

1.1 Introduction

Surface and groundwater across Europe, which is partly meant for human consumption, is being polluted by nutrient run-off and leaching from agricultural sources. To contain this pollution, the European Union issued the Nitrate Directive (91/676/EEC) to establish a safety standard of 50 mg of nitrate per litre of groundwater (WHO safety standard). The main emphasis in the Nitrate Directive is on nitrogen. In the Netherlands both nitrogen (N) and phosphorus (P) levels are creating environmental pressures (De Walle and Sevenster, 1998). The Netherlands therefore implemented the Mineral Accounting System (MINAS) in 1998, which focuses on nutrient flows (N and P_2O_5) on individual farms, and taxes farms whose nutrient surpluses exceed an environmentally safe threshold, known as the Levy Free Surplus (LFS). LFS will gradually be reduced, until, in 2003, the WHO safety standard is met. Data, which have only recently become available, show that of the checked MINAS-balances, 38% of the specialised dairy farms[1] in 1998 and 48% of the specialised dairy farms[1] in 1999 had to pay a MINAS levy (CBS, 2002). These levies are on average €2340 in 1998 and €2020 in 1999 for extensive dairy farms (less than 2.5 Livestock Units (LU)/ha) and €1820 in 1998 and €1840 in 1999 for the dairy farms with more than 2.5 LU/ha. These amounts indicate that changes in the way farmers handle nutrients on their farm are necessary to avoid high levies otherwise MINAS can seriously threaten viable economic performance. Strikingly, the less intensive dairy farms had to pay a higher average levy.

Several studies on nutrient management on dairy farms have already been done (e.g. Van de Ven, 1996; Berentsen, 1999; Aarts, 2000; Hack ten Broeke, 2000). These studies focus either on data collected on experimental farm 'De Marke', which was set up as an environmental prototype, or are based on normative model research. The current study is of empirical nature and focuses on changes in nutrient management at the farm level caused by MINAS regulations. The goal is to gain more insight into how commercial dairy farmers improve nutrient management and whether or not this affects their financial results.

[1] A farm is considered a specialised dairy farm by CBS if more than 66.7% of DSUs stems from dairy activities

1.2 Research objectives

The general objective of this research is to gain insight into nutrient management on specialised dairy farms, and the decisions farmers make to move towards the nutrient surplus standards of MINAS. More specifically, the following research questions will be addressed:

1) What are the possible implications of MINAS for different land-based farm-types;
2) What is the efficiency of nutrient use and nutrient productivity of specialised dairy farms and how has this changed in a three-year time span;
3) What is the importance of farm structure and farm management on nutrient surpluses and what are the implications for financial performance on specialised dairy farms;
4) What are the relevant farmer characteristics and farm strategies which direct change in nutrient management and performance of specialised dairy farmers;
5) How do specialised dairy farmers perceive the environment of their business and how does this relate to the choice for a farm strategy;
6) How do specialised dairy farmers plan nutrient management on their farms, to meet the final MINAS-standards.

1.3 Research framework

To answer the research questions raised in the §1.2, the study uses the conceptual framework outlined in Figure 1.1. The figure shows how the organisation of the farm, in its environment leads to its performance. The arrows represent the steps involved in decision-making, which ultimately result in farm performance.

The farmer is central in the model because he is the crucial element in the operation of the family farm. He is the owner, manager and craftsman and as such he has total management responsibility (sometimes shared with spouse and/or children). He defines the mission or long-term goal that he wants to achieve with his farm, selects relevant data from his environment, translates it into useful information for meeting this mission, and gathers information from his own farm to evaluate past decisions (dotted arrow). These external and internal analyses will lead to new decisions regarding structure and management, depending on his personal preferences. This idea of management is generally called the strategic management concept (David, 2001) and is applicable to agriculture according to Harling (1992).

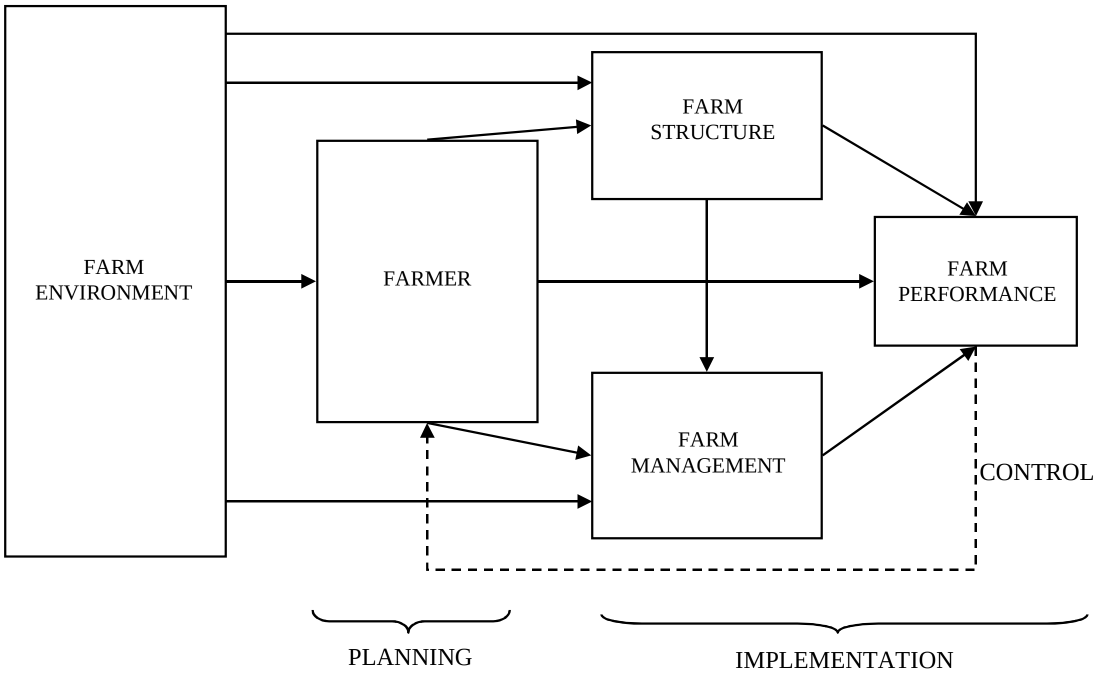

Figure 1.1 Conceptual framework for analysis

In literature management is defined as the process of allocating and utilising resources to achieve specific objectives through the functions of planning, implementation and control and it is often called the 'fourth factor of production' (see e.g. Case and Johnston, 1953; Rougoor, 1998). The drives, motivations, and objectives of the farmer are the driving forces behind decision-making. In addition, the social, political, technological and economical environment is constantly influencing him. This environment is becoming increasingly important since agriculture has to reposition itself within the food system and the rural economy (Ward and Munton, 1992). Not only pollution but also other aspects of production like animal welfare and landscape issues require a high level of flexibility and adaptability at the farm level.

1.4 Project Praktijkcijfers, the FDP-project

This thesis is based on data collected by a project called Farm Data in Practice (FDP, in Dutch: 'Project Praktijkcijfers'). The project resulted from a discussion between policy makers and farm organisations on the feasibility of the final MINAS surplus standards of 2003. Research showed that *if* farmers would meet the levy free surpluses, the maximum nitrate content of groundwater as directed by the EC would be met (Oenema *et al.*, 1998). Farm organisations (LTO) on the other hand considered the MINASsurplus standards infeasible on commercial farms. The project had two main goals. First and foremost, insight into nutrient management on commercial farms and the feasible level of nutrient surpluses when working according to Good Agricultural Practice (GAP) needed to be determined. GAP was not clearly defined at the beginning of the project and was therefore based on the then prevailing technical guidelines for feeding and fertilisation. The second goal was to disseminate the results of the project to Dutch agriculture so that 50% of all Dutch farmers would be aware of the experiences and results of the FDP-project. The results of the FDP-project were to be used in the evaluation of the manure policy in 2000 (Anonymous, 1996).

Model-based research indicated that improvements in performance and nutrient balances could be made by improving tactical and operational management (e.g. Van de Meer and Van de Putten, 1995; Hellegers, 1996). Management was therefore the focus of the project and no structural changes were asked from the participants. Approximately 240 participants in the 3-year (1997-1999) project focussed on tactical and operational management to show what is feasible in terms of nutrient surpluses. Five farm types, all land-based, were studied in the FDP-project. The focus on land-based farms follows from the objective of MINAS, which is to lead towards a balanced fertilisation of land. Farms in the FDP-project were selected out of a voluntary enrolment, to meet a predetermined stratification that represented the spread of farms and soil types over The Netherlands. Furthermore, the phosphate conditions of the soil had to be sufficient (Anonymous, 1996). The project proved to be a success and a sequel was started in 2000 (FDP-II), in which both ‘old’ and new farmers participated.

1.5 Outline of the thesis

The thesis is arranged according to the research questions outlined in §1.2. It passes from right to left through the model presented in Figure 1.1, and concludes with a chapter on nutrient management planning by commercial dairy farmers. Chapter 2 gives a policy overview and describes the results of the participants (of all farm types) of the FDP-project. The contribution of farm structure and farm management to the nutrient surpluses and the gross margin per unit of milk production is studied in chapter 3. Chapter 4 determines the efficiency of nutrient use and calculates the change in productivity of nutrients over a three-year time span. Furthermore, the relationship of farm structure and farm management characteristics with between nutrient efficiency and nutrient productivity are analysed. Chapter 5 analyses a management survey conducted in 1998 by the Agricultural Economics Research Institute (LEI). It identifies the farmer characteristics important for change in nutrient management, and the relationship between farm strategies and the direction of change. Chapters 3-5 are based on the data of specialised dairy farms in the FDP-project. Chapter 6 describes the results of another survey, executed in 2000, focussing on measurement of the external environment of the FDP-farms and the uncertainty this creates for farmers in relation to the strategies farmers choose. Both specialised dairy farms as well as mixed dairy farm types are studied. Chapter 7 uses data from participants in both the FDP-project and FDP-II to analyse the way in which farmers plan to meet (or consciously decide not to meet) the final MINAS surplus standards of 2003. It is a case-study analysis, in which detailed background information from FDP-I is used to try to explain the choices regarding nutrient management planning on specialised dairy farms in FDP-II. Chapter 8 combines the results of the different chapters into a general discussion and gives the main conclusions of this thesis.

II The Dutch Mineral Accounting System and the European Nitrate Directive: Implications for N and P management and farm performance

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Abstract

Agricultural nutrients can be a significant source of groundwater pollution. This paper studies the possible effects on farm management of a newly introduced policy instrument to control nitrogen and phosphorus pollution of groundwater bodies in The Netherlands. Ecological, technical, political, as well as financial issues, associated with the agricultural nutrient pollution problem, are considered. In response to the concern of the European Community for pollution of groundwater, The Netherlands implemented the Mineral Accounting System (MINAS), which focuses on nutrient (nitrogen and phosphorus flows) on individual farms, and taxes farms whose nutrient surplus exceeds a defined limit. To investigate the implications of MINAS for individual farm performance, financial and nutrient bookkeeping data of 194 farms, distributed over 5 farm types, were collected from 1997 through 1999. This paper shows that nutrient management performance of farmers varied largely between and within farm types, not only in absolute figures but also in terms of nutrient efficiency. The study also indicated that levies or taxes for excess nutrient surpluses could be high, ranging from €179 per ha for arable farmers to €404 per ha for mixed dairy and intensive livestock producers. These levies would reduce gross margin by 8% on average and can threaten continuity on an individual farm level. Therefore, current performance has to change considerably for farmers to be able to make the final surplus standards in 2003. Furthermore, as a consequence of objections of the European Community to the Dutch policy, application standards for manure were introduced. This study showed that this does not prove to guarantee safe nutrient management as well as MINAS does, but will impact financial performance more, due to higher manure disposal costs.

2.1 Introduction

In the past decade it has repeatedly been shown that agriculture is a significant source of ground- and surface water pollution (e.g. Heathwaite *et al.*, 1996; Yadav *et al.*, 1997; Carpenter *et al.*, 1998; Hadas *et al.*, 1999). Consequences are possible health hazards like the 'blue baby syndrome' and stomach cancer, which are associated with an overexposure to nitrogen (Harrison, 1996), and neurological damage which has recently been associated with toxic chemicals produced by a dinoflagellate, which is able to bloom in the presence of excessive phosphates (Carpenter *et al.*, 1998). Probabilities of occurrence of these hazards in developed countries are low since drinking water is cleansed thoroughly (Griffith, 1999). However, costs of drinking water purification are high and will increase in the future if nutrient levels do not decrease. Another urgent problem associated with nutrient pollution by agriculture is eutrophication of surface and marine waters, which has many negative effects on aquatic ecosystems, like explosive algae growth, causing hypoxia (oxygen shortage) (Carpenter *et al.*, 1998; Rejesus and Hornbaker, 1999).

The problems accompanying leaching of agricultural nutrients has led to a variety of policy measures in Europe ranging from strict regulations to voluntary adaptation of financially attractive management practices by farmers, often dubbed Best Management Practices (BMPs). The European Community (EC) initially focussed its efforts on water for human consumption (Goodchild, 1998). Since the early 1990s the EC shifted its concerns towards the environmental effects of excess nutrients, particularly nitrogen. This resulted in several directives of which one has direct impact on agriculture: Council Directive 91/676/EEC, also called The Nitrate Directive. The Nitrate Directive concerns the protection of water against pollution caused by nitrates from agricultural sources (EEC, 1991). The main goal is to ensure nitrate safety of European drinking water through upholding a maximum level of 50 mg nitrate (NO_3) or 11.3 mg nitrogen (N) per litre of groundwater. Implementation (by 1994) of the Directive is the responsibility of individual member states (Frederiksen, 1994).

Dutch agriculture is one of the most intensive ones in the world in terms of capital and external nutrient inputs (Van Bruchem *et al.*, 1999). Rapid intensification of livestock production, a result of the focus on increasing productivity from the 1950s onward, has contributed to a large increase in nutrient surpluses (Oenema *et al.*, 1998). Dutch policy concerning nutrient pollution by agriculture stems from the mid-1980s when the Manure and Fertiliser Act and the Soil Protection Act were introduced (Breembroek *et al.*, 1996; De Walle and Sevenster, 1998). In 1998 the Dutch government introduced the Mineral Accounting System (MINAS) which taxes every farmer individually, based on nutrient surpluses generated on his farm. MINAS was introduced to ensure compliance with the EC Nitrate Directive.

To date, the study of the impact of MINAS and the EC Nitrate Directive on environmental and financial performance of individual farms has lacked empirical evidence. This lack of knowledge hampers proper decision making for all parties involved, i.e., policy makers, farm advisors, and individual farmers themselves. The goal of this study is therefore to show the implications of both measures for Dutch land-based farms. Using detailed financial and nutrient accounting data from a sample of 194 farms from 1997 through 1999, the paper first shows environmental performance in terms of nutrient surpluses. Second, the financial consequences of this level of environmental performance are assessed for both the Dutch Mineral Accounting System and the EC Nitrate Directive. Third, the possible implications for nutrient management on Dutch dairy farms are considered, using a measure of nutrient efficiency and deviations from the final surplus standards. Finally, a comparison of MINAS surpluses and deviations from the European application standards for nitrogen from manure shows the efficacy of both measures in managing nutrient pollution of groundwater in The Netherlands.

2.2 Policy overview

The European Nitrate Directive (91/676/EEC) states that member states must monitor all waters and identify zones vulnerable to agricultural nitrate leaching. A Code of Good Agricultural Practice has to be established and an Action Program concerning the vulnerable zones must be formulated and contain restrictions on manure application (Frederiksen, 1994). The Netherlands have been monitoring groundwater bodies for years, and an increasing number of extraction points exceeded the allowed 50 mg of NO_3 (De Walle and Sevenster, 1998). The Dutch government decided therefore to designate their whole territory as a vulnerable zone. A direct implementation of the manure application restriction would thus affect all farmers and would lead to a serious cutback in cattle, pig and poultry production. Instead of this general approach, MINAS was introduced to be able to individually address nutrient management on farms. MINAS is a 'farm gate balance approach' (Brouwer and Kleinhanss, 1997; Van den Brandt and Smit, 1998) that calculates the difference between nutrients entering and leaving the farm 'through the farm gate'. Figure 2.1 gives a graphic overview of the system.

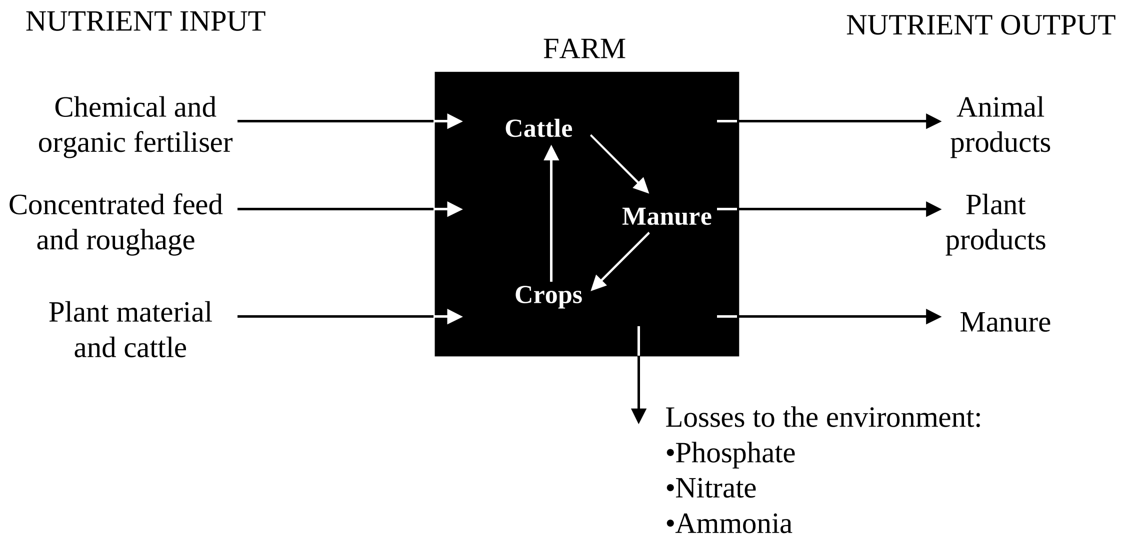

Figure 2.1 The concept of MINAS, considering the farm a black box (based on: Wossink, 2000)

Only nitrogen and phosphorus entering (input) and leaving (output) the farm through the farm gate is taken into account while the farm itself is considered a black box. The difference between inputs and outputs is called the farm surplus and is assumed to be lost to the environment. The surpluses are regulated by comparing them to environmentally safe surplus standards, also called levy free surpluses (LFS). If the individual farm surplus exceeds the LFS, the farmer will be taxed for every kilogram of nitrogen or phosphate exceeding the LFS. Expressing phosphorus in terms of phosphates in MINAS stems from earlier Dutch nutrient policy, in which phosphate (P_2O_5) was chosen as the common unit to be used in policy-making. Nitrogen was likewise chosen as the basis for future policy, to be compatible with European regulations. The MINAS system neglects inputs like atmospheric deposition, mineralisation, and biological nitrogen fixation that do not enter or leave the gate but are the result of natural processes. In spite of this shortcoming, a farm-gate approach like this is often preferred for policy purposes, because of its simplicity and relative ease of data acquisition (Oenema and Heinen, 1999).

Initially, the surplus standards would gradually be reduced until 2008 when, for nitrogen, the European-wide desired 50 mg of NO_3 per litre of groundwater would be met (Oenema *et al.*, 1998). Since the first announcement of the introduction of MINAS things have changed dramatically (e.g. Van den Brandt and Smit, 1998; Oenema and Roest, 1998). The EC did not accept the proposal of the Dutch government because, according to the EC, MINAS did not sufficiently address the application of manure. Furthermore, goals would be effectuated too late (2008/2010), and the levies were considered insufficient to be an incentive to farmers to reduce nutrient losses (Brinkhorst, 2000). The Dutch government responded to these critiques with a proposal for application standards (AS) for manure (Brinkhorst and

Pronk, 1999). These standards exceed the ones stated by the EC by 80 kg of N in 2003 for grassland (250 kg N ha^{-1} instead of 170) and level with the EC standards for arable land (170 kg N ha^{-1}). Using the option of derogation for grassland, the Dutch government argues that long growing seasons with high nitrogen uptake ensures meeting safe drinking water standards. MINAS will be used as a safety-net (Willems *et al.*, 2000). A Manure Transfer Agreement System (MTAS) will be introduced in which farmers who have excess manure must have a contract with a farm, which has excess application space to ensure that manure production does not exceed application possibilities. Furthermore, the final LFS are shifted from 2008 backward to 2003 in order to reach a balanced fertilisation in time, and levies will be increased. Starting 2002, 1 kg of nitrogen will be taxed with € 2.27 instead of € 0.68. Excess phosphate will be taxed with € 9.08 instead of € 2.27 for the first 10 kg and € 9.08 for each additional kg (Brinkhorst and Pronk, 1999). The reason for these increases is to make it less (or not at all) attractive for farmers to find an 'optimal' nutrient surplus, where the marginal costs of the levy is equal to the marginal returns of extra output. Table 2.1 shows the currently used LFS (1998-2001) and new LFS and AS to be implemented in 2002.

Table 2.1 Nutrient policy in The Netherlands: Levy free surpluses for nitrogen and phosphate within the Mineral Accounting System, and application standards for nitrogen from manure

	1998-1999	2000-2001	2002	2003[a]
Levy free surpluses in kg N ha^{-1} yr^{-1} or kg P_2O_5 ha^{-1} yr^{-1}[b]				
Grassland				
N surplus	300	250	190	180
P_2O_5 surplus	40	35	25	20
Arable and fallow land				
N surplus	175	125	100	100
P_2O_5 surplus	40	35	25	20
Conservation areas				
N surplus	50	50	50	50
P_2O_5 surplus	10	10	10	10
Application standards in kg N ha^{-1} yr^{-1}				
Grassland			300	250
Arable land, ex. fodder maize land			170	170
Fodder maize land			210	170

[a]More stringent measures are announced for sandy soils vulnerable to leaching (levy free surplus 140 kg N on grassland and 60 kg N on arable land). Locations of sandy soils have not yet been designated however

(Source: Brinkhorst and Pronk, 1999).

[b]P = P_2O_5/2.291

2.3 Materials and methods

2.3.1 Sample selection

Research has shown that *if* farmers would meet the levy free surpluses, the maximum nitrate content of groundwater as directed by the EC would be met (Oenema *et al.*, 1998). A discussion between policy makers and farm organisations on the feasibility of the surplus standards initiated a project called Farm Data in Practice (FDP, in Dutch: 'Project Praktijkcijfers'). Model-based research indicated that improvements in performance and nutrient budgets could be made by improving tactical and operational management (e.g. Van de Meer and Van de Putten, 1995; Hellegers, 1996). Approximately 240 participants in the 3-year (1997-1999) project focussed on tactical and operational management to show what is feasible in terms of nutrient surpluses. Five farm types, all land-based, were studied in the FDP project. The focus on land-based farms follows from the objective of MINAS, which is to lead towards a balanced fertilisation of land. Farms in the FDP project were selected out of a voluntary enrolment, to meet a predetermined stratification that represents the spread of farm types and soil types over The Netherlands. Furthermore, phosphate conditions of the soil had to be sufficient (Anonymous, 1996).

For the analysis only farms with complete data for three years were used. Data include a detailed financial account as well as technical data on production, farm characteristics and management. Furthermore, a MINAS bookkeeping was collected from each participant. Nitrogen and phosphorus in all feed, fertilisers, and animals are considered inputs, while nitrogen and phosphorus in all animals, animal products, plant products, and manure are taken as outputs. According to MINAS regulations, data of N and P content in concentrates and chemical fertilisers were provided by the suppliers to the farmers. N and P content of organic manure (both incoming and outgoing) was assessed using samples that were sent to laboratory, and standards were used for N and P in roughage, animals, animal products and plant products. According to Dutch policy convention all N was expressed in N, and all P expressed in P_2O_5. In the remainder of the study, nitrogen and N will be used to indicate all nitrogen, in whichever form present. Similarly, phosphates and P_2O_5 will be used to indicate all phosphorus.

Organic farms were discarded from the analysis because of the significant differences between nutrient management on conventional and organic farming systems (see e.g. Korsaeth and Eltun, 2000). Furthermore, farms were not allowed to have switched between farm types during the three years under investigation. This way, a homogenous sample of farms with regards to nutrient management characteristics was created. A total of 194 farms were used in the analysis, which were split into 5 different farm types according to the portion of Dutch Size Units (DSUs), an economic size unit, based on standard gross margins (GMs)

(CBS, 1998), of different farm enterprises. A 95% limit was used, meaning that at least 95% of all DSUs had to be either dairy or arable to be classified as a specialised dairy or arable farm respectively. Below the 95% boundary farms were classified as mixed dairy and intensive livestock farms, mixed dairy and arable farms and mixed arable and intensive livestock farms, depending on the largest portion of other farm enterprises (intensive livestock mainly includes pigs and poultry). Figure 2.2 shows the spread of the farms over the Netherlands and Table 2.2 gives an overview of the main farm characteristics. Livestock Units (LUs), mentioned in Table 2.2, are based on phosphorus production in manure per animal species. The reference point is the phosphorus production of a milking cow (=1 LU).

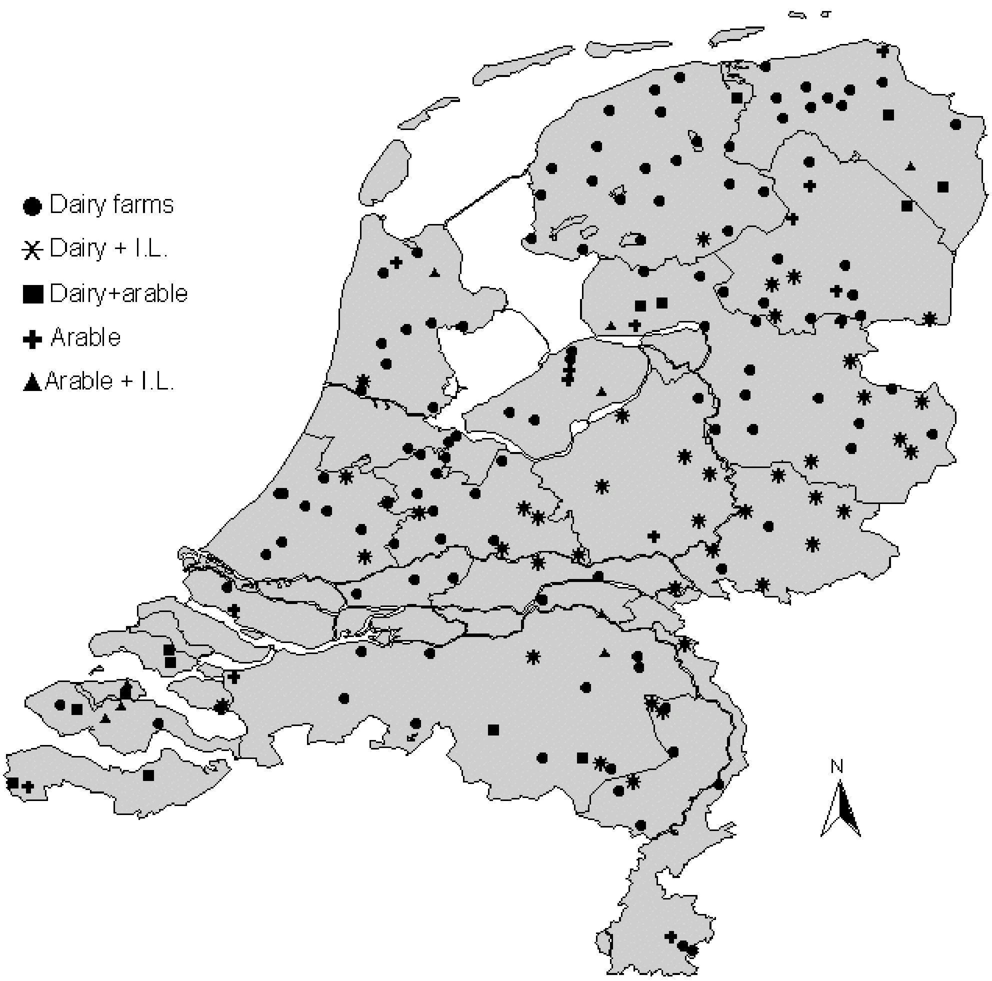

Figure 2.2 Sample spread over the Netherlands and type of farms in the sample

Table 2.2 Main characteristics of farms per farm type; three-year averages (1997-1999) and standard deviations in parentheses

	Dairy	Dairy + IL[a]	Dairy+arable	Arable	Arable + IL[a]
# of farms	114	42	14	15	9
Total hectares[b]	41 (12)	33 (14)	54 (26)	63 (24)	43 (20)
Grass (ha)	35 (11)	26 (12)	25 (13)	1 (2)	1 (3)
Fodder maize (ha)	6 (6)	7 (4)	10 (4)	0 (0)	0 (1)
Arable land (ha)[c]:	0 (0)	0 (1)	17 (17)	60 (22)	41 (20)
% root crops[d]	100 $(0)_{N=3}$	67 $(58)_{N=3}$	68 (37)	51 (8)	52 (12)
% cereals[d]	0 $(0)_{N=3}$	22 $(38)_{N=3}$	5 (11)	28 (15)	29 (5)
% field vegetable[d]	0 $(0)_{N=3}$	0 $(0)_{N=3}$	7 (18)	8 (10)	8 (9)
# of dairy cows	71 (22)	55 (16)	66 (24)	0 (0)	0 (0)
Livestock Units dairy	92 (29)	72 (23)	88 (33)	1 (5)	3 (10)
Livestock Units IL[a]	0 (2)	64 (42)	9 (34)	0 (0)	185 (133)
FPCM/ha [e]	14425 (3581)	14654 (3633)	16344 (4452)	0 (0)	0 (0)
Gross Margin (€)[f]	27.4 (2.1)	32.3 (6.3)	36.7 (11.9)	1701 (363)	3322 (1076)

[a]IL = Intensive Livestock production

[b]Total hectares consists of grass + fodder maize + arable land + fallow land/conservation areas

[c]Arable land consists of root crops + cereals + field vegetable + other crops

[d]Subscript indicates the actual number of farms producing the respective crops

[e]FPCM/ha = Kg of fat and protein corrected milk per ha roughage production

[f]Gross margin is calculated per 100 kg FPCM for specialised dairy, dairy + IL and dairy + arable farms. Gross margin is calculated per ha for specialised arable and arable + IL farms

2.3.2 Environmental performance

Similar to Aarts *et al.* (1992), three-year averages were used to represent farms and their performance. In this way weather and other potentially influential characteristics of a certain year, like stock changes, were averaged out. Averages and standard deviations were calculated for each farm type to show the state of performance and variation between and within farm types. Both the MINAS N and P_2O_5 balance were calculated for the sample. Beside data on the balance sheet, another important figure in the analysis is 'nutrient use efficiency' or NUE (Aarts *et al.*, 1988; Van Bruchem *et al.*, 1999). The NUE was calculated as the ratio between outputs and inputs of either N or P_2O_5 and represents the efficiency with which farmers used the imported nutrients. Equation 1 and 2 show the relationship between efficiency and the nutrient surplus.

$$Surplus / ha = input / ha - output / ha \quad (1)$$

$$Surplus / ha = \left[1 - \frac{output}{input} \right] \times input / ha \quad (2)$$

Equation 2 shows that if NUE increases, the surplus will decrease. The absolute amount of input can be seen as an intercept: the more input a farmer uses, the more efficient he needs to be to generate a similar surplus as the surplus of the farmer who uses less input.

2.3.3 Implications of MINAS and Nitrate Directive

The implications of the environmental performance in terms of the final MINAS levies were calculated according to MINAS regulations. According to these regulations, the nitrogen surplus was reduced with a fixed loss per animal to correct for volatilisation. Next, the LFS was deducted to calculate the taxable surplus. If this was larger then 0, it was multiplied by € 2.27 to determine the levy for nitrogen. A similar procedure exists for phosphate, which does not volatilise. Instead, phosphates from chemical fertilisers were deducted from the total surplus and the remaining surplus was then compared to the LFS. Where it exceeded 0, it was multiplied by € 9.08. The LFS was considered a variable cost in this study and was therefore deducted from the gross margin to show the implications of the system for financial performance.

The Nitrate Directive was translated into application standards for manure (Table 2.1). They do not restrict manure application directly but through a limit on the amount of cattle that is allowed on a farm. Regulations state that if manure production exceeds the application standards, a farmer will have to contract land from a farm, which has excess room for application. This does not mean that a farmer is forced to remove manure from the farm to the contracted land. The use of nutrients from manure is still controlled by MINAS. In this study, the individual application standard was calculated on the basis of three-year averages for land and the nitrogen production for animal manure was based on the three-year averages of animal numbers, multiplied by a standard production (LNV, 1998). Both were calculated on a hectare basis and the difference between the production and the application standard indicates how much nitrogen from manure a farm produced above (excess) or below (shortage) the hectare based standards. The relationship between MINAS and the Nitrate Directive was analysed by graphically comparing the MINAS nitrogen surplus to the Nitrate Directive.

2.3.4 Feasibility of LFS

Whether or not the final surplus standards of 2003 are feasible, depends on two issues. First of all, the relationship between efficiency and surplus is important. If farms with high nutrient surpluses also show high nutrient efficiencies, there is hardly any room to reduce a high surplus by improving nutrient management. On the other hand, when farms with high surpluses show low efficiencies, they may be able to reduce surpluses with relative ease. More accurate management with regards to timing of fertilisation, and fertilising and feeding based on the needs of plant and animal could accomplish this. Correlation analysis was used to show the relationship between NUE and the MINAS surplus for both nitrogen and phosphate.

Second, the time period in which farms will have to meet the standards is short. Efficiency improvement might not be the only necessary change when farms currently show a large deviation from the future LFSs. Farms with large deviations from the final standards will have more difficulty meeting the 2003 standards then do farms that are already in close proximity. This would mean that unless they are able to reduce their surplus by means of manure disposal, radical changes like a restructuring, will be needed for Dutch agriculture to meet the environmental safety standards set by the government. A graphical analysis shows the distribution of the deviation from the LFS for both nitrogen and phosphate.

2.4 Results

2.4.1 Environmental performance

Table 2.3 shows the MINAS balance for nitrogen and phosphate as well as NUE-N and NUE-P_2O_5. Large variation existed between as well as within farm types. Lowest surpluses were generated by arable farms for both nitrogen and phosphate, 77 and 19 kg ha^{-1} respectively. The mixed dairy and intensive livestock farms showed worst performance in terms of nutrient surpluses with 344 and 54 kg ha^{-1}. Specialised dairy farms had an equal phosphate surplus of 54 kg ha^{-1}. Within variation was also large however, which can be shown by calculating the coefficient of variation. For nitrogen the coefficient of variation ranged from 21% for mixed dairy and intensive livestock farms to 86% for specialised arable farms. For phosphate the range was 31% to 119% for the same farm types.

Table 2.3 Three-year averages of nitrogen and phosphate balances in kg ha^{-1} yr^{-1}, Nutrient Use Efficiency (NUE) and results ranges, standard deviations in parentheses

	Dairy		Dairy + IL[a]		Dairy + arable		Arable		Arable + IL[a]	
INPUT	N	P_2O_5[b]	N	P_2O_5[b]	N	P_2O_5[b]	N	P_2O_5[b]	N	P_2O_5[b]
Feed	148 (68)	54 (22)	382 (192)	153 (76)	159 (103)	56 (37)	0 (2)	0 (0)	574 (473)	233 (197)
Fertilizer	251 (67)	32 (20)	217 (43)	16 (14)	250 (66)	41 (19)	154 (61)	28 (16)	140 (44)	22 (20)
Organic manure	14 (19)	8 (10)	4 (7)	2 (4)	27 (32)	16 (21)	83 (34)	54 (25)	5 (11)	2 (4)
Start material	1 (2)	1 (1)	17 (15)	9 (8)	2 (4)	1 (2)	3 (1)	1(1)	15 (16)	5 (5)
OUTPUT										
Animal products	88 (21)	37 (9)	184 (76)	82 (35)	79 (34)	34 (15)	0 (1)	0 (1)	240 (175)	86 (43)
Plant products	1 (4)	0 (1)	3 (8)	1 (3)	54 (29)	21 (11)	163 (8)	64 (3)	157 (16)	62 (6)
Organic manure	12 (27)	4 (10)	89 (92)	43 (45)	20 (28)	8 (12)	0 (0)	0 (0)	106 (218)	71 (162)
RESULTS										
Surplus	313 (72)	54 (21)	344 (71)	54 (17)	285 (81)	51 (20)	77 (66)	19 (22)	231 (134)	43 (32)
Range	166 ↔ 558	7 ↔ 135	190 ↔ 505	20 ↔ 98	139 ↔ 397	4 ↔ 73	-22 ↔ 201	-9 ↔ 65	49 ↔ 509	-16 ↔ 75
NUE	24 (6)	45 (12)	42 (12)	65 (16)	35 (10)	56 (16)	73 (22)	82 (20)	66 (13)	79 (16)
Range	13 ↔ 53	20 ↔ 83	16 ↔ 64	33 ↔ 90	23 ↔ 57	34 ↔ 91	46 ↔ 117	50 ↔ 118	51 ↔ 91	60 ↔ 108

[a]IL = Intensive Livestock production

[b]$P = P_2O_5/2.291$

Between and within variation were apparently inversely related. Between variation can be explained by differences in farming systems, whereas within variation is partly determined by farm layout characteristics like cattle density or cropping plan and partly by management characteristics like fertilising and feeding considerations. Differences in within variation between farm types can be explained by the amount of control that can be exercised on the production process. This is lowest in arable farming systems and highest in intensive livestock production.

Table 2.3 shows that the arable farms had the highest NUEs, whereas the dairy farms had the lowest ones. The intensive livestock producers were in between since addition of the enterprise to arable farms decreased the NUE and addition of the enterprise to dairy farms increased NUE. The reason behind this phenomenon is the volatilisation loss that occurs during manure production and utilisation. Arable farms do not produce any manure and have only the necessary manure supplied to their farm. Dairy farms on the other hand produce and use most of the manure on their farm. Intensive livestock producers generally do not have the land available to use the manure for their own purposes and need to dispose of it. Furthermore, MINAS uses fixed standards to account for arable output. These standards are generally high compared to real output, which increases the NUE for arable farms even further. The NUEs calculated in this study differed from the ones in Aarts *et al.* (1992) and Bruchem *et al.* (1999), which incorporated atmospheric deposition and stock changes. In this study NUE was based on inputs and outputs as they were determined by MINAS. This made a comparison invalid. N-efficiency was smaller than P_2O_5-efficiency due to the nature of the N-cycle. Natural processes like ammonia volatilisation and denitrification all cause leaks in the N-cycle (Rauschkolb and Hornsby, 1994). This causes the maximum possible N-efficiency to be within 70% and 90% depending on multiple factors (Miller and Donahue, 1995). Since these processes do not occur in the P-cycle, efficiencies of 100% are possible, efficiencies above 100% indicate exhaustion of soil phosphates.

2.4.2 Implications of MINAS and the Nitrate Directive

The results from Table 2.3 showed large differences both for nutrient surpluses as well as efficiency between and within farm types. The implications of these results with regards to MINAS-compliance are shown in Table 2.4.

Table 2.4 Percentage of farms exceeding the Levy Free Surplus (LFS) for 2003, average levies and gross margin (GM) after levies, average Application Standards (AS), percentage of farms exceeding the AS and average nitrogen excess and shortage (standard deviations in parentheses)

	Dairy	Dairy + IL	Dairy+arable	Arable	Arable + IL
Dutch MINAS					
% > LFS '03	98%	100%	100%	33%%	67%
Levy/ha (€)[a]	330 (186)	404 (192)	276 (166)	179 (218)	344 (160)
% > LFS '03$_{incl.\ P2O5\ (cf)}$	100%	100%	100%	53%	78%
Levy/ha$_{incl.\ P2O5\ (cf)\ (€)}$[a]	579 (299)	545 (218)	540 (275)	212 (221)	530 (142)
GM$_{after\ levy}$ (€)[b]	25.1 (2.6)	29.2 (6.0)	34.1 (11.8)	1639 (383)	3064 (940)
GM$_{after\ levy\ incl.\ P2O5\ (cf)}$ (€)[b]	23.3 (2.9)	28.2 (6.2)	31.3 (11.0)	1586 (391)	2882 (991)
European AS for nitrogen from manure					
AS '03 kg N/ha	239 (10)	232 (8)	207 (13)	169 (3)	172 (8)
% > AS '03	96%	100%	71%	0%	89%
Excess kg N ha^{-1}	98 (68)	257 (150)	122 (78)		220 (394)
Shortage kg N ha^{-1}	22 (20)		41 (35)	164 (17)	17[c]

[a]Excluding levies of € 0

[b]GM is calculated per 100 litres of FPCM for specialised dairy, dairy + I.L. and dairy + arable farms. GM is calculated per ha for specialised arable and arable and I.L. farms

[c]N=1; no standard deviation can be calculated

Table 2.4 shows the percentage of participants that would have to pay a levy and the average levy (excluding € 0-levies) for both the current situation, and a situation in which phosphates from chemical fertiliser were no longer excluded from taxation. Furthermore, GMs after levies were calculated for both these situations. Beside a decrease in LFS, farmers must also take into account application standards for nitrogen from manure. Table 2.4 also shows the average application standards (AS) per farm type, the percentage of participants that exceeded the nitrogen application standards and the level of the excess for which farms would have to close a contract.

