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Reality and modelling: Operational validation of an environmental-economic model of a dairy farm

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Abstract

Operational validation of a linear programming model of a dairy farm is done on the basis of representative results from reality. The model will be used to determine the effects of institutional, technical and price changes on the results of dairy farms. Average results of specialized dairy farms on sandy soil from 1992/93 are presented and representativeness of the year has been checked.

Validation of the model was done in a number of steps. In the simulation step many available information from reality has been used in the model. Comparison of the simulated economic and environmental results with those from reality shows that the model is quite capable of simulating reality. In the optimization step a number of behavioral restrictions, which were included in the model in the simulation step, were lifted to give the model back its necessary flexibility. The differences between optimization and simulation results show, among other things, the effects of risk aversion and of lack of information and knowledge. In the optimal situation labour income is 15% higher while N losses and P_2O_5 losses are 9% and 41% lower than in the simulated situation.

Key words:

Dutch dairy farming, environmental-economic modelling, model validation, nutrient losses.

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1 Introduction

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

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

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

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

2 Research objectives and consequences

Assessment of a representative dairy farm and validation of the model based on this dairy farm are done to serve the objectives of a wider project. The main objective of this project concerns an analysis of possible effects of technical and institutional changes on Dutch dairy farms. The results are of interest to policy makers as well as to dairy farmers, as they will show the effects of certain policy changes and also the optimum way to react to these changes. The main interest concerns the economic and environmental results of farms different in size and in animal density. The research subject is restricted to specialized dairy farms on sandy soil. This soil type presents the most serious environmental problems. A linear programming model developed for this research was presented and tested (Berentsen and Giesen, 1995) and some problems were examined by using the model (see for example Berentsen *et al*, 1993).

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

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

3 Assessment of a representative dairy farm

For the assessment of a representative dairy farm, data from the Dutch Farm Accountancy Data Network (FADN) were provided by the Agricultural Economics Research Institute. The FADN was set up to provide the national government and the EU with average results of different types of farms in the Netherlands. A secondary goal was to collect data for agricultural economic research. To obtain representative results a stratified sample of all farms between 20 and 500 Dutch size units (dsu) is taken. A 20-dsu farm that is efficiently organized provides employment to about 0.5 full-time equivalent. Stratification is based on economic farm size, acreage, age of the farmer, region and type of farm. Every year some 20% of the farms in the sample are replaced by new farms to keep the stratification correct. The economic accounting of the farm covers the whole farm, which means that all revenues and costs are included. Costs are based on replacement costs of inputs.

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

Table 1 shows the average farm plan of the specialized dairy farms on sandy soil for 1989/90 to 1992/93. The total area of the farm has remained quite constant over the years. Shifts among grassland, fodder crops and cash crops are small. The average milk quota and the average milk production per cow slowly but steadily increase. As a result the numbers of dairy cows and young stock remain fairly constant. The bottom part of the table shows that there is beside dairy cattle and feed production some intensive livestock and cash crop production on these farms. The results of these other branches have to be omitted when validating the model.

Table 1 Average farm plan of the specialized dairy farms on sandy soil for 1989/90 to 1992/93 based on FADN-data

	1989/90	**1990/91**	**1991/92**	**1992/93**
Land use (ha):				
- area of grassland	22.0	22.0	22.8	21.7
- area of fodder crops	4.5	4.6	4.7	5.3
- area of cash crops	0.7	0.6	0.5	0.5
Milk quota (1000 kg)	320.8	323.4	327.5	330.3
Milk production per cow (kg/year)	6476	6422	6507	6682
Cattle:				

- dairy cows	50.3	50.7	50.9	49.4
- young stock	42.8	45.1	46.3	46.5
Economic size (% of total sfu **1**)				
- dairy cattle	66.9	67.8	68.8	68.1
- grassland and fodder crops	30.1	30.2	29.4	29.0
- pigs and poultry	2.0	2.0	1.0	2.3
- cash crops	1.0	1.0	0.8	0.6
1 standard farm unit				

Table 2 shows average revenues, costs and labour income for the dairy farming part of the farm. The revenues from milk and cattle sold show substantial differences between the years. This is for the greater part due to changes in prices of milk and cattle sold. The average milk price received from the factory, for example, decreased from NLG 83.58 per 100 kg in 1989/90 to NLG 76.92 in 1990/91 and went up again to NLG 80.49 in 1992/93. The other revenues come from roughage and sheep sold, product premiums, renting out milk quota, etcetera. Changes in the costs of feed purchased were caused by changing prices and amounts. A changing amount reflects a difference in home-produced fodder, which may be caused by less-favourable weather conditions.

