Developments in mineral surpluses and water quality in the Dutch dairy sector, 1960-2010

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Abstract

This article shows developments in mineral surpluses and in water quality in the Dutch dairy sector in relation to agricultural and environmental policy. In the 1960s and 1970s a major intensification of animal production took place in the Netherlands due to an agricultural policy aimed at high productivity and low prices. Nitrogen and phosphate soil surpluses on dairy farms increased up to 400 kg/ha and 82 kg/ha respectively in 1985. This development resulted in high nitrate levels in the groundwater and loading of the soil with phosphate. From 1984 onwards, measures have been taken to tackle these problems. From 1985 to 2010, this environmental policy realised a reduction on dairy farms of nitrogen soil surpluses by 60% and of phosphate soil surpluses by 85%, while the milk production per ha increased by about 12%. The reduction in mineral surpluses was realised by lowering the input from nitrogen and phosphate in purchased fodder by 15 to 30% and the application of nitrogen and phosphate by chemical fertilisers by 65 to 90%. On dairy farms in the Sand region, the average nitrate concentrations in water leaving the root zone decreased from more than 150 mg/l (1992-1995) to 47 mg/l (2008-2011). Analysis of the relation between mineral surpluses and economic results shows that, on average, dairy farmers with relative low surpluses of nitrogen and phosphate have relative high economic results.

Introduction

After World War II, society, government and the agricultural sector had a clear view of the aims of agricultural development: the production of sufficient quantities of cheap food and the realisation of a good income for its producers: farmers. National agricultural policies, and from 1957 onwards also the European agricultural policy, were devoted to this mission; production was stimulated, e.g. by supporting training and investing in extension services and research. This agricultural policy led to a major intensification of the dairy production between 1950 and 1980. The number of dairy cows in the Netherlands increased by 71% (Oenema *et al.*, 2004; Westhoek *et al.*, 2002).

It was clear that the impact on the environment was not taken into account. In the 1960s and 1970s researchers recognised that production and use of manure created environmental problems (Frouws, 1993). In later years, the acidifying effect of ammonia emissions was acknowledged, and the stench of manure on the fields became an increasing nuisance (Bobbink *et al.*, 1992). Even in the1990s and later the nitrogen and phosphate soil surpluses in the Netherlands for the agricultural sector as a whole were high compared with other EU countries (Table 1). Moreover, the original agricultural policy objective of sufficient and cheap food had largely been achieved. Increased production, both at national and at European level, resulted in surpluses of milk powder and butter, which could only be sold on the world market at the expense of important subsidies.

In this setting, priorities for the agricultural policies shifted and broadened to rural development and agri-environment policies. Conservation of the landscape, the environment and biodiversity became more important.

In the 1980s and 1990s, the Dutch government introduced rules to limit the growth of the livestock, to decrease leaching of nutrients to the groundwater, and to decrease the emission of ammonia. In 1991, the European Commission introduced the Nitrate Directive for the protection of groundwater.

Table 1. Soil surpluses for nitrogen and phosphate in some EU countries for the agricultural sector as a whole (kg/ha)

	1990		1995		2000		2005		2007	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
The Netherlands	215	85	280	75	215	55	180	45	155	27
Flanders (Belgium)	250	280	190	190	150	100	90	30	85	15
Denmark	160	40	160	35	135	35	110	23	110	23
Germany	92	64 [1)]	70	23 [1)]	76	-	45	2 [1)]	54 [2)]	-
France	-	-	56	-	68	-	62		45	-
United Kingdom	50	35	40	35	25	25	22 [3)]	25 [3)]	-	-

Source: Fraters *et al.*, 2011; Zwart *et al.*, 2008.

[1]) OECD data for the years 1985, 1995 and 2004.

[2]) 2006

[3]) 2002

The objective of this paper is to present the developments in mineral surpluses in the Dutch dairy sector in three periods: 1) 1960-1985, before the introduction of policies limiting inputs and outputs; 2) 1985-2007, when environmental policy increased and 3) 2007 and onwards, when fertiliser application standards were introduced (Figure 1). The developments will be discussed in relation to the agricultural and environmental policies. Next, the effect of the environmental policy on water quality will be presented. Furthermore, the relation between mineral surpluses and economic results will be analysed.