When no actions are taken, most farms, regardless of farm type, will exceed the LFS standards in 2003. Levies per ha differed significantly, showing the difference between farms that were close to meeting the standards and those who lagged behind. When phosphates from chemical fertilisers were included in the surplus, the percentage of farmers that did not make the standards went up, as well as the average levy farmers had to pay. For an individual farm levies could be very high, over €800 per ha, and over €45,000 total, posing a serious threat to continuity and economic viability. GMs were reduced by 4% for arable farms and up to 10% for mixed dairy and intensive livestock farms. On average a decrease of 8% in GM was induced. These numbers were 10%-20% and an average of 14% in case phosphates from chemical fertiliser were included. It is clear from Table 2.4 that farmers will have to start acting, not only to meet the standards but also to maintain a financially viable farm.

As with the LFS, nearly every farm with animal production exceeded the AS. Excesses were large and varied considerably among farms, depending on livestock density. In this study nitrogen production was based on standard production figures for 1998 (LNV, 1998). In the future, nitrogen production standards will be differentiated for production level, resulting in a lower percentage of farms that exceed the application standard.

Figure 2.3 shows the nitrogen surplus as a function of the deviation from the application standard that will become effective in 2003. Each dot represents a farm. An asterisk indicates a farm that does not meet the surplus standards of 2003 yet, whereas a circle represents those farms that do.

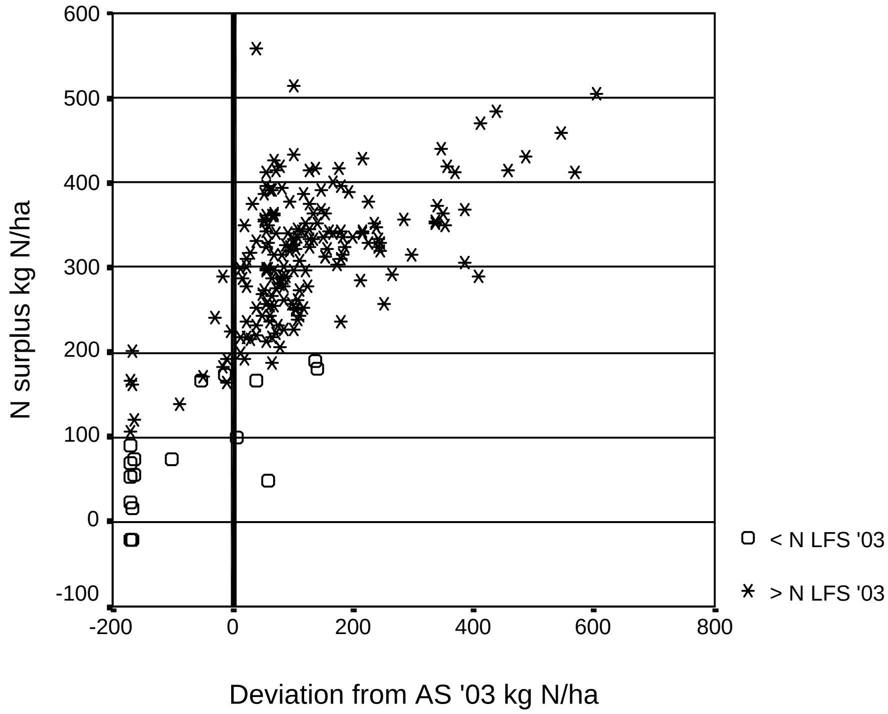

Figure 2.3 Scatterplot of farms in the sample currently exceeding the application standard (AS) for 2003 in relation to MINAS nitrogen surplus

As can be seen from Figure 2.3, most farms did not perform within the proposed limits of 2003. Only a few farms (3%) that exceeded the application standard (right of the vertical line) met the MINAS standards and in doing so posed a small environmental burden on their farmland. On the other hand, farms that had plenty of room for manure placement (left of the vertical 0-line) managed to achieve lower surpluses but did not meet the MINAS standards (52%), due to a large proportion of arable land, which allows for lower surpluses (Table 2.1). Figure 2.3 is an indication that the Nitrate Directive, translated into application standards might not necessarily guarantee safe nutrient management on an individual farm. Even though it might bring about 'balanced fertilisation' at a national level, pollution on individual farms is still possible.

2.4.3 Feasibility of LFS

The relationship between NUE and the nutrient surplus are quantified in Table 2.5, using Pearson correlation.

Table 2.5 Pearson correlation between surplus and Nutrient Use Efficiency for nitrogen and phosphate per farm type

	Dairy	Dairy + IL	Dairy+arable	Arable	Arable + IL
Nitrogen (N)	-0.25**	n.s.[a]	-0.72**	-0.95**	n.s.[a]
Phosphate (P_2O_5)	-0.74**	-0.59**	-0.94**	-0.96**	-0.85**

** Correlation is significant at the 0.01 level (2-tailed)

[a] No significant correlation was found

The relationship between nitrogen surplus and efficiency was not equally strong for all farm types. The correlation between NUE-N and the nitrogen surplus was not as strong as the one for NUE-P_2O_5 and the phosphate surplus. The presence of cattle seemed to decrease the strength of the relationship for nitrogen until no significance could be found anymore for the most intensive livestock producers. This was likely due to the disposal of manure from the intensive livestock enterprises. All correlations for phosphate were highly significant and showed a similar decrease as nitrogen, when cattle density increased. Nitrogen was apparently harder to track and control than phosphate.

Figure 2.4 shows the current level of deviation from the final surplus standards. The left panel in Figure 2.4 shows that most farmers (91%) did not comply with the final N surplus standards yet. The bigger part of those farms (75%) was within a range of 150 kg N ha^{-1}, 28% within 75 kg ha^{-1}. The right panel shows that a large part of the FDP participants (44%) has already met the 2003 standards for phosphate in 1998 when phosphates from chemical fertiliser were excluded from the taxable surplus. Almost half (42%) of those who didn't, was within 10 kilograms per ha of the standard. When phosphates from chemical fertilisers would be taxed, only 8% of the total sample would meet the LFS.

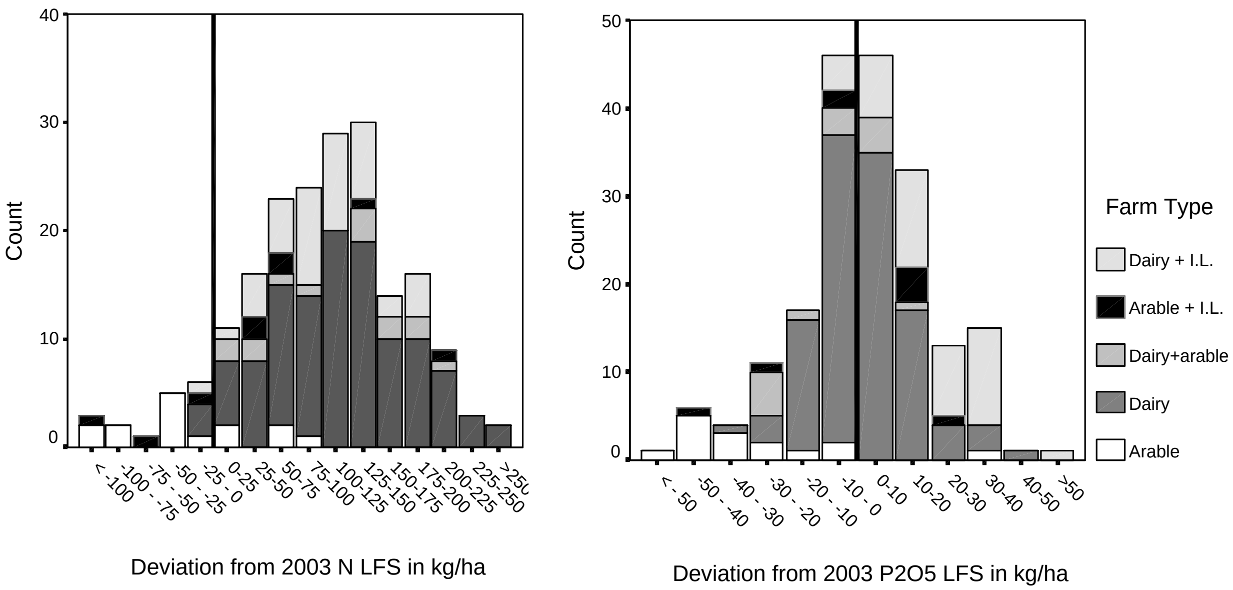

Figure 2.4 Deviation from the 2003 Levy Free Surplus (left panel: nitrogen; right panel: phosphate)

All farm types, except maybe the intensive livestock combinations, will benefit with regards to nitrogen surpluses if they would first focus on nitrogen efficiency rather than using other strategies like manure disposal or more rigorous measures like extensification of the farm resulting in less manure production per hectare. The distance to the surplus standard can be large however, and possibly more structural changes with regards to cropping plan and young stock for instance, might have to be considered for those farms. Considering phosphate, we can see that it is definitely in every farmer's best interest to first work on phosphate efficiency rather than turning to more extreme measures. Both Table 2.5 and Figure 2.4 show that the opportunity exists to reduce nutrient surpluses with relative ease. Increasing efficiency may also have financial consequences since a decrease in waste will result in a decrease in cost. Improving efficiency might therefore be a key issue in battling excess nutrients.

2.5 Discussion

MINAS embodies a new approach to environmental problems caused by agriculture. This new approach focuses on the individual farmer and his management, because studies have shown that diversity among adequate measures to reach balanced fertilisation is high among farms. Comparative studies have also shown that intensive farming systems do not necessarily produce higher surpluses than extensive ones, when quality of nutrient management on the farm is high. Nutrient management is therefore considered more important than farm characteristics like livestock density (Van de Brandt and Smit, 1998). Focussing on the individual farmer has two major advantages. First, individuals are considered polluters and are individually held accountable for their pollution, according to the 'polluter pays' principle. Second, individuals have control over their pollution problem and will be able to deal with it on an individual level instead of being forced to comply with general measures that may be ineffective for their specific situation. Due to objections of the EC however, Dutch farmers are also subjected to indirect AS for manure as a result of the EC Nitrate Directive. These standards alone do by no means guarantee safe nutrient management at the individual farm level, as was assessed in this study. Manure disposal might become problematic however, due to the AS. Tension on the manure market, leading to high disposal prices, will make it harder for a farmer to do away with manure. The implications of this weak disposability of manure on one end and the obligation to have disposal room of excess manure available on the other, is unclear but will impact the surplus.

Of the total sample studied, 92% is not yet able to meet the final surplus standards. A large part of the farms will most likely manage to fulfil the MINAS requirements for 2003 with relative ease since they are in close proximity to the LFS. An analysis of efficiency showed that farms with low efficiency have high nutrient surpluses for both nitrogen and phosphate, meaning that surpluses can be decreased by focussing on efficiency. If that is not enough, manure disposal is an option for reducing the surplus. When no disposal options are available however, changes in farm structure might have to be considered. Several reasons can be found for the high percentage of farms not meeting the standards. First of all, the final standards were not yet mandatory in 1997. This means that farm management was not aimed at meeting the targets. Furthermore, the introduction of MINAS was a stepwise process, with farms exceeding a livestock density of 2.5 LU ha^{-1} first to enrol in the system in 1998. Only in 2000, all other farms are subjected to the system. This manner of introduction led a lot of farmers to build up stock mainly for chemical fertilisers. These nutrients were accounted for in the year that they were bought but were likely meant for use in a subsequent year, when MINAS would become mandatory for the farm.

Farmers in the FDP project stated that MINAS provides enormous and often surprising insights into their management. Adjusting to this new way of farming might prove difficult however, because of possible mental boundaries. Producing less than technically possible in order to protect the environment is a relatively new thought in agriculture, not only in The Netherlands. More active management of feeding and fertilisation might prove necessary to meet the standards. Further research should therefore focus on several aspects of nutrient management. First the magnitude of the decrease in surplus that is possible by focussing on efficiency improvement should be investigated to get a better picture of the optimisation options of nutrient flows at the farm level. Second, the background of decisions of farmers should be examined to see why farmers make certain decisions with regards to optimising nutrient and financial management. These insights might be especially valuable since the

European Community is establishing a Water Framework Directive which focuses not only on groundwater but also surface water pollution (EEC, 1999) and will very likely lead towards even stricter regulations with regards to water pollution by nutrients.

2.6 Conclusion

The present study showed that large variation in nitrogen and phosphate surpluses exists within and between land-based farm types in The Netherlands. A serious reduction in surpluses is needed if farmers want to avoid levies imposed by MINAS. If a reduction is not achieved, the MINAS levy could threaten the continuity of individual farms. To avoid this, farmers in The Netherlands, regardless of farm type, are forced to change nutrient management on their farms. Depending on the level of the surplus, either changes in tactical and operational management, or more strategic choices with regards to farm structure, will have to be made. In doing so, a more sustainable agriculture, both with regards to the economy and the environment will be created.

The comparison of the Dutch MINAS system and the EC Nitrate Directive showed that MINAS would be more effective in solving the nutrient pollution problem. Even though the Nitrate Directive may lead to balanced fertilisation on a national level, individual farms may still pollute groundwater bodies due to irresponsible management of agricultural nutrients. It seems therefore obvious that one must continue to address (environmental) performance of farms individually, in order to generate the most effective changes in management possible. This involves rather complex policy measures however, and asks consultants to gear advice towards specific farm situations. For farmers this means more individual and entrepreneurial decision-making regarding their production goals, rather than producing according to the somehow persistent paradigm of production maximisation. The present analysis supports this multi-party, multi-criteria decision-making in that it addresses ecological, technical, political as well financial issues involved in agricultural decision-making.

III Nutrient efficiency and nutrient productivity growth on Dutch dairy farms

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Abstract:

Regulations regarding N and P have put pressure on the environmental performance of dairy farms in The Netherlands. This paper calculates DEA technical and nutrient efficiency measures, and develops a subvector Malmquist productivity measures to explore improvement of nutrient management by Dutch dairy farms in the period 1997-1999. The results showed an average nutrient efficiency of about 80% each year. Nutrient productivity showed an average growth of 60% per year, made up out of an average 31% nutrient technological change and 27% nutrient efficiency change. These numbers indicate that in a short time period large improvements can be made in the environmental department. Tobit analyses show that active rather that passive nutrient management, results in these considerable environmental performance improvements, while maintaining technical performance. This change from passive to active involvement in nutrient management can for the main part be accredited to activities of a nutrient management project initiated by the Dutch government in collaboration with farm organisations.

3.1 Introduction

Pollution of groundwater bodies by agricultural nutrients has led to strict European regulations with regard to nitrogen (specified in the Nitrate Directive (91/676/EEC)). The Nitrate Directive essentially limits the usage of nitrogen from manure for fertilisation purposes. Since Dutch agriculture is highly intensive in terms of cattle units per unit of land, this Directive would have a serious impact on the viability of individual farms if it were to be implemented directly. Dutch policy makers decided to deviate from the general standard for manure application and introduced a nutrient bookkeeping system, also called Mineral Accounting System (MINAS). MINAS allows farmers to individually address the nutrient problem on their farm, and fines those who do not manage to comply with the nutrient surplus standards (e.g. Van den Brandt and Smit, 1998, Ondersteijn *et al.*, 2002). The system is output oriented, meaning that farmers are fined according to their final nutrient surplus, irrespective of the way they arrive at it. In this way, the Dutch government aims at internalising the negative externalities (bads) associated with inefficient nutrient use. The incentive for change in nutrient management in The Netherlands will be most substantial in 2003, when MINAS has reached the final introduction phase[1] (Ondersteijn *et al.*, 2002). The practical feasibility of the final surplus standards has been and is still being questioned. To gain insight into this matter, the Dutch government and farm organisations joined forces and initiated a three-year nation-wide project, in which participating farmers received support to enhance nutrient management on their farms. The goal of the project was to investigate the feasibility of the surplus standards through changes in nutrient management, and gather and diffuse knowledge about nutrient management on commercial farms.

If farmers want to meet the final MINAS surplus standards of 2003 they have to improve nutrient performance. To do so, it is essential to learn from successful colleagues who can act as benchmarks, rather than focussing on average performance. Since the goal of (environmental) performance research is to improve this performance (Charnes *et al.*, 1994) a frontier approach, in which farm performance is measured relative to the best practice frontier, provides important insights. The estimated efficiency measures reveal the possibilities for improvement far better than for instance regression coefficients, which focus on average rather than best performance. Beside the position of farms with respect to the best practice farms, it is also useful to check whether or not possibilities for improvements over time exist. Either improving nutrient efficiency, i.e. moving towards the frontier, or changing the technology with which nutrients are used, i.e. a shift of the frontier itself, contribute to

[1] The final standards are set to 180 kg ha^{-1} of nitrogen (N) for land covered with grass and 100 kg for arable land. An excess of 20 kg of phosphate (P_2O_5) is allowed per hectare regardless of cropping type. Farmers will be taxed €2.30 for every kg of N that exceeds the standard, and €9.00 for every kg P_2O_5.

improvements in environmental performance over time. This paper contributes to the literature by developing the concept of subvector productivity change (productivity change in one dimension) in order to provide insight into the possibilities for improvement of nutrient performance, through efficiency and technical change.

Using the data of specialised dairy farms participating in the project, this paper studies the feasibility for Dutch dairy farmers to improve nutrient performance through technical and efficiency change. First, Data Envelopment Analysis (DEA) is used to estimate technical and nutrient efficiency. Second, overall productivity and nutrient productivity changes and the underlying technological and efficiency changes are calculated. This is done using the concept of Malmquist Total Factor Productivity and the development of a Malmquist Subvector Productivity Index. Finally, the DEA efficiency measures and measures of technical and efficiency change are explained using farm structure and farm management characteristics in Tobit regression analyses.

3.2 Method

3.2.1 Technical and nutrient efficiency

Farrell (Farrell, 1957) specified an operational definition of efficiency that complies with the theoretical definition of technical efficiency of Koopmans. The latter states that a producer is technically efficient if an input reduction requires an increase in another input or a decrease in at least one output (Koopmans, 1951). The Farrell measure of technical efficiency is defined as one minus the maximum equiproportionate reduction in all inputs that still allows continued production of given outputs. A score of unity indicates full efficiency, whereas a score below one suggests that a reduction in inputs is possible without sacrificing output.

Efficiency measurement in agriculture is complicated by the fact that agricultural processes are largely stochastic due to for instance weather. The choice of stochastic frontier analysis (SFA) seems therefore obvious. Coelli (1995) and Coelli *et al.* (1999) recommend the use of SFA over non-parametric approaches in agricultural research, especially when using data of developing countries (measurement error). However, the problem with SFA is that it assumes a functional form for production technology, which can confound the efficiency results (Reinhard, 1999). It also expects the researchers to choose a distributional form for the inefficiency effect, which is arbitrary. Furthermore, it does not yet readily accommodate multiple outputs, unless a cost minimisation strategy is assumed (Kumbhakar, 1996; Coelli *et al.*, 1999). Non-parametric programming approaches, currently known as Data Envelopment Analysis (DEA), have more flexibility in that they avoid a parametric specification of technology and the distribution of efficiency, and can easily incorporate multiple outputs (Coelli *et al.*, 1999). On the other hand, any statistical noise due to for instance weather fluctuations will be attributed to the inefficiency measure. Despite this shortcoming, DEA is used in this study because of the flexibility of DEA and the fact that the data available for this study are of high quality (little measurement error)[2].

DEA yields a measure of Farrell-efficiency of a farm relative to the best practice farms in the sample using linear programming. In an input oriented DEA model the objective is to produce the observed outputs with as little inputs as possible. This is a reasonable assumption in European milk production, which is limited by a quota for every individual farm. In a homogenous market with input and output prices equal for all producers and more or less constant over short time periods, the only way to maximise profit is thus input minimisation. Therefore, in this study, an input orientation is used.

The production of milk on Dutch dairy farms generates negative externalities in the form of nutrient surpluses. These bads associated with the production of milk are not freely disposable. If the nutrient surpluses exceed the standards, farmers will be taxed. In order to avoid taxation, farms could for instance dispose of manure or change to a more extensive farming system, all leading to costs. These cost involved with disposing of bads cannot be ignored if we want to get a true measure of technical efficiency (Pittman, 1983, Färe *et al.*, 1989). Tyteca (1997) and Ball *et al.* (2000) realised that the incorporation of bads into the production process provided the opportunity to measure environmental performance, and changes in performance under environmental constraints (Tyteca, 1997; Ball *et al.*, 2000). Bads can be modelled as a weakly disposable output in a distance function approach (Ball *et al.*, 1994; Chung *et al.*, 1997), or as a weakly disposable input to be minimised (Reinhard *et al.*, 1999; Shaik and Helmers, 1999). Since the nutrient surpluses can be seen as net inputs rather than outputs resulting from the production process, they are modelled as weakly disposable inputs in this study.

[2] For further information on the benefits of DEA over SFA or other parametric approaches see for instance Jaforullah and Whiteman (1999), Färe *et al.* (1996), and Cloutier and Rowley (1993).

Programming problem (1) is used to calculate the Farrell input-oriented overall technical efficiency under variable returns to scale conditions, incorporating nutrient surpluses as weakly disposable inputs:

$$F(y,x,w\,|\,V,W) = \underset{\theta,\lambda,\delta}{Min}\,\theta$$

Subject to:

$$\begin{aligned} & y_i \le Y\lambda \\ & \theta x_i \ge X\lambda \\ & \theta\delta w_i = W\lambda \\ & N'\lambda = 1 \\ & \lambda \ge 0 \\ & 0 < \delta \le 1 \end{aligned} \qquad (1)$$

In which θ represents overall technical Farrell-efficiency ($\theta \in [0,1]$) for the *i*-th firm under the assumption of weak disposability of the nitrogen and phosphate surplus, *Y* is the observed vector of outputs, *X* is the observed vector of conventional inputs and *W* is the observed vector of the environmentally detrimental inputs (nitrogen and phosphate surplus). The intensity variables, or firm weights are represented by an $N\times 1$ vector λ, where *N* is the number of farms in the sample. The intuitive interpretation of the problem is that it takes the *i*-th firm and then seeks to radially minimise the input vector, made up out of *X* and *W*, while still remaining within the feasible input set (Färe *et al.*, 1994a; Coelli *et al.*, 1999). The first and second constraints reflect strong disposability of outputs and conventional inputs respectively. The equality in the third constraint imposes weak disposability of the nutrient surpluses. The fourth constraint allows for a technology characterised by variable returns to scale (VRS), which envelopes the data most tightly, compared to constant returns to scale and non-increasing returns to scale. The scaling parameter δ ensures that there is a feasible solution of the DEA problem with weakly disposable inputs under VRS (δ = 1 under CRS) (Färe *et al.*, 1994a). Figure 3.1 gives a graphic explanation of the concept of input-orientated technical efficiency, using two inputs, x_1 and x_2. A, B, and P^t, represent farms that use a different combination of x_1 and x_2 in time-period t. DEA creates a piecewise linear isoquant t from the observations, representing the most efficient technologies used by the farms in the sample in time period t (in this case farm A and B). Technical efficiency for farm P^t can be calculated as the radial measure OP'^t/OP^t.

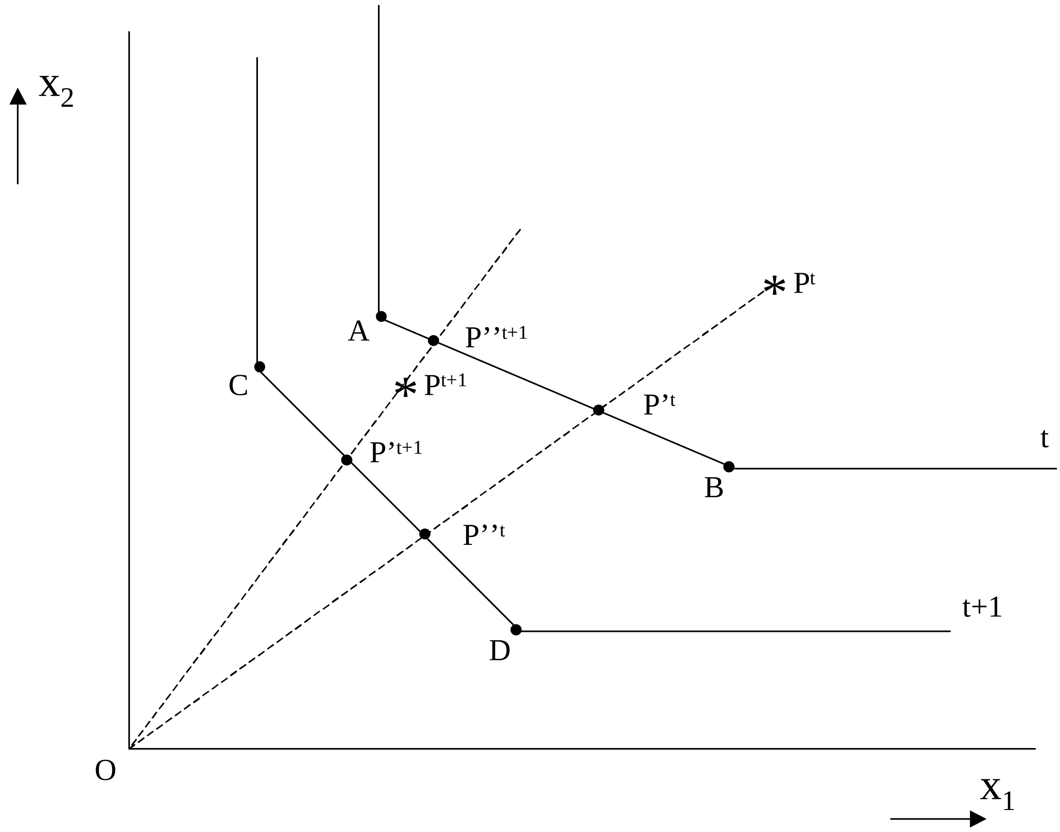

Figure 3.1 Input-oriented technical efficiency and Malmquist Total Factor Productivity Growth

Using the concept of non-radial efficiency (Färe *et al.*, 1994a), an efficiency estimate for surpluses of both nutrients simultaneously can be calculated providing an indication of nutrient performance of the farm. The nutrient efficiency measure is defined as the ratio of minimum feasible to observed nutrient surpluses, conditional on observed levels of outputs and conventional inputs (Reinhard *et al.*, 2000). This is described in linear programming problem (2):

$$SF(y,x,w \mid V,W) = \underset{\gamma,\lambda,\delta}{Min} \ \gamma$$

Subject to:

$$\begin{aligned} & y_i \leq Y\lambda \\ & x_i \geq X\lambda \\ & \gamma\delta w_i = W\lambda \\ & N'\lambda = 1 \\ & \lambda \geq 0 \\ & 0 < \delta \leq 1 \end{aligned} \qquad (2)$$

Nutrient Farrell-efficiency for the *i*-th firm is represented by γ. The other variables are analogous to the previous linear programming problem. The interpretation is this problem is that it takes the *i*-th firm and then contracts only the inputs of interest (in this case both the nitrogen and phosphate surplus, represented by *W*). Figure 3.2 explains the way nutrient efficiency, a non-radial measure of efficiency, is derived. Again, A, B, and P^t, represent farms that use a different combination of x_1 and x_2 in time-period t. Suppose x_1 represents the nutrient surpluses. Farm P^t can reduce the nutrient surpluses on the farm by S'^tP^t. Nutrient efficiency can then be calculated as $O^tS'^t/O^tP^t$.

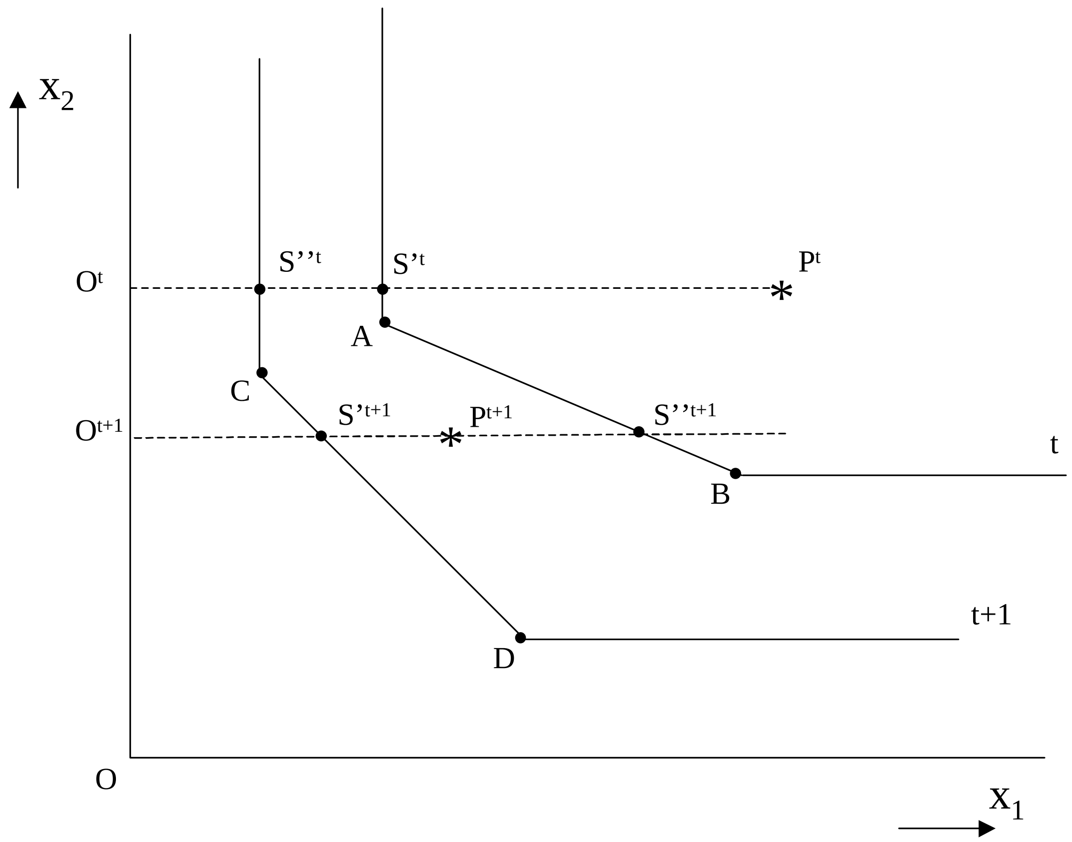

Figure 3.2 Input-oriented subvector efficiency and Malmquist Subvector Productivity Growth

Separate production sets and efficiencies are calculated for each year of the panel, as done by Reinhard *et al.* (2000). Window analysis (Charnes *et al.*, 1985), which incorporates every preceding year in the calculation of efficiencies in subsequent years, would mix up technological change and (stochastic) year effects in the calculated efficiencies. Since our sample is sufficiently large (see section 3.3), this can be avoided by calculating efficiencies for every year in the sample separately, and then averaging over the total period.

3.2.2 Total and nutrient productivity growth

The availability of panel data has the advantage that changes in performance over time can be studied. In studying the concept of performance changes, use is made of the concept of total factor productivity, which is defined as an index of output divided by an index of total input usage. A change in productivity, or Total Factor Productivity Growth (TFPG), is then equal to the change in total factor productivity between periods t and t+1. TFPG is defined as the net change in output due to efficiency change and technical change (Färe and Grosskopf, 1996). The former equals the change in the distance between an observation and the frontier, and the latter equals a shift in the production frontier itself (Grosskopf, 1993, Coelli *et al.*, 1999). These are calculated using the geometric mean version of TFPG, introduced by Färe *et al.* (1994b). The Malmquist Index is based on distance functions (D), which are inversely related to technical Farrell-efficiency measures. Calculating Malmquist indexes requires constant returns to scale technology (C) and strong disposability of inputs (S) in order to assure feasible solutions to the programming problem. In this case, VRS and weak disposability of two inputs was used. Checks were done to check for infeasible solutions but none were found. Since VRS is the less restrictive model, it is preferred over CRS. The Malmquist Input-Based Total Factor Productivity Index is defined as (Färe *et al.*, 1994b):

$$M_i(y^{t+1}, x^{t+1}, y^t, x^t | C,S) = \left[\frac{D_i^t(y^{t+1}, x^{t+1} | C,S)}{D_i^t(y^t, x^t | C,S)} \times \frac{D_i^{t+1}(y^{t+1}, x^{t+1} | C,S)}{D_i^{t+1}(y^t, x^t | C,S)} \right]^{1/2} \quad (3)$$

or, in terms of Farrell-efficiency measures:

$$\frac{F_i^{t+1}(y^{t+1}, x^{t+1} | C,S)}{F_i^t(y^t, x^t | C,S)} \times \left[\frac{F_i^t(y^{t+1}, x^{t+1} | C,S)}{F_i^{t+1}(y^{t+1}, x^{t+1} | C,S)} \times \frac{F_i^t(y^t, x^t | C,S)}{F_i^{t+1}(y^t, x^t | C,S)} \right]^{1/2} \quad 4)$$

Figure 3.1 explains the concept of Malmquist TFPG. It shows two isoquants, t and t+1, and two data points, P^t and P^{t+1}, for time period t and time period t+1. The Malmquist TFPG is equal to $\frac{OP'^{t+1}/OP^{t+1}}{OP'^t/OP^t} \times \left[\frac{OP''^{t+1}/OP^{t+1}}{OP'^{t+1}/OP^{t+1}} \times \frac{OP'^t/OP^t}{OP''^t/OP^t} \right]^{1/2}$.

In the present study, the changes in nutrient performance are of importance because farmers need to adjust their nutrient management in order to meet the standards of 2003. A measure similar to TFPG but focussed on nutrients would provide insight into this matter. Analogue to TFPG, a measure of growth of a subvector (in this case nutrient surpluses) of inputs can be established and decomposed in a measure of subvector efficiency change and change in subvector technology.

$$SM_i(y^{t+1},x^{t+1},w^{t+1},y^t,x^t,w^t|C,S)=\left[\frac{S_i^t(y^{t+1},x^{t+1},w^{t+1}|C,S)}{S_i^t(y^t,x^t,w^t|C,S)}\times\frac{S_i^{t+1}(y^{t+1},x^{t+1},w^{t+1}|C,S)}{S_i^{t+1}(y^t,x^t,w^t|C,S)}\right]^{½}$$

or, expressed in Farrell-efficiency measures,

$$\frac{SF_i^{t+1}(y^{t+1},x^{t+1},w^{t+1}|C,S)^b}{SF_i^t(y^t,x^t,w^t|C,S)^a}\times\left[\frac{SF_i^t(y^{t+1},x^{t+1},w^{t+1}|C,S)^c}{SF_i^{t+1}(y^{t+1},x^{t+1},w^{t+1}|C,S)}\times\frac{SF_i^t(y^t,x^t,w^t|C,S)}{SF_i^{t+1}(y^t,x^t,w^t|C,S)^d}\right]^{½}$$

The concept of subvector productivity change is graphically explained in Figure 3.2. Suppose x_1 represents the input of interest. P^t represents a farm in period t and P^{t+1} is the same farm a period later. As is the case with subvector efficiency, subvector productivity change is a non-radial measure, consisting of a non-radial shift of the frontier, and a non-radial change in efficiency: $\frac{O^{t+1}S'^{t+1}/OP^{t+1}}{O^tS'^t/OP^t}\times\left[\frac{O^{t+1}S''^{t+1}/OP^{t+1}}{O^{t+1}S'^{t+1}/OP^{t+1}}\times\frac{O^tS'^t/OP^t}{O^tS''^t/OP^t}\right]^{1/2}$.

The Malmquist Subvector Productivity Index (SVP Index) represents the changes that occurred in part of the production process. In the case at hand, the SVP Index gives an indication of the changes in nutrient efficiency (shift of efficiency in one dimension) and the changes in the technology with which nutrients are used (shift of the frontier in one dimension). The product of these two measures gives an indication of the change in the productivity with which nutrients are used. As with subvector efficiency, subvector productivity is based on all inputs and outputs of the production process. It is not a partial measure, like for instance labour productivity, but it is a measure of productivity growth of one input, corrected for all other inputs.

3.3 Data description

Data of 114 specialised dairy farms were collected over a period of three years (1997-1999) as part of a large government supported project called Farm Data in Practice (FDP, Project Praktijkcijfers in Dutch). The goal of the project was to gain empirical insight into nutrient management on 'real-life' farms, and to support and improve nutrient management practices. Since mineral surpluses on most dairy farms were still far below the threshold levels of taxable surpluses in this period, the effects reported in this paper will be a reflection of active nutrient management rather than economic incentives (e.g. surplus taxes). Farms were selected to give an accurate representation of specialised dairy farms in The Netherlands. Farms are classified as a specialized dairy farm if at least 95% of all Dutch Size Units (DSUs) can be attributed to dairy production (the DSU is an economic size unit, based on standard gross margins). Both financial and nutrient accounting data were collected as well as data on farm structure and management characteristics. Screening and cleaning of data was done twice, once by the project organisation and once by the authors.

A problem that may arise in DEA efficiency measurement is that of dimensionality, i.e. efficiency ratings are dependent on the number of firms and the number of defined outputs and inputs. Chambers *et al.* (1998) provided a rule of thumb for this 'degrees of freedom' problem, i.e. there should be at least three times as many observations as inputs and outputs. As Tauer and Hanchar (1995) showed, defining ten or more inputs will result in almost all firms being efficient. Parsimony of inputs and outputs is therefore desirable. On the other hand, compromising on completeness of all resources used and outputs produced is dangerous, since observed inefficiency may then represent misspecification of the production model. Aggregation of similar inputs and outputs is therefore necessary but one should be cautious not to incorporate aggregation bias into the model. Aggregation is usually achieved by linearly summing up separate inputs using prices as relative weights. The technical efficiency measure then approximates economic efficiency, comprising both technical and allocative efficiency, thus creating an aggregation bias (Thomas and Tauer 1994). Therefore only those inputs that are measured in the same physical units are aggregated. In total 8 inputs and 2 outputs are used, of which descriptive statistics are shown in Table 3.1 for the total sample (three years).

The outputs distinguished are total milk production corrected for fat and protein content, and the value of cattle output, expressed in 1997€. They represent the major outputs for the highly specialised farms. The inputs used are cultivated land in hectares (ha), total stock, aggregated in livestock units (LU), total labour used (both unpaid and paid) in full time equivalents (FTE), total nitrogen from chemical fertiliser in kg, and total phosphate from chemical fertiliser in kg. Net feed purchases contains both concentrates and roughage, aggregated using Net Energy for Lactation in Megajoules (MJ NEL), and corrected for sales and stock changes[3]. Environmentally detrimental inputs are the nitrogen and phosphate surpluses, calculated as the difference between the production and use of nutrients.

[3] Data on machinery and equipment were considered to be of insufficient quality to be used in the analysis, and data on work by contractors do not accurately represent the level of mechanisation. Omission of these inputs in the DEA model may result in a small negative bias of the technical efficiency scores.

Incorporation of both fertiliser and surpluses does not hamper the calculation of the efficiency measures. Fertiliser may be a component of the nutrient surplus but the surplus is a result of the total production process and therefore the result of many other factors, i.e. purchases and sales of cattle and feed. Furthermore, fertiliser is a strongly disposable input, whereas nutrient surpluses are considered weakly disposable because of the costs involved with ridding of them.

