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The influence of trade on the flow of nutrients

A case study between Brazil and the Netherlands

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MASTER THESIS

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THE INFLUENCE OF TRADE ON THE FLOW OF NUTRIENTS

A CASE STUDY BETWEEN BRAZIL AND THE NETHERLANDS

Master thesis in Civil Engineering and Management

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SUMMARY

With trade of crops nutrients are being transported from one country to another. This can cause nutrient depletion in the exporting country and nutrient enrichment in the importing country. By looking at a case study about the export of soybeans from Brazil to the Netherlands it can be determined how trade is influencing the nutrient balance in both countries and how this is affecting the environment.

Brazil is the second largest soybean producer in the world, producing an average of 74,815,442 tonnes of soybeans each year. Out of these 75 million tonnes almost half is exported. In 2011 an amount of approximately 6,818,402 tonnes of soybeans was necessary for export to the Netherlands. Due to the production of soybeans for export to the Netherlands the soil in Brazil is experiencing a depletion of 51,203 tonnes N/y, an amount equal to 13.6% of the nitrogen demand of the soybean plant. The soil is experiencing a phosphorus enrichment of 30,964 tonnes P/y, an amount which is equal to 34.2% of the phosphorus demand of the soybean plant.

Out of the soybean products imported into the Netherlands, a part is re-exported. The remaining soybean products are used domestically, mainly in animal feed. One of the most important destinations is the use of soybeans in the feed for pigs. Out of the 5,657,191 number of pigs kept in the Netherlands half of them are finishing pigs, i.e. pigs that are kept for their meat. As a result of eating soybeans imported from Brazil, finishing pigs in the Netherlands excreted 7,379 tonnes N/y and 1,088 tonnes P/y. Due to agriculture the Dutch soil is experiencing both a nitrogen and a phosphorus enrichment. The nitrogen enrichment is larger with an amount of 50,000 tonnes N/y. The phosphorus enrichment consists of 3,100 tonnes P/y. A part of the enrichment can be traced back to nutrients imported in soybeans from Brazil and excreted by finishing pigs. For nitrogen 1.1% of the surplus can be traced back to Brazil. For phosphorus this amount is equal to 1.8%.

Both Brazil and the Netherlands are experiencing negative effects from the export of soybeans from Brazil to the Netherlands and in both countries the environment is affected by the change in nutrient balance. There are six possible measures that can be implemented to reduce the impact of this trade on the environment in both countries. Figure 1 shows an overview of the discussed case study with the measures and there effects. There are four measures which are effective in reducing the influence of trade on the environment. The first two measures do not affect the influence of trade directly, but make the production processes more sustainable. These measures are the replacement of artificial fertiliser use in both Brazil and the Netherlands. In Brazil artificial fertiliser is the main fertiliser source used and in the Netherlands still 38% of the nitrogen fertiliser use and 8% of the phosphorus fertiliser use does still originate from artificial fertiliser. In both countries it is estimated that livestock produces enough nutrients to fulfil the crops demands.

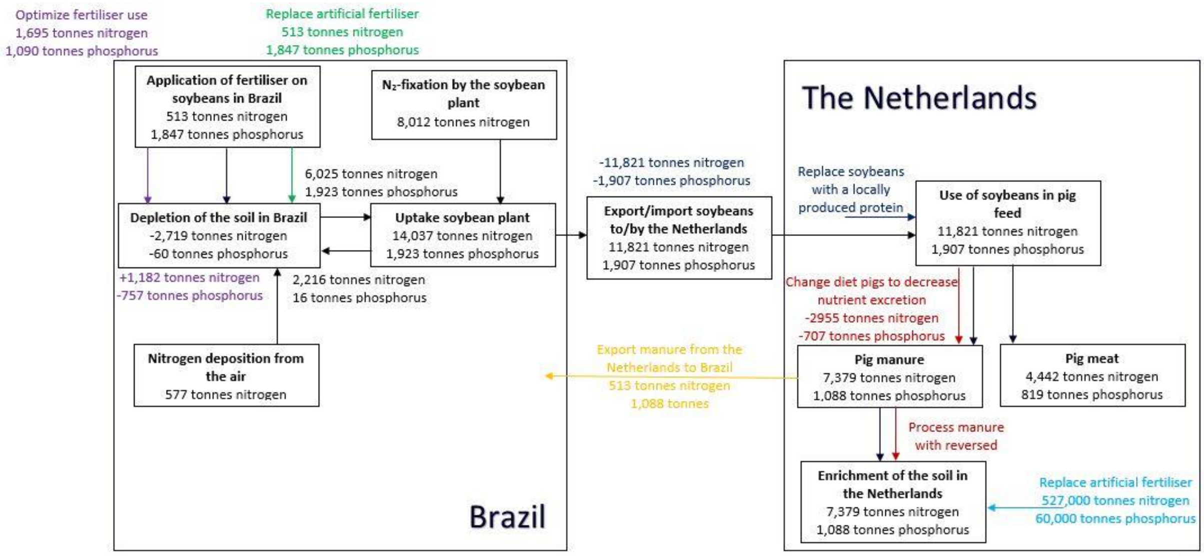

Figure 1: An overview of the case study, with the effect of possible measures that could reduce the influence of trade on the environment

Another measure that could be implemented In Brazil to make the production of soybeans more sustainable is the use of an optimum fertiliser amount. The optimum fertiliser amount is equal to the crops demands, minus other fertiliser sources like crop residues and nitrogen fixation. For soybeans the use of nitrogen fertiliser should increase with 230% and the use of phosphorus fertiliser should decrease with 40%. In the Netherlands the production of pork meat can be made more sustainable by changing the diet of finishing pigs or processing their manure in a different way. By changing the diet of finishing pigs the nitrogen excretion could be reduced by 25% and for phosphorus a reduction of 65% could be possible. By processing the manure with reversed osmosis to obtain two end products being either high in nitrogen or high in phosphorus. This would make the application of manure more effective and, as a result, the manure surplus in the Netherlands could decrease.

The last two measures focus on changing the trade relationship between Brazil and the Netherlands. The trade relationship could be altered if nutrients were exported from the Netherlands to Brazil or if soybeans could be replaced by a locally produced protein source, so less soybeans would need to be imported. Unfortunately neither measure is effective. Pigs in the Netherlands do not produce enough nutrients in their manure to substitute the fertiliser use on soybeans in Brazil and the only protein sources which could be a suitable replacement are still to innovative. For insects and algae meal to be a suitable replacement for soybeans in pig feed more research needs to be carried out about the digestibility of these protein sources and there production process needs to be optimized. Potatoes and maize, other protein sources, would need an increase in agricultural land or replacement of other crops.

All measures described above focus on changing a part of the current production cycles. However there is one solution that could reduce the influence of trade all together: reducing the scale of the pork meat production in the Netherlands. If less pigs would be kept in the Netherlands, less manure would be produced. With a fewer number of pigs, the amount of feed needed would also decrease, leading to a lower demand and import of soybeans. This could lead to a reduction in the soybean production in Brazil. However this could have negative consequences for the Brazilian economy. But for the Netherlands it could have a positive economic effect. Due to a decrease in supply of meat the currently low prices for pork meat could increase.

PREFACE

This report represents the finalisation of my master Civil Engineering & Management at the University of Twente. I was looking forward to finding out more about this topic and I have really enjoyed working on this thesis. The results are different than what was expected at the start, but they give new insights into the relation between trade and the influence of nutrients on the environment.

Working on my master thesis did not always go the way I expected. I have encountered several setbacks along the way, which have influenced the progress of my master thesis. It has taken me longer to finish but I am proud of the work that is presented before you. I would really like to thank my supervisors Denie Augustijn and Arjen Hoekstra for their feedback and their patience. Without a clear schedule or deadline you trusted me in finishing my work, even though it would take longer. With your feedback you helped me creating this report.

Next I would like to thank my friends and family for supporting me and always being there for me. This whole process has sometimes been difficult, but you always kept faith in me and made sure I kept faith in myself as well. Whenever I needed distraction or when I was feeling down you always knew a way to cheer me up. Your presence has really made this process a lot easier and I would like to thank you all for that.

Laura Cazemier
Enschede, January 2016

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1. INTRODUCTION

Trade is an important part of the global economy. With trade products that are produced in one country are shipped to another country, where they are used or further processed. What many people do not realize is that to develop these products materials and substances are used and incorporated, which often cannot be used again. An exporting country is therefore using, and partly exporting, materials that are lost from the exporting country's balance. The importing country is adding materials to its balance. This can be virtual, when the material is used but not incorporated, or actual, when the material is incorporated in the product. This exchange in materials and substances in trade can cause shortages in one country and an enrichment in other countries. One of the substances incorporated in products and traded all over the world are nutrients (Schipanski & Bennett, 2012).

1.1. PROBLEM DEFINITION

Due to the export in agricultural products one country is exporting nutrients to another country. This can cause nutrient depletion in the exporting country and nutrient enrichment in the importing country. Van Egmond et al. (2002) discovered that one of the reasons the nutrient balance in Europe is increasing rapidly, is the import of nutrients incorporated in various imported products. There are several types of nutrients available, but probably the most important ones are nitrogen (N) and phosphorus (P). These nutrients influence the growth rate of crops the most, and have a large impact on the environment (Oenema & Pietrzak, 2002).

The Netherlands is a country which imports more agricultural commodities than that it exports (FAOSTAT, 2012). As a result the Netherlands is probably importing more nutrients than that it is exporting, resulting in an increase in nutrients on the nutrient balance. Trade is therefore increasing the amount of nutrients in the Netherlands. The product that is imported the most is soybeans, with the largest inflow originating from Brazil (39%) (FAOSTAT, 2011g). Brazil is the second largest soybean producer in the world (FAOSTAT, 2011j). Only the United States of America produces more soybeans. In order to produce soybeans fertiliser is added to the soil. Without fertiliser use the crop revenues would be limited to the amount of nutrients that are present in the soil and by producing on the same locations for a long period of time the soil could get depleted. With most of the soybeans produced in Brazil being exported to other countries, Brazil is losing nutrients from its nutrient balance.

In literature several studies have been carried out about the influence of trade on nutrients in the environment (Craswell et al., 2004; Schipanski & Bennett, 2012; Van Egmond et al., 2002). Nutrient balances have been established for one country or one part of the world, showing the influence of export or import on this balance. However, none of the studies have looked at the influence of one trade relationship on the nutrient balance in the countries involved. Therefore in this research a case study will be carried out about the trade in soybeans between Brazil and the Netherlands focussing on the flow of nutrients between these two specific countries in the involved production processes. In Brazil the research will focus on the production of soybeans for export. In the Netherlands the research will focus on the usage of soybeans in the feed of finishing pigs, pigs that are kept for their meat. One of the main destinations of soybeans imported into the Netherlands is animal feed, especially for pigs and poultry (Stichting Ketentransitie Verantwoorde Soja, 2012).

1.2. OBJECTIVE AND RESEARCH QUESTIONS

The objective of this study is to investigate the influence of trade on the flow of nutrients during the production of soybeans in Brazil and the production of pork meat in the Netherlands. The influence of trade on both production processes will be related to the influence on the environment. When the influence of trade on the production processes is established it will be possible to look at several measures that could reduce the influence of trade on the environment in both Brazil and the Netherlands. In order to achieve the objective several research questions will be answered. The research questions that will be answered during this study are:

1) How much fertiliser is used to produce soybeans in Brazil for export to the Netherlands?
2) How many nutrients are present in the manure of pigs, as a result of eating soybeans that originate from Brazil?
3) How could the influence of trade on the environment in both Brazil and the Netherlands be reduced?

1.3. METHODS

The production of soybeans in Brazil and the production of pork meat in the Netherlands are connected to each other through trade. Figure 2 gives a schematic overview of the situation. It shows that there are three different processes: the production of soybeans in Brazil, the production of pork meat in the Netherlands and the trade itself. These three processes will all be investigated separately.

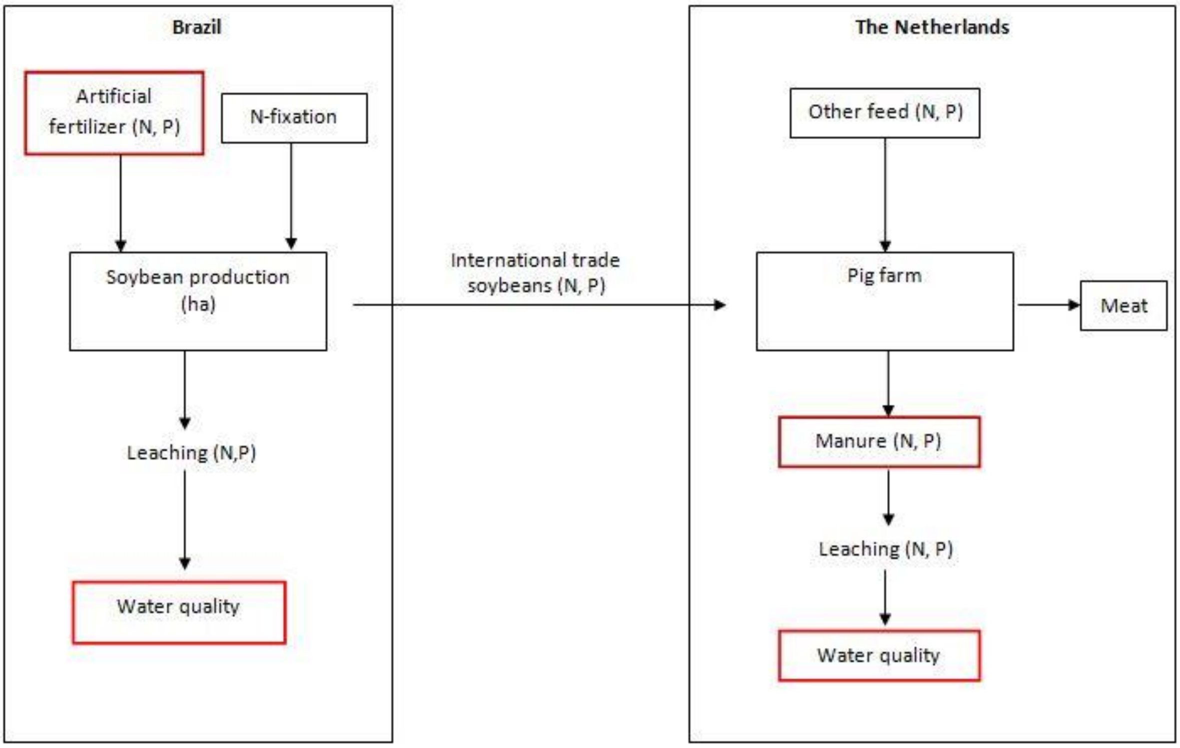

Figure 2: A schematic overview of the case study that will be investigated during this research, consisting of the production of soybeans in Brazil, the trade of soybeans from Brazil to the Netherlands, and the use of soybeans in pig feed in the Netherlands

The first step in determining the influence of trade is determining the flow of nutrients through the production of soybeans in Brazil and the production of pork meat in the Netherlands. In order to determine this flow of nutrients a nitrogen and a phosphorus cycle will be created for both production processes separately, containing all possible nitrogen and phosphorus flows. With this overview it will be possible to quantify the different flows. The quantification will be based on literature, together with specific data of both the FAOSTAT database, from the Food and Agriculture Organization of the United Nations (FAO), and the Dutch StatLine database, from the Central Bureau for Statistics (CBS). Many studies have investigated the effect of both nitrogen and phosphorus on several parts of the production chain of soybeans and due to the production of manure having been a problem in the Netherlands for several years, enough information is available on both the use of soybeans in pig feed and the specific manure production and fertiliser use in the Netherlands. Where possible the data for Brazil will be taken for the year 2011. For this year most data is available. For the Netherlands the data for 2013 will be used. The data for this year will give the most complete overview.

The second step is determining the influence of both production processes on the environment. This will be done by comparing the quantified leaching of nutrients to the surface water with quantities of nitrogen and phosphorus in the surface water as given by literature. It will give an overview of the current effectiveness of the production processes and their sustainability.

After the flow of nutrients in both production processes has been quantified, the third step is to determine the influence of trade. This will be done by creating a process cycle for all three exported soybean products. The cycles will consist of the different quantities imported and exported. The data will originate from the FAOSTAT database. With the cycles it will be possible to estimate the direct flow of nitrogen and phosphorus between Brazil and the Netherlands. The flow of both nitrogen and phosphorus will be given by a Sankey diagram. This is a diagram which shows the flow through a system with the size of the flows being directly related to the quantity. It directly shows the influence of trade of both nitrogen and phosphorus on the environment in both Brazil and the Netherlands.

With the influence of trade on the flow of nutrients known, it will be possible to carry out the fourth and final step of this research, the discussion of possible measures that can reduce the influence of trade on the environment in both Brazil and the Netherlands. These measures focus on changing the trade relationship, or making the production process more sustainable. A schematic overview will be made of the trade between Brazil and the Netherlands focusing on the main nitrogen and phosphorus sources, like manure and fertiliser use, showing the parts of the production processes that can be adapted. In total six different measures will be discussed, which focus on closing the production cycles on a smaller scale or reducing the scale of the production. The measures treated consist of examples from literature which will be discussed in relation to the case study shown in figure 2.

1.4. OUTLINE OF THE REPORT

This report will consist of both the quantification of nutrient flows and the discussion of possible measures that can influence the trade relationship between Brazil and the Netherlands. Chapter 2 discusses the flow of nitrogen and phosphorus during the production of soybeans in Brazil. Chapter 3 discusses the flow of nitrogen through the production of pork meat in the Netherlands and Chapter 4 shows the actual influence of trade on the environment in both countries. In chapter 5 the measures will be discussed that can have a positive influence on the trade relationship between Brazil and the Netherlands and the report will finish with a discussion, a conclusion and recommendations.

2. BRAZIL

The case study of exporting soybeans from Brazil to the Netherlands can be divided into three parts: the production of soybeans in Brazil, the production of pork meat in the Netherlands and the trade of soybeans between the Netherlands and Brazil. In this chapter the production of soybeans in Brazil will be investigated and the flow of nutrients will be quantified. First an outline of the situation in Brazil is given. Second the flows of nutrients are quantified and third and final the influence of the production of soybeans on the water quality in Brazil is examined.