Table 2 Average revenues and costs for specialized dairy farms on sandy soil for 1989/90 to 1992/93 (NLG) based on FADN-data

	1989/90	**1990/91**	**1991/92**	**1992/93**
Revenues:				
- milk	267,141	245,949	256,460	261,058
- cattle sold	57,385	45,345	45,015	50,808
- other	8477	6238	6991	5190
total	333,003	297,532	308,466	317,056
Costs:				
- feed purchased	60,715	56,436	64,713	59,951
- livestock costs	14,503	14,542	15,356	15,816
- fertilizer	11,656	9889	10,202	8821
- contract work	10,931	11,099	12,118	13,243
- machinery and equipment	46,790	50,141	50,986	47,919
- land and buildings	49,228	51,393	55,314	55,218
- costs of quota purchased	9165	11297	16379	19770

- other	31,995	33,906	34,991	32,921
total	234,983	238,703	260,059	253,659
Labour income	98,021	58,830	48,408	63,396

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

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

In Table 3 the average mineral balances for nitrogen (N), phosphate (P_2O_5) and potash (K_2O) for 1992/93 are given. These balances have also been corrected for the other branches on the farm. For all three minerals the majority of the input stems from concentrates and fertilizer. For N also atmospheric deposition is substantial. However, this last input cannot be influenced by the farmer. It must be noticed that the figures for roughage purchased, manure supplied and meat have been adjusted. On average, there is input of minerals through manure supplied and roughage and cattle purchased as well as output through manure removed and roughage and cattle sold. In Table 3 only the difference between input and output is given. Other input mainly concerns mainly manure supplied by other livestock branches on the farm. Output of minerals takes place through milk and meat. Subtraction of output from input results in the losses of minerals. The losses of N and P_2O_5 are slowly decreasing. For 1983-1986 Aarts *et al* (1988) calculated average yearly losses of 486 kg/ha for N and 74 kg for P_2O_5 on dairy farms on sandy soil.

Table 3 Average mineral balances for N, P_2O_5 and K_2O for specialized dairy farms

on sandy soil for 1992/93 (kg/ha) based on FADN-data			
	N	**P_2O_5**	**K_2O**
Nutrient input:			
- concentrates	117	45	70
- roughage purchased	26	8	23
- milk powder	2	1	1
- fertilizer	244	26	13
- manure supplied	13	8	9
- deposition	53	2	5
- others	27	13	25
total	482	103	146
Nutrient output:			
- milk	67	25	22
- meat	14	10	1
total	81	35	23
Nutrient losses	401	68	123

4 Method

4.1 Factors determining farm results

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

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

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

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

4.2 The model

A linear programming model is used to model the dairy farm. The object function maximizes labour income. Maximization of income appears to be the most general first objective of farmers (Zachariasse, 1972). The basic element in the model is a dairy cow, calving in February with a fixed milk production. Feed requirements are determined, using formulas of Groen (1988). For replacement of dairy cows young stock can be kept. If housing place is available beef bulls can be raised on a ration of silage maize and concentrates. The cultivated area can be used for producing grass, maize and fodder beets. Grass can be grown at a level of 100, 200, 300, 400 or 500 kg of mineral N. In addition to home-produced roughage, silage maize and three kinds of concentrates with different protein contents can be purchased. Nutrients for plant production can be supplied by home-produced manure, by fertilizer and by manure supplied by other farms.

The model contains nutrient balances at farm level for N, P_2O_5 and K_2O that register nutrient input and output and consequently nutrient losses. In the model labour is supplied by the farmer and the family. All production activities require labour. Activities such as mowing and ensiling of grass and appliance of manure can be done with the farmerþs own machinery or can be contracted out. Lastly, investment in land, housing capacity and basic machinery are not optional, therefore costs are calculated separately. For a more detailed description of the model see Berentsen and Giesen (1995).

4.3 Calculation of unknown parameters

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

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

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

4.4 The validation process

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

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

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

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

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

5 Results

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

The results of calculations with the basis model and with the further adapted models are given in tables 4, 5 and 6.

