Working Paper

NUTRIENT EFFICIENCY IN DAIRY FARMING

Nitrogen, phosphorus and potassium use in the Netherlands, Spain and Poland

J.W.A. Langeveld

WP-94-14
March 1994

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FOREWORD

Nutrients play an important role in agriculture. They are applied as fertilizers, used as animal feeds and sold with farm products. Much attention has been given to ensure sufficient availability of nutrients in production situations. This has lead to the consequent overuse of nutrients in many parts of Europe. However, more and more attention is given to improvement of nutrient use efficiency. Global change processes have drawn attention to the effect of greenhouse gas emissions, which partly originate from agriculture. In addition, the economic value of nutrient losses now receives more attention as margins in animal and crop production have declined significantly.

Analyzing nutrient supply and production flows can provide a good overview of the amount of nutrients that are involved in agricultural production and the nutrient efficiency of production processes. Early work on nutrient efficiency concentrated on national or regional balances. More recent work studies complete farms and tries to asses the efficiency of nutrients in agriculture. Analyzing production at the farm level has some advantages. It offers insight into the day to day practices of the farmer and shows how flows occur in different parts of the farm. Estimations of economic costs can easily be made.

Data on nutrient use at different types of farms are however still scarce. During a three months stay at the International Institute of Applied Systems Analyses (IIASA) for the YSSP programme, nutrient efficiency was calculated for major agricultural nutrients in The Netherlands, Spain and Poland. The focus was on dairy farming, but data for Spain or Poland did not allow sufficient stratification of farm practices. In these cases, more general data were used.

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ABSTRACT

Nutrient flows are calculated for dairy farms in three countries: The Netherlands, Spain and Poland. Incoming flows are compared with outgoing flows, where a distinction is made between nutrients that leave the farm in the form of farm products and other flows. Non-product flows are considered as undesirable although they may contain storage of nutrients in the soil. Efficiency of farm production is expressed as total amount of unutilized nutrients per hectare (nutrient surplus) or as part of available nutrients that are recovered in the products (nutrient efficiency). This allows comparison of efficiency rates in the countries that were studied.

Nutrient efficiency is calculated for the use of nitrogen, phosphorus and potassium, being the most important nutrients in agriculture. Specific data for dairy farming were lacking for Spain and Poland. In these cases, general data were used.

Large differences are found between the countries. Nutrient surplus is very high in The Netherlands, where efficiency is low: about 20 % of the available nitrogen and 35 % of phosphorus and potassium is recovered in farm products. Surplus of nutrients in Spain is limited to 65 kg of nitrogen and less than 10 kg of phosphorus and potassium. Polish agriculture fully utilizes available phosphate and potassium while nitrogen surplus is less than 30 kg per hectare. Efficiency rates in this country are very high (50 to 100 %). They are about double of those in Spain.

Differences that are found between countries reflect differences in production background. They refer to other farm styles, where production takes place under specific policy or economic conditions. Figures on The Netherlands apply to intensive and specialized in dairy farms, while data for Spain and Poland refer to general and mixed farming conditions. Using comparable, average, data for The Netherlands does not change the outcome. This is due to the high animal density (number of animals per hectare) and general intensive farming practices in this country.

The influence of policy environment on nutrient applications and efficiency is demonstrated by a comparison of efficiency rates in Dutch dairy farming during different years. It appears that policy measures like production quotation has lead to a steady improvement of nutrient efficiency (efficiency increased with 40 %). Likewise, economic changes in Poland have lead to a strong decline in fertilizer and feed purchases per farm. This has had however limited effect on nutrient efficiency.

Comparison of efficiency rates should be accompanied by an analysis of farming conditions. While most figures relate to averages of large numbers of farms in different areas, little is known of the effect this has on the outcome of the calculations. Nutrient efficiency can vary enormously between farm types or regions. Studies reveal that these differences probably are related to animal density, fertilizer application and production of animal feed.

Notwithstanding the use of average and general data it is felt that the outcome of this study sheds some light on different production practices in Europe and the efficiency of nutrient use in The Netherlands, Spain and Poland. The outcome, however, is general and not applicable to specific local production situations.

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Section 1

INTRODUCTION

Nutrient balances can be used to give insight in nutrient flows at farm level. The percentage of available nutrients that is found in final products gives an idea of the efficiency of the production process. Remaining nutrients are partly lost. These losses go at the expenses of farm income, but also cause large environmental costs. Information on nutrient efficiency therefore can be of great interest.

In order to compare nutrient efficiency this study calculated nutrient balances for three countries: The Netherlands, Spain and Poland. These countries have been selected because they represent different farming conditions in Europe. In principle, balances will be calculated for dairy farming. Such information could however not be obtained for Spain and Poland. In stead, general data are taken.

The outline of the paper is as follows. The concept of a nutrient balance is presented in chapter 2. Nutrient balances for The Netherlands, Spain and Poland are given in chapter 3. They are compared in chapter 4. Conclusions are drawn in chapter 5.

Section 2

NUTRIENT SURPLUS AND EFFICIENCY

A nutrient balance compares incoming and outgoing flows of nutrients. It is a scale neutral concept, which can be calculated for a farm, a field, a region or a nation. Most applications concentrate however on the farm level. At a dairy farm, three types of nutrient flows can be distinguished: supply, removal and emissions. Nutrients are supplied by purchases of fertilizers and animal feeds. They are supplemented by additional flows like deposition from the air, use of cleaning materials and milk powder used for feeding the calves. In some cases weathering of soil minerals can release nutrients as well, but usually speed of weathering is so low that this is not an important nutrient source.

Supply		Removal		Emissions	
fertilizer		milk		air	
feeds		animals		water	
roughage		manure		soil	
other in		roughage			
Total in		Total out		Total	

Figure 1: Nutrient flows in a Dutch dairy farm

Nutrients can be removed by sales of farm products and byproducts (milk, animals, manure, feeds), or lost during production. In the latter case we speak of losses or emissions. These take place in the form of ammonia volatization, denitrification, nutrient leaching or flushing to the surface water. Nutrients can also be stored in the soil, to be released in a later year. Nutrients that are stored should not be regarded as losses, although they can be lost after release.

A nutrient balance compares supply and removal flows. A positive balance is called surplus. Such a surplus comprises all nutrients that are not recovered in the final products. Products usually consist of crops or animal products, but can take the form of feed or manure as well. All commodities that are sold are considered 'products'.

Nutrient flows in agriculture can be considered from different angles. This study considers the efficiency of nutrient use in agricultural production. Two concepts are central in the evaluation of nutrient efficiency. One is the absolute amount of nutrients that are not recovered in products: the surplus. The other concept refers to the fraction of total available nutrients that is recovered. This is called nutrient efficiency or simply efficiency. It is expressed in procents, and considered as a general measure of agricultural efficiency. A third way to measure efficiency is the calculation of the nutrient surplus per ton of milk or agricultural product.