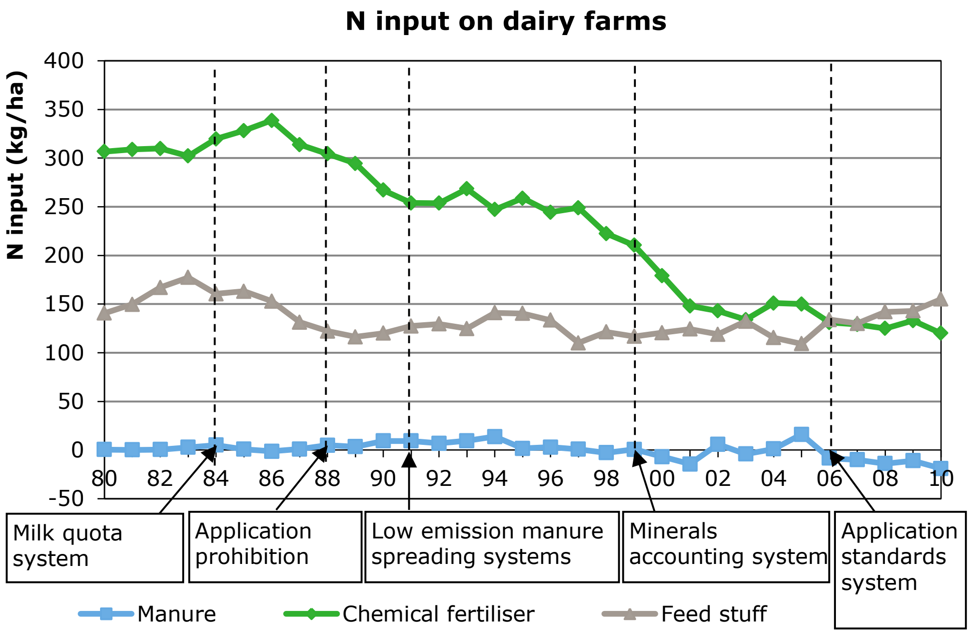

Figure 1. N input on dairy farms by manure, feed and chemical fertiliser linked to EU and Dutch legislation in the Netherlands, 1980-2010

Source: FADN-LMM, LEI.

Method and material

The data on mineral surpluses have been derived from the Dutch Agricultural census (CBS/LEI, several years) and from the Dutch Farm Accountancy Data Network (FADN), which is a sample from the Dutch

Agricultural census (Vrolijk *et al.*, 2009; Fraters *et al.*, 2005). The Agricultural census contains data on the structure of the Dutch farms, e.g. number of hectares, and number of cattle and crops grown. At farm level, the FADN contains data on farm management and the economic results. Moreover, FADN contains information on mineral management at farm level. A substantial number of these farms - 300 - also participate in the Minerals Policy Monitoring Programme (LMM). For those farms, nitrate concentrations in the upper groundwater are available as well and we used those data for this article too.

In this paper we use the terms 'root zone leaching' and 'soil nutrient balance.' Root zone leaching is defined as water leaving the root zone and ending up in the groundwater and surface water system (De Goffau *et al.*, 2012). The 'soil nutrient balance' is defined as the farm gate balance, corrected to account for input and output items on the soil surface balance, as mineralisation, atmospheric deposition and nitrogen fixation by leguminous plants. 'Farm gate balance' is defined as the amount of nutrients, imported into the farm (i.e. in fertilisers, feedstuffs, etc.) and exported from the farm, i.e. in animal products (e.g. milk, meat) and crops (Hooijboer *et al.*, 2013).The calculation of the soil nutrient surplus on dairy farms is performed at farm level. The balance between the use of manure and the removal of crops therefore is quantified by totalling all imports and exports of nutrients at farm level (De Goffau *et al.*, 2012).

