Netherlands Journal of Agricultural Science 50 (2002) 47-65

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

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Received: 22 March 2002; accepted: 9 August 2002

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 this system they will be taxed, which could constitute a threat to the financial viability of their farms. This paper presents the results of 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 from 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 optimization proved to be: (1) the optimization 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 ways farmers choose to cope with nutrient management problems on their farm appeared to be related to factors like preferences and competencies. These factors affect the choices farmers make to deal with environmental problems.

Additional keywords: nutrient management, farm strategy, dairy farming, MINAS

Introduction

Farming in the Netherlands is becoming increasingly complex due to an increase in environmental regulations. The most important one of recent date is the Mineral Accounting System (MINAS) introduced in 1998, which affects every single Dutch farm (Van De Brandt & Smit, 1998). MINAS consists of a nutrient bookkeeping system and addresses both nitrogen (N) and phosphorus (P). 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 2003 when the final standards are supposed to lead to health- and environmental-wise safe concentrations of nutrient constituents in ground- and surface waters (Oenema & Roest, 1998). These standards are set to 180 kg N ha^{-1} for grassland and 100 kg N ha^{-1} for arable land. An excess of 20 kg phosphate (P_2O_5) per hectare is allowed regardless the cropping system. Farmers will be taxed € 2.30 for every kg N and € 9.00 for every kg P_2O_5 exceeding the standard.

The introduction of MINAS poses a serious threat to the financial viability and continuity of farms due to high levies and the large number of farms not yet meeting the standards (Ondersteijn *et al.*, 2002). Research has shown that the average N 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 their mission (long-term goals for the farm), many farms will have to alter their management practices considerably to meet the final surplus standards. In the light of the new conditions this includes optimizing operational, tactical as well as strategic management.

This paper focuses on specialized dairy farms. The typical Dutch dairy farm integrates animal and plant production activities and therefore has complex nutrient flows. Several farming-system studies have been conducted to examine whether dairy farms could meet the 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. But as differences in farm structure and environment, and personal characteristics of the farmer will to a certain degree affect the choice for input-output relations of a specific farm, a variety of nutrient management measures can be 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'.

This paper presents 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 a strategic management model combined with a literature review on nutrient management. These propositions will be explored using technical, financial and nutrient bookkeeping data over a period of three years (1997–1999) and 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 of MINAS.

Materials and methods

Materials

To monitor the changes that farmers implemented on their farms, data were collected over a four-year period (1997–2000) from specialized dairy farmers who participated in a project aiming at improving nutrient management (specialized dairy farms are farms that for at least 95% are engaged in dairy and dairy-related activities). The project was a collaborative effort of the Dutch government and farmers' organizations. It consisted of two parts. In the period 1997–1999, 125 participating dairy farmers focused on improving and learning about nutrient management in the Netherlands (Ondersteijn *et al.*, 2002). To meet the objectives of this first stage, technical, financial and nutrient bookkeeping data were collected, and management surveys were carried out to gain insight into farmers' missions and motivations. During the second stage of the project – from 2000 through 2002 with 175 farmers participating – the goal was explicitly to meet the nutrient surplus standards of 2003. To help farmers define the path towards meeting these standards for their farm an Interactive Simulation Model (ISM) was used in a workshop organized in 2000 (Baarda, 1999).

The workshop lasted two days. 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 to their farms. The farmers 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.

ISM is a Windows-based programme by which participants are confronted with the structure, management and results of their farms. It uses regression techniques to estimate the consequences virtual nutrient-management changes made by participants have for the financial performance of their farms and the impact these changes have on the N and P_2O_5 balances (Hennen, 1995). If 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. An overview of the measures in ISM that farmers can select and the direction in which these measures will change farm results according to the model are presented in the Appendix.

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 statistically 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 from farms with a complete data set, which resulted in a sample of 72 farms of which the nutrient management characteristics and the choices made in ISM are shown in Table 1.

Methods

Nutrient-management research tends to focus on the results from an experimental farm, from 'the average' dairy farm, or from a single case-study, which in most instances does not reflect the actual decision-making environment, internal as well as external, of commercial farms. The research question of this study is exploratory and focuses on how a change in the external environment affects farmers' strategic, tactical and operational behaviour. Furthermore, since this was a real-time project with commercial farms, little influence could be exerted on the behaviour of the participating farmers. Case study analysis seems very suitable 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 carried out 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 could not easily be extracted from past behaviour. Diversity and specificity among farms and farmers are large and therefore the case study approach is the better choice.

