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Economics of environmental measures on experimental farm 'De Marke'

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Abstract

Experimental farm 'De Marke' aims at realizing very low mineral surpluses by implementation of a variety of measures that not only lead to low mineral surpluses but also have economic consequences. The aim of this study was to calculate the economic consequences of individual environmental measures using simulation models. The measures were implemented sequentially, starting from a base situation and ending with a situation closely resembling 'De Marke'. The order of implementing the measures that could have a decisive influence on the economic effect, represents declining cost effectiveness. The base situation, which also affects the size of the effects of the individual measures, represents 'De Marke' without strict environmental targets. Most of the measures implemented at 'De Marke' led to a lower income. However, keeping less young stock, more efficient grazing, and crop rotation of maize and grass increased net income, while the nitrogen surplus declined. Growing grass under maize and a better protein feeding strategy were rather cheap. Especially grass under maize substantially reduced the nitrogen surplus (15 kg ha^{-1}). Shortening the grazing period, low-emission housing and home production of concentrate were expensive measures that hardly reduced the nitrogen surplus. Reducing nitrogen fertilization and growing and feeding maize drastically reduced net income but also substantially reduced nitrogen surplus. These measures were effective.

All measures combined led to a (calculated) reduction in net income for 'De Marke' of about Dfl. 37,500[a] or almost Dfl. 6 per 100 kg milk. Farmers' income decreased with more than Dfl. 5 per 100 kg milk. The results of this study, which are valid for 'De Marke', also hold for farms under the same conditions at the end of the 1990s.

Keywords: economics, environmental measures, model, farm budgeting programme (BBPR), nitrogen surplus.

Introduction

Experimental farm 'De Marke' tries to realize very strict environmental goals. The farming system of 'De Marke' is based, therefore, on various measures (Biewinga *et*

[a] Dfl. 100 = € 45.38.

al., 1992) that not only lead to very low mineral surpluses, but also have economic consequences. Various economic evaluations of 'De Marke' have been performed. Daatselaar & De Hoop (1999) carried out an economic evaluation from the start of 'De Marke' until 1998, and compared its results with representative groups of farms on the basis of actual economic indicators from the past financial years. Mandersloot *et al.* (1998) and Van Assen *et al.* (1998) have shown the differences between 'De Marke' *with* and 'De Marke' *without* strict environmental standards. The two farm situations have been compared in a model study, in which economic differences resulting from all imposed environmental measures combined were analysed. However, such an analysis does not provide information on the economic effects of individual measures.

The aim of the present study is to calculate economic consequences of individual environmental measures. This is achieved by introducing the measures sequentially, starting from a base situation and ending with a situation in which all environmental measures have been introduced. In other words, the effect of each new measure is calculated following implementation of the preceding one. The order in which the various measures are introduced can have a decisive influence on the economic effect. Therefore, the results of the WUR-ABE study (Wolleswinkel, 1999) were used. In this study the economic effect of each individual measure was determined separately, but not before the farm situation was optimized. The effects of each individual measure were calculated one by one, using linear programming (Berentsen & Giesen, 1995). The order of stacking the measures in the present study is based on 'cost effectiveness', i.e., the change in net farm income (Dfl. per 100 kg milk) associated with a reduction in nitrogen (N) surplus of 1 kg ha^{-1} (Wolleswinkel, 1999). In other words, introduction of the measures starts from the one that is economically most attractive. Apart from the order of stacking, the assumed base situation ('De Marke' without strict environmental targets) is important for the effects of the individual measures. That situation is (essentially) the same as the one calculated by Wolleswinkel (1999) and represents the 'model' farm on which all measures are introduced sequentially. The technical relations in this study are similar to those of Mandersloot *et al.* (1998), Van Assen *et al.* (1998) and Wolleswinkel (1999).

To realize the objective of the present study – apart from introducing the measures sequentially – simulation models are used for the following reasons. Firstly, only differences in farming strategy associated with the specific environmental measures are of interest. In simulation models these can be isolated. Secondly, the farming system 'De Marke' is unique. Moreover, various farm specialists are involved in 'De Marke'. So the results are not only the consequences of the measures that have been introduced, but also those of the management level and the specific situation at 'De Marke'. By applying simulation models, corrections can be introduced for management effects. Another advantage of using simulation models is that in farm management 'Good Agricultural Practice' (Anon., 1993) can be assumed.