The mineral surpluses in the Dutch dairy sector in three periods

1960-1985, the period of growth and intensification

In the 1960s and 1970s the cheap import of fodder and mineral fertiliser caused a waning of interest in proper processing of manure. This development was reinforced by the increasing availability of manure from the growing number of livestock, in combination with increased inputs. Storage capacity of manure did not keep pace with increased production. Most manure was applied during winter, either to the fields of the owner of the livestock or to fields of fellow farmers in the neighbourhood. The Dutch agricultural sector could be characterised by scale increase, specialisation and intensification (Table 2). The number of milk cows increased by nearly 50%; the milk production per cow per year increased by about 25%. As a result, the total Dutch milk production increased by about 85% and the milk production per hectare even doubled. Parallel to this development, dairy farms increasingly opted for specialisation. The number of farms in 1985 decreased to about 33% in comparison with 1960.

Table 2. Evolution of production characteristics in the Dutch dairy sector

	1960	1975	1985	1995	2000	2005	2007	2010
No. of dairy farms (x 1,000)	180	91.5	58	37.5	29.5	23.5	21.3	19.8
Average no. of cows per farm	9	24	41	45.5	51	61	71	75
Total milk production (106 kg)	6,721	10,286	12,525	11,280	11,155	10,827	11,227	11,910
Milk production (kg/ha/yr)*	5,500	8,864	12,512	12,018	12,340	12,560	12,850	14,070
No. of milk cows (x 1,000)	1,628	2,218	2,367	1,708	1,504	1,433	1,413	1,479
Milk production (x 1,000 kg/farm)	37	112.5	216	301	379	460	551	600
Milk production per cow	4,200	4,625	5,330	6,613	7,296	7,554	7,744	8,000
Kg of milk produced per hour of labour	8	37	72	89	108	115	125	135

Sources: Van Horne and Prins (2002); Agricultural and horticultural statistics, several years; FADN.
* Based on the number of hectares of grassland and fodder crops on dairy farms (agricultural data FADN, LEI Wageningen UR; CBS/LEI several years.

Nutrition of cattle improved, induced by continuous advances in grassland and fodder management and by better fodder processing methods. The intensification and the availability of cheap imported feed concentrates and fertilisers led to higher inputs of minerals (Table 3). Since fertilisers and feed concentrates were imported cheaply, there was no economic incentive to manage minerals efficiently (Berkhout and Van Bruchem, 2011). From the 1970s onwards, excess manure was handled by the 'manure bank' for transport to more remote areas with manure deficits. This was initiated by the government to promote a suitable export of surpluses of manure.

Table 3. Development of the amounts of feed concentrates, the supply of nutrients in fodder and chemical fertilisers, and the resulting nitrogen and phosphate soil surpluses per hectare on dairy farms

	1960	1975	1985	1995	2001	2005	2007	2010
Milk production (kg/cow/yr)	4,200	4,625	5,330	6,613	7,420	7,554	7,744	8,000
Young stock (number/10 cows)		8.5	7.3	8.8	7.6	7.2	7.1	7.8
Fodder concentrates (kg/cow/yr)	830	1.890	2.280	2.210	2.000	2.020	2.120	2.060
N supply in fodder (kg/ha/yr)	25 [1)]	141*	163	182	141	119	156	155
P_2O_5 supply in fodder (kg/ha/yr)	10 [1)]	82*	90	70	58	49	61	54
N in chemical fertiliser (kg/ha/yr)	115	275	350	252	148	150	129	120
P_2O_5 in chemical fertiliser (kg/ha/yr)	30	30	37	29	16	22	8	3
N soil surplus (kg/ha/yr)		350*	400	342	200	184	183	160
P_2O_5 soil surplus (kg/ha/yr)		65*	82	59	32	36	15	12

Sources: Kolenbrander (1972); Huntjens (1972); Van Horne and Prins (2002); FADN_LMM, LEI Wageningen UR.
[1]) Ketelaars and Van de Ven (1992)
[*]) 1980

Limited manure storage capacity sometimes forced farmers to spread manure during unsuitable agronomical conditions, causing damage to the grass cover. This agronomical risk caused farmers to limit manure application primarily to maize fields, especially in the central, eastern and southern sand districts, up to several hundreds of tonnes per hectare. These practices of manure and fertiliser application, both in timing and in quantities, had important effects on the nitrate concentrations in water leaving the root zone, especially under maize in the Sand region (322 mg NO_3/l in 1992; Fraters *et al.*, 1997). For quite a long period, these impacts on the environment due to the excessive input of minerals remained largely unnoticed by the dairy farmers and their advisors, despite signals from researchers and environmental groups (Frouws, 1993).

