Netherlands Journal of Agricultural Science 42-1 (1994) 11-19

Economic and environmental consequences of different governmental policies to reduce N losses on dairy farms

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Received 27 December 1993; accepted 16 February 1994

Abstract

Dairy farming contributes substantially to Dutch environmental problems. In this paper the central issue is to quantify the consequences of four government environmental policies on labour income and losses of nitrogen on dairy farms situated on sandy soil. Two policies impose a legal regulation and two impose a financial incentive to farmers. A linear programming model is used to model some typical dairy farms. The most important decision variables affecting nitrogen use and nitrogen losses are: the animal density on the farm, the feed ration of the cows and young stock, the method and length of storing manure, the method of applying manure to the land, whether the land is used for grassland or fodder crops and the level of nitrogen application on grassland. The results show net farm income decreases (excluding levies paid) on the intensive farm up to Dfl. 13 910 (17%). N losses on this farm decrease up to 283 kg.ha^{-1} (54%). Finally, it appears from the results that it is much more expensive to reduce ammonia emission than to reduce the same amount of other N losses (leaching and run-off).

Keywords: dairy farming, governmental policies, economic effects, nitrogen losses

Introduction

Agriculture, and in particular animal husbandry, contributes substantially to Dutch environmental problems. In 1989, volatilization of ammonia from manure in the sheds, in storage and on the land amounted to about 94% of the Dutch ammonia emission which is one of the three main sources of acidification in the Netherlands (Heij & Schneider, 1991). Although acidification as a whole is a continental problem (there is much import and export of acidifying compounds through the air), emission of ammonia has especially important regional consequences. In 1989 about 81% of the ammonia deposition in the Netherlands was also emitted in the Netherlands (for SO_x this figure was 28% and for NO_x 41% (Heij & Schneider 1991)). Other environmental problems in which animal husbandry plays a major role are high contents of nitrate and phosphate in ground and surface water. Nitrates and phosphates can reach these waters through leaching and run-off.

In dairy farming, losses of phosphates are relatively small. Even the most severe legal limitations on the amount of phosphate that can be brought on the land (a policy for the year 2000) appear to have no effect on an average dairy farm (Berentsen et al., 1992). On the other hand, nitrogen losses are considerable. Calculations with nitrogen balances based on average results in 1983-1986 pointed out that on an average Dutch dairy farm situated on sandy soil, nitrogen losses amount to 486 kg ha^{-1}, which means that 85.5% of the nitrogen input is lost to the environment (Aarts et al., 1988).

The three policy instruments available to government for reducing nutrient losses to the environment are: education and extension, financial stimulations such as levies and subsidies, and legal regulations. It is obvious that the use of education and extension will only lead to a change in behaviour if farmers benefit from this change. With regard to nitrogen losses, calculations for an average farm on sandy soil pointed out that in going from average productivity of land and cattle to normative productivity (based on the results of experimental stations) labour income increases by Dfl 16 000 while nitrogen losses decrease by 54 kg ha^{-1} (Aarts et al., 1988). As further reductions in emission can only be achieved by measures that reduce farm income, either financial incentives or legal regulations are required to get these measures adopted by farmers.

In this paper the central issue is to quantify the consequences of various governmental policies that impose either a legal regulation or a financial incentive to farmers, on labour income and on the losses of nitrogen on dairy farms on sandy soil.

Governmental policies

Four governmental policies to reduce N losses are examined: two that impose a legal regulation to farmers and two that impose a financial incentive. The policies are:

I a a legal requirement to invest in a closed manure storage and to apply manure to the land by means of injection;
  b a legal restriction on the total amount of nitrogen that can be applied on the land;
II a a levy on fertilizer N;
  b a levy on part of the N losses of the farm.

Policy I a represents actual legislation in the Netherlands to decrease emission of ammonia. As will be explained in the next section, the manner in which manure is stored and applied has a great impact on ammonia volatilization.

Policies to further reduce N losses are the subject of study and discussion. These policies can take the form of a legal regulation (I b) or of financial stimulations (II a and II b). It is plausible that after 1995 one of these three policies will be applied in addition to policy I a.

