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Guiding commercial pilot farms to bridge the gap between experimental and commercial dairy farms; the project 'Cows & Opportunities'

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Abstract

In the Netherlands there is a remarkable difference in environmental performance between the average commercial dairy farm and some experimental dairy farms. Despite 15 years of policies and measures to decrease nutrient losses, experimental dairy farms based on careful nutrient management, like 'De Marke', realize much higher resource use efficiencies and much lower nutrient surpluses than the average commercial dairy farm.

This paper discusses the transitions that are needed to bridge the gap between experimental dairy farms and commercial pilot farms. In the project 'Cows & Opportunities', 17 farms were selected representing the full range of conditions for dairy farming, with emphasis on dry sandy soils because of their environmental constraints. There are intensive discussions and communications between farmers, extension services, advisers from the industry, researchers and policy makers. Firstly, all farms were thoroughly analysed in terms of agronomic and environmental performance in the original situation. Secondly, opportunities for improving their performance were analysed using sustainability criteria like nutrient losses, energy and water use, emission of greenhouse gases, crop protection, accumulation of heavy metals, and nature development. Thirdly, an outline for a farm development plan was formulated to meet the nitrogen and phosphorus surplus targets set by the Dutch government. These first outlines (designs) were thoroughly discussed between farmers and researchers. After modelling the farm design to calculate the environmental and economic effects, the farm development plan was adjusted wherever needed, approved and implemented. The performance of the farm will be monitored and evaluated over the next few years. In the original situation, the MINAS nitrogen surplus on the farms ranged from 47 to 349 kg ha^{-1}, with an average of 207 kg. The modelling results indicated an average N surplus of 131 kg ha^{-1} after implementation of the farm development plans, i.e., 19 kg ha^{-1} less than the target surplus. The project 'Cows & Opportunities' demonstrates that it is possible to meet the nitrogen and phosphorus surplus targets by taking simple measures. The project yields useful information on the relations between management measures, constraints, nutrient balances and environmental performance.

Keywords: nitrogen, Netherlands, knowledge transfer, farming systems, environmental impact, policy, nutrient management.

Introduction

Intensive dairy farming systems rely on (i) import of fertilizers to boost forage production, and (ii) import of animal feed to increase milk production to economically attractive levels. Only a fraction of the nutrients contained in the imported fertilizers and animal feed is converted into animal products exported from the farm. The remainder is excreted via dung and urine and can be utilized again for crop production or is lost to the environment. It has become clear now that continued high imports of fertilizer and feed can lead to nutrient imbalances that result in emission of excess nutrients from the farm to ground- and surface water and the atmosphere, with potentially adverse environmental impacts (Jarvis *et al.*, 1995).

Currently, there is much information about nutrient flows, transformations and losses that can be used to improve nutrient use efficiency and reduce nutrient losses from the major compartments of dairy farming systems (e.g. Aarts *et al.*, 1992). Substantial reductions in nutrient losses can be realized immediately by improved management of animal manure (Van Der Meer *et al.*, 1987; Rees *et al.*, 1992; Van Der Meer & Van Der Putten, 1995; Schils *et al.*, 1999), and improved fertilizer recommendations (Oenema *et al.*, 1992; Titchen & Scholefield, 1992). However, for long-term success and sustainability it is essential that whole systems are considered because changes introduced to remedy one loss process may exacerbate other problems (e.g. Aarts *et al.*, 1992; Jarvis *et al.*, 1996).

Despite this abundance of information, nutrient surpluses from commercial dairy farms in the Netherlands (e.g. Reijneveld *et al.*, 2000) and in many other countries and regions in the European Union (e.g. Walle & Sevenster, 1998) remain very high. In the Netherlands, the MINeral Accounting System, MINAS (Van Den Brandt & Smit, 1998; Neeteson, 2000), was introduced in 1998 as a policy instrument to reduce nitrogen (N) and phosphorus (P) losses, and to meet the standard of the EU Nitrate Directive (Anon., 1991) of 50 mg l^{-1} in the upper groundwater. Between 1998 and 2003, dairy farms in the Netherlands have to reduce the average N and P surpluses by a factor of 2 or more, which indeed is a major task.

There are about 35,000 dairy farms in the Netherlands, managing about 70% of the agricultural area or 1,3 million ha. These farms are in transition because of decreasing milk and meat prices and high stress on the environment (e.g. Dietz, 2000). Dairy farms are confronted ever more by constraints concerning the sustainability in ecological (e.g. stress on the environment), agro-technical (e.g. soil fertility) and socio-economic sense (e.g. WTO is decreasing product support and at the same time increasing income support in exchange for landscape maintenance).

The environmental problems in Dutch dairy farming have led to the establishment of the experimental dairy farm 'De Marke' (Aarts *et al.*, 1992). 'De Marke' aims at improving the utilization of fertilizers and feeds by minimizing nutrient requirements, maximizing the use of nutrients in organic manure and home-grown feeds, and by importing specific fertilizers and feed (Aarts *et al.*, 1999b). The results of 'De Marke' show, amongst other things, that by taking a coherent set of simple measures at farm level, the input of nutrients can be drastically reduced (Hilhorst *et al.*, 2001; Aarts, 2000). Nitrate concentrations in the upper groundwater on the light sandy soils have decreased to a level that nearly meets the EU Drinking Water Quality Directive of 50 mg nitrate l^{-1} (Aarts *et al.*, 2000; Van Keulen *et al.*, 2000). Comparing the results of 'De Marke' with those from Dutch dairy farmers, there still is a huge gap between what is technically feasible and possible and what commercial dairy farmers realize in practice. The average MINAS nitrogen surplus at 'De Marke' in the period 1993–1999 was 90 kg ha^{-1} (Hilhorst & Oenema, unpublished data) compared with 304 kg ha^{-1} for all Dutch dairy farmers in 1997 (Reijneveld *et al.*, 2000).