1985-2007, the period of increasing environmental policy

Since the mid-1980s, the agricultural developments as described have been curbed to some extent by an evolving regulatory framework, formulated to reduce and minimise their negative environmental impacts. In 1984 the milk quota system was introduced to limit the 'butter mountain' and drain the 'milk lake'. After 1984, scale increase, specialisation and a decrease in the number of dairy farms continued. In general, a further upscaling and intensification of agricultural production has taken place (Table 2). Although the number of animals showed a drop after 1985, the production per head or per surface unit continued to increase as a result of better agricultural systems (nutrition of cattle, manuring of grassland and maize land and breeding programmes) and legislation (milk quota system, introduction of manure laws).

The government's intention, after recognition of the manure problem, was to tackle the problem in several stages. First, the continuing growth of the manure production was to be stopped (1984-1987). The agricultural sector was increasingly confronted with measures to restrict production (Berkhout and Van Bruchem, 2011).

Second, application standards for phosphate were introduced, which were tightened gradually (1987-1998). In 1987, two framework acts were adopted: the act on the protection of soils and the Fertilizer Act[1]. In 1987 the maximum amount of phosphate on grassland from animal manure was set at 250 kg/ha, and on maize land at 350 kg/ha. For other types of agricultural land an amount of 125 kg/ha was permitted (LNV, 1986). These amounts were merely set to make a first start in lowering manure application rates.

During the implementation of the Fertilizer Act, several stand-alone measures were promulgated, each focusing on a specific element in the production and disposal chain of manure. The shorter period in

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[1] To be more precise: the Fertilizer Act was not enacted in 1987 but rather 'revitalised'. The original Fertilizer Act dates from 1947 and only pertained to chemical fertilisers. An important modification of the 1987 revision was the inclusion of organic fertiliser (animal manure) under the remit of this Act.

which manure spreading was allowed (spring and summer) resulted in the need for more manure storage capacity. In addition, measures were implemented related to the housing of cattle, the capping of manure depots, low-emission application of manure and the composition of fodder (Figure 1). Most measures up to 2003 did not primarily focus on a reduction of the nitrogen loading of the soil but rather on limiting the ammonia emissions from manure[2] (Dougle and Kroon, 2005). This objective was achieved by prescribing low-emission application of slurry, by reducing emissions from stables and by capping manure/slurry depots.

From 1998 to 2002, the Minerals Accounting Systems (MINAS) was introduced and implemented on nearly all dairy farms. MINAS is a balance approach on farm level, based on inputs of minerals to the farm and outputs of minerals off the farm. These inputs and outputs are registered. The differences between inputs and outputs are the surpluses of minerals (nitrogen and phosphate). MINAS gradually led to an increased efficiency, especially in use of fodder and chemical fertiliser. MINAS was based on the principle that farmers paid levies on the overdose of minerals utilised and it focused on the concept of 'loss standards[3]'. The concept of 'application standards' was thus abandoned.

The new regulations resulted in better farm management and farm practices, which in turn had positive environmental effects. The nitrogen content and phosphate content in fodder decreased, which contributed to the decrease in nutrients supplied to agricultural land with manure. In addition, the supply of chemical fertiliser to agricultural land decreased, especially from 1995 onwards. Through better farm management, the farmers realised 50% more milk per cow whilst stabilising the amount of fodder concentrates at about 2,000 kg/cow/year (Van den Ham *et al.*, 2010). Consequently, the amount of fodder concentrates per 100 kg of milk decreased from about 40 kg in the period 1975-1985 to about 30 kg in the 1990s and to about 25 kg after the year 2000. Farmers realised strong reductions in fertiliser use (Table 3) while the yield of grassland and fodder maize only slightly decreased (Aarts *et al.*, 2008). In the 1980s, dairy farmers expanded the number of calves and yearlings per 10 milking cows from 7 to 9 to eat the surplus of roughage. In the second part of the 1990s, they reduced this number to 7 in 2006 (Van den Ham *et al.*, 2010). The dairy farmers thought having many calves and yearlings on an economic basis no longer made sense after the introduction of MINAS.