- Table 4 shows the farm structure and the technical results (5.1.1)
- Table 5 the economic results (5.1.2)
- Table 6 the environmental results (5.1.3)

5.1 Results of the basis model

5.1.1 Technical results

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

Table 4 Technical results from reality and from calculations with the basis model, the simulation model and the optimization model of the average dairy farm on sandy soil for 1992/93

	reality	**basis model**	**simulation model**	**optimization model**
Cattle:				
- dairy cows	49.4	49.4	49.4	49.4
- young stock	48.2	27.4	48.2	46.5
- beef bulls	5.2	51.4	5.2	5.2
Land use:				
- grassland (ha)	21.7	24.2	21.7	27.0
- N level grassland (kg/ha)	408	319	408	320
- silage maize (ha)	5.3	2.8	5.3	0.0000
Feed purchased (1000 MJ NEL):				
- concentrates	718	677	718	406
- roughage	283	945	283	747
Fertilizer purchased (kg/ha):				
- N	244	194	244	202
- P_2O_5	26	0.0000	26	0.0000
- K_2O	13	0.0000	13	0.0000

Manure used (m3):				
- from cattle	742	1006	742	735
- from other livestock	115	0.0000	115	115
- from other farms	51	0.0000	51	51

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

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

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

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

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

5.1.2 Economic results

The economic results are divided into revenues and costs. Using average realized prices (Bloem *et al*, 1993) the revenues from milk calculated by the model equal those in reality. Due to the large number of beef bulls, the revenues from cattle sold are more than twice as high as in reality. The other revenues in Table 5 differ from Table 2, because the revenues from roughage sold were left out in Table 5. Consequently, the costs of roughage purchased are corrected for with the same amount. The other revenues calculated differ from reality but also their composition is quite different. The modelþs other revenues consist totally of price premiums from the EU for beef bulls, while the other revenues from reality also come from sheep sold and renting out milk quota.

The costs of concentrates calculated by the model are slightly higher than those in reality although the amount of concentrates is lower. However, the price of concentrates for beef bulls is higher than the price of most of the concentrates for dairy cattle. More in general, a difference may arise between the model results and reality in costs of concentrates, even if the same amount of concentrates is used, due to the fact that in reality a large variety of concentrates is fed at a variety of prices.

Table 5 Economic results from reality and of calculations with the basis model, the simulation model and the optimization model of the average dairy farm on sandy soil for 1992/93

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

The model uses only three types of concentrates for dairy cows, two types for young stock and one for beef bulls. The costs of milk powder calculated by the model are higher than in reality, due to the number of beef bulls and to the fact that in the model a standard amount of milk powder per animal is taken. In the simulation model the realized amount per animal is taken. The above-mentioned comment on the large variety of concentrates used in reality also applies to roughage purchased.

However, in reality the majority of roughage purchased is silage maize. In the model silage maize is the only option. The costs of fertilizer follow from the amount used. The livestock costs calculated by the model are higher than the costs in reality, due to the high number of beef bulls and to the fact that the model uses standards that are higher than the costs per animal in reality. In the simulation model the realized costs per animal are taken. The costs of contract work calculated differ only slightly from those in reality. However, it should be noticed that the area of silage maize calculated is lower than the real area. The costs of contract work of growing silage maize for the farmþs own use amount to NLG 1730 per ha. It is quite difficult to compare the costs of machinery and equipment, because the number and type of machines in reality are unknown. This makes it necessary to consider the costs of machinery and equipment always in combination with the costs of contract work. Besides that, in the model the costs of machinery and equipment as well as of buildings are based on standards, which may differ from the costs in the FADN-data which are partly based on standards and partly on reality:

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

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

5.1.3 Environmental results

Table 6 shows the input, the output and the resulting losses of N, P_2O_5 and K_2O. The nutrient input with roughage purchased calculated by the model is higher than in reality, due to the large number of beef bulls. The input with fertilizer is lower due to the lower N use on grassland. No P_2O_5 and K_2O from fertilizer is required. In the basis model no activity is included for manure supplied by other livestock on the farm or by other farms. Consequently, no nutrient input from these sources exists. In the simulation model this activity is added set at the realized level. Also activities for deposition of P_2O_5 and K_2O are added. Total N and P_2O_5 input calculated by the basis model is considerably lower than in reality, while total

K_2O input is higher. This difference can be explained by differences between N, P_2O_5 and K_2O in weight of specific inputs related to total nutrient input.