To bridge this gap requires coaching and transfer of knowledge. On experimental farms, innovative and possibly risky farm designs can be tested, adjusted and further improved easily, on the basis of the experimental results. In practice, dairy farmers are often reluctant to adjust management, because of lack of information and lack of confidence in the results. Intensive coaching and transfer of knowledge will help dairy farmers to adopt changes in management more easily. Our hypothesis is that intensive coaching and increased interaction between researchers and farmers will lead to rapid adoption of efficient farm management in practice. Currently, the following 4 levels of coaching and knowledge transfer are distinguished (see also Figure 1):

1. Highly intensive participation of researchers, coaching of farm personnel and exchange of knowledge on experimental farms (e.g. 'De Marke').
2. Intensive coaching and knowledge transfer on commercial pilot farms. Extrapolating knowledge and experience gained on experimental farms (e.g. 'De Marke') to pilot farms ('Cows & Opportunities'). A group of 17 farmers was selected to support and demonstrate transfer to suitable farming systems in practice. Participants receive weekly to monthly advice, and have to realize strict targets.
3. Extensive coaching and knowledge transfer on dairy farms in practice. An example is the project 'Farmers Data II' with 180 dairy farms. Participants of this project obtain advice twice a year, but there are no strict targets.
4. Incidental coaching and knowledge transfer by appointment. Extension specialists visit farmers on request. Knowledge transfer via agricultural magazines and discussions in farmers' study groups is also part of this type of coaching. This group is by far the largest (35,000 dairy farmers), and also is the group 'that lags behind'.

This paper focuses on the intensive coaching and knowledge transfer on commercial pilot farms. The project 'Cows & Opportunities' is innovative in the collecting and transfer of knowledge. An intensive 'analysis-modelling-planning-implementation-monitoring-analysis' cycle is followed, involving active participation of farmers, researchers and extension specialists. Measurable targets (sustainability criteria) have been formulated for the following themes: nutrient losses, crop protection, energy and water use, emission of greenhouse gases, accumulation of heavy metals, and na-

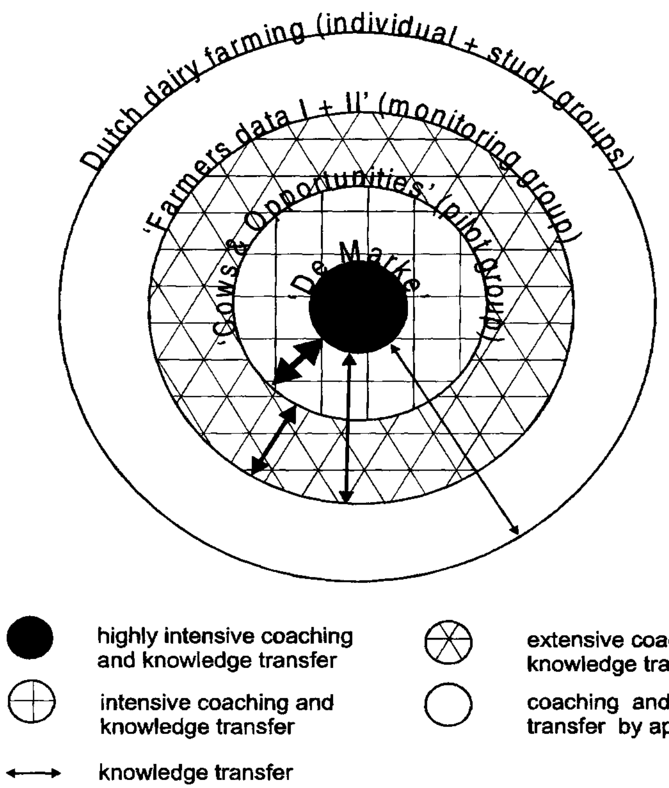


Figure 1. Coaching levels and knowledge exchange in Dutch dairy farming.

ture development. In the first three years of the project, 'nutrient losses' is the most important objective.

The purpose of this paper is (i) to discuss the selection of the farms in the project 'Cows & Opportunities', (ii) to discuss the research methodology of transition management, and (iii) to discuss the targets and required changes in the N balance of the farms.

Materials and methods

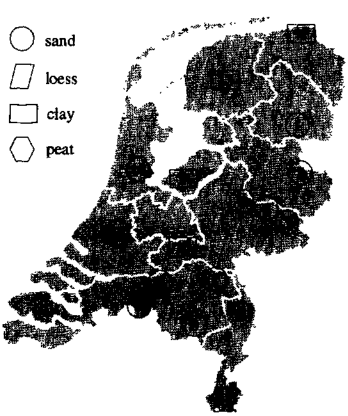
Selection of commercial pilot farms

The pilot farms must represent the full range of conditions for dairy farming to facilitate acceptance of the results from these pilot farms by other farms. Selection of the pilot farms required a number of steps. First, all dairy farms in the Netherlands were analysed in terms of agronomic performance (size, fodder production, milk production, nutrient surpluses, etc.) and environmental conditions (soil, region, etc.) to characterize the variability in dairy farming systems (Reijneveld *et al.*, 2000). Then, the results of this study were used to determine the most important selection criteria (region, intensity, and soil type). Advertisements and articles in agricultural magazines were used for publicity and for recruitment of potential participants. After a first screening, potential participants were visited and evaluated in terms of management, motivation, specific circumstances and communication ability (Aarts, 2001). Finally, 17 farms were selected, with emphasis on dry sandy soil, because of the specific constraints. Location and some characteristics of the farms are shown in Table 1.