Case studies are based on multiple sources of evidence and on 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 specialized dairy farms, because the larger the sample the more insight is gained into the development paths of dairy farms towards optimization of farm management to meet the nutrient surplus standards. Sub-samples of farms were selected according to the proposition under consideration.

Propositions on farm management to meet environmental conditions

To develop 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 & Quale, 1990; Harling, 1992). In this 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

Table 1. Nutrient management measures: changes over the period 1997–1999, situation in 1999, and the percentage of farmers in 2000 that intend to take a certain measure in the Interactive Simulation Model (ISM).

	Changes 1997–1999	Situation 1999	Selected in ISM 2000 (% farmers)
Operational management			
Feeding- and grassland management (MJ NEL ha^{-1})[1]	–200	7152	64
Utilization of N in organic manure	n.a.[2]	n.a.	64
Technical management			
Young stock (LU[3] per 10 cows)	–0.3	2.7	49
Grazing intensity (LU grazing days per ha grass)	–12	338	49
Nitrogen level in concentrates (g N kg^{-1})	2.9	32.9	18
Phosphate level in concentrates (g P_2O_5 kg^{-1})	0.3	5.4	17
Inorganic fertilizer nitrogen on grass (kg N ha^{-1})	–48	242	
Reduce			75
Increase			1
Inorganic fertilizer phosphate (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[4])	–8.6	188	
Reduce			22
Increase			18
Strategic management			
Farm intensity (kg FCPM ha^{-1})	545	13869	
Reduce			8
Increase			62
Milk production per cow (kg FCPM)	84	8333	60
Taxable nutrient surpluses			
Deviation from 1999 LFS[5]			*Simulated deviation from 2003 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

[1] 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.
[2] n.a. = not available.
[3] LU = livestock unit.
[4] FPCM = fat and protein corrected milk.
[5] LFS = levy free surplus standard.

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 tactical 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. However, depending on the current state of his nutrient management (strength or weakness), he may need to alter his operational, tactical or strategic management. If 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 available to a farmer to reduce nutrient surpluses are shown in the Appendix.

Optimizing operational management: low cost and low risk

If farms show only small deviations from the final surplus standards, adjustment of operational management may suffice. Such adjustments 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 fertilizing, 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. Optimizing operational management (i.e. efficiency) is therefore something a farmer with profit-maximizing 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 can unburden them from the need to optimize 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 optimizing 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 recognize their incapability to improve it

According to Aarts *et al.* (1992), operational measures are relatively simple and are easily implemented. What these authors do not recognize in their study, however, is that efficiency improvement requires a large effort in terms of farmers' management skills. Optimizing operational management leans towards precision agriculture and not all farmers possess the skill, the knowledge, the drive or even the time to optimize their farming system. For these farmers, optimizing 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 optimization path and reduce the inputs to the farm. Because of lack of management skills they will need to reduce these inputs further than does a farmer with better skills (Aarts, 1999b).

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

Optimizing 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 other ones. For instance, given the high level of fertilization in the Netherlands a reduction in N fertilization level of grassland strongly reduces the N surplus (Berentsen *et al.*, 1992). This is also true for P fertilizer, 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 also depends on factors like mowing and grazing system. Composition and amount of concentrates supplied depends on roughage fed and milk production goals. The area of grass grown relative to maize depends on roughage needs of the herd and on growing conditions. An increase in maize area relative to grass would reduce the fertilizer needed for roughage production, but since the nutrient surplus standard for N is 80 kg ha^{-1} higher for grassland than for arable land, this measure does not result in a large nutrient management advantage.

Because nutrient management decisions at the tactical level could have a significant impact on inputs and outputs, they result in changes in income (De Haan, 2001). So it is likely that farmers will opt for selecting 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 individually introduced (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 but are costly (normative feeding and reducing inorganic fertilizer N being cheaper). These farm-specific studies give an indication of the possible effects on farm income. However, their farm specificity prevents a straightforward translation of effects to the entire dairy farming population, since the environmental and financial consequences of changes in tactical management depend on the base farm situation and on 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 farming population, to estimate farm-specific effects under different farming conditions.

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

Optimizing 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). However, changing the intensity of the farm is 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 maximize the returns to land through maximizing milk production per unit of land within the environmental constraints (Korevaar, 1992; Aarts *et al.,* 1999b). So decreasing farm intensity does not seem 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 depend on whether a proper fit can be found between the farmer's operational and tactical management skills and farm intensity. Since it is difficult to make a precise assessment of these skills, correct beforehand 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 these decisions. So it seems most effective, regardless of the intensity level of the farm, to try and optimize operational and tactical management of nutrients while at the same time increasing the intensity of the farming system.