Policy I b is a possibility to force intensive farms to decrease the level of nitrogen use on the land. The total amount of nitrogen produced by the cattle (based on standards) plus the total amount of fertilizer N purchased may not exceed the number of hectares times the N limit per ha.

In policy II a a levy on N input from fertilizer is used. As fertilizer becomes more expensive, farms will change their production plan to decrease the use of fertilizer N. Policy II b is aimed directly at the losses of nitrogen to the environment. Because it is not possible to reduce these losses to zero, an acceptable N loss per hectare can be left untaxed. The untaxed level of N losses is set to 200 kg ha^{-1}.

Materials and methods

The analysis in this study is based on three typical dairy farms on sandy soil. All three farms are characterized by a cultivated area of 24 ha and a milk production per cow per year of 6695 kg. The farms differ in intensity of farming. Farm 1 has a quota of 192000 kg, farm 2 of 288000 kg and farm 3 of 384000 kg.

A linear programming model is used to model the dairy farms. The objective function maximizes labour income (i.e. return on labour and management). The basic element in the model is a dairy cow, calving in February and having a fixed milk production. Feed requirements are determined using formulas of Groen (1988). The cultivated area can be used for producing various combinations of grass, maize and fodder beets.

The main decision variables affecting nitrogen use and nitrogen losses are: the animal density on the farm, the feed ration of the cows and young stock, the method and length of storing manure, the method of applying manure to the land, whether the land is used for grass or fodder crops and the level of nitrogen application on grassland.

The animal density on the farm determines the amount of manure produced per hectare. A decrease of this amount also means a decrease in nitrogen losses. In the model a fixed ratio is assumed between the numbers of dairy cows and young stock, so animal density can only be decreased by decreasing the numbers of dairy cows and young stock proportionately.

The feed ration influences the nitrogen content of the manure produced by the cattle. The quantity of nitrogen in the manure is calculated by subtracting the nitrogen output (in milk and meat) from the nitrogen input (in feed intake). This is done separately for the summer and winter period. The nitrogen input can be decreased by changing the feed ration. Because the nitrogen output in milk and meat is fixed, this leads to a decrease of nitrogen in the manure.

The method and length of storing manure and the manner in which manure is applied to the land both influence the emission of ammonia. The farm has a storage capacity for 2 months under the slatted floor in the cowshed and an additional open manure storage facility for 4 months. Ammonia losses from floor and storage together are assumed to be 20% of total nitrogen in manure (Van der Hoek & Snel, 1989). An investment in the closure of the open manure storage facility is possible and decreases the losses by ammonia volatilization from floor and storage together to 14%. Applying manure to grassland by means of surface spreading leads to a loss by ammonia volatilization of 25% of the nitrogen still present after storage. When manure is applied to crop land by means of surface spreading it is assumed that tillage of the ground takes place 24 h after applying manure. In that case 9% is assumed to be lost by ammonia volatilization. When manure is injected instead of surface spread, only 1% is assumed to be lost (Van der Hoek & Snel, 1989).

Losses of nitrogen from leaching, run-off and denitrification are determined by subtracting the nitrogen that is removed from the land with grass or with fodder crops from the nitrogen input to the land. This indicates the importance of the use of land and of the level of nitrogen applied to grassland (which are management options in the model). The use of land can be changed so that fodder crops that use nitrogen more efficiently take the place of less efficient crops. Lowering the level of nitrogen application on grassland decreases the N losses from grass production in spite of a decrease in grass production (Van der Meer et al., 1986). In summer, all nitrogen excreted in manure during grazing is assumed to be lost, of which 17% is by volatilization of ammonia (Middelkoop & Deenen, 1990).

For the basic situation, the model computes the optimum farm results without any government policy concerning N losses to the environment. Then the policies for reducing N losses are incorporated into the model. With every policy, new optimum results are calculated. The effects of policies are determined by comparing the new optimum results with the optimum results in the basic situation. Altogether this means that a comparative static approach is used.