Research methodology

For designing suitable farming systems the method of prototyping (Figure 2) was used, which implies a combination of system modelling and system implementation (Aarts *et al.*, 1992; Aarts, 2000). After collecting farm data, each participating farm was thoroughly analysed to identify its strengths and weaknesses in the original situation and to analyse the opportunities (Koskamp, 2000). This analysis also identified the gap between the targets for the various sustainability criteria and the reality of the original situation. Subsequently, outlines for farm designs were formulated for each participant. Consultations between farmer and research team yielded a list of measures based on best professional judgement; farmers had a strong influence on farm design (Beldman & Zaalmink, 2000). The next step was to simulate the effects of the new farm design with the farm-budgeting model BBPR (Alem & Van Scheppingen, 1993), to calculate the environmental and economic effects of the farm de-

Table 1. Location and characteristics of the commercial pilot farms in the Netherlands.



	Name	Domicile	Area (ha)	Kg milk ha^{-1}
1	Post[1]	Nieweroord	33	12,200
2	Kuks	Nutter	51	10,120
3	Bomers	Eibergen	49	12,930
4	Eggink[1]	Laren (Gld.)	33	15,290
5	Menkveld & Wijnbergen	Gorssel	47	15,470
6	De Kleijne	Landhorst	29	19,820
7	Pijnenborg-van Kempen	IJsselstein	26	20,990
8	Schepens[1]	Maarheze	27	16,660
9	van Laarhoven[1]	Loon op Zand	32	15,600
10	Hoefmans[1]	Alphen (NBr)	36	15,350
11	Van Hoven	Cadier en Keer	42	15,600
12	Sikkenga-Bleker	Bedum	54	9,990
13	Miedema	Haskerdyken	40	11,820
14	Dekker	Zeewolde	47	22,840
15	Van Wijk	Waardenburg	34	16,840
16	Boekel	Assendelft	72	10,740
17	De Vries	Stolwijk	36	12,130

[1] from 1999

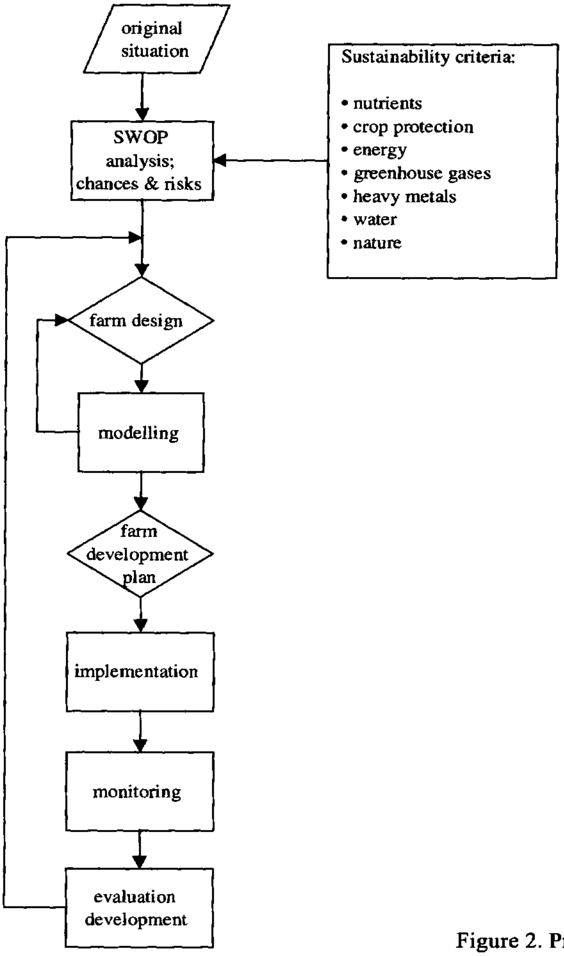


Figure 2. Prototyping process in 'Cows & Opportunities'.

sign, and to identify the best farm strategies (Galama *et al.*, 2000). After modelling and adjusting the farm design, the farm development plan (FDP) was constructed, approved and implemented (Koskamp, 2001).

Targets for nutrient surpluses

The target nutrient surpluses are based on MINAS. In this system, farmers have to monitor all incoming and outgoing N and P with imported and exported products at farm level on an annual basis (Figure 3). Surpluses of N and P (the difference between input and output) are linked to a target. Target surpluses for 2003, based on acceptable N and P losses to the soil, are shown in Table 2. Levies have to be paid if these targets are exceeded (Henkens & Van Keulen, 2001). The 'Cows & Opportunities' farms have to realize the targets for 2003 by the year 2000/2001.

Table 2. MINAS target surpluses for nitrogen and phosphate for the year 2003, in kg ha^{-1} (Henkens & Van Keulen, 2001).

Land use	Target surpluses (kg ha^{-1} per year)
Nitrogen	
Grassland	180
Grassland (dry sandy soil, löss)	140
Arable land	100
Arable land (dry sandy soil, löss)	60
Phosphate (P_2O_5) [1]	
All types of land use	20
Phosphate level insufficient[2]	50

[1] Inorganic phosphate fertilizers included.
[2] Only in 'Cows & Opportunities'

Targets for manure disposal

As a consequence of the implementation of the EU Nitrate Directive and the permitted amount of manure on agricultural land (Anon., 1991), the Dutch government will introduce a system of manure disposal agreements (Anon., 2000; Henkens & Van Keulen, 2001) from 2002 onwards. Farmers need a manure disposal contract if manure production at the farm exceeds the permitted quantity for application of manure on agricultural land. The calculated maximum manure production per farm is shown in Table 3.

