Reducing nitrate emissions from Europe's dairy production. The contribution of efficient farming systems.
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Abstract

High nitrate loads in Europe’s ground and surface water have hazardous effects on ecosystems and public health.

The main share of the European nitrate emissions has its origin in agriculture, where nitrogen is used in fertilizers.

Realizing the severity of the nitrate problem, the European Union started different programs to decrease the nitrogen emissions from agriculture and supports the development towards extensive and organic agriculture. The EU policies are aiming on limiting the allowed nitrogen emissions per ha to reduce the negative impacts.

Concerning nitrogen emissions, dairy farming appears to be the most polluting farming type in Europe. This farming type can differ considerably in the intensity of production. Production can be intensive or extensive, depending on the amount of animals per ha. Due to the farming intensity, the use of nitrogen per ha and per unit of milk can also vary.

In this research we applied a case study to investigate the most efficient way of dairy food production. An intensive Dutch farm and a medium-intensive German farm delivered data about the in- and outgoing nitrogen streams on both farms.

One result of the case study was that the use of nitrogen per ha was almost double as high on the Dutch farm as on the German farm. However, the use of nitrogen per unit of milk was lower. This means that on the Dutch farm the same amount of milk was produced with a lower input of nitrogen. The explanation for this fact is the higher productivity on the Dutch farm with more cows per ha, more concentrates and cows, that are more productive.

The conclusion of these findings is that there are different routes to tackle the problem of the high nitrate loads in Europe. The EU limited the allowed application of nitrogen per ha. However, it could also be considered to go for a more intensive agriculture, which uses less nitrogen per unit of milk and saves nitrogen in this way. Additionally, by intensifying and concentrating agriculture, more space for other kinds of use, like natural areas, would remain.
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1 Introduction

Nitrogen is a main chemical element and without it, no life would be possible on this planet. Even if our atmosphere consists of 78% nitrogen, a special compound is necessary to make nitrogen available for plants, which need it for their chemical constitution. This special compound is called nitrate.

Due to human impacts by agriculture, industry and traffic, the natural nitrogen cycle is out of balance. High quantities of different-nitrogen-compounds enter the natural cycle and soil bacteria transform these molecules to nitrates. Increased nitrate loads concern ground and surface water. The oversupply with this important compound has a negative effect on drink water quality and on aquatic ecosystems. It causes acid rainfalls and other ecological problems.

Since ground water is the main source for drinking water in many European countries, the high nitrate loads cause extraordinary expenses during the cleaning process. The nitrate concentration must not exceed 50 mg/l in drinking water. Bacteria in the blood reduce the absorbed nitrate to nitrite, which can be harmful for human health. In the blood circle of infants, nitrite reacts with hemoglobin and reduces its absorbing capacity for oxygen. In the worst case, an inner suffocation is the consequence.

In the body of adults, nitrites can react with amines to nitrosamines (Shirley, 1975). These are carcinogenic and can have a hazardous effect on genetic material.

High nitrate loads in ground and surface waters do not only have negative effects on human health but also on ecosystems. An oversupply of nutrients like nitrates and phosphates causes eutrophication in lakes, rivers and seas. Consequences are a damage of habitats and a loss of biodiversity in these aquatic ecosystems (Redman, 2002).

With a share of up to 80% agriculture is the main source for yearly nitrogen emissions in Europe (European Environmental Agency [EEA], 2005). Especially dairy farming contributes substantially since the production of dairy food is very nitrogen intensive (Kristensen, 2005).² Facing this large impact, it becomes clear that a remedy concerning

---

² 90% of all nitrogen from agriculture come from secondary, i.e. animal farming (see also appendix A)
the nitrogen losses from dairy farming is overdue. Two general possibilities emerge. The first one is to apply a solution at the consumption side and the second is to tackle the problem on the production side. The first approach would imply a decrease of milk consumption. Milk, however, is an important and, in the end, very healthy element of a balanced diet. A decrease of consumption is thus not feasible. Hence, production has to stay stable as well. At least it has to, if Europe wants to stay self-sufficient in supply with dairy products, as it is nowadays (Hocquette & Gigli, 2002). Accepting that dairy farming is of major importance, we have to search for an environmental-friendly way of milk production.

Since nitrogen emissions can cause a severe damage to our environment and our health, this research is aiming at answering the following question: Which is the most efficient way of dairy food production concerning the use of nitrogen?

Agriculture is a major field of common EU policies. In the past, the member states attempted to tackle the nitrogen problem on European level. The resulting policy approaches will be introduced to the reader of this research as well as a system description of nitrogen cycles and nitrogen balances as necessary background information.

The EU-approach of decreasing the total nitrate load is to limit the nitrogen emissions of agriculture everywhere in Europe in equal shares. With the ‘European Action Plan for Organic Food and Farming’ the EU Commission stimulates farmers to shift to organic or at least to extensive farming. In general, the public perceives this attempt as a positive development on the way to a more environmental-friendly agriculture. Recent studies, however, indicate that this shift in direction is eventually not the most effective way to decrease total emissions. In a research about greenhouse gas emissions from agriculture, Huis in ’t Veld and Monteny (2003) found out that organic farming systems produce the double amount of methane emissions as traditional farming systems do. The question arises if this could be true for nitrogen emissions as well.

As a part of this research, a case study will answer the question whether intensive farming is more efficient concerning the use of nitrogen. If so, it could be considered to allow for higher nitrogen losses in productive areas and restrict the losses in less productive areas.
Since data is available for a case study of a German and a Dutch dairy farm, Germany and the Netherlands will be taken as investigation areas for the research. It will be observed in which country the farming practice is more efficient concerning the use of nitrogen. In order to do this, the use of nitrogen per produced ton of milk will be of main interest.
2 System Description

Since the field of nitrogen emissions and nitrogen policies is quite complex, this chapter will provide the reader with an overview of the actual situation of legislation in the Netherlands, in Germany and in Europe in general.

To achieve knowledge about the scale of the nitrogen problem, it is necessary to observe the released amount of nitrogen. In practice, this cannot be done by measuring the emissions since the greatest part of the released nitrogen does not originate from point but from diffuse sources which are difficult to control. Thus, the policy tool ‘nitrogen balances’ was implemented. The meaning of this concept will be explained in the second part of this chapter.

As an introduction to the system description, there will be a short overview of the main different compounds of nitrogen. This is meant as a little support for the unknowing reader of this research. The knowledge about the different nitrogen compounds, their impact on the environment and about their origin could be handy to obtain a broader understanding of the problem.

2.1 Overview of main nitrogen compounds

Nitrogen is a component of amino acids, DNA and vitamins. It is thus essential for life. Only 1% of all nitrogen is bound in biosphere, hydrosphere and lithosphere. 99% of the world’s nitrogen is gaseous and constitutes with 78% the main component of the air. Nitrogen can appear in several different forms. The main important compounds and their ecological effects are listed in table 2-1.
Table 2-1: main nitrogen compounds and their origin and effects (Flechsig, 2001)

<table>
<thead>
<tr>
<th>main N-compounds</th>
<th>origin</th>
<th>human</th>
<th>ecological effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>chemical name</td>
<td>natural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N₂</td>
<td>nitrogen</td>
<td>denitrification</td>
<td></td>
</tr>
<tr>
<td>NO</td>
<td>nitrate monoxide</td>
<td>nitrification</td>
<td>burning processes</td>
</tr>
<tr>
<td>NO₂</td>
<td>nitrite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>nitrate</td>
<td>nitrification</td>
<td>over-fertilization, leaching</td>
</tr>
<tr>
<td>NH₃</td>
<td>ammoniac</td>
<td>ammonification</td>
<td>gas emission/leaching</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>ammonium</td>
<td></td>
<td>from manure</td>
</tr>
<tr>
<td>N₂O</td>
<td>nitrous oxide</td>
<td>over-fertilization, gas emission</td>
<td>greenhouse effect, ozone depletion</td>
</tr>
</tbody>
</table>

2.2 Policy

2.2.1 Methods

In order to achieve the necessary background information on policies, literature from 1990 onwards was reviewed. Older literature was less informative since the first policy measures on nitrogen were implemented during the early nineties. Only for the research about the Common Agricultural Policy, which had its beginning in 1962, older material was considered.

2.2.2 Common Agricultural Policy (CAP) in Europe

In 1962 the ministers of the European Community (EC)² adopted the Common Agricultural Policy, in short: CAP. Major aims were to create a common market for agricultural products and financial solidarity in this field.

² Precursor organization of the European Union (EU)
As a result from the post-war food shortages, over years the Common Agricultural Policy was characterized by the intention to guarantee self-sufficiency in basic foodstuff. This ended up in an inflexible, production-oriented subvention policy. With reaching the target of an increased production, negative side effects occurred. Since agricultural producers were focusing on mass production, the effect was an over production of many basic goods. This again led to trade distortions on the world markets and to increasing environmental problems. Additionally, food scandals such as the BSE crisis led to the result that consumers and taxpayers started to lose faith in the agricultural policy of the European Union (EU).

These challenges were the initial factors for the EU to develop a new approach of agricultural policy in the 1990s. The CAP was underlying elementary changes and the process of reformation is not yet finished. Production limitations, so as a milk quota, helped to get the over production under control and the whole policy focused more than ever on environmental concerns.