Table 3.1 Descriptive statistics of inputs, outputs, farm structure and management characteristics

	Mean	Standard Deviation
Input		
Cultivated land (ha)	41.65	11.93
Livestock (LU[a])	92.43	28.83
Labour (FTE[b])	1.76	0.54
Nitrogen fertiliser (kg N)	11013	5304
Phosphate fertiliser (kg P_2O_5)	1677	1307
Net feed purchases (MJ NEL[c])	1233679	699915
Nitrogen surplus (kg N)	11163	4467
Phosphate surplus (kg P_2O_5)	2152	1238
Output		
Milk production (kg FPCM[d])	590437	201928
Cattle output (1997 €)	21196	8568
Farm structure		
Farm size (DSU[e])	161.2	50.8
Farm intensity (quota (4.25% fat)/ha)	13867	3490
FPCM/cow	8340	744
% Grassland	85.9	12.8
Farm management		
Female young stock LU/10 cows	2.8	0.6
Ratio of organic and chemical fertiliser for extra N supply	-0.05	0.20
Concentrates used in MJ NEL/100 kg FPCM	197.7	30.6
Grazing intensity (LU grazing days/ha)	126	42

[a] LU = Livestock Units

[b] FTE = Full Time Equivalent

[c] MJ NEL = MegaJoules Net Energy for Lactation

[d] FPCM = Fat and Protein Corrected Milk Production

[e] DSU = Dutch Size Unit

All other inputs are considered strongly disposable as well. Even though land may be seen as a factor that is hard to acquire, disposing of it easy. In an input orientated DEA the goal is to minimise inputs which means that it is not the availability property but the disposability that is important. Land is therefore modelled as strongly disposable. Specialised dairy farming in the Netherlands relies mainly on family labour. Adjustment costs of acquiring or disposing of hired labour is therefore of minor importance. Furthermore, tension on the labour market in The Netherlands and recent experiences with Classical Swine Fever (1997) and Foot and Mouth Disease (2001) showed that farmers who are temporarily without farm work easily find replacing employment. Labour is therefor also modelled as strongly disposable. Both the nitrogen and phosphate surplus are assumed to be weakly disposable, since there is a cost involved in disposing of it.

The advantage of a highly homogenous group of farms like the present one, and low aggregation level of inputs and outputs is that variance found can be more correctly attributed to management characteristics, rather than to noise in the data. While the inputs and outputs described above determine the location of the production frontier, the variables described below (farm structure and farm management in Table 3.1) explain the distance to the frontier in a so-called two-stage approach (Coelli *et al.*, 1999). The first stage determines the efficiency and productivity with DEA, the second stage tries to explain the differences in efficiency and productivity between farms. Efficiency measures are bounded by a lower and upper limit (0-100), and productivity by a lower limit of 0, and therefore a Tobit model (Tobin, 1958), which allows for limited distributions, is appropriate (Greene, 1997). The explanatory variables can be divided into farm structure characteristics and farm management characteristics. Four farm structure characteristics are considered. Size is of importance because farmers may be able to make use of economies of scale. On the other hand, the size of the dairy operation may be limiting the optimisation of the dairy production process because of labour restrictions. Size is represented by the total of DSUs on the farm. The intensity of the dairy enterprise greatly affects nutrient surpluses because of the high amounts of inputs relative to land. For a highly intensive farming system to meet the environmental regulations, the quality of management (and therefore efficiency) has to be high (Aarts *et al.*, 1999b). Intensity is expressed in quota per ha. The production potential of the dairy stock, expressed in kg of fat and protein corrected milk (FPCM) per cow, reflects the efficiency with which the dairy herd is able to convert feed into milk. Highly productive cows are more energy and protein efficient (Veerkamp *et al.*, 1993). A high milk production per cow means that less cows and therefore less inputs are needed on a farm to produce the same amount of outputs as a farm with low productive cows (Steverink *et al.*, 1994). Land use on dairy farms in The Netherlands consists mainly of grass and maize. Grass is a more nutrient efficient crop (Willems *et al.*, 2000) but leads to a large amount of protein in the dairy ration. Also, when grass is used to graze cattle, this efficiency advantage is lost, due to grazing losses. Land use is therefore represented by the percentage of grassland.

Farm management is represented by four variables. Heifer management is important because selection of good quality replacement heifers ensures the maintenance of a high quality dairy herd. A large number of heifers on the farm does, however press heavily on the nutrient balance (Mourits *et al.*, 2000). A reduction might therefore improve efficiency. Heifer management is expressed in the number of Livestock Units (LU) of young stock per 10 cows present on the farm. Fertilising is another important aspect of management. Dairy farms use manure produced by the dairy herd and supply the farm with additional N from either organic manure of chemical fertiliser, the latter being easier to utilise (Aarts *et al.*, 1999b). Fertilising management is therefore represented by the ratio between net use of organic and of chemical fertiliser to supply the farm with extra nitrogen. In theory, this ratio can range from negative to positive infinity. For this sample, all observations lie between -1 and +1. Feeding management concerns several aspects of the farm, like forage production and ration formulation which are translated in the amount of concentrates needed. Concentrate supply according to the individual needs of the animals will improve concentrate utilisation and will therefore reduce concentrate inputs (Aarts *et al.*, 1992). Feeding tactics are represented by MJ NEL of concentrates used per 100 kg of FPCM produced. Finally, grazing tactics are of importance because grazing is an inefficient form of manure nutrient use (Aarts *et al.*, 1992). Restricting grazing time is assumed to increase nutrient efficiency and reduce nutrient surpluses (Aarts *et al.*, 1999b). Grazing management is expressed in the total number of days that cattle are grazed corrected for the grazing system used. Year (1997, 1998, 1999) and soil type were included as dummy variables (40.4% sandy soils, 44.7% clay soils, and 14.9% peat soils). Note that soil type, size, intensity and land use reflect regional differences. Other regional effects were not expected. The farm structure and farm management variables are selected for the second stage of the analysis because they are dependent on preferences, motivation and management skills of the farmer, and thus influence efficiency and productivity.

3.4 Results and discussion

3.4.1 Technical and nutrient efficiency

Technical and nutrient efficiency measures were calculated according to model (1) and (2). Both average technical and nutrient efficiencies (TE and NE) over three years and for every individual year are presented in Table 3.2. It appears that a large proportion of the farms in the sample were technically efficient, especially within years (73.7%). Because of this, and the small spread in efficiency, average efficiencies were also high. The mean efficiency score of farms that were not fully efficient was calculated separately. Over the whole period, 52% of all farms were 100% efficient, and the average efficiency score of the non-efficient farms was high (95.25%).

Nutrient efficiencies, incorporating both nitrogen and phosphate efficiency, were considerably lower (Table 3.2). The nutrient efficiencies for the separate years were approximately 80%. The number of fully efficient farms differed slightly among years, with 1998 having the highest number (61%) of fully efficient farms. The mean nutrient efficiency for the non-efficient farms increased over time, indicating that the non-efficient farms had made improvements. The three year average was 80%, meaning that a simultaneous reduction of 20% was possible for the nitrogen and phosphate surplus. Only 29% of the farms in the sample were fully efficient over the three-year period, and the farms which were not, can lower their surpluses by about 28% if they were to produce on the frontier. Technical and nutrient efficiency were highly correlated ($\rho = 0.58$, $P<0.01$), indicating that technical and nutrient efficiency could be achieved simultaneously. This result is in agreement with an earlier study by Reinhard *et al.* (1999).

Table 3.2 Input reducing technical efficiency, and nutrient efficiency scores

	1997	1998	1999	1997-1999
Technical Efficiency				
Mean all farms	98.02	97.70	97.41	97.71
% of fully efficient farms	73.7	73.7	73.7	51.8[a]
Mean non-efficient farms	92.47	91.27	90.17	95.25
Nutrient Efficiency				
Mean all farms	78.04	81.96	80.49	80.16
% of fully efficient farms	55.3	61.4	56.1	28.9[a]
Mean non-efficient farms	50.90	53.25	55.52	72.08

[a] Farms may be fully efficient in individual years, but not necessarily in the whole period.

One of the causes of a deviation from the efficient frontier can be scale inefficiency. Considering their input mix, farms can produce at either too small or too large scales. A comparison of different returns to scale technologies shows that, for the three year average, 20.2% of all farms were producing at an optimal scale (mean TE = 99.22, mean NE = 89.90). Of the other farms, 64.9% were producing at increasing returns to scale (mean TE = 97.48, mean NE = 79.49), indicating that increasing the use of all inputs simultaneously would be beneficial for technical and nutrient efficiency, whereas 14.9% were producing at decreasing returns to scale (mean TE = 96.67, mean NE 69.90), meaning that a reduction in input use would, *ceteris paribus*, improve efficiency. Apparently, the scale-efficient farms also perform best with regard to nutrients. The farms producing at decreasing returns to scale farms perform considerably worse (20% less efficient) than the scale-efficient farms.

Based on earlier Monte Carlo simulation studies mentioned in section 3.3 (Tauer and Hanchar, 1995), it may be expected that approximately 30%-50% of farms is fully efficient. In the present study this percentage is as high as 74% for the separate years and 52% overall, indicating that the dairy farms in the sample are highly efficient. The average technical and nutrient efficiencies that were found in this study were also high compared with other studies (e.g. Weersink *et al.*, 1990; Reinhard, 1999). The facts that the results were obtained from a highly homogenous group of specialised farms, having at least 95% of all their enterprises in dairy farming, and inputs were only aggregated in physical units and corrected for quality differences may explain the high efficiencies found.

To explain differences in efficiencies between farms a Tobit model is estimated using data of the three consecutive years with dummies for the time effect, for both TE and NE. The ML estimates of the Tobit analysis are shown in Table 3.3. The size of the farm affected TE negatively, i.e. larger farms tend to be less efficient. This can be due to a loss of control and overview of an enterprise that is large[4]. Another possible reason is that the pressure to be efficient with the use of inputs is smaller, since the sheer bulk of the operation provides the farmer with enough income to meet his financial objectives. The farm structure characteristics that positively influenced TE are intensity in terms of quota per ha, and production capacity in terms of milk production per cow. In an intensive farming system the degree of control on input-output relationships is generally higher, which explains the positive effect.

The positive effect of a high production capacity (FPCM per cow) can be explained by the fact that highly productive cows use less input (e.g. feed) per unit of output. The percentage of grassland had a negative effect on TE. Generally, maize production yields more energy in terms of feed than does grassland production (Aarts, 2000). A high percentage of grassland will therefore lead to relatively more feed purchases. Grazing is the only management characteristic that had an effect on TE. Grazing is accompanied by 'grazing losses' that occur because of low utilisation of nutrients excreted by the cows while grazing, causing efficiency to decrease. The McKelvey-Zavoina R^2 (R^2_{MZ}) (Veall and Zimmermann, 1994) for the TE regression was 25.8[5].

[4] The negative impact of farm size as reflected by DSU on technical efficiency seems to contradict the result that most farms operate in the range of increasing returns to scale. The explanation for this result is that DSU is a measure that is inferred from land use and the number of livestock on the farm (with weights depending on the contribution to the gross margin). In the DEA model, size is a reflection of the quantities of all inputs distinguished (with equal weights).

[5] R^2_{MZ} is a Pseudo-R^2, and is the best predictor of what OLS-R^2 would be under uncensored data (Veal and Zimmermann, 1994).

Table 3.3 Maximum Likelihood estimates of the Tobit regression for technical and nutrient efficiency

Variable	Technical Efficiency		Nutrient Efficiency	
	Parameter	t-ratio	Parameter	t-ratio
Constant	1.009	6.072**	1.545	2.904**
Dummy 1998	-0.023	-1.054	-0.016	-0.221
Dummy 1999	-0.032	-1.457	-0.019	-0.265
Dummy sandy soils	0.000	0.008	-0.095	-0.964
Dummy clay soils	0.036	1.440	0.056	0.643
Size (DSU[a])	-0.055	-2.620**	-0.253	-3.757**
Quota (4.25% fat)/ha	0.118	2.908**	0.326	2.536**
FPCM[a]/cow	0.031	2.175**	0.086	1.838*
% Grassland	-0.191	-2.168**	-0.801	-2.843**
Female young stock LU[a]/10 cows	-0.015	-0.796	-0.053	-0.860
Ratio of organic and chemical fertiliser for extra N supply	-0.000	-0.219	-0.508	-5.414**
Concentrates MJ NEL[a]/100 kg FPCM	0.029	0.159	-0.735	-1.223
Grazing (LU grazing days/ha)	-0.051	-2.219**	-0.155	-2.108**
σ	0.118	11.575**	0.446	14.797**
McKelvey-Zavoina R^2	25.8%		24.0%	

* $P < 0.10$, ** $P < 0.05$

[a] See Table 3.1.

Nutrient efficiency (NE) had slightly different determinants. The size of the farm was negatively related to NE, whereas intensity showed a positively relationship with NE. Farm size, and the related lack of control and absence of the need for technical efficiency, may also be the reason that larger farms show lower nutrient efficiencies. The lack of fine tuning of the production process causes losses in nutrient input use that result in higher nutrient surpluses per unit of output than are technically necessary. Farm intensity had a positive effect on NE. The need to make more feed purchases enables an intensive farm to better gear to feeding needs of the dairy cattle. Furthermore, intensive farming systems often dispose of their manure, thus lowering nutrient surpluses on the farm.

FPCM per cow also positively influenced NE. High milk production per cow generally means more nutrients leaving the farm through milk, not ending up in manure. Land use, in terms of the percentage of grassland of the total acreage was negatively related to NE. This is due to the fact that, considering the high fertilisation levels of grassland, silage maize proves to be a more efficient production process than grassland production (Aarts, 2000). Furthermore, due to the high percentage of grassland, the feeding ration will be high in nitrogen. This will not be fully used by the cattle and will be excreted in manure, which is a less efficient fertiliser, especially during the grazing period. Among the management characteristics, the ratio of organic and chemical fertiliser for extra nitrogen supply affected NE negatively. For a ratio between 0 and 1 this means that the more the extra nitrogen stems from organic fertiliser instead of chemical fertiliser, the lower nutrient efficiency. When the ratio lies between 0 and -1, organic fertiliser is disposed of, and replaced by chemical fertiliser (input of inorganic fertiliser exceeds manure disposal in this range, resulting in a net supply). This has a positive (double negative) effect on NE. Grazing tactics influenced NE negatively as well. Farms that tended to graze their cows for a long period of time showed lower nutrient efficiencies. Even though soil type is often considered an important determinant of nutrient performance, the Tobit regression did not show any statistical evidence of this. Also, the dummy for year showed no significant effect indicating that the average efficiency level did not differ between years. The R_{MZ}^2 for NE is 24.0%

3.4.2 Total and nutrient productivity

The overall TFP Index and SVP Index for nutrients are shown in Table 3.4. Table 3.4 shows that a TFP growth of 1.5% per year was achieved as well as a SVP growth of as much as 60%. TFP growth was mainly achieved through technological change, which compensated for a slight decrease in technical efficiency. SVP growth was achieved by a change in nutrient technology, as well as a change in nutrient efficiency. The focus of change was different for each your of the sample, however. The first year, farmers focussed mainly on changing the technology with which nutrients are used, whereas the second year efficiency became the focal point of management. The TFP Index and SVP Index are significantly positively correlated (ρ=0.48, $P<0.01$). This shows that not only high technical and nutrient performance can go together, but technical productivity growth and nutrient productivity growth can be achieved simultaneously.

Table 3.4 Average changes in (nutrient) technology, (nutrient) efficiency and (nutrient) productivity growth, and average total change per year over the period 1997-1999[a].

	1997-1998	1998-1999	1997-1999 average per year
Technological change	1.026	0.992	1.009
Technical efficiency change	0.998	0.998	0.998
Total Factor Productivity Change	1.029	1.001	1.015
Nutrient technological change	1.840	0.783	1.312
Nutrient efficiency change	1.092	1.452	1.272
Nutrient Productivity Change	1.981	1.515	1.602

[a] These are arithmetic averages across farms. Average (nutrient) technological change and (nutrient) efficiency change can therefore not be multiplied to find the average TFPG and NPG.

The large improvements found here for nutrient productivity can be explained by the incentive given by the project organisation for active, rather than passive nutrient management. Furthermore, farms have received advice and support on their management practices, and were monitored for three years. Note that improvements in technology and efficiency do not necessarily mean a reduction of nutrient surpluses. If farms improve their nutrient performance either through a technology change or an efficiency change, but at the same time intensify production, the net result may be just a small decrease or even an increase of surpluses. In this study this appeared to be the case. Farm intensity increased on average with approximately 600 kg of milk quota (4.25% fat) per ha over the whole period. The average nitrogen surplus showed a slight increase of 4 kg of N per ha, compared to 1997, the average phosphate surplus increased with 9 kg of P_2O_5 per ha. The surpluses are subject to a year effect. This does, however not affect the general point that gains achieved by improving nutrient performance can be nullified by an increase in intensity (Aarts *et al.*, 1999c; Ondersteijn *et al.*, 2001).

Tobit analyses were executed to explain changes in technical and nutrient efficiency and changes in general and nutrient technology (Table 3.5). A change in technical efficiency was positively related to FPCM per cow. Farms who manage a highly productive herd generally have better management skills. These skills have been put to use to increase the overall technical efficiency of the farm, not just of the dairy herd. The ratio of organic versus chemical fertiliser for additional N-supply is negatively associated with technological efficiency changes. It is obviously more difficult to fully utilise the nutrients from organic rather than inorganic fertilisers. Technological change is positively related to the amount of concentrates used per unit of milk. The amount of concentrates used may lead them to make use of the potential of systems like automated concentrate feeding, which increases milk production per cow due to accurate performance-related concentrate provision (Van Asseldonk *et al.*, 1999). These farmers may also receive more advice from their concentrate supplier to improve their dairy production process. R^2_{MZ} of 41.2 and 58.6% were calculated for technical efficiency change and technology change respectively.

Nutrient efficiency and nutrient technology change show a year effect. The efficiency change was much smaller in 1998, whereas the technology change was much larger in the first year, which was also shown in Table 3.4. This is very likely due to the focus of the project support, which was on nutrient technology change the first year rather than on efficiency improvement. Farm intensity has a negative impact on nutrient efficiency change. The more intensive farming systems already showed high nutrient efficiencies, indicating that not much room for improvement is left. These farms should shift their production frontier in order to improve performance but there is no significant relationship between intensity and nutrient technology change. As with technical efficiency change, the ratio of organic versus

Table 3.5 Maximum Likelihood estimates of the Tobit regression for technical efficiency and technology change, and nutrient efficiency and nutrient technology change

Variable	Technical efficiency change		Technology change		Nutrient efficiency change		Nutrient technology change	
	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio	Parameter	t-ratio
Constant	0.774	5.883**	0.594	2.833**	0.700	0.712	0.729	0.455
Dummy 1998	0.002	0.105	0.035	1.527	-0.357	-3.318**	1.088	6.198**
Dummy sandy soils	-0.000	-0.001	0.058	1.400	0.047	0.243	-0.183	-0.576
Dummy clay soils	-0.020	-0.844	-0.005	-0.143	-0.088	-0.504	-0.134	-0.470
Size (DSU[a])	-0.002	-0.134	0.005	0.200	-0.019	-0.160	0.028	0.147
Quota (4.25% fat)/ha	-0.027	-1.051	-0.019	-0.468	-0.468	-2.411**	-0.096	-0.302
FPCM[a]/cow	0.026	2.241**	0.028	1.530	0.125	1.434	0.070	0.494
% Grassland	-0.017	-0.254	0.114	1.061	-0.316	-0.623	0.073	0.088
Female young stock LU[a]/10 cows	0.014	0.879	-0.028	-1.109	0.111	0.934	-0.127	-0.650
Ratio of organic and chemical fertiliser for extra N supply	-0.0003	-4.015**	-0.0002	-1.477	-0.002	-3.948**	-0.001	-1.090
Concentrates MJ NEL[a]/100 kg FPCM	0.144	0.907	0.538	2.123**	0.893	0.750	0.915	0.472
Grazing (LU grazing days/ha)	-0.010	-0.529	-0.015	-0.506	0.870	0.637	-0.260	-1.165
σ	0.106	21.354**	0.169	21.354**	0.795	21.354**	1.296	21.354**
McKelvey-Zavoina R^2	41.2%		58.6%		90.5%		15.6%	

* $P < 0.10$, ** $P < 0.05$

[a] See Table 3.1.

chemical fertiliser is negatively related to the change in efficiency. Fully utilising the nutrients in manure is a problem. The R^2_{MZ} for nutrient efficiency change is as high as 90.5, while the R^2_{MZ} for nutrient technology change is 15.6. Nutrient efficiency changes are better explained by farm characteristics than are changes in technology. Tobit analyses for the TFP Index as well as the SVP Index are the product of the two components of the respective Indices. The same variables are significant in similar directions. They are therefore not shown in a Table 3.5.

3.5 Conclusion

The relative technical efficiencies found in this study showed that the farms in the sample are highly technically efficient producers. Nutrient efficiencies on the other hand, showed that there is still significant room for improvement of the latter. It must be noted that the measures calculated here are relative to the best management practices of the sample. Introduction of farms in the sample that are able to produce the same amount of output with less input will cause calculated efficiencies of the current sample to drop. A positive relationship between technical efficiency and nutrient efficiency indicated that better environmental performance does not have to be achieved at the expense of worsened technical results. Furthermore, full efficiency does not mean that there is no improvement possible. First of all, subvector efficiencies showed that an individual input could still be reduced, even for technically efficient farms. Second, farms that produce on the frontier can improve nutrient management by improving technology and therefore shift the frontier towards better input/output ratios.

The results from the Tobit analyses indicate that frictions may exist between current agricultural and environmental policy and farmers' interests. These frictions arise due to the different requirements government bodies put on dairy farmers. Intensive farming systems, in terms of quota per hectare, show higher efficiencies, both on a technical and nutrient level. The result is relatively low nutrient surplus per kilogram of produced milk. However, due to their intensity, they tend to have higher absolute levels of nutrient surpluses per hectare, even though they shift a large part of fodder production to less intensive farms by buying their excess fodder. Improving nutrient efficiency by increasing intensity will therefore lead at the same time to higher nutrient surpluses per ha, which are the base for taxation in MINAS. Another point of friction is grazing. Grazing cattle is considered to be part of the Dutch landscape by consumers and policy makers. However, this study shows that the longer the grazing period, the less efficient farms are in terms of both technical and nutrient efficiency. Currently, policy makers are considering mandatory grazing. The results in this study show that this collides with nutrient policy and will therefore complicate matters further for Dutch dairy farmers.

Both total factor productivity and subvector productivity growth were attained by the farmers in the sample. Especially nutrient productivity increased enormously, indicating that large improvements in environmental performance can be achieved in a short time period when farmers actively try to increase their efficiency. The farmers in the sample were participants in a project specifically focussing on nutrient management. The changes in productivity found here may therefore be high, compared to other Dutch farms, who did not receive the same kind of support. However, the important observation to make here is that, with some effort, it is possible to considerably improve nutrient performance and thus produce in a more environmentally sound way. The positive relationship between total factor productivity growth and nutrient productivity growth indicate that this does not have to mean a decrease in technological progress. The main conclusion from the Tobit analyses was that the intensity of the farm is a limiting factor in nutrient productivity growth. These are the farms, which will have the most trouble meeting the environmental standards in 2003, since their intensity leads to higher nutrient surpluses per ha, even though their nutrient efficiency shows a lower surplus per unit of output. If they want to maintain the current level of intensity, innovation is required to improve productivity.

The goals farmers try to optimise are different for each one of them and do not only pertain to economic goals (e.g. Gasson, 1973; Huirne *et al.*, 1997). Deviation of the efficient frontier can therefore be a (deliberate) result of the pursuit of alternative objectives (Reinhard 1999). Also, differences in changes in technological and efficiency may arise from other than technical or economical causes. Depending on alternative objectives and their preferences and motivations, farmers adopt different strategies to meet their goals. Further research should therefore focus on finding an explanation for differences in efficiencies between farmers in strategic management and characteristics of the farmer himself.

IV Farm structure or farm management: effective ways to reduce nutrient surpluses on dairy farms and their financial impacts

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Abstract

To control and prevent nutrient pollution from agricultural non-point sources, the Dutch government introduced the Mineral Accounting System (MINAS), a nutrient bookkeeping system which taxes farms with nutrient surpluses exceeding safe threshold values. Since the levies can be severe it is imperative to know what causes high nutrient surpluses. The large variation in surpluses is usually attributed to management factors like grazing, feeding and fertilising. Reducing surpluses is therefore assumed to be most effective through an improvement of management. No empirical study has ever shown if this assumption is correct however. Using technical and nutrient bookkeeping data of specialised dairy farms over three years (1997-1999) the effect of farm structure and farm management on nutrient surpluses is analysed. Furthermore, the financial impacts are studied.

The ratio between structure and management for the explanation of the nitrogen surplus was 1:3, and for phosphate 1:4 over the period 1997-1999. These ratios show that in current practices management is far more important than structure. Changing farm management rather than farm structure can therefore reduce nutrient surpluses more effectively, making it a more interesting approach for policy makers. Furthermore, improving management will also improve financial results.

4.1 Introduction

Agricultural nutrient leaching and run-off are known to be possible pollutants of ground- and surface waters (Carpenter *et al.*, 1998). To control and prevent this form of pollution, the European Commission issued the Nitrate Directive (91/676/EEC) in 1991, which limits the use of manure and requires the establishment and enforcement of a Code of Good Agricultural Practice (GAP) The limit on manure use is 170 kg N/ha, and affects cattle intensity, a structural feature of farms (Ondersteijn *et al.*, 2002). Compliance of the member states with the Nitrate Directive is poor. In 2001, the policy actions of member states range from strict N-input quotas (Denmark) to no clear action programmes at all (Ireland) (De Clercq *et al.*, 2001). The issue in many cases is, that a strict implementation of the manure application standard leads to structural changes in agriculture, and could pose a threat to the viability of individual farms.

Dutch agriculture is one of the most intensive in Europe in terms of animal density and inputs (Van Bruchem *et al.*, 1999), leading to large nutrient surpluses locally, which could leach into groundwater. Studies have shown, however, that a large variation in nutrient surpluses between farms exist (Rougoor *et al.*, 1997). According to Van den Brandt and Smit (1998), these differences are caused by variation in management characteristics rather than by differences in farm structure. To reduce nutrient surpluses the Dutch government introduced the Mineral Accounting System (MINAS) in 1998. MINAS is a nutrient bookkeeping system in which nitrogen and phosphate outputs are subtracted from the inputs. The resulting surpluses are taxed if they exceed a predetermined surplus standard, which is to lead to compliance with EU groundwater quality targets (Oenema *et al.*, 1998). The surplus standards are being reduced until, in 2003 the final standards will become mandatory. The final surplus standards are set at 180 kg/ha of nitrogen (N) for land covered with grass and 100 kg of nitrogen for every hectare of arable land (both 40 kg lower for sandy soils vulnerable to leaching). A surplus of 20 kg of phosphate (P_2O_5) is allowed per hectare regardless of cropping type. Farmers will be taxed €2.30 for every kg of N that exceeds the standard, and €9.00 for every kg P_2O_5. These fines can run into thousands of €s for an individual farm. The average fine in 2000 was €2560 for extensive dairy farms (<2.5 Livestock Units (LU)/ha), and €2470 for intensive dairy farms (>2.5 LU/ha) (RIVM, 2002).

MINAS focuses on management of nutrients rather than farm structure. The EC does not accept MINAS as a way to combat nutrient pollution of groundwater, its main objection being that it does not entail strict manure application regulations. The Netherlands subsequently introduced a Manure Transfer Agreement System (MTAS) in 2002 in which farmers have to ensure sufficient land for application of manure through contracts with other less intensive farms. This structural measure is turning out to be expensive (RIVM, 2002) and affecting farm viability. They cannot, however, guarantee low surpluses (Ondersteijn *et al.*, 2002).

Whether or not MINAS is effective in reducing nutrient surpluses on individual farms without affecting farm structure, depends on the separate contribution of farm structure and farm management to the surpluses. Furthermore, the slow decrease in surplus standards will lead farmers to change their management over a period of time. The purpose of this paper is to determine the impact of farm structure and farm management on the nutrient surpluses and financial results of specialised dairy farms and the changes that have occurred in these relationships in a three-year time period. A panel data set (1997-1999) is used to provide insight into the different contributions of structure and management as well as changes in the relative importance of farm structure and farm management over time and the effect of these factors on gross margin.

4.2 Materials and methods

4.2.1 Farm selection

Controversy over the efficacy and feasibility of MINAS led to a collaborative effort of the Dutch government and farm organisations to gain more insight into the effects of the introduction of MINAS and whether or not the surplus standards are feasible on commercial farms. In 1997 the project 'Farm Data in Practice' (FDP, Project Praktijkcijfers in Dutch) was initiated for this purpose, and comprised approximately 240 farms, divided over 5 farm types (farms were selected to represent land-based farms in The Netherlands). The project was to last 3 years (1997-1999) and farmers received technical and managerial support from consultants, laboratories and research institutes to improve nutrient management. Financial and nutrient bookkeeping data were collected over this time period. For the purpose of this study, data of 114 participating specialised dairy farms[1] are used. Comparison of the characteristics of the FDP-farms, and specialised dairy farms represented in the FADN-database, the representative sample of Dutch agriculture (Van Dijk *et al.*, 2002), showed that FDP-farms are slightly smaller in terms of ha (e.g. 41 ha versus 46 ha in 1997) and more intensive in terms of milk production/ha (e.g. 13560 kg milk/ha versus 11372 kg milk/ha in 1997). The FDP-farms also managed a higher milk production level per cow than the average dairy farm (8300 versus 7769 in 1997). These are all significantly different from each other ($P<0.01$) and should be considered when interpreting the results.

[1] Farms are classified as a specialised dairy farm if at least 95% of all Dutch Size Units (DSUs) can be attributed to dairy production. The DSU is an economic size unit, based on standard gross margins.

4.2.2 Variable selection

In the present study, the distinction between farm structure and farm management variables is based on the extent to which they relate to strategic decisions or tactical and operational decisions. Variables and their means and standard deviations are given in Table 4.1. The structural variables chosen, are soil type (peat or not, 15% of the farmers have peat soil), farm size (in DSUs), presence of another agricultural enterprise on the farm (the percentage of marketable crops, and the N-factor, which is a measure of intensive livestock production in kg N-production in manure per ha), farm intensity (in kg Fat and Protein Corrected Milk (FPCM)/ha), milk production capacity of the herd (kg FPCM/cow), and the percentage of fodder crops covered with grassland. This choice is largely based on a study by Beldman and Prins (1999). Peat soils are considered because peat has a larger N-supplying capacity than other soils, which means that these farms need less additional N (Aarts *et al.*, 1992). Farm size may affect the surpluses because labour restrictions could affect control on the production process, and therefore lead to sub-optimal production[2]. A second enterprise on the farm, be it arable or intensive livestock, affects the nutrient surpluses through the different nutrient management characteristics of different enterprises. High farm intensity (in kg FPCM/ha) has shown to increase nutrient surpluses (Rougoor *et al.*, 1997), but at a decreasing rate due to the fact that more intensive farms start to dispose of manure. To correct for this phenomenon, a quadratic term is used in further analyses. The milk production capacity of the herd represents the genetic milk production characteristics as well as feeding and milking installations on the farm, which determine to possibilities for optimal feeding and milking. The percentage of grassland is considered structural as well, since it is largely dependent on soil type and parcellation of the farm (Beldman and Prins, 1999).

The choice of farm management variables is based on the four main tactical management areas (heifer management, grazing management, fertilisation, and feeding management) and a measure of operational management. The number Livestock Units (LU) of young stock kept per 10 cows represents heifer management. A reduction will lead to a lower animal density and therefore lowers surpluses (Berentsen and Giesen, 1994; Van Keulen *et al.*, 1996), even though Mourits (2000) found only a small effect. A small number might affect optimal heifer replacement decisions, however, thus possibly affecting the development of the production capacity of the herd. Grazing management is represented by the grazing intensity, expressed in LU grazing days per ha of grassland. Grazing is accompanied by nutrient losses due to sub-optimal allocation of nutrients from faeces and urine (Aarts *et al.*, 1999a). A more intensive grazing system will therefore be accompanied by more losses. Fertilisation is based on decisions regarding the amount of fertiliser needed and the way additional fertiliser needs are met (through chemical or organic fertiliser). Chemical

[2] See Chapter 3

fertiliser can be utilised more readily and efficiently, while nutrients in manure do not immediately become fully available for plant uptake. Utilisation levels of nutrients in manure are therefore lower, making chemical fertiliser a more attractive alternative (Aarts *et al.*, 1999b).

Table 4.1 Overview and mean (standard deviation) of variables used in the analysis

	1997	1998	1999
Farm structure			
Size (DSU[a])	156 (50)	162 (50)	166 (52)
% ha with marketable crops	0.08 (0.49)	0.10 (0.55)	0.17 (0.75)
N-factor[b]	0.27 (1.69)	0.18 (1.34)	0.11 (0.90)
Intensity (kg FPCM[c]/ha)	13560 (3383)	13879 (3448)	14215 (3693)
Milk production capacity (kg FPCM/cow)	8300 (734)	8348 (703)	8373 (796)
% grassland of fodder crops	87 (12)	86 (13)	85 (13)
Farm management			
Young stock (LU[d]/10 cows)	3.02 (0.59)	2.78 (0.49)	2.63 (0.52)
Grazing intensity (LU grazing days/ha)	354 (115)	316 (110)	326 (123)
Fertiliser N (kg N/ha grassland)	289 (67)	258 (74)	246 (72)
Fertiliser P (kg P_2O_5/ha)	32 (22)	29 (20)	27 (19)
Net manure import (kg N/ha)	0 (47)	-19 (45)	14 (39)
Net manure import (kg P_2O_5/ha)	3 (18)	-5 (19)	8 (17)
Concentrates (MJ NEL[e]/kg FPCM)	175 (37)	177 (35)	170 (33)
N in concentrates (g N/kg concentrates)	30 (6)	31 (6)	33 (6)
P in concentrates (g P/kg concentrates)	5 (1)	5 (1)	5 (1)
Actual–standard feed purchases (MJ NEL/ha)	1129 (1597)	1394 (1552)	1194 (1734)
Farm results			
Kg N-surplus/ha	276 (74)	255 (76)	280 (83)
Kg P_2O_5-surplus/ha	42 (26)	38 (23)	51 (27)
Gross margin (€/100 kg FPCM)	28.0 (2.3)	29.2 (2.5)	26.9 (2.4)

[a] Dutch Size Units

[b] N factor: total N-production by intensive livestock /ha

[c] Fat and Protein Corrected Milk

[d] Livestock Units (reference: phosphate production of 1 cow=1 LU)

[e] Net Energy for Lactation

Feeding management is based on the choice of the feeding ration, one of the major determinants of nutrient surpluses (Van Keulen *et al.*, 1996; Aarts *et al.*, 1999a). The amount of concentrates used (in MJ Net Energy for Lactation NEL)/100 kg FPCM) and the composition of concentrates (in terms of N and P content) represent feeding management in the present study. Finally, a general measure of the quality of operational management, measured as the difference between actual and standard feed purchases is used in the analysis. The standard feed purchases are determined as standard energy needs of the dairy herd minus the standard on-farm produced energy in grass and maize. This measure comprises the efficiency of both crop and animal production on the farm, with more efficient farmers needing less additional feed. The measure is expressed in MJ NEL/ha.

The dairy production process results in a nitrogen and phosphate surplus. In this study, the MINAS surplus per ha is used, corrected for yearly stock changes. The reason to correct the MINAS-surpluses for stock changes is that MINAS was not introduced until 1998, and not all dairy farmers became subject to it right away (dependent on animal density). This gave farmers the opportunity to build up stock of nutrients (in feed and fertiliser) previous to they became subject to MINAS regulations. Since MINAS is a result-oriented system, focussing on management changes, the financial result considered here is the gross margin. The gross margin is defined as the total revenues minus all variable costs, including costs of manure disposal, excluding costs for contractors. It is expressed per 100 kg FPCM because the quota system in Europe makes milk production rights the limiting factor in the dairy production process. Furthermore, the impact of farm management (variable costs) will become apparent in changes in gross margin rather than total farm results, which also includes fixed costs.

4.2.3 Analytical techniques

The problem encountered in trying to identify the separate contribution of farm structure and farm management to nutrient surpluses and gross margin is that the two groups of variables are correlated. Intensive farming systems (in terms of milk production per ha), for instance, are generally accompanied by more intensive crop production (high fertilisation levels) because of the roughage needs of the herd. If one were to regress the nitrogen surplus for instance on the group of farm structure variables, the coefficient of determination (R^2) would also include variance explained which farm structure variables share with farm management variables, thus overstating the effect of farm structure on the nitrogen surplus. To eliminate this shared variance, the Frish-Waugh Theorem is used (Frisch and Waugh, 1933), which states that the subvector b_2 is the set of coefficients obtained when the residuals from a regression of output vector y on matrix X_1 alone are regressed on the set of residuals obtained when each column of X_2 is regressed in X_1 (Greene, 1997). Algebraically, the partitioned linear regression model can be written as:

$$y = X_1\beta_1 + X_2\beta_2 + \varepsilon$$

In which y represents either of three result variables (nitrogen surplus, phosphate surplus, or gross margin/100 kg FPCM). X_i refers to (sets of) variables of separate interest and β_i refers to the subvector of β coefficients. The solution for subvector b_2 can be written as (Fiebig *et al.*, 1996; Greene, 1997):

$$b_2 = (X_2^{*\prime} X_2^{*})^{-1} X_2^{*\prime} y^{*}$$

where

$$X_2^* = M_1 X_2 \qquad \text{and} \qquad y^* = M_1 y .$$

M_1 is the n×n matrix $(I-X_1(X_1'X_1)^{-1}X_1')$, which produces the residuals of the least squares regression of y on X_1. This result is called the Frisch-Waugh Theorem and partials out the effects of X_1, and enables us to calculate the separate effects of X_2. To determine the effects of X_1, an analogue approach should be used. The choice for using the Frish-Waugh theorem over for instance 2-SLS stems from the goal of the study, which focuses on the determination of two specific sets of variables on nutrient surpluses and gross margin, rather than a set of instrumental variables and a set of variables of interest. For the present problem, the Frisch-Waugh Theorem states that the R^2 of farm structure can be determined by first regressing the nitrogen surplus and farm structure variables on farm management variables, and using the residuals form these regressions in a second regression. For the R^2 of farm management, the same approach can be used. In this paper this is not only done for the nitrogen surplus, but for the phosphate surplus and the gross margin as well.

To explore the relationship between all farm characteristics and the surpluses and gross margin, a single regression equation is estimated, in which both farm structure and farm management variables are used simultaneously as independent variables for the different years. The coefficients are the same as the coefficients found in the partial regression analyses (stems from the Frisch-Waugh Theorem), except that slight differences caused by rounding off do not enter the results. Changes in the relationships between years and over the three year time-period become clear this way as well.

4.3 Results and discussion

4.3.1 The relative contribution of farm structure and farm management

Table 4.2 shows the results of the partitioned regression for the nutrient surplus and the gross margin. In 1997, the R^2 of the regression of the nitrogen surplus on management variables (A_N) was 67.7%, meaning that 67.7% of the variance in the nitrogen surplus is explained by farm management and common variance of management and structure. This leaves (for 1997) 100%-67.7%=32.3% to be explained purely by farm structure. Regressing the residuals of the N-surplus on the residuals of the farm structure variables, results in an R^2 70% (B_N), meaning that 70% of the residual 32.3% can be explained purely by farm structure variables.

Table 4.2. Partitioned regression results on N-surplus, P_2O_5-surplus and gross margin (€/100 kg FPCM) of farm structure and farm management variables

	1997	1998	1999
N-surplus/ha			
Farm structure effect			
R^2 N-surplus on management (A_N)	67.7	69.0	69.8
R^2 residuals N-surplus on residuals structure (B_N)	70.0	62.3	74.2
R^2 structure $(1-A_N/100) * B_N$	22.6	19.3	22.4
Farm management effect			
R^2 N-surplus on structure (C_N)	28.3	29.9	28.7
R^2 residuals N-surplus on residuals management (D_N)	86.5	83.3	88.9
R^2 management $(1-C_N/100) * D_N$	62.0	58.4	63.4
P_2O_5-surplus/ha			
Farm structure effect			
R^2 P_2O_5-surplus on management (A_P)	75.3	74.0	77.7
R^2 residuals P_2O_5-surplus on residuals structure (B_P)	73.3	69.3	74.5
R^2 structure $(1-A_P/100) * B_P$	18.1	18.0	16.6
Farm management effect			
R^2 P_2O_5-surplus on structure (C_P)	-	-	-
R^2 residuals P_2O_5-surplus on residuals management (D_P)	-	-	-
R^2 management $(1-C_P/100) * D_P$	-	-	-
Approximated R^2 management (R^2_{total}- R^2 structure)	75.3	74.0	77.7
Gross margin/100 kg FPCM			
Farm structure effect			
R^2 gross margin on management (A_G)	22.0	20.4	15.7
R^2 residuals gross margin on residuals structure (B_G)	27.4	21.5	19.0
R^2 structure $(1-A_G/100) * B_G$	21.4	17.1	16.0
Farm management effect			
R^2 gross margin on structure (C_G)	27.7	23.7	19.5
R^2 residuals gross margin on residuals management (D_G)	21.8	18.1	15.7
R^2 management $(1-C_G/100) * D_G$	15.7	13.8	12.6

The explanatory power of farm structure on the nitrogen surplus in 1997 is therefore 22.6%. The effect of farm management on the nitrogen surplus was derived in a similar way, resulting in a farm management effect ranging from 58.4%-63.4%. Farm structure was far less important than farm management in the period 1997-1999, with a ratio of approximately 1:3 for every year in the panel, confirming the assumption of Van den Brandt and Smit (1998) that most of the variation in N-surplus is explained by differences in management. The ratio was rather stable over this period, not showing any change in the relative importance of farm structure and farm management.