2.1. OUTLINE OF THE SITUATION

Brazil is one of the biggest soybean producers in the world. It produces about 75 million tonnes per year of which about 33 million is exported. Starting in the 1970s the demand for soybeans on the international market started to increase rapidly. As a result the production of soybeans in Brazil was expanded (Flaskerud, 2003).

Figure 3 shows a map of Brazil with the names of each state. Originally soybeans were being produced in the South of Brazil, predominantly centred in the populated coast states Parana, Santa Catarina, and Rio Grande do Sul (Schnepf et al., 2011). As the demand for soybeans rose, the production was expanded into the Cerrado, Brazil's Center-West, including the states Mato Grosso, Mato Grosso do Sul, Goias and the Federal District surrounding Brasília (Schnepf et al., 2011). The graph in the left corner of figure 4 shows the change in hectares on which soybeans were being produced between 1970 and 2000 for both regions. It shows that the production in the South remains somewhat stable, but the production in the Center-West has been increasing, leading to almost 14 million ha being used for the production of soybeans in Brazil in 2000. This corresponds to the increase in harvested area in figure 4 itself, showing the harvested area of all soybean production in Brazil till 2013, having the total area being increased to over 25 million ha in these 13 years (FAOSTAT, 2011c). Currently both parts are rivalling each other as the main producers of soybeans, with Mato Grosso being the leading soybean producing state (Foreign Agricultural Service, 2012).

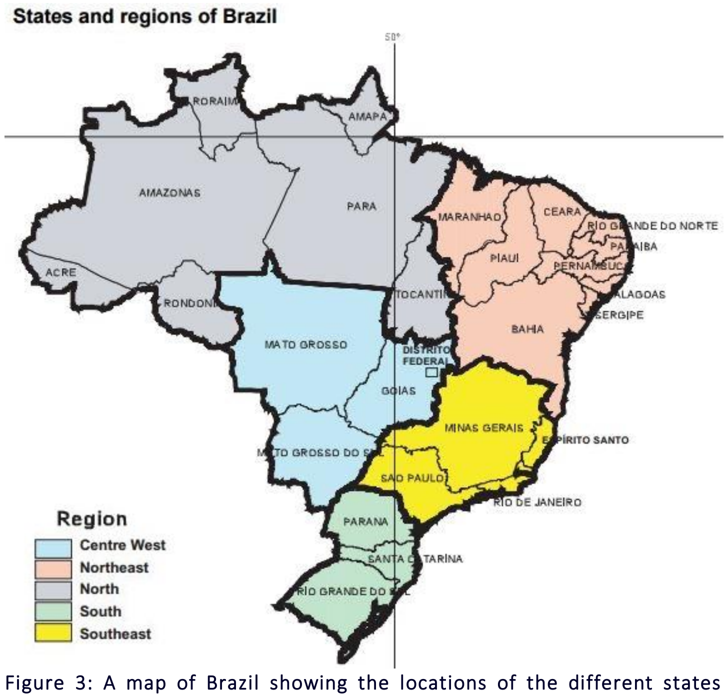

Figure 3: A map of Brazil showing the locations of the different states together with the division between the South and the Center-West (FAO, 2004)

The soils in the South of Brazil are highly fertile and are very suited for the production of soybeans. The lands in the Cerrado however, have a different structure and become rapidly depleted and infertile when soybeans are being produced (Schnepf et al., 2011). Without interference the production of soybeans will decrease rapidly, so proper soil management is necessary to maintain yield (Schnepf et al., 2011). Due to moderate elevation in the Cerrado, the soils are easy accessible for machinery and therefore still attractive as agricultural land. The possibility of using heavy machinery results in larger farms than in the South (Flaskerud, 2003).

The climate in both areas of Brazil is also different. The South has a more semitropical climate and the Center-West has a tropical climate (Flaskerud, 2003). The temperatures in the Center-West are generally a bit higher than in the South, but both regions experience very little seasonal changes in temperature. Compared to other soybean producing countries both regions in Brazil experience higher precipitation rates with monthly averages of 114 – 183 mm in the South and 125 – 204 mm in the Center-West (Schnepf et al., 2011). The growing season of the soybean plant is from September till February. The plants are planted from September till December and harvested from March till May.

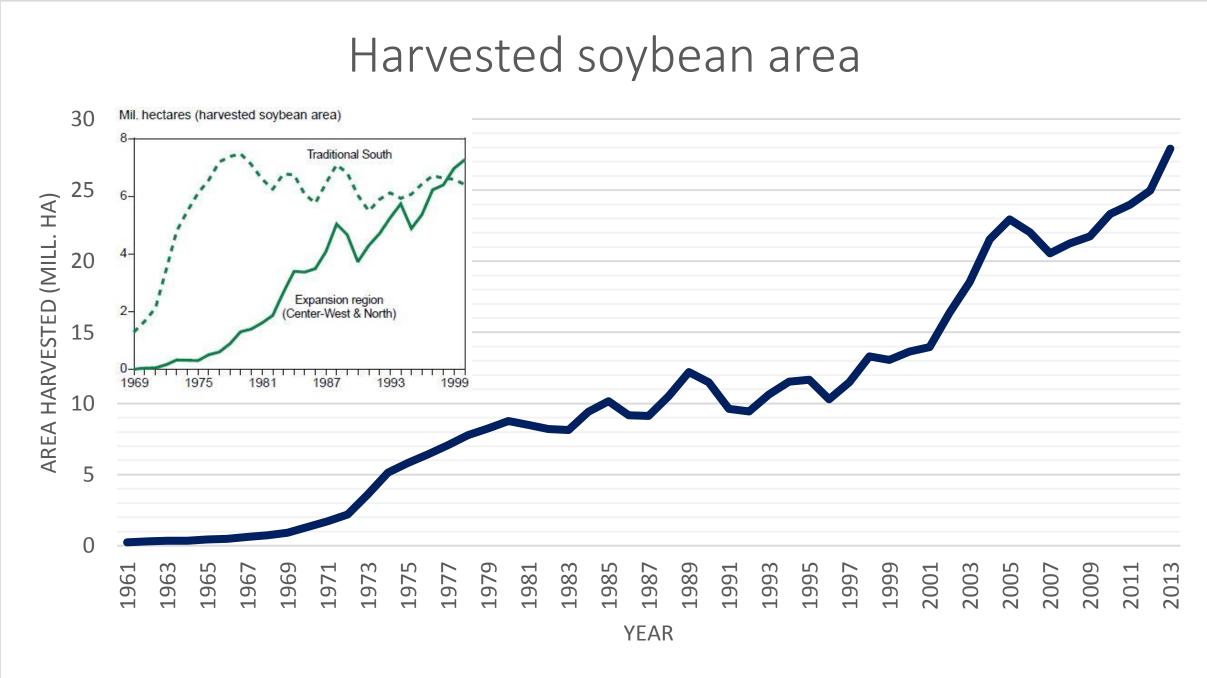

Figure 4: The change in harvested soybean area in Brazil between 1961 and 2013 in the whole country (FAOSTAT, 2011c), with the figure in the left corner showing the change in harvested soybean area in the South and the Center-West of Brazil between 1970 and 2000 (Schnepf et al., 2011)

2.2. QUANTIFICATION OF NUTRIENT FLOWS

To produce soybeans, nutrients are needed for the plant to grow. In this section the use of both nitrogen and phosphorus during the production of soybeans will be estimated, in order to determine the influence of the soybean production on the water quality.

2.2.1. NITROGEN

The production of soybeans in Brazil can be schematized to give a clear overview of the different flows that are present in the system. Taking into account the nitrogen cycle, the nitrogen involved in the production of soybeans can be represented by the system given in figure 6. The values have been determined for the production of soybeans in Brazil during the year 2011 using literature and databases, as will be explained below.

Fertiliser use

Figure 5 gives an overview of the artificial fertiliser consumption in Brazil between 1979 and 2003. It shows that the use of nitrogen fertiliser is smaller than the use of phosphorus and potassium fertiliser, another import nutrient. Looking at international standards for the ratio between N and P of 2.8 N : 1.0 P_2O_5 the ratio in Brazil of 0.7 N : 1.0 P_2O_5 is low (FAO, 2004). This ratio can partly be explained by the agriculture in the Cerrado, where the soils are P deficient (FAO, 2006). Soybeans are a major influence on the ratio between nitrogen and phosphorus. If soybeans are not taken into account the ratio between N and P changes to 1.1 N : 1.0 P_2O_5, which is closer to the international standards (FAO, 2004).

The FAO (2004) has determined the fertiliser consumption in Brazil per crop. The fertiliser consumption in Brazil consists of inorganic manufactured products, or artificial fertiliser (N_{art}). The use of organic fertiliser (N_{org}) is uncommon (FAO, 2004). It is only used in special situations, like on fruit orchids or small family farms (FAO, 2004).

Reliable statistics about the consumption of commercial organic fertiliser are therefore unknown. The FAO (2011i) does give a value of 279,883 tonnes N for organic fertiliser use as a total for 2011, but it is unclear how much of this nitrogen is used for the production of soybeans. The organic fertiliser use for the production of soybeans will therefore not be taken into account.

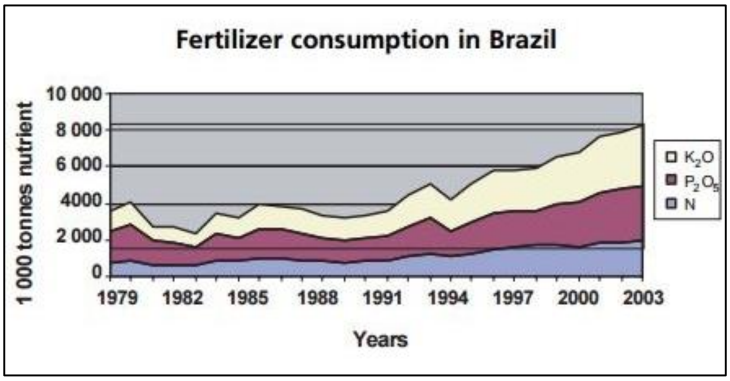

Figure 5: The consumption of artificial fertiliser in Brazil between 1979 and 2003 (FAO, 2004)

The nitrogen fertiliser consumption of soybeans in Brazil is equal to 8 kg N/ha/y (FAO, 2004). Assuming that the organic fertiliser use is zero this is also the total fertiliser use (N_{fer}) (see equation 1).

$$N_{fer} = N_{art} + N_{nat} \quad (1)$$

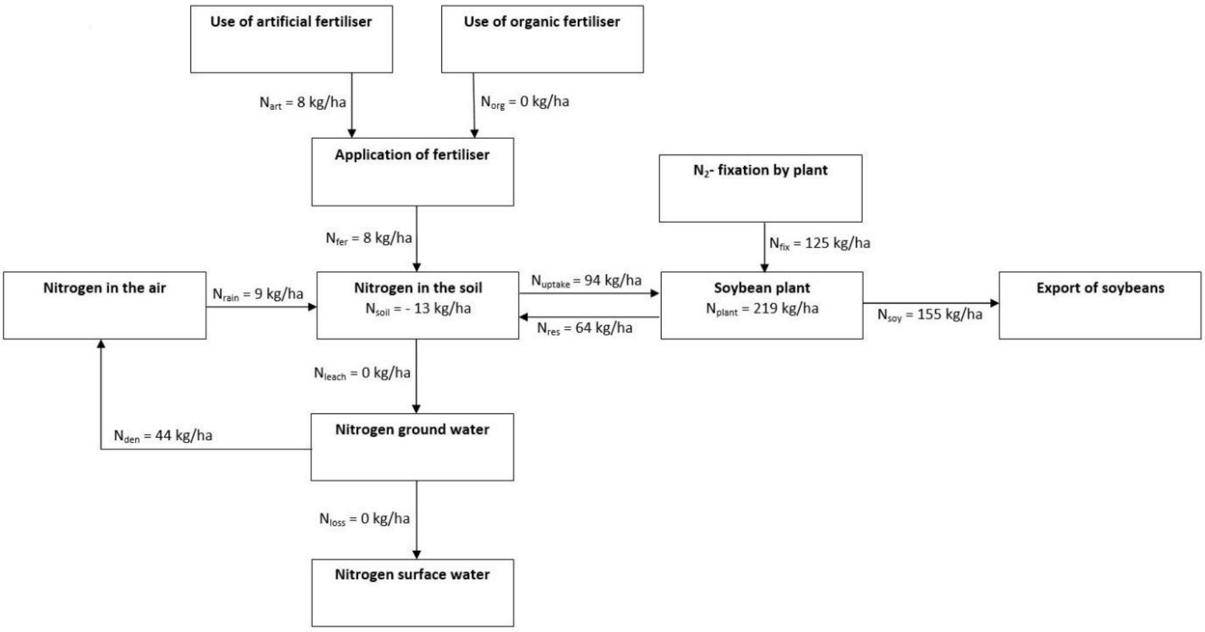

Figure 6: The nitrogen cycle for the production of soybeans in Brazil as determined for the year 2011 for the hectares on which soybeans are produced

N_2-fixation, uptake and nitrogen content from the soybean plant

Salvagiotti et al. (2008) made a review of several studies that look at nitrogen uptake, nitrogen fixation and the response of the soybean plant to nitrogen fertiliser. They collected all the data of the different studies and made a clear overview. In total 637 data-sets were used, of which 11 originated from Brazil. The outcome of the research was a table with the maximum, minimum and mean nitrogen uptake of the soybean plant (N_{plant}), the amount of nitrogen fixated by the plant from the air (N_{fix}), the nitrogen content in the grains (N_{soy}) and the nitrogen content of the residues (N_{res}) in kilograms per hectare. For the quantification of the nitrogen flows, the mean values of the research will be used, resulting in 219 kg N/ha for N_{plant}, 155 kg N/ha for N_{soy}, 59 kg N/ha for N_{res} and 111 kg N/ha for N_{fix}. As these values are the average of several studies the output products of the soybean plant (N_{res} + N_{soy}) are not equal to the total amount of nitrogen in the plant (N_{plant}). The number of N_{res} will therefore be adapted to 64 kg N/ha, to ensure that the total output is equal to the total input (see figure 6).

In their research Salvagiotti et al. (2008) concluded that, when the fertiliser use increases, the amount of nitrogen taken up by the plant from the air decreases. When no fertiliser was added, the average uptake through N_2-fixation was 125 kg N/ha, which is approximately 58% of the total nutrient uptake. They have drafted an exponential relationship between fertiliser use and N_2-fixation, with both having units of kg N/ha. This relationship is shown in equation 2.

$$N_{fix} = 337e^{-0.0098N_{fer}} \qquad (2)$$

The 337 stands for the highest number of N_2-fixation found, given that the maximum uptake of nitrogen found was 485 kg N/ha. With a fertiliser use of 8 kg N/ha in Brazil, the N_2-fixation would become 312 kg N/ha according to the equation. This is higher than the total uptake. The use of nitrogen fertiliser in Brazil on soybeans plants is small. Therefore it will be assumed that the soybean plants will fixate an average of 125 kg N/ha nitrogen from the air.

Nitrogen in the soil

With the values given by Salvagiotti et al (2008) the nitrogen demand of the soybean plant has been determined. The only value still unknown is the uptake by the plant from the soil (N_{uptake}). The uptake can be determined by subtracting the amount of nitrogen fixated by the plant itself, from the nitrogen demand from the plant (equation 3). This results in an uptake of 94 kg N/ha nitrogen from the soil.

$$N_{uptake} = N_{plant} - N_{fix} \qquad (3)$$

The change in nitrogen content in the soil (N_{soil}) depends on the nitrogen added to the soil. Besides fertiliser use and the residues from the soybean plant, nitrogen is added to the soil through deposition (N_{rain}). Allen et al. (2011) have done a study about the deposition of reactive nitrogen in southeast Brazil. Southeast Brazil is not one of the main locations of soybean production, but it is close to both regions (see figure 3). The climate shares characteristics with both the South as the Center-West and agriculture takes place in the form of sugar cane production.

The deposition of nitrogen has been divided into two parts, wet deposition and dry deposition. Both types of deposition have been determined for forest, sugar cane area and water. The wet deposition of nitrogen on all surfaces is approximately 4.7 kg N/ha/y (Allen et al., 2011). The dry deposition differs between the three surfaces ranging from 6.3 kg N/ha/y for forest and 1.5 kg N/ha/y for water. Sugar cane is in the middle with approximately 4.2 kg N/ha/y (Allen et al., 2011). As surface area the production of sugar cane probably resembles the production of soybeans the best. Therefore the value for dry deposition of 4.2 kg N/ha/y will be used. This brings the total nitrogen deposition in Brazil to 9 kg N/ha/y.

Vet et al. (2014) did a global assessment of nitrogen deposition. One of the countries investigated was Brazil. They found ranges for total deposition of nitrogen in Brazil between 2 and 10 kg N/ha/y. This complies with the values measured by Allen et al. (2011). Also the ranges for wet and dry deposition of 2 - 10 kg N/ha and 2 - 4 kg N/ha respectively, are similar.

With the nitrogen deposition, the inputs and the outputs of the soil are known. It can now be determined how much the soil balance changes (N_{soil}). By subtracting the outputs of the soil from the inputs of the soil the change in nitrogen in the soil is estimated (equation 4). The resulting value found for the soil balance is -13 kg N/ha. This means that, with the current fertiliser scheme in Brazil for soybeans, the soil experiences depletion. This depletion was also found by the FAO (2004).

$$N_{soil} = N_{rain} + N_{fer} + N_{res} - N_{uptake} \qquad (4)$$

Leaching of nitrogen

Due to the negative soil balance in the Brazilian soil, there is no leaching of nitrogen to the environment due to the production of soybeans (N_{leach} = 0). The production of soybeans is actually subtracting more nitrogen from the soil than is added, causing a shortage of nitrogen rather than a surplus. So instead of nitrogen being added to the groundwater, that flow remains zero. There can still be nitrogen leaving the groundwater through denitrification (N_{den}). Values for denitrification in Brazil range from 0.4 kg N/ha/y to 123.4 kg N/ha/y for different locations (Abe et al., 2003; Bayer et al., 2015; Kern et al., 1996; Liengaard et al., 2014). It is chosen to use the value found by Abe et al. (2003) of 44 kg N/ha/y for the denitrification of nitrogen, because their measurements took place on the border of Mato Grosso Do Sul and Sao Paulo, which are closest to both regions in which soybeans are being planted (see figure 3).