In 2003 the EU decided to further reform its CAP. The responsible ministers agreed on a very important change in granting subsidies to farms. The EU started to decouple subsidies from the production. Instead of paying subsidies for quantity the EU started grant direct income supplements, so called ‘single farm payments’. Since this means a fundamental conversion in farm management, the new granting-system will be implemented in three steps. The implementation started in 2005. Whilst guaranteeing a certain basic income, the connection of production and subsidy will be severed. Farmers will gain more freedom to choose what they want to produce, leading to a more market oriented production. It will be more lucrative for the farmers to consider the demand of the consumers.

The receiving of direct supplements is connected to a number of duties farmers have to carry out. Those obligations address environmental aspects, animal rights and food security. The concept is called ‘cross compliance concept’ and will be further outlined in paragraph 2.2.4.4 of this report.

2.2.3 Milk supply policy in Europe, Germany and the Netherlands

Since the above-mentioned food shortages during the post-war period, countries in Europe were aiming on a self-sufficiency of main agricultural products like milk, meat
and crops. With the start of the political cooperation between the governments, which resulted in the foundation of the EC and later the EU, this became an important issue of the common agricultural policy.

Table 2-2: Milk balance in EU-15, Germany and the Netherlands in 2003 in milk equivalents\(^3\) (ZMP\(^4\), 2004; FAOSTAT data, 2006; Statistisches Bundesamt [destatis], 2005; own calculations)

<table>
<thead>
<tr>
<th>milk balance in 2003 in mln t</th>
<th>EU-15</th>
<th>D</th>
<th>NL</th>
</tr>
</thead>
<tbody>
<tr>
<td>milk production</td>
<td>122.00</td>
<td>28.56</td>
<td>11.08</td>
</tr>
<tr>
<td>milk delivery</td>
<td>116.04</td>
<td>27.32</td>
<td>10.70</td>
</tr>
<tr>
<td>imports</td>
<td>4.44</td>
<td>8.03</td>
<td>5.41</td>
</tr>
<tr>
<td>total available amount</td>
<td>120.48</td>
<td>36.59</td>
<td>17.01</td>
</tr>
<tr>
<td>consumption (at the market price)</td>
<td>94.73</td>
<td>28.35</td>
<td>8.51</td>
</tr>
<tr>
<td>additional consumption with aids</td>
<td>10.52</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>exports</td>
<td>14.54</td>
<td>8.34</td>
<td>8.50</td>
</tr>
<tr>
<td>rate of self sufficiency in %</td>
<td>110</td>
<td>101</td>
<td>130</td>
</tr>
<tr>
<td>rate of self sufficiency (aid adjusted) in %</td>
<td>119</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>consumption per capita in kg</td>
<td>255.1</td>
<td>255</td>
<td>328</td>
</tr>
<tr>
<td>population</td>
<td>380.050.000</td>
<td>82.476.000</td>
<td>16.149.000</td>
</tr>
</tbody>
</table>

Tab. 2-2 gives an overview of the milk balances in EU-15, Germany and the Netherlands. With a yearly production of 122 million tons of milk the EU-15 accounts for 23.9 % of the worldwide production and is thus the world’s largest supranational producer (Hofstetter, 2005). The rate of self-sufficiency concerning milk supply in Europe is 110 %. With 101 % Germany is self-sufficient, but only slight decreases in production or increases in consumption would lead to a negative supply balance. The Dutch value, however, is with 130 % clearly over the European average.

\(^3\) Milk equivalent: translation unit for different milk products like butter, cheese or milk powder; one milk equivalent corresponds to the average fat and protein content of one liter of milk (73g) and is used as a measuring unit for the amount of milk used for a milk product (Hofstetter, 2005)

\(^4\) ZMP=Zentrale Markt- und Preisberichtstelle für Erzeugnisse der Land-, Forst- und Ernährungswirtschaft GmbH, Bonn
In the Netherlands, the agrarian exports exceed the imports by far; the German trade balance is negative (Eurostat, 2004). This fact fits into the picture of the Netherlands as a European leader in the exports of agrarian goods and Germany as an importing country (see fig. 2-1). With 20 billions Euros, the Dutch trade balance is highly positive. The German trade balance, however, is negative (about 12 billion Euro) and indicates that the import of agrarian goods exceed their exports.

Figure 2-2: EU trade balance for different milk products (Hofstetter, 2005)
For the EU, export plays a more important role than import. Fig. 2-2 shows this fact for most milk products. In 2003, the total EU-export, expressed in milk equivalents, was 14.5 mln t, which was about 11% of the total production. This value was relatively constant during the last years (Salomon, 2003). On the one hand, this stability has its origin in the constant consumption of the EU population with a per capita consumption of about 255 kg of milk equivalents per year (FAO data, 2006). On the other hand, it is due to production limits, which came into force in the course of the changes in the CAP in 1984. For the dairy sector, a so called ‘milk quota’ was implemented to limit the EU-wide production. Fig. 2-3 indicates that the times of high oversupplies in Europe are over since its implementation.

![Figure 2-3: Since two decades no very high oversupply in the EU (ZMP, 2006)](image)

The milk quota ensures that production exceeds the consumption within Europe not too far. Since milk production in Europe is relatively expensive compared to other terrestrial regions, the European milk is not competitive on the world market. Selling the European oversupply requires expensive export subsidies. For European producers, the world market is thus more a surplus valve than a place where they actually can make a profit.
2.2.4 Nitrogen policy in Europe

European policy is more and more effecting the national legislation in all member states. The best way to tackle a transboundary environmental problem, like nitrogen emissions from agriculture, is to agree upon a common legislation that is binding for all concerned parties. The following paragraph will describe the history, present and future of a common EU policy on nitrogen emissions.

2.2.4.1 History of EU nitrogen policy

The alarming level of nitrate concentration in drinking water and the simultaneous increasing impairment of ecosystems of surface waters through eutrophication were the initial factors for European politicians to take measures for an improved water quality. The problem of the high nitrate load in Europe is due to the development in the European agriculture in the last 50 years. An intensification of farming systems and an increased productivity came along with a severe increase in the use of mineral fertilizers. Mineral fertilizers include high amounts of nitrates. In the middle of the eighties, the use of inorganic nitrogen to fertilize farmland was at a peak of 11 million tons per year and is now slightly lowered to 9-10 million tons (see fig. 2-4). Additionally, livestock increased as well and added another 8 million tons of nitrogen originating from manure to the balance. Production quotas on European level that were implemented in the eighties and nineties helped to stabilize at least the number of cattle in Europe.

---

5 Inorganic nitrogen can be a special strain for environment since it is washed out quickly, whereas organic nitrogen first has to be transformed by soil bacteria.
The situation was deteriorated by a decrease of permanent grassland and buffer zones like hedges, wetlands and ditches what accelerated the erosion of the soil\textsuperscript{7}. The discharge of surface water was boosted as well as the draining of nutrients to the soil and the ground water.

Additionally, the loss of wetlands is severe for another reason. Natural denitrification and assimilation by plants take place in wet ecosystems. This enables wetlands to break down up to 2 kg N/ha per day (0,8 t N/ha per year) of the nitrogen contained in water (Fleischer et al., 1997, Hoffmann, 1998). Thus, the loss of these areas has an adverse effect on water quality (European Commission, 2002).

Furthermore, the increased density of livestock and the storage and application of manure lead to a strengthened release of gaseous ammonia (NH\textsubscript{3}) to the atmosphere. Thereby, nitrate is transported to nearby soils and water bodies. In areas with intensive farming this atmospheric deposition can add up to 50-60 kg N/ha per year.

---

\textsuperscript{6} in million tons nitrogen per year
\textsuperscript{7} Germany, e.g., lost 57 % of all wetlands on its territory since the 1950s.
(Environmental Monitoring, Evaluation and Protection [EMEP], 1999; Rijksinstituut voor Volksgezondheid en Milieu [RIVM], 2000).

Being aware of these problems, policy makers started a first phase of common European water legislation. This process began already in 1975 with the implementation of standards for rivers and lakes for drinking water abstraction. Those standards were introduced with the:

- Dangerous Substances Directive (76/464/EEC), implemented 05/04/1976

The Frankfurt ministerial seminar on water met in 1988 and concluded that further improvements of water policies were necessary. As published by the European Commission (1999) the second phase of the common European water legislation resulted in the implementation of the


In the year 2000 a complete restructuring of the common EU water policy ended in the implementation of the


For agriculture, the most severe changes came in 1991 with the implementation of the Nitrate Directive since it is aiming directly at the farming practice and in 2000 with the Water Framework Directive. The aims and consequences of both directives are described below.
2.2.4.2 The Nitrate Directive


The directive demands the member states to observe the water quality in relation to agriculture and to designate especially ‘vulnerable zones’ (VNZs). Additionally it will be necessary that the member states develop voluntary ‘codes of good agricultural practice’ which farmers can use as guidelines to run their farms in a nitrogen efficient way. Action programs are to implement for the VNZs in order to meet their needs of special protection. The directive also demands a national monitoring of the impacts of the action programs and a possible revising of the VNZs or the taken measures. Further, the directive determines a maximum value of 170 kg N/ha for nitrates originated from manure. Every four years the member states have to submit a national report to the European Commission.

The different steps of implementation of the directive are displayed in figure 2-5.