Each farm has its specific target for N surplus and its target for maximum permitted manure production. Figure 7 explains the consequences if targets are not realized. The horizontal axis presents the deviation from the permitted farm-specific N surplus (MINAS target). All farms attempt to realize a value below zero. The devia-

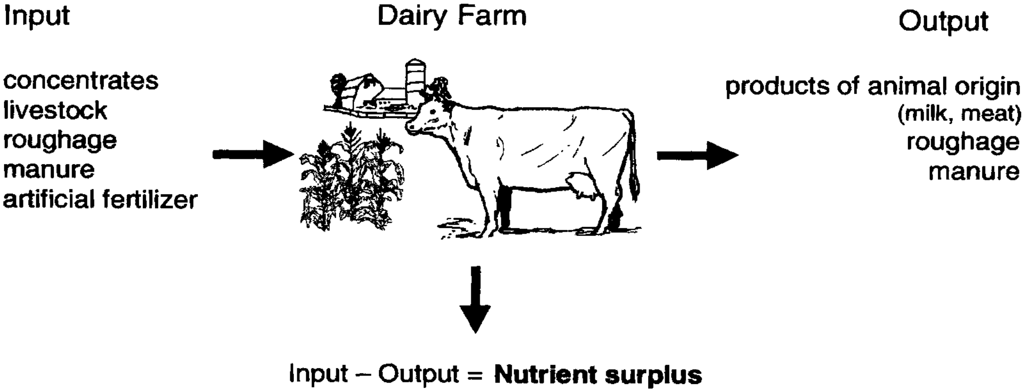


Figure 3. Inputs and outputs considered in the MINAS nutrient accounting system, expressed in kg N and kg phosphate per ha per year.

Table 3. Values for the calculation of manure production per farm (Anon., 2000).

	N target kg N per year
N production per animal category	
Cow	107,4
Young stock 1 year and older	73,8
Young stock up to 1 year	36,1
Maximum N application via animal manure from 2003 onwards	
Grassland (per ha)	250
Arable land (per ha)	170

tion from the maximum permitted manure production is presented on the vertical axis. These axes result in 4 quadrants:

1. *Bottom left: no problem*
   The MINAS targets are realized and a manure disposal contract is not necessary.
2. *Top left: (empty) manure disposal contracts*
   Manure production exceeds the permitted N application in manure, but the MINAS targets are realized. So a manure disposal contract is necessary, but no obligation to export manure to other farms.
3. *Bottom right: MINAS targets not realized*
   Manure production is lower than the permitted N application in manure, but the MINAS targets are not realized.
4. *Top right: manure disposal contract and MINAS targets not realized*
   Manure production exceeds the permitted N application in manure and the MINAS targets are not realized. A manure disposal contract is necessary, manure has to be exported to other farms and a fine has to be paid.

Data acquisition and analysis

At the start, farmers had to complete a questionnaire for the year 1997/1998 or 1998/1999 (original situation). Most of the data were derived from existing accounting administration. In the course of the project, data collection takes place on a monthly to annual basis. All data, originating from various sources, are entered in a database, as shown in Figure 4. Farmers themselves collect most data, half of them electronically, half on paper. Industry and services supply other data. Data from the Dutch Herd Book and from milk factories are collected through Electronic Data Interchange (EDI) and automatically stored in the central database. The third group of data is collected by the participating research organizations, which are also responsible for data flow and analysis. The results of the data analyses are also stored in the central database. Efficient data collecting and data processing have been identified as a critical success factor in this project.

Data are analysed for nutrients, economics, fertilization and soil fertility, forage production, animal nutrition and animal health, crop protection, energy, greenhouse

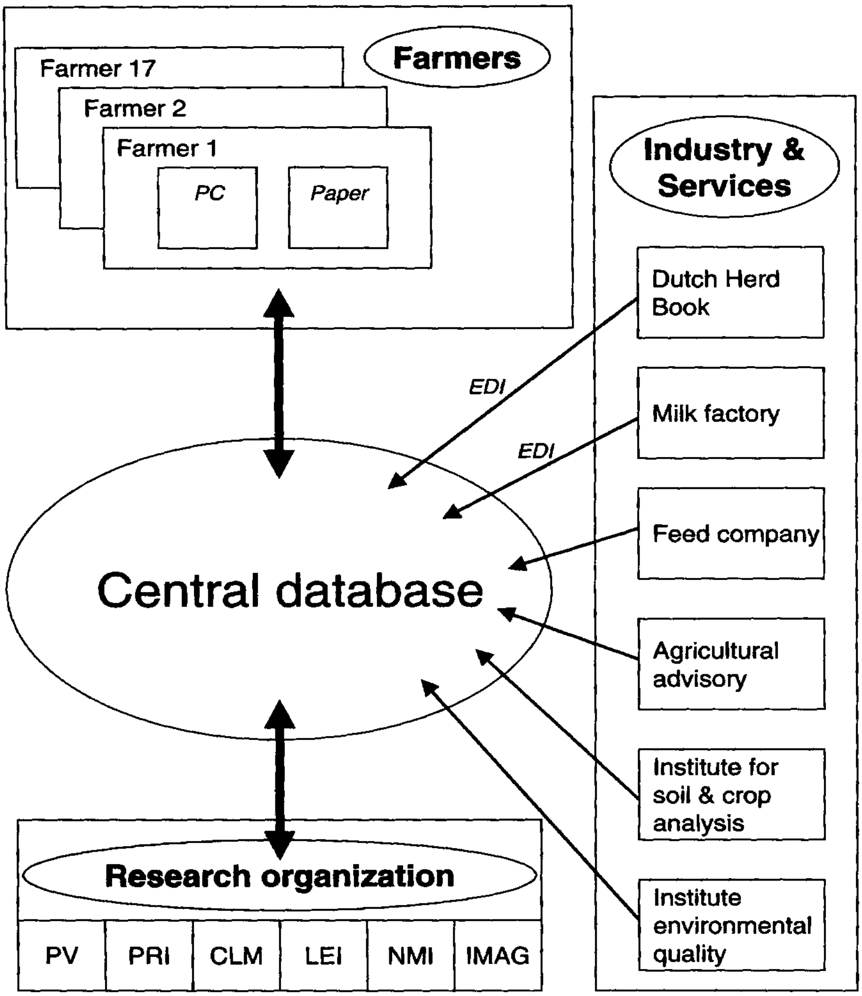


Figure 4. Structure of the data bank in the project 'Cows & Opportunities'.

gases, heavy metals, water, and nature development. As for nutrients, system balances at farm level are quantified (Oenema *et al.*, 2000). These system balances provide detailed information on inputs, outputs, losses and internal recycling, usually for a number of compartments, e.g. soil, crop, herd, and manure. Depending on the level of detail required, these compartments can be further subdivided into different pools (Jarvis, 1999). A schematic representation of the N cycle is given in Figure 5.