Material and methods

Models

The models used in this study were developed at the Research Station for Cattle, Sheep and Horse Husbandry in Lelystad. The 'dairy model' (Anon., 1997) was used to calculate the feed rations and the feeding strategy. The farm budgeting programme (BBPR; Van Alem & Van Scheppingen, 1993) was used to carry out farm economic calculations, and the module 'mineral flow' (Schreuder *et al.*, 1996) of the farm budgeting programme, to calculate effects on mineral surpluses. The starting points and the situations that are compared are very important in model calculations. In this study always two situations are compared, i.e., a situation *with* and a situation *without* a certain environmental measure. Each situation refers to very dry sandy soil and to new buildings, slurry and feed storage. As in the long run the technical effects of all adjustments on 'De Marke' are still unknown, the results of this study are valid for a rather short period of time (a number of years).

Base situation: farm characteristics

As the base situation ('De Marke' without strict environmental targets) influences the effects of the individual measures, this 'model' farm is the starting point. Some farm characteristics in the base situation are similar to those of 'De Marke', others are different (De Haan, 2000; Table 1). Prices and tariffs applied are averages of recent years, as used by Mandersloot *et al.* (1998), Van Assen *et al.* (1998) and Wolleswinkel (1999), and so are different from those in the actual situation at 'De Marke'.

The base farm – like 'De Marke' – has 55 ha of very dry sandy soils and a milk quotum of 658,500 kg with 4.33% fat reference (Aarts *et al.*, 1994). The area of maize, fertilizer application rates and herd composition differ from those at 'De Marke'. The area of maize and the cattle ration have been determined through optimization (Wolleswinkel, 1999). The work force comprises exactly two full-time labourers. The size of the farm buildings exactly matches the requirements of the herd and the required slurry storage capacity. Feed storage capacity can hold all the roughage, and the available machinery covers the requirements for all own activities. Each autumn, 16.7% of the grassland is renovated resulting in a 15% lower yield from the first cut in the following year.

The cropping plan in the base situation was optimized to 36.6 ha of grassland and 18.4 ha of maize land. Gross yields of the grassland were 11,100 kg dry matter (DM) per ha, used partly for grazing and partly for ensiling. Grazing losses were set at 17%, harvest and conservation losses both at 6%. On grassland the N application rate was 350 kg ha^{-1}. After conservation, approximately 150,000 kg DM in the form of grass silage was available. Gross yields of maize were 11,750 kg DM ha^{-1}, which amounts to approximately 215,000 kg DM for the whole farm. The roughage surplus in this situation was sold. On maize 150 kg N ha^{-1} were applied.

Contractors carried out ensiling, maize harvesting, slurry injection and grassland renovation.

Table 1. Farm characteristics in the base situation.

Area	(ha)	55
grassland	(ha)	36.6
maize	(ha)	18.4
Land at distance from farm	(ha)	16.5
Milk quotum	(*10^3 kg)	658.5
Quotum ha^{-1}	(kg milk)	11,973
Fat reference	(%)	4.33
Annual milk production	(kg per cow)	8,300
Fat	(%)	4.40
Protein	(%)	3.50
Milk price	(Dfl. per kg)	0.74
Number of cows		78.35
Replacement rate	(%)	38.03
Number of heifers		30.4
Number of calves		31.0
N application grassland	(kg ha^{-1})	350
N application maize	(kg ha^{-1})	150
Cattle housing	Cubicle barn with slurry storage	

Base situation: cattle rations

In the base situation, milking cows grazed on average 12 hours per day from May till November, with 18 hours per day during the first two months and 9 hours during the remainder of the period. Dry cows never grazed. Heifers grazed from May till November, and calves in July and August.