![Figure 2-5: Steps of implementation of the nitrate directive (European Parliament [EP] and the Council of the European Union (Ed.), 1991)](image-url)
In order to reduce the nitrogen losses from agriculture the directive demands the member states to implement the below-mentioned measures. They can be found in the annex of the ‘codes of good agricultural practice’ and the ‘action programs’:

- Crop rotation, keeping soil covered with vegetation during the winter, using of intercrops in order to avoid draining of nitrogen during periods of high rainfalls
- Adjusted use of mineral fertilizer (depending of N-need of plants, N-deposition and N-supply from the soil), frequent soil and fertilizer analyses, obligating fertilizer application plans and a general constraint of the use of artificial fertilizers
- Appropriate time spans for manure application; sufficient space for the storage of manure; recommendations for the application methods
- Creation of ‘buffer zones’ like not fertilized grasslands and hedges near water streams
- Constraining of agricultural cultivation on slopes; reduction of irrigation

A good indicator for the level of nitrate load on farm, regional or national level is the ‘nitrogen surplus’. The indicator results from the simple calculation: nitrogen-inputs to the soil minus nitrogen-outputs form the soil. In practice, data gathering is of course not always that simple but the indicator became widely accepted.

Statistics show that there are large differences in nitrogen strain within Europe. Regions with a high livestock density are likely to have high nitrogen losses. In addition, regions with intensive crop growing are very vulnerable, especially as long as there is no protecting vegetation cover during the winter period.

Figure 2-3 shows clearly, which countries are most concerned by high nitrogen surpluses.
2.2.4.3 The Water Framework Directive

On 23 October 2000, the ‘Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy’ or short the ‘EU Water Framework Directive’ (or even shorter the WFD) was adopted. Its target is to conserve and improve the quality of water bodies in order to achieve a "good ecological and chemical status" for all waters by a set deadline. Therefore, the member states are requested to put up a catalogue of required measurements and to realize these. By implementing an observation network, the chemical status of ground water shall be observed. Further, the directive strives to a "combined approach" of emission limit values at point sources and general minimum quality standard for water bodies (European Commission). New is also that water management is now based on the area of river basins and is not depending on national boundaries anymore. This means that member states have to develop international networks to tackle their water problems together.
2.2.4.4 Cross-compliance and nitrogen emissions

The term ‘cross-compliance’ represents the part of the agricultural reforms that strives to uncouple the subsidies from the production and to tie the direct payments to the compliance of certain standards in the field of environment, animal rights and food security.

According to Farmer and Swales (2004), the farmers have to follow some ‘Statutory Management Requirements’ (SMRs) which belong to one of the following classifications:

- Firstly, farmers are required to stick to certain already existing EC-legislations. These 19 ordinances concern food safety, animal and plant health and animal welfare standards.
- Secondly, farmers have to respect the requirement to keep all farmland in ‘good agricultural and environmental condition’ (GAEC). This GAEC is to define by the member states themselves.

In case that farmers break the SMRs, their direct aid will be cut.

Guidelines about nitrogen emissions of agriculture are included as well. All recipients of direct aids are concerned as soon as they use fertilizers, soil auxiliary substances, culture medias or crop protection products (with more than 1,5 % nitrogen dry matter contents). The guidelines regulate that fertilizer use has to be in balance with the crop demand, that fertilizers are only applied during the growing season and under keeping a certain distance to water bodies. Further more, farmers are required to have appropriate possibilities to store the manure of their animals on the farm.

2.2.5 Nitrogen policy in Germany

Even if Germany is not a large exporter of dairy food, it still has a relatively intensive agriculture to maintain its self-sufficiency concerning dairy products. In general, environmental standards are high in Germany and many different regulations concern the problem of emissions from agriculture. This paragraph gives a short overview.

Important legal regulations are included in:

- Federal Water Act
- Fertilizers Act
• Plant Protection Act
• Soil Protection Act
• Waste Avoidance, Recycling and Disposal Act
• Directive against pollution caused by nitrate inputs from agriculture (‘Nitrate Directive’)
• Integrated Pollution and Control (IPPC)

The ordinances of the European Nitrate Directive were implemented in ‘The Use of Fertilizers Ordinance’\textsuperscript{8} in 1996. This paper includes national regulations about the good agricultural practice in fertilizing. It requires farmers to keep an account of fertilizer balances and to adjust the applied quantities to the demand of the crop and the soil conditions. A threshold of 170 kg/ha for manure is included in the guidelines.

Further, there are the “Good professional practice in plant protection” (1998) and “Good professional practice in agricultural land use” (1999) which contain a large number of not legally binding recommendations.

2.2.5.1 Prognosis

All over Germany 799 measuring points give information about the nitrate concentration. For the time period of 2000-2002 2/3 of these test points show a nitrate concentration of less than 25 mg/l and 1/6 show concentrations of more than 50 mg/l. The situation of water bodies in Germany is properly observed but since actual test series are short, compared to the long reaction time of nitrogen in the environment\textsuperscript{9}, a prognosis about the future development of the N-content in ground water bodies is generally difficult. Influences are manifold and it is impossible to predict precisely when the N-value at a certain measuring point will be below the limit of 50 mg/l.

Since it will take several decades until the measuring points will indicate the effectiveness of the actions taken today, the most important assessment tool is the application level of fertilizers in agricultural systems. Farmers have to keep an account of

\textsuperscript{8} In German: ‘Düngeverordnung’
\textsuperscript{9} According to the Federal Environmental Agency of Germany, the time N flows from earth surface to main streams in Germany is 5-20 years
their fertilizing practice. With the aid of this data, nitrogen balances can be set up and the level of nitrogen surpluses can be investigated.

Thanks to the already reached improvements in cultivation practice, shrinking N contents can be expected in the middle- and long-term. The Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit [BMU] expects that especially the enhancements of the cross compliance concept will contribute to the lowering of the value.

2.2.6 Nitrogen policy in the Netherlands

Due to its long history of N management, the Netherlands had to face the problem of high nitrate loads in ground and surface water quite early. Several policy measures were developed to solve this situation.

Erisman, J.W. & Domburg, P. (2005) divided those policy approaches into three different categories:

- **Regulations by law**: measures that are compulsory for the users of nitrogen
  - Reconstruction of intensive agriculture
  - Horticulture Act
  - Groundwater Act
  - Regulations concerning manure
  - Law on Ammonia and Livestock
  - Arable Cropping Act
  - Act on Fertilizer and Manure Use

- **Guidelines and encouragements**: measures aiming on motivating users of nitrogen to use it in an efficient way
  - Incentives for sustainable agr.
  - Tax reduction for green investments
  - Subsidies for green practices (e.g. tree planting, set aside, ...)
  - Subsidies for test facilities
  - sustainable agr.

- **Education**: the target of this last approach is to stimulate positive behavior by supplying the users of nitrogen with the needed information
  - Subsidies for knowledge transfer concerning sustainable agriculture
  - Nitrate projects
2.3 Nitrogen balances

2.3.1 Methods

In order to achieve the necessary background information about the processes of nitrogen in the environment, a literature review was applied. In this case, also ancient literature was reviewed since those sources provided information about the physical nitrogen balance as well. Knowledge about the field and farm gate balance was gathered from actual sources since these concepts provide a basis for recent policy concepts that tackle the nitrogen problematic.

2.3.2 Physical nitrogen balance

The nitrogen balance is the physical difference between the input and output of nitrogen to the soil. The nitrogen flows can be displayed as a cycle of organic and inorganic nitrogen.

The organic nitrogen cycle is a natural nutrient cycle and it can be described in the following steps: plant and animal wastes decompose and add nitrogen to the soil. Bacteria in the soil convert those forms of nitrogen into forms plants can use\(^{10}\). Plants need the nitrogen in the soil to build up amino acids. Humans and animals eat the plants. In form of manure or animal and plant residues nitrogen returns to the soil, completing the cycle (Killpack & Buchholz, 2006).

Fig. 2-7 shows an overview of the complex processes that are included in the nitrogen balance.

Nitrogen occurs mainly in five different types of compounds:

- Organic nitrogen (assembled in proteins, amino acids, urea, etc.)
- Ammonium (\(\text{NH}_4^+\))
- Nitrites (\(\text{NO}_2^-\))

\(^{10}\) Plants can take up ammonium but prefer nitrate since assimilation of ammonium contributes to an acidification of the soil.
- Nitrate ($\text{NO}_3^-$)
- Atmospheric nitrogen ($\text{N}_2$)

The fixation of atmospheric nitrogen can happen in three different ways:

- **Atmospheric fixation** (lightening breaks nitrogen ($\text{N}_2$) and allows for a combination with oxygen, leading to the generation of nitrates ($\text{NO}_2$, $\text{NO}_3$), which can be washed out from the air and deposed on the upper soil layer)
- **Biological fixation** (unlike plants, certain bacteria are able to proceed nitrogen from the air and fixate it to nitrates [nitrification] or ammoniac [ammonification])
- **Industrial fixation** (artificial fertilizers for farm land, generated in the Haber-Bosch-Process, bring additional nitrogen\(^{11}\) into the cycle)

The release of nitrogen from the soil to the air and to water bodies can occur by:

- **Denitrification by bacteria** (turning fixated nitrogen to atmospheric nitrogen)
- **Volatilization** (urea from fertilizers is turned into atmospheric nitrogen as well)
- **Leaching** (rainwater transports nitrogen to deep soil layers, where plants can not reach it anymore)

\(^{11}\) Inorganic nitrogen
• **Runoff** (all nitrogen, that is lost by draining surface water)

In this research, especially the inorganic nitrogen in the cycle is of importance. Inorganic nitrogen comes into play with emissions from agriculture, industry and traffic. In the Haber-Bosch process, ammonia is generated, which can be transformed to nitrates by soil bacteria.