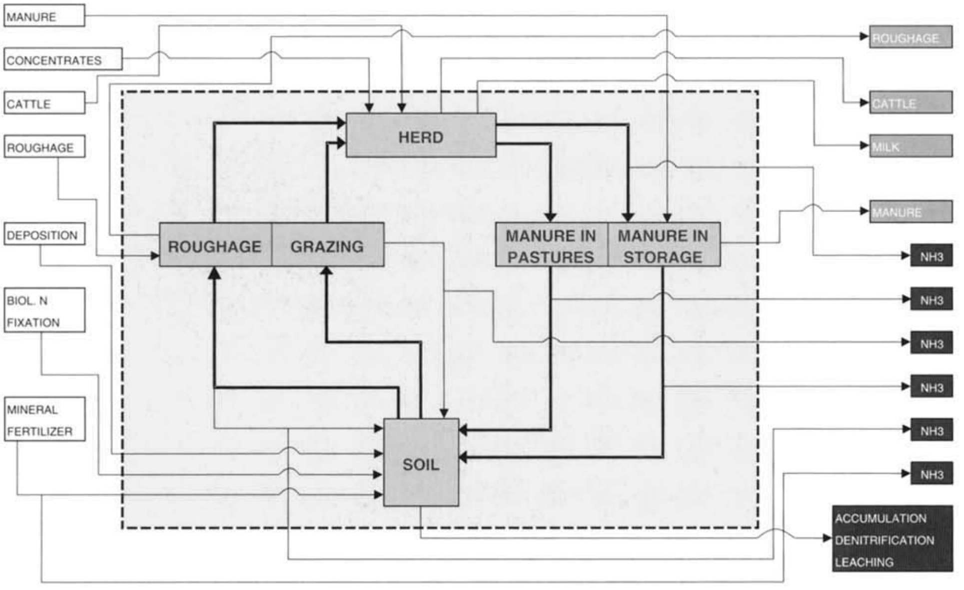


Figure 5. N cycle, with left the farm input, right the farm output and in de middle the internal recycling.

Results

N balance in original situation

The MINAS nitrogen balance in the original situation (1997/1998) for all farms is shown in Table 4. The farms have been arranged according to increasing level of milk production per ha (intensity). The N balance of 'De Marke' is given for comparison. The N surplus ranged from 47 to 349 kg ha^{-1}. The difference between the surplus in 1997/1998 and the MINAS target 2003 indicates the gap between the original situation and the objective. This difference ranges from 97 kg below to 243 above the target. Five of the 17 participating farms already realized the MINAS target. Four of these five are situated on sandy soil and one on peat soil. None of the 4 farms situated on clay soil realized the final MINAS target. Differences in surplus among farms are mainly related to differences in intensity, soil type, management and farming style.

Farm Development Plans (FDP)

The urgency to take measures varies among farms. Some farms already realized the final MINAS target in the original situation, while others still had to bridge a huge gap (see Figure 6). With a few exceptions, all measures that were suggested for the participating farms (Table 5) have already been tested on 'De Marke'. However, each measure has a farm-specific interpretation and a specific effect, because of the dif-

Table 4. MINAS nitrogen balance of the commercial pilot farms in the original situation (1997/1998).

	Sikkenga-Bleker	Kuks	Boekel	De Vries	Miedema	Post	Bomers	Eggink	Van Hoven	Hoefmans	Van Wijk	Van Laarhoven	Menkveld & Wijnbergen	Schepens	De Kleijne	Pijnenborg-Van Kempen	Dekker	De Marke
INPUT																		
Cattle	0	5	0	1	0	0	11	0	0	0	0	0	0	0	0	0	3	0
Manure	0	10	0	4	13	0	0	2	0	27	0	0	10	74	38	48	0	0
Inorganic fertilizers	232	117	197	145	234	222	0	113	228	183	249	224	206	171	109	218	221	63
Concentrates	79	102	102	131	83	83	78	117	122	111	140	103	124	201	172	196	194	73
Imported roughage	0	0	54	12	26	13	78	33	57	7	47	66	9	68	45	47	79	10
Total	311	234	352	292	357	317	167	265	407	329	436	393	349	514	363	508	498	146
OUTPUT																		
Milk	54	55	58	63	65	65	69	76	79	82	84	84	87	93	109	113	120	63
Cattle	9	10	9	18	11	10	15	13	3	13	12	23	16	20	18	17	17	7
Manure	0	0	0	42	0	9	0	16	91	0	0	0	0	0	76	94	93	7
Permitted NH3 losses	2	27	7	7	24	20	36	43	42	38	29	40	38	52	59	54	50	13
Total	65	93	73	130	99	104	121	148	215	133	125	147	141	165	262	277	281	90
SURPLUS	245	141	279	162	257	214	47	117	192	196	311	246	208	349	101	231	217	56
MINAS target 2003	170	142	174	180	172	135	144	120	117	110	174	128	144	106	115	160	157	132
SURPLUS – target	75	0	104	–18	85	79	–97	–3	75	86	136	118	64	243	–14	71	59	–76