A problem appeared when trying to estimate the separate effects of farm structure and farm management on the P_2O_5-surplus/ha. No significant models could be estimated for the regression of the surplus on farm structure. To get an approximate estimation for the effect of farm management on the P_2O_5-surplus, the R^2 for structure was subtracted from the R^2 of the total model, resulting in R^2s of 74.0%-77.7%. This percentage is likely smaller, however, because the common variance of farm structure and farm management is included in this measure as well. The ratio of importance of farm structure versus farm management is 1:4.

The effect of the farm structure and farm management variables used in the explanation of the N-surplus on the gross margin is shown in the last rows of Table 4.2. In the case of the gross margin, structure is relatively more important (ratio of approximately 1:0.8), contrary to the nutrient surpluses. The explanatory power of farm structure and farm management is low. The independent variables were chosen to explain N-surpluses rather than financial results, explaining these low percentages.

4.3.2 Total regression results

Nitrogen

Table 4.3 shows the regression results of both the structure and management variables on the nitrogen surplus per ha. Both B and β values are given, to show the absolute and relative importance of the variables. The main (significant in every year) farm structure characteristics are farm intensity and milk production per cow. Farm intensity significantly increases the N-surplus/ha, which is according to the expectations that when production per unit of land increases, the nutrient surpluses will rise as well. Higher milk production per cow is able to significantly undo some of that effect, because with a high milk production per cow, fewer cows are needed to fill the milk quota, thus reducing stocking rate, and consequently feed needs. In 1997 and 1998 the percentage of grassland was significant, but not in 1999. Apparently, the significance, as well as the relative importance of the share of grassland has decreased over the years. It is likely that the quality of grassland management has been (is being) optimised through less chemical fertiliser application (better timing and application methods) and better utilisation of N in manure, resulting in a decrease in the generally higher losses from grassland relative to losses associated with maize production.

Table 4.3 Regression coefficients for N-surplus/ha

	1997			1998			1999		
	B	β	t	B	β	t	B	β	t
Constant	-282.16		-4.73^{***}	-239.15		-3.55^{***}	-316.37		-5.10^{***}
Farm Structure									
Dummy peat soil	-6.27	-0.03	-0.82	-12.63	-0.06	-1.42	16.84	0.07	2.06^{*}
Size (100 DSU)	-2.29	-0.15	-0.41	-7.05	-0.05	-1.12	-5.18	-0.03	-0.98
N-factor	1.56	0.04	1.08	1.09	0.02	0.53	3.72	0.04	1.39
% ha with arable crops	2.21	0.02	0.43	-4.08	-0.03	-0.79	-3.94	-0.04	-1.07
Intensity (100 kg FPCM/ha)	2.30	1.06	5.26^{***}	1.60	0.72	3.42^{**}	2.05	0.91	5.33^{***}
$Intensity^2$ (1,000,000 kg FPCM/ha)	-0.19	-0.29	-1.50	-0.01	-0.02	-0.08	-0.09	-0.14	-0.84
FPCM/cow (100 kg FPCM/cow)	-1.63	-0.16	-3.99^{***}	-1.23	-0.11	-2.50^{*}	-1.22	-0.12	-3.21^{**}
% grassland	0.81	0.14	2.47^{*}	0.72	0.12	2.33^{*}	0.38	0.06	1.15
Farm Management									
Young stock (LU/10 cows)	19.85	0.16	4.19^{***}	13.06	0.08	2.05^{*}	28.95	0.18	5.16^{***}
Grazing intensity (100 LU grazing days/ha)	-2.71	-0.04	-1.09	7.13	0.10	2.44^{*}	-0.15	-0.00	-0.07
Fertiliser N (kg N/ha grassland)	0.80	0.73	18.11^{***}	0.76	0.74	15.97^{***}	0.84	0.73	19.98^{***}
Net manure import (kg N/ha)	0.73	0.46	9.45^{***}	0.76	0.45	9.38^{***}	0.79	0.37	10.22^{***}
Concentrates (MJ NEL/kg FPCM)	-2.40	-0.01	-0.28	0.17	0.07	1.53	0.15	0.05	1.51
N in concentrates (g N/kg concentrates)	1.41	0.12	2.34^{*}	0.70	0.06	1.10	1.44	0.11	2.53^{*}
Actual – standard feed purchases (100 MJ NEL/ha)	2.86	0.61	12.65^{***}	2.67	0.54	9.66^{***}	2.96	0.60	11.96^{***}
Model summary									
F		60.20^{***}			49.08^{***}			75.78^{***}	
R^2/R^2_{adj}		90.3/88.8			88.4/86.6			92.2/91.0	

* P< 0.05, ** P< 0.01, ***P<0.001

The β–coefficients of the significant farm management variables show that of these variables, nitrogen use in fertilisers is the main contributor to a higher surplus. The B shows that for each kg of N in chemical fertiliser per ha, the surplus increases with 0.76-0.84 kg/ha. This high ratio shows that the efficiency of the use of N in chemical fertiliser is low and could be improved. Second, the difference between actual and standard feed purchases, or operational management is found to be most important, with a larger difference leading to a larger surplus. When the difference is negative (less feed needed compared to the standard), this reduces the surplus. Third, the N, which is imported via manure, increases the surplus and finally the larger the number of young stock per cow, the larger the N-surplus. All these findings are according to the expectations.

The total model explains 86.6%-91.0% in the different years (R^2_{adj}), indicating that the main variables for explaining the N-surplus are in the model. Comparing the normal R^2 with the sum of the separate effects of farm structure and farm management in Table 4.2, it appears that there is 5.7% (in 1997) to 10.7% (in 1998) of variance, which cannot be separated (note that this number can also be determined from Table 4.2, by subtracting e.g. the farm management effect from A_N). This part of the variance in N-surpluses is associated with both structure and management characteristics. Optimisation through fine-tuning of individual farm characteristics is therefore possible if one does not neglect the mutual dependency of structural and/or management characteristics.

Phosphate

Table 4.4 shows the results of the regressions of the phosphate surplus on both farm structure and farm management variables. Three significant farm structure variables show up from 1997-1999. Farm intensity is the main one, with higher intensities leading to higher P_2O_5-surpluses per ha, because of more inputs (especially feed) per unit of land. A higher production capacity of the herd decreases the surplus, due to fewer animals on the farm. The direction of these relationships is similar to the ones of the N-surplus/ha. Relatively more grassland reduces the surplus significantly, however, a direction contrary to the one found in the explanation of the N-surplus. Grassland requires less phosphate compared to maize, and more grass in the cropping plan will therefore lead to lower phosphate surpluses.

Table 4.4 Regression coefficients for P_2O_5-surplus/ha

	1997			1998			1999		
	B	β	t	B	β	t	B	β	t
Constant	-67.67		-4.82***	-61.46		-4.32***	-85.48		-6.68***
Farm Structure									
Dummy peat soil	0.10	0.00	0.05	0.68	0.01	0.32	6.13	0.08	2.77**
Size (100 DSU)	-0.97	-0.02	-0.60	-0.75	-0.02	-0.51	-0.91	-0.02	-0.64
N-factor	1.88	0.12	0.65	0.08	0.01	0.02	4.32	0.15	1.29
N-factor^2	-0.08	-0.06	-0.30	0.06	0.04	0.15	-0.36	-0.10	-0.88
% ha with arable crops	-0.15	-0.00	-0.11	-0.32	-0.01	-0.26	-0.35	-0.03	-1.10
Intensity (100 kg FPCM/ha)	0.49	0.64	14.51***	0.45	0.69	13.66***	0.47	0.65	15.33***
FPCM/cow (100 kg FPCM/cow)	-0.51	-0.15	-4.58***	-0.30	-0.09	-2.45*	-0.24	-0.07	-2.36*
% grassland	-0.25	-0.12	-3.07**	-0.29	-0.16	-4.11***	-0.35	-0.17	-4.23***
Farm Management									
Young stock (LU/10 cows)	5.21	0.12	3.97***	4.22	0.09	2.68**	7.61	0.15	4.90***
Grazing intensity (100 LU grazing days/ha)	0.46	0.02	0.66	1.71	0.08	2.41*	0.05	0.02	0.75
Fertiliser P (kg P_2O_5/ha)	0.97	0.82	28.79***	0.90	0.78	23.15***	0.98	0.71	26.54***
Net manure import (kg P_2O_5/ha)	0.91	0.64	18.41***	0.92	0.76	19.41***	0.88	0.57	19.14***
Concentrates (MJ NEL/kg FPCM)	11.00	0.15	4.64***	9.30	0.14	3.47**	13.90	0.16	5.40***
P in concentrates (g P/kg concentrates)	5.64	0.24	7.68***	3.94	0.19	5.42***	5.73	0.22	7.51***
Actual – standard feed purchases (100 MJ NEL/ha)	0.73	0.45	11.60***	0.82	0.55	12.28***	0.83	0.53	12.27***
Model summary									
F		91.53***			74.71***			106.10***	
R^2/R^2_{adj}		93.4/92.4			92.0/90.8			94.3/93.4	

* P< 0.05, ** P< 0.01, ***P<0.001

All but one management variable proved to be significantly related to the P_2O_5-surplus/ha. Only grazing intensity was not significantly related to the surplus in 1997 and 1999. The two relatively most important variables (see βs) are the use of P in fertiliser and the net amount of P imported to the farm in manure, both matters of fertilisation management. This positive relationship could be expected because they are directly linked to the surplus. Next, operational management (actual – standard feed purchases) is of importance, with worse operational performance increasing the surpluses, as could be expected. Feeding management, expressed in the amount of concentrates fed and the P-content of concentrates is of importance as well, with more concentrates and more P in concentrates resulting in higher surpluses. In many cases P and (less likely) energy are overfed to avoid problems with fertility and gestation, but more accurate feeding will lead to a lower P_2O_5-surplus. This finding is important for the phosphate surplus. In MINAS, the main management variable, P in fertiliser, is exempt from the taxable P-surplus and will thus reduce the P-surplus, but not the levy. Other ways will therefore have to be used to reduce the levied components of the surplus. Another way is to reduce the number of young stock, which is effective for both N and P_2O_5. Like the case of N, in 1998 grazing intensity becomes significant, due to the same reason. Totally as much as 90.8%-93.4% could be explained using both farm structure and farm management variables, the models being highly significant. The common variance of farm structure and farm management cannot be determined in the case of P_2O_5, because of the inability to exactly determine the separate effect of management.

Gross margin

Table 4.5 shows the results of the regression of the gross margin on the farm characteristics used in the explanation of the N-surplus. It shows the relationship between farm characteristics (be it structure or management) important for the nutrient surpluses and the effect of these characteristics on financial results. To check whether or not farms were operating at the level of decreasing marginal returns, a squared term for milk production per cow and N in fertiliser was tried. This did not yield any significant result, indicating that the dairy farms in the sample are operating in the linear range of both milk production per cow and use of fertiliser per ha grassland. The main variables (significant in all three years) are intensity of the farming system, as well as the level of operational management. In 1997 several other farm characteristics significantly affect gross margin, but their significance either declined or disappeared over the period under consideration. The coefficient of determination declines from 34.8% to 21.2% in the course of three years, indicating that other factors like prices (of milk, manure and cattle) become more important.

Table 4.5 Regression coefficients for gross margin/100 kg FPCM (€)

	1997			1998			1999		
	B	β	t	B	β	t	B	β	t
Constant	33.56		7.74^{***}	39.65		7.78^{***}	36.67		7.27^{***}
Farm Structure									
Dummy peat soil	-1.09	-0.17	-1.91^{*}	-0.43	-0.06	-0.63	-1.73	-0.25	-2.45^{**}
Size (100 DSU)	0.94	0.21	2.26^{*}	0.46	0.09	0.96	0.02	0.00	0.04
N-factor	0.32	0.23	2.94^{**}	0.23	0.13	1.50	0.02	0.01	0.10
% ha with arable crops	0.00	0.00	0.01	-0.34	-0.08	-0.86	0.25	0.08	0.80
Intensity (100 kg FPCM/ha)	-0.13	-1.90	-3.94^{***}	-0.13	-1.75	-3.56^{***}	-0.09	-1.30	-2.57^{**}
$Intensity^2$ (1,000,000 kg FPCM/ha)	0.03	1.39	2.97^{**}	0.02	1.14	2.41^{**}	0.01	0.74	1.54
FPCM/cow (100 kg FPCM/cow)	0.00	0.01	0.07	0.06	0.18	1.68^{*}	0.01	0.04	0.37
% grassland	0.05	0.29	2.20^{*}	-0.00	-0.00	-0.04	0.02	0.12	0.79
Farm Management									
Young stock (LU/10 cows)	0.86	0.22	2.44^{**}	-0.04	-0.01	-0.08	-0.62	-0.13	-1.29
Grazing intensity (100 LU grazing days/ha)	0.01	0.05	0.55	0.11	0.05	0.51	-0.04	-0.02	-0.20
Fertiliser N (kg N/ha grassland)	-0.01	-0.17	-1.73^{*}	-0.01	-0.16	-1.47	-0.00	-0.08	-0.72
Net manure import (kg N/ha)	0.00	0.02	0.20	-0.00	-0.00	-0.01	0.00	0.08	0.71
Concentrates (MJ NEL/kg FPCM)	0.00	0.02	0.18	0.00	0.03	0.29	0.00	0.03	0.34
N in concentrates (g N/kg concentrates)	-0.02	-0.07	-0.53	-0.06	-0.15	-1.26	-0.02	-0.05	-0.40
Actual – standard feed purchases (100 MJ NEL/ha)	-0.06	-0.44	-3.89^{***}	-0.07	-0.46	-3.79^{***}	-0.07	-0.51	-3.54^{***}
Model summary									
F		5.017^{***}			3.93^{***}			3.007^{***}	
R^2/R^2_{adj}		43.4/34.8			37.5/28.0			31.7/21.2	

* P< 0.05, ** P< 0.01, ***P<0.001

Higher intensity of the farming system is accompanied by more inputs (especially feed purchases) per unit of milk, thus reducing the gross margin per unit of milk. This factor also increases the N as well as the P_2O_5-surplus per ha. The obvious thing to do would therefore be to reduce farm intensity. Looking only at gross margin per unit of milk production, however, does not take into account fixed costs of the dairy production process. Beside milk quota, land is an increasingly scarce resource in Dutch agricultural and horticultural production, with an average price as high as prices ranging from €25.000/ha to over €130.000/ha, depending on region and main type of production (Brouwer *et al.*, 2002). The average price for land is as high as €38.727/ha for all agricultural enterprises and €36.909 for dairy farms in 2000 (Brouwer *et al.*, 2002). A high intensity (milk quota/ha) generally results in a high gross margin/ha and in this way farmers can maximise the returns to scarce land. It is therefore economically rational to maximise farm intensity, and MINAS is an extra constraint on the maximally feasible intensity.

Operational management is important because the fewer feed purchases necessary relative to the standard, the lower the feed costs, affecting the gross margin in a positive way. At the same time, an improvement in operational management lowers the nutrient surpluses (see Table 4.3 and Table 4.4). Apparently, an improvement of operational management is beneficial for both financial and environmental results. An improvement of operational management can be achieved by measures such as improving fodder production and grassland management at given nutrient levels, feeding at the individual needs of animals, better timing of fertilisation, restricted grazing, reducing storage losses et cetera.

According to Aarts *et al.* (1992), operational measures are relatively simple and easily implemented. The success of implementation is highly dependent on the characteristics of the farmer however. Interests and preferences, as well as craftsmanship are essential for the quality of operational management. The link between farm intensity and operational management is essential. The higher the quality level of operational management, the more a farmer can increase his farm intensity and remain within the limits of MINAS, without having to dispose of manure.

4.4 Conclusion

The main part of the variation in both nitrogen and phosphate surpluses is currently being explained by management characteristics. Reducing nutrient surpluses will therefore be more effective if farmers try to optimise nutrient management rather than changing farm structure. The main structural characteristics explaining differences in nutrient surpluses are farm intensity in terms of milk quota/ha and milk production per cow. A higher intensity results in higher nutrient surpluses, but increasing milk production per cow will reduce cattle intensity so less animals are needed to complete the milk quota. Of the management variables, especially fertiliser reduction and improving operational management will significantly reduce the nutrient surpluses. Operational improvements like more accurate feeding based on the needs of individual animals and improvement of grassland management by better timing of fertilising, grazing and harvesting and choosing a better way of conservation, require a large effort from farmers' management skills, however.

Changing nutrient management to reduce nutrient surpluses might alter financial results. The main structural factor affecting gross margin per unit of milk production was farm intensity. Reducing farm intensity would both reduce the nutrient surpluses and increase gross margin per unit of milk. This does not take into account the returns to land however, and with land being one of the scarcest and most expensive resources in dairy farming, this is not a wise option. Improving operational management will reduce the nutrient surpluses and at the same time increase the financial returns. This is an option, which should therefore always be tried.

V Identification of farmer characteristics and farm strategies explaining changes in environmental management and performance of dairy farms

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Abstract

In 1998 the Mineral Accounting System (MINAS) was introduced in The Netherlands. MINAS penalises farms with a levy if the farm's nutrient surpluses exceed a certain threshold. The threshold is strict, meaning that most farmers need to change their environmental management and performance to avoid high levies. Since MINAS is designed to leave ample room for farmers to follow the course of change of their choice, it is crucial to know whether or not different farmers and different farm strategies lead to different environmental results. A strategic management framework is used to model changes in implementation and performance on specialised dairy farms. Financial and nutrient bookkeeping data of 114 farms, collected over the period 1997-1999 are combined with survey data on farmer characteristics and farm strategies. Results of LISREL analysis showed that the main farmer characteristic explaining change in environmental management was education. Better-educated farmers chose to increase the intensity of the farming system, and cope with the corresponding increase in environmental pressure by improving the production capacity of the herd and improving operational management. Farm strategies explain the differences in the changes in nutrient management. Process control focuses on optimising tactical management, whereas growth and diversification are strongly related to changes in farm structure. Changes in technical and environmental performance on top of the changes resulting from implementation changes are positively affected by education, but show no strong relationship with any strategy, indicating that environmental improvements can be achieved regardless of the way a farmer chooses to develop his farm. Finally, an improvement of financial performance was shown to be significantly related to an improvement of environmental performance.

5.1 Introduction

Stringent environmental legislation to reduce nutrient pollution of groundwater by agricultural non-point sources has left Dutch farmers in a situation in which they need to choose between paying (large) fines or change farming towards more environmentally sound practices (Ondersteijn *et al.*, 2002). This is largely due to the introduction of the Mineral Accounting System (MINAS) in 1998. MINAS is a nitrogen- and phosphate bookkeeping system, which determines the difference between nutrient inputs and outputs, called the surplus. If this surplus exceeds a safe threshold, a farmer will be taxed. Since the fines are large, and the threshold is gradually being reduced[1] until in 2003 the WHO safety standard of 50 mg NO_3 per litre of groundwater will be reached, farmers will have to alter their management practices in order to achieve the acceptable nutrient surpluses.

According to a large body of research, the decisions farmers make to adjust to new circumstances are not only led by economic factors, but also by socio-economic and psychological characteristics (Gow and Stayner, 1995; Traore *et al.*, 1998; Willock *et al.*, 1999). This strong relationship between farmer characteristics and farm decisions is due to the fact that in The Netherlands farms are mainly run as family businesses in which the farmer (and his family) is at the same time entrepreneur, manager and main labor force of the farm. This also implies that the strategy of a farming business is chosen by the farmer alone and is thus mainly the result of his preferences, interests, capabilities and his assessment of the internal and external environment. The choice of a farm strategy leads to a certain direction in which environmental management and performance of individual farms will develop. Since environmental concerns caused by intensive and industrialising agriculture are surfacing all over the world, it is imperative to get a clear understanding of the relationship between farmer characteristics, farm strategies and the environmental changes on a farm. Moreover, insight into this relationship is of vital importance for effective environmental policy making and agricultural consulting.

Most of the relevant literature focuses on intentional, rather than factual environmental management behaviour, due to a lack of cases in which environmental policies are actually put in place (e.g. Ervin and Ervin, 1982; Featherstone and Goodwin, 1993; Elnagheeb *et al.*, 1995; Austin *et al.*, 1998; Traore *et al.*, 1998). The Dutch case provides an opportunity to study the effect of the introduction of environmental legislation on farm management and farm results. The purpose of this paper is to identify the farmer characteristics and farm

[1] The final standards are set at 180 kg/ha of nitrogen (N) for land covered with grass and 100 kg of nitrogen for every hectare of arable land. A surplus of 20 kg of phosphate (P_2O_5) is allowed per hectare regardless of cropping type. Farmers will be taxed €2.30 for every kg of N that exceeds the standard, and €9.00 for every kg P_2O_5.

strategies, which explain the changes in environmental management and in technical, environmental and financial performance. Using technical, financial and nutrient bookkeeping data of 114 specialised dairy farms collected over three years (1997-1999) and a survey held in 1998 pertaining personal and management factors, a Structural Equation Modelling (SEM) approach is employed to explore the relationships of interest.

5.2 Theoretical background

Studies by Harling and Quail (1990) and Harling (1992) showed that general and strategic management approaches are applicable to farm businesses. It helps to structure the complexity of farm decision-making. In general, strategic management allows a business to be more proactive than reactive in shaping its future (David, 2001). Harling and Quail (1990), and Harling (1992) also find that more successful farmers seem to employ strategic management concepts, whereas less successful ones do not. The strategic management model describes the path the decision-maker intends to take from the existing position towards the desired position. David (2001) defined strategic management as 'the art and science of formulating, implementing and evaluating cross-functional decisions that enable an organisation to achieve its objectives'. Since the farmer is at the same time owner or tenant, manager, and (part of) the workforce of the agricultural enterprise, the sole purpose of farming is to fulfil the needs of the farmer. The farmer can define his needs in a mission statement. The mission addresses the basic question in farming: why farm? In order to be able to specify a mission into objectives, the internal strengths and weaknesses need to be identified. At the same time external opportunities and threats must be examined. During synthesis different strategies are generated, evaluated and selected. Strategies are the means to achieve the objectives. They have to meet the objectives within a certain time span and are dependent upon the strengths and weaknesses of the farm, the opportunities it is able to seize and the threats it can avoid. When a strategy is chosen, it has to be translated into tactics so the farmer can implement the strategy in the farms’ production process.

The analytical model, based on the strategic management framework, is presented in Figure 5.1. The numbered arrows (1 through 4) indicate the relationships of interest. The decision path from mission, via strategic choice to implementation, resulting in performance, is causal according to the general strategic management model. Due to his unique position, the farmer affects both strategic planning (as an entrepreneur or manager) as well as the implementation of the chosen plan (as a manager or craftsman), and the resulting performance (as a craftsman). The path from implementation to performance is not considered because it represents a technical rather than management relationship. The internal and external environments are also not taken into account, even though the strategy is a product of the farmer's assessment of both environments.

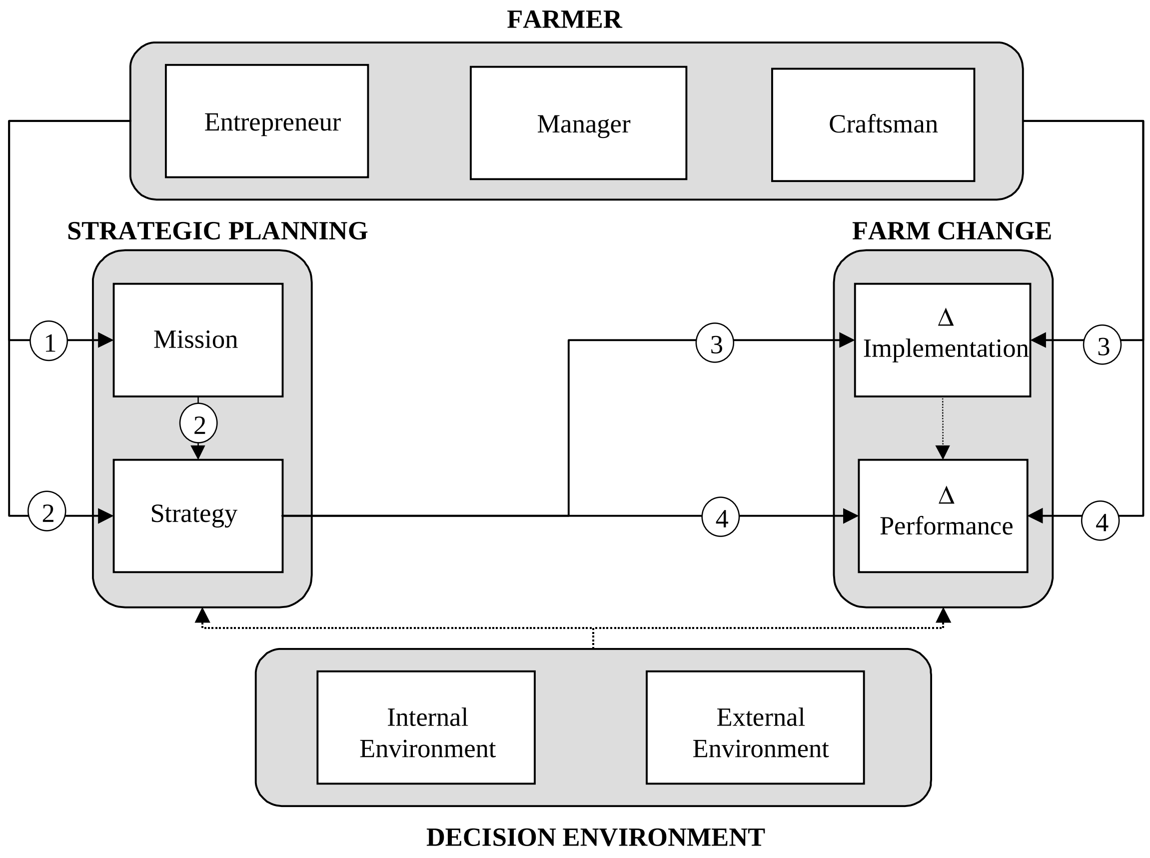

Figure 5.1 Analytical framework of farmer characteristics, strategic planning, and farm change

Summarising Figure 5.1, the relationships of interest are as follows:

(1) Farmer -> Farm mission
(2) Farmer + Farm mission -> Farm Strategy
(3) Farmer + Farm Strategy -> ΔImplementation
(4) Farmer + Farm strategy -> ΔPerformance

Farmer

According to Rougoor (1998) and Nuthall (2001), the management capacity of a farmer consists of two parts, namely personal characteristics (drives, motivations, abilities and biographical factors), and aspects of the decision making process. A wide range of personal characteristics of the farmer that could possibly influence management behaviour and farm performance has previously been studied. Age, for instance was addressed by e.g. Kerridge (1978), Frawley and Reidy (1986), Anosike and Coughenour (1990), Ilbery (1991), Tauer

(1995), Andreakos *et al.* (1997), Burki and Terrell (1998), and Tauer and Lordkipanidze (2000). These studies showed mixed results. Age represents experience to a certain extent, and may also explain part of the variation found in motivations and goals. The phase in the lifecycle of the family-farm is considered a possibly important variable in the analysis based on studies by Anosike and Coughenour (1990), Andreakos *et al.* (1997), and Robinson (2000). Different phases are accompanied by different motivations and interests and will therefore influence management decisions. Education was studied by Kerridge (1978), Frawley and Reidy (1986), Anosike and Coughenour (1990), Phillips (1994), Andreakos *et al.* (1997), Wilson *et al.* (2001) and is generally considered of importance for farm performance, even though conclusive proof has yet to be found (Gasson, 1998). A variable, representing farmers' information gathering and processing behaviour was used in an analysis by (Wilson *et al.*, 2001). According to Wilson *et al.* (2001), this measure provides an indication of practices and procedures in planning and will directly influence the decision-making process as suggested by Rougoor (1998).

Farm mission

Several authors (e.g. Gasson, 1973; Kerridge, 1978; Patrick *et al.*, 1983; McGregor *et al.*, 1996; Robinson, 2000) distinguish 4 categories of mission statements: expressive or personal, instrumental, social, and intrinsic. High importance addressed to expressive mission statements suggests that farming is seen as a means of self-expression or personal fulfilment. High scores on instrumental mission statements indicate that farming is viewed as a means of obtaining income and security under pleasant working conditions. A social orientation towards farming means that one farms for the interpersonal relations and recognition associated with farming, and finally, intrinsic mission statements represent the idea that farming is an activity in its own right. The basis of this distinction was founded in Gassons' paper of 1973 and has proved to apply ever since (Fairweather and Keating, 1990).

Farm strategy

Farm strategy research has usually focussed on one or a couple of specific strategies. Horizontal diversification versus expansion decisions for instance, were studied by McGregor *et al.* (1996). The choice for horizontal diversification or of-farm employment was studied by Anosike and Coughenour (1990). Frawley and Reidy (1986) identified three categories of dairy farmers based on past milk supply patterns: expanders, contractors and static suppliers. A study by Huirne *et al.*(1997) focussed on the rational behind different roughage production strategies. These studies all addressed strategies that were put into effect in the past. However, Grant (1997) suggests to distinguish between intended and realised strategy. The intended strategy is the strategy that is formulated and which managers intend to pursue. The realised strategy is what has finally been achieved of the intended strategy due to changing internal and external circumstances. In this study we focus on intended strategies: which path are dairy farmers intended to take given their personal characteristics and mission statements.

Implementation and Performance

A strategy needs to be implemented and translated into actual farm decisions. The implementation stage needs to consider task areas like production, marketing, and financing, and because of the introduction of MINAS, also the environmental consequences of these decisions. Decisions range from structural decisions like farming intensity, to very detailed operational decisions like timing of fertiliser application. Implementation of the strategy leads to changes in technical, financial and environmental farm results. In this study the purpose is to find the explanatory power of farmer characteristics and farm strategies additional to implementation. Therefore, the technical, environmental, and financial results need to be corrected for differences in implementation among farms, to be able to estimate the relationship between farmer characteristic, farm strategies and the residual results.

5.3 Material and Method

5.3.1 Material

Both financial and nutrient accounting data of 114 specialised dairy farms[2] were collected over a period of three years (1997-1999) as part of a large government supported project called Farm Data in Practice (FDP, Project Praktijkcijfers in Dutch). Gaining empirical insight into nutrient management on commercial farms, and to support and improve nutrient management practices to deal with MINAS regulation, were the main goals of the project. For a more detailed description see Ondersteijn *et al.* (2002). In 1998 a management survey was conducted among the participants of the project, pertaining questions on farmer characteristics, mission statements, and strategies. Of the responses, 5 were discarded from further analysis due to the large number of missing values. This lead to an effective sample size of 109 highly specialised dairy farmers.

Farmer

Table 5.1 shows the farmer characteristics used in the study. Age was asked straightforward. The phase in the family-farm lifecycle is based on the measurement of two indicators, the organisational structure, and with whom the farm is managed. These two variables resulted in four types of organisation: partnerships between parents and children, husband-wife

[2] A farm is classified as a specialised dairy farm if at least 95% of all DSUs can be attributed to dairy production. The DSU is an economic size unit, based on the contribution of an agricultural activity to the standard gross margin.

partnerships, one-man operations and others. Farms with a partnership between parents and children were considered to be in the transitional stage and got a score of 1. All the other organisational structures were considered to be in the growth and/or consolidation stage and received a score of 0. Educational level is measured on three levels of secondary education, low, medium and high. All but few farmers in the sample had received secondary education. Those few were grouped along with respondents having low level secondary education. A few respondents received MSc-level education, and were grouped with respondents having BSc-level education. This group was scored high. All others mostly attended specialised agricultural education of medium level. Finally information use was measured by summing several items (course participation, study group participation, subscriptions to specialist journals, and the use of management tools). This measure is equal to Wilson's measure of information seeking behaviour (Wilson *et al.* 2001).

Table 5.1 Descriptive statistics of farmer characteristics

	Mean	Std. dev.	Percentage
Age	39.47	8.25	
Phase in the family farm lifecycle			
Entry/exit			33%
Growth/consolidation			67%
Educational level			
Low			17%
Medium			63%
High			20%
Information use	10.65	2.36	

Farm mission

Studies exploring mission statements, generally use 4 to 5 statements to represent each of the four categories. The selection of the 10 statements used in the current survey is the result of several Dutch studies performed on dairy farmers in the Farm Accounting Data Network (FADN). In these studies (Van den Ham *et al.*, 1998a; Van den Ham *et al.*, 1998b, Van den Ham *et al.*, 1998c; Van den Ham and Van der Schans., 1999) the survey was modified and improved according to the results. Furthermore, farm growth is usually considered a mission in other studies. In this study, growth is considered a strategy to fulfil the more abstract mission of the farmer. This was also suggested by Marsden *et al.* (1989) and Ilbery (1991). Table 5.2 gives an overview of the average scores and standard deviations of the importance addressed to the mission statements in the survey. To check for the validity of the four-factor model suggested by literature, a confirmatory factor analysis was employed of which factor loadings and eigenvalues are shown in Table 5.2. The factors extracted corresponded well to the categories mentioned by previous authors and identical categories are therefore used in this study.

Table 5.2 Descriptive statistics of strategic planning (scores on 5-point Likert scales, ranging from very unimportant to very important)

	Mean	Std. dev.	Factor loading	Eigenvalue
MISSION				
Expressive				2.12
Feed the world	3.28	0.84	0.80	
Care for a clean environment	3.68	0.56	0.61	
Pass on land in good condition	3.99	0.83	0.65	
Social				1.55
Appreciation from society	3.93	0.73	0.79	
Appreciation from colleagues	3.46	0.80	0.80	
Instrumental				1.38
Earn a high income	3.94	0.71	0.68	
Sufficient spare time	3.24	0.82	-0.04	
Intrinsic				1.00
Work and live in nice surroundings	4.11	0.89	-0.02	
Independence	4.26	0.69	0.12	
Enjoy farm work	4.76	0.45	0.61	
STRATEGY				
Process control				2.36
Accurate feeding and fertilisation	4.49	0.54	0.78	
Production of high quality milk	4.58	0.53	0.55	
Production of high energy roughage	4.62	0.51	0.68	
Labour efficiency	4.37	0.57	0.70	
Diversification				1.43
Horizontal or vertical diversification	2.24	1.09	0.81	
Of-farm employment	2.18	0.88	0.84	
Growth				1.07
Expansion	3.95	0.73	0.77	
Cattle intensive farming system	2.89	0.93	0.84	

Farm strategy

The survey question on strategies was composed of 21 strategy components based on Van den Ham *et al.* 1998a; Van den Ham *et al.*, 1998b; Van den Ham *et al.*, 1998c, Van den Ham and Van der Schans, 1999. An exploratory factor analysis was employed to check which ‘strategy factors’ showed up and if they agree with literature. This resulted in a 6-factor solution.

Combing literature and findings in the data led to the distinction of 3 clear strategies, based on 8 strategy components. The other factors were considered farming styles rather than farm strategies. A confirmatory factor analysis on the 8 items showed that the 3 factors were correctly distinguished. These strategies and their corresponding observed variables with factor loadings and eigenvalues are shown in Table 5.2. First a strategy focussing on controlling the production process was distinguished. It is based on fine-tuning several aspects of the production process and production of high quality products. Second, a diversification strategy could be distinguished which focuses on differentiation of the farm activities. Finally, a growth strategy could be identified. Either through expansion or increasing the number of animals per hectare, farmers intend to increase production.

Changes in implementation and performance

Table 5.3 gives an overview of the implementation and performance variables in the analysis. Since we are especially interested in environmental behaviour of farms, implementation variables were chosen, which have a significant effect on the nitrogen and phosphate surplus of dairy farms[3]. In general, a higher level of the implementation variables results in higher surpluses (worse performance), except for milk production per cow. Changes in implementation were determined by calculating the difference between the values of 1999 and 1997.

Table 5.3. Descriptives of implementation and performance change over 1997-1999

	Change 1997-1999		1997 value	
	Average	Std. dev.	Average	Std. dev.
IMPLEMENTATION				
Kg milk quota (4.24% fat)/ha	694	1742	13560	3383
Fat and protein corrected milk production/cow	76	518	8300	734
LU young stock/10 cows	-0.40	0.50	3.02	0.59
Fertiliser N/ha grassland (kg N/ha grass)	-45	66	289	67
Net N import in manure (kg N/ha)	15	46	0.17	46.80
Actual-standard net feed supply (MJ NEL/ha)	42	1425	1129	1597
PERFORMANCE				
Total Factor Productivity Growth	1.023	0.19		
Nutrient Productivity Growth	1.202	0.63		
Δ residual FAS Gross Margin/100 kg FPCM (€)	-0.07	2.16		
Technical Efficiency			98	4.45
Nutrient Efficiency			78	26.48
Residual FAS Gross Margin/ 100 kg FPCM (€)			-0.05	1.99

[3]See Chapter 4

Three performance measures can be distinguished: technical, environmental, and financial performance. Because performance of farms is the result of implementation, the effect of this factor has to be eliminated to be able to determine the additional explanatory power of farmer characteristics and farm strategies on performance of farms. For technical and environmental performance, Malmquist indices were therefore calculated to represent Total Factor Productivity Growth (TFPG) and Nutrient Productivity Growth (NPG), which is a measure of change in nutrient productivity[4]. The indices are based on efficiency measures calculated by Data Envelopment Analysis (DEA) (e.g. Coelli *et al.*, 1999). TFPG and NPG are a ratio of change in total output to total input (or a change in output to nutrient surpluses, given the other inputs in the case of NPG), where 1 represents no change, and a number smaller or larger than 1 decline or growth respectively. Due to a lack of data on prices, no financial equivalent of a Malmquist Index could be calculated. Instead, the difference between the 1999 and 1997 residuals of the Farm Adjusted Standards (FAS) of the gross margin per 100 kg of fat and protein corrected milk (FPCM) were used (Hennen, 1995). FAS measures are measures of performance corrected for farm specific structure and management using regression equations. The residuals represent the financial management qualities of the farmer, with negative residuals being better and positive residuals being worse than average performers. Descriptive statistics of changes in implementation and performance are shown in the first two columns of Table 5.3.

The effects of farmer characteristics and farm strategies on changes in implementation and performance may be affected by the past state of affairs of the farm. Therefore, a correction may be necessary for two reasons: First of all, farmers have a certain desired situation in mind, and the distance to this situation differs for farms, thus affecting the magnitude of needed change (as suggested by Gow and Stayner, 1995). Another reason is that MINAS influences certain behavioural aspects of farms equally. For example fertiliser-N is reduced by (in different amounts) virtually all farmers because it was over-used due to relatively low costs. A correction is therefore made through inclusion of the 1997 values of the implementation and performance variables in the statistical model. The average values of the 1997 implementation and performance variables, are shown in the last two columns of Table 5.3. For technical and environmental performance, DEA measures of technical and nutrient efficiency are used (Ondersteijn *et al.*, 2001), for financial performance, FAS residuals are used.

5.3.2 Method

To analyse relationships 1 through 4, Structural Equation Modelling (SEM) is employed. SEM has two main features. First of all, it enables the estimation of multiple and interrelated

[4] See Chapter 3

dependence relationships, and second, it is able to represent unobserved concepts, or hypothetical constructs (latent variables) in these relationships and accounts for measurement error in the estimation process (Hair *et al.*, 1998). In the present study LISREL 8.30 (Jöreskog and Sörbom, 1996) is used to estimate the parameters in the model. For matters of consistency, the LISREL notation is therefore used throughout the remainder of the paper. The basic LISREL model consists of two parts: a measurement model and a structural equation model. The measurement model specifies how latent variables are indicated by the observed or manifest variables (analogue to factor analysis). The structural model specifies the causal relationships among the latent variables, describes the causal effects, and assigns the explained and unexplained variance (analogue to linear regression). The full LISREL model for single samples is defined, by the following three equations (Jöreskog and Sörbom, 1996):

The structural equation model:

$$\eta = \mathrm{B}\eta + \Gamma\xi + \zeta$$

The measurement model for y:

$$y = \Lambda_y \eta + \varepsilon$$

The measurement model for x:

$$x = \Lambda_x \xi + \delta$$

In which y is a p×1 vector of observed response or outcome variables and x is a q×1 vector of predictors, covariates or input variables. The symbol η represents an m×1 random vector of latent dependent, or endogenous, variables, ξ is an n×1 random vector of latent independent, or exogenous, variables. The errors in the model are represented by ε, a p×1 vector of measurement errors in y, and δ a q×1 vector of measurement errors in x. The matrices of λ's in the measurement models are a p×m matrix of coefficients of the regression of y on η (Λ_y), and a q×n matrix of coefficients of the regression of x on ξ (Λ_x). The parameter estimates in the structural model are given in Γ, a m×n matrix of coefficients of the ξ-variables in the structural relationship, and B, an m×m matrix of coefficients of the η-variables in the structural relationship. B has zeros in the diagonal, and I–B is required to be non-singular. Finally, ζ is an m×1 vector of equation errors (random disturbances) in the structural relationship.