As a result of denitrification and the production of soybeans, the soil in Brazil is losing 57 kg N/ha (equation 5). This does not flow from the groundwater to the surface water (N_{loss} = 0), but is lost from the environment as a whole. The uptake of nitrogen from the soil by soybean plants, together with the denitrification is causing depletion. The uptake by plants is 68% of the total outflow and only 8.5% nitrogen is contributed by humans through fertiliser, which is approximately 10% of the total inputs. If the farmers in Brazil do not change their production process, the soil will become completely depleted and the production will be limited to the nutrients added by fertilisers.

$$Total\ loss = N_{soil} + N_{den} \tag{5}$$

The results of the quantification of the nitrogen flows in Brazil are given in table 1. By multiplying the numbers from figure 6 with the total amount of hectares on which soybeans are being produced, the total amount of nitrogen can be determined. The production of soybeans in Brazil takes place on 23,968,663 hectares (FAOSTAT, 2011c).

Table 1: The quantification of nitrogen flows that arise during the production of soybeans in Brazil for the year 2011 for the hectares on which soybeans are produced (23,968,663 ha) (FAOSTAT, 2011c)

Flow	**Symbol**	**Quantification of nitrogen (kg N/ha/y)**	**Total nitrogen flow during the production of soybeans (tonnes N/y)**	**Source**
The use of artificial fertiliser	N_{art}	8	191,749	FAO (2004)
The use of organic fertiliser	N_{org}	0	0	FAO (2004)
The total fertiliser use	N_{fer}	8	191,749	FAO (2004)
N_2-fixation by the soybean plant	N_{fix}	125	2,996,083	Salvagiotti et al. (2008)
Total uptake of the soybean plant	N_{plant}	219	5,249,137	Salvagiotti et al. (2008)
Nitrogen present in soybeans	N_{soy}	155	3,715,143	Salvagiotti et al. (2008)
Nitrogen left in the residues of the soybean plant	N_{res}	64	1,533,994	Salvagiotti et al. (2008)
Nitrogen taken up from the soil	N_{uptake}	94	2,253,054	Calculated
Deposition of nitrogen	N_{rain}	9	213,321	Allen et al. (2011)
Nitrogen change in the soil balance	N_{soil}	- 13	- 313,989	Calculated
Leaching of nitrogen	N_{leach}	0	0	Calculated
Denitrification of nitrogen	N_{den}	44	1,061,040	Abe et al. (2003)
Nitrogen lost to the surface water	N_{loss}	0	0	Calculated
Total loss of nitrogen	-	- 57	- 1,375,030	Calculated

2.2.2. PHOSPHORUS

Like nitrogen, phosphorus is a part of the production of soybeans. Figure 7 gives an overview of the phosphorus flows during the production of soybeans, taking into account the phosphorus cycle. The values have been determined for the production of soybeans in Brazil during the year 2011 using literature and databases, as will be explained below.

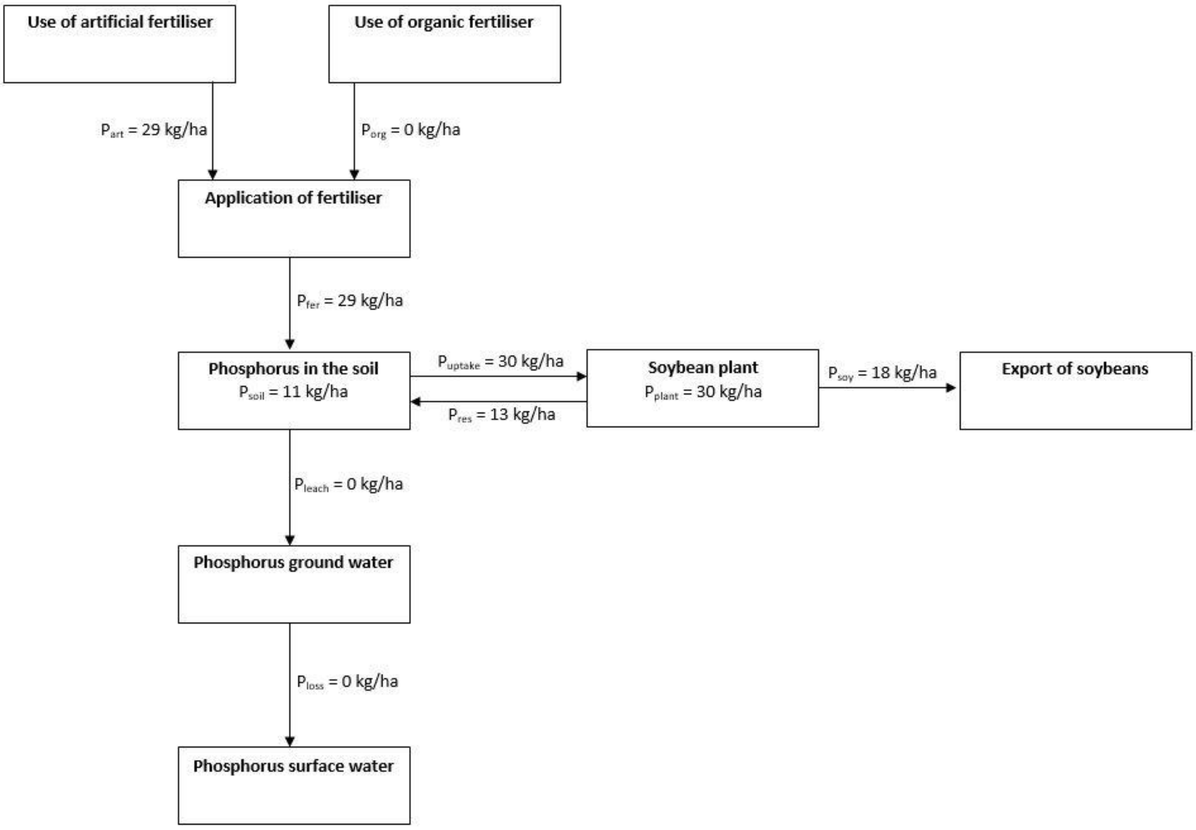

Figure 7: The phosphorus cycle for the production of soybeans in Brazil as determined for the year 2011 for the hectares on which soybeans are being produced

Fertiliser use

The use of phosphorus fertiliser on soybeans in Brazil is high, compared to other crops and countries. According to the FAO (2004) 66 kg P_2O_5/ha/y of artificial fertiliser (P_{art}) was used in Brazil to produce soybeans. This is equal to 29 kg P/ha/y (Schoumans et al., 2008). The total fertiliser use (P_{fer}) is equal to the artificial fertiliser use plus the organic fertiliser use (equation 6). The organic fertiliser will be assumed zero, because no data is available and the use of organic fertiliser in Brazil is uncommon. The total fertiliser use will therefore be equal to the artificial fertiliser use of 29 kg P/ha/y.

$$P_{fer} = P_{art} + P_{org} \tag{6}$$

Phosphorus use soybean plant

The phosphorus content of the soybean plant is determined using the studies by Ao et al. (2014) and Morshed et al. (2008). Ao et al. (2014) conducted a study about the P content in the soybean plant under different circumstances. It is chosen to use the data for high P efficiency and a high P level added. The fertiliser data collected in the previous section suggest a high addition of phosphorus fertiliser and therefore a high P level in the study by Ao et al. (2014). In Brazil more productive cultivars of soybeans have been used over the past years (Hungria et al., 2006). The soybean cultivars used in Brazil are different from the ones used by Ao et al. (2014), but it is expected that the productivity corresponds to the high P efficiency cultivars.

For a mature soybean plant the percentage of phosphorus in soybeans is 0.77% of the dry weight (Ao et al., 2014). The moisture content in soybeans lies between 8 - 24% (Kashaninejad et al., 2008). With a total production of 74,815,447 tonnes of soybeans in 2011 (FAOSTAT, 2011l), the dry weight lies between 68,830,211 and 56,859,740 tonnes. As a result the phosphorus content of soybeans (P_{soy}) lies between 529,992 and 437,820 tonnes. Dividing by the amount of hectares of 23,968,663 on which soybeans are being produced (FAOSTAT, 2011c), these values can be converted to 22 kg P/ha/y and 18 kg P/ha/y phosphorus.

Morshed et al. (2008) studied the effect of nitrogen fertiliser on seed yield, protein content and nutrient uptake of soybeans. They determined both the nitrogen and the phosphorus content in soybeans resulting in a ratio between N and P in soybeans of 12:1. With a nitrogen content of 155 kg P/ha in soybeans, determined in section 2.2.1., the phosphorus content should lie around 13 kg P/ha. This is lower than the value determined based on the study by Ao et al. (2014).

With the percentage of phosphorus given by Morshed et al. (2008), it can be determined whether this phosphorus content lies closer to the expected phosphorus content of 13 kg P/ha. The phosphorus concentration in soybeans is equal to 0.57% of the total weight (Morshed et al., 2008). With the total production of soybeans in Brazil of 74,815,447 tonnes this results in an amount of phosphorus of 426,448 or 18 kg P/ha/y.

Both Ao et al. (2014) and Morshed et al. (2008) come up with a phosphorus content of 18 kg P/ha. With the calculated nitrogen content of 155 kg P/ha the resulting N : P ratio is 9:1. This is higher than the ratio of 12:1 calculated earlier. The determined nitrogen value in section 2.2.1 is an average of several studies and can therefore be different in a specific case. The average nitrogen content in the seeds is 6.34% (Salvagiotti et al., 2008), which is almost equal to the percentage of 6.16% found by Morshed et al. (2008). Multiplying both percentages with the production of soybeans per hectare in Brazil the results are 192 kg N/ha/y and 198 kg N/ha/y. The resulted ratio in N and P now lies around 11:1.

It can be concluded that the percentage of phosphorus given by Morshed et al. (2008) is accurate, even though the resulting ratio differs from the expected ratio. It is therefore chosen to use the value of 18 kg P/ha for the phosphorus content in soybeans (P_{soy}). The amount of nitrogen in soybeans of 155 kg N/ha will still be used during the quantification, even though the percentage gives a different outcome. It is expected that this is an accurate number, as it is an average of several studies. With different production hectares or production quantities the amount of nitrogen can differ.

Of the total amount of phosphorus in a soybean plant 58.5% is located in the soybeans (Ao et al., 2014). With a phosphorus content of 426,448 tonnes soybeans the whole soybean plant (P_{plant}) contains 728,971 tonnes of phosphorus or 30 kg P/ha/y. The amount of phosphorus in the residues of the soybean plant (P_{res}) can now be determined by subtracting the phosphorus in the beans from the phosphorus in the plant (equation 7). This results in a value of 13 kg P/ha/y.

$$P_{res} = P_{plant} - P_{soy} \tag{7}$$

Phosphorus in the soil
To determine the change in phosphorus in the soil, the uptake of the plant from the soil (P_{uptake}) needs to be known. The uptake can be calculated by subtracting the inputs of the soybean plant from the demand of phosphorus of the soybean plant. In the case of phosphorus the plant can only take up phosphorus from the soil, so the uptake of the plant is equal to the demand of the plant, which results in a value of 30 kg P/ha/y phosphorus.

With the inputs and outputs of the soil known, the change in soil balance (P_{soil}) can be determined. The inputs of the soil are the fertiliser use and the residues of the soybean plant. The outputs of the soil are the uptake by the soybean plant. According to equation 8 the change is soil balance is equal to 11 kg P/ha/y. This is a different result than found by the FAO (2004), which determined a depletion of -4.2 kg P/ha/y phosphorus. However, this is determined for the entire country and was only calculated for mineral (artificial) fertilisers. The influence of plant residues was not taken into account.

$$P_{soil} = P_{fer} + P_{res} - P_{uptake} \tag{8}$$

Leaching of Phosphorus
With depletion taking place in most of the country it is likely that the phosphorus surplus found by the production of soybeans is accumulating in the soil. Especially when soybeans are used in crop rotation the soil needs the extra phosphorus to maintain fertile. In Brazil the soils on which soybeans are being produced are usually used for the production of maize or millet straight after, without tillage (Foreign Agricultural Service, 2012). As a result the soybean producing states all have deficits higher than the Brazilian average (FAO, 2004).

Hunke et al. (2015) have sampled soils from a soybean field to determine their chemical properties. They discovered high values of extractable phosphorus concentrations in the top soil, but looking at deeper soils they found no accumulation. This means that the phosphorus stays in the top soil to be used as nutrition for plants and they assumed that leaching of phosphorus was unlikely.

Due to depletion being the main issue in Brazil and in the soybean producing states, it is assumed that all phosphorus that is added to the soil, and not taken up by the soybean plant, stays available for other plants and does not leach to the groundwater. Therefore there will be no leaching of phosphorus (P_{leach} = 0) or loss of phosphorus to the environment (P_{loss} = 0).

Table 2 gives on overview of the quantification of the phosphorus flows during the production of soybeans. The total values are obtained by multiplying with the amount of hectares of 23,968,663 on which soybeans are being produced in Brazil (FAOSTAT, 2011c). With phosphorus accumulating in the soil, the uptake by soybeans is the only outflow from the soil. The amount of fertiliser added, is equal to the phosphorus demand of the soybean plant.

Table 2: The quantification of phosphorus flows that arise during the production of soybeans in Brazil in 2011 for the hectares on which soybeans are being produced (23,968,663 ha) (FAOSTAT, 2011c)

Flow	Symbol	Quantification of phosphorus (kg P/ha/y)	Total phosphorus flow during the production of soybeans (tonnes P/y)	Source
The use of artificial fertiliser	P_{art}	29	690,800	FAO (2004)
The use of organic fertiliser	P_{org}	0	0	FAO (2004)
The total fertiliser use	P_{fer}	29	690,800	FAO (2004)
Total uptake of the soybean plant	P_{plant}	30	728,971	Ao et al. (2014)
Phosphorus present in soybeans	P_{soy}	18	426,448	Morshed et al. (2008)
Phosphorus left in the residues of the plant	P_{res}	13	302,523	Calculated
Phosphorus taken up from the soil	P_{uptake}	30	728,971	Calculated
Phosphorus change in the soil balance	P_{soil}	11	264,352	Calculated
Leaching of phosphorus	P_{leach}	0	0	Calculated
Total loss of phosphorus	P_{loss}	0	0	Calculated

2.3. WATER QUALITY

A final step in the quantification of nutrient flows in Brazil is to determine the influence of the production of soybeans on the water quality. Even though there was no leaching determined, it is still important to determine the amount of nutrients in the surface water of Brazil, because the production of soybeans can still have an influence on these values.

The influence on the water quality will be determined in three steps. First the total values of nitrogen and phosphorus in Brazil will be estimated and second the natural or base-line concentrations of nitrogen and phosphorus in Brazil will be determined. These values can be compared to the results found in section 2.2 to assess the influence of the soybean production in Brazil on the water quality.

2.3.1. TOTAL NITROGEN AND PHOSPHORUS BRAZILIAN SURFACE WATER

The amount of nitrogen and phosphorus in the Brazilian surface water is influenced by many different factors. Besides agriculture, the effluent from industries and households can also bring nutrients into the surface water. Another factor that needs to be taken into account is the present of nutrients in the surface water, before it is even influenced by other factors. These nutrients can arise from the background concentrations, which will be discussed in section 2.3.2, but also from external parties like neighbouring countries, when rivers cross borders.

Nitrogen

The amount of nitrogen in the Brazilian surface water will be estimated by using data collected by Hunke et al. (2015). They conducted a study about the change in soil characteristics in the Cerrado of Mato Grosso due to land changes, partly caused by the production of soybean. The studied catchment is located in the south of Mato Grosso. 70% of the catchment consists of agriculture, predominantly sugar cane and soybean with crop rotation of maize and cotton.

Mato Grosso is one of the main producers of soybeans (Foreign Agricultural Service, 2012). In Brazil as a whole 32.5% of the total land area is used for agriculture (FAOSTAT, 2011a), and about 60% consists of natural cover (FAO, 2004). With agriculture taking place predominantly in the South and Center-West, a percentage of 70 for soybean and sugar cane production seems representative for these parts of the country. Since soybeans are mainly being produced in the South and Center-West the values determined by Hunke et al. (2015) will be used to determine the nitrogen concentration in the surface water with respect to the soybean production.

Table 3 gives an overview of the values for nitrite and nitrate measured by Hunke et al. (2015) in 2010. There are no measurements given for ammonium. Either this value was not measured, or it did not occur in the water of the catchment. The measurements took place over two days in both the dry and the wet season at 19 different locations. At each location three different samples were taken and analysed.

For the determination of the nitrogen content in the surface water the values measured at the outflow point of the catchment will be used. At this location all nitrogen from the entire catchment has reached the surface water and from here the nitrogen will flow into the São Lourenço River spreading through (parts of) the country. In table 3 both the values for the dry and the wet season are given. At the time of measurements of the wet season soybeans were just being harvested, during the dry season there were no soybeans planted yet.

To determine the values of nitrogen in nitrite and nitrate the atomic weight of the components was used. This results in a percentage of nitrogen of both substances, with which the total amount of nitrogen in the Brazilian surface water can be determined. The values for the wet season will give a better impression of the water quality during the production of soybeans, because in the dry season no soybeans were present. In that period maize or cotton is being produced.

