CONVERSION FROM CONVENTIONAL TO BIOLOGICAL DAIRY FARMING: SUSTAINABILITY ASPECTS FROM A FARM MODELLING PERSPECTIVE

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ABSTRACT

In this paper the central issue is to quantify economic and environmental consequences for dairy farms when converting to biological dairy farming. A linear programming model is used to model a typical extensive and intensive dairy farm in The Netherlands. From the results it appears that extensive farms benefit from conversion while intensive farms lose income. Environmental consequences are quite diverse. The nitrogen surplus after conversion is much lower than before while ammonia emission is higher after conversion due to a higher number of animals. On the extensive farm the phosphate surplus is much higher after conversion due to the fact that a shortage of nitrogen in the biological situation can only be made up by applying animal manure (slurry) from other farms with consequential overfertilization of phosphate. When environmental legislation is introduced, biological farms appear to lose more income than conventional farms.

INTRODUCTION

Dairy farmers in the Netherlands who consider conversion to biological farming generally have three types of motives. Concern about environmental problems is a first motive. Main environmental problems caused by dairy farming include eutrophication through excessive fertilization with N and P_2O_5 by means of fertilizer and manure application and acidification through ammonia (NH_3) emission.

The second motive has to do with animal welfare. Some dairy farmers have doubts about high production levels based on a high level of concentrate feeding, about certain breeding techniques, some types of preventive and curative disease control and certain types of animal housing. In biological farming these issues get more attention than in conventional farming.

The final motive is an economic one. From an economic point of view biological farming can be interesting because of the higher price farmers receive for biologically produced milk.

The objectives of this paper are (1) to asses economic and environmental consequences at farm level of conversion to biological dairy farming and (2) to determine the impact of future environmental legislation on the economic consequences of conversion to biological dairy farming. The approach is a modelling one.

BIOLOGICAL DAIRY FARMING IN THE NETHERLANDS

In the Netherlands all farms with a biological practice get the EKO quality mark. The standards and requirements for biological practice that have to be fulfilled to receive the quality mark are set up and controlled by the Inspection Organization for Organic Production Methods (SKAL). The most important standards and requirements for biological dairy farming are (SKAL, 1996):

- Application of artificial fertilizer is not allowed. In biological dairy farming, nitrogen (N) is supplied by growing a mixture of legumes and grass and by application of animal manure from the farm itself or from other farms. Often energy production from biological grassland is lower than from conventional grassland (see for example Halberg & Kristensen, 1995). In contrast to N fertilizer, some types of phosphate (P_2O_5) and potassium fertilizer can be used as they are not artificially produced.
- Chemical-synthetical crop protection is not allowed. Abandonment of this type of crop protection means that silage maize production is affected by weeds, resulting in a lower production per hectare. Decreases in crop yields of 10 to 40% are reported (Padel & Lampkin, 1994). Besides, more labour for mechanical weed control is required.
- The amount of concentrate used on the farm per cow per year (expressed in kg dm) may not exceed 20% of the yearly milk production (expressed in kg). Besides, only

biologically produced feed may be used on the farm. This results in a lower yearly milk production per cow. Differences in milk yield per cow between conventional and biological farming vary from 10 to 30% (Lampkin, 1994; Dubgaard, 1994).

- Use of artificial milk for feeding calves is not allowed;
- Cows have to have a grazing period of at least 120 days per year. This is quite common in conventional dairy farming in the Netherlands.

Inevitably, fulfilment of the requirements and standards for biological farming lead to higher costs and lower physical production. Compensation arises from a higher price for biologically produced foodstuffs. In Northern European countries in the early nineties the price for biologically produced milk was 10 to 25% higher than for conventional milk (Padel & Lampkin, 1994). In the Netherlands, the price for biologically produced milk in 1995 amounted to NLG 85 per 100 kg. This was nearly 15% higher than the price for conventional milk with the same composition (Verhoek, 1996)

MATERIALS AND METHOD

Analysis was based on two typical Dutch dairy farms, an extensive farm with a milk quota per hectare of 8500 kg and an intensive farm with a quota per hectare of 14000 kg. The two farms are both characterized by a cultivated area of 28 ha and milk production per cow of 7400 kg y^{-1}.