Although SEM was initially developed to analyse the structure of covariance matrices, the analysis of correlation matrices has gained widespread use. According to Hair *et al.*

(1998), the use of correlations is appropriate when the objective of the research is only to understand the pattern of relationships between constructs, but not to explain the total variance of a construct. The use of correlations is also preferred when comparisons across different variables are made, since the scale of measurement is arbitrary and affects the covariances. Furthermore, concerns about the significance of estimated coefficients (e.g. Cudeck, 1989) can be met because according to Dillon (1987) a correlation matrix provides more conservative estimates and is not upwardly biased (Dillon *et al.*, 1987). Since the variables in our models range from binary to censored, we use PRELIS to estimate so-called polychoric correlation matrices (Boomsma, 1992; Jöreskog, 1994). Correlation matrices are generally estimated using Weighted Least Squares (WLS), which makes use of an estimated asymptotic covariance matrix to generate the weights. Due to the small sample size however, the estimated asymptotic covariance matrix is unreliable, and therefore Maximum Likelihood (ML) estimation is preferred, which is robust for smaller sample sizes (Boomsma, 2000).

5.4 Estimation and Results

5.4.1 Farmer → Farm mission

The first step in the analysis contains the relationship between the characteristics of the farmer and the farm goals he pursues. The results of the ML-estimation are shown in Table 5.4. During the estimation, two Heywood cases (i.e. negative error variance estimates) appeared. These are likely caused by insufficient information due to the relatively small sample, thus causing sampling fluctuations (Dillon *et al.*, 1987). Using equality constraints, which ensure positive error variance estimates, the model was estimated again with reasonable results. The model fit the data reasonably well (χ^2/df = 1.54 with P = 0.01). The Goodness of Fit Index (GFI) was 0.89, and the Adjusted Goodness of Fit Index (AGFI) 0.80, which are slightly smaller than the proposed 0.90 for a good fit. The Standardised Root Mean square Residuals (SRMR) is small (0.088). Small residuals may compensate for possible lack of fit. The Q-plot of standardised residuals showed a sloped line, slightly less steep than 45º, indicating that the residuals are normal but slightly more variable than would be expected (Hayduk, 1987). The Root Mean Square Error of Approximation (RMSEA) was 0.072. The RMSEA approximates the lack of fit of the model and models with a value below 0.08 are considered to have reasonable fit (Browne and Cudeck, 1992).

Table 5.4 ML-estimates of farmer characteristics on mission statements (N=105)

		Age	LC-Phase	Education	Info-use	R^2
Expressive	γ	0.24	-0.07	0.08	0.01	0.07
	z-value	2.10**	-0.65	0.76	0.12	
Social	γ	-0.10	0.23	-0.31	-0.09	0.12
	z-value	-0.97	2.22**	-3.09***	-0.93	
Intrinsic	γ	0.08	-0.19	0.06	-0.08	0.05
	z-value	0.62	-1.65*	0.51	-0.70	
Instrumental	γ	-0.10	0.18	0.13	0.17	0.10
	z-value	-0.53	0.66	0.60	0.66	

*** $P < 0.01$, ** $P < 0.05$, * $P < 0.10$

Goodness of fit statistics :χ^2/df=1.54 (P<0.01), GFI=0.89, AGFI=0.80, SRMR=0.088, RMSEA=0.072

The results in Table 5.4 show that older farmers significantly address more importance to expressive goals. They farm because of what they can do with farming for others. Farmers in a transition state significantly address more importance to social acceptance. These are generally younger people (in accordance with the negative effect of age on social goals), oriented towards the future. Since they are working on a future in farming, it seems reasonable that they find social acceptance more important than their consolidating colleagues. Respondents with higher education tend to give significantly less importance to social acceptance than respondents with lower education levels. Farmers who are in a transitional stage find the intrinsic value of farming less important than farmers who are consolidating. Apparently being in the process of transferring the farm takes away the emphasis on the intrinsic qualities of farming. None of the parameter estimates proved to be significant in the explanation of instrumental goals. Apparently, income and spare time are basic necessities for all farmers, regardless of age, phase in the family farm lifecycle, education and information use.

5.4.2 Farmer + Farm mission → Farm strategy

The estimation of the relationship between farmer characteristics and mission statements on strategies was not successful. The input matrix proved not to be positive definite, which was solved by using a Ridge option, but still several Heywood cases existed (even in the estimates of the structural model) and the model could not be estimated to the authors' satisfaction. Possibly, a lack of information due to the small sample size is detrimental to this. Separate models were estimated for farmer characteristics and farm missions. Only for farmer characteristics an acceptable model could be estimated. A likely reason for not finding an acceptable model for farm missions and farm strategies is that there are several ways in which farmers manage to fulfil their missions. The strategies chosen are partly determined by the capacities of the farmer, and his internal and external environment. In other words, different strategies may lead to the same mission fulfilment in farming. The results of the estimation of farmer characteristics on farm strategies are shown in Table 5.5. Two Heywood cases had to be resolved, after which the model could be estimated. The Modification Indices (MI) suggested to add a path from the latent variable 'Diversification' to the observed variable 'Labour Efficiency', to improve fit. Furthermore, 'Growth' and 'Process Control' were correlated ($\rho = 0.44$, $z = 3.64$). Goodness of fit statistics are given below the Table and can be interpreted analogue to the previous model.

Process control is significantly positively influenced by the level of information use of the farmer. This relationship is according to the expectations; farmers who use a lot of information are more likely to follow a process control strategy. Process control requires a lot of information processing in order to be able to fine-tune production. The other farmer aspects did not prove to be significant for process control. Growth is negatively influenced by the age of the farmer. Diversification is significantly related to three farmer characteristics. First of all, farms in a transition stage are more likely to make use of a diversifying strategy. Often times the entering farmer is working part-time of the farm to build up equity or to avoid having excess labour on the farm. Another reason could be that diversification of farm activities is seen as an opportunity to spread risk of specialisation. Education is negatively related to diversification, indicating that more specialised dairy farms are operated by higher educated farmers. Also, farmers that make a lot of use of management tools and other information sources are less likely to implement a diversification strategy. These farmers are more prone to choose a specialisation and optimise the particular production process.

Table 5.5 ML-estimates of farmer characteristics on farm strategies (N=102)

		Age	LC-Phase	Education	Info-use	R^2
Process Control	γ	-0.05	0.06	0.10	0.38	0.14
	z-value	-0.37	0.51	0.84	3.15***	
Growth	γ	-0.29	-0.08	-0.06	0.10	0.07
	z-value	-2.70***	-0.78	-0.58	0.98	
Diversification	γ	0.05	0.20	-0.34	-0.16	0.14
	z-value	0.67	2.82***	-4.31***	-2.35***	

*** P < 0.01, ** P < 0.05, * P < 0.10

Goodness of fit statistics :χ^2/df=1.40 (P<0.05), GFI=0.92, AGFI=0.83, SRMR=0.080, RMSEA=0.063

5.4.3 Farmer + Farm strategy → ΔImplementation

Table 5.6 provides the estimates for equation 3. No feasible solution could be estimated for the total model because the number of parameters to be estimated was larger than the total sample size. Two separate models, one for farmer characteristics (model 3a) and one for farm strategies (model 3b) were therefore estimated. For model 3a, a correlation between change in farm intensity (Δ milk quota/ha) and change in manure import (ρ = -0.21, z = -2.97) was added, based on the MIs. This correlation indicates that farmers who increased the intensity of their farming system, decreased manure import. The MIs also suggested to add a path from base farm intensity (milk quota/ha in 1997) to Δ milk production per cow, indicating that farmers with a high farming intensity have increased milk production per cow more (γ = 0.37, z = 4.18). For matters of consistency, these paths were also added to model 3b. In model 3b the correlation between change in farm intensity and change in manure import proved to be insignificant, while the path from intensity to change in milk production per cow was positive like in model 3a, and significant (γ = 0.29, z = 2.68) The goodness-of-fit statistics are given below Table 5.6. The coefficient estimates show that the educational level of farmers significantly affects some of the choices a farmer makes in the changes he applies to his farm. Generally speaking, better-educated farmers choose for increasing intensity (milk quota/ha), and increasing young stock per cow, both surplus increasing measures. They try to keep the extra number of dairy cattle needed to fill the extra milk quota down by increasing animal productivity. They also aim to improve the level of operational management to compensate for the increased farm intensity. The phase in the family-farm lifecycle is of importance for the change in milk production per cow, with farmers in the transition state being more likely to increase milk production per cow. Farms in the transition phase are also more likely to increase manure import. The change of farm ownership apparently brings a new approach to milk production and manure management with it.

The 1997 values of implementation variables are all significant. Note that the change in milk production per cow is also significantly positively related to the base level of farm intensity. Since the changes can be either positive (an increase) or negative (a decrease), except for young stock/cow and fertiliser N/ha, which are mainly negative, the explanation should be interpreted accordingly. Therefore, the more intensive a farming system was in 1997, the more it has reduced intensity or the less it has increased intensity. Farms with a relatively low productive herd have increased milk production per cow more (or decreased less) than the farms with already high productive cows. More intensive farming systems however, have increased animal productivity more than less intensive farming system. Since the more intensive farming systems generally have a better producing herd (ρ = 0.30 in our sample), it can be concluded that the farmers who have been increasing milk production per cow are relatively intensive farming systems with relative low animal productivity.

Table 5.6 ML-estimates of farmer characteristics on implementation change (Model 3a; N=108) and farm strategies on implementation change (Model 3b; N=103)

		Model 3a						Model 3b				
		Age	LC-phase	Education	Info-use	Base 1997#	R^2	Process control	Growth	Diversification	Base 1997#	R^2
Δ Kg milk quota (4.24% fat)/ha	γ	-0.17	-0.12	0.25	-0.09	-0.16	0.14	-0.18	0.49	-0.60	0.13	0.06
	z-value	-1.59	-1.10	2.34**	-0.91	-1.72*		-1.35	2.55**	-2.84***	1.09	
Δ Kg FPCM/cow	γ	0.12	0.17	0.36	0.06	-0.34	0.33	-0.31	-0.21	0.28	-0.03	0.28
	z-value	1.22	1.78*	3.82***	0.64	-3.84***		-2.87***	-1.28	1.63	-0.23	
Δ LU young stock/10 cows	γ	0.02	-0.03	0.32	0.10	-0.56	0.41	-0.26	1.08	-1.25	0.33	0.37
	z-value	0.25	-0.39	3.64***	1.21	-7.15***		-1.53	4.18***	-4.85***	2.74***	
Δ Fertiliser N/ha grassland (kg N/ha)	γ	-0.04	0.14	0.04	-0.02	-0.47	0.23	0.21	0.50	-0.49	0.29	0.26
	z-value	-0.38	1.45	0.40	-0.21	-4.83***		1.78*	2.86***	-2.84***	2.86***	
Δ Net N import in manure (kg N/ha)	γ	0.10	0.27	0.03	-0.05	-0.64	0.49	-0.33	-0.02	0.17	-0.20	0.16
	z-value	1.24	3.34***	0.33	-0.67	-8.92***		-2.88***	-0.10	0.65	-1.35	
Δ Actual-standard net feed supply (MJ NEL/ha)	γ	0.05	0.05	-0.18	-0.12	-0.38	0.15	-0.22	-0.55	0.72	-0.27	0.34
	z-value	0.49	0.51	-1.68*	-1.22	-3.88***		-1.77*	-2.99***	3.90***	-2.89***	

*** $P < 0.01$ ** $P < 0.05$, * $P < 0.10$

'Base' = the value of the Δ variable in 1997, representing past behaviour

Goodness of fit statistics Model 3a: χ^2/df=1.84 (P<0.001), GFI=0.91, AGFI=0.73, SRMR=0.064, RMSEA=0.094

Goodness of fit statistics Model 3b: χ^2/df=1.91 (P<0.001), GFI=0.80, AGFI=0.67, SRMR=0.083, RMSEA=0.095

Since most farmers in the sample reduced the number of young stock on the farm, the negative relationship between the 1997-value indicates that farms with more young stock in 1997 have reduced this number more than others. The same can be said for fertiliser use; the more they used in 1997, the more they have reduced the use of fertiliser N. Manure import is negatively affected by the situation in 1997, indicating that the higher the import was previously, the more this import was reduced, or the less it was increased. Finally, farms with high levels of actual – standard net feed supply (poor operational management) in 1997, have improved this more than farms with low levels (good operational management). The former farms had more opportunities to reduce losses and improve efficiency of roughage production.

Model 3b shows that a large emphasis on a strategy of process control has led to a decrease (or smaller increase) in milk production per cow, a smaller decrease in use of fertiliser N, a decrease (smaller increase) in manure import, and an improvement (smaller worsening) of operational management. Since nutrients in manure are more difficult to utilise than those in fertiliser, the process controller has made a substitution. The improvement of operational management has not (yet) led to a farm which is able to supply his dairy herd with the feed it needs to maintain the production level. However, in time this problem may be solved. A growth strategy has resulted in a significant increase in farm intensity. These farms also have reduced the number of young stock significantly less than other farms, probably because they need the young stock for the increase in production. They also increased fertiliser N (or decreased less), because a larger herd requires more roughage. At the same time they have improved operational management to reduce the surpluses. Diversifying farmers have decreased the intensity of the farming system significantly more compared to the other strategies, and also reduced the number of young stock per cow and fertiliser use. Diversification has also led to a decrease in the quality of operational management. This strategy is the only one leading to a larger difference between actual and standard feed supply.

Comparing model 3b with model 3a, it is clear that when strategies are included in the model, the 1997 situation becomes less relevant for change. Only for young stock per cow, fertiliser use and operational management is the 1997-value of importance. More importantly, the sign of the coefficient changes for young stock per cow and fertiliser use indicating that some of the variance associated with the 1997 situation in model 3a is really variance associated with strategy. The γ-values of model 3b are larger for the strategies than for the 1997 values, indicating the larger importance.

Summarising it can be said that education is important for the changes, which a farmer implements on his farm. Better-educated farmers aim for a farming system with higher production intensity, but relatively fewer animals and more efficient operational management. The growth and diversification strategies explain changes in variables of more structural nature, like intensity, milk production per cow and heifer management. Note that the effects on these variables are opposite for the two strategies, with growers increasing intensity, and diversifiers reducing. The process control strategy focuses more on the optimisation within the existing structure of the farm through replacement of manure import for fertiliser N and an improvement of operational management.

5.4.4 Farmer + Farm strategy → ΔPerformance

For equation 4, no reliable estimates could be determined due the large number of parameters relative to sample size. Again, two separate models were estimated to determine the influence of farm characteristics and farm strategies (Table 5.7, model 4a and 4b respectively). The goodness-of-fit statistics of model 4a show that the χ^2 is not significant, indicating that no statistical difference exists between the 0-model and the estimated model. Still, since the residuals are small, the model is judged to have good fit (Boomsma, 2001, personal communication). For both models a highly significant positive correlation was added between TFPG and NPG to improve model fit (ρ_{4a}=0.53, z=9.20; ρ_{4b}=0.54, z=8.59).

Model 4a shows that the main characteristic of the farmer to influence performance change, additional to changes which are the result of implementation changes, is education. Education has a significant positive effect on TFPG and NPG, indicating that higher educated farmers have shown more improvement in performance on top of the improvements through implementation than did lower educated farmers. Performance of 1997 affects technical, environmental and financial performance improvement negatively. Apparently, farmers with already high standard of performance, have not managed to improve this as much as other farmers did. Improvement of environmental performance apparently has lead to better financial performance (note that residuals are used, hence the reverse relation). Model 4b shows that different types of strategies do not significantly influence performance changes (except for diversification, which positively affects TFPG). This indicates that no strategy is superior in improvements of technical, environmental or financial performance additional to improvement through implementation change. Again, a significant negative relationship between environmental improvement and financial improvement was found indicating that environmental and financial improvements are positively related.

From the analysis it can be concluded that education is of importance for the explanation of changes in technical and environmental performance additional to the changes which are the result of changes in implementation. Strategic differences are, however, not relevant for performance improvement, meaning that each strategy can lead a performance improvement. Interestingly, financial performance improvement is strongly related to the environmental performance improvements. Increasing nutrient efficiency through more accurate management or improving nutrient technology apparently has a positive effect on the financial results.

Table 5.7 ML-estimates of farmer characteristics on performance changes (Model 4a; N=108) and farm strategies on performance changes (Model 4b; N=103)

Model 4a

		Age	LC-phase	Education	Info-use	TFPG 97-99	NPG 97-99	Base 1997#	R^2
Total Factor Productivity Growth	γ	-0.00	-0.06	0.24	-0.04			-0.14	0.08
(TFPG) 97-99	*z*-value	-0.01	-0.58	2.30**	0.40			-1.73*	
Nutrient Productivity Growth	γ	0.05	0.07	0.24	0.03			-0.19	0.10
(NPG) 97-99	*z*-value	0.45	0.73	2.29**	0.27			-2.31**	
Δ residual FAS# Gross	γ	0.01	-0.03	0.02	-0.10	0.03	-0.30	-0.58	0.46
Margin/100 kg FPCM	*z*-value	0.10	-0.32	0.25	-1.26	0.28	-3.15***	-6.08***	

Model 4b

		Process control	Growth	Diversification	TFPG 97-99	NPG 97-99	Base 1997#	R^2
Total Factor Productivity Growth	γ	0.14	0.07	0.23			-0.13	0.06
(TFPG) 97-99	*z*-value	0.67	0.37	1.67*			-1.48	
Nutrient Productivity Growth	γ	0.05	-0.00	0.20			-0.16	0.07
(NPG) 97-99#	*z*-value	0.24	-0.02	1.49			-1.94*	
Δ residual FAS# Gross	γ	-0.21	0.17	-0.10	0.02	-0.26	-0.61	0.51
Margin/100 kg FPCM	*z*-value	-1.32	1.22	-0.95	0.17	-2.85***	-6.43***	

*** $P < 0.01$ ** $P < 0.05$, * $P < 0.10$

'Base' = the value of the Δ variable in 1997, representing past behaviour; for productivity growths, technical and nutrient efficiency are used

Goodness of fit statistics Model 4a: χ^2/df=1.65 (P<0.13), GFI=0.98, AGFI=0.83, SRMR=0.036, RMSEA=0.078

Goodness of fit statistics Model 4a: χ^2/df=1.81 (P<0.001), GFI=0.87, AGFI=0.75, SRMR=0.072, RMSEA=0.089

5.5 Discussion

Comparing our findings with previous studies shows that contrary to the results of Kerridge (1978) age is positively related to expressive and intrinsic goals (though not significantly) and negatively to instrumental goals. He reasons that older farmers feel more financial and family responsibilities. Here, age, corrected for stage in the family-farm life cycle (which confounds age due to the high financial burden for farmers in the transition stage) shows an opposite effect, mainly for expressive goals. The expressive goals used have a high level of social desirability. The new generation of farmers may consider societal concerns more important because they represent a declining trade. They naturally interact more and more with people with other occupations, often times spouses don't have an agricultural background, all increasing the awareness of the place of farming within society. Kerridge (1978) found education to be positively related to intrinsic values, hypothesising that farmers with a high level of education choose more consciously for farming because they have more options. A positive relation is also found here, but not significant.

While Robinson (2000) only suggested that farmer characteristics may be of importance for strategic choice, other authors studied empirical relationships. Frawley and Reidy (1986) for instance found that age is negatively related to a growth strategy, while Ilbiry (1991) found a positive effect of age on diversification. The former result is confirmed in this study. Younger farmers have just taken over the farm or are in the process of doing so, and are therefore in the growth stage of the family-farm life-cycle. Age, however, does not seem to significantly increase the likelihood of the choice for diversification. This might be explained by the fact that Ilbiry's study was done for farmers in urban fringes while this study covers farmers in all locations. Anosike and Coughenour (1990) found no relationship between the phase in the family-farm lifecycle and diversification decisions. Here, a significant positive effect was found indicating that farmers in a transition phase are more likely to choose to diversify. There could be excess labour on the farm, which is an incentive for the successor to work off the farm for a while, building up equity to reduce the financial risks associated with transition. Another reason for this finding could be that the interests or risk attitudes of the transferring and succeeding farmer differ, leading to a strategy of diversification. The relationship between education and strategy was studied by Frawley and Reidy (1986) and Anosike and Coughenour (1990). The first study found no evidence that education can distinguish between the choice of a growth strategy, while the latter found that better educated farmers are more likely to choose a diversification strategy, because they are better able to co-ordinate activities and allocate resources to diverse activities. A significant opposite effect is found in this study. The reason for this might be that current agricultural practices in The Netherlands require a lot of highly specialised knowledge, due to very high productivity, and accumulating regulations. Therefore, to be able to perform well (and be competitive) in a highly specialised farming system, and to bear the risk associated with a high degree of specialisation, a higher educational level is needed. No studies were found in which information-use was related to strategic choice. This study showed that it is of importance for strategic choice. Farmers who are more keen on gathering (internal and external) information through courses and journals and management tools, are more inclined to choose a strategy of process-control and are less likely to diversify. Rationale behind this is that these farmers have an interest in detailed improvement and optimisation of a single production process.

No studies were found that study changes in implementation, and the relationship of these changes with different strategies and farmer characteristics. The most important factors according to the results found in this study are educational level and strategic choice. Better educated farmers seem to make use of economies of scale by choosing a more intensive farming system in terms of milk production per ha. They relieve the resulting high environmental pressure by an increase in milk production per cow, so they need relatively fewer animals, and improve the accurateness of their operational management. Strategic choice is important for the way farmers implement changes. Farmers who choose a growth strategy increase the intensity of their farm, which is accompanied by an increased need for fertiliser to produce the necessary feed. Their main way of reducing nutrient surpluses is improving operational management. Diversifiers on the other hand reduce the intensity of their farm, combined with other environmental friendly measures. This strategy has also resulted however in a decrease in the quality of operational management, possibly due to the time spend on other activities. The process control strategy focuses on optimising within the current structure of the farm, leading to an environmentally friendly increase in productivity.

Age was found to positively affect technical efficiency by Andreakos *et al.* (1997) and Wilson *et al.* (2001). It does however not affect TFPG, indicating that both older and younger farmers are able to make improvements on their farm. Education positively influences technical efficiency (Andreakos *et al.*, 1997; Burki and Terrell, 1998; Wilson *et al.*, 2001), and productivity (Philips, 1994), with a peak in TFPG at age 25-35 (Tauer, 1995). The results found in the present study show that education is highly significant in explaining changes in both technical and environmental productivity. Better-educated farmers apparently make better choices in measures to improve productivity, be it technical or environmental. Differences in information-use, though important for high technical efficiency (Wilson *et al.*, 2001), do not prove to be important for change additional to the changes through implementation. Strategies did not prove to be significant in explaining the changes in performance additional to changes in implementation, indicating that different ways do not necessarily mean different technical and, more importantly, environmental results. The results also show that positive changes in financial performance additional to implementation changes are the result of financial management capabilities (expressed in the base situation) and, interestingly by an improvement, additional to the improvements through implementation, of environmental performance.

The strategic management framework proved to be very useful for this type of study. To gain even more insight into the reasons for behaviour or behavioural change, an in-depth analysis of the internal and external environment could be made. The perceptions of the farmer on his internal strengths and weaknesses and his external opportunities and threats explain, together with a mission statement, why a farmer chooses a particular strategy. A more specific assessment of farmer characteristics might also prove useful. Factors pertaining to attitudes (risk attitude for instance) have been found to be of importance for environmental management (Babcock, 1992, Ozanne, *et al.*, 2001), preferences and motivations might help explain why a farmer perceives the internal and external environment the way he does and thus helps explain strategic choices. Information on the capabilities of the farmer as manager and craftsman will help identifying why the implementation of the strategy and performance deviate from expectations.

5.6 Conclusion

It can be concluded from the analysis that farmer characteristics, and especially education, are of importance for farm change. This conclusion holds for changes in implementation as well as changes in performance additional to changes in implementation. Farm strategies give direction to the way a farm implements changes but they cannot explain differences in technical, environmental and financial performance. A farmer's mission is related to farmer characteristics, but cannot help explain differences in development paths that farmers choose. The starting point from which a farmer changes implementation is of importance, but not as important as the strategy a farmer chooses. For farm changes in performance additional to the changes resulting from implementation, however, the starting point is very relevant with better technical and environmental producers showing to be less able to additionally improve this performance, while poor financial performers have made additional improvements, mainly through the improvement of environmental performance.

These conclusions show that environmental policy that leaves freedom to the farmer to change his farm in a way he chooses, can invariably lead to performance improvement. Forcing a farmer to work in a particular manner by using constraints or obligatory measures might no be this effective. For consulting agencies the results of this study imply that it is important to know the strategy of the farmer, so advice can be better geared towards the fulfilment of the farmer's goals.

VI Perceived Environmental Uncertainty in Dutch dairy farming; consequences for strategic choice

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Abstract

This paper studies the way in which dairy farmers perceive their environment, and the way this affects the strategy they choose for their farm. Data from a survey of 103 Dutch dairy farmers was analysed using regression analysis. The results indicate that environmental uncertainty is not related to complexity or dynamism, but to illiberality of the environment. Especially the institutional environmental is considered illiberal, thus causing uncertainty. Farmers with high environmental uncertainty are more likely to choose a diversification strategy, while low uncertainty results in the choice for a process-control strategy. A growth strategy is not affected by perceived uncertainty. Awareness of the environment and a fit between internal and external factors provide important components for the successful pursuit of a strategy.

6.1 Introduction

Farmers in developed countries operate in an environment that becomes more and more complex and is of growing importance to their decision-making (e.g. Kay, 1998; Jókövi *et al.*, 2001; Policy Commission on the Future of Farming and Food, 2002). In the Netherlands in particular, agricultural policy is becoming increasingly strict. In 1998 the Mineral Accounting System (MINAS) was introduced as one of the pillars of agricultural environmental policy (Ondersteijn *et al.*, 2002). Strict rules apply to pesticide use as well as wildlife conservation. While regulations are becoming stricter, other changes in the external environment of Dutch farms occur simultaneously. In 1999 the European Committee decided on Agenda 2000, which continues the introduction of European agricultural markets to the world market (Zervoudaki, 1999). Also, since the Netherlands is the most densely populated country in Europe, the claims from society on agricultural land are increasing. Controversies over food safety, due to for instance dioxin and BSE-scares, and animal welfare issues further increase the impact of society on agriculture.

The shift from a protected, subsidised agriculture to a more open and independent industry causes a rising importance of the external environment of farms. Farmers will have to respond to emerging issues with an appropriate strategy. Failure could cause large problems for the farm, in particular in the long run. It can be argued that the external environment of farms in a certain region or country is equal for all of them. In a sense this is true since they all produce under equal circumstances. But characteristics of the environment have to be processed into information of value for the decision-making process, to become relevant for the decision-maker (Alter, 1999; Laudon and Laudon, 2002).

To provide more insight into the perception of the environment and the consequent actions farmers take, the purpose of this exploratory paper is threefold. First, it gives an overview of the relevant literature of the theory and measurement of the perception of the environment and the consequences for strategic choice. Second, it explores the way dairy farmers perceive their environment in terms of the opportunities and threats it poses and the uncertainty this results in. Third, the paper will explain the strategic choices dairy farmers make, based on their perception of environmental uncertainty.

6.2 Theory and scope of the study[1]

6.2.1 Perceived environment and perceived environmental uncertainty

The boundaries of the Perceived Environment (PE) are set by the organisational domain (Child, 1972; Miles *et al.*, 1974; Jauch and Kraft, 1986), what is nowadays called the mission of a firm (e.g. David, 2001). Decision-makers will (or should) limit the environment according to their perception of necessity for the achievement of the mission. Miles *et al.* (1974) argued furthermore that firm characteristics influence PE through its effect on managerial attention processes. Perception is also an individual process (Duncan, 1972) steered by personal characteristics of the decision-maker.

Research suggests that PE has three dimensions: complexity, illiberality and dynamism (e.g. Child, 1972; Duncan, 1972; Lawless and Finch, 1989; Sharfman and Dean, 1991). Complexity describes the number and similarity of environmental factors, which are perceived relevant for decision-making. The more, and more different factors, are deemed relevant, the more complex the environment. Second, environmental illiberality refers to the degree of threat from the industry (e.g. competition) that decision-makers face in the achievement of their mission. The opposite term, munificence is also used (Castrogiovanni, 1991; Goll and Rasheed, 1997). Dynamism reflects the degree to which environmental factors change over time and the rate with which new environmental factors emerge.

Perceived Environmental Uncertainty (PEU) occurs when decision-makers perceive the environment of their organisation as unpredictable (Milliken, 1987). Beside the individual perceptual process, PEU may be partially a function of the characteristics of the PE-dimensions of complexity, illiberality, and dynamism (Buschko, 1994). Downey *et al.* (1977) found that cognitive process variables were more consistently related to a decision-maker's perceived uncertainty than perceived environmental variables. Empirical research has also shown that environmental dynamism explains more variance in PEU than does complexity (Duncan, 1972; Lindsay and Rue, 1980). PE and PEU are thus closely related but there are more influences (like personal characteristics) that might explain variation in perceived uncertainty.

PEU can be divided into three kinds of uncertainty; state uncertainty, effect uncertainty, and response uncertainty (Milliken, 1987; Gerloff *et al.*, 1991). State uncertainty exists when a decision-maker feels unable to assign accurate probabilities to the occurrence of possible state changes. Effect uncertainty occurs when a decision-maker is unsure about the effect an

[1] Management research has been working on issues arising from the perception of the environment since the 1970s. Basic theory and measurement of the concepts was developed in that era. Much of the literature referred to in this paper is therefore of that time-period. Nevertheless, advanced research is still going on in this area and will be referred to if applicable to this exploratory study.

environmental event or change will have on their organisation. Response uncertainty refers to the confidence in the responsive action that must be taken.

It is clear from this description from PE and PEU that objective environmental conditions cannot be regarded as a direct source of organisational variation. The critical link is the perception of the decision-maker of the position of the organisation in the environmental areas he deems important, and the consequent actions he takes to respond to it (Child, 1972). Several authors, however, have emphasised the importance of the objective environment, which will constrain the range of possible choices a firm has and could have a direct impact on organisational performance (Jauch and Kraft, 1986; McCabe, 1990). Both orientations seem to have their merits but beside theory, there is hardly any empirical support for the relationship between objective environmental characteristics and perception, let alone performance (see e.g. Child, 1972; Tosi *et al.*, 1973; McCabe, 1990). The objective environment can impact performance and sets clear boundaries for decision-making but within the same objective environment it is the perception and interpretation of environmental opportunities and threats that makes the difference.

6.2.2 PE, PEU, strategic choice, and performance

According to Goll and Rasheed (1997), environmental characteristics are of major importance for all aspects of management, including strategic decision-making, implementation and performance. Tymon *et al.* (1998) suggests that if firms intend to remain viable and have a right to exist, there needs to be a fit between perceived environment and firm strategy. This is in accordance with the prevailing concepts of the strategic management process. An external assessment is part of this concept to identify key opportunities and threats (e.g. David, 2001). However, similar perceptions may still lead towards different strategies (Miles *et al.*, 1974). This depends on the mission the firm wants to achieve, its internal strengths and weaknesses, or simply on the preferences of the decision-maker. In general it can be said that relative complex and uncertain environments tend to be met by diversification strategies to reduce risk (Buschko, 1994; Courtney *et al.*, 1997). This is, however, entirely dependent on the risk-attitude of the decision-maker (Courtney *et al.*, 1997).

Bourgeois (1985) and McCabe (1990) found that the match between real environmental characteristics and PEU influences performance. Decision-makers who are better able to interpret the objective environment and translate it into useful information for decision-making will therefore produce better results. The interpretation and translation process however depends on the needs of the organisation. There is therefore no such thing as one 'correct' environmental interpretation. Interpreting the relationship between environmental perception and firm performance is complicated because of the conceptually large distance between perception and performance. A direct relation will therefore be hard to find. Strategy can be seen as the connecting link between the two. The concepts and relationships discussed in section 6.2.1 and 6.2.2 are graphically shown in Figure 6.1.

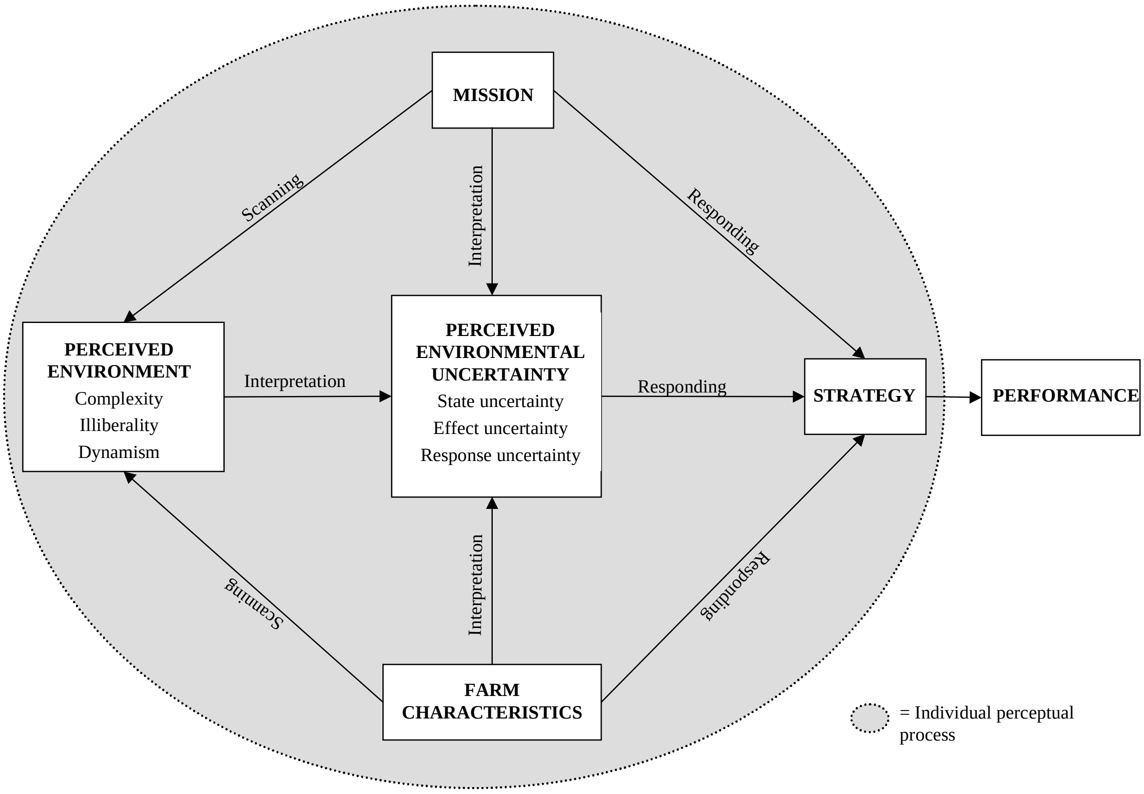

Figure 6.1 Perceived environment and perceived environmental uncertainty in relation to farm management

6.3 Materials and methods

6.3.1 Description of the sample

In 1997 a nation-wide project was started in The Netherlands to study nutrient management on different farm types and the changes needed to meet the surplus standards posed in MINAS[2]. Farms were selected out of a voluntary enrolment to give a reasonable representation of dairy farm characteristics, the spread over the Netherlands and over different soil types (for more information, see Ondersteijn *et al.*, 2002). The fact that farmers in the sample voluntarily enrolled indicates that the study deals with a specific type of farmer. Furthermore, comparison of the characteristics of the farm types with the characteristics of the

[2] MINAS calculates the difference between nutrient inputs and outputs of the farm, and compares this difference (surplus) with an environmentally safe surplus standard. Farms are taxed heavily if they do not meet the standards.

farm types in the Farm Accounting Data Network (FADN) sample showed that the dairy farms were significantly more intensive in terms of milk quota per ha. For exploratory purposes the issue of representativeness is not critical, however, but the results should still be considered in light of these characteristics. For three years (1997-1999) nutrient, technical and financial data were collected on a sample of 114 specialised dairy farms (SD), 42 mixed dairy + intensive livestock (MDIL, i.e. pigs and poultry) farms and 14 mixed dairy + arable farms (MDA). A farm is classified as an SDF if at least 95% of all Dutch Size Units[3] (DSUs) can be attributed to dairy production. Mixed dairy types are defined based on the second largest farm enterprise (either intensive livestock or arable farming). In the beginning of 2000, a mail survey on PE, PEU and strategic choice was held. Of the 114 returned surveys (69 from SDs, 33 from MDILs, and 12 from MDAs), 11 were discarded from further analysis due to too many missing values. The variables representing farmer characteristics (based on a 1998 survey), detailed farm characteristics, and farm results (based on the 1999 bookkeeping data) of the 103 farms in the analysis are given in Table 6.1.

The impact of environmental perception on strategy and therefore performance depends on ownership structures, and the characteristics of the owners/managers who have influence on decision-making (Ireland *et al.*, 1987; Li and Simerly, 1998). Even though most studies on PE and PEU recognise that the individual perceptual process is important (e.g. Sutcliffe and Huber, 1998), no studies have been found which specifically address this topic. In this study age, education, phase in the family-farm lifecycle and information-use are studied. Age and education are generally considered important for perception, but Thomas *et al.* (1993) did not find any influence of these factors neither on perception nor strategic decision-making. Since this study deals with one decision-maker in a small enterprise, however, they might become important and are therefore used in this analysis. The phase in the family-farm lifecycle contributes to uncertainty because of the complex decision to take over the farm or not. The number of information sources a farmer uses represents his information seeking behaviour and is of importance for environmental interpretation (Jauch and Kraft, 1986; Thomas *et al.*, 1993). The farms in the current sample used on average 10.8 sources of information (journals, courses, study groups, management tools). Finally two attitudes were measured in relation to environmental policies. Farmers were asked to score the importance of reasons for joining the FDP project on a 5-point Likert scale. One was to show the Dutch government that MINAS was not feasible (average = 3.39), while the other was to learn (more) about nutrient management in order to be able to meet the standards (average = 4.51). These variables are used in the analysis because they are hypothesised to affect the perception of opportunities and threats in the survey, and thus PEU.

[3] The DSU is an economic size unit, based on standard gross margins

Table 6.1 Farmer characteristics, 1999 farm characteristics and financial and environmental results of farms in the sample

	Mean	Std. dev.	Percentage
Farmer characteristics			
Age	40.77	8.76	
Educational level (1=low: 3=high)	2.05	0.59	
Phase in the family-farm lifecycle			
• Entry/exit phase			33
• Growth/consolidation phase			67
Information-use (# of information sources)	10.80	2.52	
Negative MINAS-attitude (5-point Likert scale)	3.39	1.10	
Learner attitude (5-point Likert scale)	4.51	0.60	
Farm characteristics			
Soil type			
• Sandy			50
• Clay			36
• Peat			14
Farm size (DSU[a])	173.45	55.03	
Degree of specialisation (% of DSUs[a] in dairy)	93	12	
Farm intensity			
• Kg milk quota (4.25% fat content)/ha	14336	4475	
• Deviation from manure application standard (MTAS) (kg N/ha)	122.62	132.46	
Milk production/cow (FPCM[b]/cow)	8371	694	
Farm results			
Gross margin €/100 kg FPCM[b]	27.90	5.39	
Deviation N-surplus standard (MINAS) (kg N/ha)	71.00	73.69	
Deviation P_2O_5-surplus standard (MINAS) (kg P_2O_5/ha)	3.20	21.87	

[a] The DSU is an economic size unit, based on standard gross margins

[b] Milk production corrected for fat and protein content

Since the structure of the organisation is of relevance for PE, PEU and strategic choice, several farm characteristics were selected for use in the analysis. First soil type, even though part of the objective external environment, is considered. Farm size, measured in DSUs and the degree of specialisation have been studied in relation to PE and PEU by several authors (e.g. Keats and Hitt, 1988; Goll and Rasheed, 1997; Li and Simerly, 1998). The three other characteristics are typical of (Dutch) dairy farms. Farm intensity is of importance for two reasons. First of all it represents returns to land (milk quota/ha), which is the most scarce commodity in Dutch agriculture. Second, the intensity poses a major environmental burden and is limited by environmental policy. Milk production per cow is a critical success factor because a high milk production per cow reduces the number of cattle needed on the farm. Both financial and environmental farm results are used in the analysis. The gross margin is expressed in €s per 100 kg of FPCM, environmental performance is based on the deviation of the actual farm nitrogen of phosphate surplus from the standards in MINAS. To check for biases in response, the farm, and farmer characteristics of the respondents were compared to the participants in the sample who did not respond. No significant differences were found for farmer characteristics, farm characteristics and farm results.