Under a milk quota system, maximizing milk production per ha depends on 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 accomplish the milk quota (Steverink *et al.*, 1994). Furthermore, a smaller dairy herd requires less replacement heifers, and so less feed is required, which positively affects the nutrient balance (Korevaar, 1992; Aarts *et al.*, 1999a). A high-producing herd will therefore increase the possibilities to maximize 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 of the farm (more kg milk per ha) in order to capitalize on economies of scale, have to optimize their farming system with operational and tactical measures and increase milk production per cow

Results

Proposition 1

It is mainly feeding management and grassland management that determine operational management, so these terms are used here interchangeably. 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. The standard additional feed supply was calculated by subtracting the standard on-farm produced energy in roughage from the standard energy requirements of cattle. Energy and production standards were taken from Dutch standard norms (Anon., 1997; Philipsen *et al.*, 2001). To explore Proposition 1, farms were selected that did not choose to improve operational management (n = 26). Table 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 ha^{-1}). All these farms but two (1.6 and 1.8) have been improving in this respect since 1997. Even so, the level of operational management of these two farms is still in the lower quartile of the sample's performance, and the SMRs show that both farmers consider feeding- and grassland management as one of their strengths.

Farms 1.11–1.26 can gain economic benefits from improving their operational performance. Most farmers realize this and have started to improve performance since 1997. Farms 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 strength of their farms. Farmer 1.24 does think that grassland management is a weakness, but compensates that with low feeding and fertilization costs as strengths. He chooses to reduce the fertilizer N dose and to increase milk production per cow (7399 kg FPCM in 1999) rather than improving operational management. The other farmers do not mention feeding- and grassland management in their SMRs. Apparently, they do not realize their poor performance or the benefits of good operational management.

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.

Proposition 2

To investigate Proposition 2, farms were selected in the upper quartile of the change in operational management performance and in 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 had large deviations from the

Table 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[1]		Farming intensity	MINAS Performance[2]
	Situation 1999	Changes 1997–1999		
	-------------- (MJ NEL ha^{-1})	------------	(kg FCPM[3] ha^{-1})	(kg N ha^{-1})
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

[1] Operational management is defined as the actual – standard additional feed supply expressed in MJ net energy for lactation (NEL) per ha.
[2] Difference between 1999 N surplus and surplus standard for N in 2003.
[3] FPCM = fat and protein corrected milk.

final N surplus standards, which for most farms have actually increased from 1997 till 1999 (Table 3). Farm 2.2 actually met the final surplus standards in 1997. Deteriorating operational management, an increase in fertilizer N use with 123 kg ha^{-1}, and falling milk production per cow are the main reasons for this huge increase.

To reduce their nutrient surpluses, Proposition 2 expects these farmers to plan more tactical measures than other farmers. All but one farmer still choose to improve feeding- and grassland management and five farmers also intend to improve the utilization 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. All farmers selected reducing N input from inorganic fertilizers.

Table 3. Operational management, farming intensity, MINAS performance and planned management measures for farms with a large drop in operational management. (Proposition 2)

	Farm number							Mean[1]	
	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.1–2.7	Rest of sample
Operational management[2] ($MJ NEL ha^{-1}$)									
Situation 1999	–2103	14143	21683	19140	12564	19337	19804		
Changes 1997–1999	17282	12920	11877	9835	8711	7612	7590		
Farming intensity 1999 (kg FPCM[3] ha^{-1})	13412	19695	11876	16126	14009	15276	16063		
MINAS performance[4] ($kg\ N\ ha^{-1}$)									
Situation 1999	161	190	154	152	197	201	116		
Changes 1997–1999	151	234	102	38	72	–8	–13		
No. of operational measures ISM[5]	0	2	2	2	2	2	1		
No. of tactical measures ISM	4	4	4	3	4	4	4	3.9	2.9***

[1] *** = statistically different at 0.1% level.
[2] See Table 2.
[3] See Table 2.
[4] See Table 2.
[5] ISM = (in the) Interactive Simulation Model.

Comparing the number of tactical measures these farmers have selected with that of other farmers should indicate whether these farmers indeed use more tactical measures. The first comparison 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 selected farms with the farms that did manage to improve operational management performance (not shown here) and with the total group of farms in Table 3, gave significantly ($P < 0.01$) higher numbers of tactical measures taken by the group of 7, providing support for Proposition 2.