Nutrient flows are described on an annual basis. Total amounts are averaged over the year. Flows are

Total in	Emissions air
- Total out	+ Water
= Surplus	= Losses
- Losses	
= Soil	

Figure 2: A simple nutrient balance

calculated for the entire farm. Animal population of the farm is equally distributed over the total farm area, be it grassland or arable land.

Calculations are done with average data that cover a whole range of farms. Variability between farms is not considered. Results are not applicable to individual farms, nor to specific regions or groups of farms other than the whole sample.

This study considers three nutrients: nitrogen, phosphate and potassium, often referred to as 'macro' nutrients because of their importance in agriculture. They also play an important role in global climatic change, acidification and eutrophication processes. The three 'macro' nutrients can be measured in different units. Nitrogen is found as nitrate or ammonia, while phosphorus and potassium often are applied as oxides. In this study all nutrients are expressed in their pure form. Figures from other sources are recalculated. Conversion factors are given in annexe 1.

Section 3

NUTRIENT BALANCES IN DAIRY FARMING

This chapter will present nutrient balances for The Netherlands, Spain and Poland. The type of data that are used to calculate the balance differs per country. This is discussed in the text. Balances will be described shortly. Full balances are given in annexe 2. Detailed description is presented in annexe 3.

3.1 The Netherlands

An important study on nutrient flows in the Netherlands was published in 1988 (Aarts et al., 1988). Since then various authors have done research on nutrient balances. Most work has been done by the Agricultural Economics Research Institute (LEI-DLO). Using a sample of dairy farms this institute collected actual data that were converted into nutrient flows. Being not originally collected for this purpose, some tricks had to be applied in order to translate them into nutrient flows (Daatselaar, 1989; 13). Results can however be considered as being representative for dairy farming in The Netherlands.

Efficiency has been calculated with the most recent data set that currently is available (1989/90 season; Mulder and Poppe, 1993). Data apply to 400 highly specialized dairy farms. Average size is 29 ha (of which three hectares of silage maize). Animal population is 52 dairy cows plus youngsters. Milk production accounts to 12 tons per hectare (see also annexe 3.1).

Fertilizer use is high with more than 300 kg of nitrogen fertilizers per hectare. Animal density (almost two dairy cows per hectare) and purchase of animal feeds are high as well. Nutrient supply is more than 500 kg of nitrogen per hectare. Removal by farm products and byproducts is considerable but surplus still is very high: more than 400 kg of nitrogen, 50 kg of phosphorus and 120 kg of potassium per hectare (tables 1 and 2).

Table 1: Nutrient supply in Dutch dairy farming

	Fertilizer	Feed	Other	Total
N	323	147	59	529
P	23	27	3	53
K	31	85	5	121

Note: Flows in kg/ha.
Source: Mulder and Poppe (1993)

Nutrient efficiency (table 2) is not very high. Only one fifth of available nitrogen and one third of phosphorus and potassium is recovered. The rest volatizes, leaches or is stored in the soil. Nutrient surplus per ton of milk is rather favourable due to a high production of milk per hectare (12000 kg).

Table 2: Nutrient removal and surplus in Dutch dairy farming

	Removal	Surplus	Surplus per ton of milk produced	Efficiency (%)
N	106	423	35	20
P	20	33	3	38
K	41	81	7	33

Note: Flows in kg/ha.
Source: Mulder and Poppe (1993).

3.2 Spain

Specific data on dairy farming in Spain were not at our disposal. In stead, general data were collected from the 1986 statistical report of the Ministry of Agriculture, Fisheries and Food (1986). They refer to a farm with on average 8 ha (of which three hectare of grassland), two heads of cattle and three other animal units[1] (sheep, goats or pigs). Milk production is 330 kg/ha (annexe 3.2).

Fertilizer use in Spain is not so high. Application of nitrogen fertilizer is some 50 kg/ha. Farms considered are mixed, combining both arable farming and animal husbandry. This means that most animal feeds are produced on the farm, and purchase of feed is very low. Nutrient supply by feeds is less than 20 kg/ha. Deposition of nutrients is less than in The Netherlands. Generally, nutrient supply is rather low (table 3).

Table 3: Nutrient supply in Spanish agriculture

	Fertilizer	Feed	Other	Total
N	51	11	24	86
P	11	2	0	13
K	14	4	0	18

Note: Flows in kg/ha.
Source: Calculated from Ministry of Agriculture, Fisheries and Food, 1986.

As nutrient removal is low, surplus per hectare is not very high. Nitrogen surplus has been calculated at 65 kg/ha, but figures for phosphorus and potassium are much lower. Milk production per hectare is very low (300 kg). Surplus per ton of milk therefore is high with almost 200 kg of nitrogen, 23 kg of phosphorus and 28 kg of potassium. Nutrient efficiency is however reasonable (26, 41 and 47 % respectively; table 4).

[1] Animal units are used to compare different types of animals. One unit equals to an adult cow. All other animals are given as weight equivalents. See also Poppe (1992).

Table 4: Nutrient removal and surplus in Spanish farming

	Removal	Surplus	Surplus per ton of milk produced	Efficiency (%)
N	22	64	191	26
P	5	8	23	41
K	8	9	28	47

Note: Flows in kg/ha.
Source: Calculated from Ministry of Agriculture, Fisheries and Food, 1986.

3.3 Poland

Input and output flows of dairy production in Poland are calculated from data provided by the Polish Statistical Office (GUS; mainly GUS, 1992). Data from the Institute of Agricultural and Food Economics' bookkeeping project are available, but were not yet translated to nutrient flows. In order to be able to compare data with the situation in the other two countries we use data on private farms.

Data on specialized dairy farms could not be obtained during the exercise; calculations are done with general data from the most recent year available, 1991. They refer to a farm with 6.3 ha of land, of which 3 ha of cereals and some 2 ha of grassland. There are 3 heads of cattle at this farm, as well as one other animal unit. Milk production per hectare is 835 kg. More details can be found in annexe 3.3.

Nutrient supply is very small. Not more than 60 kg of nitrogen is available per hectare. Most nutrients come from fertilizers, but as application rates are very low other sources are important as well. Deposition and fixation supply about 50 % of all nitrogen. Purchased animal feed plays no role of importance (table 5).

Table 5: Nutrient supply in Polish agriculture

	Fertilizer	Feed	Other	Total
N	32	1	27	60
P	7	0	1	8
K	18	1	2	21

Note: Flows in kg/ha.
Source: calculated from GUS, 1992.

Considering the low supply, nutrient removal still is considerable. Especially milk production per hectare is at a reasonable level. Not surprising, nutrient surpluses are very low. Nitrogen surplus is below 28 kg/ha. Surplus of phosphorus and potassium are negative, indicating a net decline of soil fertility. Efficiency for these nutrients could not be calculated. It is set at 100 % (all supplied nutrients are removed by products). Nutrient efficiency for nitrogen has been calculated at 54 %. Surplus per ton of milk is 33 kg. See also table 6.