Due to the changes in farm practices the nitrogen soil surplus on highly specialised dairy farms decreased strongly, especially from 1995 to 2002. The phosphate surpluses on the soil nutrient balance decreased strongly, especially from 1994 to 2002 (Figure 2).

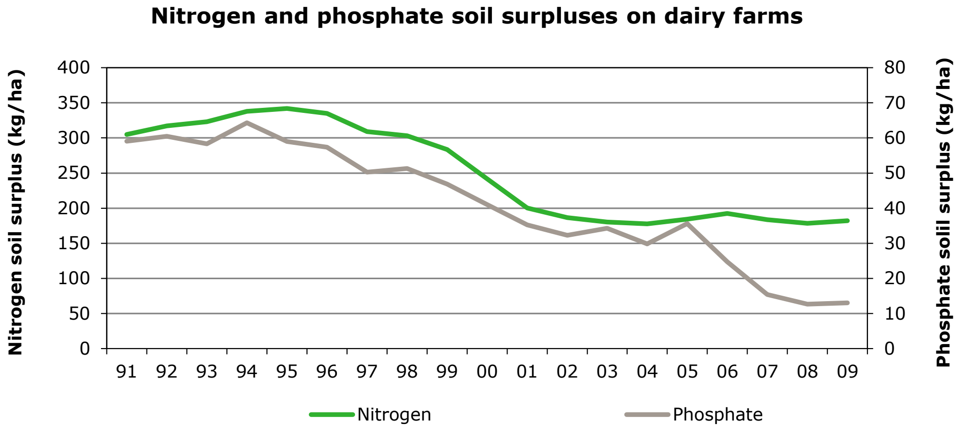

Figure 2. Average nitrogen and phosphate surpluses on the soil nutrient balance on highly specialised dairy farms
Source: Van den Ham *et al.* (2012).

[2] It is noted though that synchronous introduction of milk quota has led to a reduction of the amount of cattle dung.
[3] Permissable losses of minerals into the soil.

From 2007 onwards: Application standards once again

The Dutch legislation on manure management is directly linked to the EU regulatory framework. The European Nitrates Directive (EU, 1991) aims to reduce, and ultimately to prevent, water pollution by nitrate from agriculture. Member States are obliged to act upon action programmes for nitrate vulnerable areas (NVZ). Member States also have the obligation to operate monitoring schemes with the objective of determining the level of nitrate pollution by agriculture and investigating the effectiveness of their action programmes[4]. In the Netherlands, the LMM programme monitors the way the targets are realised. Important objectives of LMM are monitoring the nitrate concentrations in the water leaving the root zone, and the agricultural practice (e.g. nutrient use) at selected farms (Fraters *et al.*, 2005). The LMM serves as an instrument to meet the monitoring requirements as imposed by the EC (Nitrates Directive and derogation decision).

The European Nitrates Directive limits the application of nitrogen from animal manure to 170 kg/ha. Under specific conditions, the European Commission (EC) may allow countries to deviate from this regulation (derogation). By the end of 2005, the EC granted the Netherlands derogation for the application of manure from grazing animals for the period 2006-2009, allowing certain farmers to apply up to 250 kg N/ha when they cultivate grass on at least 70% of their land (EU, 2005). In February 2010, this derogation was prolonged until 31 December 2013 (LNV, 2009). One of the conditions for this derogation obliged the Dutch government to establish a dedicated monitoring network on at least 300 farms with derogation. The monitoring network must provide data on the nitrate and phosphorus concentrations in water leaving the root zone.