Table 3: The values for nitrite and nitrate for both the wet and dry season, measured in a catchment in Mato Grosso in Brazil by Hunke et al. (2015) during the year 2010

		Average measured concentration NO_2^-/ NO_3^- in the catchment (μg/l)	Percentage of nitrogen	Total nitrogen present in the catchment (mg N/m^3)	Total nitrogen in the surface water (kg N/ha/y)
NO_2^-	Dry	38.78	30.44%	11.81	0.17
	Wet	129.92		39.56	0.58
NO_3^-	Dry	305.40	22.59%	69.00	1.01
	Wet	391.08		88.36	1.89

Phosphorus

Besides nitrite and nitrate Hunke et al. (2015) also measured phosphate. The measured values for phosphate are given in table 4. There was no phosphate measured in the wet season. Due to the harvesting of soybeans, there was no extra fertiliser added to the soil. The phosphorus that was still in the ground was most likely washed away with the first rain fall of the season (Hunke et al., 2015). Due to the lack of phosphorus in the wet season the value of the dry season will be used to give an impression of the water quality in the Brazilian surface water. The determination of the amount of phosphorus present in the water was again done by using the atomic weight.

Table 4: The measurement of phosphate during the dry and wet season in a catchment in Mato Grosso in Brazil by Hunke et al. (2015) during the year 2010

		Average measured concentration PO_4^{3-} in the catchment (μg/l)	Percentage of phosphorus	Total phosphorus present in the catchment (mg P/m^3)	Total phosphorus in the surface water (kg P/ha)
PO_4^{3-}	Dry	396.69	32.61%	129.36	1.89
	Wet	0.00		0.00	0.00

Influence soybean production

In order to compare the measured values by Hunke et al. (2015) with the estimated values of nitrogen and phosphorus caused by the production of soybeans of section 2.2, the water quality parameters will be converted by using the average annual precipitation and the curve number method. The average precipitation in this catchment in Mato Grosso is 1500 mm per year (Hunke et al., 2015). Of this 1500 mm, 80% fell during the wet season, the season during which soybeans are being produced.

The soil on which soybeans are being produced consists of about 60% sand, 8% silt and 30% clay. The soil has an impermeable water table close under surface, causing the soil to have a very high run-off potential and a low infiltration rate (Hunke et al., 2015). With all rainfall events observed by Hunke et al. (2015), they noticed overland flow. Looking at the soil characteristics for the curve-number method, the soil described by Hunke et al. (2015) falls in category D (Soil Conservation Service, 1965). The soybean crops present reduce the infiltration rate, compared with the Cerrado site, so it is assumed that the hydrological condition of the soil is poor. This results in a curve number (CN) of 89 (Soil Conservation Service, 1965).

The curve number method uses equations 9 and 10 to determine the discharge in mm. CN stands for the determined curve number, S is the potential maximum retention after runoff begins in mm, R is the precipitation in mm and Q is the discharge in mm. By filling in the mean annual precipitation of 1500 mm (Hunke et al., 2015), and the curve number of 89 (Soil Conservation Service, 1965) the discharge in the catchment can be determined.

$$S = \frac{25400}{CN} - 254 \tag{9}$$

$$Q = \frac{(R - 0.2S)^2}{R + 0.8S} \tag{10}$$

The discharge of the catchment is equal to 1463 mm/y. Multiplying with the surface area of the catchment of 865 km^2 this can be rewritten as 40 m^3/s (Hunke et al., 2015). Wantzen et al. (2006) have studied the same catchment and determined a discharge of approximately 50 m^3/s at the confluence. The calculated discharge with the data by Hunke et al. (2015) does not differ much. The difference between the mean average precipitation and the discharge is small. Due to most precipitation falling in the wet season, the influence of vaporization is small.

By multiplying the concentrations of N and P in the surface water with the discharge, the values can be compared to the amount of nitrogen and phosphorus in the production of soybeans. The result is given in table 3 and 4. The total amount of nitrogen in the dry season is equal to 1.18 kg N/ha and the nitrogen concentration in the wet season is equal to 1.87 kg N/ha. With soybeans being produced in the wet season the result of 1.87 kg N/ha gives the best overview of the water quality during the production of soybeans. With 10% of the total nitrogen inputs coming from humans fertilising you could say that 10% of the water quality is caused by soybean production. However, with the result of depletion this is unlikely.

For phosphorus the total amount in the surface water is equal to 1.89 kg P/ha. Even though this was measured in the dry season, it still gives an estimate of the phosphorus content present in the surface water. With about 70% of the phosphorus being added through fertiliser, the influence of humans on the water quality can be estimated as being the same. However, with the fertiliser use being equal to the uptake by the soybeans plant and the assumption that most phosphorus accumulates in the soil, the influence of the soybean production on phosphorus in the surface water is small and it is likely to originate from other sources.

2.3.2. NATURAL BACKGROUND CONCENTRATIONS NITROGEN AND PHOSPHORUS

Besides the total concentration of nitrogen and phosphorus in the surface water, it is also important to look at the background concentrations. These are concentrations that occur in nature when no interference takes place. Fonseca et al. (2014) have tried to develop base-line concentrations for several nutrients, including nitrite, nitrate ammonium and phosphorus. They investigated streams around the Federal District in Brazil, by taking water samples at 14 different locations, to classify the streams from natural to very impacted based on the water quality. The measurements were taken between 2006 and 2009 during both the dry and the wet season. The

Federal District lies in an area in which soybeans are being produced (see section 2.1), and it is not that far from the catchment described in section 2.3.1.

For the estimation of the natural background concentration in the Brazilian surface water, the 'natural' values determined by Fonseca et al. (2014) et al will be used. The 'natural' values for nitrite, nitrate, ammonium and phosphorus are given in table 5. The catchment to which the streams in the Federal District belong to, has the same characteristics as the catchment studied in section 2.3.1, including a mean precipitation of 1500 mm. Due to the large amount of streams investigated it is hard to determine one discharge, but is assumed that the discharged is somewhat similar to the discharge determined in section 2.3.1 for the Tenente Amaral basin, due to the similar characteristics. The concentrations can be multiplied with this discharge of 1463 mm/y to compare the values with the data about the production of soybeans.

Table 5: The base-line concentrations for nitrite, nitrate, ammonium and phosphorus as measured by Fonseca et al. (2014) in the Federation District between 2006 and 2009

	Determined base-line concentration(µg/l)	Percentage of nitrogen or phosphorus	Quantity nitrogen or phosphorus (mg/m^3)	Total N or P present in the catchment (kg/ha/y)
NO_2^-	5	30.4%	2	0.02
NO_3^-	40	22.6%	9	0.13
NH_4^+	39	77.7%	30	0.44
P	6	-	6	0.09

The natural concentration of nitrogen in the Brazilian surface water can be estimated at 0.59 kg N/ha. This is approximately 51% of the nitrogen content determined for the dry season and 32% of the nitrogen content determined for the wet season. This means that, especially in the wet season, more nitrogen is added to the surface by agriculture and other sources.

For phosphorus the natural concentration can be estimated at 0.09 kg P/ha, which is only 4.6% of the total phosphorus content determined. So more than 90% of the phosphorus in the Brazilian surface is added by human influences. Compared to the percentages found for nitrogen, this influence is big, but looking at the fertiliser use determined in section 2.2 it does not seem unlikely. In Brazil more phosphorus is added to the soil than nitrogen, and for soybeans in particular the amount of phosphorus compared to nitrogen is almost 4 times larger. With phosphorus staying in the top soil and easily flushed to the surface water with rain, the concentration of phosphorus found is larger.

Even though the ground experiences depletion due to agriculture, there is an excess amount of nitrogen and phosphorus in the surface water. This can originate from agriculture, but also from industry and households. With mainly artificial fertiliser being used and an unusual ration between N and P, the agriculture in Brazil can be optimized to change the influence of the production of soybeans on the water quality.

3. THE NETHERLANDS

After soybeans have been produced in Brazil, a part is exported to the Netherlands. In the Netherlands a portion of the soybeans are being used in pig feed. In this chapter the production of pork meat in the Netherlands will be investigated. The focus will be on the amount of nutrients in pig manure as a result of their feed. First an outline of the situation will be given. Second the flow of nutrients that is present during the production of pork meat will be quantified. Third and final the influence on the water quality will be determined.

3.1. OUTLINE OF THE SITUATION

The Netherlands is a country with approximately 12 million pigs and 5.000 pig farms (CBS, 2014c). Figure 8 shows the change in the number of pigs and pig farms over the past couple of years. The amount of pig farms has been decreasing, but the amount of pigs, at least for the last three years, has stayed the same. This results in more pigs per farm. Pigs can be kept as part of a breeding program or for the production of meat. Almost half of the pigs that are kept in the Netherlands are kept for their meat (CBS, 2014c). Both the number of pigs and the number of companies that produce meat have decreased over the last three years (LEI, 2014).

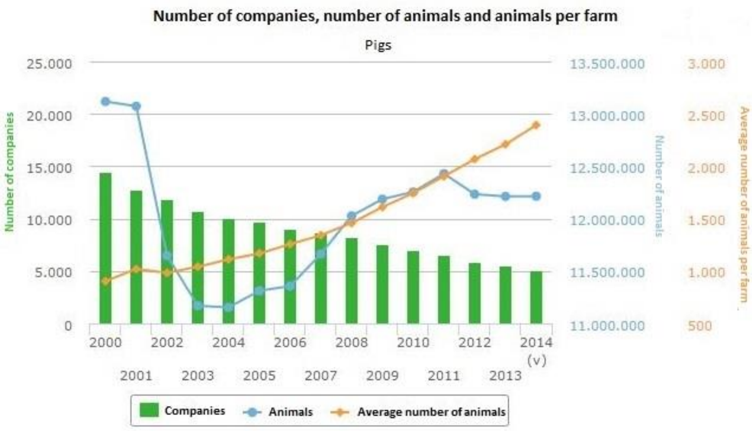

Figure 8: The change in the amount of pigs and the number of farms in the Netherlands between 2000 and 2014 (LEI, 2014)

Figure 9 shows a map of the Netherlands with the number of companies that keep pigs for their meat per province in 2014 (CBS, 2014c). It shows that most companies are located in the south-east of the country. The production of nitrogen and phosphorus in this part of the country can be expected to be the highest.

During their life pigs get different types of food. When the pigs are six weeks old they start to be fed solid feed (Jongbloed & Kemme, 2005). This feed is specially blended for these little pigs. After approximately 38 days the piglets have reach a weight of 25 kg and are ready to be transported to their new home. They can either become part of a breeding program themselves, or they are going to grow up for the purpose of their meat.

The piglets that will be raised for their meat will live for another 115 days, after they have reached their new home. During this time they will gain approximately 762 g per day until they have reached a weight of 114 kg (Jongbloed & Kemme, 2005). In order for the pigs to gain this weight they get fed three different types of feed. During the first month they get fed starting feed, which is similar to the piglet feed they were given before. After they have reached a weight of about 30 kg the pigs will be switched to growing feed, which they will eat till they reach a weight of 70 kg. This will also take about a month. For the remaining days of their life, approximately 55 days, the pigs are fed grow finishing feed until they are ready to be slaughtered (Jongbloed & Kemme, 2005).

3.2. QUANTIFICATION OF NUTRIENT FLOWS

Nutrients are an important part of the diet of pigs, as they are used to help the pigs to grow. The nutrients enter pigs through the feed and a part leaves the body in manure. In this section the flow of nutrients during the production of pork meat will be estimated and quantified. The focus will again be on nitrogen and phosphorus, which will be quantified separately.

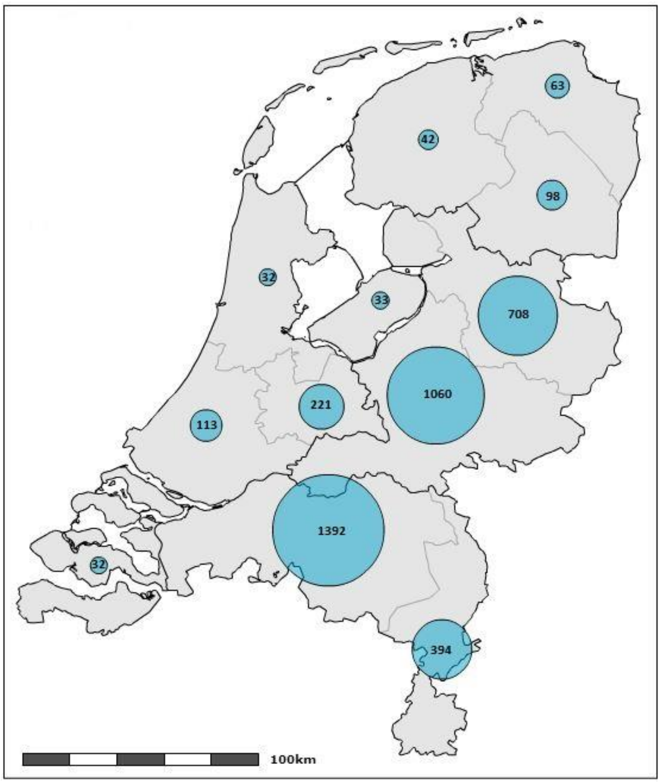

Figure 9: The location of pig farms that keep finishing pigs in the Netherlands per province for the year 2014 (CBS, 2014c)

3.2.1. NITROGEN

Figure 10 shows a schematic overview of the flow of nitrogen through Dutch agriculture, specifying the situation for pigs. It shows the different processes that take place and the connections they have to each other. It is connected to the production of soybeans in Brazil through the import shown in the top left box. The values are determined for crop land and pastures in the Netherlands for 2013 using databases and literature, as will be explained below.

Nitrogen in pigs

Jongbloed & Kemme (2005) have carried out a study about the nitrogen and phosphorus content of several types of animals due to a change in the manure legislation of the Dutch government. They have determined values for 2002 and, with the expected changes, have estimated values for 2006. Because the values for 2006 are estimations, the values from 2002 will be used in quantifying the nutrient flows. There is not a significant difference between the two years.

Table 6 gives an overview of the values for nitrogen found by Jongbloed & Kemme (2005) for finishing pigs in 2002. The given values are calculated per living space for one pig during one year. They assume that one pig lives for about 115 days, so during one year 3.16 pigs can live on one space.

Table 6: An overview of the nitrogen content in pigs themselves, in their feed and in their manure as given by Jongbloed & Kemme (2005) for the year 2002

	kg pig feed/y	g N/kg pig feed	kg nitrogen used each year	kg nitrogen per pig per year	Total amount of nitrogen used (tonnes N/y)
Starter feed	120	27.1	3.25		
Growth feed	221	26.2	5.80		
Grow finishing feed	401	23.6	9.47		
Total feed (N_{feed})	742		18.52	5.86	33,155
N taken up by the pig (N_{meat})			6.96	2.20	12,460
N in manure (N_{manure})			11.56	3.66	20,695

In order to get a clear overview of the nitrogen during the production of pork meat the values in table 6 will be divided by 3.16 to convert the values to nitrogen per pig per year. The new values are also given in table 6. By multiplying with the total number of pigs raised for their meat in the Netherlands the total amount of nitrogen in the pigs can be determined. The number of finishing pigs in 2014 in the Netherlands was equal to 5,657,191 (CBS, 2014c).

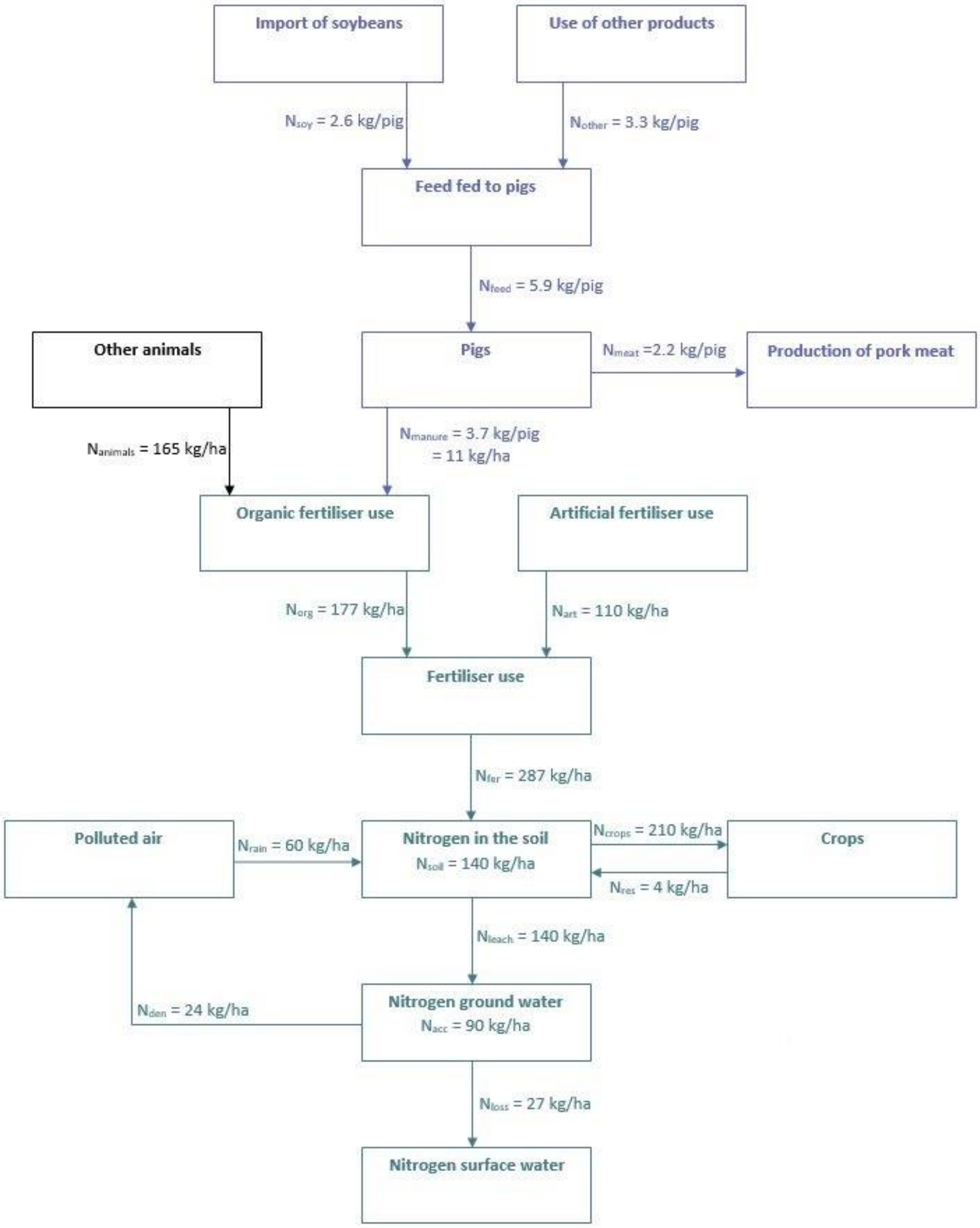

Figure 10: The nitrogen cycle for Dutch agriculture for both cropland and pastures in green, specifying the situation of pigs in blue as determined for 2013

Soybeans in feed

The percentage of soybeans in pig feed lies between 4 and 19% (Alles over vlees, 2015; Kok et al., 2004; Kortstee et al.2011; Sevenster & Hueting, 2007). It is difficult to determine the exact amount of soybeans in pig feed, because every supplier uses a different blend and therefore a different percentage.