Although a certain policy may affect prices for production factors and products, they are assumed to be the same in the basic and in the alternative situations.

Results

Basic situations and effects of policies

Table 1 shows the results for the three farms in the basic situation. Total N use on land includes all N from fertilizer, manure and deposition. Policy I b applies to total N use. In N mineral organic N from manure is excluded. Labour income, N input and N losses increase with the intensity of farming. N output on farm 1 (78 kg ha^{-1}) is higher than that on farm 2 (71 kg ha^{-1}) because farm 1 sells silage mais. These results form the standard against which the results when applying the policies should be compared.

Policy I a does not affect the farm plan of the three farms. Yet costs rise because all manure is injected, which is more expensive than surface spreading, and because of the investment in closing the manure storage. Labour income decreases by Dfl. 2299, Dfl. 2694 and Dfl. 3434 on farms 1, 2 and 3 respectively. The effect on the nitrogen balance is small. The N losses decrease by 7.4 kg ha^{-1} (3%), 184 kg ha^{-1} (5%) and 29.4 kg ha^{-1} (5.6%) on farms 1, 2 and 3 respectively. This is entirely caused by a reduction in ammonia emission.

It will be clear that the reductions in N-losses and in labour income that are the result of policies I b, II a and II b depend heavily on the N limit that is used, respec-

Table 1. Results from the optimizations of the three farms in the basic situation.

	Farm 1	Farm 2	Farm 3
Milk quota (x 1000 kg)	192	288	384
Number of dairy cows	29	43	57
Grassland (ha)	14.3	19.6	24
Silage maize (ha)	9.7	4.4	0
N mineral grassland (kg ha^{-1})	312	403	500
Total N use on land (kg ha^{-1})	368	548	758
Labour income (Dfl)	15228	51409	81219
N balance:			
N input (kg ha^{-1})			
☐ Fertilizer	227	336	477
☐ Concentrates and roughage	48	88	161
☐ Deposition	49	49	49
N output (kg ha^{-1})	78	71	94
N losses (kg ha^{-1})	246	402	523
☐ of which NH_3 emission (kg N ha^{-1})	36	63	89

tively on the levy that has to be paid. As N use is the highest on farm 3 (758 kg ha^{-1}), the consequences of policy I b will be most severe on farm 3. When a high N limit (550-750 kg ha^{-1}) is used, only farm 3 has to decrease N use. Below a N limit of 550 kg ha^{-1} farm 2 also has to decrease N use. The extensive farm (farm 1) is only affected when the N limit is below 350 kg ha^{-1} or lower. The actual measures that are taken on the farm to reduce N losses do not differ from the situation when levies are used. These measures are described below.

To obtain insight into the way policies II a and II b work out, the levies are increased stepwise from 0 to 6 Dfl kg^{-1} (in 12 steps). The relation between the levies on the one hand and the N losses and labour income of the three farms on the other hand, are shown in Figures 1 and 2.

A levy either on the input of fertilizer N or on N losses has immediate consequences for all three farms. When the levy is increased, N losses and labour income go down. On farms 2 and 3 three measures are taken. For farm 1, only the first two measures are relevant. The first measure is that the farms reduce nitrogen use on grassland. For farm 3 this is done in two steps. At a levy of Dfl 0.50 N use is decreased by 100 kg ha^{-1} and at a levy of Dfl 1.50 a second decrease of N use by 100 kg ha^{-1} takes place. The second measure is that farms inject all manure that is applied to grassland. This is done at a levy between Dfl 2 and 3. From Figure 1 it can be seen that this leads to only small reductions in N losses. The last measure (which is taken at a higher levy) consists of the feeding of silage maize during summer. This reduces the surplus of protein in the feed ration and consequently it reduces the N losses. Besides, the lower N level of grassland also results in a lower protein content of the grass. At a levy of Dfl 4 per kg a more or less stable situation is reached. The loss of labour income is higher with a levy on fertilizer than with a levy on N losses. The difference in loss of labour income decreases with the intensity of farming. This difference varies with the untaxed amount of N losses.