Proposition 3

Proposition 3 requires ranking of the tactical measures based on their environmental and financial efficacy (based on experimental farm studies and ISM) (Tables 4 and 5). Table 4 shows the percentages of farmers who changed more than 10% of a particular input in the period 1997–1999. In this period farmers mainly implemented the environmentally and financially most effective measures (inorganic N, number of young stock and grazing intensity). The high percentage of farmers who reduced fertilizer P is surprising, since it does not bring a farmer closer to the P_2O_5 surplus

Table 4. Percentages of farmers taking tactical measures in the period 1997–1999, and percentages of farmers planning to take measures in the Interactive Simulation Model (ISM). (Proposition 3)

	1997–1999		ISM (2000)	
	Reduce	Increase	Reduce	Increase
Highly effective tactical measures				
Inorganic fertilizer 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 fertilizer P	44	40	8	

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 optimized and carefully monitored, especially in winter. In summer, a surplus of protein is often supplied because of intensive grazing. Many farmers recognize this and intend to reduce grazing intensity and grow more maize as low-protein roughage in summer.

Table 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 a 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 significantly different, but that the level of fertilizer 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 the period 1997–1999 are indeed planning to implement significantly more tactical measures, which have an uncertain outcome both environmentally and financially. So these farmers are now selecting more uncertain measures, providing evidence for Proposition 3. Farmers who did not select the most effective tactical

Table 5. Average number of highly effective (reduction in organic fertilizer N, redaction in young stock), moderately effective (grazing intensity, protein in concentrates, P in concentrates, energy in concentrates, percentage grassland) and not-effective (reduction in inorganic fertilizer P) tactical measures for farms that did not (Group 1; n = 15) and for farms that did implement (Group 2; n = 57) highly effective measures in the period 1997–1999. (Proposition 3)

	Group 1	Group 2	t-value[1]
No. of moderately effective tactical measures	1.20	1.18	–0.07
No. of not-effective tactical measures	0.33	0.47	0.98
MINAS performance[2] N in 1999 (kg N ha^{-1})	98	68	–1.49
MINAS performance P_2O_5 in 1999 (kg P_2O_5 ha^{-1})	–9	3	2.54*
No. of highly effective tactical measures ISM[3]	1.20	1.25	0.25
Percentage planned change in N fertilizer ISM	–17	–13	0.67
Inorganic fertilizer N 1999 (kg ha^{-1})	289	229	–3.16**
Percentage planned change in young stock ISM	–0.07	–0.19	–1.83
Young stock 1999 (LU[4] per 10 cows)	2.7	2.7	–0.02
No. of moderately effective tactical measures ISM	0.87	1.54	2.61*
No. of not-effective tactical measures ISM	0.07	0.09	0.26
MINAS performance N ISM (kg N ha^{-1})	–10	–3	0.74
MINAS performance P_2O_5 ISM (kg P_2O_5 ha^{-1})	–17	–10	2.25*

[1] * = statistically significant at $P < 0.05$; ** = statistically significant at $P < 0.01$.
[2] Difference between surplus and surplus standard in 2003.
[3] ISM = (in the) Interactive Simulation Model.
[4] LU = livestock unit.

measures in the period 1997–1999 are aiming for larger reductions, especially for inorganic fertilizer N, and appear to be planning to implement the most environmentally effective tactical measures in the period 2000–2003.

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 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 other ones plan reductions from about 1500 to 3300 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 of Table 6 present the average number of measures for these 6 farms as well as for the rest of the sample. T-tests showed no statistically 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 to buy or lease 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 its SMR it

Table 6. Management characteristics, farming intensity, MINAS performance and planned management measures for farms that plan to reduce farming intensity. (Proposition 4)

	Farm number						Mean[1]	
	4.1	4.2	4.3	4.4	4.5	4.6	4.1–4.6	Rest of sample
Operational management[1] (MJ NEL ha^{-1})								
Situation 1999	–16580	10409	–105	7112	12546	16128		
Changes 1997–1999	–12037	6184	–10380	–10362	8711	–2112		
Farming intensity (kg FPCM[2] ha^{-1})								
Situation 1999	29906	17008	15272	14188	14009	11911		
Planned situation ISM[3]	15812	14121	13210	12804	10702	10431		
MINAS performance[4] (kg N ha^{-1})								
Situation 1999	–2	94	102	67	197	185		
Planned situation ISM	–46	0	43	–9	–23	6		
Manure disposal (kg N ha^{-1})								
Situation 1999	210	0	6	0	0	0		
Planned situation ISM	0	0	0	0	0	0		
No. and type of measures selected in ISM								
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

[1] See Table 2.
[2] See Table 2.
[3] ISM = (in the) Interactive Simulation Model.
[4] See Table 5.