Kok et al. (2004) give an overview of the average materials used in different types of animal feed per year, one of which is pig feed, between 1998 and 2001. They have divided the materials in several different categories and give values for the use of soybean cake, soybean oil and whole soybeans. Because of this separation in soybean products and the detail in the study these values will be used to estimate the amount of nitrogen in pig feed as a result of soybeans.

Table 7 gives an overview of the values of soybean cake, soybean oil and soybeans used in pig feed as given by Kok et al. (2004). By dividing them with the total amount of feed the percentage of soybean products in the feed can be determined. Because these values are for pig feed eaten by all pigs in one year the percentages will be used to determine the amount of soybean cake, soybean oil and soybeans in the amount of feed of given by Jongbloed & Kemme (2005). They determined a total amount of feed for finishing pigs of 742 kg per year, which can be converted to 235 kg feed/pig/y. Even though these values are not specifically for this blend of feed it is assumed that these values would be somewhat similar, and due to lack of specific data about pig feed for finishing pigs these numbers will be used to give a crude estimate. The result can be found in table 7.

Table 7: The determination of the amount of nitrogen in pig feed as a result of soybeans (Jongbloed & Kemme, 2005; Kok et al., 2004) (d.m. = dry matter)

	Total in pig feed (tonnes/y)	% soy in pig feed	Soy in pig feed (kg/pig/y)	% N in soy products	N content pig feed (kg N/pig/y)	Total N content (tonnes N/y)
Soybean cake	1,013,000	14.7	34.4	8 (d.m.)	2.5	13,876
Soybean oil	9,000	0.1	0.3	-	-	-
Soybeans	32,000	0.5	1.1	6	0.1	390
Total (N_{soy})	6,914,000	15.2	35.8	-	2.6	14,266

Soybean cake
Looking at several studies that research the use of soybean cake the amount of nitrogen is approximately 8% of the dry matter (Batterham et al., 1990; Dentinho et al., 2014; Prawirodigdo et al., 1997). This corresponds to the percentage of soybeans in pig feed given by Sevenster & Hueting (2007) for dry matter of 7.3%, taking into account that the main soybean component of pig feed is soybean cake.

In order to determine the amount of nitrogen in the soybean cake first the dry weight of the soybean cake needs to be determined. The number given by Kok et al. (2004) is the total weight. So is the weight given by Jongbloed & Kemme (2005). Hammond et al. (2005) determined that, depending on the processing method, the moisture content in soybean cake is about 11%. The dry matter in soybean cake is therefore 89% resulting in a weight of 31.6 kg/pig/y. Multiplying with the 8% found for the nitrogen content, the amount of nitrogen in the soybean cake is equal to 2.5 kg N/pig/y (see table 7).

Soybean oil
Looking at the typical composition of crude soybean oil given by Hammond et al. (2005), there is no nitrogen present in the oil. Looking at other sources there is no study that comments on the amount of nitrogen in soybean oil. Therefore the amount of nitrogen in the soybean oil is assumed to be zero.

Soybeans
The percentage of nitrogen in soybeans is equal to 6.34% of the total weight (Salvagiotti et al., 2008). Multiplying with the amount of soybeans in the pig feed the nitrogen content becomes 0.1 kg N/pig/y (see table 7).

To determine the total amount of nitrogen in the pig feed as a result of soybeans, the nitrogen content per pig needs to be multiplied with the total amount of finishing pigs in the Netherlands of 5,657,191 (CBS, 2014c). The results are given in table 7.

Nitrogen in other feed
In the previous two sections the total amount of nitrogen in pig feed and the amount of nitrogen as a result of soybeans in pig feed have been determined. Now the nitrogen content caused by the other feed can be determined (N_{other}). The amount of nitrogen in the other feed can be calculated by subtracting the nitrogen caused by soybeans from the total amount of nitrogen in the feed (see equation 11). This results in a value of nitrogen of 3.3 kg N/pig/y.

$$N_{other} = N_{feed} - N_{soy} \quad (11)$$

Nitrogen deposition

Nitrogen occurs in the air in different forms. Due to a growth of intensive livestock farming and the use of fossil fuels the concentrations of nitrogen in the air has increased. Figure 11 shows the development of the concentrations of nitrogen in the air for the past century. After a peak around 1988 the nitrogen concentrations have been decreasing, but they are still higher than 50 years ago.

Due to the high concentration of nitrogen in the air a part of the nitrogen is deposited on the ground. This can be as wet deposition, in rain, or dry deposition. The average deposition of nitrogen in the Netherlands in 2004 was 30 kg N/ha per year (Kros et al., 2008). In areas with intensive livestock farming, like the south-east of the country, this value rises to 60 kg N/ha nitrogen per year (Kros et al., 2008). The pig farms are a type of intensive livestock farming. Finishing pigs alone caused an emission 12,900 tonnes NH_3/y in 2004 (Kros et al., 2008). Only cattle had a higher ammonia emission (Kros et al., 2008). For the deposition of nitrogen (N_{rain}) in the system of producing pork meat the local value of 60 kg N/ha/y will therefore be used.

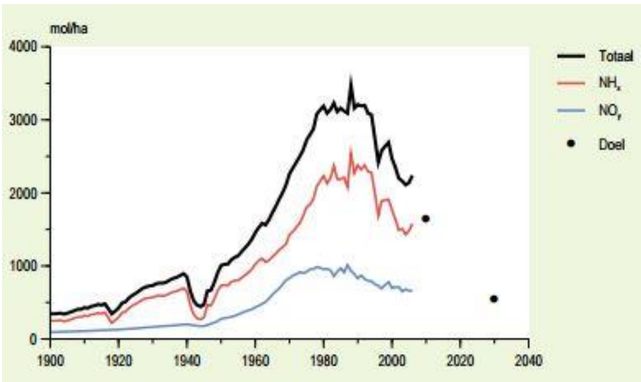

Figure 11: The concentration of nitrogen in the Dutch air between 1990 and 2006 with the goals set for 2010 and 2030 (De Haan et al., 2008)

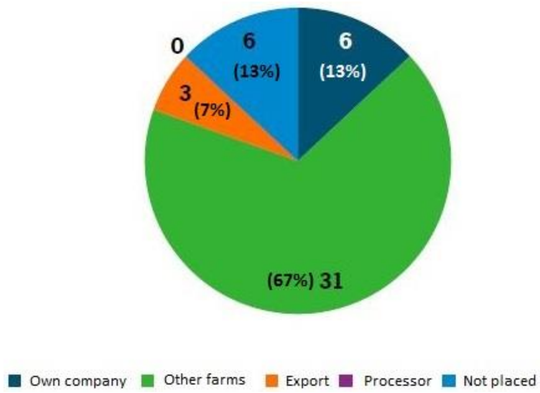

Figure 12: The destination of phosphate originating from pig manure in million kg for 2010 (Luesink et al., 2011)

Nitrogen in the soil

To get a clear overview of the amount of nitrogen in the soil of crop land and pastures in the Netherlands, all nitrogen inputs need to be known. Besides the use of manure from pigs and nitrogen deposition, also other fertiliser is used. The CBS (2013) gives a nitrogen balance for the Netherlands, with specific values for agriculture. Besides fertiliser use they specify accumulation, leaching, and removal with crops. With these values the quantification can be extended to give an overview of the whole situation.

On crop land and pastures in the Netherlands 325 million kg nitrogen from manure (N_{org}) and 202 million kg nitrogen from artificial fertiliser (N_{art}) is applied in 2013 (CBS, 2013). Figure 12 shows the destination of phosphate from pig manure for the year 2010. It shows that more than three quarters of the manure is used on agricultural land and almost a quarter of the manure is exported or could not be placed. For simplicity it is assumed that all calculated nitrogen and phosphorus in pig manure is used as fertiliser. With the values calculated above, the amount of nitrogen from pigs is 6% of the total applied nitrogen from manure. The rest originates from other animals. The amount of nitrogen applied to the soil as a result of fertiliser (N_{fer}) is 527 million kg N/y. Dividing by the amount of hectares of crop land and pastures of 1,839,020 in the Netherlands (CBS, 2014b), this can be rewritten as 287 kg N/ha/y on average. This is in compliance with the values found by Schröder et al. (2005).

The inputs into the soil are now quantified. In order to determine the amount of nitrogen leaching to the groundwater, the outputs of the soil, the nitrogen accumulation in the soil (N_{soil}), the nitrogen removed when harvesting crops (N_{crops}), and the amount of nitrogen returned to the soil by residues and compost, need to be determined. When harvesting crops 387 million kg of nitrogen is removed each year as well (CBS, 2013). This results in a removal of nitrogen of 210 kg N/ha/y, which is similar to the value found by Kroeze et al. (2003). The crop residues returned back to the soil are 8 million kg of nitrogen per year, which results in 4 kg N/ha/y of nitrogen (CBS, 2013).

With all the inputs and outputs known, the change in soil balance (N_{soil}) can be determined by subtracting them from each other (equation 12). This results in a surplus of 140 kg N/ha, close to the surplus determined by Schröder et al. (2005) in their case study. It is generally assumed that this surplus denitrifies and leaches and accumulates in the soil and the groundwater. These terms are hard to quantify and usually only estimates are given.

$$N_{soil} = N_{fer} + N_{rain} + N_{res} - N_{crops} \tag{12}$$

Nitrogen lost to the environment

Not all nitrogen that leaches to the groundwater is lost. Some nitrogen returns back into the cycle through denitrification, in which nitrogen escapes back to the air. Denitrification is hard to measure and quantify. Kroeze et al. (2003) estimated that with denitrification between 0 - 100 kg N/ha/y moves to the air. On arable land the N losses are estimated on ranging from 10 to 25 kg N/ha/y (Kroeze et al., 2003).

The CBS (2013) has calculated that approximately 50 million kg of nitrogen originating from agriculture leaches to the surface water each year (N_{loss}). This is less than the 90,000 tonnes N/y determined by Kroeze et al. (2003). However, the data determined by Kroeze et al. (2003) is for 1995 and the data by the CBS (2013) is for 2013. In between these year regulations have changed, which could be an explanation for this significant difference. As a result of humans eating pork, nitrogen can also reach the surface water through waste water treatment plants. This is, however, a very small percentage and will not be taken into account during this study. With an amount of 50 million kg or 27 kg nitrogen per ha per year leaching to the surface there is still a surplus left of 113 kg N/ha/y. A part will denitrify and the rest will accumulate in the soil and the groundwater.

Kroeze et al. (2003) state that, in the long term, the accumulation in the soil can be assumed minor (< 5000 tonnes N/y). The CBS (2013) has determined that the accumulation in the soil and the groundwater in 2013 was equal to 165 million kg N (or 90 kg N/ha/y). This is the difference between the inputs and the outputs. For simplicity it will be assumed that no nitrogen is accumulating in the soil and that the whole surplus of nitrogen leaches to the groundwater (N_{leach}). The accumulation will than take place in the groundwater with a part of the nitrogen leaching to the deeper groundwater. The accumulation in the groundwater (N_{acc}) will be equal to 90 kg N/ha/y.

With a surplus of 113 kg N/ha/y and with 90 kg N/ha/y accumulation in either the soil or the groundwater the denitrification will be equal to 24 kg/ha/y (see equation 13). This lies in the expected range of 10 - 25 kg N/ha/y determined by Kroeze et al. (2003).

$$N_{den} = N_{leach} - N_{acc} - N_{loss} \tag{13}$$

The quantification of nitrogen for the production of pork meat is shown in table 8. It gives an overview of all the different flows calculated above and shows the total amounts of nitrogen that flows through the system. In total 6% of the organic fertiliser use originates from pig manure, which is 4% of the total fertiliser inputs. Also taking into account deposition and residues this percentage drops to 3%. So out of the nitrogen leaching to the environment 3% is caused by finishing pigs.

Table 8: The quantification of nitrogen for the production of pork meat in the Netherlands for the year 2013

Flow	Symbol	Quantification of nitrogen (kg N/pig/y)	Quantification of nitrogen (kg N/ha/y)	Total nitrogen flow during the production of pork meat (tonnes N/y)	Source
Use soybeans in pig feed	N_{soy}	2.6		14,266	Kok et al. (2004)
Use of other feed	N_{other}	3.3		18,889	Calculated
Total pig feed	N_{feed}	5.9		33,155	Jongbloed & Kemme (2005)
Nitrogen pork meat	N_{meat}	2.2		12,460	Jongbloed & Kemme (2005)
Nitrogen in pig manure	N_{manure}	3.7	11	20,695	Jongbloed & Kemme (2005)
Nitrogen manure other animals	$N_{animals}$		165	304,305	Calculated
Use of manure as fertiliser	N_{org}		177	325,000	CBS (2013)
Use of artificial fertiliser	N_{art}		110	202,000	CBS (2013)
Total fertiliser use	N_{fer}		287	527,000	Calculated
Nitrogen deposition	N_{rain}		60	110,341	Kros et al. (2008)
Nitrogen change in the soil balance	N_{soil}		140	258,341	Calculated
Nitrogen harvested with crops	N_{crops}		210	387,000	(CBS, 2013)
Nitrogen left in crop residues	N_{res}		4	8,000	(CBS, 2013)
Leaching of nitrogen to the groundwater	N_{leach}		140	258,341	(CBS, 2013)
Accumulation of nitrogen	N_{acc}		90	165,000	(CBS, 2013)
Nitrogen denitrification	N_{den}		24	43,341	Calculated
Total loss of nitrogen	N_{lost}		27	50,000	Calculated

3.2.2. PHOSPHORUS

The flow of phosphorus during the production of pork meat in the Netherlands is shown in figure 13. As for nitrogen all processes that take place in the Netherlands are shown with their connections. The quantification of the processes will be explained below.

Phosphorus in pigs
In the same study by Jongbloed & Kemme (2005), used in quantifying the nitrogen in pigs, also the values for phosphorus in pigs are given. Table 9 gives an overview of the data found by Jongbloed & Kemme (2005) for the phosphorus in pigs in the year 2002. These values are again determined per living space per year.

To be able to interpret the result in comparison to other data the values of phosphorus are divided by 3.16 to convert the values to phosphorus per pig per year. By multiplying again with the total number of pigs of 5,657,191, the total amount phosphorus can be determined (CBS, 2014c). The values per pig for phosphorus per year can also be found in table 9.

Table 9: The amount of phosphorous in pigs themselves, pig feed and manure given by Jongbloed & Kemme (2005) for the year 2002

	kg pig feed/y	g P/kg pig feed	kg phosphorus used each year	kg phosphorus per pig per year	Total amount of phosphorus used (tonnes P/y)
Starter feed	120	4.7	0.56		
Growth feed	221	4.8	1.06		
Grow finishing feed	401	4.6	1.85		
Total feed (P_{feed})	743		3.47	1.10	6,212
P taken up by the pig (P_{pig})			1.49	0.47	2,667
P in manure (P_{manure})			1.98	0.63	3,545

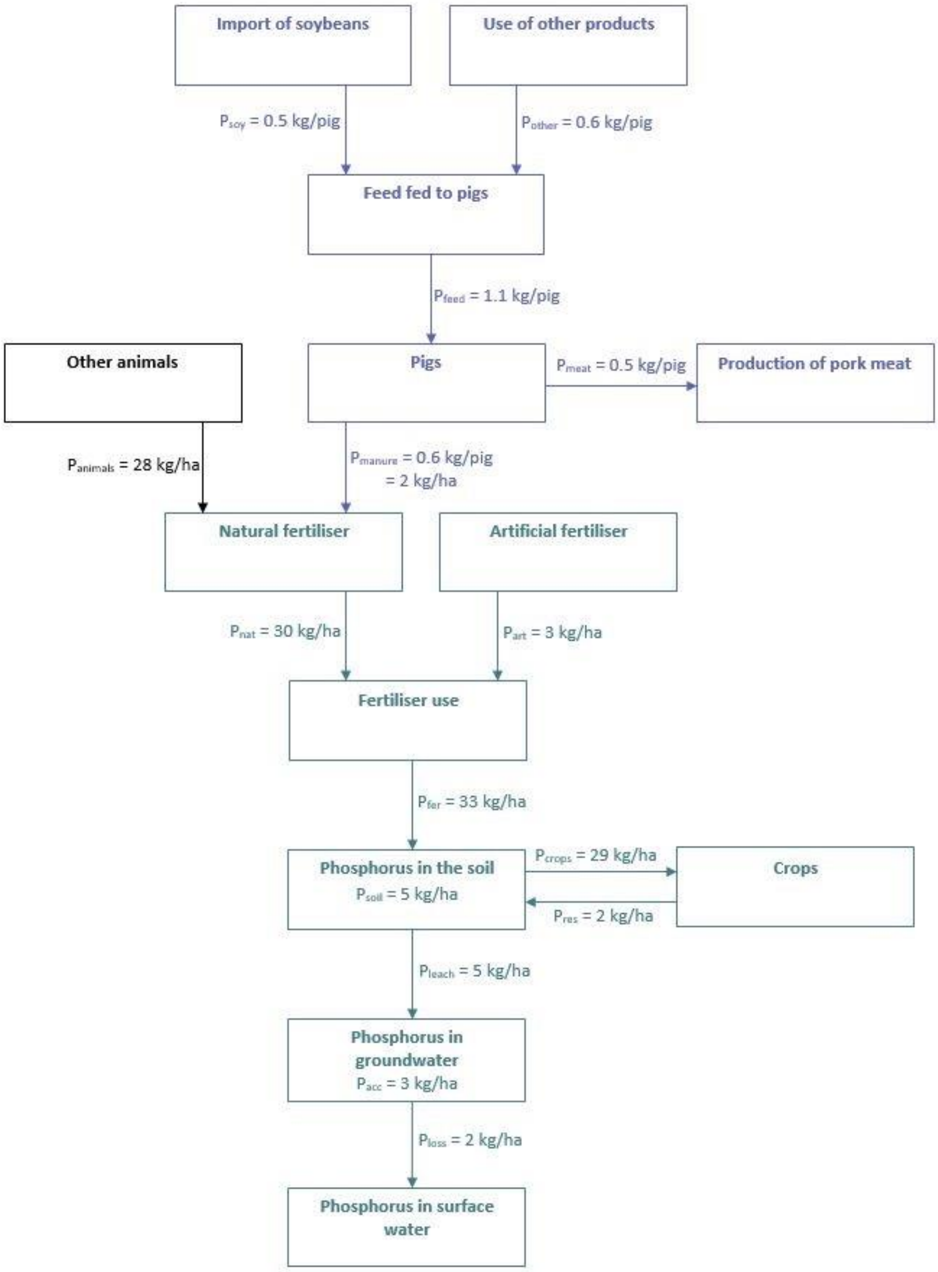

Figure 13: The phosphorus cycle for Dutch agriculture for both cropland and pastures in green, specifying the situation of pigs in blue as determined for 2013

Soybeans in feed

The amount of soybeans used in pig feed is the same as explained in the section about nitrogen. Using the data from Kok et al. (2004) there is 14.7% soybean cake, 0.1% soybean oil and 0.5% soybeans. To determine the amount of phosphorus in pig feed the amount of phosphorus per product needs to be determined. The results are given in table 10.