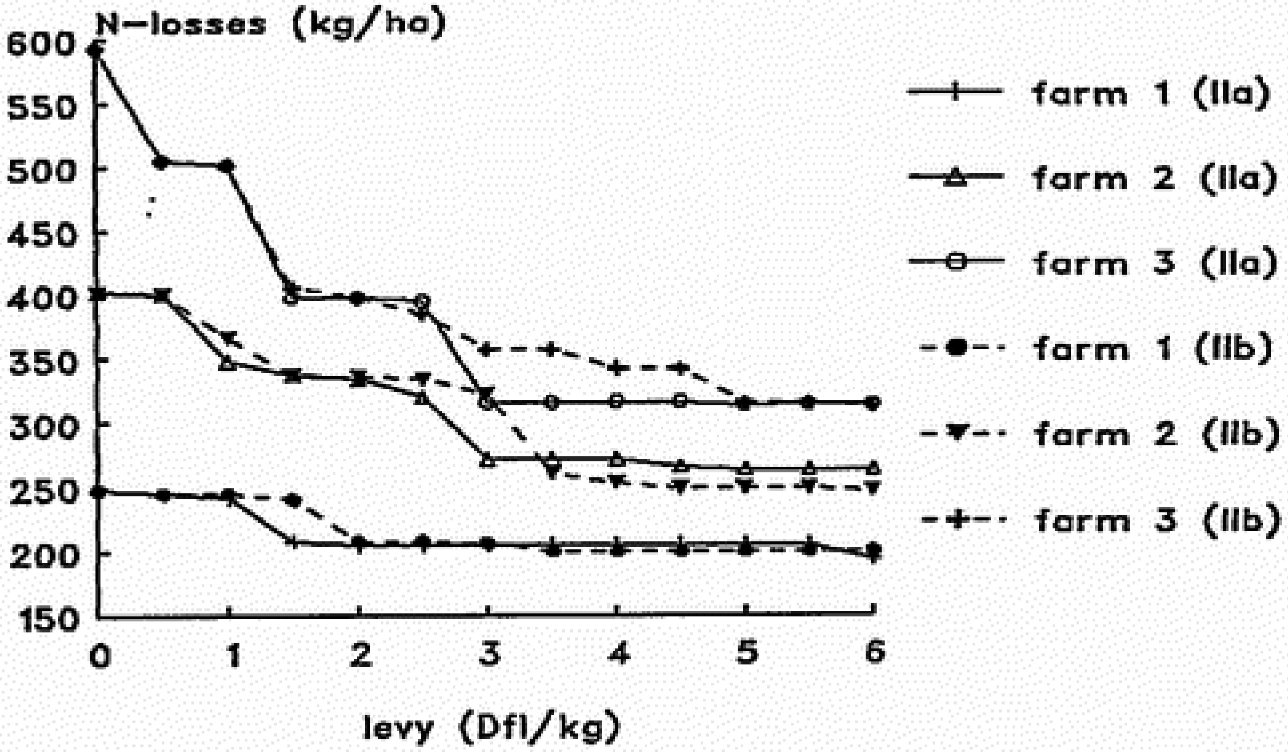

Figure 1. Effects of a levy on fertilizer (IIa) and of a levy on N losses (IIb) on N losses.