During the summer period, cows received a substantial amount of maize in addition to a daily supply of about 12 kg DM grass, and about 4.5 kg of concentrate. Heifers ingested 7.3 kg DM grass, and calves 4 kg DM grass and 0.5 kg of concentrate during grazing. During the winter period cows ingested 8.7 kg DM grass silage, 5.3 kg DM maize and 7 kg of concentrate. Dry cows were offered grass silage of poor quality, maize and straw. To attain a balanced ration, dry cows received 0.5 kg of concentrate. Heifers were fed the same products as dry cows in the winter period, but were offered more grass silage and less maize silage. Calves received grass silage of good quality, maize and almost 1 kg of concentrate. Straw for feeding dry cows and heifers was bought. As the feeding strategy resulted in a maize surplus, maize was sold.

Base situation: economy and N surplus

The farm economic results in the base situation (Table 2) show that income consisted of the proceeds from sales of milk (Dfl. 74 per 100 kg), cattle and maize (45,000 kg at Dfl. 0.185 per kg DM), and a premium for growing maize (Dfl. 10,948).

Feeding costs were the main item in the variable costs, followed by costs for fertilizer and direct cattle costs. Although variable costs were high, fixed costs, i.e., costs

Table 2. Farm economic results in the base situation.

	Total	Per 100 kg milk
	Dfl.[1]	Dfl.[1]
A. INCOME	549216	84.46
B. VARIABLE COSTS	135882	20.90
of which:		
– Feeds	61136	9.40
– Crop protection	6112	0.94
– Fertilizer	14602	2.25
– Seed and plant costs (incl. interest)	11152	1.71
– Direct cattle costs	42880	6.59
C. BALANCE (A - B)	413334	63.56
D. FIXED COSTS	538425	82.80
of which:		
– (E) Labour	171200	26.33
– Contract work	56191	8.64
– Machinery, installations and equipment	108409	16.67
– Land and buildings	174091	26.77
– General costs	28534	4.39
F. NET INCOME (C – D)	–125091	–19.24
G. FARMERS' INCOME (E + F)	46109	7.09

[1] Dfl. 100 = € 45.38.

of labour, land and buildings, machinery, contract work and general costs exceeded them. The two labourers represented costs of over Dfl. 170,000. Especially the costs of contract work were high.

The milk quotum in the base situation was almost 12,000 kg ha^{-1}, indicating that the situation was not very intensive. Animal density, calculated according to the phosphate norm, was below 1.8 Livestock Units per hectare, so that introduction of the Mineral Accounting System (MINAS) becomes compulsory only in the year 2001 (Henkens & Van Keulen, 2001). The farm N balance in the base situation (Table 3) shows that input of N in concentrate was just over 75 kg ha^{-1}. N input in fertilizer was less than 200, whereas the output in milk, cattle and roughage amount-

Table 3. Nitrogen balance (kg ha^{-1}) in the base situation.

Inputs		Outputs	
Roughage	4	Cattle	10
Concentrate	76	Milk	65
Fertilizer	197	Roughage	10
Miscellaneous (straw, etc.)	1		
Atmospheric deposition	49		
Total	327	Total	85
N surplus (inputs – outputs): 242 kg ha^{-1}			

ed to 85 kg N ha^{-1}. Including deposition and straw, the N surplus was almost 250 kg ha^{-1}. However, currently MINAS does not take into account deposition and straw, but does correct the balance for animal density (20 kg ha^{-1}) as output. As a result the MINAS-N surplus is 172 kg ha^{-1} (Table 3).

Environmental measures

The various environmental measures introduced at 'De Marke' (Biewinga *et al.*, 1992; Mandersloot, 1993; Aarts *et al.*, 1994; Aarts, 1995; Van Dijk *et al.*, 1995a; 1995b; Mandersloot & Hageman, 1995; Schröder & Van Dijk, 1995; Hack-Ten Broeke & Aarts, 1996; Nijssen *et al.*, 1996; Zom & Meijer, 1998) were implemented sequentially in the calculation procedure. The measures can be classified into three groups: (1) cattle and crop rotation, (2) fertilization and feeding, and (3) building adjustments (Table 4). In addition to consequences for the environment, the measures also have effects on farm management and economic results. In the current study a few measures were added to those of Wolleswinkel (1999), viz. *reduced phosphate fertilization* (Oenema & Van Dijk, 1994; Anon., 1995; Den Boer *et al.*, 1995a; 1995b; Schreuder *et al.*, 1996) and *growing 25 ha of maize* (instead of 18.4 ha).