A linear programming model, developed by Berentsen & Giesen (1995), was used to model the conventional dairy farms. The objective function maximizes labour income (i.e. return to labour and management). The basic element in the model is a dairy cow, which is assumed to calve in February. Energy and protein requirements are based on Groen (1988) and on the Central Bureau for Livestock Feeding (1995). The cultivated area can be used for producing grass at different N levels, maize and fodder beets. Nutrient supply on fodder crops is based on advice given by the Dutch extension service (Asijee, 1993). Fodders that can be purchased are silage maize, dried beet pulp and three types of concentrate with the same energy content but with different protein content. A full description of the model was given by Berentsen & Giesen (1995).

To model the dairy farms after conversion to biological farming, a new model was developed, based on the model of Berentsen & Giesen (1995). The five levels of N use on grassland (100, 200, 300, 400 and 500 kg ha^{-1}) in the conventional model were replaced by two new activities, grass/red clover and grass/white clover. The energy content (measured in MJ NEL $kgdm^{-1}$) of grass/clover is some 7% lower than that of grass produced at an N level of 300 kg ha^{-1} while the protein content is almost the same. Grass/red clover produces more energy than grass/white clover, but costs are higher due to more frequent renewal. Energy production per hectare of conventional and biological produced grass(/clover), maize and fodder beets are shown in Table 1. Nutrient supply on biological fodder crops is based on Baars & Van Dongen (1993) and on Melgers (1988). This includes the assumption that all fodder crops are grown in monoculture on the same fields every year. Milk production per cow in biological farming is assumed to be 6000 kg. This is 81% of the level in conventional farming. In the biological dairy farm model artificial milk for calve feeding is replaced by natural cow milk. The requirement to restrict the yearly amount of concentrate fed to 20% of the yearly milk production was implemented in the model. Prices and energy content of concentrate and other purchased feed are given in Table 2. The prices are higher for biological farming because of the requirement that this feed is biologically produced. Finally, the possibility of using hired labour was implemented in the model. In biological farming, family labour often is not sufficient to run the farm.

For both the extensive and the intensive farm two situations were compared, producing conventionally and producing according to the biological standards.

Table 1. Energy production of conventional and biological roughage.

	Conventional	Biological
	(MJ NEL ha^{-1})	
Grass:		
- 100 kg N	50.0	-
- 200 kg N	63.5	-
- 300 kg N	71.8	-
- 400 kg N	76.6	-
Grass/white clover	-	57.8
Grass/red clover	-	74.5
Silage maize	83.8	68.3
Fodder beets	100.7	89.7

Sources: Baars & Van Dongen (1988), Baars & Van Dongen (1993), Berentsen & Giesen (1995), and Baars (1997)

Table 2. Prices and energy content of purchased feed.

	Conventional price	Biological price	Energy content
	(NLG kgdm^{-1})		(MJ NEL kgdm^{-1})
Standard concentrate	0.34	0.55	6.5
Low protein concentrate	0.35	0.51	6.5
High protein concentrate	0.43	0.58	6.5
Dried beet pulp	0.34	0.55	6.4
Silage maize	0.31	0.35	6.2

Source: Verhoek (1996).