Elements of the Dutch Second Action Programme (1999-2003) were rejected by the European Court of Justice. More specifically, the system of 'loss standards' (MINAS) was rejected for lacking conformity with the Nitrates Directive. Consequently, a new set of regulations was promulgated on 1 January 2006, to be applied within the framework of the Third Action Programme for the period 2004-2009 (LNV, 2005). A system of 'application standards' was introduced again in 2006, replacing MINAS. In this new system, standards are set per crop type for the maximum allowable nitrogen and phosphorus application. Since 1 January 2006, phosphate in chemical fertiliser has been regulated.

A direct steering of the input of minerals in the feed stuff was lost due to the introduction of application standards. Nearly from the very start in 2006 indeed the farm-specific excretion calculation (BEX) was developed but in practice the farmers hardly used this. The more farmers use the BEX, the more the direct steering on the input of minerals in the feed stuff came back. A further decrease of the nitrogen soil surplus, however, was hardly seen after 2005. The phosphate soil surplus decreased considerably from 2006 onwards (Figure 2). The most important reason is that from 2006 the input of phosphate by chemical fertilisers was taken into account. Consequently dairy farmers lowered the input of phosphate by chemical fertiliser considerably.

Effects on the nitrate concentrations in water leaving the root zone

In the first part of the 90s, the nitrate contents in the water leaving the root zone were high, especially in the Sand region. In the second part of that decade, the nitrate contents dropped. In the Peat region and the Clay region, on average, the target (less than 50 mg/l) was realised (Figure 3). In the Sand region and the Löss region this was not yet the case in 2004-2007, although the nitrogen soil surplus dropped below 200 kg/ha then (Figure 2 and Figure 3). Although the nitrogen soil surpluses did not decrease after 2005, the nitrate concentrations in water leaving the root zone did decrease, especially in the Sand region and the Löss region (Figure 3). On average the nitrate concentrations in water leaving the root zone on dairy farms was realised then.

[4] The ongoing and growing monitoring effort within the LMM is also to be viewed in this light.

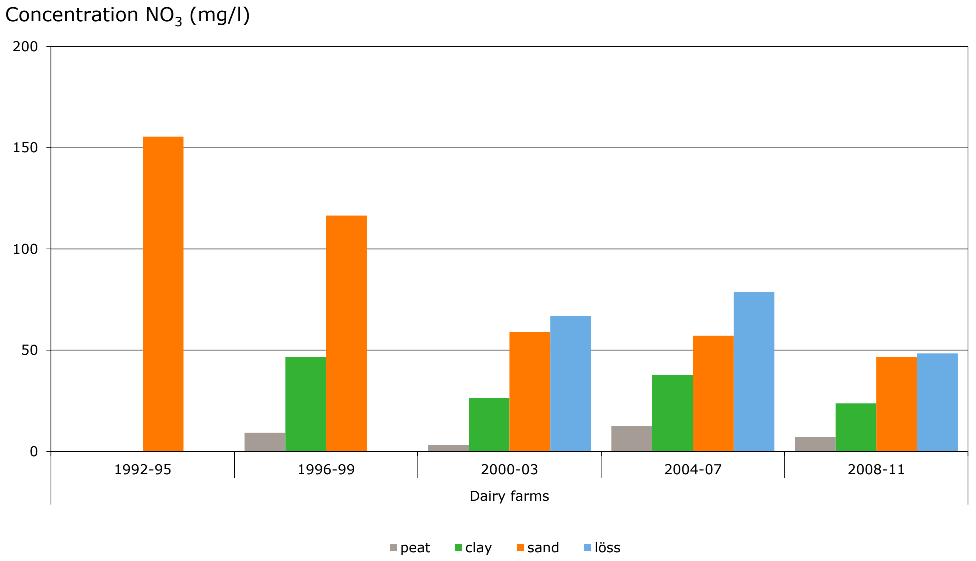

Figure 3. Average nitrate concentrations in water leaching from the root zone at dairy farms in the period 1992-2011 (until 2010 for the Löss region)
Source: Baumann *et al.* (2012).