In the analysis, the measures were stacked in the following order:

1. Keeping less young stock and reducing replacement rate of cattle.
2. Rotation of grassland with maize.
3. More efficient grazing system, i.e., siesta grazing and heifers grazing for two days following the milking cows.

Table 4. Adjustments in farm management to approach the situation of 'De Marke'.

Adjustment	Environmental effect
Cattle and crop rotation	
Less young stock	Lower mineral supply in feed
Growing and feeding ground maize ear silage	Lower supply of concentrate, regional mineral management
Crop rotation of grassland with maize	Reduced fertilizer level, higher maize yields
Fertilizer level and feeding	
Reduced phosphate fertilizer level	Lower phosphate surplus
Reduced nitrogen application	Reduced fertilizer requirement, reduced nitrate leaching
More efficient grazing system	Improved utilization of grass
Catch crop under maize	Reduced fertilizer requirement, reduced nitrate leaching
Feeding of milking cows according to norm	Improved utilization of nitrogen in feed
Feeding more maize in the summer period	Improved utilization of nitrogen by cattle
Shortening grazing period of milking cows	Reduced nitrate leaching, improved utilization of grass
Building adjustments	
Low-emission housing	Reduced ammonia emission

4. Feeding milking cows according to protein norms by creating production groups.
5. Catch crop under maize.
6. Reduced N fertilizer application and shortening the period of application of animal manure.
7. Reduced phosphate fertilization.
8. Feeding more maize in the summer period.
9. Expanding the area of maize to 25 ha.
10. Shortening the grazing period for milking cows.
11. Low-emission housing.
12. Preventing roughage surplus, which means harvesting and feeding ground maize ear silage.

Results

Most of the measures taken aim at reducing the N surplus. This also affects the economic results. Table 5 shows the farm economic results for all calculated situations. For detailed information on all calculations see De Haan (2000). The financial results are presented as 'net income' and 'farmers' income', where costs for labour *are* included in net income, but *are not* in the farmers' income. Labour in general represents costs, but not always expenses. Estimation of labour costs is based on calculations of WUR-ABE (Wolleswinkel, 1999) and the project team 'De Marke'.

Table 6 shows the N balances for the 13 situations considered, each representing a situation in which one additional measure has been implemented. Both the 'real' N surplus and the MINAS-N surplus are given. All measures resulted in reduced N surpluses, except implementing *reduced phosphate fertilization*, but this measure strongly reduces phosphate surplus.

Economic effects and effects of each measure on N surplus are described below.

Keeping less young stock and reducing replacement rate of cattle

As fewer animals are sold, this measure led to reduced income. However, income from the sale of roughage slightly increased. Feeding costs decreased, while costs for fertilizer slightly increased. Furthermore, costs for veterinary care are assumed to have increased. Costs for contract work and buildings strongly decreased. Net income increased by Dfl. 2200 and farmers' income by Dfl. 1250. N surplus was reduced by approximately 5 kg ha^{-1}.

Rotation of grassland with maize

This measure led to additional maize production, so that income from sale of roughage slightly increased. Costs for concentrate and crop protection decreased, as did labour costs. Costs for seed and costs for contract work increased. Fencing led to additional expenses. Net income decreased by more than Dfl. 300, whereas farmers' income decreased by Dfl. 2000. N surplus was reduced by about 3 kg ha^{-1}.

Table 5. Farm economic results (Dfl. per farm) for the various situations, in which measures have been implemented sequentially.