Additionally, the same comparison was made with future environmental policy included. Concerning eutrophication, the governmental standards for acceptable nutrient surpluses and levies of 2010 were used. Nutrient surpluses are determined by nutrient balances that register all yearly nutrient input and output at farm level. For P_2O_5 the acceptable surplus is 20 kg ha^{-1} and the levy is NLG 5 kg^{-1} for the first 5 kg ha^{-1} above the acceptable surplus and NLG 20 kg^{-1} for any higher surplus. For N the acceptable surplus depends on the use of the land. For grassland the acceptable N surplus amounts to 180 kg ha^{-1} and for arable land to 100 kg ha^{-1}. The levy amounts to NLG 1.50 kg^{-1} (Anon., 1997). Concerning acidification it was assumed that a system of an acceptable emission and a levy on emission exceeding the acceptable level will be used. Based on Berentsen *et al.* (1996), an acceptable emission of 25 kg NH_3 ha^{-1} and a levy of NLG 60 kg^{-1} was assumed.

RESULTS

In all situations the number of dairy cows is maximal given the milk quota and the milk production per cow and the number of young stock is minimal given the replacement rate of the dairy cattle. Another general point concerns the composition of the rations. As grass for grazing is the cheapest energy source, summer rations consist of a maximum amount of grass or grass/clover combined with a small amount of concentrate. Winter rations consist of grass or grass/clover silage, maize silage and concentrate.

The extensive farm

In the conventional situation without levies almost half of the land is used for growing grass at the optimum N level of 300 kg ha^{-1} (Table 3). The rest is used for growing silage maize part of which is sold. Revenues (Table 4) arise from selling milk, animals and silage maize. Costs arise from purchasing concentrate and fertilizer, from growing and harvesting crops, from keeping animals and from investments in buildings and machines. Revenues and costs result in a labour income of NLG 11550. The N and the P_2O_5 balance show input through concentrate and fertilizer, output through milk, meat and sold silage maize and the difference between input and output, the surplus.

In the biological situation without levies feed production on the farm is maximised by growing grass/red clover. The surplus of silage maize is sold. To fulfil the requirement for N that is still needed for grass/red clover and silage maize, animal manure from other farms is required. Total revenues in the biological situation are higher than in the conventional situation because of the higher milk price, the higher number of animals sold and in spite of the lower area of silage maize sold. Differences in costs arise from the higher price of biologically produced concentrate, from the greater amount of manure that has to be injected and from the larger cowshed that is required. In the situation without levies biological farming leads to an income that is NLG 5354 higher than with conventional farming. The N balance

Table 3. Technical results of the extensive farm in four situations

	Conventional without levies	Biological without levies	Conventional with levies	Biological with levies
Number of dairy cows	32	40	32	40
Number of young stock	18	22	18	22
Land use:				
- grass land (ha)	14.8	-	14.8	-
- N level grass land (kg N ha^{-1})	300	-	300	-
- grass/red clover	-	16.7	-	9.2
- grass/white clover	-	0	-	12.5
- silage maize for on farm use (ha)	5.5	8.1	5.5	6.3
- silage maize sold (ha)	7.7	3.2	7.7	0
Purchase of concentrate (1000 MJ NEL)	273	224	273	197
Animal manure from other farms (m^3)	-	385	-	418

shows the advantage of the use of clover. As N binding by clover is not recorded the input is some 130 kg ha^{-1} lower than in the conventional situation. This is partly compensated by lower N output caused by a lower amount of silage maize sold. The resulting N surplus is about one fourth of the surplus in the conventional situation. For P_2O_5 the situation is quite different. P_2O_5 input is almost the same as in the conventional situation but P_2O_5 output is much lower due to the lower amount of silage maize sold. Consequently the surplus is some 30% higher. Here a negative consequence of the SKAL standards arises. N can be supplied only by using animal manure, which has a fixed ratio between N and P_2O_5 content. The N and P_2O_5 requirements of silage maize are such that the amount of manure necessary to satisfy the N requirements leads to excessive supply of P_2O_5. On grass/clover the situation is reverse. Here only a small amount of N is required. The gap between P_2O_5 requirement and P_2O_5 supply by animal manure on grassland is bridged by purchasing P_2O_5 fertilizer. As a whole, the ban on the use of N fertilizer in biological farming leads to a higher P_2O_5 surplus.