Table 6: Nutrient removal and surplus in Polish farming

	Removal	Surplus	Surplus per ton of milk produced	Efficiency (%)
N	32	27	33	54
P	11	(-3)	0	100
K	26	(-5)	0	100

Note: Flows in kg/ha.
Source: Calculated from GUS, 1992.

Section 4

DIFFERENCES IN NUTRIENT EFFICIENCY

In this chapter nutrient efficiency in The Netherlands, Spain and Poland will be compared. Factors that lay behind differences in efficiency will be discussed, especially farm type, inter-annual variability of nutrient application and nutrient prices.

4.1 Comparison of balances

Nutrient supply in The Netherlands is high. Many fertilizers are applied and there is a large number of animals per hectare. As a result, nutrient surplus is very high. Efficiency of nutrient use is low, but more favourable if it is expressed in surplus per ton of milk produced. This is caused by a high production of milk per hectare (12000 kg).

Animal density in Spain is low, as is nutrient supply in the form of (purchased) feeds and fertilizer application. Nutrient surplus therefore is low. However, efficiency is not much higher than in The Netherlands, except for potassium. Milk production is low and surplus per ton of milk is six times higher than in the Dutch situation.

Poland has a nutrient supply comparable to that in Spain. Removal is however much higher, and surplus lower. Phosphorus and potassium even show a negative balance: stocks are being mined. If one corrects for emissions the situation is even worse. This is an indication of the unique situation in Polish agriculture at this moment. As a result nutrient efficiency is very high (50 % for nitrogen and 100 % for potassium and phosphorus are finally found in the product). Surplus per ton of milk produced is favourable.

A full comparison of the balances should be done with utmost care. Farming conditions are vastly different in the given countries. Data on The Netherlands cover specialized dairy farms, while general data are taken for Spain and Poland. As a result, animal density per hectare is high in The Netherlands, and low in Spain and Poland. Use of inputs in Poland is extremely low. Surprising, productivity still is considerable. Generally, differences in farming conditions dictate different nutrient strategies. In the following paragraphs we will consider some of these factors in more detail.

4.2 Farm types

Part of the differences between the balances are caused by the fact that different types of data are used. Data for The Netherlands cover specialized dairy farms, while the balance for Spain and Poland has been calculated with general data. This influences the results. Dutch dairy farms are known for their intensive use of fertilizers and high number of dairy cows per hectare. Data on such farms can not be compared with national statistics that cover arable farming as well as different types of animal husbandry. Such a comparison only is useful if the same type of data is used.

Nutrient efficiency also has been calculated with average data for the entire Dutch agriculture, featuring both arable farming and animal husbandry. An average farm now is 18 ha, and has 32 heads of cattle of which 18 cows. Milk production here is 6 tons per hectare (see annexe 3.4).

The result of the calculations are given in tables 7 and 8, and annexe 2.4. Nutrient supply in this balance is comparable to supply in dairy farms. Removal of nutrients is about the same. Only for potassium there is a difference. Potassium applications in arable farming and non-cattle animal husbandry is considerably higher. Nutrient removal by products is comparable to that in dairy farms. Surplus is almost the same for nitrogen and phosphorus, but higher in the general situation for potassium. Differences occur however in nutrient efficiency.

Efficiency of phosphorus is better in the general situation, while potassium efficiency is higher on dairy farms. Nitrogen efficiency is about the same. Nutrient surplus per ton of milk produced is lower on dairy farms. These differences disappear however if crop production is considered as well. Surplus per ton of production on dairy farms then is comparable to figures for general agriculture (see table 7 or annexe 2.4).

Table 7: Comparison of efficiency in the Netherlands with different data sources

	Supply		Surplus		Surplus per ton of milk		Nutrient efficiency	
	Dairy	General	Dairy	General	Dairy	General	Dairy	General
N	529	535	421	426	35	72	20	21
P	53	65	33	34	3	6	38	49
K	121	222	81	167	7	28	33	25

Note: Flows in kg/ha.
Source: Mulder and Poppe (1993) and calculated from LEI/CBS (1991).

The fact that these balances are so similar can come as a surprise, but is rather easily explained. Dairy farming plays an important role in The Netherlands. One quarter of all farms is specialized in dairy production, while one third can be characterized as dairy farm. In other agricultural sectors also many animals are kept. Per hectare five animals are found, compared to 0.7 in Spain and Poland. Use of fertilizers and animal feeds on dairy farms in The Netherlands therefore gives a good indication of the average situation in agriculture. This does however not mean that there is no variation between different sectors.

Mulder and Poppe (1993; 138) calculated balances for different farm types in The Netherlands. Nutrient surplus per hectare is highest on farms with intensive animal husbandry (pigs, poultry, calves), followed by dairy farms. The more animals that are found on one hectare, the higher is the surplus. But also within sectors considerable differences occur. In a detailed factor analysis, Daatselaar (1989) and Daatselaar et al. (1990) showed that the nutrient surplus in dairy farming depends to a high extent on the milk production per hectare. The latter depends on the number of dairy cows per hectare, but also on the milk production per cow. Another important factor is application of nitrogen fertilizers on grassland.

4.3 Inter-annual variation

Fertilizer applications, purchases of animal feeds, but also production per animal and per hectare are subject to changes over time. As a result, nutrient efficiency gradually changes over time. The extent of these changes can only be studied if data on subsequent years are available. Such data could not be found for Spain and Poland. Therefore we will confine ourselves to The Netherlands.

Table 8 gives average data for the period 1983-1986, as well as for tow more recent seasons: 1986-1987 and 1989-1990. It also presents data from the Dutch research farm on nutrient flows "De Marke" connected to the Centre for Agriculture and Environment (CLM), the Centre for Agrobiological Research (CABO-DLO) and the Research Station for Cattle, Sheep and Horse Husbandry (PR). Data for De Marke are not measured, they consist of efficiency goals that have been set for the farm (see Biewenga et al., 1992). The goals are in line with Dutch environmental policy for agriculture. They comprise:
- reduction of ammonia emissions with 70 %;
- reduction of N_2O emissions with 40 %;
- maximum concentration of nitrate in groundwater of 50 mg/l.

Table 8: Trends in nutrient efficiency of Dutch dairy farming

	Year	83/86	86/87	89/90	De Marke
Surplus (kg/ha)	N	472.0	504.0	421.0	122.0
	P	32.0	36.0	33.0	0.0
	K	99.0	120.0	80.0	28.0
Surplus per ton of milk (kg)	N	38.0	37.3	35.1	10.3
	P	2.6	2.7	2.8	0.0
	K	8.0	8.9	6.7	2.4
Efficiency (%)	N	14.0	16.0	20.0	36.0
	P	31.0	34.0	38.0	100.0
	K	16.0	20.0	34.0	39.0

Source: Calculated from Aarts et al., 1988 (data 1983-1986); Daatselaar, 1989 (1986-1987); Mulder and Poppe, 1993 (1989-1990); Biewenga et al., 1992 (De Marke).