		Base situation	Less young stock	Crop rotation	More efficient grazing	Improved feeding protein norm	Catch crop under maize	Reduced N fertilizer	Reduced P fertilizer	Feeding more maize in summer	Growing more maize	Shorter grazing period	Low emission housing	Harvesting and feeding maize ear silage
Number of cows		78.35	78.35	78.35	77.75	77.75	77.75	77.75	77.75	76.85	76.85	77.08	77.08	77.08
Milk quotum	(tons)	650.28	650.28	650.28	667.84	667.84	667.84	667.84	667.84	667.84	667.84	664.39	664.39	664.39
Area grassland	(ha)	36.6	36.6	36.6	36.6	36.6	36.6	36.6	36.6	36.6	30	30	30	30
Area maize	(ha)	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	18.4	25	25	25	20.4
Area maize ear silage	(ha)	0	0	0	0	0	0	0	0	0	0	0	0	4.6
Number of young stock		61	53	53	52	52	52	52	52	52	52	52	52	52
Milk production	(kg per cow)	8300	8300	8300	8590	8590	8590	8590	8590	8690	8690	8620	8620	8620
N application to grassland	(kg ha^{-1})	350	350	350	350	350	350	250	250	250	250	250	250	250
A. INCOME (Dfl[1])		549 216	548 007	548 391	553 186	553 142	553 890	543 310	543 310	547 709	547 579	543 949	543 949	538 877
B. VARIABLE COSTS (Dfl.)		135 882	138 062	138 211	137 948	137 385	137 594	134 054	133 748	137 194	141 325	137 306	136 880	129 948
of which:														
Feed		61 136	60 517	60 135	61 547	60 885	60 238	60 473	60 463	64 721	64 767	60 339	60 339	53 647
Crop protection		6 112	6 112	6 008	6 008	6 008	6 008	6 008	6 008	6 008	6 901	6 901	6 901	6 901
Fertilizer		14 602	14 838	14 614	13 286	13 385	12 449	8 674	8 378	8 090	7 474	7 274	6 848	6 608
Seed and plant costs (incl. interest)		11 152	11 152	12 011	12 011	12 011	13 851	13 851	13 851	13 851	17 659	17 659	17 659	17 659
Direct cattle costs		42 880	45 443	45 443	45 096	45 096	45 048	45 048	45 048	44 524	44 524	45 133	45 133	45 133
C. BALANCE (A – B) (Dfl.)		413 334	409 945	410 180	415 238	415 757	416 296	409 256	409 562	410 515	406 254	406 643	407 069	408 929
D. FIXED COSTS (Dfl.)		538425	532 795	533 367	536 672	538 143	539 940	542 333	542 309	546 569	547 017	557 604	568 846	576 196
of which:														
(E) Labour		171 200	170 225	168 600	171 200	172 695	173 345	172 533	172 533	175 783	172 533	179 033	179 033	180 658
Contract work		56 191	54 485	55 923	56 518	56 494	57 537	59 133	59 110	60 011	65 643	68 039	68 039	72 930
Machinery, installations, inventory etc		108 409	108 487	109 281	109 389	109 388	109 441	109 339	109 339	109 642	107 976	108 404	108 404	108 619
Ground and buildings		174 091	171 101	171 066	171 178	171 179	171 230	172 941	172 941	172 912	172 644	173 864	185 106	185 724
General costs		28 534	28 497	28 497	28 387	28 387	28 387	28 387	28 387	28 221	28 221	28 265	28 265	28 265
F. NET FARM INCOME (C – D)		–125 091	–122 850	–123 187	–121 434	–122 386	–123 644	–133 077	–132 747	–136 054	–140 763	–150 961	–161 777	–167 267
G. FARMERS' INCOME (E + F)		46 109	47 375	45 413	49 766	50 309	49 701	39 456	39 785	39 729	31 770	28 071	17 255	13 391

[1] Dfl. 100 = € 45.38.

Table 6. Nitrogen balances for the various situations in which measures have been implemented sequentially.

N balance (kg ha^{-1})	Base situation	Less young stock	Crop rotation	More efficient grazing	Improved feeding protein norm	Catch crop under maize	Reduced N applica-tion	Reduced phosphate fertilizer	Feeding more maize in summer	Growing more maize	Shorter grazing period	Low-emission housing	Harvesting and feeding maize ear silage
INPUT													
Roughage	4	3	3	3	3	3	3	3	3	3	0	0	0
Concentrate	76	76	76	78	76	76	77	77	83	85	83	83	76
Fertilizer	197	196	193	182	183	170	107	107	104	91	90	81	81
Miscellaneous (straw, etc.)	1	1	1	1	1	1	1	1	1	1	1	1	1
Deposition	49	49	49	49	49	49	49	49	49	49	49	49	49
Total	327	325	322	313	312	299	237	237	240	229	223	214	207
OUTPUT													
Cattle	10	9	9	9	9	9	9	9	9	9	9	9	9
Milk	65	65	65	66	66	66	66	66	66	66	66	66	66
Roughage	10	14	14	17	18	18	5	5	10	10	6	6	0
Total	85	88	88	92	93	93	80	80	85	85	81	81	75
Total N surplus (kg ha^{-1})	242	237	234	221	219	206	157	157	155	144	142	133	132
Animal correction (kg ha^{-1})	20	17	17	17	17	17	17	17	16	23	23	23	23
MINAS N surplus (kg ha^{-1})	172	170	167	154	152	139	90	90	89	71	69	60	59