Table 6 Environmental results from reality and from calculations with the basis model, the simulation model and the optimization model (kg/ha) of the average dairy farm on sandy soil for 1992/93

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

■ basis model
● simulation model
▲ optimization model

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

5.2 Results from the simulation model

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

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

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

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

5.3 Results of the optimization model

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

In the optimal situation the numbers of dairy cows and of beef bulls are the same as in the simulated situation (Table 4). The number of young stock is slightly smaller. In this case it is economically not attractive to keep extra young stock that are sold as heifers, because this young stock has to be fed with feed purchased and with grass that can only be grown by raising the N level above 320 kg/ha. The total area is used as grassland to supply enough grass to be able to feed a maximum amount of grass in summer (when it is the cheapest energy source) and a minimally required amount of silage grass in winter. Due to the lower production of home-produced fodder, the amount of feed purchased is higher than in the simulated situation; the amount of concentrates, however, is substantially lower. Part of the concentrates is replaced by silage maize in winter and by grass in summer. The amount of N fertilizer purchased follows from the N level of grassland. Manure produced by cattle on the farm and from other sources satisfies the requirements for P_2O_5 and K_2O by silage maize and grass, so no P_2O_5 and K_2O through fertilizer is needed.

The small difference in number of young stock causes a small difference in revenues and livestock costs (Table 5). The changes in costs of concentrates, milk powder, roughage and fertilizer purchased follow from the changed amounts used. The costs of contract work decrease substantially due to the fact that no silage maize is grown on the farm. The other costs, which are partly related to the numbers of animals and partly to land use, decrease because no silage maize is grown and the number of young stock is lower. On balance, the total costs decrease by NLG 10,901. Consequently, labour income increases by NLG 9365.

Compared with the results of the simulation model the input of nutrients through concentrates and fertilizer decreases substantially (Table 6). The input through roughage purchased increases which leads to a decrease for N and P_2O_5 in total input. The total input of K_2O increases, due to a different ratio between K_2O content of concentrates and roughage. Nutrient output decreases slightly as a result of the lower number of young stock. Consequently, N losses decrease by 8.8%; P_2O_5 losses by 41% and K_2O losses increase by 3.7%.

5.4 Using the validated model for other intensities

As could be expected fixed assets and grassland and milk production of the average extensive and intensive farm differ from the overall average results that were presented in section 3. On the extensive farm, the area of land is greater and the milk quota smaller than the overall average (Table 7). Milk production per cow and grassland production per hectare on the extensive farm are below the overall average. The lower grassland production can only partly be explained by the lower nitrogen level on grassland. The realized grassland production appears to be 6300 MJ NEL/ha (8.3%) lower than the production that could be expected using the overall average production curve and taking into account the nitrogen level on grassland on the average extensive farm. Reasons for this may be grassland management or soil fertility that is worse than average. Finally, labour income and nutrient losses per hectare are lower than the overall average. Concerning all aspects, the intensive farm can be found at the opposite side of the overall average.

Table 7 Fixed assets, levels of production, economic results and nutrient losses for the average extensive farm, the average intensive farm and the overall average on sandy soil based on FADN-data

	extensive	intensive	overall average
Fixed assets:			
- area of land (ha)	28.9	23.4	26.9
- milk quota (1000 kg)	259.9	385.0	330.3
Level of production:			
- milk production per cow (kg)	6293	6887	6682
- grassland production (1000 MJ NEL/ha)	65.7	81.1	73.1
- N level grassland (kg/ha)	386	441	408
- grassland production minus expected production (1000 MJ NEL/ha)	-9.9	3.6	-3.7
Labour income (NLG)	50,472	66,529	63,396
Nutrient losses (kg/ha):			
- N	357	451	401
- P_2O	52	82	68
- K_2O	88	167	123

When using fixed assets and production levels for model simulation the same kind of adaptations have to be made to the model as described in section 5.2. The model has to be forced to grow grass at a higher nitrogen level, to purchase more concentrates and less roughage, to keep more young stock for replacement and to sell heifers, to grow more silage maize and to purchase more P_2O_5 and K_2O fertilizer than optimal. Also the same kind of small differences between simulation results and results from reality become apparent. They can be attributed to the same causes as described in section 5.2. However, some other deviations come to light.

First, in reality the revenues of cattle sold on the extensive farm and the livestock costs are lower than the results simulated by the model. For the intensive farm the opposite is true. It can be assumed that these findings are related to the level of milk production per cow on the farms. The lower level of milk production on the extensive farm may partly be caused by lower breeding costs, which are included in the livestock costs. In turn, the lower level of milk production may cause a lower price of the heifers sold, which results in lower revenues of cattle sold.