Table 4. Economic and environmental results of the extensive farm in four situations.

	Conventional without levies	Biological without levies	Conventional with levies	Biological with levies
Economic results (NLG)				
- Total revenues	220328	242962	220328	229705
- Total costs	208778	226058	209526	216570
- Labour income	11550	16904	10802	13135
N balance (kg ha^{-1})				
- N input:				
• concentrate	44.5	39.5	42.1	32.5
• fertilizer	185.5	-	186.7	-
• animal manure	-	57.8	-	62.8
Total	230.0	97.3	228.8	95.3
- N output (milk, meat and sold maize)	99.6	68.3	99.6	51.4
- N surplus	130.4	29.0	129.2	43.9
- of which NH_3 emission	19.6	25.0	19.3	24.2
P_2O_5 balance (kg ha^{-1})				
- P_2O_5 input:				
• concentrate	21.2	12.5	17.9	9.4
• fertilizer	44.4	25.5	44.7	11.0
• animal manure	-	24.8	-	26.9
Total	65.6	62.7	62.6	47.3
- P_2O_5 output (milk, meat and sold maize)	38.4	28.2	38.4	22.3
- P_2O_5 surplus	27.2	34.6	24.3	25.0

Introduction of levies has only very limited consequences in the conventional situation. The levies particularly replace concentrate in the summer ration by dried beet pulp in order to minimise P_2O_5 input. Higher costs for feed purchased and the levy on P_2O_5 surplus that has to be paid result in a decrease of income of NLG 748. The N balance remains almost unchanged. A P_2O_5 surplus remains of 24.3 kg ha^{-1}. Apparently, the levy on P_2O_5 surplus is not high enough to change land use in such a way that P_2O_5 surpluses decrease.

In the biological situation the farm is confronted with the high levy on P_2O_5 surpluses, so changes are bigger. Beside changing the type of concentrate in the summer ration, the area of silage maize is decreased which decreases overfertilization with P_2O_5. By introduction of grass/white clover roughage production is decreased such that the farm becomes exactly self-sufficient for roughage. Revenues decrease considerably as no silage maize is sold anymore. Costs decrease because less concentrate is purchased, less P_2O_5 fertilizer is purchased, and less silage maize is grown. The decrease in labour income, amounting NLG 3769 shows that it is more difficult in the biological situation to comply to environmental legislation than in the conventional situation. However, switching from conventional to biological farming is still economically profitable. The N balance shows only small differences. The P_2O_5 balance shows an input decrease through concentrate and fertilizer as well as a decrease through output.

The intensive farm

The conventional situation without levies results in a much higher labour income than on the extensive farm. This is caused by the higher number of dairy cows on the farm (Table 5). N surplus and NH_3 emission are strongly related to the number of animals. The P_2O_5 surplus on the other hand is strongly related to plant production. P_2O_5 from fertilizer on the extensive farm is replaced by P_2O_5 from manure on the intensive farm (Table 6). In both biological situations extra labour has to be hired to run the farm. This means that labour influences the farm plan. In the situation without levies grass/red clover and grass/white clover are grown in a ratio such that enough grass is available. Silage maize is purchased. In contrast to the extensive farm, labour income for the intensive farm is lower in the biological situation than in animal manure from other farms because there is no silage maize in the production plan anymore.

In the conventional situation with levies, the farm plan is determined by the levies on NH_3 emission and on P_2O_5 surplus. Minimization of N input in the rations and of P_2O_5 input at farm level leads to extensification of the farm plan resulting in higher costs of purchased feed and lower feed production costs. The high animal density results in NLG 5206 that has to be paid as a levy on NH_3 emission. On total labour income decreases by almost NLG 8000. The target for P_2O_5 surplus is exactly met.