Table 10: The determination of the amount of phosphorus in pig feed due the presence of soybeans (Jongbloed & Kemme, 2005; Kok et al., 2004)

	% soy in pig feed	Soy in pig feed (kg/pig/y)	% P in soy products	P content pig feed (kg P/pig/y)	Total P content (tonnes P/y)
Soybean cake	14.7	34.4	1.3	0.4	2,534
Soybean oil	0.1	0.3	0.05	$1.6 \cdot 10^{-4}$	1
Soybeans	0.5	1.1	0.57	$6.2 \cdot 10^{-3}$	35
Total (P_{soy})	15.2	35.8	1.9	0.5	2,570

Soybean cake

Mutucumara et al. (2015) have carried out a study about the phosphorus digestibility of maize and soybean cake. They analysed the composition of the soybean cake used in their experiments and discovered that the total phosphorus content in the soybean cake fed to chickens was equal to 6.72 g P/kg. They fed the chickens an average of 510 g/kg soybean cake in a composed diet of 1000 g/kg. Given that, on average, there was 6.72 g P/kg in 510 g/kg soybean cake the percentage of phosphorus in soybean cake is equal to 1.3%. Now the total amount phosphorus fed to finishing pigs can be determined by multiplying this percentage with the amount of feed fed, resulting in a phosphorus content of 0.5 kg P/pig/y.

Soybean oil

Crude soybean oil has 510 ppm phosphorus (Hammond et al., 2005). This is equal to $510 \cdot 10^{-4}$% phosphorus of the total weight of oil. By multiplying this number with the total weight of soybean oil in pig feed the amount of phosphorus contributed by the soybean oil can be determined. This results in a phosphorus content of $1.6 \cdot 10^{-4}$ kg P/pig/y.

Soybeans

The percentage of phosphorus in soybeans is equal to 0.57% (Morshed et al., 2008). With this percentage the total amount of phosphorus in soybeans is equal to $6.2 \cdot 10^{-3}$ kg P/pig/y.

Phosphorus other feed

With the total phosphorus content in pig feed and the phosphorus content contributed by soybeans the phosphorus content contributed by other feed (P_{other}) can be determined. The amount of phosphorus contributed by other feed can be determined by subtracting the amount of phosphorus contributed by soybeans from the total amount of phosphorus in the feed (equation 14). This results in a value of 0.6 kg P/pig/y for P_{other}.

$$P_{other} = P_{feed} - P_{soy} \tag{14}$$

Phosphorus in the soil

To determine the change in phosphorus in the soil all the inputs and the outputs in the soil need to be known. The inputs of the soil consist of fertiliser use and residues from crops. The output of the soil is equal to the phosphorus taken up by the crops. The fertiliser use consists of manure and artificial fertiliser use. The use of pig manure is only a small part of the total fertiliser use. In 2013 on agricultural lands 55 million kg of phosphorus originating from manure and 5 million kg phosphorus originating from artificial fertiliser was used (CBS, 2013). With an amount of phosphorus of 3,545 tonnes P/y originating from pig manure, pigs provide 6% of the total fertiliser use. The phosphorus coming from manure from other animals can be determined by subtracting the phosphorus from pigs from the total phosphorus from manure (equation 15). This results in a value of 51.5 million kg P.

$$P_{animals} = P_{nat} - P_{manure} \tag{15}$$

Crops take up phosphorus from the soil, but they also return phosphorus to the soil through residues and compost. When harvested 54 million kg of phosphorus is incorporated in the crops each year (CBS, 2013). 3 million kg of phosphorus is returned back to the soil through residues and compost (CBS, 2013). Given these values the total inputs and outputs of the soil are known. The values calculated above can be divided by the amount of hectares on which crops are grown, which is equal to 1,839,020 ha (CBS, 2014b), to obtain the values seen in figure 13. These values are similar to values found by Schoumans et al. (2008).

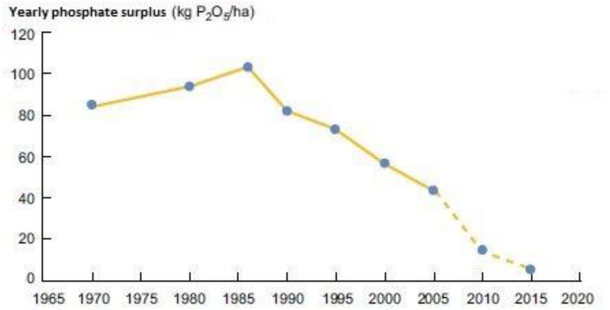

Figure 14: The phosphate surplus for the Netherlands between 1965 and 2005 with the prognoses to 2015 (Schoumans et al., 2008)

With the inputs and outputs of the soil known the change in soil balance of phosphorus can be determined by subtracting the outputs from the inputs (equation 16). This results in a surplus of 5 kg/ha/y. This is a lot less than the calculated surplus of Schoumans et al. (2008) for 2005, but looking at figure 14, which shows the prognoses of the change in surplus of phosphate, it does seem like a realistic number given that 5 kg phosphorus per hectare per year is equal to 11 kg of phosphate per hectare per year (Schoumans et al., 2008).

$$P_{soil} = P_{fer} + P_{res} - P_{crops} \quad (16)$$

Leaching of phosphorus

Schoumans et al. (2008) have written a report about phosphorus. In this report they address the problem of phosphorus leaching with respect to phosphorus accumulation. For agricultural lands in 2005 the leaching of phosphorus to the surface water was equal to 2 kg P/ha/y, which is similar to the value determined by the CBS (2013). This value will be used for the leaching of phosphorus to the surface water (P_{loss}).

With the leaching of 2 kg phosphorus per hectare per year to the groundwater, there is still a surplus of 3 kg P/ha/y of phosphorus left. The CBS (2013) determined the same value for the accumulation of phosphorus in both the soil and the groundwater. For the results of the study it is not important if the accumulation takes place in the soil or in the groundwater. For simplicity it is assumed that the phosphorus accumulates in the groundwater (P_{acc}), and therefore all excess nutrients from the soil will leach to the groundwater (P_{leach}).

The quantification of phosphorus for the production of pork meat is shown in table 11. It gives an overview of all the different flows calculated above and shows the total amounts of phosphorus that flows through the system. 6% of the phosphorus from manure originates from pigs. Out of the total inputs this percentages stays the same. So of the phosphorus leaching to the environment 6% is caused by pig manure from finishing pigs that are fed soybeans.

Table 11: The quantification of phosphorus during the production of pork meat in the Netherlands for the year 2013

Flow	Symbol	Quantification of phosphorus (kg P/pig/y)	Quantification of phosphorus (kg P/ha/y)	Total phosphorus flow during the production of pork meat (tonnes P/y)	Source
Use of soybeans in pig feed	P_{soy}	0.5		2,570	Kok et al. (2004)
Use of other feed	P_{other}	0.6		3,643	Calculated
Total pig feed	P_{feed}	1.1		6,212	Jongbloed & Kemme (2005)
Phosphorus pork meat	P_{meat}	0.5		2,667	Jongbloed & Kemme (2005)
Phosphorus in pig manure	P_{manure}	0.6	2	3,545	Jongbloed & Kemme (2005)
Phosphorus manure other animals	$P_{animals}$		28	51,455	Calculated
Use of manure as fertiliser	P_{org}		30	55,000	(CBS, 2013)
Use of artificial fertiliser	P_{art}		3	5,000	(CBS, 2013)
Total fertiliser use	P_{fer}		33	60,000	Calculated
Phosphorus harvested with crops	P_{crops}		29	54,000	(CBS, 2013)
Phosphorus left in crop residues	P_{res}		2	3,000	(CBS, 2013)
Phosphorus change in the soil balance	P_{soil}		5	9,000	Calculated
Leaching of phosphorus to the surface water	P_{leach}		5	9,000	Calculated
Accumulation of phosphorus	P_{acc}		3	5,900	Calculated
Total loss of phosphorus	P_{loss}		2	3,100	Schoumans et al. (2008)

3.3. WATER QUALITY

With the quantification of nutrient flows during the production of pork meat it has been determined how many nutrients get lost to the environment. If the total amount of nutrients in the environment and the natural background concentrations in the environment are determined, the influence of the production of pork meat on the total water quality can be estimated.

3.3.1. TOTAL NITROGEN AND PHOSPHORUS DUTCH SURFACE WATER

The amount of nitrogen and phosphorus in the surface water depends on many different factors. Besides the influence from agriculture there are nutrients coming from the industry, households as well as rivers that flow into the country. These rivers carry nutrients disposed by other countries, which eventually flow into the sea. There is however a difference between the inflow of nutrients through rivers and the outflow of nutrients to the sea (CBS, 2013). Therefore it can be concluded that these external nutrients do influence the internal nutrient balance.

Nitrogen

The total supply of nitrogen to the Dutch surface water is 344 million kg N/y. Of this supply 81 million kg N/y is domestic and 263 million kg N/y is external nitrogen that flows into the country through rivers (CBS, 2013). The nitrogen content in manure produced by pigs is equal to 20,695 tonnes N/y. From this nitrogen 3% has an influence on the environment (see section 3.2.1). This is equal to a value of 664 tonnes of nitrogen per year. The influence of this nitrogen on the total supply is given in table 12.

Table 12: The influence of pig manure on the amount of nitrogen in Dutch surface waters in 2013 (CBS, 2013)

	Supply of nitrogen (tonnes N/y)	Part caused by pig manure (%)
Domestic origin	81,000	0.8%
Supply rivers	263,000	-
Total	344,000	0.2%

The amount of nitrogen supplied by pigs is small compared to the total amount of nitrogen in the surface waters. 0.8% of the total domestic supply of nitrogen is caused by pig manure originating from pigs that are kept for their meat. Out of the total supply this percentage drops to 0.2%, because most nitrogen in Dutch surface waters is supplied by rivers.

The domestic supply of nitrogen mainly originates from households and agriculture. Looking at the data supplied by the CBS (2013), the input of households accounts for 15% of the nitrogen, industry accounts for 4% of the nitrogen and agriculture accounts for 62% of the nitrogen. The remainder of the nitrogen originates from other small sources like natural grounds or deposition. It shows that the input of agriculture is still the largest. Pigs only account for a part of the agricultural influence, but lowering the nitrogen input as a result of pigs, could have a positive influence on the total nitrogen balance.

Phosphorus

As for nitrogen, the CBS (2013) gives values for the amount of phosphorus supplied to the surface water. The total amount of phosphorus supplied to the Dutch surface waters is equal to 16 million kg P/y, with 9 million kg phosphorus per year originating from rivers that cross the borders (CBS, 2013). These values comply with data determined by Schoumans et al. (2008). The total amount of phosphorus in pig manure is equal to 3,545 tonnes P/y. 6% of this phosphorus reaches the surface water, resulting in a value of 199 tonnes of phosphorus per year originating from finishing pigs, that influence the phosphorus content of the surface water. An overview of the influence of the phosphorus from pigs on the total supply of phosphorus is given in table 13.

Table 13: The influence of pig manure on the supply of phosphorus in Dutch surface waters for the year 2013 (CBS, 2013)

	Supply of phosphorus (tonnes P/y)	Part caused by pig manure (%)
Domestic origin	7,000	2.8%
Supply rivers	9,000	-
Total	16,000	1.2%

The influence of pig manure on the phosphorus supply is larger than the influence on the nitrogen supply. With values of 2.8% of the domestic supply and 1.2% of the total supply the influence of pig manure on the phosphorus supply is more than twice the influence on the nitrogen supply. Even though the nitrogen supply is larger. The difference is that besides fertiliser, nitrogen also reaches the soil through deposition.

Table 14 gives an overview of the origin of the phosphorus in Dutch surface waters between 1985 and 2005. It shows that, for 2005, the origin of agriculture accounts for almost have of the total phosphorus (44%). Phosphorus originating from households, through waste water treatment plants, is the other big source with a percentage 39%. These percentages show that, even though pigs account for only a small percentage of the total agriculture, it is important to try to change the influence on the phosphorus balance. If measures prove to be successful in the reducing phosphorus surplus they could be applied to other sectors or animals as well.

Table 14: The domestic origin of phosphorus found in Dutch surface water between 1985 and 2005 (Schoumans et al., 2008)

	1985	1990	1995	2000	2005
Waste Water Treatment Plant	10.8	6.2	3.5	2.8	2.7
Industry	13.4	11.0	3.6	1.9	0.4
Agriculture	2.9	2.0	4.6	3.6	3.1
Nature	0.4	0.3	0.4	0.5	0.4
Others	3.4	1.2	0.8	0.6	0.4
Total	30.9	20.8	12.8	9.4	7.0

3.3.2. NATURAL BACKGROUND CONCENTRATIONS NITROGEN AND PHOSPHORUS

Besides the influence of pig manure on the total nutrient supply, it is also important to look at the influence of the manure on the natural background concentrations or maximum allowable concentrations in the surface water. These values are important for human health and the environment as a whole.

Nitrogen

The maximum allowable nitrogen level in the Dutch surface water is equal to 2.2 mg N/l (Schoumans et al., 2008). In order to determine the total amount of nitrogen allowed in Dutch surface waters an estimate has to be made of the total amount of surface water in the Netherlands. Out of the big rivers in the Netherlands the Rhine delta is the largest (see figure 15). The water that reaches the Netherlands at Lobith, flows through more than halve of the country. Only the south is not covered. This is covered by the watershed of the Meuse.

Figure 15: The Rhine delta (Rijkswaterstaat, 2009)

The pig farms are located in the south and the east of the country which are covered by the Meuse and the Rhine. By taking the average discharge from both rivers and determining the total average discharge for a year an estimate can be made of the surface water present in the Netherlands. The average discharge of the Rhine is equal to 2200 m^3/s and the average discharge of the Meuse is equal to 230 m^3/s (Rijkswaterstaat, 2015).

By transforming the discharge from seconds to year and multiplying with the allowable concentration of nitrogen of 2.2 mg N/l an estimate can be made of the allowable nitrogen concentration in the Dutch surface water. The results are given in table 15. The allowable nitrogen concentration in Dutch surface waters is equal to 168,591 tonnes N/y. Finishing pigs influence the environment with 688 tonnes N/y, so pigs contribute 0.4% of the allowable nitrogen concentration in Dutch surface waters. Compared to the total nitrogen estimated in the surface water there is an excess amount of nitrogen of 175,409 tonnes N/y. So the total amount of nitrogen is twice as large as the background concentrations. This is a large difference. By reducing the influence of pigs on the total nitrogen content it could be possible to reduce this surplus, even if it is only by a small percentage.

Table 15: The influence of pig manure on the allowable nitrogen levels in Dutch surface waters

	Discharge (m^3/s)	Allowable nitrogen levels ($\mu g\ N/m^3$)	Total allowable nitrogen (tonnes N/y)	Percentage caused by pigs (%)

Rhine	2200	2.2	152,634	
Meuse	230	2.2	15,957	
Total			168,591	0.4%

In order to maintain a proper ecological state the concentration of nitrogen in Dutch surface water should not exceed a value of approximately 1.5 mg N/l (Schoumans et al., 2008). However this value does depend on the type of surface water, lakes or rivers for example, and can be higher or lower for specific cases. As a result the total allowable nitrogen level drops to 114,949 tonnes N/y. The contribution of pigs rises to 0.6%. The surplus is now equal to 229,051 tonnes N/y.

Phosphorus
The maximum allowable concentration level of phosphorus in Dutch surface water is equal to 0.15 mg P/l (Schoumans et al., 2008). This is lower than the nitrogen concentration, because an excess of phosphorus is more damaging for the environment. With the discharges of the Rhine and the Meuse the total amount of phosphorus allowed in Dutch surface water can be estimated. The result is given in table 16. The total allowable phosphorus level in the surface water is equal to 11,495 tonnes P/y. With an amount of 199 tonnes P/y originating from finishing pigs the influence of pigs on the allowable phosphorus concentration is 1.7%. Compared to the total amount of phosphorus estimated in the surface water there is a surplus of 4,505 tonnes P/y. If the influence of pigs on the total phosphorus content can be reduced, it could be possible to reduce this surplus.