6.3.2 PE/PEU survey

The environment can be conceptualised as having several sectors that exist in two layers: the macro environment and the task environment (Elenkov, 1997). The macro environment is not under the direct control of farmers and can be split into sectors according to the STEP principle (social, technological, economic and political forces). The task environment can, to a varying extent, be influenced by the farmer. Porter (1980) suggested five basic competitive (task environmental) forces that arise from an industry; the threat of new entries, the intensity of rivalry among existing competitors, the threat of substitute products or services (all three pertaining to competition), the bargaining power of buyers and the bargaining power of suppliers (Porter, 1980). In the case of agriculture, another environmental force must be identified, the natural environment (called ecological structure by (Duram, 2000). Even though the unreliable processes of nature have become more under control of agriculture through the intervention of science and technology, it is still a major factor in determining production level and quality. It has both macro and task characteristics.

Perceived Environment

The environmental sectors in the survey were represented by multiple items. The respondents had the opportunity to add one item for each sector. The farmers had to assign the degree of opportunity or threat on a 5 point Likert-scale (1 = large threat, 5 = large opportunity). The middle category was neutral, indicating no influence on decision-making. The more neutral scores, the less complex the environment. This is measured by opportunities and threats divided by neutral scores. The ratio between threats and opportunities gives an indication of illiberality. Furthermore, they were asked to score this for their current situation as well as for the situation when they joined the FDP project in 1997, indicating dynamism of the environment.

The different characteristics of the perceived environment are defined using the following equations:

$$Complexity = \frac{\sum Opportunities + Threaths}{\sum Neutralscores} \quad (1)$$

$$Illiberality = \frac{\sum Threaths}{\sum Opportunities} \quad (2)$$

$$Dynamism = \frac{Complexity_{t=0}}{Complexity_{t=-1}} \times \frac{Illiberality_{t=0}}{Illiberality_{t=-1}} \quad (3)$$

Calculation of complexity and illiberality for environmental sectors is infeasible in case of no neutral scores or no opportunities. In such cases, a division by 1 was used. For the total environment the number of neutral scores or number of opportunities were always larger than 0. To prevent infeasible solutions for dynamism and because dynamism gives an indication of the magnitude of change, 1 was added to all elements of equation 3.

Perceived Environmental Uncertainty

Measurement of the PEU concept has proved difficult. Problems range from difficulty in defining an appropriate measure for PEU to internal and test-retest reliability issues of the scales used. Basically two mainstreams in PEU measurement can be found: Duncan-based measures and Khandwalla/Miles and Snow measures (Duncan, 1972; Khandwalla, 1972; Miles and Snow, 1978). Duncan-based measures elicit state, effect and response uncertainty, aggregating these into one measure of PEU, but the scale items do not only pertain to external environmental factors, but also internal firm characteristics. Reproduction of the scale by Downey *et al.* (1976) showed among other things that reliability measures could not be met for the total Duncan scale. Milliken (1990) therefore separately approached the three different kinds of uncertainty. Khandwalla/Miles and Snow measures only elicit state uncertainty, but do this for pure external factors. Ireland *et al.* (1987) and Buschko (1994) examined the reliability of the Miles and Snow scale. They found reasonable internal reliability of the scale, concluding that the scale was appropriate to use for research purposes (Ireland *et al.*, 1987; Buschko, 1994). Buschko (1994) found low test-retest reliability for the measure, however, explaining this by stating that even though PEU may be a key variable in understanding managers' actions, perceptions change over time and can easily be influenced by events in the environment. The low test-retest reliability could therefore very likely reflect the nature of the perceptual process (Buschko, 1994). Tymon *et al.* (1998) provide an overview of the state of affairs in PEU measurement. They conclude that Duncan based measures do not adequately measure PEU as a strategic construct dealing with the external environment, while the Khandwalla/Miles and Snow measure does not yield insight into the different components of PEU (Tymon *et al.*, 1998). They suggest to separately approach state, effect and response uncertainty (as in Milliken, 1990) while at the same time using a summating scale (as in Duncan, 1972), and to do this for pure external environmental factors (as in Khandwalla, 1972; Miles and Snow, 1978).

In this study the suggestion of Tymon *et al.* (1998) is made operational using the survey in Appendix 6.1. State, effect, and response uncertainty were determined by calculating the mean of the scores on the environmental items in the survey. For PEU the average of state, effect and response uncertainty was calculated for every environmental sector. The total PEU score was determined by calculating the average of the PEU for the 8 sectors. In this way both the three different uncertainty types as well as the eight different sectors in the environment are weighed equally. In the survey the scores for state, effect, and response uncertainty as well as PEU scores range from 1-5, with 1 being highly uncertain, and 5 being highly certain. To obtain an intuitively more attractive measure for analysis, the scores were re-scaled such that 1 meant highly certain and 5 highly uncertain (the higher the score, the higher the uncertainty).

6.3.3 Mission and strategies

The elicitation of farm mission and farm strategy was based on previous studies done by (Van den Ham *et al.*, 1998a; Van den Ham *et al.*, 1998b; Van den Ham *et al.*, 1998c; Van den Ham and Van de Schans, 1999), who studied mission and strategies of Dutch dairy farmers in FADN. Farmers had to address the importance on a 5-point Likert scale to several mission statements. According to the literature four general missions can be distinguished: expressive, social, instrumental and intrinsic (e.g. Gasson, 1973; McGregor *et al.*, 1996; Robinson, 2000). Expressive missions relate to the personal fulfilment through farming, social missions are associated with interpersonal relations and recognition, instrumental missions concern obtaining an income through farming, while intrinsic missions regard farming as an activity in its own right. A factor analysis was used to check for a factor-solution identical to the categories mentioned by literature. No satisfactory solution was found, and therefore the most representative items were chosen to represent the mission: pass on fertile land for expressive, appreciation from society for social, obtaining a high income for instrumental and enjoying farm work for the intrinsic mission (Table 6.2).

Farm strategies were composed using a factor-analysis. Farmers were asked to rate the importance of several strategy components, which were subsequently factor-analysed in an exploratory analysis. A 6-factor solution was found, in which three major strategies were distinguished: process-control, growth, and diversification. Since not all strategic components in the survey were part of these strategies, a confirmatory factor analysis was performed on the components that loaded on the three strategic factors, with good results. The process-control strategy focuses on the efficient production of high quality products. Growth focuses on both expansion and increasing the milk production intensity of the farm. The diversification strategy relates to either horizontal or vertical diversification and of-farm employment. Table 6.2 shows the average scores and standard deviation of the representative mission variables, as well as the average scores, standard deviations, factor loading and eigenvalues of the strategies.

Table 6.2 Descriptives of mission statements, and descriptives and results of factor-analysis of strategies

	Mean	Std. dev.	Factor loading	Eigenvalue
Mission				
Expressive: Pass on fertile land	4.00	0.81		
Social: Appreciation from society	4.11	0.66		
Instrumental: Obtain a high income	3.90	0.68		
Intrinsic: Enjoy farm work	4.77	0.42		
Strategy				
Process-control				2.03
Production of high quality milk	4.48	0.63	0.71	
Production of high energy roughage	4.18	0.77	0.70	
Accurate feeding and fertilisation	4.62	0.51	0.65	
Growth				1.25
Cattle-intensive farming system	2.80	1.00	0.72	
Expansion	4.07	0.67	0.70	
Labour efficiency	4.40	0.62	0.67	
Diversification				1.10
Horizontal or vertical diversification	2.35	1.17	0.82	
Of-farm employment	2.18	0.93	0.80	

6.3.4 Analytical techniques

To determine the effect of PE on PEU, and the effect of PEU on strategic choice, a linear regression approach was used as is common in this type of research (e.g. Priem *et al.*, 1995; Goll and Rasheed, 1997; Dean *et al.*, 1998; Li and Simerly, 1998). Including all variables (4 for mission, 6 for farmer, 5 for farm + 4 dummies, 2 for soil type and 2 for farm type, and 4 for results totals 23), which could be of relevance for the moderation of the explanatory PE and PEU variables in the regressions on both PEU, and strategic choice, would lead to an overly specified regression model. Therefore, the environmental variables were forced into the model, leaving the choice for the most important moderators to a stepwise regression procedure.

6.4 Results and discussion

6.4.1 PE and PEU

Perceived Environment

Table 6.3 shows the complexity, illiberality and dynamism for the total sample. The three most complex environmental sectors are the institutional environment, the social environment and the technological environment. These three environmental sectors are part of the macro-environment, which the farmer cannot control and hardly influence. The demands of society in terms of for instance food safety and animal welfare, the opportunities innovations provide or the unfamiliarity with new technologies, and the accumulating policy measures cause this high complexity. Note that complexity is the sum of both opportunities and threats relative to the number of neutral environmental items, so high complexity is not necessarily negative. The environment considered least complex is the natural environment.

Table 6.3 Averages of perceived complexity, illiberality and dynamics of the external environment

	Perceived Complexity	Perceived Illiberality	Perceived Dynamism
Social environment	3.04	1.23	3.17
Technological environment	2.90	0.26	1.80
Economical environment	2.16	1.17	2.27
Institutional environment	3.58	3.05	4.30
Suppliers	2.06	1.57	2.56
Buyers	2.16	1.16	3.19
Competition	1.93	1.14	2.00
Natural environment	1.58	0.94	2.14
Total environment	3.31	1.76	2.79

The most illiberal environmental sector is the institutional environment, the least illiberal environment, is the technological environment. Since the number is smaller than 1, farmers apparently perceive that technological developments provide more opportunities than threats for the future. The institutional environment was perceived to be most dynamic, followed by the buyers and social environment. This could be the result of a change in the nature of agricultural production, which is changing from a production-oriented chain to a more demand oriented chain. Farmers have to be more and more aware of the demands of society and changes in regulations, product- and process quality demands of buyers, and changes in customer preferences apparently yield much uncertainty. F-tests showed no significant differences in complexity, illiberality and dynamism scores between farm types, except for the complexity of the competitive environment ($P<0.05$). Summarising it can be said that, while the MDA-farmers consider their environment as most complex of all three farm types, they find it the least illiberal and dynamic. Highest illiberality is scored by the SD-farmers, while highest dynamism is scored by MDIL-farmers.

Perceived Environmental Uncertainty

Table 6.4 gives an overview of the different components of PEU, together with the total PEU measure for the different farm types. Large differences exist between farm types in the environmental sector they perceive uncertain, and which type of uncertainty they associate with the environmental sectors. The environmental sectors, which are among the three highest state uncertainties for all farm types are the institutional and economical environment. Technology, institutions and buyers cause the most effect uncertainty for all farm types, while competition and institutions cause the most response uncertainty. SD-farmers perceive the suppliers as the least uncertainty provoking environmental sector, across all types of uncertainty. They likely have long-term relationships with suppliers of for instance concentrates and fertilisers, and banks. This leads to trust in suppliers, possibly low costs of supplies, and access to external financing. As could be expected, the MDIL-farmers perceive the natural environment as the least uncertain environmental sector. They are the least dependent on it of all farm types. Between environmental sectors, the MDA-farmers perceive the least state and response uncertainty from the natural environment, even though they are most dependent on it. It is possible that these farmers' experience with outdoor production processes is reason for this. The same can be said for the lowest PEU for the social environment of sectors. Issues like quality certifications, contracting with retailers, pesticide pollution issues, and crop improvements to better meet consumer demand, have been going on in arable farming for quite some time. Totally, the MDIL-farmers perceive the most state, effect and response uncertainty, as well as PEU and the MDA-farmers the least, reflecting the current situation the different dairy farm types are in.

Reliability analyses were performed for the different uncertainties of Table 6.4. The reliabilities (Cronbach's α) for state, effect and response uncertainty of the total environment for the total sample were 0.85, 0.90, and 0.89 respectively. The reliabilities for PEU for the separate environmental sectors ranged from 0.72 to 0.86, with one exception; Cronbach's α for the natural environment was 0.57. The reliability for the PEU measure of the total environment was 0.81, however. These reliability measures are considered sufficient (lower limit is generally agreed to be 0.70, Hair (1998)) to assume that the correct items are being measured and combined so they can be used in subsequent regression analysis.

Table 6.4 Averages of state, effect, response and perceived environmental uncertainty (PEU)

	State uncertainty	Effect uncertainty	Response Uncertainty	PEU
	Specialised Dairy farms			
Social environment	2.87	2.85	2.60	2.77
Technological environment	2.95	3.09	2.85	2.96
Economical environment	3.35	2.77	2.89	3.01
Institutional environment	3.38	3.03	2.85	3.08
Suppliers	2.54	2.23	2.38	2.38
Buyers	3.23	2.62	2.76	2.88
Competition	3.13	2.95	3.09	3.06
Natural Environment	2.80	2.52	2.50	2.61
Total environment	3.05	2.82	2.76	2.84
	Mixed Dairy + Intensive Livestock farms			
Social environment	2.98	2.91	2.91	2.92
Technological environment	3.04	2.91	2.98	2.96
Economical environment	3.23	2.86	3.07	3.06
Institutional environment	3.64	3.13	3.16	3.31
Suppliers	2.98	2.60	2.79	2.79
Buyers	3.48	2.65	2.84	2.99
Competition	3.06	3.10	3.12	3.07
Natural Environment	2.77	2.64	2.70	2.70
Total Environment	3.17	2.90	2.98	2.98
	Mixed Dairy + Arable farms			
Social environment	2.40	2.30	1.80	2.17
Technological environment	2.58	2.72	2.50	2.60
Economical environment	2.77	2.30	2.40	2.49
Institutional environment	2.93	2.45	2.50	2.63
Suppliers	2.62	2.28	2.42	2.44
Buyers	2.60	2.17	2.43	2.40
Competition	3.05	2.94	2.72	2.91
Natural Environment	2.33	2.10	2.40	2.28
Total environment	2.69	2.45	2.39	2.49

6.4.2 Explaining PEU and strategic choice

The results of the regression analysis for state, effect, response and total PEU are shown in Table 6.5. The main goal of the regression analysis was to assess the effect of complexity, illiberality and dynamics on state, effect, response uncertainty and PEU (the left horizontal arrow in Figure 6.1). Perceived complexity shows a significant negative relationship with all uncertainties, indicating that the more complex the environment is perceived, the lower the uncertainty. This result is in agreement with Downey *et al.* (1977) who suggested that an environment may be complex, but if it is predictable, the effect on performance can be foreseen and one knows how to respond, it does not cause uncertainty. Illiberality shows the expected positive relationship with uncertainty, even though it is only significant for response uncertainty and PEU. The more illiberal the environment is perceived, the more uncertain one views the environment. Surprisingly, dynamism did not show any significant relationship with uncertainty.

For both state uncertainty and effect uncertainty farm size was included in the model. A significant negative relationship indicates that farmers on larger farms perceive the environment as less uncertain. Having a small farm apparently leads to higher state and effect uncertainty. It does however not influence response uncertainty. A negative attitude towards MINAS shows a positive relationship with effect and response uncertainty, and PEU, but not state uncertainty. This attitude apparently is not related to the perceived predictability of MINAS regulations but it is positively related to the uncertainty associated with the effect it might have on the farm and the way they have to respond. Response uncertainty is furthermore significantly negatively related to the deviation from the N-surplus standard in MINAS. This result seems curious at first, but it should be considered that MINAS was introduced stepwise, with the most intensive farms being subjected to it firstly in 1998, until in 2000 all farms became subject, and the surplus standards are being reduced until 2003. This causes MINAS to not being restrictive for all farms in the sample. These farmers probably have gained knowledge in the project and know now how to respond if MINAS does become restrictive, causing a negative relationship with response uncertainty. The MDIL-farms are more response uncertain relative to the other farm types. This is likely due to the fact that they have been subject to several changes of recent, like government buyouts, animal housing regulations, and an outbreak of Classical Swine Fever. PEU is significantly related to all the above-mentioned factors, excepts for the dummy for MDIL. In total 38.8% of PEU can be explained using this model.

Table 6.5 Step-wise regression results for state, effect, response and total Perceived Environmental Uncertainty

	State Uncertainty	Effect Uncertainty	Response Uncertainty	Perceived Environmental Uncertainty
Constant	.***	.***	.***	.***
Complexity	-0.33**	-0.34**	-0.36**	-0.40***
Illiberality	0.17	0.14	0.18*	0.18*
Dynamism	0.04	0.05	0.16	0.12
Farm size	-0.34***	-0.27**		-0.21*
Negative MINAS-attitude		0.24*	0.27**	0.28**
Dev. N-surplus standard			-0.19*	-0.34*
Dummy dairy + IL			0.22*	
F-ratio	7.777***	6.294***	6.862***	10.510***
R^2	23.1	22.7	28.1	38.8

$^{***}P< 0.001$, $^{**}P<0.01$, $^{*}P<0.05$

Table 6.6 shows the regression results on the factor scores of strategies of PEU (the right horizontal arrow in Figure 6.1), and the other variables in the analysis. PEU appears to be of importance for strategic choice. It significantly negatively affects the choice for a process-control strategy and significantly positively affects the choice for diversification. Apparently, higher PEU reduces the likelihood that farmers will choose to employ a strategy of increased specialisation through quality improvement and more accurate operational management. Farmers with high PEU might be more risk-averse, and do not want to risk yield losses due to precision practices. No significant relationship was found between PEU and a growth strategy. Planning to intensify and expand while improving labour efficiency apparently is not influenced by the PEU of the farmer. It could be that these farmers are relatively risk-neutral, compared to the other farmers in the sample. Higher PEU increases the tendency for diversification. Apparently, diversification is also in dairy farming an uncertainty reducing strategy by spreading risk over several enterprises. To check for effects of differences between PEU for different farm types a regression equation was estimated including dummies for farm type. This did not yield any different coefficients for PEU, and thus the originally estimated equation was maintained.

Table 6.6 Step-wise regression results for strategic choice

	Process-control	Growth	Diversification
Constant	.***	.***	.***
PEU	-0.20*	0.07	0.23*
Educational level	-0.22*		-0.19*
Learner-attitude	0.25*		-0.27**
Expressive mission	0.25*		
Farm intensity (milk quota/ha)		0.32**	
Instrumental mission		0.25**	
Farm size (DSU)		0.21*	
Degree of specialisation			-0.37***
F-ratio	4.322***	9.446***	9.354***
R^2	18.0	27.5	27.3

***P< 0.001, **P<0.01, *P<0.05

The choice for process-control is furthermore negatively related to the level of education of the farmer. Higher educated farmers possibly realise that milk quality is subject to regulations. Extra efforts through more accurate operational management to surpass these quality standards may not be beneficial. Those farmers who entered the FDP-project with a learner attitude are more likely to employ process-control. These farmers focus probably on improving product quality through learning about more accurate feeding and fertilisation. High importance to an expressive mission is also positively related to a process-control strategy. Personal fulfilment through farming is likely to be attained sooner by an accurate production process leading to high quality products then by growth or diversification. The growth strategy is significantly positively related to a large farm and high intensity. Apparently, farmers on a large farm, regardless of high intensity, and on an intensive farm, regardless of size want to grow, either through expansion, or through intensification. It is possible that farmers have been pursuing this strategy already and intend to go on with that in order to fulfil their instrumental mission (significant positive relationship). Diversification is, like process-control, negatively related to the educational level of the farmer. Higher educated farmers might be better able to understand the risks and benefits involved in diversification and process-control (increased specialisation) than others are and choose instead for growth. A learner attitude is also significantly negatively associated with diversification. The attitude to learn about nutrient management apparently does not lead to the choice for diversification. And finally, the higher specialised a dairy farm is, the less likely it is the farmer will opt for diversification. Like with the growth strategy, the existence of a certain situation (large/intensive or diversified) seems to be of importance for the strategy a farmer chooses. It is likely that farmers have chosen or inherited a certain farm type and keep pursuing this form of operation.

6.5 Conclusion

The reduction of governmental protection and subsidies of agriculture in Europe causes farmers to focus more on entrepreneurial and management activities rather than craftsmanship. This paper shows the uncertainty, which accompanies decision-making in agriculture and the relationship with the choice for a farm strategy. The results of this exploratory study on the perception of farmers of the environment they operate in showed that the environmental sector, which was found to be the most complex, illiberal and dynamic, was the institutional environment. This could be suspected based on the increasing and constantly changing in legislation and regulations of recent, while subsidies are decreased. The two environmental sectors causing most PEU were found to be the institutional environment and competition. The increasing legislation in The Netherlands, which is often times more strict than in other European countries, are detrimental to the competitive position of Dutch farmers. The advantage of a lead in knowledge over other European farmers is declining while production costs are increasing due to scarcity of land and accumulating regulations.

The relative level of PEU is associated with animal density of the farm. The farmers on the most animal-intensive type of farm (MDIL) suffer most from environmental regulations like MINAS. The high uncertainty might well be related to decisions on whether or not to keep pursuing an enterprise in pigs or poultry, areas of production which are also pressured by animal-welfare regulations. PEU and its components are negatively related to the perception of complexity of the environment but not as much to illiberality or dynamism. These findings indicate that increasing complexity of the environment, does not have to lead to increasing uncertainty among farmers. Awareness of the complexity of the environment might be an important factor. Farmers, who were confronted with the survey while they had not given environmentally emerging issues much thought, possibly expressed their lack of understanding of the environment with uncertainty.

The process-control and diversification strategies are significantly affected by PEU, while growth is not. Less well educated farmers, who are likely to be less able to interpret the environment, tend to choose strategies of diversification or process-control, in the former case to spread risk, in the latter to try to make use of additional benefits that might befall high quality products. Growth is not affected by PEU and this could be due to the risk attitude of the farmers who choose this strategy. They likely have a clear vision of their future farm and work towards achieving that goal. The significant relationship between uncertainty and strategic choice calls for a closer look at concerns of farmers about the external environment and how to support the fit between environmental perception and farm strategy. Negative attitudes towards certain components of the external environment can increase uncertainty. They may be due to lack of knowledge of the current situation a farm is in. It is therefore necessary to improve the perception of the environment by farmers, because it will become more and more important in the future.

Translating these results to the entire population of Dutch dairy farmers means that it is important for farmers to find a fit between internal and constantly changing external factors in order to be able to pursue a strategy and thus meet the mission of the farm. Awareness of the (changes in the) environment is a key issue for perceived uncertainty, making complexity and dynamism irrelevant. Illiberality is important, however, and mainly associated with the institutional environment. A reduction of institutional illiberality will likely result in more co-operation of farmers and more effective (agri-environmental) policy-making.

Appendix 6.1 Construction of the PEU survey

Environmental sectors and items in the questionnaire

Social Environment	**Technological Environment**
Food consumption pattern of society	Automation and internet
Attention to food safety issues of society	Development of manure processing techniques
Environmental awareness of society	Biotechnology
Attention to animal welfare of society	Environmental technology
Attention to rural development of society	Speed of technological environment
Economical environment	**Institutional environment**
Interest rate	Dutch environmental policy
Economic growth in The Netherlands	Mineral Accounting System (MINAS)
Opening of agricultural markets (Agenda 2000)	European Nitrate Directive
	Policy on subsidies
	EU Market- Price- and Income policy
	Rural development policy
Suppliers	**Buyers**
Production costs	Output prices
Availability of land	Sale opportunities
Availability of financing	Quality demands of buyers
Competition	**Natural environment**
National competition	Soil type
International competition	Vicinity of conservation areas
Niche markets	Weather (precipitation, temperature)
Agricultural production chains	
Bulk markets	

To elicit PE, two questions were asked:

1) Does the item create a threat or an opportunity for your farm at this moment?

2) Did the item create a threat or an opportunity for your farm at the beginning of the FDP project?

The response could be given on a 5-point Likert scale, in which 1 meant a great threat, 3 meant neutral/no threat or opportunity, and 5 a great opportunity.

To elicit PEU, three questions were asked:

3) How well is the item predictable? (to determine state uncertainty)

The response could be given on a 5-point Likert scale, in which 1 meant highly unpredictable, 3 meant neutral, and 5 highly predictable.

4) How well can you assess the effect of the item on your farm performance? (to determine effect uncertainty)

The response could be given on a 5-point Likert scale, in which 1 meant very difficult to asses, 3 meant neutral, and 5 easy to assess.

5) How sure do you know how to respond to the item? (to determine response uncertainty)

The response could be given on a 5-point Likert scale, in which 1 meant very unsure, 3 meant neutral, and 5 very sure

VII Management strategies on Dutch dairy farms to meet environmental regulations: a multi-case study

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Abstract

In 1998, the Dutch government introduced the Mineral Accounting System (MINAS) to prevent and reduce pollution of groundwater resources by agricultural nutrients. If farmers do not comply with the system they will be taxed, which might constitute a threat to the financial viability of the farm. This paper applies a multi-case study approach to explore the ways in which dairy farms cope strategically, tactically and operationally with the introduction of MINAS. Using three-year panel data of 72 farms, and the results of an interactive workshop, propositions regarding nutrient management decisions were formulated and tested. In general, the most environmentally and cost-effective order of nutrient management optimisation proved to be: (1) the optimisation of production through more accurate management (operational level); (2) the reduction of inputs (tactical level), and (3) a re-evaluation of farm intensity (strategic level). Even though MINAS constitutes a significant change in the external environment of farms it does not cause farmers to alter their strategy. The large variation found, in the manner farmers chose to cope with nutrient management problems on their farm appeared to be related to factors like preferences and competencies. These factors affect the choices farmer make to deal with environmental problems.

7.1 Introduction

Farming in the Netherlands is becoming increasingly complex due to an accruement of environmental regulations. The most important one of recent is the Mineral Accounting System (MINAS), introduced in 1998, which affects every single Dutch farm (Van den Brandt and Smit, 1998). MINAS constitutes a nutrient bookkeeping system and addresses both nitrogen and phosphorus. It determines the difference between nutrients in inputs to the farm and nutrients in products leaving the farm. The difference is called the surplus and is compared with maximally allowed surplus standards. If these standards are not met, a levy will be imposed. The maximum allowed nutrient surpluses will be reduced from 1998 onward, until the year 2003, when the final standards are supposed to lead to health- and environmental-wise safe concentrations of nutrient constituents in ground- and surface waters[1] (Oenema and Roest, 1998).

The introduction of MINAS poses a serious threat to the financial viability and continuity of farms due to high levies and the large part of farms not yet meeting the standards (Ondersteijn *et al.*, 2002). Research has shown that the average nitrogen surplus per ha on individual Dutch dairy farms has to be reduced by 58% compared with the level of 1985 (Oenema *et al.*, 1998). Assuming that farmers continue to pursue the mission (long-term goals for the farm), many farms will have to alter their management practices considerably to meet the final surplus standards. This encompasses optimising operational, tactical as well as strategic management in light of the new conditions.

This paper focuses on specialised dairy farms. The typical Dutch dairy farm integrates animal and plant production activities and therefore has complex nutrient flows. Several farming-systems studies have been conducted to examine whether dairy farms could meet environmental standards. Modelling studies (e.g. Berentsen, 1999), prototype research (e.g. Aarts, 2000), and single case studies (e.g. Klausner *et al.*, 1998) have been used to gain insight into the consequences of environmentally friendly nutrient management on ‘average’ dairy farms. Differences in farm structure and environment, and personal characteristics of the farmer will all, however, to a certain degree affect the choice for input-output relations of a specific farm. A variety of nutrient management measures may therefore expected to be taken on commercial dairy farms. Aarts *et al.* (1992) state that “in principle for each group of farms with the same relevant characteristics, or even for each farm, a specific set of consistent measures to meet environmental and economic goals should be developed”.

[1] The final standards are set to 180 kg ha^{-1} of nitrogen (N) for land covered with grass and 100 kg for arable land. An excess of 20 kg of phosphate (P_2O_5) is allowed per hectare regardless of cropping type. Farmers will be taxed €2.30 for every kg of N that exceeds the standard, and €9.00 for every kg P_2O_5.

This paper employs a multi-case study approach to explore the ways in which dairy farms cope strategically, tactically and operationally with a significant change in their external environment. Five propositions are put forward based on the strategic management model combined with a literature review on nutrient management. These propositions will be explored using technical data, financial and nutrient bookkeeping data of three years (1997-1999) as well as nutrient management plans farmers developed using an Interactive Simulation Model (ISM). In this way, insight is provided into the way farmers modify their strategies, tactics and operational management to meet the environmental standards in MINAS.

7.2 Materials and methods

7.2.1 Materials

Data were collected over a four-year period (1997-2000) in order to monitor the changes that farmers implemented on their farms. Data were collected from specialised dairy farmers[2] participating in a project aimed at improving nutrient management; a collaborative effort of the Dutch government and farm organisations. The project consists of two parts. From 1997 through 1999, 125 participating dairy farmers aimed at improving and learning about nutrient management in the Netherlands (Ondersteijn *et al.*, 2002). To meet the objectives of the first stage, technical, financial and nutrient bookkeeping data were collected, and management surveys were executed to gain insight in farmers' mission and motivations. During the second stage of the project-from 2000 through 2002-the goal was explicitly to meet the nutrient surplus standards of 2003 (175 dairy farmers participated in the second stage). To help farmers define the path towards meeting the standards for their farm an Interactive Simulation Model (ISM) was used in a workshop set-up in 2000 (Baarda, 1999).

The workshop consisted of two days, and farmers were divided into groups of 8-10 participants. The first day, farmers were informed about the goal of the workshop: to write a strategic plan to meet or approach the final surplus standards. The first day was used to complete a Strategic Management Report (SMR), designed by the Agricultural Economics Research Institute (LEI) to elicit farmers' missions and the strengths, weaknesses, opportunities and threats of their farm. They used this as the basis for the second day of the workshop, several weeks later, when the use of the ISM was explained in support of the development of a strategic plan for their farm.

[2] Farms are considered specialised dairy farms if at least 95% of all Dutch Size Units (DSUs) on the farm can be attributed to dairy production. The DSU is an economic size unit, based on standard gross margins.

ISM is a windows-based system in which participants are confronted with their farm structure, management and results. It uses regression techniques to estimate the consequences of virtual nutrient management changes by participants for the financial performance of the farm as well as the impact on both N and P_2O_5 balances (Hennen, 1995). When not satisfied with the results, the participant can return to the first window and try other strategies. Finally, the farmer decides which nutrient management plan suits him and his farm goals best. The Appendix gives an overview of the measures in ISM farmers can select and the direction in which these will change farm results according to the model.

Not all farmers participated in both stages of the project. So not for every farmer in the sample a complete set with four data-points (results of 1997, 1998, and 1999, and ISM plan of 2000) is available. This could cause a selection bias. An analysis of the differences between the farmers that participated in the second stage of the project and those that did not shows that in the latter group N and P_2O_5 surpluses were significantly higher ($P < 0.01$). There are no demographic differences but there is a significant ($P < 0.01$) difference in the importance attached to societal concerns, which was higher among the farmers participating in the second stage. In the present study only data were used of farms that were complete, which resulted in a sample of 72 farms of which the nutrient management characteristics and the choices made in ISM are shown in Table 7.1.

7.2.2 Methods

Nutrient management research tends to focus on the results of an experimental farm, 'the average' dairy farm, or a single case-study, which in most instances does not reflect the actual decision making environment, internal as well as external, commercial farms are in. The research question of this study is exploratory and focuses on how a change in the external environment may affect farmers' strategic, tactical and operational behaviour. Furthermore, since this was a real-time project with commercial farms, little control over the behaviour of the participating farmers could be exerted. Case study analysis seems well apt to accommodate this exploratory nature of the research, the lack of control, and contemporary issue (Yin, 1994). Case study research allows the selection of a specific subject (single-case study), or a group of subjects (multiple-case study), to find in-depth answers to a specific research question. It can deal with the fact that there are many more variables of interest than there are data-points. This is definitely the case in the present study. Trials with cluster and discriminant analysis did not yield any satisfying results, indicating that the sample was too small to reveal distinct nutrient management plans. Probit analyses were executed on the choice for a certain measure. Again, the analyses did not yield many statistically significant models, indicating that factors determining the choice for a certain measure could be manifold and not easily extracted from past behaviour. Diversity and specificity among farms and farmers is large and therefore the case study approach is the better choice.

Table 7.1 Nutrient management measures: changes over the period 1997-1999, situation in 1999, and % of farmers in 2000 that intend to take a certain measure in the Interactive Simulation Model (ISM)

	Changes 1997-1999	**Situation 1999**	**ISM 2000 (% farmers)**
Operational management			
Feeding and grassland management (MJ NEL per ha)[a]	-200	7152	64
Utilisation of N in organic manure	n.a.[b]	n.a.[b]	64
Tactical management			
Young stock (Livestock Units (LU) per 10 cows)	-0.3	2.7	49
Grazing intensity (LU grazing days per ha grass)	-12	338	49
N-level in concentrates (g kg^{-1})	2.9	32.9	18
P-level in concentrates (g kg^{-1})	0.3	5.4	17
Inorganic fertiliser N on grass (kg N ha^{-1})	-48	242	
Reduce			75
Increase			1
Inorganic fertiliser P (kg P_2O_5 ha^{-1})	-2	27	8
Grass/maize ratio (%grass)	-3	85	
Reduce			32
Increase			11
Concentrate use (MJ NEL per 100 kg FPCM[c])	-8.6	188	
Reduce			22
Increase			18
Strategic management			
Farm intensity (kg FPCM[c] ha^{-1})	545	13869	
Reduce			8
Increase			62
Milk production per cow (kg FPCM[c] per cow)	84	8333	60
Taxable nutrient surplus			
Deviation from 1999 Levy Free Surplus (LFS)			***Simulated deviation from ’03 LFS***
Nitrogen (kg N ha^{-1})	-6	-39	
Phosphate (kg P_2O_5 ha^{-1})	11	-20	
Deviation from 2003 LFS			
Nitrogen (kg N ha^{-1})	-6	74	-4
Phosphate (kg P_2O_5 ha^{-1})	11	0	-11

[a] Actual – standard additional feed supply in MJ NEL (Net Energy for Lactation) per ha. Standard additional feed supply was calculated by subtracting standard on-farm produced energy in roughage from the standard energy needs of cattle. Energy and production standards were taken from Dutch norms.
[b] n.a. = not available.
[c] FPCM = Fat and Protein Corrected Milk.

Case studies are based on multiple sources of evidence and the prior development of theoretical propositions to guide data collection and analysis (Yin, 1994). In the present study no specific selection of farms has been made beforehand, other than that they were all specialised dairy farms because the larger the sample, the more insight is gained in the development paths of dairy farms towards optimisation of farm management to meet the nutrient surplus standards. Sub-samples of farms will be selected based on the proposition at hand.

7.3 Propositions on farm management to meet environmental conditions

To develop the propositions to study the impact of a change in the external environment of a firm, the strategic management model is used (see e.g. David, 2001), which has been shown to be applicable to farm businesses (Harling and Quail, 1990; Harling, 1992). In the model, the farmer first defines a mission statement, which addresses the question: ‘why farm?’. In order to be able to translate a mission into objectives, the internal strengths and weaknesses of the farm and farmer need to be identified. At the same time external opportunities and threats must be examined in an external audit. During synthesis, different strategies are generated, evaluated and selected. Strategies are the means to achieve the objectives within a certain time span. When a strategy has been chosen, it has to be translated into tactics and operational activities so it can be implemented.

Since the farmer is the sole decision-maker he is responsible for all steps in the development of a strategic plan. MINAS constitutes a change in the external environment and is not expected to alter the mission of the farmer. Depending on the current state of his nutrient management (strength or weakness) however, he may need to alter his operational, tactical or strategic management. When the surplus situation and competencies of a farm and farmer are such that he can manage to reduce the surpluses with only operational and maybe tactical changes, he will be able to keep pursuing his strategy. If not, his current strategy may be threatened and may need reconsideration. The strategic, tactical and operational options a farmer has available to reduce nutrient surpluses are shown in the Appendix. The options are part of ISM and the effects on the surpluses and gross margin in the model are given as well.

7.3.1. Optimising operational management: low-cost and low-risk

When farms show only small deviations from the final surplus standards, adjustment of operational management may suffice. These measures have low costs and low risk, and imply more accurate management. More accurate feeding based on the needs of individual animals and improvement of grassland management by better timing of fertilising, grazing and harvesting and choosing a better method of conservation will not only reduce nutrient surpluses but also reduce input needs (Berentsen *et al.*, 1996). Producing the same output with less input through these types of measures is an improvement of both technical and economic efficiency of the farming system. Optimising operational management (i.e. efficiency) is therefore something a farmer with profit-maximising aims should do under any circumstances. Some farmers may operate an extensive farming system, and have no intention of expanding or growing through intensification (more milk quota per ha). This objective may unburden them from the need to optimise farm management as a first step towards meeting environmental standards but it also leads to higher costs for the farm compared with more efficient farms. Another reason not to opt for optimising operational management could be awareness of weak operational management and the incapability to improve it.

> *Proposition 1. Farmers who do not choose to improve operational management already pursue good operational management, meet the surplus standards or recognise their incapability to improve it*

According to Aarts *et al.* (1992), operational measures are relatively simple and easily implemented. What they do not recognise in their study however, is that efficiency improvement requires a large effort in terms of farmers' management skills. Optimising operational management leans towards precision agriculture and not all farmers possess the skill, the knowledge, the drive or even the time to optimise their farming system. For these farmers, optimising operational management is not the solution. For farmers lacking sufficient management skills, the best solution may be to proceed to the next step of the nutrient management optimisation path and reduce the inputs to the farm. Because of their lack of management skills they will need to reduce these inputs further than a farmer with better skills (Aarts, 1999c).

> *Proposition 2. Farmers who have shown deteriorating operational management in the past and have nutrient problems on their farm, resort more to use of tactical solutions than farmers who have been improving operational management performance*

7.3.2 Optimising tactical management: reducing dependency on inputs

Tactical decisions are the next step to reduce surpluses, without having to alter the farm strategy. The choice for a tactical nutrient management measure depends on the efficacy in reducing the nutrient surpluses and the cost effectiveness (cost per reduced kg N per ha) of the measure. Certain tactical measures will be more effective in reducing the nutrient surpluses than others. A reduction in N fertilisation level of grassland for instance, strongly reduces the

N surplus given the high level of fertilisation in the Netherlands (Berentsen *et al.*, 1992). This is also true for P fertiliser, but since that is not included in calculating the taxable P_2O_5 surplus, it does not bring a farm closer to meeting the surplus standard for P_2O_5. The magnitude of the effect of a reduction in grazing intensity is dependent on more factors like mowing and grazing system. Composition and amount of concentrates supplied is dependent on roughage fed, and milk production goals. The area of grass grown relative to maize is dependent on roughage needs of the herd and growing conditions. An increase in maize area relative to grass would reduce the fertilisers needed for roughage production, but since the nutrient surplus standards for N are 80 kg ha^{-1} higher for grass land than for arable land, this measure does not result in a large nutrient management advantage.

Because nutrient management decisions on the tactical level could have a significant impact on inputs and outputs, this results in changes in income (De Haan, 2001). It is therefore likely that farmers will opt to select a sequence of tactical decisions based on the income change associated with a certain measure. The economic effects of different measures have been determined for the experimental farm De Marke for measures individually (Wolleswinkel, 1999) and for sequentially introduced measures (De Haan, 2001). According to these modelling studies, reducing the number of young stock, and more efficient grazing reduce the N surplus and have a positive effect on financial returns, whereas other measures reduce the surplus as well, but are costly (normative feeding and reducing inorganic fertiliser N being the cheaper ones). These farm-specific studies give an indication of the possible effects on farm income. Their farm specificity prevents a straightforward translation of effects to the entire population, however, since both the environmental and financial consequences of changes in tactical management are dependent on the base farm situation and the competence of the farmer to adjust to the changes in the external environment. ISM therefore, uses data from the Farm Accounting Data Network (FADN), a stratified sample of the Dutch dairy population to estimate farm-specific effects under different farm conditions.