More efficient grazing

This measure implies siesta grazing. As a result, grazing losses decreased and more milk was produced at lower fat contents. The latter means that higher milk deliveries (in kg) are allowed. Though protein content decreased, income from milk increased. Feeding costs slightly increased and costs for fertilizer were lower. Because of fewer animals, costs of labour, contract work and slurry storage increased, and those of buildings decreased. Net income increased by more than Dfl. 1750 and farmers' income by more than Dfl. 4000. N surplus decreased substantially: about 13 kg ha^{-1}.

Feeding of milking cows according to protein norms, by making production groups

This measure led to more efficient utilization of feed protein. Feeding costs decreased, while costs for fertilizer slightly increased because the slurry contains less N. The measure led to additional labour costs. Net income decreased by almost Dfl.1000. Farmers' income, however, increased by Dfl. 500. N surplus slightly decreased.

Catch crop under maize

The catch crop was grazed in autumn by heifers. This led to extra roughage being available and thus to a reduction of feeding costs. Costs of fertilizer decreased considerably, but costs for seeds increased. Costs for labour and contract work slightly increased. Net income decreased by more than Dfl. 1200, farmers' income by Dfl. 600. N surplus substantially decreased by13 kg ha^{-1}.

Reduced N application and shortening the period of manure application

This measure resulted in a 10% reduction in grass yield and 8% in maize yield. So considerably less feed could be sold. Feeding costs slightly increased, costs of fertilizer strongly decreased. Labour costs decreased and costs for contract work increased. Shortening the period of manure application implies higher costs for slurry storage. Net income decreased by Dfl. 9500, and farmers' income by Dfl. 10,300. This measure had the strongest effect on N surplus, leading to a reduction of 50 kg ha^{-1}.

Reduced phosphate fertilizer application

Assuming that reduced phosphate application does not affect crop yield, income did not change. So only the costs of fertilizer slightly decreased. As a result, both net income and farmers' income increased with Dfl. 300. N surplus was not affected, but phosphate surplus strongly decreased.

Feeding more maize in the summer period

This measure led to a slightly higher milk and protein production, and to a reduction in animal numbers. Income from milk and roughage increased. Feeding costs increased, because of the need for additional, expensive, protein-rich concentrate. Costs for fertilizer and buildings decreased but costs for labour, contract work and feed storage increased. Net income decreased by Dfl. 3300 and farmers' income by Dfl. 60. N surplus slightly decreased.

Expanding the area of maize to 25 ha

In this situation, the animals ingested more roughage and less of the expensive concentrate. Costs of crop protection, seed and contract work increased. The costs for fertilizer and labour decreased, as did those for fuel en feed storage. Net income decreased by more than Dfl. 4500, and farmers' income by Dfl. 8000. N surplus decreased by 11 kg ha^{-1}.

Shortening grazing period of milking cows

This measure led to a slightly lower milk production, and to ensiling grass in October. Heifers and dry cows were fed this silage instead of straw. As a result less roughage was sold, but feeding costs decreased. Costs for fertilizer decreased. Costs for labour and contract work increased, as did those for slurry and feed storage. Net income decreased by almost Dfl. 5500 and farmers' income by Dfl. 3700. N surplus was reduced slightly.

Low-emission housing

To prevent ammonia emission, the stable was adapted at high costs. In this situation slurry N content was higher, so less fertilizer was needed, which led to lower fertilizer costs. But costs for buildings increased substantially. Net income and farmers' income decreased each by Dfl. 10,800. N surplus decreased by 8 kg ha^{-1}.