Contrary to organic nitrogen, that enters the soil in form of complex compounds, which are not immediately available for plants, inorganic nitrogen can be taken up by plants more quickly. A problematic side effect is that the danger of leaching is much higher for inorganic nitrogen since it is more flexible in the soil.

### 2.3.3 The nitrogen balance as a policy instrument

In order to reduce the nitrate load of soils, a model is necessary to visualize and understand the different nitrogen flows. It is important to understand the level and the variety of the flows in order to appraise policies and to evaluate their application. The fact that there are some variables, which are not measurable, poses a problem. Some variable in the nitrogen cycle are measurable but only with disproportional expenses. If policy is prompting farmers to reduce their emissions, it should also offer an adequate tool to control the nitrogen emissions. This was the reason to develop a practical and simplified version of the nitrogen balance that is easy to apply even for people without academic background. Two different approaches were developed. One is the ‘field balance’ approach and the second one is called ‘farm gate balance’.

#### 2.3.3.1 Field balance

‘Field balance’ means a calculation of nitrogen flows in which all those N-streams are considered that go in and out the soil on the farm area. The balance is the result of the subtraction of the outgoing streams from the ingoing streams.

\[
\text{N-Inputs} - \text{N-Outputs} = \text{N-Balance (surplus or deficit)}
\]
Fig. 2-8 shows all relevant factors included in the calculation of the nitrogen field balance, as they were defined by the Organization for Economic Cooperation and Development (OECD). Six different nitrogen flows are summed up to the input term. Some of these are depending on the individual farming practice:

- Inorganic fertilizers
- Livestock manure
- Organic manure
- Seeds and planting materials

Some variables depend more on the actual physical conditions:

- Biological nitrogen fixation (by sowing of legumes\textsuperscript{12} to a certain degree also controllable by the farmer)
- Atmospheric deposition

The output term is made up by two different variables, which both depend on the farming practice and on the physical conditions like soil quality and climate:

- Harvested crop production
- Gras and fodder crop production

\textsuperscript{12} Bacteria living in symbiosis with legumes have the ability to fix atmospheric nitrogen
By calculating the difference between the inputs and the outputs, we gain the nitrogen balance, which can be positive or negative (surplus or deficit). On most agricultural soils, the balance is positive because farmers tend to apply more artificial fertilizers as the plants are able to take up.

In all European countries with the obligation to draw nitrogen balances, this main idea of a field balance is the underlying concept. Although the implementation is based on the same concept, not all national balances require the same input and output variables. Sometimes certain constants differ or some variables are not included because they are considered to be less important or too vague. The German legislation for instance requires input-data about the particular amount of

- Nitrogen in inorganic fertilizers
- Nitrogen in livestock manure (to calculate with the aid of a constant per animal)
- Nitrogen in organic manure (this can be sewage sludge or the like)
- Nitrogen from biological fixation (to calculate with the aid of a constant)

They do not ask the farmers for data about

- Atmospheric deposition
- Remaining plant material

The nitrogen content of the harvested crop production and the grass and fodder crop production is calculated with specific constants that are related to the hectares, the crop and the soil quality.

### 2.3.3.2 Farm gate balance

Another approach of calculating the nitrogen emissions from agricultural systems is the ‘farm gate balance’. This system is based on the idea of comparing the in- and outgoing nitrogen streams on farm level and not on field level.

---

13 The European Court decided that the MINAS-system was not sufficient to meet the demands of the European Nitrate Directive; since 1.1.2006 the Dutch farmers have to calculate their emissions with the aid of the field balance
According to the Livestock and Poultry Environmental Stewardship (LPES), farmers generally have to keep an account of the following nitrogen inputs:

- Feed
- Animals
- Irrigation water
- Fertilizers
- Biological nitrogen fixation

The output terms that are to regard are:

- Agricultural products (milk, meat, crops, etc.)
- Manure (if it leaves the farm)

The difference of these factors is the nitrogen loss to the soil, respectively the extraction from the soil.

The farm gate method was used in the Netherlands until the European Commission brought in an accusation against the so-called ‘MINAS aangifte system’ at the European Court. The court decided that the system does not meet the requirements of the
European Nitrate Directive. There it is instructed that the national regulations have to be able to prevent too high nitrogen emissions with the aid of application norms. The Dutch system, however, uses loss norms. The European Commission criticized that the calculation is based on farm level and does not consider special features of different fields of a farm. Further, the allowed losses were considered as being far too high. Since 1.1.2006 the Dutch farmers have to calculate their emissions with the aid of the field balance.

Tab. 2-3 delivers an overview of the different terms that can be taken into account in both balances. Not all of them are mandatory in all countries.

Table 2-3: Overview of the different input and output terms of field and farm gate balance (LPES)

<table>
<thead>
<tr>
<th>field balance</th>
<th>farm gate balance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>input to the field</strong></td>
<td><strong>input to the farm</strong></td>
</tr>
<tr>
<td>inorganic fertilizers</td>
<td>fodder</td>
</tr>
<tr>
<td>livestock manure</td>
<td>animals</td>
</tr>
<tr>
<td>organic manure</td>
<td>irrigation water</td>
</tr>
<tr>
<td>seeds, planting materials</td>
<td>fertilizers</td>
</tr>
<tr>
<td>biological fixation</td>
<td>biological fixation</td>
</tr>
<tr>
<td>atmospheric deposition</td>
<td></td>
</tr>
<tr>
<td><strong>output of the field</strong></td>
<td><strong>output of the farm</strong></td>
</tr>
<tr>
<td>harvested crop</td>
<td>agricultural products</td>
</tr>
<tr>
<td>grass and fodder crop</td>
<td>manure</td>
</tr>
</tbody>
</table>

2.3.3.3 Comparison between both balances

If the nitrogen emissions of a farm are calculated with both, the field and the farm gate balance, it is very likely that differences occur. The reasons for these differences are the imprecise gathering of the input and output data and the estimated nitrogen contents of products. The differences are increasing with a higher share of animal breeding on a farm. In addition, the level of deviation from the standard farm is influencing the deviation (Bodengesundheitsdienst [BGD], 2006).

For farmers it is more complicated to use the farm gate balance since more different values are to calculate. On the other hand, it allowed more adjusting during the year in case of unforeseen developments. It was mentioned by Dutch farmers that they felt quite comfortable with the farm gate balance since it allowed adjusting the farm management during the
season\textsuperscript{14}. In case that it became obvious that the nitrogen surplus would exceed the limits, it was possible to feed less concentrates. Assuming that a farmer is not willing to decrease his amount of cows, the only possibility to adjust the farming system in the field balance is to apply less fertilizers.

In general, all kinds of nitrogen balances are only approximation procedures that can never really reproduce the reality. For instant, nitrogen can be fixated from the atmosphere, released to the air or dissolved by water. These nitrogen streams can only be estimated and not measured (Paul-Vall & Vidal, n.d.).

\footnote{14 Personal communication from v. d. Weerd, 2006}
3 Results: Case study – A farm comparison

3.1 The aim of the case study

In the following case study two farms are chosen to give an example of a Dutch, respective German dairy farming system. It is expected to reach a deeper understanding of the actual farming practice in both countries by means of comparing two farms in a case study.

We are interested in the question which production system is more efficient concerning the use of nitrogen. Therefore, the use of nitrogen per ton of produced milk is the main indicator. How large are possible differences and what are the reasons for these?

The application of a case study in this small scale was considered instructive since both farms serve only as an example for a large-scale system. The results are not representative but can serve as examples to achieve more insight in the main differences between the production systems.

3.2 Methods

In order to be able to assess the differences in efficiency and farming practice, it was necessary to collect operational data of both farms.

Data from the German farm was mainly obtained from balance forms\textsuperscript{15} that German farmers have to fill in yearly. With the aid of those forms, the regional chamber for agriculture\textsuperscript{16} controls the emission levels of nitrogen and phosphates. The forms include a field balance that shows the in- and outgoing nitrogen streams.

Documented ingoing streams were:

- the amount of nitrogen in manure
- the amount of nitrogen in mulch and
- the nitrogen fixation rate due to leguminous plants.

\textsuperscript{15} Nährstoffvergleich gemäß § 5 Düngerordnung auf Feld-Stall-Basis (see appendixes C and D)
\textsuperscript{16} Landwirtschaftskammer Weser-Ems
Information was provided about the total nitrogen output:

- N-output included in harvested products that left the German farm.

Finally, the forms provided not N-specific information about the area of grassland, the intensity of farming\textsuperscript{17} and the number of cattle on the farm.

In order to gain knowledge about the use of fertilizers, it was necessary to analyze some folders of bills from agrarian retail markets and from the agricultural cooperative society. The amount of fertilizers and concentrates was expressed in total kg. Thus, it was required to transform the given numbers with the aid of a factor into the total N-content.

The data for the Dutch farm was mainly obtained from forms as well (see appendixes E and F). The data gathering was still different since another type of form was used. In the past, Dutch farmers were asked to document their nitrogen emissions in a farm and not in a field balance.

The following information about ingoing streams was obtained from the form:

- the amount of nitrogen in fertilizers
- the amount of nitrogen in concentrates
- the amount of nitrogen in bought animals.

Outgoing nitrogen was contained in

- animal products and
- sold animals.

Further, the documents delivered data about the area of grassland and the number of cattle on the Dutch farm.

The collected data was all merged into a data table (see appendixes G-J) and used for the calculation of further values and for the creation of graphs.

The information about the farms themselves was gathered from personal interviews with the farmers and inspections on location.