Proposition 3. The sequence of selected tactical decisions is based on the expected environmental and financial efficacy of the measure

7.3.3 Optimising strategic management: structural farm changes

If, for some reason, operational and tactical measures do not lead to the required reduction in nutrient surpluses, decisions at a more strategic level are necessary. Dairy farms can meet the environmental standards by changing the farming system from intensive to more extensive, for instance by buying land to reduce milk production per ha (Neeteson, 2000). Changing the intensity of the farm is, however, a strategic decision based on financial rather than environmental considerations. The price of land in the Netherlands is such that a rational decision-maker with expansion and continuity objectives would want to maximise the returns to land through maximising milk production per unit of land, within the environmental constraints (Korevaar, 1992; Aarts *et al.* 1999c). Decreasing farm intensity therefore does not seem like a very attractive option and will only be chosen if absolutely necessary.

Proposition 4. Farmers will extensify (less kg milk quota per ha) if, and only if operational and tactical measures do not suffice to meet the final surplus standards

Farmers may consider increasing the returns to land so important, that they continue to intensify their farming system. The consequences of an increase in farm intensity depends on whether a proper fit between the farmer's operational and tactical management skills and the intensity can be found. Since it is difficult to make a correct assessment of these skills, correct a priori decisions on the appropriate intensity level of the farm can only be a guess. Furthermore, these management skills can improve over time, requiring adjustment of this decision. It seems therefore most effective, regardless of the intensity level of the farm, to try to optimise operational and tactical management of nutrients while increasing intensity of the farming system.

Under a milk quota system, maximising milk production per ha is dependent upon the genetic production capacity of the dairy cows in the herd. Increasing milk production per cow, while maintaining or increasing fat and protein content is a way to reduce the number of cows needed to fill in the milk quota (Steverink *et al.*, 1994). Furthermore, a smaller dairy herd requires less replacement heifers, and therefore less feed is required, which positively affects the nutrient balance (Korevaar, 1992; Aarts *et al.*, 1999b). A high producing herd will therefore increase the possibilities to maximise the returns to land. In this way, the new environmental legislation will lead to a higher breeding value for milk production (Steverink *et al.*, 1994).

Proposition 5. Farmers whose strategy is to increase the intensity (more kg milk per ha) of the farm to capitalise on economies of scale, have to optimise their farming system with operational and tactical measures and increase milk production per cow

7.4 Results

Proposition 1

Operational management is mainly determined by feeding and grassland management and these terms are therefore used interchangeably here. Feeding and grassland management is determined as actual minus standard additional feed supply expressed in MegaJoules Net Energy for Lactation (MJ NEL). This definition implies that good feeding and grassland management is associated with small or negative values. To calculate standard additional feed supply, the standard energy requirements of cattle were calculated and standard on-farm produced energy in roughage was subtracted. Energy and production standards were taken from Dutch standard norms (Anonymous, 1997; Philipsen *et al.*, 2001). To explore proposition 1, farms were selected that did not choose to improve operational management (n=26). Table 7.2 shows operational management performance, intensity in terms of milk production per ha and the deviation from the final N surplus standard.

Farms 1.1-1.10 perform in the lower quartile of operational management for the total sample (< 86 MJ NEL per ha). All these farms but two (nos. 1.6 and 1.8) have been improving in this aspect since 1997. Even so, the level of operational management of both these farms is still in the lower quartile of the sample's performance. The SMRs of these farms show that both farmers consider feeding- and grassland management as one of their strengths. Farms 1.11 to 1.26 can gain economic benefits from improving their operational performance. Most farmers realise this and have started to improve performance since 1997. Farms nos. 1.15, 1.17, 1.20, 1.21, 1.22, and 1.24 however, have not. The SMRs show that farmers 1.17 and 1.21 consider feeding and grassland management as a strength of their farms. Farm no. 1.24 does think that grassland management is a weakness, but compensates that with low feeding and fertilisation costs as strengths. He chooses to reduce the fertiliser N dose and increase milk production per cow (7399 kg FPCM per cow in 1999) rather than improving operational management. The other farmers do not mention feeding and grassland management in their SMRs. Apparently, they do not realise the benefits of good operational management or their poor performance.

Proposition 1 is supported by these findings. The farmers who do not choose to improve operational management in the ISM either already show excellent performance, or have been improving performance over the period 1997-1999. Furthermore, farmers who do not choose to improve operational management and show poor operational management seem to have either a misconception of their performance or do not consider it important.

Table 7.2 Operational management performance, farming intensity and MINAS performance for farms that did not choose to improve operational management (Proposition 1).

Farm number	Operational management[a] (MJ NEL per ha) Situation 1999	Changes 1997-1999	Farming intensity (kg FPCM[c] per ha)	MINAS performance[b] Kg N per ha
1.1.	-16580	-12038	29906	-2
1.2	-13823	-17390	15009	-10
1.3	-8478	-963	16411	130
1.4	-5786	-10107	18044	108
1.5	-5061	-4721	13063	0
1.6	-3635	1516	15480	57
1.7	-3147	-5363	24631	172
1.8	-2103	17292	13412	161
1.9	-1602	-2608	13789	37
1.10	-607	-1143	12553	101
1.11	659	-6743	15160	42
1.12	1592	-1003	14560	119
1.13	2922	-11406	12286	67
1.14	3123	-10967	10099	30
1.15	3128	1646	13942	64
1.16	4668	-951	10315	9
1.17	5548	2	13576	54
1.18	5796	-4819	11202	11
1.19	7112	-10362	14188	67
1.20	7345	4723	15940	142
1.21	9740	4356	14757	20
1.22	11071	4395	13973	233
1.23	11198	-5194	11992	-8
1.24	13413	11789	11049	58
1.25	15638	-7387	11583	220
1.26	16745	-20503	11052	12

[a] Operational management is defined as the actual – standard additional feed supply expressed in MJ Net Energy for Lactation (NEL) per ha.

[b] Difference between 1999 N surplus and surplus standard for N in 2003.

c FPCM = Fat and Protein Corrected Milk.

Proposition 2

To investigate proposition 2, farms were selected in the upper quartile of the change in operational management performance as well as the upper quartile of the deviation from the final N surplus standard. Seven farms met these criteria. They all showed deteriorating feeding- and grassland performance and have large deviations from the final N surplus standards, which, for most farms, have actually increased from 1997-1999 (Table 7.3). Farm no. 2.2 actually met the final surplus standards in 1997. Deteriorating operational management, an increase in N fertiliser use with 123 kg ha^{-1}, and falling milk production per cow are the main reasons for this huge increase.

Proposition 2 expects these farmers to plan more tactical measures than other farmers to reduce their nutrient surpluses. All but one farmer still choose to improve feeding and grassland management and five farmers also intend to improve the utilisation of N from manure. Apparently, they perceive that need but they may not properly judge their capacities (based on the previous three years) to do so. Most of the farmers selected 4 tactical measures to take from 2000 onward. Reducing N input from inorganic fertilisers is selected by all farmers.

Comparing the number of tactical measures these farms have selected with that of other farms should indicate whether these farmers indeed use more tactical measures. The first comparison (not in Table 7.3) was done with farms that did manage to improve operational management, but still had high nutrient surpluses. The two farms that met these criteria selected 2 and 5 tactical measures respectively. These numbers do not indicate any difference. Comparing the 7 farms with all farms that did manage to improve operational management performance (not in Table 7.3), and with the total group of farms (in Table 7.3), gave significantly ($P<0.01$) higher numbers of tactical measures taken by the group of 7, providing support for proposition 2.

Table 7.3 Operational management, farming intensity, MINAS performance, and planned management measures for farms with a large drop in operational management (Proposition 2).

	Farm number							**t-test**	
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	Mean 2.1-2.7	Rest of sample
Operational management[a] (MJ NEL per ha)									
Situation 1999	-2103	14143	21683	19140	12564	19337	19804		
Changes 1997-1999	17282	12920	11877	9835	8711	7612	7590		
Farming intensity 1999 (kg FPCM[b] per ha)	13412	19695	11876	16126	14009	15276	16063		
MINAS performance[c] (kg N per ha)									
Situation 1999	161	190	154	152	197	201	116		
Changes 1997-1999	151	234	102	38	72	-8	-13		
No. of operational measures ISM[d]	0	2	2	2	2	2	1		
No. of tactical measures ISM[d]	4	4	4	3	4	4	4	3.9	2.9^{***}

$^{***}P < 0.001$

[a] See Table 7.2.

[b] See Table 7.2.

[c] See Table 7.2.

[d] ISM = (in the) Interactive Simulation Model.

Proposition 3

The third proposition requires ranking of the tactical measures based on their environmental and financial efficacy (based on experimental farm studies and ISM) (Tables 7.4 and 7.5). Table 7.4 shows the percentages of farmers having changed more than 10% of a particular input in 1997-1999. The last two columns show the percentages of farmers selecting a change in a particular input use in the ISM. During 1997-1999, farmers have implemented mainly the environmentally and financially most effective measures (inorganic N, number of young stock and grazing intensity). The high percentage of farmers that has reduced P from fertiliser is surprising, since it does not bring a farmer closer to the P_2O_5 surplus standards (inorganic P is exempt from taxation). This was understood in 2000 when ISM was used. In ISM farmers again selected mainly the environmentally and financially most effective tactical measures. A likely reason is that the other tactical measures intervene in feeding. Feeding dairy cattle has for a long time been an important issue on dairy farms. Milk is their main product and therefore dairy farmers are not likely to compromise on the feed requirements of their production herd. The energy and nutrient requirements are generally optimised and carefully monitored, especially in winter. In summer, a surplus of protein is often supplied, because of intensive grazing. Many farmers recognise this and intend to reduce grazing intensity and grow more maize, which can be supplied as low-protein roughage in summer.

Table 7.4 Percentages of farmers taking a tactical measures in the period 1997-1999 and percentage of farmers planning to take measures in Interactive Simulation Model (ISM) (Proposition 3).

	1997-1999		**ISM (2000)**	
	Reduce	Increase	Reduce	Increase
Highly effective tactical measures				
Inorganic fertiliser N	58	8	75	1
Number of young stock	56	13	49	
Moderately effective tactical measures				
Grazing intensity	40	26	49	
Protein level in concentrates	11	39	18	
P level in concentrates	19	29	17	
Grass/maize ratio	17	4	32	11
Quantity of concentrates per cow	31	15	22	18
Not-effective tactical measures				
Inorganic fertiliser P	44	40	8	

Table 7.5 shows the difference between farms that reduced the two most environmentally effective tactical measures in the period 1997-1999, and those that did not. There is no statistical difference in other tactical measures selected in 1997-1999. The farms that did not

implement the environmentally effective tactical measures show a higher N surplus and significantly lower P_2O_5 surplus than the other farms, though the absolute difference is small. There is no statistically significant difference between the number of environmentally effective tactical measures selected in the ISM between the two groups. A closer look reveals that the planned changes are not statistically significantly different, but the level of fertiliser N in 1999 is ($P<0.01$). The planned reduction is therefore smaller in the group that already implemented these measures before. According to proposition 3, it is expected that the former group will implement more of the environmentally uncertain tactical measures in the future. Farmers that have implemented the most environmentally effective tactical measures in 1997-1999 are indeed planning to implement significantly more tactical measures, which have an uncertain outcome, both environmentally and financially. Hence, these farmers are now selecting more uncertain measures, providing evidence for proposition 3. Farmers who did not select the most effective tactical measures in 1997-1999, are aiming for larger reductions, especially for inorganic fertiliser N and appear to be planning to implement the most environmentally effective tactical measures in 2000-2003.

Table 7.5 Average number of highly effective (reduction in inorganic fertiliser N, reduction in young stock), moderately effective (grazing intensity, protein in concentrates, P in concentrates; energy in concentrates; percentage of grassland) and not-effective (reduction in inorganic fertiliser P) tactical measures for farms that did not (Group 1; n = 15) and farms that did implement highly effective measures (Group 2; n = 57) in the period 1997-1999 (Proposition 3).

	Group 1	**Group 2**	**t-value**
No. of moderately effective tactical measures 1997-1999	1.20	1.18	-0.07
No. of not effective tactical measures 1997-1999	0.33	0.47	0.98
MINAS performance[a] N in 1999 (kg N per ha)	98	68	-1.49
MINAS performance[a] P_2O_5 in 1999 (kg P_2O_5 per ha)	-9	3	2.54*
No. of highly effective tactical measures ISM[b]	1.20	1.25	0.25
Percentage planned change in N fertiliser ISM[b]	-17	-13	0.67
Inorganic fertiliser N kg/ha 1999	289	229	-3.16**
Percentage planned change in young stock ISM[b]	-0.07	-0.19	-1.83
Young stock 1999 (in Livestock Units per 10 cows)	2.7	2.7	-0.02
No. of moderately effective tactical measures ISM[b]	0.87	1.54	2.61*
No. of not effective tactical measures ISM[b]	0.07	0.09	0.26
MINAS performance[a] N ISM[b] (kg N per ha)	-10	-3	0.74
MINAS performance[a] P_2O_5 ISM[b] (kg P_2O_5 per ha)	-17	-10	2.25*

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

[a] Difference between surplus and surplus standard in 2003.

[b] ISM = (in the) Interactive Simulation model.

Proposition 4

To study proposition 4, farms were selected that planned to make their farm more extensive. Of the total sample, 6 farms (8%) selected this option (Table 7.6). This small number already indicates that the option of reducing intensity is not something farmers see as an attractive way to reduce nutrient surpluses. Farm 4.1 intends to reduce intensity with approximately 14.000 kg milk per ha, the others plan reductions from about 1.500 to 3.300 kg milk per ha. In addition to a reduction in intensity, the farms are also planning to make operational and tactical changes. The last two columns show the average number of measures for the 6 farms as well as for the rest of the sample. T-tests showed no significant differences between the farms, indicating that reducing intensity is not considered an alternative to operational or tactical measures.

A closer look at the plans developed with ISM reveals that none of the farmers intends to sell any milk quota. All farms are planning on buying or leasing land and milk quota, except for farm 4.4 that only opts for buying or leasing additional land. Except for farm 4.1, none of the farmers considers the intensity of their farm a weakness. Farm 4.1 heavily depends on manure disposal and according to his SMR, he wants to avoid this in the future and therefore has to reduce intensity. The introduction of MINAS in 1998 apparently did not affect the growth strategy of these farms, which they all explicitly state as (part of) their strategy in their SMR. They aim at a farm of a certain size with a certain area of land and nobody but farmer 4.1 thinks a reduction in intensity is needed to meet the nutrient surplus standards. They also do not consider it a way to avoid having to take operational or tactical measures. The reduction in intensity as a consequence of the selection of measures in ISM is incidentally related to the farm structure they are aiming at.

Proposition 5

To check whether farms that plan to increase the intensity of the farm are different from farms that do not, two groups of farms were selected (Table 7.7, NI and I). Although only one of the characteristics appears to be significantly different (P<0.05), environmental performance of the farms that plan to intensify, appears to be better than that of farms that do not. Intensifying is accompanied, however, by significantly more manure disposal (P<0.05), which is costly. Manure disposal is not considered an alternative to taking operational or tactical measures, neither does it make any difference in the choice for genetic improvement of the herd (Table 7.7, last three rows). On the contrary: a farmer intends to use more operational and tactical measures if he wants to intensify.

To explore this notion further, the intensifying farms were split into those that planned to dispose of manure or pay a levy, and those that did not (Table 7.7, I+MD/L and I-MD/L). The first group produces more milk per ha and shows slightly more unfavourable operational

Table 7.6 Management characteristics, farming intensity, MINAS performance, and planned management measures for farms that plan to reduce farming intensity (Proposition 4).

	Farm number						**Mean**	**Mean rest of**
	4.1	4.2	4.3	4.4	4.5	4.6	**4.1-4.6**	**sample**
Operational management[a] (MJ NEL per ha)								
Situation 1999[a]	-16580	10409	-105	7112	12564	16128		
Changes 1997-1999[a]	-12037	6184	-10380	-10362	8711	-2112		
Farming intensity (kg FPCM[b] per ha)								
Situation 1999	29906	17008	15272	14188	14009	11911		
Planned situation in ISM[c]	15812	14121	13210	12804	10702	10431		
MINAS performance[d] (kg N per ha)								
Situation 1999[c]	-2	94	102	67	197	185		
Planned situation in ISM[c]	-46	0	43	-9	-23	6		
Manure disposal (kg N per ha)								
Situation 1999	210	0	6	0	0	0		
Planned situation in ISM[c]	0	0	0	0	0	0		
No. and type of measures selected in ISM[c]								
Operational measures	1	1	1	1	2	1	1.17	1.29
Tactical measures	3	5	3	3	4	3	3.50	2.95
Kg FPCM per cow	1	0	0	0	0	1	0.33	0.62

[a] See Table 7.2.
[b] See Table 7.2.
[c] ISM = (in the) Interactive Simulation Model.
[d] See Table 7.5.

management, leading to significantly larger deviations from the final surplus standard ($P<0.001$). Those more intensive farming systems opt for manure disposal or paying a levy rather than changing their strategic plans. At the same time, they plan to improve operational management significantly more, implement more tactical measures (although not significantly) and increase the genetic production capacity of the herd significantly more ($P<0.05$). Concluding, it can be said that these observations support proposition 5. All farmers, especially those that want to increase the intensity of their farm, will improve operational and tactical management and will only resort to manure disposal and paying levies if really necessary.

7.5 Discussion and outlook

A drastic modification in the external environment of farms, as for Dutch farmers when MINAS was introduced, did affect management at operational, tactical as well as strategic level. In general, implementation of nutrient management measures proved to be first, operational optimisation of the production process, second a reduction in inputs and third a re-evaluation of the intensity of the farm, the most environmentally and cost effective order. This order of decisions strongly depends on farmers' goals and the (perception of) strengths and weaknesses of his management and his farm organisation. Operational management may be a weakness so that the only way to avoid paying levies is to implement more tactical changes or change strategic management and reduce intensity.

Operational management should be improved under any circumstances if one wants to avoid unnecessary costs related to inadequate skills. Not selecting improvement of operational performance is related to the lack of importance the farmer attributes to operational management or to the farmer's perception of his competence in operational management, which may not always be justified by his performance. Farmers showing poor operational performance and are far removed from the final surplus standards will have to increase their efforts and take more risk if they want to avoid heavy taxation. This study illustrates that farmers facing high levies do take more tactical measures. At the same time, some are still relying on their ability to reduce nutrient surpluses trough improved operational management. This may prove to be very risky and not well thought-out. Selecting a plan that heavily relies on one of the weaknesses of farm management has a high probability of failure. The sequence of implementing tactical measures depends both on the environmental and cost effectiveness of the tactical measure. Environmental effectiveness in this situation is determined, however, by the efficacy of a measure to bring a farm closer to the legal surplus standards, rather than by the reduction in surpluses per se. This is due to the nature of MINAS that punishes farmers

Table 7.7 Management characteristics and ISM results for farms that do not intend to increase farming intensity (NI), and farms that do (I), with or without changes in manure disposal or paying a levy (MD/L). Results presented as averages per farm category (Proposition 5).

	NI (n=21)	**I (n=45)**	**t-value**	**I+MD/L (n=20)**	**I-MD/L (n=25)**	**t-value**
Operational management[a]						
Situation 1999	9501	6353	1.11	7659	5307	0.73
Changes 1997-1999	2435	-1012	1.60	568	-2276	1.14
Farming intensity (kg FPCM[b] per ha)						
Situation 1999	13482	13626	-0.17	14575	12866	1.77
Planned situation in ISM[c]	13754	15687	-2.23^{*}	17035	14609	-2.42^{*}
Kg FPCM[b] per cow 1999[c]	8305	8376	-0.39	8498	8278	1.05
Manure disposal ISM[c] (kg N per ha)	1	11	-2.12^{*}	25	0	2.61^{*}
MINAS performance[d] (kg N per ha)						
Situation 1999	14	-15	0.11	105	44	3.71^{***}
Planned situation in ISM[c]	-3	-5	0.16	15	-20	4.64^{***}
No. and type of measures selected in ISM[c]						
Operational measures	1.19	1.33	-0.80	1.55	1.16	2.11^{*}
Tactical measures	2.81	3.02	-0.51	3.20	2.88	0.88
Kg FPCM[c] per cow	0.62	0.62	-0.02	0.80	0.48	2.33^{*}

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$

[a] See Table 7.2.

[b] See Table 7.2.

[c] ISM = (in the) Interactive Simulation Model

[d] See Table 7.5.

who do not meet the standards, but does not reward farmers who perform better than the standards. Decisions at strategic level are not taken to avoid operational or tactical measures. Strategic decisions are largely motivated by the farmer's mission for his farm: most farmers intend to grow in size and in intensity (kg milk per ha) to be able to survive in the current harsh environment in which Dutch agriculture operates.

Because farmers focus on the most environmentally and cost-effective way to meet the environmental standards set by the government, policy-makers intending to introduce a system based on (prohibitive) levies, should set environmental standards that ensure a safe environment, as a levies-based system does not provide any incentive to perform better than the standards. Producing below the standards will reduce a farm's competitive advantage, if this brings about extra costs (in terms of both money and effort). This makes producing below regulatory standards not a likely choice for a farmer. The study has shown that farmers decide 'rationally' on the nutrient management measures to implement, in such a way that he can keep pursuing the original strategy of the farm. Hence, extension and consulting services should reorganise their advice into coaching the entire farm. This will very likely be more effective than itemised advice, since farmers decide with their farm mission in mind. Farmers who appear not to select rationally lack insight in their strengths and weaknesses, or incorrectly perceive the importance of certain measures. Here too, extension and consulting can provide insight resulting in more effective change.

Extrapolating the above conclusions to the entire dairy farming population is difficult. Due to selection bias, the results here are representative for those farmers having great concern for their position with respect to societal objectives. The development paths of other farms could be, but not necessarily, different. Furthermore, the nutrient management plans were developed using a regression-based model. This means that average input-output relations have been estimated, based on a sample of specialised dairy farms. This implies that implementing the selected plan does not guarantee realisation of the planned nutrient surplus, due to differences in capabilities among farmers and among farm circumstances.

Regardless of these methodological issues, three major conclusions can be drawn. Firstly, there is a hierarchy in management measures taken. Farmers select to act in order of operational, tactical, and strategic adaptation, trying to solve nutrient management problems through operations and tactics so they can continue pursuing their strategy. Secondly, there is a large variation in the way farmers select to deal with nutrient management problems on their farm. Each farmer selects his own strategy, and success is dependent on the match between strategy and competencies of the farmer. Thirdly, it is an illusion to assume that nutrient management problems on a farm can be solved by one or a few measures. For most farms, meeting the environmentally safe surplus standards, and thus avoiding levies, requires an entirely different nutrient management approach, which affects all aspects of the farm.

Appendix 7.1 Measures and effects of management options in the Interactive Simulation Model (ISM)

Excluded are the options that were not selected by any farmer in the sample. These were irrigation (tactical), employing a milking robot, switching to organic farming, and discarding pig- and/or poultry farming (strategic).

Measures and effects of management options in the Interactive Simulation Model (ISM)

Nutrient management measure	N surplus per ha	P_2O_5 surplus per ha	Total gross margin
Operational management			
Improve feeding- and grassland management	-	-	+
Improve N utilisation of organic manure	-	-	+
Tactical management			
Reduce number of young stock	-	-	+
Change grazing system to less intensive grazing	-	-	+
Reduce protein level in concentrates	-	0	+
Reduce P level in concentrates	0	-	+
Reduce N fertilisation from inorganic fertiliser	-	0	+/-
Reduce P-fertilisation from inorganic fertiliser	0	-	+/-
Decrease grass to maize ratio	-	-	-
Decrease amount of concentrates per cow	-	-	-
Strategic management			
Decrease farm intensity	-	-	-
Increase milk production through breeding	-	-	+

VIII General Discussion

8.1 Introduction

The overall objective of this study was to gain insight into the way specialised dairy farmers cope with the Mineral Accounting System (MINAS), which was introduced in 1998. This research objective was approached using a general management framework, consisting of both technical and managerial issues and applying this to panel data of 114 specialised dairy farms, participating in the project ‘Farm Data in Practice’(the FDP-project). This last chapter is dedicated to the elaboration of different emerging issues in nutrient management on Dutch dairy farms. First, the pros and cons of using data collected through this nation-wide, politically sensitive project and the methods used will be discussed (§8.2). Paragraph 8.3 addresses two issues in a future outlook. First, the importance of dissemination of knowledge and information gathered through projects like FDP, and second, the developments in water protection policies and its relation to groundwater pollution are discussed. Finally, the main conclusions of this thesis are given (§8.4).

8.2 Research issues and implications for results

8.2.1 Data issues

The research in this thesis was based on data collected by the FDP-project. Results of experiments like ‘De Marke’ (Aarts, 2000) and model-based research like that of Berentsen (1999) and Van de Ven (1996) are conditional on the set-up and the assumption made. On commercial farms, a lot of variations in farm management and farm results are observed. Commercial farms are not run like experimental farms, and do not always follow the assumptions made in normative models. The FDP-project offered the unique opportunity to gain insight into real-life nutrient management practices on commercial farms. More importantly, farmers were encouraged through coaching activities of regional co-ordinators to find a fit between the internal and external characteristics of the farm, while pursuing their own farm goals. This appeal to entrepreneurship led to a wide range of solutions to the nutrient management problem. Technical, environmental and financial data, collected over a three-year period were available. Furthermore, survey data were collected on management and environmental uncertainty issues. The commitment of the FDP-participants was high so that for both surveys high response rates were recorded. Using these data, the variation in management and performance and the importance of management quality and the effect of preferences, motivations and goals of the farmer on decision-making was studied. The set up and organisation of the project caused some complications for this thesis, however, which are discussed below.

Representativeness of participating farms: Self-selection due to the voluntary enrolment caused the FDP-specialised dairy farmers to be significantly younger than the average dairy farmer by about 8 years, and having significantly more intensive dairy farming systems. No significant differences in nutrient surpluses existed, but the FDP-dairy farmers had a significantly higher gross margin/100 kg FPCM (Hiemstra, 2001). The comparison is based on data of the FADN database, the best available in The Netherlands. Especially the fact that the participating farmers are almost a decade younger than average, makes the results of this study less representative for Dutch specialised dairy farming. Age is strongly related to the stage in the family farm lifecycle. Younger farmers are generally in the entry, or the growth and consolidation stage. This means that the sample in this study is skewed to the left with a smaller than representative part of farmers in the exit stage of the family farm lifecycle. The results could be a reflection of the farmers who intend to build a future for themselves in farming. Younger farmers are generally higher educated (better educational opportunities), and they may be better motivated to learn and improve their environmental performance in order to maintain the continuity of their farm. Being significantly more intensive and not having higher nutrient surpluses per ha shows that these farms are better nutrient managers than the average specialised dairy farmer in The Netherlands.

Data collection problems: This PhD-study was not initiated until the project was pushing towards the last year of its three-year existence, leaving no opportunity to exert any influence on formulation of research questions or on data collection within the FDP-project. Uniformity of bookkeeping-rules was a problem, even though a project specific accounting system was set up. Initial unfamiliarity with the MINAS bookkeeping was a second problem and especially the estimation of roughage and manure in stock caused problems in the first year. Several data checks were therefore needed and a thorough screening of the final data for this study caused many farms to be dropped from the sample. This left 114 specialised dairy farmers of the original 134 for analysis, which sometimes caused problems for the choice of an appropriate analytical method (§8.2.2).

Interactive Simulation Modelling (ISM): Chapter 7 is based on data collected by means of an interactive computer program. It is a regression-based system, rather than simulating effects of management changes the farmer virtually implements. The ISM comes with several problems. First of all, farmers who are not used to operating computers had more difficulty fulfilling the task of making a nutrient management plan to their satisfaction. This gave farmers with more experience in computer use more time to try out the effects of different measures than others. Second, the fact that regression models are used to determine the effects of a particular measure, makes the results for farms, of which the characteristics lie in the tail of the distribution, questionable. Nevertheless, farmers indicated that the ISM was very helpful in giving insight into the effects of nutrient management changes on their farm.

Whether or not the actual nutrient management plans resulting from the ISM will be followed remains to be seen in the sequel of the FPD-project: FDP-II, which was started in 2000 for another three years.

The time-period 1997-1999: Many farmers in the project (63%) were not subject to MINAS in 1998 because the cattle intensity on their farm did not exceed the threshold of 2.5 LU/ha or the limitations on phosphate supply in manure. Even for the farms, which were subject, the surplus standards were in many cases not restrictive yet. These factors influence the need for changes on farms. Another issue is that three years is a short time period to monitor change. Especially management changes on farms take time before the true impact can be assessed. Fortunately, the project has been expanded with another three years (2000-2003), so that a better insight can be gained into the long-term effects of nutrient management changes on (financial results of) commercial farms.

8.2.2 Methodological issues

Nutrient efficiency and nutrient productivity: Nutrient efficiency was determined as an output/input ratio in chapter 2, and even though this measure gave good insight into the absolute levels of the efficiency of nutrient use, comparison between farms was not possible, because farm characteristics were not taken into account. Chapter 3 solved this problem by calculating relative efficiency measures. For this study Data Envelopment Analysis (DEA) was chosen over Stochastic Frontier Analysis (SFA). Even though DEA includes noise into the measure of efficiency, the quality of our data was such that DEA was chosen because of the flexibility in production technology and inclusion of environmental detrimental inputs (Reinhard *et al.*, 2000). Regardless of the method chosen, one should always consider that the estimated efficiencies are relative measures of performance. Inclusion of farms, which perform more efficiently, will automatically result in a shift of the production frontier, and thus alter efficiency estimates. Comparison with other groups of farmers, based on different data should therefore always be treated with caution.

The development of a measure of Nutrient Productivity Growth led to the determination of change in nutrient efficiency and technology over a three year time period. DEA proved to be flexible in designing this measure. A problem, which could occur, is that for the mixed period-models no feasible solutions can be found because a non-radial measure of mixed-period subvector models has no intersection with the production frontier from the other time-period. Fortunately this was not the case in our study and all solutions were found feasible (if this occurs, one could use Russell measures of efficiency (Oude Lansink and Ondersteijn, 2002)).

Structural Equation Models: Chapter 5 uses Structural Equation Modelling (SEM) to estimate the relationships between latent variables. The SEM method is well suited for the type of problem presented there, but requires large sample sizes (Boomsma, 2000). SEM was initially developed to analyze the structure of covariance matrices, but the analysis of correlation matrices (as was done in this case) has gained widespread use (e.g. Vickery *et al.*, 1999). According to Hair (1998), the use of correlations is appropriate when the objective of the research is only to understand the pattern of relationships between constructs, but not to explain the total variance of a construct. Furthermore, according to Dillon (1987) a correlation matrix provides more conservative estimates and is not upwardly biased. Correlation matrices are generally estimated using Weighted Least Squares (WLS), which makes use of an estimated asymptotic covariance matrix to generate the weights. Due to the relative small sample size in this study however, the estimated asymptotic covariance matrix could be unreliable, and therefore Maximum Likelihood (ML) estimation, which is robust for small sample sizes is preferred (Boomsma, 2000.). The small sample size still didn't allow for an estimation of the model in its entirety. A step-wise approach was therefore used in which different parts of the model were evaluated one by one. A larger sample size would be beneficial to this type of study, especially since the data are based on a survey, and are often non-parametric.

Perceived Environmental Uncertainty (PEU): When trying to identify the impact of the environment on farmer decisions and farm results, one could choose to either measure the impact of the objective environment in terms of market characteristics, policy measures et cetera, or opt for measurement of the perception of this environment. This study used the latter approach because personal perceptions are closer to decisions than objective measures. Furthermore, the fairly complete market structure and strict policy measures do not explain much variation in decision-making because they are similar for most, if not all, Dutch farmers. Choosing PEU over objective measures caused the problem of how to measure it. Many authors have suggested different approaches, but a complicating factor in the measurement of PEU in Dutch dairy farming is that farmers are not used to these type of questions and in many instances have not given it much thought. A basic approach was therefore used, in which farmers were asked to rank the extent of the uncertainty they perceived form a specific environmental item. Still, the relatively low response rate of the FDP-farmers (67%, compared to 95% for the SEM study) and the quality of some of the mailed-in surveys indicated that the farmers considered the raised issue difficult. The relatively small sample size prevented a more in-depth statistical analysis of PEU and its relationship with decision-making. Nevertheless, the environment is becoming increasingly important for farmers, whether they realise it or not, and further research could therefore help to better understand the causes of uncertainty and the ways this influences decision-making.

Case study analysis: A research strategy in social sciences is based on three conditions: (1) the type of research question, (2) the control over actual behavioural events, and (3) research on contemporary or historical issues (Yin, 1994). The research question in Chapter 7 was ‘How do specialised dairy farmers plan nutrient management to meet MINAS surplus standards, and why do they choose this particular plan’. No control could be exerted on the research subjects in terms of design of the plan, other than that they all use the ISM, and the focus was on a contemporary, even future-oriented event. These characteristics make case-study analysis the most appropriate method of research. Even though several statistical techniques were tried on the responses of the 72 specialised dairy farmers, they did not yield any clear relationships and if they did, they were difficult to explain. Case study research proved to be very insightful, however, since it enables the researches to take a closer look at motivations behind decision-making. Even though case-study research is often thought of as a second-best option, or a ‘weak sibling among social science methods’ (Yin, 1994), it has proven to be very valuable in our research. It is therefore recommended to consider this type of method more often especially in cases, which address a complex new area of study.

8.2.3 Implications for results

In this study an explorative approach was chosen in which the relationships between many crucial elements of the farm for nutrient management were studied. The time period was relatively short for drawing definite conclusions on trends in the development of nutrient management on specialised dairy farms. Nevertheless, backgrounds of the direction of change could be detected, as well as enormous improvements in nutrient efficiency and technology. These improvements were achieved within a project set-up, which was geared towards this goal, backed up by advice and support. The conclusion that these gains will be possible on any commercial dairy farm is therefore questionable. Not all farmers have costly support at their disposition or are willing to operate in study-groups where this knowledge can be transferred.

Problems in data collection caused many farms to be dropped from the final sample, leaving a rather small sample to perform sophisticated statistical analysis and detect statistically significant relationships. The most troublesome factor in the interpretation and inference of the results is the representativeness of the sample of specialised dairy farmers for Dutch dairy farming. The relative young age of the farmer indicates that these are future oriented farmers, for whom it is essential to learn and adapt in order to ensure viability and continuation of their farm. They grew up in a society in which the number of farmers was declining and their social relationships extend beyond the farming community, which makes them more open to new ideas and considerations other than maintaining farming autonomy. The high gross margin per unit of milk production compared with other farmers further points towards a selection of good financial managers, especially since the higher intensity generally negatively affects gross margin per kg of milk, because of relatively high feed costs. Based on these considerations, the question of whether or not the achievements of the specialised dairy farmers in the FDP-project are feasible for other Dutch dairy farmers could therefore be more a question of willingness to change instead of ability to change.

8.3 Outlook

8.3.1 Dissemination of information

The spread of knowledge and information was not a topic in this thesis, but did constitute a major part of the FDP-project. It therefore deserves some attention here. Both policy-makers and LTO were aware of the need of information about MINAS among farmers and the findings of the FDP-project could help other farmers to implement nutrient management changes (Anonymous, 1996). The FDP-project was to fulfil a role at the lower part of the nutrient management ‘information dissemination’ pyramid (e.g. Oenema *et al.*, 2001) to make the link between research and practice. This pyramid is made up of experimental dairy farm De Marke, the project Cows and Opportunities (17 dairy farms), then the FDP-project (240 farms), and finally all other dairy farmers at the base of the pyramid. Of the FDP-farmers themselves, the main part (83%) indicated in a monitoring survey that they had learned a lot from participation. More planning and more accurate management were mentioned most often as things they had learned (Ondersteijn, 2001). This thesis showed that these are important factors in reducing nutrient surpluses. The way of learning may cause problems in knowledge transfer, however. In a study done by Proost (2001) learning from experience appeared the most important factor in understanding the possibilities of nutrient management. The understanding that certain activities were not obvious but could also be handled in a different way led to a more daring attitude towards experimenting with nutrients on the farm (Proost, 2001). As such, the FDP-project worked as a catalyst for change. These ‘moments of discovery’ are not easy to communicate, however, since it is very experiential in nature. Furthermore, acceptance of the findings of FDP by other farmers, may be hampered by the perception of (the goal of) the project among other farmers. FDP-farmers were often met with suspicion and negative attitudes from other farmers when trying to explain their experiences. The high political loading of the project was debit to this phenomenon.

Communicating clear goals and reducing political sensitivity are therefore first requirements for good knowledge transfer. This thesis shows that farmers need to find a fit between internal and external farm factors in order to improve nutrient management on their farm. This is an individual matter, in which the process of learning and experiencing needs to be facilitated to guarantee successful implementation of new policy measures. This can be done by advisors who become coaches rather than extension agents, research (both normative and empirical) providing knowledge from which farmers can ‘shop’ for the right information for their farm, and by policy-makers who need to create an environment in which searching for farm-specific solutions is encouraged. This will lead to active and innovative rather than passive (nutrient management) behaviour.

8.3.2 Agri-environmental policy-making in Europe and The Netherlands; consequences for (ground)water pollution

The ultimate goal of improving nutrient management and reducing nutrient surpluses is the reduction of discharges in the environment, especially (ground)water. While both the EU Nitrate Directive and MINAS are installed to meet these goals, their approach is quite different. The Nitrate Directive focuses indirectly on farm structure, through the manure application standard of 170 kg N/ha, whereas MINAS focuses directly on all the components of management of both N and P_2O_5. Chapters 2, 3, and 4 of this thesis showed that a limit on intensity is rather pointless because the variation in nutrient surpluses is more dependent on management characteristics than on farm structure.

The effect of a reduction in nutrient surpluses on the N content in groundwater is extensively monitored in The Netherlands. N-leaching to deeper groundwater (15-30 m.) can take years, and therefore the environmental effects of policy measures are not readily visible. The expectations are that an increase in nitrate concentrates in deep groundwater will occur as a lagged result of the peak N-load during the period 1980-1990, before a decrease will become visible (RIVM, 2002). Nitrogen surpluses have halved in 1999/2000 compared to 1986/1987 (De Hoop, 2002) and MINAS will further reduce the nutrient surpluses on all farm types in The Netherlands. This will ensure a steady decline in nitrate concentrations in the top layers of ground water, and consequently in groundwater (RIVM, 2002).

Even though the relationship between nutrient surpluses and N-concentrations in groundwater exists, the rigor with which the EU enforces a Directive stemming from 1991 with a strict 170 kg N from manure/ha, forced the Dutch government to introduce the Manure Transfer Agreement System (MTAS) in 2002. MTAS forces farmers to ensure that an acceptable application of manure can be guaranteed by closing costly contracts with less intensive farms. MTAS is considered a back-up for MINAS, however, and can be financially harmful especially in dairy farming, where most manure can be applied safely within MINAS (Bruins, 2002).

The future of agricultural-environmental policy making regarding water will for a large part be determined by the Water Framework Directive (2000/60/EC). The Water Framework Directive (WFD) is a general approach to protection of all waters, instead of only groundwater, and considers all pollutants instead of only nutrients. The WFD will therefore have an even larger impact on agriculture than the Nitrate Directive alone. This thesis provides (EU) policy-makers and farmers with empirical insight in nutrient management on specialised dairy farms. Giving room to advancing scientific knowledge and other approaches than specific quantitative measures will help to solve country-specific water safety issues.

8.4 Main conclusions

The following conclusions can be drawn from the *results* of this thesis:

- If specialised dairy farmers in the FDP-project do not alter their nutrient management they will face large fines in 2003, when the final surplus standards are introduced. This will reduce gross margin by 8% on average, threatening the continuity of a number of farms;
- FDP-specialised dairy farmers have an average nutrient efficiency of 80%, which means that they could in principle achieve the same output, with 20% less nutrient surpluses (note that these efficiencies are relative to the best farms in the FDP-sample). They have managed to improve nutrient management considerably over the period 1997-1999, by increasing nutrient productivity by 60% per year on average. Half of this is due to efficiency improvements and the other half to nutrient-technological changes. These improvements were positively related to improvements of technical and financial results in the period under study;
- In the period 1997-1999 management characteristics were 3-4 times as important as farm structure in explaining the variation in nutrient surpluses. A focus of policy measures on farm structure (intensity) does therefore not guarantee safe nutrient discharges in the environment. Policy with a result-oriented focus like MINAS, will be more effective in meeting the surplus standards by making 'the polluter pay';
- Education and farm strategy affect the direction of change in nutrient management. Better educated FDP dairy farmers and FDP-dairy farmers with a growth strategy strive for a larger, more intensive farming system with good quality operational management. Diversification leads towards extensification but also to worsened operational management in the FDP-population. A strategy of process-control focuses on optimisation of nutrient management, within the current farm structure;
- The perception of uncertainty from the environment affects the choice for a strategy. Especially uncertainty arising from the political environment was perceived high. FDP-dairy farmers with high environmental uncertainty are more likely to choose a diversification strategy, whereas low uncertainty increases the likelihood that an FDP-dairy farmer chooses process-control. A growth strategy is not related to uncertainty;
- Nutrient management planning differs considerably among specialised dairy farmers in the FDP-project. A case study analysis showed that preferences and strengths and weaknesses of the farmer were more explanatory for the chosen nutrient management plan

than farm characteristics. These results emphasise the importance of the opportunity for farmers to find an individual solution for the nutrient management problem on their farm;

- Result-oriented policies like MINAS are more effective than the more commonly used measure-oriented approach. Measure-oriented policies like the Nitrate Directive and MTAS focus on specific measures, and do not allow farmers to find a fit between internal and external farm characteristics. Result-oriented policy gives farmers the opportunity and responsibility to find a solution to the environmental problem, which fits their farm and themselves.