Nitrogen surplus per hectare first increased (during the 1986-1987 season), but later showed a considerable decline (1989-1990). In contrast, nitrogen surplus per ton of milk produced shows a constant decline, including the agricultural year of 1986-1987. During the period under study efficiency of nitrogen use improved more than 40 %. Surplus of phosphate first rises but shows a small decline later. Unlike nitrogen, surplus per ton of milk did not decline. Still, efficiency of phosphate use improved with 25 %. Potassium surplus first rose to fall steeply later. Surplus per ton of milk declined, and efficiency doubled (table 8).

During the 1980's, efficiency of nutrient use improved considerable. The largest changes are found in nitrogen surpluses (minus 50 kg/ha), while phosphate surplus went up with 1 and that of potassium decreased with 20 kg/ha. In relative terms, improvement of nutrient efficiency has been considerably larger than reduction of the surplus per hectare. This indicates that farmers have improved efficiency of nutrient application. More recent figures on nitrogen balances in The Netherlands (Daatselaar 1993; 5) show that nutrient surplus gradually is declining. Increases of efficiency, on the other hand, seem to have slowed down.

The changes can be caused by several factors. One of the most important factors will be the change of the agricultural policy during the 1980's. The system of independent intervention prices was replaced by a combination of intervention prices and production quotation. This has raised awareness of production costs in dairy farming. Fertilizers and especially animal feeds were among the factors to be economized to secure income under conditions of stagnating or decreasing production volumes. Other factors that may have played a role are increased environmental awareness, price fluctuations and environmental measures.

4.4 Nutrient prices

Use and application of nutrients are directly related to prices and profitability. In order to assess the relation between nutrient prices and nutrient efficiency price of fertilizers and animals feeds in the three countries, being the most important sources of nutrients at farm level, are studied.

Generally, costs of fertilizers are not high. Total costs vary between 4 and 10 %. Animal feeds make up a much larger portion of farm costs. Costs for animal feeds are about ten times as high as those for fertilizers in The Netherlands and Poland. However in Spain they make up a relatively small portion of farm expenses. This is partly due to the low priority for animal production in this country (see table 9).

Table 9: Relative costs of fertilizers and animal feed in agriculture (costs expressed as part of total costs)

	The Netherlands	Spain	Poland
Fertilizers	7	10	4
Animal feed	61	39	48

Source: LEI/CBS (1991; 142); Ministry of Agriculture, Fisheries and Food (1986; 597, 608, 620); GUS (1992; 317).

Farmers have only limited room for manipulation of nutrient inputs. A reduction of fertilizers or feeds that are purchased has to be compensated with increased consumption of manure or home grown feed in order to prevent major losses of production. Still, farmers react to changes in relative prices of nutrients. This is clearly shown by the example of Poland, where farmers reacted directly to increasing prices.

During recent years prices for fertilizers were more than doubled, while prices for farm products hardly changed. Table 10 gives recent price changes. Fertilizer has become 50 (nitrogen) to 80 (phosphorus) times more expensive in only three years[2], while, in the same time, product prices increased only ten times. This has made fertilizers five to ten times more expensive. Farmers reacted to this with a strong decline in fertilizer applications. In 1991, applications were halve of the year before.

So far this has not led to large declines in yield. Due to favourable weather and carry-over of fertility

[2] If one compares prices from 1991 with 1998 in stead of 1989 these figures are even higher: 80 for nitrogen and 140 for phosphorus.

from precious years good yields could be realized in 1990 and 1991. Still, yields for wheat and sugar beet declined with 6 and 13 % respectively in 1991 (American Embassy, 1992; 22, 23). Purchase of animal feeds have fallen as well.

Table 10: Comparison of fertilizer and product price changes in Poland

	1989	1990	1991	1991:1989
Ammonium nitrate	25	400	1170	47
Superphosphate	6	496	500	77
Milk	222	1,098	2,390	11
Beef	3,256	19,856	29,617	9

Note: Prices in Zloty per kg.
Source: American Ambassy 1992; A13.

In order to asses the effect of such a dramatic change in nutrient application, efficiency has also been calculated with fertilizer gifts at the old (double) level. Table 11 compares the outcome to the current situation. Nitrogen supply increases with 50 %; the supply of phosphorus and potassium doubles. It is assumed that production does not change, and removal of nutrients remains the same although small changes could be expected. Phosphorus and potassium surplus is positive now. They are no longer mined. Nitrogen surplus doubles.

Efficiency of nitrogen use is reduced with a third; efficiency of phosphorus and potassium now is one third (in stead of 100%). The old situation, with double fertilizer gifts and about the same production level, seems to be more realistic. Nitrogen efficiency remains however considerably higher than is the case in The Netherlands and Spain. Efficiency of phosphorus and potassium now lags behind rates in these countries.

Table 11: Nutrient surplus and efficiency in Poland with double fertilizer applications

	Supply		Surplus		Surplus p/ton of milk		Nutrient efficiency	
	Current	Double	Current	Double	Current	Double	Current	Double
N	60	92	28	60	33	71	54	35
P	8	15	-3	4	0	5	100	29
K	21	40	-5	14	0	16	100	35

Source: calculated from GUS, 1992.

Section 5

DISCUSSION AND CONCLUSIONS

Nutrient flows on dairy farms were calculated for three countries: The Netherlands, Spain and Poland. Incoming and outgoing flows were compared. A distinction was made between nutrients that leave the farm in the form of farm products and other losses. The latter are considered as undesirable although they contain nutrients that are stocked in the soil. Efficiency of farm production was expressed as total amount of unutilized nutrients per hectare (nutrient surplus) and as part of available nutrients that are recovered in the products (nutrient efficiency).

Nutrient surplus figures are highest in The Netherlands. Over 400 kg of nitrogen, some 35 kg of phosphorus and 80 kg of potassium do not find their way into the farm products. Nutrient efficiency in this country therefore is low; one fifth for nitrogen and one third for phosphorus and potassium. Surplus of nutrients in Spain is much lower: 65 kg of nitrogen and less than 10 kg of phosphorus or potassium per hectare. Efficiency therefore can be higher: a quart of nitrogen is found back in the products. For phosphorus and potassium this is almost fifty procent. The surplus of nitrogen in Poland is less than 30 kg per hectare. Recovery of available nitrogen is high (50 %). Fertilizer application of phosphorus and potassium is so low that farm products contain more nutrients than were applied. This means they are mined from soil reserves.

Differences in nutrient surplus and efficiency represent specific differences in farm styles. Figures on The Netherlands apply to intensive farm units that are specialized in dairy production, while data for Spain and Poland refer to mixed farms with relatively few animals. Conclusions do however not change if mixed farms are studied for The Netherlands as well. This is due to the high numbers of animals in this country, where animal density on average is seven times higher than that in Spain or Poland.