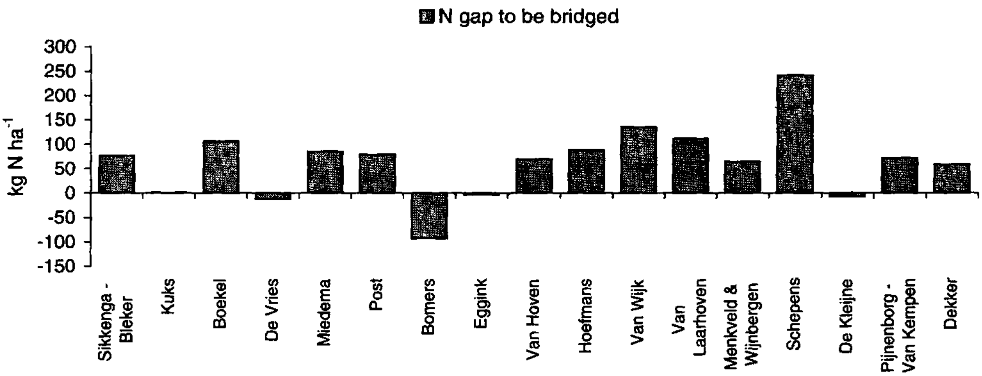


Figure 6. N surplus gap to be bridged by the farm development plan.

ferences in environmental conditions among farms, especially in soil type. Brief explanations of the important measures to be taken by the farms are as follows:

1. *Acquisition of milk quota and land*
   Many farms have invested or intend to invest in milk quota or in land. This will change the milk production per ha in subsequent years. Intensively managed farms invest mostly in land, extensively managed farms mostly in quota.
2. *Ratio grassland/maize*
   The optimal ratio for grassland to maize land varies per farm and region. Generally, it is economically attractive for the intensively managed farms on clay soil to purchase silage maize instead of producing it. Conditions for growing silage maize and for grassland on sandy soils in the south and east are different from those on clay and peat soils in the west and north of the Netherlands. It is attractive to grow maize on sandy soils. Participating farmers aim at growing both sufficient energy-rich and sufficient protein-rich fodder.
3. *Fewer cattle*
   A lower number of cattle implies less manure and often lower nutrient surpluses. This also holds for young stock. A small number of young stock can be realized when the replacement rate is low and milk production per cow high. A high milk production per cow also allows keeping fewer cattle, though this may affect the feed ration and health of the cows, with possible consequences for the cost-effectiveness of a higher milk production per cow.
4. *Lower fertilizer level*
   Lowering the rate of N application will ultimately lead to a reduction in crop yield. Many participants also have to reduce total phosphate application and to omit application of phosphate fertilizer. Its effect on crop yields in the short term is not yet clear. It is expected that crop yields will not or hardly decrease (Habekotté *et al.*, 1999). The adjusted fertilization levels at the participating farms are often lower than the current official recommendations.
5. *Less purchased concentrate feed*
   On most farms, the input of nutrients via purchased animal feed is very high. In

Table 5. List of measures per participant (farms are presented in order of increasing milk production per ha).

Measure	Sikkenga-Bleker	Kuks	Boekel	De Vries	Miedema	Post	Bomers	Eggink	Van Hoven	Hoefmans	Van Wijk	Van Laarhoven	Menkveld & Wijnbergen	Schepens	De Kleijne	Pijnenborg-Van Kempen	Dekker
Changing farm lay-out																	
More milk quota	x		x	x		x		x	x	x	x					x	
More land area			x	x		x	x					x	x			x	x
More grassland less maize					x			x									
More maize less grassland	x	x				x			x		x						
(extra) nature conservation and							x					x	x				
Less grazing						x				x		x	x			x	
Sowing grass/clover mixtures	x									x							
Catch crop after maize						x			x	x							
Changing herd																	
More milk per cow					x			x		x			x		x	x	x
Less young stock		x						x		x		x		x		x	x
Farm out raising cattle																	
Changing fertilization																	
Higher improvement manure									x						x		x
Lowering N application	x	x	x		x	x		x	x	x	x	x	x	x	x	x	
Lowering inorg. phosphate appl.	x	x	x		x	x			x	x	x	x	x	x	x	x	x
No farm input manure										x							
No farm output manure													x		x		
Changing feeding regime																	
Feeding recommended mount	x	x	x	x	x	x			x		x		x	x	x	x	x
Less P in concentrates		x									x		x			x	

the original situation it is on average 50% of total N and 75% of total P input. This is much higher than required according to the animal nutrition recommendations. So it is important to adjust nutrition to the recommendations.

The selection of measures depends on farm-specific conditions, professional skills and enterpreneurship. For example, farmer Van Wijk will be able to realize the environmental targets with a high level of concentrate use. He manages his farm intensively and aims at a high milk production per cow. High input of concentrates instead of purchased roughage saves costs of, for example, roughage storage. This also allows realization of a more balanced feed ration over the whole lactation period. Van Wijk's feed supplier has developed a new concentrate feed with a low protein content to reduce the input of N. In contrast, farmer Miedema has adopted zero grazing to realize a higher grass production. Farmers Dekker and Schepens are using 'waste products' as purchased concentrates to reduce feed costs. On the farm of Sikkenga-Bleker (clay soil), grass-clover swards have been introduced to reduce the input of N fertilizer, even though this measure may not reduce total N input.

Model-predicted N balances: the prognosis

A prognosis of the results – e.g. the MINAS nitrogen balance – after applying the proposed strategies, was formulated for each individual farm (Table 6). The N surplus ranged from 6 to 224 kg ha^{-1}. After applying the proposed strategies, 5 farms do not yet realize the final MINAS targets. They are the most intensively managed farms, three situated on clay soil and two on dry sandy soil. Miedema and Van Wijk's farms do take many measures, but the effects of these measures are partly offset by the purchase – for economic reasons – of milk quota and the associated intensification. Miedema might realize the MINAS target by renting some additional land. In the short run, Dekker might realize the target by exporting more animal manure.