Table 16: The influence of pig manure on the allowable phosphorus concentration in Dutch surface waters

	Discharge (m^3/s)	Allowable phosphorus levels (µg P/m^3)	Total allowable phosphorus (tonnes P/y)	Percentage caused by pigs (%)
Rhine	2200	0.15	10,407	
Meuse	230	0.15	1,088	
Total			11,495	1.7%

For ecological purposes, the concentration of phosphorus should not be higher than 0.08 mg P/l, again depending on the type of surface water (Schoumans et al., 2008). With this concentration the total allowable amount of phosphorus in the surface water drops to 6,131 tonnes P/y. The influence of finishing pigs rises to 3.2%. The surplus rises to 9,869 tonnes P/y.

4. TRADE BETWEEN BRAZIL AND THE NETHERLANDS

Soybeans are being traded from Brazil to the Netherlands. With this trade nutrients are transported as well. In the previous two chapters the production of soybeans in Brazil and the use of soybeans in pig feed in the Netherlands have been examined separately. For Brazil there is a nitrogen deficit and a phosphorus surplus. For the Netherlands there is both a nitrogen and a phosphorus surplus, but the surplus of nitrogen is larger. This is one of the main differences found between the two countries. The other difference is the fertiliser use. In the Netherlands the main source of fertiliser is organic fertiliser, while in Brazil there is a lack of organic fertiliser use.

In this chapter the trade relationship between the two countries will be examined, focussing on the trade in soybeans. It will be determined how this trade influences the results found in the previous two chapters. First a schematic overview will be given of the trade between Brazil and the Netherlands and second the influence of this trade on the nutrient flows will be estimated.

4.1. QUANTIFICATION

The quantification of trade between the Netherlands and Brazil will be carried out for soybean cake, soybean oil and soybeans. These three soybean products are all incorporated in pig feed (Kok et al., 2004), and are traded separately. In chapters 2 and 3 it has been determined how much nutrients are used in the production of soybeans and how much nutrients are generated during the production of meat. With the quantification below it will be determined how trade influences these nutrients.

4.1.1. SOYBEAN CAKE

In figure 16 a schematic overview is given of the production of soybean cake in Brazil and the export and usage of soybean cake in the Netherlands. Soybean cake arises when whole soybeans are being crushed and processed.

Brazil produces most of its available soybean cake themselves. Of the total 28 million tonnes available only 25 thousand tonnes are imported, mostly originating from Paraguay (FAOSTAT, 2011f). Just over half of the soybean cake is exported, of which a quarter (4 million tonnes) is exported to the Netherlands (FAOSTAT, 2011f). The remaining 14 million tonnes are used domestically in Brazil as animal feed (FAOSTAT, 2011d).

Besides export from Brazil, the Netherlands also imports soybean cake from other countries. The import from Brazil accounts for almost three quarters of the total import (FAOSTAT, 2011e). The Netherlands also produces almost 2 million tonnes soybean cake, originating from imported soybeans (FAOSTAT, 2011e). Of the total available soybean cake around one third (2.5 million tonnes) is used domestically. The rest is (re-)exported.

The domestic use in the Netherlands only consists of the use of soybean cake in animal feed (FAOSTAT, 2011e). For pig feed just over 1 million tonnes of soybean cake is used (Kok et al., 2004). Out of this 1 million tonnes, 200 thousand tonnes are used in pig feed for finishing pigs (Jongbloed & Kemme, 2005). This is equal to almost 10% of the total soybean cake used in animal feed.

4.1.2. SOYBEAN OIL

Figure 17 gives a schematic overview of the production and trade of soybean oil between Brazil and the Netherlands. Like soybean cake, soybean oil arises when soybeans are being crushed. They are the two main components of soybeans.

Most of the soybean oil is again being produced by Brazil itself (over 7 million tonnes), but 1 thousand tonnes are imported (FAOSTAT, 2011d). Of the total amount of soybean oil three quarters is used domestically in food and other products. Of the 1.7 million tonnes exported, only 3 thousand tonnes are exported to the Netherlands.

Most soybean oil imported by the Netherlands originates from other countries and the Netherlands also produces soybean oil from imported soybeans (FAOSTAT, 2011e; 2011g). The production of soybean oil by the Netherlands is their biggest inflow with 0.4 million tonnes out of a total 0.5 million tonnes being produced domestically. The Netherlands then exports 0.4 million tonnes and 0.1 million tonnes are used domestically. Out of this 0.1 million tonnes 31 thousand tonnes are used as animal feed, with 9 thousand tonnes specifically in pig feed (Kok et al., 2004). For finishing pigs 1.7 thousand tonnes of soybean oil is used in their feed (Jongbloed & Kemme, 2005).

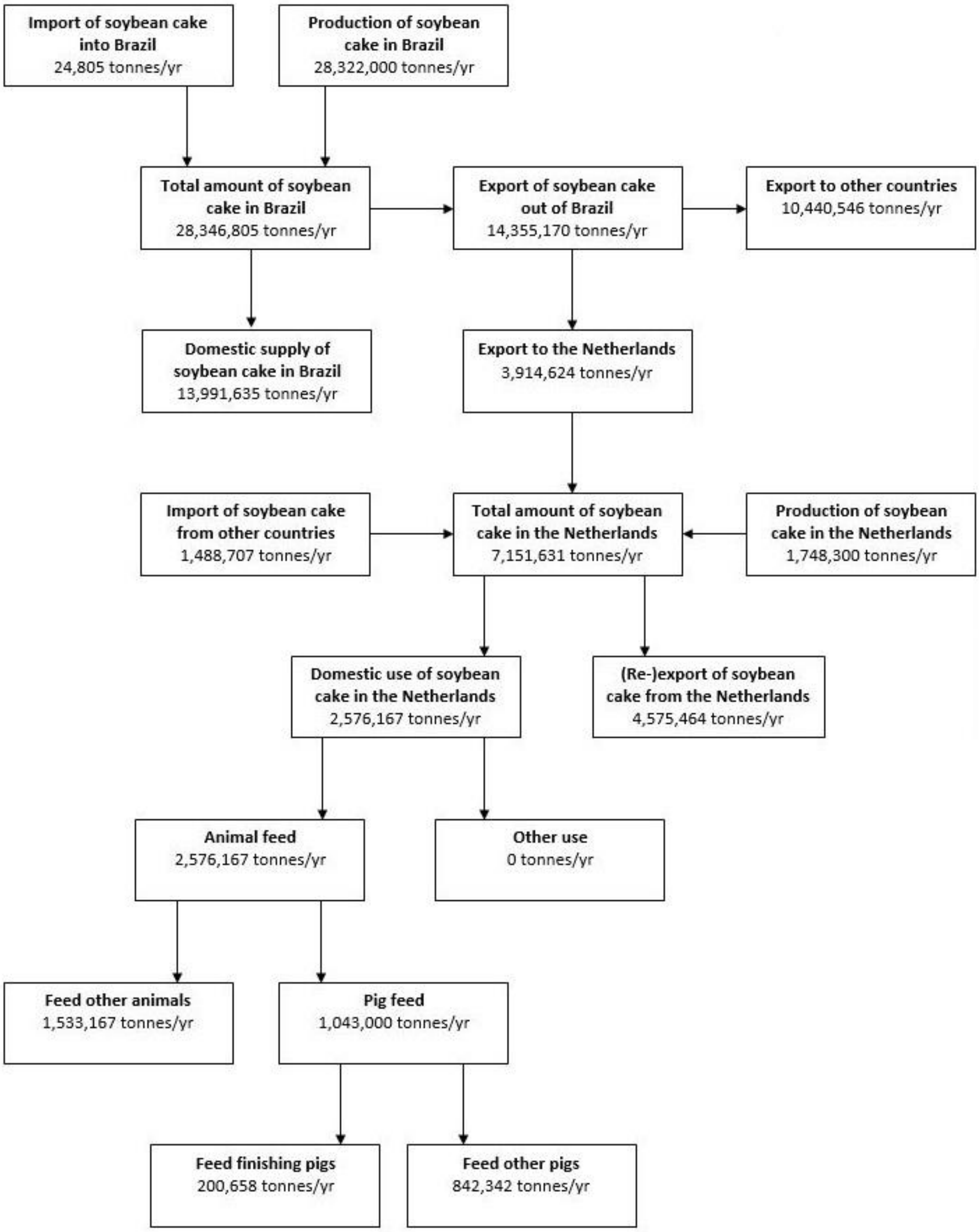

Figure 16: A schematic overview of the production of soybean cake in Brazil, the trade in soybean cake between Brazil and the Netherlands and the use of soybean cake in the Netherlands for the year 2011 (FAOSTAT, 2011a, 2011c, 2011d, 2011e; Jongbloed & Kemme, 2005; Kok et al., 2004)

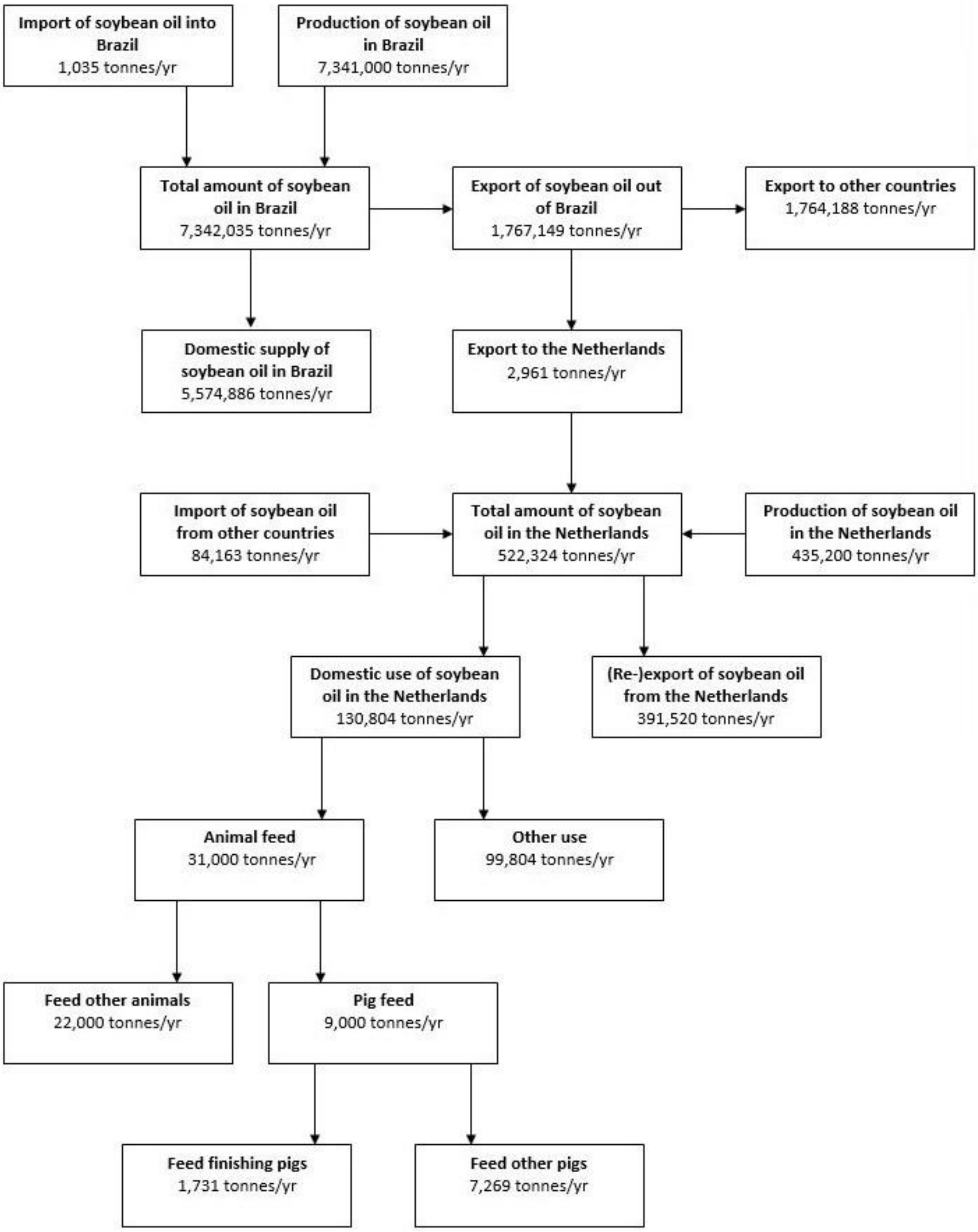

Figure 17: A schematic overview of the production of soybean oil in Brazil, the trade in soybean oil between Brazil and the Netherlands and the use of soybean oil in the Netherlands for the year 2011 (FAOSTAT, 2011a, 2011c, 2011d, 2011e; Jongbloed & Kemme, 2005; Kok et al., 2004)

4.1.3. SOYBEANS

The last soybean product that needs to be quantified, are the whole soybeans themselves. Figure 18 shows a schematic overview of the production of soybeans in Brazil, the trade of soybeans to the Netherlands and the use of soybeans.

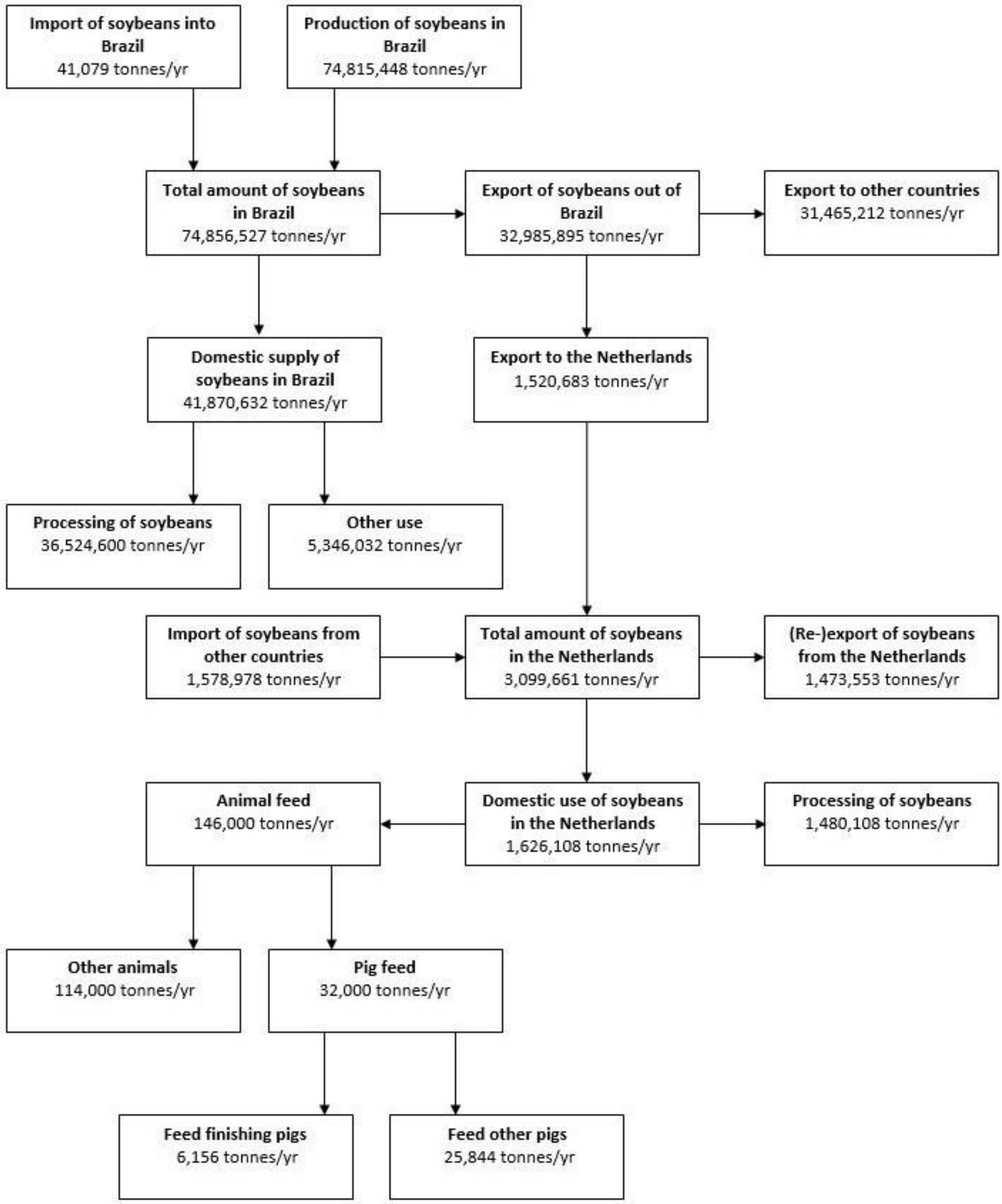

Figure 18: A schematic overview of the production of soybeans in Brazil, the trade in soybeans between Brazil and the Netherlands and the use of soybeans in the Netherlands for the year 2011 (FAOSTAT, 2011a, 2011c, 2011d, 2011e; Jongbloed & Kemme, 2005; Kok et al., 2004)

Brazil produces almost 75 million tonnes of soybeans and imports 41 thousand tonnes (FAOSTAT, 2011d). They export 33 million tonnes and use the rest domestically. Out of this 42 million tonnes used domestically, 36.5 million is processed to produce soybean cake and soybean oil (FAOSTAT, 2011d). The remaining 5 million is used for other purposes, like food.

Brazil exports 1.5 million soybeans to the Netherlands (FAOSTAT, 2011f). The Netherlands itself also imports 1.5 million tonnes from other countries, bringing their total available soybeans to 3 million tonnes (FAOSTAT, 2011g). The Netherlands than (re-)exports 1.4 million tonnes of soybeans, leaving 1.6 million tonnes for domestic use. These values do not totally comply with the values given by the FAOSTAT (2011e), because they take into account the change in stock between several years, with more being imported than used in one year, and the other way around the following year. It is chosen to alter the numbers slightly to give an estimate for one year. Therefore the domestic supply and processing values of soybeans are lower than given by FAOSTAT (2011e).