Nutrient surplus can be expressed in another way that is more directly related to farm intensity. One can for example calculate nutrient surplus per ton of milk that is produced on the farm. This is calculated by dividing the surplus by milk production per hectare. Results show the surplus is about 35 kg of nitrogen per ton of milk in The Netherlands and Poland. Due to a low milk production figure per hectare (on the average farm considered) in Spain, surplus per ton of milk produced are much higher (about 190 kg of nitrogen per ton of milk). Expressing surplus per ton of milk discriminates however against those farms that are not specialized in dairy production. This can be overcome by considering all farm production (including meat and corps). Surplus figures are much lower now in Spain and Poland, where meat and crops play a much more important role.

The influence of policy environment on nutrient applications and efficiency has been shown by the changes in Dutch dairy farming in the 1980's. Milk quotation and a change of the intervention policy led to a steady decrease of surplus figures and considerable improvements of efficiency rates. Recent data suggest these changes are still persisting.

Effects of economic changes on efficiency are illustrated by the example of Poland, where fertilizer consumption was reduced by 50 % due to recent relative price changes. It is not clear if this reduction will be maintained for longer periods. One could expect a gradual change of nutrient efficiency in the future, as fertilizer consumption will have to increase in order to maintain soil fertility. A completely recovered fertilizer application could change calculated efficiency rates considerably, and bring them more into line with figures for other countries (especially Spain). Efficiency rates will however remain very high.

Discussion on farm types, policy changes and economic background show a full comparison of efficiency rates only is possible if sufficiently is known on the conditions under which this efficiency is realised. Very little is known on the effect of spatial and temporal variability of production conditions on nutrient efficiency. Research in The Netherlands has shown that nutrient efficiency between farm types or regions varies enormously. It is suggested that this variation is mainly caused by differences in animal density and animal feed self sufficiency (Daatselaar et al., 1989; Daatselaar, 1990).

The use of average data bears several risks. One is, that by studying farming practices in general, one by no means gets a view of the real situation. Also, one should realize that variability of data is not taken into account. Although this can influence the outcome, differences in efficiency that were found are so large that we assume the conclusions will not be altered. It is therefore felt, that the study gives a reasonable indication of nutrient efficiency in The Netherlands, Spain and Poland.

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Annex 1

COMMON NUTRIENT FORMS AND THEIR CONVERSION TO PURE NUTRIENTS

Table 1.1: Nutrient conversion factor

Nutrient	Common form	Conversion factor
Nitrogen	nitrate	0.23
	ammonia	0.82
Phosphorus	phosphate	0.44
Potassium	potassiumoxyde	0.83

Source: Calculated from ILACO (1981; 719)

Annex 2

CALCULATIONS

2.1 The Netherlands

FARM PARAMETERS:

area (ha):	28.90	cattle (un):	13.00	all animals (un):	65.02
		dairy cows (un):	52.02	feed/an.un (kg):	58.33
prodsum (ton/ha):	12.70	d.cows/ha (un):	1.80	rough/cat.un (kg):	0.00
feedsum (ton/ha):	3.79	milk/d.cow (kg):	6666.67	feed/cat.un (kg):	8428.62
roughsum (ton/ha):	0.00	milk/ha (kg):	12000.00		

SUPPLY:

	fertot	feedtot	roughtot	other in	total.in	
	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(tons)
N	323.00	147.00	0.00	59.00	529.00	15.29
P	23.00	27.00	0.00	3.00	53.00	1.53
K	31.00	85.00	0.00	5.00	121.00	3.50

	REMOVAL:				SURPLUS:	
	prodtot	other out	total.out			
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	108.00	0.00	106.00	3.06	421.00	12.22
P	20.00	0.00	20.00	0.58	33.00	0.95
K	40.00	0.00	40.00	1.16	81.00	2.34

EMISSIONS:

	air	water	air + water		'soil' (= rest)	
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	70.60	69.00	139.60	4.03	283.40	8.19
P	0.00	0.00	0.00	0.00	33.00	0.95
K	0.00	40.00	40.00	1.16	41.00	1.18

	ANALYSIS SUPPLY:			ANALYSIS EMISSIONS:		
	fertilizer	feed/roughage	deposition	air	water	soil
	(%)	(%)	(%)	(%)	(%)	(%)
N	61.06	27.79	10.00	16.69	16.31	67.00
P	43.40	50.94	2.00	0.00	0.00	100.00
K	25.62	70.25	3.00	0.00	49.38	50.62

EFFICIENCY:

	/kg milk	/kg prod	/kg nut prod	% avail.nut	use efficiency
	(kg/1000 kg)	(kg/1000 kg)	(kg/kg)	(%)	(%)
N	35.25	33.31	3.99	79.96	20.04
P	2.75	2.60	1.65	62.26	37.74
K	6.75	21.36	2.03	66.94	33.06

2.2 Spain

FARM PARAMETERS:

area (ha):	7.56	cattle (un):	2.18	all animals (un):	5.34
		dairy cows (un):	0.84	feed/an.un (kg):	887.64
prodsum (ton/ha):	1.93	d.cows/ha (un):	0.11	feed/cat.un (kg):	2174.31
feedsum (ton/ha):	0.63	milk/d.cow (kg):	3002.45	rough/cat.un (kg):	0.00
roughsum(ton/ha):	0.00	milk/ha (kg):	333.61		

SUPPLY:

	fertot	feedtot	roughtot	other in	total.in	
	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(tons)
N	51.30	11.16	0.00	23.73	86.19	0.65
P	10.70	2.26	0.00	0.10	13.06	0.10
K	13.80	3.51	0.00	0.22	17.53	0.13

REMOVAL: SURPLUS:

	prodtot	other out	total.out			
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	22.45	0.00	22.45	0.17	63.74	0.48
P	5.31	0.00	5.31	0.04	7.75	0.06
K	8.21	0.00	8.21	0.06	9.32	0.07

EMISSIONS:

	air	water	air + water		soil (= rest)	
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	16.57	34.50	51.07	0.39	12.67	0.10
P	0.00	0.00	0.00	0.00	7.75	0.06
K	0.00	0.00	0.00	0.00	9.32	0.07

SUPPLY ANALYSIS: EMISSION ANALYSIS:

	fertilizer	feed/roughage	deposition	air	water	soil
	(%)	(%)	(%)	(%)	(%)	(%)
N	59.52	12.95	27.53	25.99	54.12	19.88
P	81.95	17.29	0.77	0.00	0.00	100.00
K	78.72	20.03	1.25	0.00	0.00	100.00

EFFICIENCY:

	/kg milk	/kg prod	/kg nut prod	% of avail.nut	use efficiency
	(kg/1000 kg)	(kg/1000 kg)	(kg/kg)	(%)	(%)
N	191.07	33.06	2.84	73.96	26.04
P	23.22	4.02	1.46	59.32	40.68
K	27.95	4.84	1.14	53.19	46.81