Figure 7 displays the position of the farms with respect to the N surplus target and the target for the permitted manure production. Also the (actual) position of 'De Marke' and the position of the average Dutch dairy farmer (Reijneveld *et al.*, 2000) are presented. Evidently, on a number of farms manure production per ha exceeds the standard for 2003. In other words, about half of the farms need a manure disposal contract. Of these farms, five also do not realize the N target. Dekker and Miedema exceed the N target by about an equal rate, but Dekker manages his farm more intensively. The physical conditions at Dekker's farm (well-drained clay soil) are better than at Miedema's farm (poorly drained clay over peat). Possible additional measures for these five farms are: (i) reducing chemical fertilizer, through better utilization of animal manure, (ii) reducing purchase of protein-rich concentrates, and (iii) purchasing or renting of more land, though this is very expensive. Another possible solution is to import more animal feed, instead of chemical fertilizer, but ultimately this option is not sustainable because of the externalization of the environmental costs associated with producing animal feed on other farms. Results for the farms of De Kleijne and Pijnenburg-Van Kempen show that the N surplus target can

Table 6. MINAS nitrogen balance after applying the proposed strategies (model calculations).

	Boekel	Menkveld & Wijnbergen	Kuks	Eggink	Van Laarhoven	Bomers	Post	Sikkeng-Bleker	Miedema	De Vries	Van Hoven	Van Wijk	Pijnenborg-Van Kempen	Hoefmans	Schepens	Dekker	De Kleijne
INPUT																	
Cattle	0	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0
Manure	0	0	21	6	0	0	0	0	13	5	0	0	45	0	0	0	0
Inorganic fertilizers	115	125	133	100	104	0	100	96	173	144	188	131	143	108	141	129	89
Concentrates	73	89	75	100	93	81	114	89	57	97	99	117	134	148	98	146	113
Imported roughage	39	1	2	2	4	23	2	42	72	42	29	117	31	40	87	109	94
Total	227	215	232	207	201	112	216	228	316	288	316	365	353	296	326	384	295
OUTPUT	0	0	0					0	0	0	0	0	0			0	0
Milk	60	64	64	64	65	65	69	72	79	79	82	94	102	105	106	110	113
Cattle	9	7	8	10	9	11	9	10	13	8	15	16	12	13	13	13	18
Manure	0	0	0	0	0	0	4	0	0	35	84	0	68	0	0	19	12
Roughage	3	24	19	27	15	0	4	0	0	16	0	0	0	0	0	0	0
Permitted NH3 losses	2	4	18	16	9	31	21	11	30	5	34	30	45	39	46	44	59
Total	74	99	108	118	98	106	107	93	122	143	215	141	226	157	166	185	201
SURPLUS	154	116	124	89	102	6	108	135	194	145	100	224	127	139	161	199	94
MINAS target 2003	175	148	153	138	136	173	134	171	165	180	129	180	150	122	109	158	115
SURPLUS – target	–21	–32	–29	–48	–33	–167	–26	–36	29	–35	–29	44	–23	17	52	41	–21

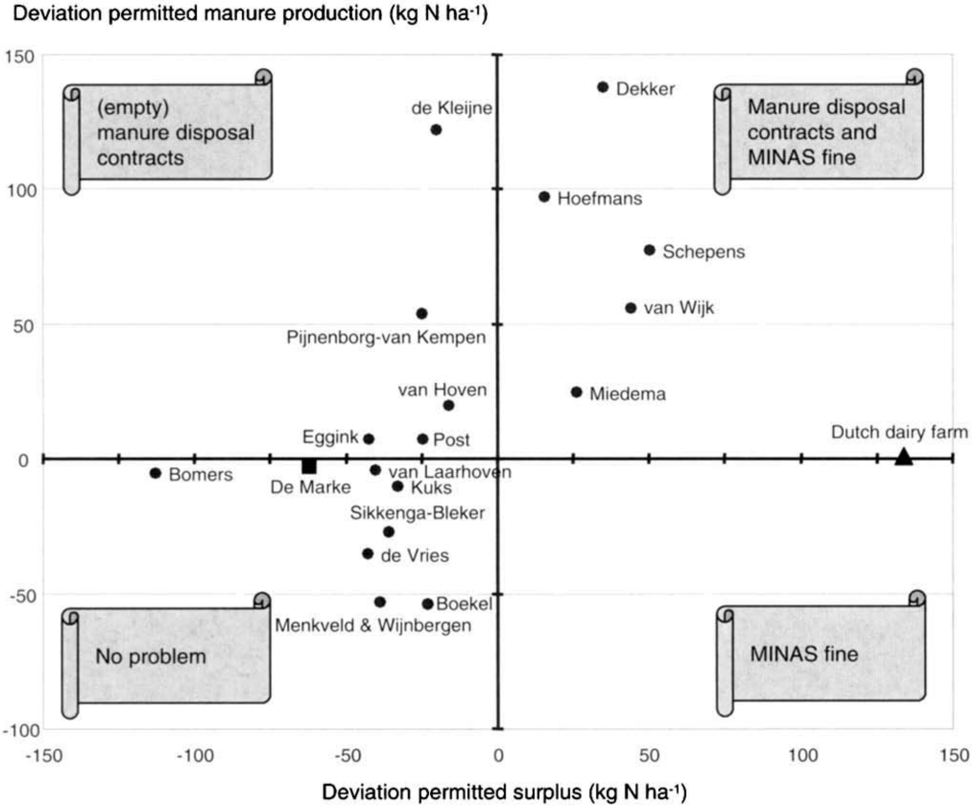


Figure 7. Expected deviation of the farms compared with the permitted manure production and compared with the permitted N surplus, after applying the strategy (kg N ha^{-1}).

also be realized on farms with highly intensive farm management without or with little manure output.