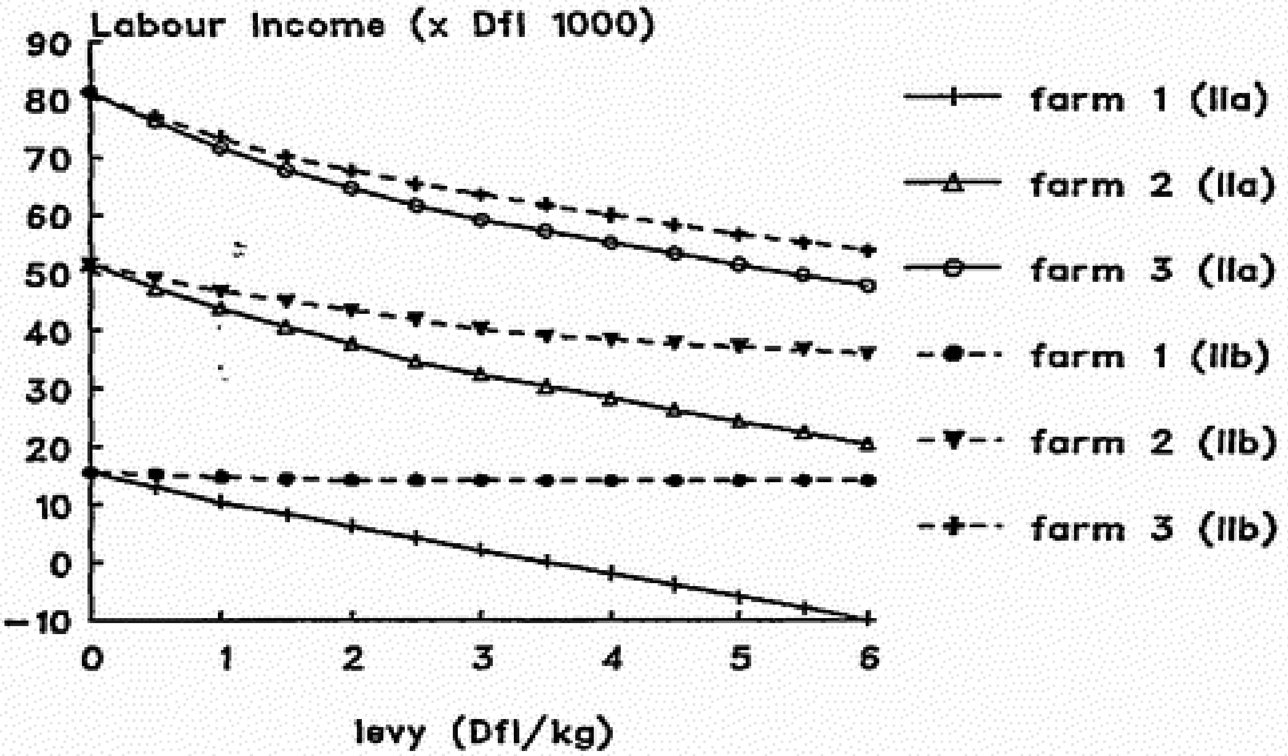

Figure 2. Effects of a levy on fertilizer (IIa) and of a levy on N losses (IIb) on labour income.

Comparison of policies and farms

A comparison of policies is difficult. Because it is to be expected that marginal costs increase with the amount of reduction of N losses (as cheap measures are followed by more expensive measures), a condition for a good comparison should be that the policies to be compared should lead to more or less the same reduction in N losses. This makes it difficult to compare policy I a with the other policies.

Another problem which makes it difficult to compare policy I a with the other policies has to do with different forms of N losses that exist. Because policy I a only reduces N losses through NH_3 emission while other policies result in a reduction of NH_3 emission as well as in a reduction of other N losses, a comparison of costs per kg reduction of N losses is a comparison of two different things. A way of overcoming this difficulty would be first to assume that the primary objective of all policies is to decrease NH_3 emission and then make a second comparison on the assumption that the objective is to reduce other N losses (like leaching and run-off). In the first case all costs can be attributed to the reduction of NH_3 emission, while in the second case all costs can be attributed to the reduction of other N losses. This is done in Table 2.

Table 2. Reduction of labour income excluding levies paid (Dfl) and of N losses (kg N ha^{-1}), decrease of labour income per kg reduction (Dfl kg^{-1}) and levy paid (Dfl) for four government policies and three farms.