Preventing roughage surplus (harvesting and feeding ground maize ear silage)

To avoid a roughage surplus, part of the maize was harvested as ground maize ear silage and fed as concentrate. As a result no roughage was sold. This reduced income, but feeding costs decreased considerably too. Costs for fertilizer slightly decreased, but those for labour, contract work and feed storage increased. Net income decreased by almost Dfl. 5500 and farmers' income by more than Dfl. 3800. N surplus was very slightly reduced.

Examining the changes in net income following sequential implementation of individual measures, four groups of measures can be distinguished (Figure 1): (1) profitable measures, (2) cheap measures, (3) expensive but effective measures, and (4) expensive but non-effective measures.

Keeping less young stock, crop rotation and more efficient grazing were profitable measures. Feeding according to the protein norm and growing a catch crop under maize were rather cheap measures. Reducing N fertilizer application and grow-

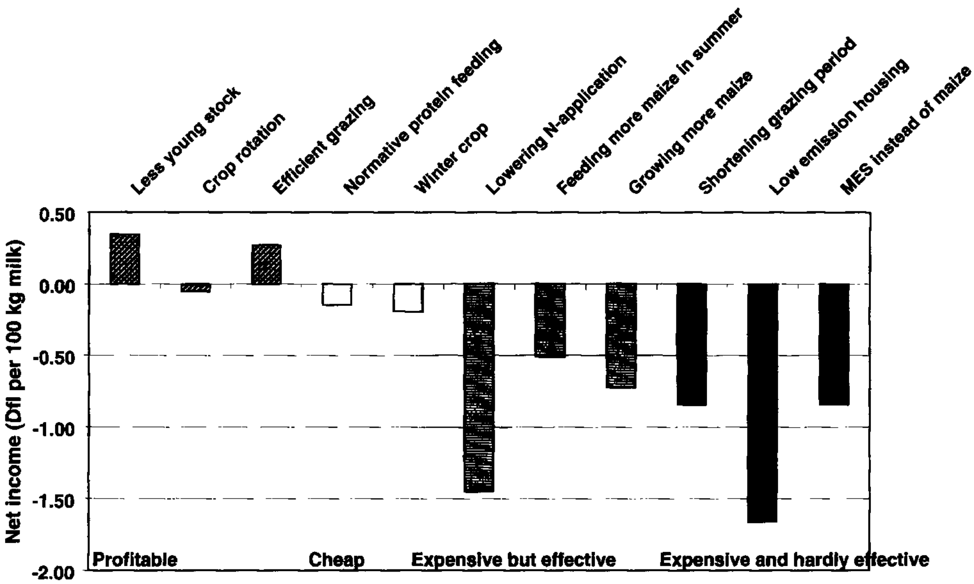

Figure 1. Changes in net income (Dfl. per 100 kg milk) for each (stacked) measure. (Dfl.100 = € 45.38)

ing and feeding more maize were effective but expensive measures. Shortening the grazing period, low-emission housing and harvesting maize ear silage were expensive and hardly effective measures.

Table 7 shows that the effects on farmers' income and net income were different. The table also shows cost effectiveness of the individual measures.

After implementing all measures, net income finally was Dfl. 37,500 lower than in the base situation, which corresponds with almost Dfl. 6 per 100 kg milk. Farmers' income is Dfl. 33,000 lower, corresponding with more than Dfl. 5 per 100 kg milk.

Discussion and conclusions

The 'normalized' starting points for this study were formulated in close co-operation with the project team of 'De Marke'. The design of the base farm and the effects of the individual measures strongly depend on these starting points and their underlying relations.

Calculations were performed with simulation models that apply to a steady-state situation, attained after long-term invariable management. So calculated results can differ from the actual situation in any specific year. The calculated economic effects of all environmental measures apply to 'De Marke' or to completely comparable situations (like soil properties, milk quotum, prices and tariffs). This also implies that the calculated results should not be extrapolated to too distant a future.

In accordance with the observations at 'De Marke' in recent years it was assumed that a reduction in phosphate fertilization would not affect the yield of grass and

Table 7. Changes in net income (NI), and in farmers' incomes (FI) and cost effectiveness (economic effect associated with a reduction of 1 kg ha^{-1} N surplus, in Dfl. per 100 kg milk) after successively taking the measures.