Nitrogen soil surpluses and economic results

Dairy farmers prefer measures for a better environment which also have a positive effect on their income. The question is: Do dairy farmers who realise low soil surpluses have the same or even a better income than dairy farmers who realise higher soil surpluses? LEI investigated this by comparing the results in 2006 of three groups consisting of about 50 dairy farms each (Table 4).

Table 4. Farm economic characteristics of three groups of dairy farms on sandy soils, classified according to nitrogen soil surpluses per hectare (Daatselaar *et al.*, 2010; Van den Ham *et al.*, 2010)

	Low	Middle	High
Number of farms	51	52	51
Dairy production/farm (kg/yr)	681,908	664,687	583,473
Dairy production/ha (kg/ha/yr)	14,296	14,398	14,451
Dairy production/cow (kg/cow/yr)	7,665 [a]	8,286 [b]	8,258 [b]
N in chemical fertiliser (kg/ha/yr)	112 [a]	160 [b]	174 [b]
N in livestock manure (kg/ha/yr)	225 [a]	250 [b]	258 [b]
N soil surplus (kg/ha/yr)	107	171	228
Part of grassland (%)	78	77	79
Concentrates kVEM/100 kg milk)	27.4	27.7	28.6
Mowing %	283	279	279
Part of grazing in autumn (%)	32	38	34
Fodder crop yield (kVEM/ha/yr)	8,578	8,268	7,914
Gross margin (€/100 kg milk)	28.72 [a]	27.03 [b]	25.95 [b]
Labour income (€/100 kg milk)	3.48 [a]	3.07 [a]	0.46 [b]
Nitrate concentration (mg/l groundwater)	53	58	65
Deviation nitrate concentration [1)]	-14 [a]	-7 [b]	3 [b]

a) and b) a different letter denotes a significant difference ($P < 0.05$)
[1]) Deviation measured in nitrate concentration when corrected for differences in ground water table and precipitation.

As Table 4 shows, dairy farms with relative low N soil surpluses realise:
- a lower milk production per cow per year;
- a lower N gift, both for chemical fertiliser and for livestock manure;
- a better income, both as gross margin and as labour income;
- a lower nitrate concentration in groundwater than expected when corrected for differences in ground water table and precipitation (rainfall, layer, fall).

Conclusions

In line with the agricultural policy during 1950-1980, which aimed at increasing production levels, inputs of fertiliser and purchased fodder increased considerably, resulting in higher milk production levels per hectare and per cow on Dutch dairy farms. This intensification of the dairy farming system resulted in a nitrogen soil surplus of 400 kg/ha and a phosphate surplus of 82 kg/ha on average on dairy farms in 1985, which led to high nitrate contents in the water leaving the root zone, especially in the Sand region.

Dairy farmers changed their nutrient management since the 1990s. The amount of concentrates per cow stabilised, while the amount of milk produced per cow, increased by about 50%. Farmers decreased the number of calves and yearlings per 10 cows from nearly 9 in the 1990s to about 7 in 2006. They lowered their nitrogen soil surplus in the 1985-2010 period while milk production per hectare increased to an average level of 14,000 kg/ha.

From 1995 onwards, policy-driven changes in farm management and farm practices led to a decrease in surpluses for nitrogen and phosphate. The amount of nitrogen and phosphate in purchased fodder in 2010 decreased by 15 to 30%. The nitrogen supply of chemical fertilisers to agricultural land decreased by 65 to 90%. This resulted in a nitrogen soil surplus of 160 kg/ha and a phosphate surplus of 12 kg/ha on average on dairy farms. The biggest decrease in nitrogen soil surpluses was reached in the 1995-2002 period. In the 2006-2010 period, the phosphate soil surplus also decreased.

The average nitrate concentrations in water leaving the root zone on dairy farms in the Sand region decreased from more than 150 mg/l in the 1992-1995 period to 47 mg/l in the 2008-2011 period.

Dairy farmers with lower surpluses of nitrogen and phosphate often have better economic results than dairy farms with higher surpluses. Although they use relative low nitrogen applications, their fodder crop yield is comparable with the yield of farmers with higher surpluses of nitrogen. Due to the relative low nitrogen surpluses they also realise lower nitrate concentrations in water leaving the root zone.

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