2.3 Poland

FARM PARAMETERS:

area (ha):	6.30	cattle (un):	3.30	all animals (un):	4.20
		dairy cows(un)	1.80	feed/an.un (kg):	120.00
prodsum(ton/ha	4.54	d.cows/ha (un)	0.29	feed/cat.un(kg):	152.73
feedsum(ton/ha	0.08	milk/d.cow(kg)	2923.00	rough/cat.un(kg):	0.00
roughsum(ton/h	0.00	milk/ha (kg):	835.14		

SUPPLY:

	fertot	feedtot	roughtot	other in	total.in	
	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(tons)
N	32.00	1.02	0.00	26.60	59.62	0.38
P	7.00	0.40	0.00	0.70	8.10	0.05
K	18.30	1.19	0.00	1.74	21.23	0.13

REMOVAL: SURPLUS:

	prodtot	other out	total.out		SURPLUS:	
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	32.11	0.00	32.11	0.20	27.51	0.17
P	10.69	0.00	10.69	0.07	-2.59	-0.02
K	25.87	0.00	25.87	0.16	-4.64	-0.03

EMISSIONS:

	air	water	air + water		soil (=rest)	
	(kg/ha)	(kg/ha)	(kg/ha)	(tons)	(kg/ha)	(tons)
N	17.40	21.00	38.40	0.24	-10.89	-0.07
P	0.00	0.00	0.00	0.00	-2.59	-0.02
K	0.00	0.00	0.00	0.00	-4.64	-0.03

ANALYSIS SUPPLY: ANALYSIS EMISSIONS:

	fertilizer	feed/roughage	deposition	air	water	soil
	(%)	(%)	(%)	(%)	(%)	(%)
N	53.67	1.72	44.61	45.31	54.69	0.00
P	86.40	4.94	8.66	0.00	0.00	100.00
K	86.20	5.61	8.19	0.00	0.00	100.00

EFFICIENCY: (surplus)

	/kg milk	/kg prod	/kg nut prod	% of avail.nut	use efficiency
	(kg/1000 kg)	(kg/1000 kg)	(kg/kg)	(%)	(%)
N	32.94	6.06	0.86	46.14	53.86
P	0.00	0.00	0.00	0.00	100.00
K	0.00	0.00	0.00	0.00	100.00

2.4 The Netherlands (general statistics)

FARM PARAMETERS:

area (ha):	18.20	cattle (un):	31.50	all animals (un):	91.20
		dairy cows (un):	18.20	feed/an.un (kg):	94.77
prodsum (ton/ha):	16.11	d.cows/ha (un):	1.01	rough/cat.un (kg):	0.00
feedsum (ton/ha):	8.64	milk/d.cow (kg):	5940.00	feed/cat.un (kg):	4993.65
roughsum (ton/ha):	0.00	milk/ha (kg):	5940.00		

SUPPLY:

	fertot (kg/ha)	feedtot (kg/ha)	roughtot (kg/ha)	other in (kg/ha)	total.in (kg/ha)	(tons)
N	226.00	248.91	0.00	59.76	534.67	9.73
P	18.80	43.21	0.00	3.43	65.44	1.19
K	87.50	128.78	0.00	6.21	222.49	4.05

REMOVAL: / SURPLUS:

	prodtot (kg/ha)	other out (kg/ha)	total.out (kg/ha)	(tons)	SURPLUS (kg/ha)	(tons)
N	108.46	0.00	108.46	1.97	426.22	7.76
P	31.89	0.00	31.89	0.58	33.55	0.61
K	55.20	0.00	55.20	1.00	167.29	3.04

EMISSIONS:

	air (kg/ha)	water (kg/ha)	air + water (kg/ha)	(tons)	'soil' (= rest) (kg/ha)	(tons)
N	123.80	69.00	192.80	3.51	233.42	4.25
P	0.00	0.00	0.00	0.00	33.55	0.61
K	0.00	40.00	40.00	0.73	127.29	2.32

ANALYSIS SUPPLY: / ANALYSIS EMISSIONS:

	fertilizer (%)	feed/roughage (%)	deposition (%)	air (%)	water (%)	soil (%)
N	42.27	46.55	10.00	29.05	16.19	54.76
P	28.73	66.03	2.00	0.00	0.00	100.00
K	39.33	57.88	3.00	0.00	23.91	76.09

EFFICIENCY:

	/kg milk (kg/1000 kg)	/kg prod (kg/1000 kg)	/kg nut prod (kg/kg)	% avail.nut (%)	use efficiency (%)
N	71.75	26.45	3.93	79.72	20.28
P	5.65	2.08	1.05	51.26	48.74
K	28.16	19.36	3.03	75.19	24.81

Annex 3

JUSTIFICATION

3.1 The Netherlands

Data on Dutch dairy farming have been taken from the LEI Farm Accounting Network. They have some restrictions (see Daatselaar, 1989; 13), but are well applicable in this study. Figures are given for the most recent year available: 1989/90. Data were presented by Mulder and Poppe (1993). References to this study are given with page numbers only. Other references are in full length.

Farm parameters

A total of 372 farms was selected out of a total of 25 thousand (1.5 %). All farms are highly specialized in dairy production. This means more than half of animal equivalents present are dairy cows and that over 95% of all activities are oriented towards dairy production (Daatselaar et al., 1990). Very small farms are excluded. Average farm size is 29 ha. Most of this area is occupied by permanent grassland. Some 3 ha is used for maize production. About half of the farms are situated on sandy soils mainly. The other half has clay, peat or intermediate soils (p. 47). Animal population consists mainly of cattle. Density is 1.8 dairy cows per ha. Figures on other animals are not given.

Supply

Fertilizer use consists of 300 kg of nitrogen per hectare, as well as 20 kg of phosphorus and 31 kg of potassium (p. 48). These figures are averages. Actual fertilizer applications on grassland are 10 % higher (p. 47). In addition to fertilizers 16 kg of nitrogen is applied in the form of animal manure from outside the farm. (Manure that is produced on the farm is considered as an internal and not an incoming flow.) Animal feed amounts to 2100 kg per cow. Per hectare this means a flow of 147, 27 and 85 kg of nutrients (nitrogen, phosphorus, potassium; p. 48). The remaining sources of nutrient supply are deposition, mineralisation, cleaning materials, milk powder for calves, etc. Together they contain 59 kg/ha of nitrogen, as well as 3 kg/ha of phosphorus and 5 kg/ha of potassium (p. 48). Deposition alone is estimated at 53, 0.9 and 4.1 kg respectively (Biewenga et al., 1992).

Removal and surplus

Major flow of outgoing nutrients is through the sale of products and byproducts. Milk and animals that are sold together contain 84 kg/ha of nitrogen. Phosphorus and potassium content is 16 and 19 kg/ha respectively. Byproducts that are sold are roughage and manure. Their nutrient content is 22 kg/ha of nitrogen, 4 kg/ha of phosphorus and 21 kg/ha of potassium (p. 48). Total nitrogen import on the farm is 15 tons. Sales of products and byproducts are responsible for removal of 3 tons. The remainder, 12 tons or 420 kg/ha, is considered as surplus. Phosphorus surplus (1 ton or 35 kg/ha) is a fraction of this, where surplus of potassium is 2.5 ton (80 kg/ha).