	Keeping less young stock	Crop rotation	More efficient grazing	Feeding less protein	Growing catch crop	Reducing N application	Feeding more maize in summer	Growing 6.6 ha more maize	1 month shorter grazing period	Low-emission housing	No sale of roughage (maize ear silage)
NI (Dfl[1] per farm)	1266	–337	1753	–952	–1258	–9433	–3306	–4709	–5486	–10816	–5489
NI(Dfl. per 100 kg milk)	0.19	–0.05	0.27	–0.15	–0.19	–1.45	–0.51	–0.72	–0.84	–1.66	–0.84
FI (Dfl. per 100 kg milk)	0.19	–0.30	0.67	0.08	–0.09	–1.58	–0.01	–1.22	–0.57	–1.66	–0.59
Cost effectiveness	0.07	–0.02	0.02	–0.07	–0.01	–0.03	–0.25	–0.07	–0.42	–0.18	–0.84

[1] Dfl.100 = € 45.38.

maize. However, the effects of reduced phosphate fertilization especially in combination with reduced N application, need investigation over a longer period. If less phosphate eventually leads to lower grass and maize yields, net income will decrease.

In the base situation the calculated N surplus was just above 240 kg ha^{-1}. The phosphate surplus was about 20 kg P_2O_5 ha^{-1}. These surpluses are remarkably low, i.e., substantially lower than on the average current farm (Aarts *et al.*, 1999). The reason is that the 'base farm' is not an average commercial farm, but a farm similar to 'De Marke' in terms of design and structure, i.e., a rather extensive dairy farm. A substantial surplus of roughage is sold, and because of their high milk production, the number of cows per ha is relatively low. As the phosphate condition of the soil is 'more than sufficient', a low phosphate surplus can be realized more easily than in a situation where the soil phosphate condition is 'sufficient' or 'fairly low'.

N and phosphate fertilizer application rates have been determined very accurately. Slurry utilization and fertilizer applications are completely in balance and match requirements. On commercial farms such a high-quality management is seldom realized. Management in the base situation was assumed to be of the same high quality, and focused on mineral management and good agricultural practices. Moreover, for commercial farms (financial) incentives for more accurate mineral management were in fact absent until 1 January 2000, when MINAS was introduced.

Mandersloot *et al.* (1998) showed a difference in net income between the base situation and the simulated 'De Marke' situation of Dfl. 5 per 100 kg milk. In the current study the estimated difference was Dfl. 1 larger, owing to differences in the base situation, modifications in estimated effects and incorporation of differences in labour requirements.

Most of the measures implemented at 'De Marke' led to a reduction in income. However, keeping less young stock, more efficient grazing, and in some cases crop rotation of maize and grass, increased net income while decreasing the N surplus. So farmers who aim at a higher income gradually will introduce these measures, even without the need to meet strict environmental standards.

Reducing N application, shortening the grazing period and low-emission housing were expensive measures for 'De Marke'. Each of these measures reduced net income by about Dfl. 10,000. However, reducing the level of N application resulted in a dramatic reduction of the N surplus. So this measure has a very high cost effectiveness. Low-emission housing was far less effective, but still led to a reduction in N surplus of about 8 kg ha^{-1}. Reducing the N surplus by shortening the grazing period was rather expensive and hardly effective. Growing and feeding maize not only led to an appreciably lower net income, but also reduced N surplus substantially (12 kg ha^{-1}). Growing grass (catch crop) under maize and improved protein feeding strategy were rather cheap measures. Especially grass under maize substantially reduced N surplus (15 kg ha^{-1}). Harvesting concentrate (ground maize ear silage) on this farm was rather expensive, with only a limited effect on the N surplus. All measures combined reduced net income of 'De Marke' by about *f* 37,500, i.e., almost Dfl. 6 per 100 kg milk. Farmers' income was more than Dfl. 5 per 100 kg milk lower. The results of this study are valid only for a 'De Marke'-like situation at the end of the

1990s. Translation of these results to other situations under different conditions is very difficult. A follow-up study to pay attention to such a translation is needed. The project 'Cows & Oportunities' (Oenema *et al.*, 2001) is a step in that direction.

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