	Closed manure storage + injection	Legal N limit (400 kg ha^{-1})	Levy on fertilizer N (Dfl 4 kg^{-1})	Levy on N losses (Dfl 4 kg^{-1})
Farm 1				
Net decrease of labour income:	2299	0	1589	890
Reduction of NH_3 emission	7.4	0	1.5	1.4
Decrease of income/kg reduction	13	0	44	26.5
Reduction of other N losses	0	0	42	40
Decrease of income/kg reduction	0	0	1.6	0.9
Levy paid	0	0	16047	523
Farm 2				
Net decrease of labour income:	2694	5730	6881	8006
Reduction of NH_3 emission	18	16	16	18
Decrease of income/kg reduction	6.2	14.1	17.9	18.5
Reduction of other N losses	0	112	114	130
Decrease of income/kg reduction	0	2.1	2.5	2.5
Levy paid	0	0	16215	5097
Farm 3				
Net decrease of labour income:	3433	13910	10830	7759
Reduction of NH_3 emission	29	36	32	31
Decrease of income/kg reduction	4.9	16.1	14.1	10.4
Reduction of other N losses	0	267	245	221
Decrease of income/kg reduction	0	2.2	1.8	1.5
Levy paid	0	0	15284	13606

The final problem is the basic difference between a legal restriction and a levy. If a levy is used, farmers have to pay extra money while they obtain the same results as when a legal restriction was used. Because the government intends to spend the money it gets from the levy in the agricultural sector, one could argue that farmers get their money back. For the sake of comparison, therefore, in Table 2 the decrease of income is corrected for the levy paid. The levy paid is shown separately.

If the objective is the reduction of NH_3 emission, it is obvious that policy I a is by far the cheapest policy. The costs per kg reduction of NH_3 emission of the other policies are 2 to 3 times higher. Looking at the difference between farms it appears that the costs per kg reduction decrease with the intensity of farming. This mainly has to do with the fact that on farm 3, the NH_3 emission decreases greatly as a result of injecting all manure instead of surface spreading on grassland. On farm 1 in the basic situation most of the manure is applied by surface spreading on crop land. As NH_3 emission from surface spreading on crop land (followed by tillage of the ground) is much lower than that from surface spreading on grassland, the reduction from shifting to injection is also much lower. Concerning the reduction of other N losses, policy II b appears to be the policy which is most costeffective, although the results are not unequivocal in this regard.

Looking at differences between farms it is clear that a N limit of 400 kg ha^{-1} affects only farms 2 and 3. The average costs per kg reduction of policies II a and II b do not differ much between farms. The size of the reduction on farm 3, however, is 4 to 5 times higher than that on farm 1.

With a levy on fertilizer N, all farms reach more or less the same level of fertilizer use, which results in almost the same amount of levy paid. With a levy on N losses above 200 kg ha^{-1} it is obvious that the levy paid increases with the intensity of farming.

Discussion

Because the government wants to reduce both ammonia emission and other N losses by at least 50% by the year 2000, the reduction in particular of ammonia emission reached in these model calculations (21%, 29% and 40% for farm 1, 2 and 3 respectively) falls short of the objective. The reduction of ammonia emission, of course, depends on the level of emission in the basis situation. Mandersloot (1992) calculates higher reductions, but in his basis situation in winter, cows get a substantial surplus of protein which leads to high ammonia emission. In this study in winter, protein is fed no more than required because this is economically optimal. A combination of policy I a with one of the other policies will certainly reduce ammonia emission further because none of the other policies leads to an investment in closing the manure storage (which decreases ammonia emission) nor to injection of all manure. From the results it can be concluded that reduction of NH_3 emission is much more expensive per kg nitrogen than reduction of other N losses. On the other hand, the amount of NH_3 emission that has to be reduced to reach the government objectives is considerably smaller than the required reduction in other N losses.

A choice between policies I b on the one hand and policies II a or II b on the other hand is a choice between reducing N losses on intensive farms only and reducing N losses on all farms. One can argue from a national economic point of view that losses should be decreased where it happens to be most cost effective to do so. This can be realized if the incentive to reduce losses is felt to be the same for all farms: this can be achieved by a levy. One N limit for all farms means that intensive farms have to reduce losses at high marginal costs while extensive farms are not forced to reduce losses at all. On the other hand, on every farm, N losses by leaching should be reduced to a certain level to avoid high nitrogen concentrations in drinking water. From this point of view especially intensive farms must be urged to reduce N losses despite higher marginal costs.

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