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 in their SMR as (part of) their strategy. 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, 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. However, intensifying is accompanied by signif-

Table 7. Management characteristics and ISM results for farms that do not (NI) and farms that do intend to increase farming intensity (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[1]	I+MD/L (n = 20)	I–MD/L (n = 25)	t-value
Operational management[2]						
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[3] ha^{-1})						
Situation 1999	13482	13626	–0.17	14575	12866	1.77
Planned situation ISM[4]	13754	15687	–2.23*	17035	14609	–2.42*
kg FPCM per cow 1999	8305	8376	–0.39	8498	8278	1.05
Manure disposal ISM (kg N ha^{-1})	1	11	–2.12*	25	0	2.61*
MINAS performance[5] (kg N ha^{-1})						
Situation 1999	73	71	0.11	105	44	3.71***
Planned situation ISM	–3	–5	0.16	15	–20	4.64***
No. and type of measures selected in ISM						
Operational measures	1.19	1.33	–0.80	1.55	1.16	2.11*
Tactical measures	2.81	3.02	–5.1	3.20	2.88	0.88
kg FPCM per cow	0.62	0.62	–0.02	0.80	0.48	2.33*

[1] * = statistically significant at $P < 0.05$; *** = statistically significant at $P < 0.001$.
[2] See Table 2.
[3] FPCM = fat and protein corrected milk.
[4] ISM = (in the) Interactive Simulation Model.
[5] See Table 5.

icantly 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, last three rows). On the contrary, if a farmer wants to intensify he intends to use more operational and tactical measures.

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, I+MD/L and I-MD/L). The first group produces more milk per ha and shows slightly more unfavourable operational management, leading to significantly larger deviations from the final surplus standard ($P < 0.001$). These 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 significantly improve operational management, implement more tactical measures (although not significantly) and significantly increase the genetic production capacity of the herd ($P < 0.05$). In conclusion, 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.

Discussion and outlook

Drastic modifications in the external environment of farms, like in the case of Dutch farmers when MINAS was introduced, did affect management at the operational, tactical as well as strategic level. In general, the most environmentally and cost-effective order of implementation of nutrient management measures proved to be: (1) operational optimization of the production process, (2) a reduction in inputs, and (3) a re-evaluation of the intensity of the farm. This order of decisions strongly depends on farmers' goals and on the (perception of) strengths and weaknesses of his management and his farm organization. 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 a farmer 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 who show poor operational performance and are far from the final surplus standards will have to increase their efforts and take more risks 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 through 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 on the environmental and on the cost effectiveness of the tactical measure. However, in this situation environmental effectiveness is determined 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, which punishes farmers 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. Such 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.

Farmers focus on the most environmentally and cost-effective way to meet the environmental standards set by the government. So 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 a farmer decides 'rationally' on the nutrient management measures to implement in such a way that he can keep pursuing the original strategy of his farm. So extension and consulting services should reorganize their advice into coaching the entire farm. This will very likely be more effective than itemized advice since farmers decide with their farm mission in mind. Farmers who appear not to select rationally lack insight into 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 who have great concern for their position with respect to societal objectives. The development paths of other farms could be different, but not necessarily so. 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 specialized dairy farms. This implies that implementing the selected plan does not guarantee realization 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 the 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 depends 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 just 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.

Acknowledgements

The authors would like to thank P.B.M. Berentsen and two anonymous reviewers for their helpful comments on earlier versions of this paper.

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Appendix

Measures and effects of management options in the Interactive Simulation Model (ISM). The options not selected by any farmer in the sample have been excluded: irrigation (tactical), employing a milking robot, switching to organic farming, and discarding pig- or poultry farming (strategic).

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 utilization of organic manure	–	–	+
Tactical management			
Reduce number of young stock	–	–	+
Reduce intensity of grazing system	–	–	+
Reduce protein level in concentrates	–	0	+
Reduce P level in concentrates	0	–	+
Reduce inorganic N fertilizer	–	0	+/–
Reduce inorganic P fertilizer	0	–	+/–
Reduce grass/maize ratio	–	–	–
Reduce amount of concentrates per cow	–	–	–
Strategic management			
Decrease farm intensity	–	–	–
Increase milk production through breeding	–	–	+