Since efficiency of the farming system is also related to the use of space, this issue was observed at first. The data analysis was done with the aid of model calculations and the

\textsuperscript{17} Intensity of farming can be extensive, medium or intensive.
evaluation of graphs. Information about the number of animals per hectare, the N-content in concentrates and fertilizers and the productivity per cow was taken into account. Thereby, we go further into the question which farm produces more units of milk per ha and where do possible differences come from.

The efficiency of the farming system concerning the use of nitrogen is of main interest. Thus, it was investigated how much nitrogen each farm uses for the production of a unit of milk. Not only printed data was used for the analysis but also the information about the two farms that was gathered in personal interviews.

Furthermore, the emission data of both farms were compared with the aid of nitrogen balances. By applying both, a field and a farm gate balance, an in-depth analysis of the relation between in- and outgoing nitrogen streams was made. This was necessary to be able to assess the farm management properly. With the input terms alone, it is not possible to get a complete picture of the efficiency of the farming performance. It is required to set those in relation to the outgoing streams. The result is the nitrogen balance, which indicates the final losses to the environment.

In order to demonstrate the differences between both types of balances, the two were applied and the results were compared.

3.3 The farms

The two farms are located in the Northern-Netherlands and in Northern-Germany, both in areas, which are comparable in climate and soil conditions. In the size of the managed area, they equal as well.

The farms were chosen for quite subjective reasons. My family background was one reason. The fact that my parents run a farm made it easier to get the data that was required for this case study. The Dutch farmers are neighbors and friends of the supervisor of this research. This made it possible to get farm specific data for a Dutch farm. On both farms, the data was not available in digital form. Considering the effort and time it cost the farmers to search for the required data, it was not an option to ask more farmers and especially strangers for their support in this case study. In addition,
the time available for the whole project was limited. Thus, it was not feasible to start a larger survey among farmers, which could have brought results that are more significant. However, this small-scale approach is regarded to be legitimate since the case study is only considered as an example for the different farming styles and their consequences in emission values.

Data is available for the years 1997 – 2005 for the German farm and for 2001 – 2004 for the Dutch farm. Tab. 3-1 delivers an overview of the most important farm data.

Table 3-1: Main data of both farms in the case study\(^\text{18}\) (v.d. Weerd, Müller, 2006; Worldclimate, 2006)

<table>
<thead>
<tr>
<th></th>
<th>Müller</th>
<th>v.d.Weerd</th>
</tr>
</thead>
<tbody>
<tr>
<td>rainfall (mm/yr)</td>
<td>747,3</td>
<td>775,5</td>
</tr>
<tr>
<td>average temperature (°C)</td>
<td>9,5</td>
<td>9,2</td>
</tr>
<tr>
<td>altitude (m)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>geographical position (°N/°E)</td>
<td>53,2/6,6</td>
<td>53/8</td>
</tr>
<tr>
<td>soil</td>
<td>clay</td>
<td>clay</td>
</tr>
<tr>
<td>data period</td>
<td>1997-2005</td>
<td>2001-2004</td>
</tr>
<tr>
<td>area (ha)</td>
<td>52</td>
<td>59</td>
</tr>
<tr>
<td>dairy cows</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>milk production (t)</td>
<td>378</td>
<td>850</td>
</tr>
<tr>
<td>milk production per cow (kg)</td>
<td>7656</td>
<td>8665</td>
</tr>
<tr>
<td>fertilizer (kg/ha)</td>
<td>62</td>
<td>132</td>
</tr>
<tr>
<td>manure (kg/ha)</td>
<td>117</td>
<td>190</td>
</tr>
<tr>
<td>N-input (kg/ha)</td>
<td>209</td>
<td>362</td>
</tr>
<tr>
<td>N-output (kg/ha)</td>
<td>235</td>
<td>300</td>
</tr>
<tr>
<td>N-balance (field) (kg/ha)</td>
<td>-26</td>
<td>62</td>
</tr>
<tr>
<td>N-balance (farm gate) (kg/ha)</td>
<td>22</td>
<td>145</td>
</tr>
</tbody>
</table>

\(^{18}\) Climate data received from <http://www.worldclimate.com/> (visited on 18/05/2006)
3.3.1 Farm description: Müller farm (Germany)

The German farm is located in Butjadingen, a municipality in the northern part of the federal state Lower Saxonia. In average Mr. and Ms. Müller managed 52.4 ha farmland (see appendix B) in the period between 1997 and 2005. One third of this area is leased. The farmers hold 50 cows and 55 other cattle. During the winter the cattle is hold in a stable with the possibility to move freely without being tied. In summer time, all cattle are on the pasture. Only the dairy cows come into the stable twice a day to be fed and milked. They spend the night outside.

Both farmers run the farm in fulltime work. In about eight years, the youngest son will be the successor of the farm. He is still in his vocational training but also working on the farm.

In the future, it is planned to expand the production of the farm. Therefore, milk quota will be bought and an additional stable will be built end of next year. The planned stable will be an open stable, similar to the stable of the Dutch farm which will be described later on. The feeding of the cows still happens manually. All cows get the same amount of fodder in the stable. Additionally each cow gets an individual amount of extra fodder while the milking process. For this, the farmers do not use a feeding computer. They know by heart how much fodder each cow gets and they apply this amount with the aid of a mechanical lever.

So far, the production of the farm is not very high because the farm does not own a lot of milk quota. This is due to the unfortunate fact that there was a low prognosis of

19 Photo: Ibon Tama
20 Photo: Frauke Müller
productivity for the farm in the year of the implementation of the milk quota. On the base of that prognosis, the milk quota was allocated. Now, the Müllers have to lease or to purchase quota by auction, which is very expensive.

3.3.2 Farm description: v. d. Weerd farm (The Netherlands)

The farm of Mr. van de Weerd and Ms. van de Weerd-van de Linde is located near the village Aduard in the North-West of the city Groningen in the northern Netherlands. Between 2001 and 2004 the farm had a size of averaged 58,5 ha of managed farmland with 100 dairy cows and 90 piece of other cattle. Further, there is a herd of sheep. The cattle are hold in three different stables. One is meant only for the dairy cows, in another stable, the young female cows are hold and in the third part, the calves are accommodated. All stables, apart from the calve stable, are with slatted floor and without tying. In summer time all cattle is outside, but the dairy cows spend their nights inside the stable. Consequently, they have more time to feed their daily amount of fodder. Additionally, the farmer save time with this practice.

Just like the Müllers, the farmers run the farm in fulltime work. The son of the family is the probable successor of the farm.

In order to simplify processes on the farm, quite a lot of modern technique is utilized. A fodder computer for example controls the daily amount of fodder each dairy cow gets.

21 Photo: Frauke Müller
22 Photo: Frauke Müller
Cows can visit a fodder machine and get small portions of fodder each time. As soon as the limit of the daily consumption is reached, cows do not get any further forage. The computer is connected with a display in the milking machine and allows the farmers to draw conclusions about the behavior of a cow or its health condition.

Since some years, the dairy cows are held in a half-open stable. Walls on both sides are open and only covered with a net. In very cold days, this part can be closed with a cover. According to the farmer, the climate of the open stable has a positive effect on the health and physiological condition of the cows.

With the milking machine, the farmer can manage to milk 12 cows simultaneously. The process of milking all cows takes about 2 hours.

### 3.4 Comparison of the farming systems

#### 3.4.1 Efficiency of milk production concerning the use of space

![Milk production per ha graph](image)

Figure 3-5: Productivity of both farms, expressed in tons of milk per ha

Productivity per ha is higher for the Dutch farm. In average they produced 14.8 tons of milk per ha. This is about the double of the amount produced on the German farm, which
produces 7.2 tons. The question arises how this difference can be explained and what the consequences for nitrogen emission levels are.

![N from fertilizers per ton milk](image1)

![N-input per ton milk](image2)

Figure 3-6: N from fertilizers per ton milk
Figure 3-7: N-input per ton milk (total N from manure, fertilizers and biological fixation)

A first idea for an answer could be that the Dutch farm applies more fertilizers per ton milk in order to increase the output of the pastures. The fact that the Dutch farm has with 362 kg N/ha a much higher N-input to the soil as the German farm has (209 kg) underlines this hypothesis at the first glance. According to the field balance, the N-inputs are nitrogen from manure, fertilizers and biological fixation. However, regarding the fertilizer application levels per ton of milk in fig. 3-6 and the input of nitrogen to the soil per ton milk (fig. 3-7), it becomes clear that this cannot be the reason. In both cases, the Dutch farm is either at the same level as the German farm or even lower.

The consideration that different climate or soil conditions can be the reason is also not appropriate. In table 3-1 we can see that climate, soil, altitude and geographical position are similar on both farms.
Another approach could be to consider the amount of animals. It appears that the Dutch farmer indeed keeps more cattle on his farm. In average he holds 2,5 animal units (AU)\textsuperscript{23} per ha, whilst there are only 1,7 AU per ha on the German farm (see fig. 3-8). However, this difference is not the only reason for the higher productivity per hectare.

Another important difference is the higher milk productivity per dairy cow. Fig. 3-9 shows that there was only one year in which the productivity on the German farm was at the same level with the Dutch farm. With 7656 kg per cow per year, the average production of the German farm was only 88 % of the production of the Dutch farm (8664 kg/cow). The productivity per cow is not alone depending on the cattle race but also on the feeding per cow.