The following conclusions can be drawn from the *methodologies used* in this thesis:

- De FDP-sample is not entirely representative in terms of farm and farmer characteristics for the Dutch population of specialised dairy farms. The consequence is that the results of this thesis are valid for the relatively young farmers, with relatively intensive dairy farming systems;
- Combining technical, financial and nutrient accounting data, with data collected through surveys and games provides a solid basis for analysing the driving forces underlying nutrient management;
- The Interactive Simulation Model (ISM) helped specialised dairy farmers in FDP-II to develop a nutrient management plan. This method of elicitation of information is very useful, not only for the development of plans, but also for understanding the consequences of different nutrient management measures. Nevertheless, whether or not the financial and environmental results found in the nutrient management plan are feasible for an individual farmer is entirely dependent on his management capacities;
- Data quality was such that a thorough screening was needed. As a result, 20 specialised dairy farms were dropped from the FDP-sample, leaving 114 farms for analysis. The consequences for sophisticated statistical analysis like LISREL is that complex theoretical models cannot be estimated in its entirety, but have to be cut up to facilitate a stage-wise approach. Furthermore, estimated coefficients and statistical significance may not be completely reliable;
- The flexibility of DEA allowed the development of a subvector efficiency and productivity index. This index showed the improvements made in the area of nutrient efficiency and nutrient technology over time and is very useful for tracking environmental improvements;
- Both statistical and case study analyses are vital in gaining insight in the background and facts of nutrient management. While statistical analysis provides the researcher with general relationships, a case study approach will lead to a better insight into backgrounds and farmer specific decision-making.

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Summary

Problem definition

Surface and groundwater across Europe, which is partly meant for human consumption, is being polluted by nutrient run-off and leaching from agricultural sources. To prevent and control this pollution, the European Union issued the Nitrate Directive (91/676/EEC) to establish a safety standard of 50 mg of nitrate per litre of groundwater (set by the World Health Organisation (WHO)). The main emphasis in the Nitrate Directive is on nitrogen (N). In the Netherlands, however, both nitrogen (N) and phosphorus (P) levels are creating environmental pressures. The Netherlands therefore implemented the Mineral Accounting System (MINAS) in 1998, which focuses on nutrient flows (nitrogen and phosphate) on individual farms, and taxes farms whose nutrient surpluses exceed an environmentally safe threshold, known as the Levy Free Surplus (LFS). The levy for each kg of N exceeding the surplus is €2.30, and €9.00 for each kg of P_2O_5. LFS will gradually be reduced until 2003 in order to achieve nutrient surpluses, which can meet the WHO safety standard.

Because of the introduction of MINAS, many farms, especially those with animal production, will face increasing financial pressure. It is therefore essential to reduce nutrient surpluses to avoid high levies and maintain the financial viability of the farm. Discussion between policy-makers and farm organisations about the feasibility of the final surplus standards led in 1997 to the start of the project ‘Farm Data in Practice’, or the FDP-project. The goal of the three-year, nation-wide FDP-project was to gain insight into (backgrounds of) nutrient management on commercial farms.

The goal of this thesis is to gain insight into the background of and changes in nutrient management on specialised dairy farms, and the effect on financial results. For this purpose the data of the specialised dairy farms in the FDP-project are used. More specifically, the following research questions were addressed:

1) What are the possible implications of MINAS for different land-based farm-types;
2) What is the efficiency of nutrient use and nutrient productivity of specialised dairy farms and how has this changed in a three-year time span;
3) What is the importance of farm structure and farm management on nutrient surpluses and what are the implications for financial performance on specialised dairy farms;
4) What are the relevant farmer characteristics and farm strategies which direct change in nutrient management and performance of specialised dairy farmers;
5) How do specialised dairy farmers perceive the environment of their business and how does this relate to the choice for a farm strategy;
6) How do specialised dairy farmers plan nutrient management on their farms, to meet the final MINAS-standards.

Method and results

The framework on which this research is based in shown in Figure 1. The words in capitals represent the main elements in the decision-making cycle of planning, implementation and evaluation on the farm. The farmer is central in the model. His personal characteristics and the way he perceives his environment determine the strategy he chooses for his farm (planning). The implementation of this strategy results in a farm with specific structural and managerial characteristics. This structure and management will result in a certain level of farm performance, depending on the managerial qualities of the farmer. This performance will subsequently be used for evaluation and new planning purposes. To answer the research questions posed in the previous section, chapter 2 through 7 use the FDP-data. Every element of Figure 1 was analysed and quantified in a separate chapter. Out of each analysis, variables appeared which had a significant relationship with the nutrient surpluses and the reduction thereof. These variables are represented in Figure 1 using lower-case letters. The results and methodologies used to determine them, are discussed below Figure 1.

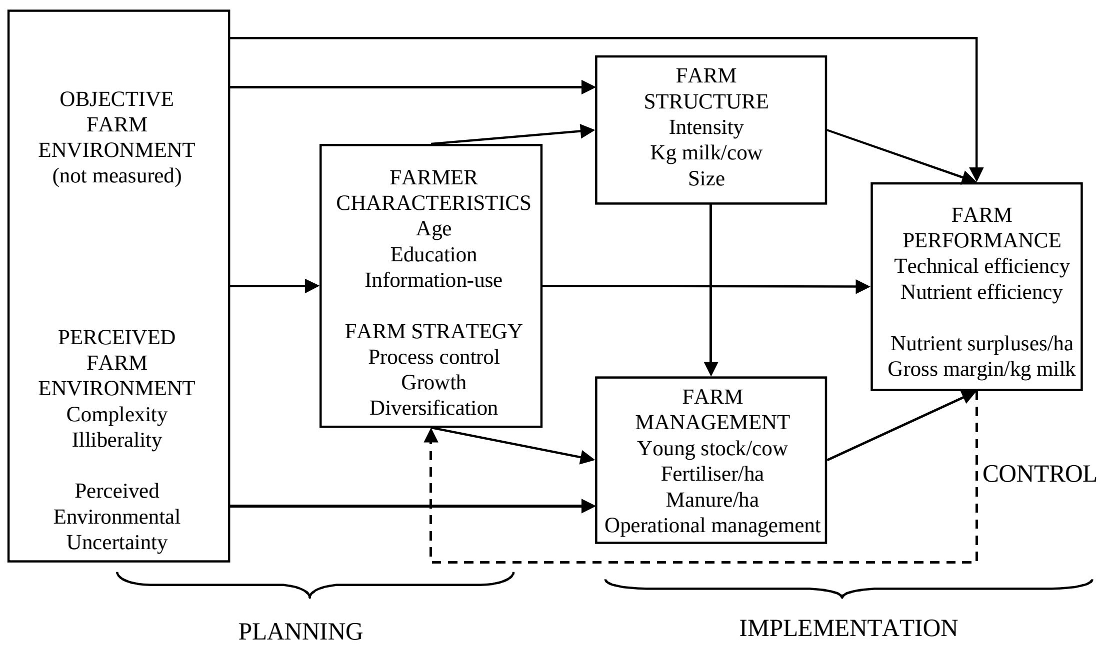


Figure 1.Research framework, including main research results

Farm performance

Chapter 2 shows that large variation in nitrogen and phosphate surpluses exists within as well as between land-based farm types in the Netherlands. If farmers would not change their management, levies were estimated to run into thousands of €s for individual farms, reducing gross margin by 8% on average. These increased costs due to MINAS-fines could (partly) be avoided through an improvement of Nutrient Use Efficiency (NUE) (the ratio between nutrient output and input). Changing management of (especially) fertilisation and feeding will reduce the nutrient surpluses because less input will be needed, which increases NUE. The possibilities for reducing nutrient surpluses by means of an improvement of NUE depend on farm characteristics. NUE is an absolute measure of efficiency, and as such it gives a good interpretation of the nutrients left at the farm. It does not, however, take into account differences in farm characteristics like cattle intensity, which are strongly related to input on a farm, especially of feed. This makes a comparison of nutrient efficiency between farms difficult.

A relative measure of nutrient efficiency, using Data Envelopment Analysis (DEA), is therefore determined in Chapter 3. This measure compares nutrient surpluses per unit of production (milk and meat) among farms, providing an indication of the quality of nutrient management. It is a relative measure because farms are compared amongst each other on the nutrient surpluses per unit of production (milk and meat). There appears to be a large variation in nutrient efficiencies with more intensive farming systems being more efficient. This is partly due to the transfer of nutrient-inefficient roughage production to more extensive farming systems. Farm intensity and nutrient efficiency may be positively correlated but they exert opposite influences on the nutrient surpluses/ha. The opportunities for reducing nutrient surpluses through an improvement of relative efficiency are therefore limited by farm intensity. At a certain intensity level, even nutrient efficiency of 100% may not be sufficient to avoid a surplus. The alternative is manure disposal or reducing intensity. Beside nutrient efficiency, a measure for nutrient productivity was developed. This measure represents the net change in production, caused by a change in nutrient technology and nutrient efficiency. The results show that the FDP-dairy farms increased nutrient productivity by on average 60% per year. Half of this was due to nutrient technology change, and the other half to nutrient efficiency change.

Farm structure and farm management

Besides improving the quality of nutrient management, dairy farmers have the opportunity to alter their farm structure and farm management in order to improve nutrient performance. Which way is most effective is shown in Chapter 4 using the Frisch-Waugh Theorem. In the period 1997-1999 management characteristics explain 3 times more of the nitrogen surplus and 4 times more of the phosphate surplus than structural characteristics. The most effective (and least costly) way to start reducing nutrient surpluses on individual dairy farms is therefore to focus on optimisation of nutrient management within the current farming system. If a farm still exceeds the (final) surplus standards, a milk-oriented breeding program could increase milk production per cow, and consequently reduce the required herd size. If that doesn’t result in a sufficient or timely reduction in nutrient surpluses, a reduction in farm intensity or disposal of manure are both reasonable options. A reduction in intensity will, however, reduce the returns to land, which is most scarce resource in The Netherlands. This will partly be compensated by a reduction in additional feed costs, but returns per ha will decrease as well. A comparison of the net effect on gross margin of a reduction in farm intensity with the cost of manure disposal should lead to an economically rational decision. Due to the introduction of the Manure Transfer Agreement System (MTAS), however, the costs of manure disposal have risen in the period 1997-2000. Nevertheless, the future price of manure disposal is uncertain, because the supply of manure is decreasing, which could have a cost-reducing effect.

Farmer characteristics and farm strategy

Farmer characteristics and farm strategies have an indirect as well as a direct effect on results of dairy farms. Chapter 5 uses LISREL analysis to study these relationships. The indirect effect appears to be most important and affects results via changes in farm management. In the period under study the most important farmer characteristic is education. A higher level of education is positively related to an increase in farm intensity and to an improvement of operational management. Beside farmer characteristics, three farm strategies are studied; growth, process-control and diversification. A growth strategy is, like educational level, accompanied by intensification and an improvement of operational management. Farmers who choose diversification reduce farm intensity but at the same time show worsening operational management performance. Farmers, who choose process-control, focused on improving management rather than structure, thus optimising within their current farming system. The direct relationship between farmer characteristics, farm strategies and farm results (corrected for the differences in nutrient management changes) showed that the higher the educational level of the farmer the more his environmental as well as technical and financial results have improved.

Perceived farm environment

Chapter 6 uses the concept of Perceived Environmental Uncertainty (PEU) to determine how much uncertainty the environment of the farm poses for the dairy farmer en the effect this has on the choice for a farm strategy. A survey was developed and held among the FDP-dairy farmers and analysed using regression analysis. The more complex (the more opportunities and threats) the environment is perceived, the lower the uncertainty farmers experience, while higher illiberality (ratio of threats and opportunities) increases PEU. Apparently, farmers who are more aware of their surroundings are less uncertain, while a relatively hostile environment leads to more uncertainty.

Three farm strategies were studied in relation to PEU. These were growth, process-control and diversification (analogue to Chapter 5). PEU is negatively related to a choice for process control and positively to diversification (spread of risk over several activities). A choice for growth is determined by other factors like farm size, farm intensity and instrumental motives of the farmer. Larger and more intensive farms tend to choose for even larger and more intensive dairy farming systems.

It is important for farmers to find a fit between the internal and external environment of their farm. Better awareness of (changes in) the external environment reduces environmental uncertainty while at the same time an appropriate strategy can be chosen to respond to these occurrences.

Nutrient management planning

Chapter 7 uses case-study analysis to show the contents and background of nutrient management plans of dairy farmers and whether or not they plan to meet the final MINAS standards or choose to pay a levy. The plans of the dairy farmers have been elicited using the Interactive Simulation Model, developed by the LEI-institute (The Hague). The theoretically most economically and technically efficient order for improvement is operational, tactical and strategic decisions. Nevertheless, large differences in choice and structure of plans could be found. These differences are mainly dependent on individual motivations and capabilities.

In relatively few cases, farmers were planning to reduce the intensity of their farming system. On the contrary, most of them planned to increase it. This leads to the conclusion that farmers seem to have a certain vision of the future size and intensity of their farm, and they work their way towards it, with MINAS being a limiting condition rather than an impediment.

Conclusions

The following conclusions can be drawn from the *results* of this thesis:

- ❖ If specialised dairy farmers in the FDP-project do not alter their nutrient management they will face large fines in 2003, when the final surplus standards are introduced. This will reduce gross margin by 8% on average, threatening the continuity of a number of farms;
- ❖ FDP-specialised dairy farmers have an average nutrient efficiency of 80%, which means that they could in principle achieve the same output, with 20% less nutrient surpluses (note that these efficiencies are relative to the best farms in the FDP-sample). They have managed to improve nutrient management considerably over the period 1997-1999, by increasing nutrient productivity by 60% per year on average. Half of this is due to nutrient efficiency improvements and the other half to nutrient-technological changes. These

improvements were positively related to improvements of technical and financial results in the period under study;

- In the period 1997-1999 management characteristics were 3-4 times as important as farm structure in explaining the variation in nutrient surpluses. A focus of policy measures on farm structure (intensity) does therefore not guarantee safe nutrient discharges in the environment. Policy with a result-oriented focus like MINAS, will be more effective in meeting the surplus standards by making ‘the polluter pay’;
- Education and farm strategy affect the direction of change in nutrient management. Better educated FDP-dairy farmers and FDP-dairy farmers with a growth strategy strive for a larger, more intensive farming system with good quality operational management. Diversification leads towards extensification but also to worsened operational management in the FDP-population. A strategy of process-control focuses on optimisation of nutrient management, within the current farm structure;
- The perception of uncertainty from the environment affects the choice for a strategy. Especially uncertainty arising from the political environment was perceived high. FDP-dairy farmers with high environmental uncertainty are more likely to choose a diversification strategy, whereas low uncertainty increases the likelihood that an FDP-dairy farmer chooses process-control. A growth strategy is not related to uncertainty;
- Nutrient management planning differs considerably among specialised dairy farmers in the FDP-project. A case study analysis showed that preferences and strengths and weaknesses of the farmer were more explanatory for the chosen nutrient management plan than farm characteristics. These results emphasise the importance of the opportunity for farmers to find an individual solution for the nutrient management problem on their farm;
- Result-oriented policies like MINAS are more effective than the more commonly used measure-oriented approach. Measure-oriented policies like the Nitrate Directive and MTAS focus on specific measures, and do not allow farmers to find a fit between internal and external farm characteristics. Result-oriented policy gives farmers the opportunity and responsibility to find a solution to the environmental problem, which fits their farm and themselves.

The following conclusions can be drawn from the *methodologies used* in this thesis:

- De FDP-sample is not entirely representative in terms of farm and farmer characteristics for the Dutch population of specialised dairy farms. The consequence is that the results of this thesis are valid for relatively young farmers, with relatively intensive dairy farming systems;

- Combining technical, financial and nutrient accounting data with data collected through surveys and games provides a solid basis for analysing the driving forces underlying nutrient management;
- The Interactive Simulation Model (ISM) helped specialised dairy farmers in FDP-II to develop a nutrient management plan. This method of elicitation of information is very useful, not only for the development of plans, but also for understanding the consequences of different nutrient management measures. Nevertheless, whether or not the environmental and financial results found in the nutrient management plan are feasible for an individual farmer is entirely dependent on his management capacities;
- Data quality was such that a thorough screening was needed. As a result, 20 specialised dairy farms were dropped from the FDP-sample, leaving 114 farms for analysis. The consequence for sophisticated statistical analysis like LISREL is that complex theoretical models cannot be estimated in its entirety, but have to be cut up to facilitate a stage-wise approach. Furthermore, estimated coefficients and statistical significance may not be completely reliable;
- The flexibility of DEA allowed the development of a subvector efficiency and productivity index. This index showed the improvements made in the area of nutrient efficiency and nutrient technology over time and is very useful for tracking environmental improvements;
- Both statistical and case study analyses are vital in gaining insight in the background and facts of nutrient management. While statistical analysis provides the researcher with general relationships, a case study approach will lead to a better insight into backgrounds and farmer-specific decision-making.

Samenvatting

Probleemstelling

Grond- en oppervlaktewater kan worden vervuild door mineralen afkomstig uit de landbouw. In Europa wordt grondwater aangetroffen, deels bedoeld voor humane consumptie, dat boven de WHO-limiet van 50 mg NO_3 per liter grondwater uitkomt. Om deze situatie te verbeteren en verdere vervuiling te voorkomen heeft de Europese Unie de zogenaamde Nitraatrichtlijn (91/676/EC) uitgevaardigd. De nadruk in de generieke Nitraatrichtlijn ligt enkel op stikstof (N). In Nederland vormt echter zowel stikstof als fosfaat een bedreiging voor de (grond)waterkwaliteit. De Nederlandse overheid introduceerde daarom in 1998 het Mineralen Aangifte Systeem (MINAS), dat zich richt op de aan- en afvoer van zowel stikstof als fosfaat op individuele agrarische bedrijven van alle bedrijfstypen. MINAS belast bedrijven met een heffing wanneer zij een groter mineralenoverschot (stikstof en/of fosfaatoverschot) hebben dan de heffingsvrije overschotnorm. Deze heffing bedraagt €2.30 voor iedere kg N en €9.00 per kg P_2O_5 die de eindnorm overschrijdt. Deze overschotnormen worden geleidelijk teruggebracht tot in het jaar 2003 de eindnorm is bereikt. Deze eindnorm moet er voor zorgen dat de genoemde WHO standaard van 50 mg NO_3 per liter kan worden bereikt.

Door de invoering van MINAS zouden vele bedrijven, en zeker die met een tak dierlijke productie, economisch verder onder druk kunnen komen staan. Voor deze bedrijven is het daarom noodzaak de mineralenoverschotten terug te brengen om hoge heffingen te voorkomen. Een discussie tussen overheid en bedrijfsleven over de haalbaarheid van de eindnormen leidde in 1997 tot de start van Project Praktijkcijfers. Project Praktijkcijfers was een driejarig, landelijk project met als doel inzicht te verschaffen in (achtergronden van) mineralenmanagement op bedrijven in de praktijk.

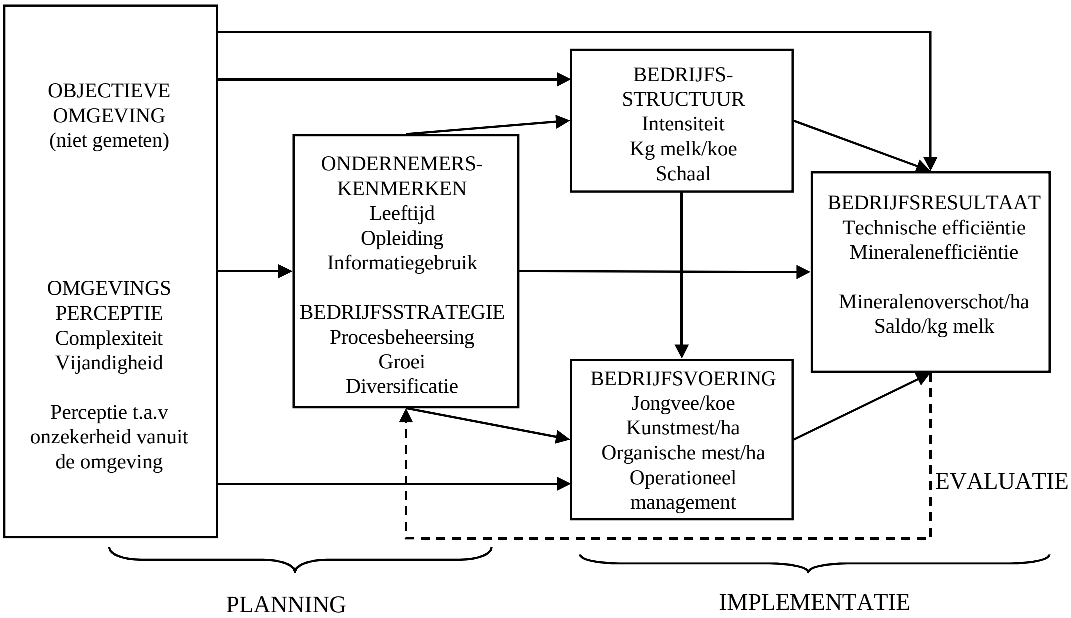
De doelstelling van dit onderzoek is het verkrijgen van inzicht in de veranderingen in mineralenmanagement op melkveebedrijven en het effect dat dit heeft op de financiële resultaten. Hiervoor is gebruik gemaakt van de data die zijn verzameld in het kader van het bovengenoemde Project Praktijkcijfers.

In het bijzonder gaat het om de volgende onderzoeksvragen:

1) Wat is de stand van zaken wat betreft mineralenoverschotten, en wat zijn de mogelijke financiële implicaties van MINAS op verschillende grondgebonden bedrijfstypen;
2) Wat is de efficiëntie van het gebruik van mineralen op gespecialiseerde melkveebedrijven en de hoe groot is de verandering van de mineralen-productiviteit over drie jaar;
3) Welke rol spelen bedrijfsstructuur en bedrijfsvoering van gespecialiseerde melkveebedrijven in de verklaring van de mineralenoverschotten en wat zijn de implicaties van veranderingen hierin voor de financiële resultaten;
4) Wat zijn de belangrijke ondernemerskenmerken en bedrijfsstrategieën die de richting van veranderingen in mineralenmanagement op gespecialiseerde melkveebedrijven bepalen;
5) Hoe zien melkveehouders hun omgeving en wat is de invloed hiervan op de strategiekeuze;
6) Hoe plannen gespecialiseerde melkveehouders mineralenmanagement binnen hun bedrijf met het oog op huidige en toekomstige MINAS regelgeving.

Methode en resultaten

De basis van het onderzoek is het onderzoeksmodel weergegeven in Figuur 1. De aanduidingen in hoofdletters geven de belangrijkste elementen weer in de cyclus planning, uitvoering en evaluatie op een agrarisch bedrijf. De ondernemer staat centraal. Zijn persoonlijke eigenschappen en de manier waarop hij naar zijn omgeving kijkt bepalen de strategie die hij uitzet voor zijn bedrijf (planning). Dit resulteert in een bepaalde bedrijfsstructuur en bedrijfsvoering die, tezamen met de management-kwaliteiten van de ondernemer resulteren in de bedrijfsresultaten(uitvoering). Deze worden vervolgens meegenomen in de volgende besluitvormingscyclus (evaluatie). Ter beantwoording van de bovengenoemde onderzoeksvragen wordt in hoofdstuk 2 tot en met 7 gebruik gemaakt van de data van Project Praktijkcijfers. Alle onderdelen van Figuur 1 worden daartoe geanalyseerd en gekwantificeerd. Uit elk van deze hoofdstukken komen variabelen naar voren die een belangrijke relatie hebben met de mineralenoverschotten en de reductie daarvan. Deze zijn in Figuur 1 weergegeven met kleine letters en worden hierna per onderdeel besproken.



Figuur 1. Onderzoeksmodel inclusief belangrijkste onderzoeksresultaten

Bedrijfsresultaat

Hoofdstuk 2 laat zien dat er een grote variatie bestaat in stikstof- en fosfaatoverschotten tussen en binnen grondgebonden bedrijfstypen in Nederland. Wanneer bedrijven hun bedrijfsvoering niet aanpassen, zal dit voor een groot deel van de bedrijven tot heffingen leiden, die in individuele gevallen tot duizenden Euro's per jaar op kunnen lopen. Het saldo gaat dan met gemiddeld 8% achteruit. Deze extra kosten in de vorm van MINAS-heffingen kunnen (deels) worden voorkomen door een verbetering van de verhouding tussen mineralenaanvoer en mineralenafvoer (verbetering van de mineralenbenutting). Het aanpassen van voornamelijk het bemestings- en voedingsregime kan de aanvoer van mineralen terugbrengen. De mogelijkheden hiertoe verschillen voor bedrijven met verschillende bedrijfsopzet. De mineralenbenutting is een absolute maat voor de efficiëntie waarmee mineralen gebruikt worden en geeft daarmee een goed beeld van de mineralen die achterblijven op het bedrijf. Het houdt echter geen rekening met een bedrijfskenmerk als intensiteit (in kg quotum/ha), wat sterk bepalend is voor de aanvoer van met name voer op een bedrijf. Hierdoor is het moeilijk de mineralenbenutting van bedrijven onderling te vergelijken.

Om aan dit bezwaar tegemoet te komen is in hoofdstuk 3 een maat voor mineralenefficiëntie ontwikkeld met behulp van Data Envelopment Analysis (DEA). Deze maat geeft een indicatie van de kwaliteit van mineralenmanagement op een bedrijf. Het is een relatieve maat omdat de bedrijven onderling worden vergeleken op de overschotten per eenheid productie (melk en vlees). Er blijkt een grote verscheidenheid aan mineralenefficiënties te bestaan, waarbij de intensievere bedrijven efficiënter zijn. Dit is deels te wijten aan de afwenteling van mineraleninefficiënte ruwvoerproductie op extensieve bedrijven. Intensiteit en mineralenefficiëntie zijn dan wel positief gecorreleerd, maar zij hebben een tegengestelde invloed op de mineralenoverschotten. De kansen om de mineralenoverschotten te verlagen door het verbeteren van de efficiëntie zijn dus afhankelijk van de intensiteit van het bedrijf. Op een bepaald punt kan de intensiteit zo hoog zijn dat zelfs bij een mineralenefficiëntie van 100% toch een overschot bestaat. Een alternatief is dan het afzetten van mest, of het terugbrengen van de intensiteit. Naast mineralenefficiëntie is een maat ontwikkeld voor de verandering van de mineralenproductiviteit. Deze maat geeft de netto verandering in productie weer, veroorzaakt door technologische - en efficiëntie verandering op mineralengebied. Het blijkt dat de bedrijven in Project Praktijkcijfers gemiddeld een stijging van mineralenproductiviteit van 60% per jaar hebben weten te bewerkstelligen. In het eerste jaar (1997-1998) is deze vooral te danken aan technologische verbeteringen, en in het tweede jaar (1998-1999) aan efficiëntie verbeteringen.

Bedrijfsstructuur en bedrijfsvoering

Naast het verbeteren van de mineralenefficiëntie hebben melkveebedrijven ook de mogelijkheid hun bedrijfsstructuur en bedrijfsvoering zodanig aan te passen dat hun overschotten dalen. Welke optie het meest effectief is, wordt onderzocht met behulp van het Frisch-Waugh theorema in hoofdstuk 4. Het blijkt dat in de periode 1997-1999 bedrijfsvoeringskenmerken 3 (voor stikstof) tot 4 (voor fosfaat) keer zo veel van de overschotten verklaarden dan structuurkenmerken. De meest effectieve (en goedkoopste) manier om te beginnen met het terugbrengen van de overschotten is daarom gericht op het optimaliseren van de bedrijfsvoering binnen de huidige bedrijfsstructuur. Wanneer een bedrijf na optimalisatie van de bedrijfsvoering nog steeds de (eind)normen overschrijdt kan een verhoging van de melkproductie per koe door een melkgericht fokbeleid de benodigde veestapel verkleinen. Als dit onvoldoende, of niet tijdig, resultaat oplevert kan worden gekozen voor het afvoeren van mest of het terugbrengen van de intensiteit. Een reductie in de intensiteit zal de opbrengsten per ha echter verlagen. Als dit niet opweegt tegen de verlaging van de kosten van voeraanvoer dan is dit geen economisch rationele optie, tenzij de afzetkosten van mest hoger zijn dan het netto saldoeffect (excl. mestafzetkosten) van een verlaging van de intensiteit. Door de introductie van het Systeem van Mestafzetcontracten zijn de kosten van mestafzet gestegen in de periode 1997-2002. De toekomstige prijs van mestafzet is echter onzeker omdat het aanbod van mest afneemt, wat een kostendrukkend effect kan hebben.

Ondernemerskenmerken en bedrijfsstrategie

Ondernemers- en bedrijfsstrategieën hebben een zowel indirect als een direct effect op de veranderingen in bedrijfsresultaten. In hoofdstuk 5 wordt dit met behulp van LISREL analyse onderzocht. Het indirecte effect blijkt het belangrijkst en loopt via veranderingen in de bedrijfsvoering. De belangrijkste ondernemersfactor is opleiding. Hoger opgeleide melkveehouders hebben in de periode 1997-1999 hun bedrijf meer geïntensiveerd dan minder hoog opgeleide ondernemers. Daarnaast hebben zij hun operationele management meer weten te verbeteren. Naast ondernemerskenmerken zijn de effecten van drie strategieën onderzocht, te weten procesbeheersing, groei en diversificatie. Een groeistrategie is, net als opleidingsniveau, positief gerelateerd aan intensivering en een verbetering van operationeel management. Melkveehouders die voor diversificatie kiezen hebben juist geëxtensiveerd en lieten tegelijkertijd een verslechtering van het operationele management zien. Procesbeheersers richtten zich op het verbeteren van de bedrijfsvoering binnen de bestaande bedrijfsstructuur. Kijkend naar de directe relatie tussen ondernemerskenmerken, strategie en resultaten (gecorrigeerd voor de eerder genoemde veranderingen), dan blijkt dat de melkveehouders met een hoger opleidingniveau de meeste verbetering in mineralenoverschotten hebben laten zien, die daarbovenop gepaard gingen met verbeteringen van de financiële resultaten.

Perceptie van de omgeving

Hoofdstuk 6 geeft weer in hoeverre de omgeving onzekerheid met zich mee brengt voor de melkveehouder en wat het effect hiervan is op de keuze voor een bedrijfsstrategie. Hiervoor is een enquête ontwikkeld, die met behulp van regressieanalyse is geëvalueerd. Hoe complexer (hoe meer kansen en bedreigingen) de omgeving wordt waargenomen, hoe minder onzekerheid er blijkt te bestaan, terwijl perceptie van grotere vijandigheid (aantal bedreigingen t.o.v. kansen) leidt tot meer onzekerheid. Blijkbaar zijn ondernemers die zich beter bewust zijn van hun omgeving minder onzeker, terwijl een relatief vijandige omgeving juist wel tot meer onzekerheid leidt.

De 3 bedrijfsstrategieën die onderzocht zijn in hoofdstuk 6 zijn procesbeheersing, diversificatie en groei (analoog aan de strategieën in hoofdstuk 5). Melkveehouders die een lagere onzekerheid ervaren met betrekking tot hun omgeving zijn eerder geneigd voor procesbeheersing te kiezen. Een hogere onzekerheid resulteert in de keus voor diversificatie om risico te spreiden over meerdere bedrijfstakken. De keuze voor een groeistrategie wordt bepaald door andere factoren dan onzekerheid. Grotere, intensievere bedrijven, met financiële doelstellingen hoog in het vaandel, kiezen eerder voor groei.

Van belang is dat de boer een goede overeenstemming vindt tussen de externe en interne (bedrijfskenmerken) omgeving van zijn bedrijf. Een beter bewustzijn van veranderingen in de externe omgeving reduceren de onzekerheid die daarmee gepaard gaat, terwijl tegelijkertijd beter gereageerd kan worden met een strategie die ook bij de interne omgeving van het bedrijf en de ondernemer zelf past.

Planning mineralenmanagement

Naast een analyse van de gerealiseerde overschotten en veranderingen werd in dit onderzoek ook gekeken naar de plannen die melkveehouders hebben ten aanzien van het behalen van de MINAS eindnormen. In hoofdstuk 7 wordt met behulp van een multi-case studie de inhoud en achtergrond van plannen ten aanzien van bedrijf en bedrijfsvoering onderzocht. De plannen van de melkveehouders zijn verworven door middel van het Interactieve Simulatie Model, ontwikkeld door het LEI. De theoretisch meest economisch en technisch efficiënte volgorde van verbeteren van mineralenmanagement loopt van operationeel via tactisch naar strategisch management. In werkelijkheid worden echter grote variaties aangetroffen in de keuze en opbouw van een plan. Deze verschillen worden met name veroorzaakt door motivatie en kunnen.

In slechts weinig gevallen zijn melkveehouders van plan de intensiteit van hun bedrijf terug te brengen. Integendeel, de meesten hebben de intentie deze te verhogen. Dit leidt tot de conclusie dat bedrijven een bepaalde visie hebben wat betreft de omvang (in grond en quotum) van hun bedrijf, en dat zij daar naar toe werken. MINAS is hierbij een randvoorwaarde en wordt door deze melkveehouders niet als een belemmering gezien.

Conclusies

De belangrijkste *resultaatgerichte* conclusies van dit proefschrift zijn:

- ❖ Als de bedrijven uit Project Praktijkcijfers (PP) hun mineralenmanagement niet aanpassen zal het saldo met gemiddeld 8% afnemen. Hierdoor komt de continuïteit van een aantal bedrijven in gevaar;
- ❖ PP-melkveehouders hebben een gemiddelde mineralenefficiëntie van 80%, wat wil zeggen dat zij met 20% lagere overschotten dezelfde output zouden kunnen halen (NB. Deze efficiënties zijn relatief t.o.v. de beste bedrijven in de steekproef). Zij hebben in 1997-1999 grote sprongen voorwaarts gemaakt wat betreft mineralenmanagement, met een gemiddelde verbetering van de mineralenproductiviteit van 60% per jaar. Hiervan is een helft toe te schrijven aan efficiëntieverbetering en de andere helft aan verbetering van de technologie. Deze verbeteringen hadden in de periode van onderzoek een positieve invloed op de financiële resultaten;
- ❖ In de onderzoeksperiode verklaarde bedrijfsvoering 3-4 maal zoveel van de mineralenoverschotten als bedrijfsstructuur. Een beleid gericht op bedrijfsstructuur

(intensiteit) zoals de EU-Nitraatrichtlijn indirect voorschrijft kan daarom geen schoon (grond)water garanderen. Beleid volgens het EU-principe 'de vervuiler betaalt' zoals MINAS, zal doelgerichter werken;

- Opleiding en strategiekeuze bepalen de richting van de veranderingen van de bedrijfsvoering en bedrijfsstructuur. Hoger opgeleide PP-melkveehouders en PP-melkveehouders met een groeistrategie streven naar een groter, intensiever bedrijf, met een goede kwaliteit operationeel management. Een diversificatiestrategie leidt tot extensivering, maar ook tot slechtere operationele resultaten. De strategie van procesbeheersing leidt tot het verbeteren van het mineralenmanagement binnen de huidige bedrijfsstructuur;
- De onzekerheid die PP-melkveehouders ervaren vanuit hun omgeving beïnvloedt de keuze voor hun bedrijfsstrategie. Vooral de onzekerheid over de politieke omgeving werd als hoog ervaren. PP-melkveehouders die erg onzeker zijn t.a.v. hun omgeving kiezen voor diversificatie, terwijl weinig onzekerheid tot de strategie van procesbeheersing leidt. Een groeistrategie is niet gerelateerd aan onzekerheid over de omgeving;
- Bedrijfsplannen met betrekking tot mineralenmanagement variëren enorm tussen PP-melkveehouders. Voorkeur, sterke en zwakke punten en de visie op de toekomst van het bedrijf blijken meer verklarend voor de keuze van het bedrijfsplan dan bedrijfskenmerken;
- Resultaatgericht beleid zoals MINAS is effectiever dan beleid dat gericht is op specifieke bedrijfsmaatregelen. Maatregelgericht beleid zoals de Nitraatrichtlijn en het stelsel van afzetovereenkomsten laten geen ruimte voor de ondernemer om een fit tussen interne en externe bedrijfskenmerken te vinden. Resultaatgericht beleid daarentegen geeft de ondernemer de vrijheid en de verantwoordelijkheid om een oplossing voor het (mineralen)probleem te vinden die optimaal aansluit bij hem en zijn bedrijf.

De belangrijkste *methodegerichte* conclusies zijn:

- De te onderzoeken groep bedrijven zijn qua bedrijfs- én ondernemerskenmerken niet geheel representatief voor de Nederlandse populatie van gespecialiseerde melkveebedrijven. Dit betekent dat de resultaten geldig zijn voor de groep jongere ondernemers, met relatief intensieve bedrijven;
- Het combineren van zowel technische als financiële en mineralenkundige data met gegevens verzameld via enquêtes en een game levert een goed inzicht in achtergronden van beslissingen;
- Het inzetten van het Interactieve Simulatie Model voor de ontwikkeling van individuele bedrijfsplannen is zinvol voor het verkrijgen van inzicht van de effecten van bepaalde maatregelen op het bedrijf. Of de resultaten gemaakt met het plan ook werkelijk haalbaar zijn is afhankelijk van de managementcapaciteiten van de ondernemer;

- De kwaliteit van de data was dusdanig dat een strenge selectie noodzakelijk was. Hierdoor vielen veel bedrijven af waardoor de uiteindelijke onderzoeksgroep uit 114 gespecialiseerde melkveebedrijven bestond. Dit heeft consequenties voor de mogelijke toepassing van statistische methoden als LISREL. Complexe theoretische modellen moeten, door gebrek aan vrijheidsgraden opgeknipt worden zodat een stapsgewijze schatting mogelijk is. Daarnaast zijn de geschatte coëfficiënten en significanties niet altijd betrouwbaar;
- DEA blijkt dermate flexibel dat relatief eenvoudig een maat voor subvector (in dit geval mineralen) efficiëntie en productiviteit kan worden bepaald. Deze maat is uitermate geschikt om het verloop van milieuvriendelijke productie te onderzoeken;
- Naast statistische analyses geeft een (multi) case-study veel inzicht in het besluitvormingsproces en de achtergronden daarvan en vormt daarom een goede aanvullende onderzoeksmethode.

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Curriculum Vitae

Christina Johanna Maria (Christien) Ondersteijn werd op 9 februari 1974 geboren te Den Dungen. In 1992 behaalde zij haar diploma aan het R.K. Gymnasium Beekvliet te Sint-Michielsgestel en ving datzelfde jaar aan met de studie Economie van Landbouw en Milieu aan de toenmalige Landbouwuniversiteit Wageningen. In het voorjaar van 1996 bracht zij een stage door aan de Timiryazev Agricultural Academy te Moskou. In het collegejaar ’96/’97 heeft zij doctoraalvakken Fiscale Economie aan de KUB te Tilburg gevolgd om tenslotte met twee afstudeervakken Agrarische Bedrijfseconomie af te studeren in november 1997. In januari 1998 is zij als toegevoegd onderzoeker bij de Leerstoelgroep Agrarische Bedrijfseconomie aan de slag gegaan met de organisatie van postdoctoraal onderwijs en monitoringonderzoek naar Project Praktijkcijfers. Dit laatste resulteerde in oktober van dat jaar in de start van dit proefschrift, financieel en inhoudelijk mede mogelijk gemaakt door samenwerking met het LEI. Een deel van dit onderzoek is verricht bij het Department of Agricultural Economics, Michigan State University. Sinds april 2002 is zij aangesteld als universitair docent bij de Leerstoelgroep Agrarische Bedrijfseconomie aan de huidige Wageningen Universiteit.

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