Second, the sum of the simulated costs of contract work and of machinery and equipment overestimates these costs in reality on the extensive farm, while these costs on the intensive farm are underestimated. From the FADN data it can be concluded that the reason may be a lower than average investment in machinery and equipment on the extensive farm, while this investment is higher than average on the intensive farm.

Finally, the costs of quota are much lower than average on the extensive farm, while they are much higher on the intensive farm. Apparently, intensive farms have bought more quota. Together these differences cause an underestimation by the model of labour income on the extensive farm of about NLG 19,000, while labour income on the intensive farm is overestimated by about NLG 11,000.

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

6 Discussion

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

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

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

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

References

Aarts, H.F.M., Biewinga, E.E, Bruin, G., Edel, B. and Korevaar, H. (1988)
Melkveehouderij en milieu; een aanpak voor het beperken van mineralenverliezen. Report nr. 111, Research Station for Cattle, Sheep and Horse Husbandry, Lelystad, Neth. (in Dutch, with English summary).

Aarts, H.F.M. and Middelkoop, N. (1990)
De invloed van bodemeigenschappen en bemesting op de opbrengst van mais en de emissies van ammoniak en nitraat. Centre for Agrobiological Research, Report nr. 131, Wageningen, Neth. (in Dutch)

Agricultural Economic Research Institute (AERI) and Central Bureau of Statistics (CBS) (1993)
Landbouwcijfers 1993. AERI/CBS, The Hague, Neth. (in Dutch)

Asijee, K. Editor (1993)
Handboek voor de rundveehouderij. Ministry of Agriculture, Nature Management and Fisheries, Lelystad, Neth. (in Dutch)

Berentsen, P.B.M., Giesen, G.W.J. and Speelman, R.F. (1993)
Economic and environmental effects of a new protein evaluation system in dairy farming. Journal of Dairy Science 76, 2332-2343.

Berentsen, P.B.M. and Giesen, G.W.J. (1995)
An environmental-economic model at farm level to analyze institutional and technical change in dairy farming. Agricultural Systems 49:153-175.

Bloem, L., Kolkman, G. and Verhoek, A. Editors (1993)
Kwantitatieve Informatie Veehouderij 1993-1994. Ministry of Agriculture, Nature Management and Fisheries, Ede, Neth. (in Dutch)

Gass, S.I. (1983)
Decision-Aiding Models: Validation, Assessment, and Related Issues for Policy Analysis. Operations Research 31, No. 4, 603-631.

Groen, A. F. (1988)
Derivation of Economic Values in Cattle Breeding. A Model at Farm Level. Agricultural Systems 27, 195-213.

Miser, H.J. (1993)
A foundational concept of science appropriate for validation in operational research. European Journal of Operational Research 66, 204-215.

Poppe, K.J., Van Everdingen, W.H., Jager, J.H., Wisman, J.H. and Venema, G.S. (1993)
Bedrijfsuitkomsten en financiële positie; samenvattend overzicht van landbouwbedrijven tot en met 1991/92. Report nr. 13-91/92, AERI, The Hague, Neth. (in Dutch)

Roeterdink, H.W. and Haaksma, J.J. (1993)
Kwantitatieve Informatie voor de Akkerbouw en de Groenteteelt in de Vollegrond. Ministry of Agriculture, Nature Management and Fisheries, Lelystad, Neth. (in Dutch)

Taylor, A.J. (1983)
The verification of dynamic simulation models. Journal of operational research society 34, 233-242.

Van Dijk, J.P.M., Douma, B.E. and Van Vliet, A.L.J. (1994)
Bedrijfsuitkomsten in de landbouw; Boekjaren 1989/90 tot 1992/93. Periodic Report nr. 11-92/93, AERI, The Hague, Neth. (in Dutch)

Van Everdingen, W.H. (1993) Melkvee 1975-1995;
Bedrijfseconomische beschouwingen. Report nr. 6-91, AERI, The Hague, Neth. (in Dutch)

Vink, I. (1993)
DELAR kengetallen analyse 92/93. Ministry of Agriculture, Nature Management and Fisheries, Lelystad, Neth. (in Dutch)
Zachariasse, L.C. (1972)
Analyse van het vraagstuk der uiteenlopende rentabiliteit van vergelijkbare agrarische bedrijven. PhD-Thesis, Wageningen, Neth. (in Dutch)