Also in the biological situation with levies the farm plan is determined by levies on NH_3 emission and P_2O_5 surplus leading to minimization of N in the rations and of P_2O_5 input at farm level. Besides, an investment in a low emission cowshed is done with consequential yearly costs of NLG 10838. All adaptations and the levy paid on P_2O_5 surplus lead to a decrease of labour income by about NLG 15400. The target for NH_3 emission is exactly met.

DISCUSSION AND CONCLUSIONS

One of the reasons for assuming a lower milk production while producing biologically was the restriction on the total amount of concentrate that could be fed. However, in all optimisations the actual amount of concentrate fed was lower than the amount allowed by the restriction. This gives cause to the assumption that the difference in milk production per cow could be smaller than the 19% used in the calculations. This means that the number of dairy cows that is required to fully exploit the milk quota could be lower on biological farms. This has a strong influence on labour income through lower housing costs and lower NH_3 emission.

The capacity of the cowshed corresponds with the numbers of cows and young stock. This means that because of the lower production per cow, in the biological situation the farm has a bigger cowshed and consequently higher fixed costs than a conventional situation with the same milk quota. However, in reality many conventional farms have a bigger cowshed than required, being the result of a fixed milk quota at farm level and a milk production per cow that has increased by 145 kg FPCM on average since the introduction of the quota system (Berentsen *et al.*, 1996). On the other hand some farmers utilise their cowshed capacity by purchasing quota. If the capacity of the animal manure from other farms because there is no silage maize in the production plan anymore.

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The environmental policy with respect to NH_3 emission is based on assumptions concerning the acceptable emission and the levy. Since NH_3 emission is strongly correlated with the number of animals, especially the intensive farm in the biological situation suffers heavily from this emission policy. Any alleviation of this rather severe policy leads to better farm economic results for the intensive farm in both the conventional and biological situation. If the alleviation would be substantial then the benefits for the biological farm are higher.

Contrary to standards for N surplus, standards for P_2O_5 surplus and NH_3 emission have more effect on biological farms than on conventional farms. The standard for P_2O_5 surplus is especially hard to realize on extensive farms. Here the problem is the difference between the ratio of N and P_2O_5 requirement of maize and the ratio of N and P_2O_5 content of animal manure. As animal manure is the only allowed source of N, P_2O_5 is supplied excessively on maize. The restriction that only N from animal manure may be used makes the biological system more rigid than the conventional system. On the other hand, rotation could solve the excessive supply of P_2O_5 since grass/clover requires additional P_2O_5 fertilizer. Furthermore, rotation could lead to lower nutrient requirements and consequently lower surpluses but this counts for biological as well as conventional farming. However, rotation is not always easy to implement. Allotment is an important reason why dairy farmers often grow maize on the same parcel every year.

From the results it appears that the extensive farm benefits from the switch to biological farming while the intensive farm loses income. On both type of farms the revenues increase due to a higher milk price and fixed costs increase due to a higher cowshed capacity. What makes the change less attractive for intensive farms is (1) that these farms are not self sufficient for roughage so they have to purchase biological feed at a high price and (2) that these farms require hired labour in the biological situation. An option for intensive farms that want to change to biological farming could be that part of the milk quota is leased out to other dairy farmers. In such a situation the farm becomes less intensive, meaning that less expensive roughage has to be purchased. At the same time the need for extra labour and extra cowshed capacity decreases. A compensation for the lower revenues comes from income from leased out quota.

The ultimate discussion point concerns the feasibility of the LP-model to simulate biological dairy farming. The viewpoint in this paper is that of a conventional farmer who considers a change from conventional to biological dairy farming and who takes into account things that necessarily have to be changed on his farm to fulfil the biological standards. Beside that the farmer wants to keep the farm running in a economically optimal sense. This view does not necessarily correspond with some of the ideals of biological farming and it can for example include the conventional rationale of fertilising single crops according to standards. It is, however, a legitimate view. There are farmers that have mainly economic motives to consider the change from conventional to biological dairy farming, so the cases represented by the models can be found in reality.

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