\textsuperscript{23} Animal units were developed to compare differences in the amount of manure produced by species. For instance, a dairy cow corresponds to 1 animal unit (AU) and a young cow equals 0,7 AU.
To a certain extent, higher milk productivity can also be achieved with more fodder. Indeed, the Dutch cows get a lot more concentrates as the German cows do. This is a conclusion of fig. 3-10, which reveals the nitrogen contents of the applied fodder on both farms. If we assume that the applied concentrates have similar N-contents in both countries, we can conclude that a cow on the German farm gets only 63% of the fodder a Dutch cow would get. However, the higher feeding rate per animal affects the productivity per cow and is thus already included in that factor.

It became clear that the Dutch farm is more efficient concerning the use of space. On one hectare, the Dutch farm produces twice as much milk as the German farm does.

### 3.4.2 Efficiency of milk production concerning the use of N

![Graph](image)

Figure 3-12: N-input per ton of milk (total N from manure, fertilizers and biological fixation)

Finally, the efficiency of the use of nitrogen comes into play. As to be seen in fig. 3-12, the nitrogen-input per ton of milk is lower on the Dutch farm. This can be reached because the farm system produces so efficiently (see the above standing paragraph). To make clear, that both farms are more efficient concerning the use of nitrogen per ton
milk as the European average, the EU-15 value (46 kg N/ton milk) is displayed in the graph as well.

If the nitrogen-input per cow is considered, the value of applied nitrogen is even lower (see fig. 3-13). This is due to the higher productivity per cow. However, since the total production is higher on the Dutch farm, the total emissions per hectare are higher as well. This is displayed in fig. 3-14. There, we can see that the N-input per hectare is about double that high as the input of the German farm.

It is interesting to see that the origin of the higher nitrogen application rate is more to find in the application rate of fodder and less in the application rate of fertilizers. The Dutch
farm applies three times as much concentrates per hectare but only twice as much fertilizer (see fig. 3-15 and 3-16).

Next to the higher animal density, the application of more concentrates seems to be a main difference between the practices of these two farms.

3.4.3 Application of different N-balances on both farms

3.4.3.1 Field balance

If the in- and output terms of both farms are calculated with the field balance concept in the way it is defined by the OECD (see chapter 3.3.3.1), the following results occur.

Figure 3-17: Field balance of Müller farm: more output than input (negative balance)
Due to its relatively low N-input, the Müller farm has a negative balance in all years (fig. 3-17). In average the balance is -25 kg N/ha. This means that more nitrogen is removed from the soil as it is applied to it. In the long run, this farming practice is only possible, if the soil itself provides enough nitrogen to avoid depletion. The low input of nitrogen is to explain with the low number of animals on the farm. According to Ms. Müller the farm land produces too much fodder for the current number of cattle. Every spring a certain amount of the winter silage is remaining. The problem is related to the little milk quota the farm has. The farmers cannot keep more animals without investing in expensive quota. In order to avoid the problem of fodder-oversupply, the farmers decided to apply less fertilizer. This decision concerns not alone the quantity of the silage but also its quality. Yearly measures show that it is quite poor. With the new stable, more quota and hence more animals, the situation could be improved.

Obviously, the Müller farm does not contribute to an increased level of nitrate in the ground. This is underlined by the fact that a nearby measure point\textsuperscript{24} shows a nitrate value in the groundwater of only 0,958 mg/l (Bundesministerium für Umwelt, Naturschutz

\textsuperscript{24} In a distance of about 1 km.
The EU defined the threshold value for drinking water as 50 mg/l.

The Dutch farm, however, shows a positive N-balance. Its average is 62.8 kg N/ha. The graph (fig. 3-18) points out that the input to the soil is higher than the output. Thus, nitrogen losses occur.

### 3.4.3.2 Farm gate balance

With the application of a farm gate balance we can assess the in- and outgoing nitrogen streams on farm level instead of soil level.

![Farm gate balance of Müller farm: positive but low balance](image1)

![Farm gate balance of v. d. Weerd farm: positive and high balance](image2)

Figure 3-19: Farm gate balance of Müller farm: positive but low balance
Figure 3-20: Farm gate balance of v. d. Weerd farm: positive and high balance

Again, the emissions leaving the Dutch farm are higher, compared to those leaving the German farm.

The balance for the German farm is low but with an average of 21.7 kg N per ha, it stays above the negative values and is thus higher as calculated in the field balance.

With 145 kg N per ha the value of the v. d. Weerd farm is double as high as in the calculation for the field balance.

As mentioned in chapter 2.3.3.3, it is normal that differences between the results of a field and a farm gate balance occur. At least for the German farm, imprecise data...
gathering could be the reason since some values (as the N-content of the animal products) are estimations because there was no data available. Despite the differences, the relation between the two farms was similar in both balances.

3.5 Conclusion of the case study

The v. d. Weerd farm is more efficient concerning the input of nitrogen. The Dutch farmers apply only 24.5 kg N per ton of produced milk. While on the German farm 29.1 kg N are applied. Additionally, the Dutch farm performs more efficiently concerning the use of land. Here, the difference is even more obvious. On one hectare, the German farm produces about 7.2 tons of milk, while the Dutch farm produces 14.8 on the same area. The difference is due to a higher amount of cattle per hectare and a higher production per cow. The latter is probably at least partly depending on a higher feeding rate per cow.

However, considering the average productivity of European grassland, both farms are comparable productive. Data from Eurostat (2005) and EFMA (2005) shows that the yield of one hectare grassland is only about 2.7 tons of milk. Keeping this value in mind, we can consider the Dutch farm as being intensive and the German farm as being medium-intensive in the way of production.

Both farms have similar production conditions concerning soil, climate and size of the farm. The comparison of the nitrogen-emissions and productivity, however, shows obvious differences. Even if both farms serve only as examples for the situation in each country, it becomes clear that they fit into the expected picture of higher productivity and higher emissions in the Netherlands and less intensive farming on the German side.

However, it is to remark that the German farm is maybe not the best example for the situation of German farms. Generally, those are also noted for their relatively high nitrogen losses to the environment. Even if the problem is less severe as in the Netherlands, in many areas in Germany high nitrate-loads of ground and surface waters are to find. In the case of the Müller farm the low cattle density of 1.7 AU lets the N-balance drop down to a negative value, which is not typical for the whole situation but due to farm specific conditions.
4 Discussion and Conclusion

The case study has proven that there are differences in productivity and nitrogen losses between a German and a Dutch farm. Only two farms were part of the investigation but since the farm comparison only has an example character for this study, the results can be used as a starting point for further analysis.

4.1 Intensification and space for nature

The case study has shown that under similar conditions and with the same use of space, it is possible to double the production with the aid of more animal units per hectare, more concentrates and cows with a higher productivity.

If we further develop this idea, it seems possible to reduce the total amount of space needed for agriculture if farming would be intensified massively. Fig. 4-1 demonstrates this suggestion in an easy sketch.

![Productivity and consequences for the use of space](image)

Figure 4-1: Limiting agriculture to productive areas means more space for nature

On two images, areas with intensive respectively extensive agriculture are displayed. The picture on the left indicates that if agriculture would be intensive and limited to very productive areas, more space for natural areas would be left. The picture on the right
represents the extensive agricultural area. The same amount of nitrogen is applied here but spread over a larger area. The production is finally the same but compared to the intensive agriculture, no space for a natural area is remaining.

Bearing this idea in mind, we look back to the results of the case study. At the first glance, we observe that the theory is underlined by the farm comparison: the Dutch farm produces twice as much milk as the German farm. At the second glance, however, we can notice that the results of the case study go even further. If the input of nitrogen comes into play, it is to note that the Dutch farm applies 173% of what the German farm applies, which is less than the double. Here, it shows again that the Dutch farm is performing more efficiently.

The conclusion is thus that a shift to a production in the way of the Dutch farm would not only safe space and allow for other uses but, additionally, this could lead to a decrease of total N-emissions without applying any further policy measures.

The target of the European Union is to decrease the total nitrogen emissions from agriculture. Above, the question came up whether it is useful to decrease total nitrogen emission everywhere in Europe in equal measure or not. As we see here, it could indeed make sense to allow for high nitrogen emissions in some productive regions and decrease it instead in regions that are less productive. This could be an opportunity to create space for valuable ecological zones and save nitrogen at the same time.

It is to notice that this idea is based on the assumption that total production levels in Europe will stay relatively constant since EU member states agreed on common production limits.

### 4.2 Intensification as a measure to decrease total N-use

Due to the common policy, agricultural enterprises in all EU member states are required to decrease their nitrogen emissions if their farms exceed a certain boundary value. Of course, farmers applying nitrogen to their fields do not do that in order to cause harm to the environment. There is a reason why they have to deploy it. Nitrogen is an important nutrient for crops and grass. If farmers have to decrease the application rate dramatically
to observe the guidelines of their governments, it is not unlikely that this will lead to a
decrease of production. The Netherlands could be concerned by this problem since
Dutch agriculture releases relatively high nitrogen loads to the environment. The
Netherlands have the most nitrogen intensive economy in the world. As to be seen in
figure 4-2, there is a big margin between the nitrogen surplus in the Netherlands and in
other European countries.

Figure 4-2: Spectrum of N-surpluses in different European countries (RIVM, 2004)

This difference was also shown clearly by fig. 2-6 in chapter 2.2.4.2, where the
Netherlands are displayed as a dark spot in the map of Europe and as the only
European country that fits into the category ‘N-surpluses between 150 and 300 kg/ha’.
If we assume that the reduction of nitrogen emissions in the Netherlands results in a
decreased production of dairy food and if we further assume that the demand in Europe
will stay stable as it was in recent years, we can conclude that production from the
Netherlands would shift to other European countries. Consequently, it will be interesting
to compare the efficiency of Dutch and European farming systems and to investigate
possible consequences for emission levels in whole Europe if production is shifted.