Nitrogen balance in 1999

Table 7 shows the average MINAS balance of the farms in 1999 compared with the original situation and as calculated (prognosis). The N surplus of the farms decreased from 207 kg per ha in the original situation (1997/1998) to 163 kg in 1999. The prognosis indicated that the average N surplus should have gone down to 138 kg ha^{-1}. In the original situation, the N surplus exceeded the MINAS target by 62 kg ha^{-1}, whereas in 1999 it was exceeded by an average of 38 kg ha^{-1}. The reduction in fertilizer input (from 180 to 150 kg N ha^{-1}) contributed most to the decrease in N surplus. Both, the purchase and the export of animal manure and organic soil amendments also decreased. Input decreased from 13 to 10 kg N ha^{-1}, while output decreased from 25 to 12 kg N ha^{-1}. This points to an attempt to improve utilization of farm-produced animal manure.

Table 7. Average MINAS nitrogen balance of the commercial pilot farms in the original situation (1997/1998), in 1999, the calculated N balance in the prognosis, and the difference between 1999 and the prognosis (kg N ha^{-1}).

	1997/ 1998 A	Range	1999 B	Range	Prognosis C	Range	B–C
INPUT							
cattle	1	(0–11)	1	(0–9)	0	(0–8)	1
manure	13	(0–74	10	(0–29)	5	(0–45)	4
inorganic fertilizers	180	(0–249	150	(0–252)	119	(0–188)	23
concentrates	126	(78–201)	122	(69–186)	101	(57–148)	19
imported roughage	38	(0–79)	37	(7–127)	43	(1–117)	–8
Total	358	(167–514)	319	(119–553)	269	(112–384)	40
OUTPUT							
milk	80	(54–120)	82	(52–115)	82	(60–113)	–1
cattle	14	(3–23)	12	(6–23)	11	(7–18)	1
manure	25	(0–94)	12	(0–74)	13	(0–84)	–2
roughage	0	(0–0)	1	(0–9)	6	(0–27)	–6
permitted NH3 losses	33	(2–59)	31	(0–54)	26	(2–59)	6
Total	152	(65–281)	138	(59–255)	139	(74–226)	–3
SURPLUS	207	(47–349)	181	(8–305)	131	(6–224)	25
MINAS target 2003	144	(106–180)	144	(106–180)	149	(109–180)	–12
SURPLUS – target	62	(–97–243)	38	(–136–174)	–19	(–167–52)	37

Discussion and conclusions

The combination of system modelling and system prototyping is an attractive method for developing strongly improved dairy farming systems (Aarts, 2000; Van Keulen *et al.*, 2000). Results of 'De Marke' indicate that such prototypes can indeed be realized on experimental dairy farms. Prototypes of sustainable dairy farming systems have also been designed, for example, in Germany and the United Kingdom (e.g. Weisbach & Ernst, 1994; Peel *et al.*, 1997), and for arable farming in the Netherlands (e.g. Vereijken, 1992). It is attractive also because it allows active participation of farmers and other stakeholders in the whole process from analysis to monitoring and evaluation (e.g. Figure 2).

'Cows & Opportunities' is the practice-oriented follow-up of experimental dairy farm 'De Marke' that involves close co-operation of enterprising and future-oriented dairy farmers, researchers and other stakeholders to develop and demonstrate strategies for sustainable dairy farming. Ultimately, the project will demonstrate whether commercial dairy farmers can realize the various prototypes in practice. At the same time, it also will prove whether the current recommendations, for instance for animal nutrition, and for fertilizer and manure application, are suitable for realizing the environmental targets. 'Cows & Opportunities' should also demonstrate whether the improved dairy farming systems are economically viable. So far, results of the project demonstrate that it is possible to realize the target N surplus for the year 2003, even on intensively managed dairy farms. Results also indicate that the targets cannot be easily realized on all farms. However, various opportunities exist for these farms to further improve management and reduce nutrient surpluses.

The gap in N surplus between what is possible and what is realized in dairy farming in practice is large. At the start of 'Cows & Opportunities', the mean N surplus (MINAS) of the farms was 207 kg ha^{-1} (Table 4), which is much lower than the 304 kg ha^{-1} averaged for all Dutch dairy farms in the same period (Reijneveld *et al.*, 2000). Both values are much higher than the N surplus (MINAS) of 90 kg ha^{-1} on 'De Marke' (Hilhorst & Oenema, unpublished data). Many dairy farmers fear that reducing the N and P surpluses to the levels required for the year 2003 (target surpluses) will be expensive, for example, because of lower forage production when reducing fertilizer application. For similar reasons farmers often buy more protein-rich animal feed than is needed for economically attractive milk production. Measures introduced on experimental dairy farm 'De Marke' to realize the environmental quality, increase the costs by almost Dfl. 6 per 100 kg milk (De Haan, 2001). Moreover, farmers are worried about the impact of lower nutrient surpluses on soil fertility.

Farmers participating in 'Cows & Opportunities' share their experiences with each other and with other farmers. So these farmers closely co-operate with farmers of the project 'Farmers Data II', with 180 participants. Also study groups were formed around 'Cows & Opportunities', to ensure that participants of 'Farmers Data II' receive first-hand information. Farmer-to-farmer communication is the best way to transfer knowledge from research to practice. Moreover, publishing results in agricultural magazines and organizing excursions are used to contact other dairy farmers.

In conclusion, the project 'Cows and Opportunities' forms a unique link in the chain of information and knowledge transfer from theoretical and experimental research to commercial dairy farms. Representative dairy farms have been selected with enterprising and future-oriented farmers who are able to quickly adopt measures. As a result, these farms will also demonstrate the practical feasibility of prototype dairy farming systems developed by research. Results of monitoring in the coming years will indicate whether this promise holds, and whether the pilot farms serve indeed as examples for other commercial dairy farms.

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