Emissions

Ammonia emissions from dairy farming have been assessed by Klaassen (1992; 33, 36). Losses per dairy cow amount to 29 kg of nitrogen per year. For 52 cows on 29 hectares this gives a loss of 52.4 kg of nitrogen per hectare. Mulder and Poppe (1993) provided no figures on other cattle at the farm. We assume a total of 13 other animals (25 % of the number of dairy cows). They cause a nitrogen loss through ammonia emission of 4.6 kg/ha. Emissions from fertilizers are estimated at 1.9 % of the nitrogen contents, or 6.1 kg/ha. Emission of nitrogen to the air further can be caused by a process called denitrification. Nitrogenoxyde (N_2O) that is formed in this process escapes to the air. The minimum extent of N_2O is estimated at 5.2 kg/ha for grassland and 2.6 kg/ha for maize fields (Biewenga et al., 1992; 11). We assume a loss of 7.5 kg/ha for the entire farm area. This gives a total loss to the air of 70.6 kg/ha, or 17 % of the nitrogen surplus.
Losses to the water mainly consist of nitrate leaching. According to RIVM (1992; 77), flows to the groundwater contain between 50 and 100 mg of nitrate per litre. As dairy farms generally are intensely fertilized we will use the highest figure here. On an annual basis (with a precipitation surplus of 300 mm per year) this totals to a loss of 69 kg of nitrogen per hectare. Losses of potassium are between 30 and 70 kg/ha on grassland (Biewenga et al., 137). We assume a flow of 40 kg/ha. Figures on phosphate losses to the water were not found. We assume they are negligible (see RIVM/RIZA, 1991; 33).
The remainder of the surpluses are assumed to be stored in the soil. This still is a considerable amount. About 8 ton of nitrogen, one ton of phosphorus and more than two ton of potassium annually are added to stocks. Per hectare this comes at 280, 35 and 75 kg respectively. In this way two thirds of the nitrogen surplus, all phosphorus and half of the potassium surplus can not be accounted for.

3.2 Spain

No specific data on dairy farming could be obtained for Spain. Therefore data were collected on general farm types. Data were taken from the 1986 statistical report of the Ministry of Agriculture, Fisheries and Food (1986). References to this book will be given by a page number only. Other references are given in full length.

Farm parameters

In Spain some 2.4 million holdings are found in agriculture (p. 36). Thirty thousand of them have no land at all. These have been excluded, and calculations have been done only with 2.3 million farms that have land. This is done as we expect the number of animals that are held on landless holdings to be negligible. It influences results (flows per hectare will be somewhat higher now). Nett effect is however very small.

The farms that are included control 11 million ha of arable land, as well as 7 million ha grassland (p. 26). This gives an average area of 7.6 ha per farm. One should note that bare land and woody crops as well as horticultural products are not included here. In reality, farm area will be larger. We will concentrate on animal and primary crop production only. Animal production and related nutrient flows (feeds, products) will be concentrated on the area that really is related to them. Horticultural production or forestry which usually are found on specialized holdings are not considered here.
The number of animals held in Spain amounts to 5 million cattle (of which 2 million dairy cows). Other animals that are found are 18 million sheep, 3 million goats and 13 million pigs and a small number of horses, mules and the like (p. 402). An average farm holding will keep 2.2 heads of cattle, 7.5 sheep,

1.2 goats and 5.7 pigs. There is less than one dairy cow per farm. Comparing these figures with farm area gives a density of 2 heads of cattle and 0.1 dairy cow per hectare. This is so low that milk production (3000 kg per cow) is hardly higher than 300 kg per hectare. Animal density (calculated with parameters provided by Poppe; 1991) is 0.7 animal unit/ha.

Supply

Average fertilizer use is not high. Application amounts to 51 kg of nitrogen, 11 kg of phosphorus and 14 kg of potassium (in its pure form) per ha (p. 596). This will not be the same on all types of land. It is not clear if woodland is included in this overview. If this is the case then average fertilizer use on arable and grassland would probably higher than figures now given. For this study it is however assumed that woodland is not included.

Part of animal feeds are grown on the farm itself. For cereals this amounts to 3 million tons (p. 43). Total feeds used is much higher: 14 million tons (FAO, Agrostat). The difference is considered to be purchased by farmers, and counted as an incoming flow. It amounts to 4.7 ton per farm. This is used for all animals. Other crops that are purchased as animal feeds mainly consist of pulses. Amounts are however too small to be included in calculations. Home grown feeds are not considered in the balance.
Nitrogen fixation in grassland can be considerable, as application of nitrogen fertilizer is only 50 kg/ha. Application of fertilizers tends however to be higher than applications on arable land. Therefore we assume a nitrogen fixation of 50 kg/ha. Total grassland area is 2.8 ha per farm, so that a total amount of 140 kg is fixed. Per hectare (all flows are given in kg/ha of total farm land) this is 18.5 kg.
Other sources of supply are deposition and seeds. Deposition is estimated at 5 kg of nitrogen per ha (RIVM, 1992; 75, 77; figure for 1990). This figure seems to be rather low but it is confirmed by other studies (RIVM/RIZA, 1991; 26). Seed purchases amount to 130 kg of cereals and 110 kg of potatoes (Ministry of Agriculture, Fishery and Feed, 1986; 43, 14). No figures could be found on deposition of other nutrients or inputs like milk powder or cleaners.

Removal and surplus

Milk production per cow is 3052 litres per year. Some 140 litres of this are used to feed calves, so that 2915 litre is sold (p. 468). Recalculation to kg's is done by multiplying it with 1.03. Fat and protein content are not known. These have been adjusted from Dutch figures. Fat content is taken at 4 %; protein content is half of that in the Netherlands.

Production of meat amounts to 1.2 ton. This includes 0.2 ton of cattle meat and 0.6 ton of pigs (p. 431). Organs or blood are not included here. To correct this 20 % of weight was added. Crop production consists of 5.3 tons of cereals, 3.3 tons of sugar beets and 1.6 tons of potatoes. In addition we have counted 0.4 tons of sunflower seeds (p. 43, 114, 125).

Emissions

Ammonia emissions are estimated by Klaassen (1992). According to this study, 4.6 % of nitrogen in fertilizers is lost (p. 36). Emissions caused by animals are given as well. Application to the animal density of our 'farm' gives a total loss of 85 kg of ammonia or 70 kg of nitrogen. This is 9 kg/ha per year. We estimate additional nitrogen losses through denitrification at 5 kg/ha (goal set for intensive dairy farming in the Netherlands; see Biewenga et al., 1992; 11) This gives a total nitrogen emissions to the air 16.6 kg nitrogen per ha, or one fourth of nitrogen surplus.