Using data delivered by Terres et. al (2000), Eurostat (2001) and the CBS (2005) we can
make the following calculation:
In the year 1997, the total use of nitrogen in the Netherlands was 422 million kg. The total milk production in the same year was 10922 million kg. Thus, to produce 1000t of milk, the Netherlands used 38.7 kg nitrogen.

In the EU-15 countries (without the Netherlands), the yearly production was 113576 million kg in 1997 and the level of used nitrogen was 5231 million kg. Per ton of milk the EU uses 46.8 kg of nitrogen, which is 18 % more as the Netherlands use (see fig. X).

In Germany the use of nitrogen per ton of milk is 42.8 kg if we calculate it in the same way.

![Efficiency of nitrogen use](image)

**Figure 4-3**: The Netherlands use 18% less nitrogen per 1000t milk as EU-15 does

The calculation shows that if production in the Netherlands is decreasing and at the same time increasing elsewhere in Europe, total nitrogen emissions can be expected to increase as well since other regions use nitrogen less efficient.

Assuming that the production in the Netherlands would be decreased by 20 % and shifted to other countries, the consequence would be a total increase of nitrogen use of more than 16 million kg. This value results from the fact that the Netherlands would need 84 million kg to produce the mentioned 20 % and the EU-15 would have to effort 101 million kg to produce the same net amount of milk.

Compared to the total amount of 5231 million kg nitrogen for the whole EU, the value of 16 million kg seems to be low. However, we should keep in mind that the small
Netherlands only count for 0.7% of the total area and 0.9% of the agricultural area of Europe\textsuperscript{25} (Energie Onderzoek Centrum Nederland [ECN], 2005).

### 4.3 Milk supply with intensive versus medium-intensive farming

Policies have to ensure food supply for the population. Supply with dairy food could possibly be concerned if environmental protection measures like the nitrogen policies partly limit the production. If farmers stick to the rules and decrease their emissions, a decrease of production is conceivable. The necessity of imports could be a possible consequence.

In this context, it is interesting to investigate the impact of the production intensity on the availability of dairy food in Europe. Next to the investigation area Europe, the two districts, in which the farms of the case study are located, are taken as additional example areas. Could a more intensive agriculture help to avoid imports?

We use the results of the case study as a basis to calculate the need of space if different production approaches are considered: medium-intensive (Müller) and intensive (v. d. Weerd). Firstly, the need for dairy food is calculated for each investigation area (see tab. 4-2). In the following, it is calculated how much space would be needed in case that all production would happen in the way of production of the Dutch and the German farm respectively.

The results of the calculation and the basis data about dairy food consumption can be seen in table 4-2. Table 4-1 delivers production specific factors that are incorporated into the calculation.

<table>
<thead>
<tr>
<th>Productivity parameter</th>
<th>Müller</th>
<th>v. d. Weerd</th>
<th>EU-15</th>
</tr>
</thead>
<tbody>
<tr>
<td>t/ha grassland</td>
<td>7.2</td>
<td>14.8</td>
<td>2.7</td>
</tr>
<tr>
<td>animal density AU/ha</td>
<td>1.7</td>
<td>2.5</td>
<td>0.6</td>
</tr>
<tr>
<td>kg/cow milk per cow</td>
<td>7840</td>
<td>8646</td>
<td>6257</td>
</tr>
</tbody>
</table>

\begin{footnotesize}\textsuperscript{25} The Dutch share of European milk production is 9.6% (ECN, 2005). \textsuperscript{26} ‘Animal Units’ for EU-15 is actually number of cows per hectare (data about AU was not available)
Table 4-2: Calculation of need of space under certain conditions of production (Müller & v.d. Weerd, 2006 Eurostat, 2005)

<table>
<thead>
<tr>
<th>2003</th>
<th>EU-15</th>
<th>Weser-Ems</th>
<th>Groningen</th>
</tr>
</thead>
<tbody>
<tr>
<td>population</td>
<td>3800500000</td>
<td>2479759</td>
<td>575234</td>
</tr>
<tr>
<td>density per km²</td>
<td>115</td>
<td>166</td>
<td>246</td>
</tr>
<tr>
<td>area</td>
<td>1000ha</td>
<td>330000</td>
<td>1497</td>
</tr>
<tr>
<td>agriculture</td>
<td>1000ha</td>
<td>138000</td>
<td>930</td>
</tr>
<tr>
<td>grassland</td>
<td>1000ha</td>
<td>41400</td>
<td>521</td>
</tr>
<tr>
<td>consumption of dairy food</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>per capita kg</td>
<td>255</td>
<td>255</td>
<td>328</td>
</tr>
<tr>
<td>total</td>
<td>96951</td>
<td>632</td>
<td>189</td>
</tr>
<tr>
<td>production</td>
<td>1000t</td>
<td>13424</td>
<td>88</td>
</tr>
<tr>
<td>Müller-wise</td>
<td>share of grassland %</td>
<td>32</td>
<td>17</td>
</tr>
<tr>
<td>production</td>
<td>area needed</td>
<td>1000ha</td>
<td>6548</td>
</tr>
<tr>
<td>v.d. Weerd-wise</td>
<td>share of grassland %</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>

If farming would be medium-intensive as it is on the German farm, dairy farming would need 32 % of all grassland to meet the requirements of the European population. Calculating this value for the German department Weser-Ems, the result is only 16 % and for the Dutch district Groningen 44 %. As we have observed before, the Dutch farm has about the double productivity as the German farm has. Consequently, production under ‘v. d. Weerd’-conditions would need about the half of the space. This means 16 % of all grassland area would be needed to meet the demand for dairy food in Europe, 8 % to fulfill the needs in Weser-Ems and about 21 % to feed all people in the province Groningen.

It is obvious that the milk supply would be ensured in all three regions with both ways of production, medium-intensive and intensive. It is also obvious that there are clear differences in the results between the regions. In the following, we will have a closer look at the reasons for these deviations.

**Europe:**

Only a relatively small proportion of Europe’s grasslands would be necessary to produce a sufficient amount of dairy products for Europe’s inhabitants. This outcome is related to the fact that milk production in Europe is far less efficient as it is on the Müller farm or on the v. d. Weerd farm. In average only 2,7 tons of milk are the yield of one hectare grassland in Europe (EFMA, 2005; Eurostat, 2005). If we consider values like 7, 2 and 14, 8 tons of milk, as we found for the farms in the case study, it becomes clear that the mentioned needed share of grassland of 32 % and 16 % respectively are realistic values.
**Weser-Ems:**
Even if the population density in Weser-Ems is a bit higher than in whole Europe, less space would be necessary to ensure the dairy food supply here. Only 17% of the total grassland were needed under ‘Müller-conditions’ and 8% under ‘v. d. Weerd-conditions’. This is due to the fact that the Weser-Ems region is dominated by agriculture and especially by dairy farming. More than one third of the total land is covered by permanent grassland. In the whole EU-15, grassland counts only for about 12%\(^{27}\) of the total area.

**Groningen:**
The Dutch district Groningen shows an interesting pattern. With 44% (medium intensive way) and 21% (intensive way), it necessitates by far the highest amount of space for dairy farming. That is despite the fact that the area covered with permanent grassland is with 25% slightly larger as the European average. The difference is to explain with the consumption in the region. Dutch people consume more dairy products as average Europeans do. Additionally, the population density in the province Groningen is about the double of the European average. This explains the high need for space for dairy production.

Concluding it is to state that both, the Müller and the v. d. Weerd farm, are quite productive systems if they are compared to the European average. Increased imports due to policy measures were not to expect if all agriculture would be as intense as the v. d. Weerd farm of the as the Müller farm. However, we should keep in mind that the farming conditions concerning rainfall, slope and soil quality are quite good on both farms. Thus, such high productivity rates are not to reach in all regions in Europe.

### 4.4 Nitrogen contained in concentrates

The physical nitrogen circle is a closed system of N-fluxes from the soil to the plants, from the plants to the animals and from the animals back to the soil. Consequently, nitrogen leaving the system in form of milk has to be replaced. Otherwise, the system would not stay sustainable. There are two general options to replace the nitrogen (see

\(^{27}\) About one third of the agricultural area is grassland.
Firstly, farmers can decide to apply fertilizer on the field. Secondly, it is a possibility to feed concentrates to the cattle. Most farmers in Europe go for a combination of both ways.

![Milk production circle](image)

Figure 4-4: Milk production circle

In the Netherlands the average use of concentrates is higher as in other European countries. According to Erismann (2005), 6.3% of all feed imports in Europe go to the Netherlands. With regard to the abovementioned Dutch share of 0.9% of the European agricultural area, it becomes apparent that this is a very high value.

The high rates of feed imports are mainly owing to the fact that Dutch farmers tend to keep more cattle per hectare as other European farmers do. The higher rate of AU/ha requires more concentrates since the capacity of land is limiting the production of green fodder.

The v. d. Weerd farm fits into this picture of Dutch farm management. It holds more animals and applies more concentrates per cow as the German farm does.

As it was mentioned in the conclusion of the case study, the Dutch farm appears to have high N-inputs per farm but the input per unit milk is comparable low. This means that at the first glance, the Dutch farm appears to be quite polluting but at the second glance, it is cleaner if the efficiency of the nitrogen use is considered. It is to remark that the use of concentrates does not play any role in the calculation of the emissions in the field balance. However, the production of concentrates also needs nitrogen-input. This means
with applying more concentrates per cow instead of applying more fertilizers, “hidden” nitrogen emissions occur which do not show up in the balance.

In a model calculation, it was investigated whether the results would be different if the nitrogen contained in concentrates would have been taken into account as well. According to Bock and Hergert (1991) the apparent recovery fraction\(^{28}\) of grassland with medium efficiency of N application timing\(^{29}\) is about 70 %. For a rough calculation, we applied the same proportion for concentrates. We used this value and the known N-content in the concentrates of the Müller and the v. d. Weerd farm to calculate the nitrogen inputs again. The results appear in the table below (tab4-3).

Table 4-3: overview of the field balances exclusive and inclusive nitrogen from concentrate production

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>INPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[kg N]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>manure N-input minus 20% losses</td>
<td>5569</td>
<td>5569</td>
<td>11116</td>
<td>11116</td>
</tr>
<tr>
<td>secondary resource fertilizer (straw)</td>
<td>23</td>
<td>23</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>mineral fertilizer</td>
<td>3267</td>
<td>3267</td>
<td>7714</td>
<td>7714</td>
</tr>
<tr>
<td>biological N-fixation (10 % clover)</td>
<td>2096</td>
<td>2096</td>
<td>2341</td>
<td>2341</td>
</tr>
<tr>
<td>N from concentrate production</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>► per farm</td>
<td>10955</td>
<td>11971</td>
<td>21170</td>
<td>24603</td>
</tr>
<tr>
<td>► per ha</td>
<td>209</td>
<td>228</td>
<td>362</td>
<td>421</td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[kg N]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>grassland intensive</td>
<td>5000</td>
<td>5000</td>
<td>17555</td>
<td>17555</td>
</tr>
<tr>
<td>grassland medium</td>
<td>7303</td>
<td>7303</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>► per farm</td>
<td>12303</td>
<td>12303</td>
<td>17555</td>
<td>17555</td>
</tr>
<tr>
<td>► per ha</td>
<td>235</td>
<td>235</td>
<td>300</td>
<td>300</td>
</tr>
<tr>
<td><strong>BALANCE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[kg N]</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>► per farm</td>
<td>-1348</td>
<td>-333</td>
<td>3616</td>
<td>7048</td>
</tr>
<tr>
<td>► per ha</td>
<td>-26</td>
<td>-6</td>
<td>62</td>
<td>120</td>
</tr>
</tbody>
</table>

If the nitrogen that was used to produce the concentrates is included in the balance, a different effect on the results of both farms is to observe. As it was expected, the value for the Dutch farm increased considerably. Without including the concentrates, it was 62 kg N per ha. After including it, the value raised with 58 kg per ha to 120 kg, what is equal to an increase of about 50 %.

For the German farm, the raise was less severe. The value increased only with 20 kg N per ha but remained negative (-6 kg per ha).

\(^{28}\) Apparent recovery fraction (ARF): the relation between nutrient application and nutrient uptake; gives information about the proportion of the nutrient that is taken up by the plant and not lost to the environment.  
\(^{29}\) medium efficiency of N application timing: One N application near beginning of growing season (Bock and Hergert, 1991).
As a consequence of the less severe increase of the German value, the farms are now less different concerning their input of N per ton of milk. Before, the German farm used 5 kg N more per produced ton of milk\textsuperscript{30}. After including the concentrates into the balance, the difference shrank to 3 kg N per ton milk\textsuperscript{31}.

Concluding, we can say that it could indeed make sense to consider the nitrogen input of concentrate production in a nitrogen balance of a farm. It would change the results considerably.

In our model, however, we used an estimated value for the nitrogen input of concentrate production. In reality, there are many different types of concentrates with different basic ingredients. Depending on the type of ingredient the amount of nitrogen needed can differ. Thus, it would be too complicated for farmers to include the nitrogen input of concentrate production in their field balance. Science, however, should keep in mind that the ‘hidden’ nitrogen of concentrate production could make a difference.

4.5 Recommendation for further research

In this study, we only had a superficial look at the problem of nitrogen that was used to produce concentrates. As indirect input, it does not show up in the balance of the farm where the concentrates are fed to the cattle. In chapter 4.4 we found out that the farming performance concerning the use of concentrates could make a difference in the total balance of a farm. This issue is especially interesting if countries with a high import rate of concentrates are investigated. The animal fodder that countries like the Netherlands import could cause severe nitrogen emissions in the exporting country. In this study, the data taken as a basis for the calculation was not detailed enough to come to a general conclusion for the situation in the Netherlands but more detailed data is available to do further research. It could therefore be worth to investigate and compare the indirect use of nitrogen on cattle farms as it was done before with indirect use of energy.

\textsuperscript{30} German farm: 29 kg N/ha; Dutch farm: 24 kg N/ha  
\textsuperscript{31} German farm: 31 kg N/ha; Dutch farm: 28 kg N/ha
5 Remarks

Even if there was an EU-enlargement in May 2004, for this report only EU-15 data was used. The reason for this proceeding was the better availability of data for EU-15 as for EU-25 and the longer period of constant data gathering in the past.
6 Literature

6.1 References


Appendix A: N-surpluses per farm type (red line: dairy farming) (RIVM, 2002)
Appendix B: Map of the Müller farm area
Appendix C: German form: ‘Nährstoffvergleich gemäss § 5 Düngeverordnung auf Feld-Stall-Basis’ – Input to the soil on the whole farming area
<table>
<thead>
<tr>
<th>Haupternährstoffe/ Grünland</th>
<th>fläche ha</th>
<th>a m²</th>
<th>Ertrag dt/ha</th>
<th>N kg/ha</th>
<th>P₂O₅</th>
<th>K₂O</th>
<th>Nährstoffabfuhr kg/Betrieb P₂O₅</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grünland, mittel</td>
<td>0050</td>
<td>89</td>
<td>90,0</td>
<td>231</td>
<td>77</td>
<td>231</td>
<td>11.756</td>
<td>3.919</td>
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</tr>
<tr>
<td>Verfütterte und/oder verkauft Ernterückstände</td>
<td>fläche ha</td>
<td>a m²</td>
<td>Ertrag dt/ha</td>
<td>N kg/ha</td>
<td>P₂O₅</td>
<td>K₂O</td>
<td>N</td>
<td>P₂O₅</td>
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</tr>
<tr>
<td>Verfütterte und/oder verkauft Zwischenfrüchte</td>
<td>fläche ha</td>
<td>a m²</td>
<td>Ertrag dt/ha</td>
<td>N kg/ha</td>
<td>P₂O₅</td>
<td>K₂O</td>
<td>N</td>
<td>P₂O₅</td>
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<td>Menge dt bzw. m³</td>
<td>kg/dt bzw. kg/m³</td>
<td>N</td>
<td>P₂O₅</td>
<td>K₂O</td>
<td>N</td>
<td>P₂O₅</td>
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<td>minus gasförmige N-Verluste bei der Ausbringung (20 %)</td>
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Nährstoffabfuhr des Gesamtbetriebes **

11.756 3.919 11.756

Appendix D: German form: ‘Nährstoffvergleich gemäß § 5 Düngeverordnung auf Feld-Stall-Basis’ – Output of the soil of the whole farming area
Appendix E: Dutch form: ‘MINAS-Aanvoer’ – Nitrogen-input on farm level
### Appendix F: Dutch form: ‘MINAS-Afvoer’ – Nitrogen-input on farm level

#### Aanvoer in 2005

<table>
<thead>
<tr>
<th>Invulwijzer</th>
<th>Postuur (P2O5) in kg</th>
<th>Stikstof (N) in kg</th>
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<td>Ruwvoer en/of enkelvoudig diervoer betrokken van een erkende diervoederleverancier</td>
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<td>Voorkaart (V) van Tabellenbrochure 2006</td>
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<td>Dieren</td>
<td>Voetsteken</td>
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<tr>
<td>Uitgeschaarde dieren</td>
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#### Bepaling van dierlijk mest (in bepaald bedrijfssysteem)

- Sensoormetingen dierlijke meststoffen
- Analyseprestaties en Vervoersbevattingen dierlijke meststoffen
- Overige organische meststoffen (zoutverzending, compost en zwart grond)
- Stikstof in andere meststoffen (bijvoorbeeld kunstmest)
- Stikstofbinding door vleesbevatten en vleesbevatten
- Beginvoorraad dierlijke mest in geregistreerde mestopslag
- Totaal aanvoer

---

- U mag verenigd aangifte doen.
- De vragen in een blauw vak mag u overslaan.
- Zie pagina 7 van de Toelichting.
- U hoeft de vragen niet te beantwoorden.

---

- Neem een van de Vraaglijsten voor meestvragen, die u aan het einde vindt.
- Hoeveel zijn er diersoorten in?
- Hoeveel zijn er diersoorten in?
- Vervolg dan op een bijlage met een vertaling van het relatie nummer.
### Appendix G: Data table Müller farm

#### Nitrogen Balance - N Values

<table>
<thead>
<tr>
<th>Year</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
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<th>2003</th>
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<td>224.23</td>
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#### Input

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<td>7500.00</td>
<td>7500.00</td>
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#### Output

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### Appendixes

#### Farm data v. d. Weerd

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<td>130.2</td>
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Appendix I: MINAS-table Müller farm

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Appendix J: MINAS-table v. d. Weerd farm