Large parts of Spain are not cultivated. Land that is used shows variable amounts of nitrate leaching figures (RIVM, 1992; 75, 77). We take 50 mg of nitrate per litre (34.5 kg of nitrogen per ha per year, considering a precipitation surplus of 300 mm). Leaching of other nutrients could not be assessed.
Comparing nutrient emissions with surpluses gives a positive balance. Annually some 100 kg of nitrogen, 60 kg of phosphorus and 70 kg of potassium are stored in the soil. Per hectare this is respectively 13, 8 and 9 kg. Some 20 % of the nitrogen surplus can not be accounted for by emissions. As no emissions could be estimated for other nutrients, their surpluses are fully stored in the soil.

3.3 Poland

Data on specialized dairy farms could not be obtained. In stead, general data were taken from the national statistical office (GUS, 1992). References to this study are given by page numbers only. Other references are in full length. Data presented are for 1991 and only consider private farms. State farms or cooperatives are not included.

Farm parameters

In 1991, Poland had more than 2 million private farms (p. 310). They utilized 14.2 million ha of agricultural land. This includes 10.9 million ha of arable land and 3.5 million ha of grassland (p. 305). Horticultural crops or forests are not included in these figures. They are not considered in this study. Average farm size is 6.3 ha, which includes 3.2 ha of cereals and 1.6 ha of grassland. Figures on farm performance can be disturbed by the fact that land use considers all agricultural land, while the number of farms only includes farms bigger than one ha. This disturbance is however very small, and not considered relevant.

Private farms keep some 7.4 million heads of cattle, 4 million of which are dairy cows. They have 16.4 million pigs, 0.9 million horses and 40 million chickens (p. 324, 325). Animal population per farm comes at 3.3 heads of cattle (1.8 cow), 7.2 pigs, 0.4 horse and 18 chicken. This gives an average of 0.3 cow per hectare.

Supply

Fertilizer use is very low with 32 kg of nitrogen per ha. Application of phosphorus and potassium is 7 and 18 kg/ha respectively (p. 332). This is an average for arable as well as grassland.
Purchase of animal feed is very low. Per farm some 500 kg is bought (p. 308). Feed generally is low in nutrients (Van Berkum and Rutten, 1992; 104). Composition is estimated at that of standard feed in the Netherlands (CLM, 1989; 47), with halved nitrogen contents. Van Berkum and Rutten estimate that only 10 % of all feed is bought. The rest is produced on the farm. We consider the complete production of fodder beets (4.4 tons per farm), hay (5.3 tons) and straw (8.5 tons; p. 321, 322) as feed, as well as 3.6 ton of home grown cereals (2 ton per dairy cow). As they are grown on the farm, these products are not considered as incoming flows but as internal ones. They are however subtracted from the amount of products that are sold. No figures exist on purchase of roughage. The amounts of straw and hay that are produced on the farm can however be considered sufficient. Total amount of roughage that are bought are expected to be negligible.

The average area of cereals is 3.2 ha per farm. Potato covers 0.75 ha (p. 320). Multiplication of the area with demands for seed and seedlings (about 90 kg for cereals and 1.5 ton for potato) gives a demand for

288 kg of cereals and 1125 kg of potato tubers. Combined with the composition of potato and cereals (0.44 , 0.30 and 0.8 % and 1.78, 0.36 and 0.56 % of nitrogen, phosphorus and potassium respectively; ILACO, 1989) give a nutrient flow of 10 kg of nitrogen, 4 kg of phosphorus and 11 kg of potassium. Division by 6.3 results in the flows per hectare. Deposition of nitrogen is estimated at 10 kg/ha per year (RIVM, 1992; 75, 77). This figure holds for 1990 but it is expected that it has not changed much since then. Nitrogen fixation in grassland is estimated at 50 kg/ha. As grassland covers 25 % of the farm area this figure has to be divided by four. Fixation of free living organisms has been estimated at 2.4 kg of nitrogen per ha (Sapek, p.c.). Figures for deposition of other nutrients or nutrient flows of cleaners etc. could not be found.

Removal and surplus

Milk production is close to 3000 litre per cow (p. 327). We subtracted 5 % for milk consumption by calves. Multiplication of the remainder by 1.03 for weight correction (one litre is more than one kg) gives a production of 2923 kg/cow or 835 kg/ha of farmland. Composition of the milk is taken the same as that in the Netherlands, except for nitrogen contents which is halved because of low nitrogen availability. Production of meat is very low. A total of 1.2 million ton of cattle, 2.6 million ton of pigs and 0.5 million ton of poultry gives an average production of 243 kg live weight per 100 ha (p. 325). For an average farm this means a flow of 15 kg of animals, or 2.4 kg per ha. This seems to be very low, but home consumption is not included. Crop production for sale totals to 6.0 ton of cereals, 12.9 ton of potato and 4.4 ton of sugar beet per farm (p. 321, 322). This does not include home grown feed (3.6 ton of cereals and 3.8 tons of fodder beets) and roughage (hay, straw) that are used on the farm.

Emissions

According to Klaassen (1992; 33), emissions of ammonia from animals are 27.8 kg per dairy cow, 12.5 kg per head of other cattle, and 5.1 kg per pig. Ammonia losses from fertilizers are 9.8 % of applied nitrogen. We take emissions for horses the same as those for other cattle, and arrive at a total loss to the air of 94 kg of nitrogen per year. Division with farm area gives losses per hectare (14.9 kg of nitrogen). No figures are known on N_2O emissions. We assume a loss of 2.5 kg of nitrogen per hectare (half of the 5 kg that has been set as a goal for intensive dairy production in The Netherlands; see Biewenga et al., 1992; 11).

Losses from leaching are not equal throughout the country. In the west losses are low (less than 50 mg/l) with local spots of higher leaching (more than 100 mg/l). Losses in the east range from 50 to 100 mg/l (RIVM, 1992; 77). We assume a loss of 30 mg/l or 21 kg of pure nitrogen per hectare. The amount of phosphorus or potassium lost through leaching is not known.

Assessments of emissions could only be done for nitrogen. The exact amount of phosphorus and potassium that was depleted from the soil therefore is not known. Fertilizer application and animal density are however very low, and losses through leaching will probably not be very big. As the total amount of nitrogen emissions is larger than nitrogen surplus there is no storage of this element in the soil phase. Calculations show that its depletion will be about 12 kg/ha.

3.4 The Netherlands (general statistics)

Data for this balance have been taken from national statistics (LEI/CBS, 1991). Farms smaller than two hectares and horticultural enterprises were excluded. All animal husbandry and arable farming is included. The average farm has 18.2 hectares, 18 dairy cows and 13 other cattle units. Total animal population is 91 units. Milk production per cow is almost 6000 kg per year which is also the amount of milk produced per hectare. Figures on nutrient supply and removal are not given here. Calculations are found in annexe 2.4