Out of the 1.6 million tonnes available domestically, 1.5 million tonnes are processed to acquire soybean oil and soybean cake (FAOSTAT, 2011e). The remaining 0.1 million tonnes are used in animal feed, with 32 thousand tonnes used in pig feed (Kok et al., 2004). For finishing pigs 6 thousand tonnes of soybeans are used (Jongbloed & Kemme, 2005).

4.2. NUTRIENTS

The data in section 4.1 gives an overview of the trade in soybean products. In chapters 2 and 3 the amount of nutrients in these soybean products have been determined. By comparing the findings of both chapter 2 and 3 and section 4.1 an overview can be made of the influence of trade on the flow of nutrients.

4.2.1. NITROGEN

Trade has an influence on several aspects of the production cycle. In Brazil the most important flows are the nitrogen added to the soil and the nitrogen incorporated in the products that are consequently exported to a foreign country. For the Netherlands the most important flows are the import of nitrogen in pig feed and the amount of nitrogen in manure. Figure 19 shows the flow of nitrogen through trade in soybean products between the Netherlands and Brazil. The arrows show the direction of the flow and the width, together with the quantity, show how much nitrogen is transported. Below it will be explained how the quantities of nitrogen have been determined.

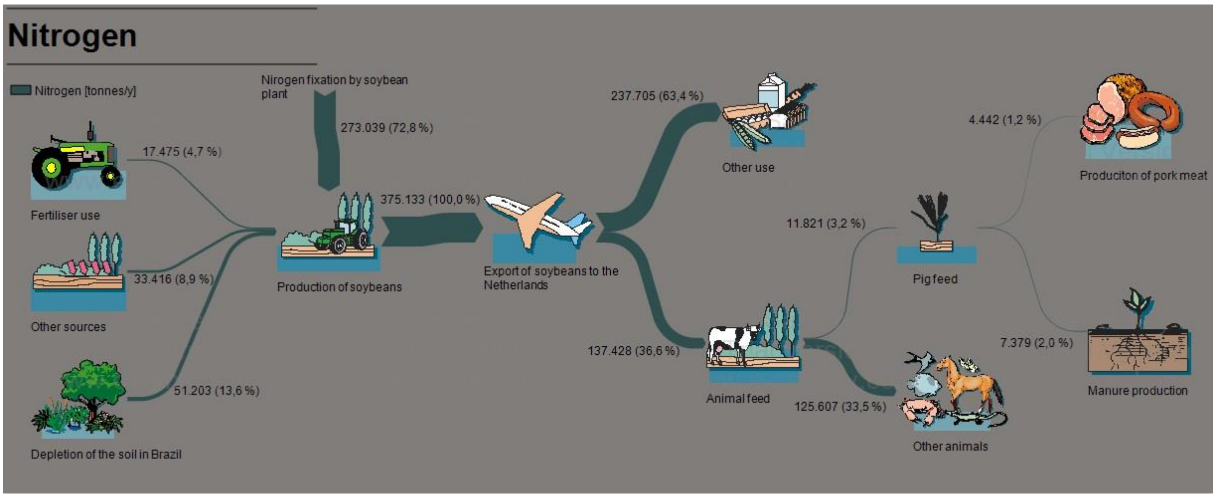

Figure 19: The flow of nitrogen through the trade in soybeans between Brazil and the Netherlands in 2011 with the percentages showing the share of the flow in comparison to the amount nitrogen incorporated in the soybean products

Nitrogen exported

Brazil produces 74,815,448 tonnes of soybeans in 2011 (FAOSTAT, 2011d), on 23,968,663 ha (FAOSTAT, 2011c). In chapter 3 it has been determined that 6% of the soybeans consists of nitrogen (Salvagiotti et al., 2008). This means that Brazil produces 4,743,299 tonnes of nitrogen in soybeans in 2011. Besides soybeans, Brazil also exports soybean products like soybean cake and soybean oil, originating from soybeans that have been processed in Brazil itself. In all these soybean products nitrogen is present. Table 17 shows the calculation of the amount of nitrogen exported by Brazil. In total an amount of 3,113,394 tonnes of nitrogen is exported out of Brazil in 2011, which is 65.6% out of the total nitrogen production in soybeans that year.

Table 17: The amount of nitrogen exported by Brazil in 2011 in soybean products (d.m. = dry matter)

	Export of soybean products from Brazil (tonnes/y)	% of nitrogen present in the soybean products	Amount of nitrogen exported (tonnes N/y)
Soybean cake	14,355,170	8 (d.m.)	1,022,088
Soybean oil	1,767,149	-	0
Soybeans	32,985,895	6	2,091,306
Total exported	-	-	3,113,394

A part of the soybean products exported by Brazil, are exported to the Netherlands. As a result the nitrogen incorporated in these products is also exported to the Netherlands. Table 18 shows the calculation of the amount of nitrogen that is exported to the Netherlands. The amount of nitrogen is estimated using the percentages determined in chapter 3. In total 375,133 tonnes of nitrogen is exported to the Netherlands in 2011 incorporated in soybean products. This is 12.0% out of the total nitrogen exported and 7.9% out of the total nitrogen production in soybeans in 2011 in Brazil.

Table 18: The amount of nitrogen that is exported from Brazil to the Netherlands in 2011 (d.m. = dry matter)

	Export from Brazil to the Netherlands (tonnes/y)	% of nitrogen present in the soybean products	Amount of nitrogen exported (tonnes N/y)
Soybean cake	3,914,624	8 (d.m.)	278,721
Soybean oil	2,961	-	0
Soybeans	1,520,683	6	96,411
Total exported	-	-	375,133

Nitrogen fertiliser use

The nitrogen that is exported in the soybean products is taken up by the plant from the soil. A part of this nitrogen is provided through fertiliser. Brazil uses 191,749 tonnes of nitrogen to produce soybeans each year (chapter 2). To determine the amount of fertiliser that is used for the production of soybeans for export to the Netherlands, the total exported amount of soybeans needs to be known. Besides the export of whole soybeans, soybeans are also used to produce the soybean cake and soybean oil that is exported.

Hammond et al. (2005) determined that processing one bushel of soybeans (27.2 kg) results in 5.0 kg soybean oil and 20.1 kg soybean cake. This means that 1 kg soybeans consists of 73.9% soybean cake and 18.4% soybean oil. This is similar to the values found in section 4.1. It was found that in Brazil 36,524,600 tonnes of soybeans are being processed each year. As a result they produce 28,322,000 tonnes of soybean cake and 7,341,000 tonnes of soybean oil leading to a percentage of 77.5% for soybean cake and 20.1% for soybean oil.

By dividing the values of soybean cake and soybean oil with the percentages of 73.9% and 18.4%, the total amount of soybeans needed for the export to the Netherlands can be determined. The results are given in table 19. To produce enough soybean cake 5,297,402 tonnes of soybeans per year are required. For the production of soybean oil only 16,108 tonnes of soybeans per year are required. The amount of soybean oil needed, can easily be made out of the soybeans that are required for the production of enough soybean cake. Therefore an amount of 5,297,402 tonnes of soybeans per year needs to be grown in Brazil for the export of soybean products to the Netherlands. This brings the total amount of soybeans needed for the export to the Netherlands in 2011 to 6,818,085 tonnes/y.

With the total production of soybeans in Brazil being equal to 74,815,448 tonnes/y (FAOSTAT, 2011d), the total export to the Netherlands is equal to about 9% of the total production. The use of fertiliser for the production of soybeans for export to the Netherlands is therefore equal to 9% of the total fertiliser use. This result in a fertiliser use of 17,475 tonnes of nitrogen per year for the production of soybeans used for export to the Netherlands, which is 4.7% of the nitrogen exported to the Netherlands.

It can now also be determined how much hectares are needed for the export of soybean products to the Netherlands in 2011. In total 23,968,663 ha are used in Brazil for the production of 74,815,448 tonnes of soybeans (FAOSTAT, 2011c; 2011d). This means that on one hectare 3.1 tonnes of soybeans can be produced. So for the production of 6,818,085 tonnes of soybeans 2,184,313 hectares are needed.

Table 19: The amount of soybeans needed for the production of soybean cake and soybean oil exported to the Netherlands in 2011

	Export from Brazil to the Netherlands (tonnes/y)	Percentage present in soybeans	Amount of soybeans required (tonnes/y)
Soybean cake	3,914,624	73.9%	5,297,402
Soybean oil	2,961	18.4%	16,108

Other nitrogen input sources
Besides nitrogen fertiliser use by farmers, the soybean plant also uses nitrogen from the soil originating from crop residues and deposition and nitrogen fixated from the air by the plant itself. The amount of nitrogen supplied by these three sources can be determined by multiplying its values determined in chapter 2 with the amount of hectares that are needed for the production of soybeans for the export of soybean products to the Netherlands in 2011. The results are shown in table 20.

The amount of nitrogen of these sources, together with the nitrogen from fertiliser, is not enough to provide the amount of nitrogen exported. The rest of the nitrogen originates from nature, which means depletion of the soil. The extent of this depletion can be determined by subtracting the inputs from the nitrogen exported. This results in a depletion of 51,203 tonnes of nitrogen in 2011. This is 13.6% of the nitrogen exported to the Netherlands.

Table 20: The amount of nitrogen originating from residues, deposition and nitrogen fixation used for the production of soybean products in Brazil for export to the Netherlands in 2011

	Nitrogen per hectare (kg/ha)	Total amount of nitrogen (tonnes N/y)	Percentage of total nitrogen exported
Nitrogen from residues	64	13,975	5.2%
Nitrogen deposition	9	19,440	3.7%
Nitrogen fixation	125	273,039	72.8%

Nitrogen in feed
With the amount of nitrogen exported and the amount of nitrogen used as fertiliser known, the next step is to determine how much nitrogen in pig feed is coming from Brazil. For this, the share of import from Brazil of the total import to the Netherlands is determined, and it is assumed that this ratio is the same for the amount of soybean products in pig feed and animal feed as a whole. The determination of the ratio of Brazilian soybean products can be seen in table 21. By dividing the amount of Brazil by the total import, the share can be determined. In table 21 also the amount of nitrogen originating from soybean products from Brazil in animal feed is given. This is determined using the values of section 4.1. and the percentages of nitrogen in soybean products of chapter 3. In total 137,428 tonnes of nitrogen in animal feed originates from Brazil, which is equal to 36.6% of the total amount of nitrogen imported.

Table 21: The ratio of Brazilian soybean products of the total amount of soybean products imported by the Netherlands, together with the amount of nitrogen in animal feed as a result of this import in 2011

	Import from Brazil (tonnes/y)	Total import (tonnes/y)	% share Brazil soybean products	Soybeans present in animal feed (tonnes/y)	Soybeans originating from Brazil (tonnes/y)	Total amount of N originating from Brazil (tonnes N/y)
Soybean cake	3,914,624	5,403,331	72	2,576,167	1,866,390	132,887
Soybean oil	2,961	87,124	3	31,000	1,054	0
Soybeans	1,520,683	3,099,661	49	146,000	71,627	4,541
Total in feed	-	-	-	-	-	137,428

In a similar way the amount of nitrogen in pig feed originating from soybean products from Brazil can be determined. This has been done in table 22. The ratio of soybean products of Brazil of the total import stays the same, as well as the percentage of nitrogen in the products. In total 11,821 tonnes of nitrogen in pig feed in the Netherlands in 2011 originates from soybean products imported out of Brazil. This is 3.2% of the total nitrogen imported.

Table 22: The amount of nitrogen in pig feed, originating from soybean products from Brazil in 2011

	Soybeans present in pig feed (tonnes/y)	Soybeans originating from Brazil (tonnes/y)	Total amount of N originating from Brazil (tonnes N/y)
Soybean cake	200,658	145,373	11,630
Soybean oil	1,731	59	0
Soybeans	6,156	3,020	191
Total in feed	-	-	11,821

Nitrogen in manure

The final step in determining the influence of trade on the flow of nutrients is determining the nitrogen in manure of pigs, which can be traced back to Brazil. The amount of nitrogen in the manure of finishing pigs is equal to 20,695 tonnes N/y (see chapter 3). This is 62% of the intake of pigs through feed. The total amount of nitrogen in feed as a result of soybeans is equal to 14,266 tonnes N/y, with 11,821 tonnes N/y originating from Brazil. With the total nitrogen in feed being equal to 33,155 tonnes N/y, Brazil supplies 35.7% of this nitrogen. Multiplying with the total amount of nitrogen in manure, results in an amount of nitrogen originating from Brazil of 7,379 tonnes N/y. This is equal to 2.0% of the total nitrogen imported from Brazil.

In the Netherlands pig manure is used as fertiliser. In total the Netherlands uses 527,000 tonnes of nitrogen fertiliser in 2011, with 325,000 tonnes of nitrogen originating from animals. This is 61.7% of the total fertiliser use. With Brazil supplying 7,379 tonnes of nitrogen of the nitrogen in pig manure, Brazil supplies 2.3% of the organic fertiliser and 1.4% of the total fertiliser use.

In the Netherlands an excess amount of nitrogen is added to the soil. In chapter 3 it has been determined that in 2011 50,000 tonnes of nitrogen leached to the surface water, influencing the environment and possibly causing eutrophication. Brazil is supplying 7,379 tonnes of nitrogen. Looking at all inputs into the Dutch soil in 2011, which is equal to 645,341 tonnes of nitrogen, Brazil supplies 1.1% of the total inputs. It can be expected this ratio does not change when the nitrogen flows through the system. So out of the surplus of nitrogen in the Dutch environment Brazil supplies 1.1%.

The trade in soybeans between Brazil and the Netherlands influences the environment in both countries. In Brazil 13.6% of the total nitrogen exported, is withdrawn from the environment and in the Netherlands 1.1% of the nitrogen that is added to the soil originates from soybeans from Brazil. The influence of trade on the environment in Brazil is larger than the influence in the Netherlands. Even though the influence in the Netherlands is small, it is still important to see if the influence of trade on the nutrient cycle can be changed. Pigs eat only a small part of the nitrogen in soybean products in animal feed (8.6%). If the cycle of the production of pork meat can successfully be adapted, this could also be applied to other animal groups eating soybean products like cattle and poultry. With 36.6% of the imported nitrogen being used in animal feed and most of that being likely part of manure, it could change the environmental issues in the Netherlands.

4.2.2. PHOSPHORUS

As with nitrogen the important phosphorus flows in relation with trade are fertiliser use, the amount of phosphorus incorporated in soybean products and exported to another country and the phosphorus incorporated in pig feed and pig manure. Figure 20 shows the flow of phosphorus through trade in soybean products between Brazil and the Netherlands. The arrows show the direction of flow and the magnitude can be seen by the width of the arrow, together with the mentioned quantity. Below it will be explained how these quantities have been determined.

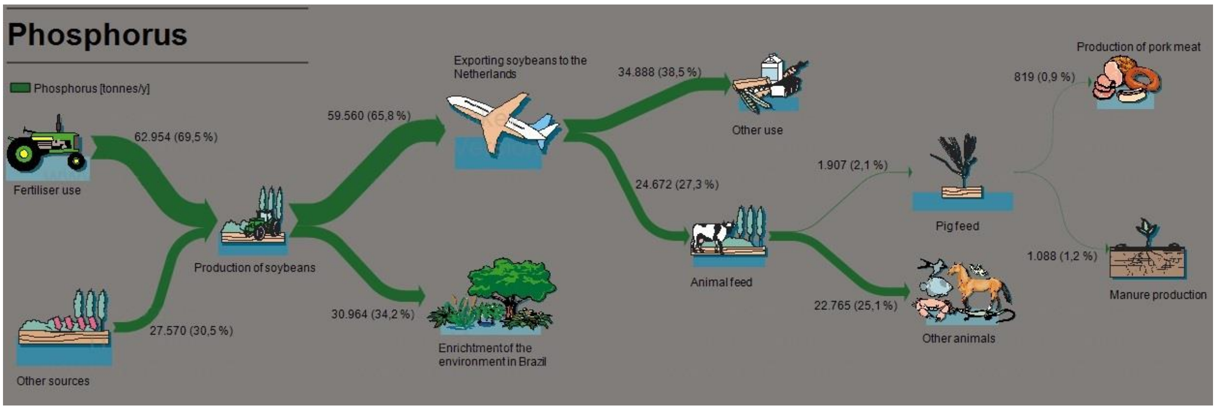

Figure 20: The flow of phosphorus through the trade in soybeans between Brazil and the Netherlands in 2011

Phosphorus exported

As determined in section 4.2.1., Brazil produces 74,815,448 tonnes of soybeans that contain 4,743,299 tonnes of nitrogen. To determine the phosphorus content in the soybean the percentage of phosphorus determined in chapter 3 will be used. This percentage is equal to 0.57% (Morshed et al., 2008). Multiplying with the total amount of soybeans produced, results in a production of 426,448 tonnes of phosphorus. A part of this phosphorus is exported in soybeans, but phosphorus is also exported in soybean products like soybean cake and soybean oil. Table 23 shows the total amount of phosphorus that is exported out of Brazil, which has been determined using the percentages of phosphorus determined in chapter 3. In total 375,538 tonnes of phosphorus is exported out of Brazil in soybean products in 2011. This is 88.1% out of the total amount of phosphorus incorporated in all soybeans. This high percentage can be explained by the higher concentration of phosphorus in soybean cake.

Table 23: The amount of phosphorus exported by Brazil in 2011 in soybean products

	Export of soybean products from Brazil (tonnes/y)	% of phosphorus present in the soybean products	Amount of phosphorus exported (tonnes P/y)
Soybean cake	14,355,170	1.3	186,617
Soybean oil	1,767,149	0.05	9,01
Soybeans	32,985,895	0.57	188,020
Total exported	-	-	375,538

It can also be determined how much phosphorus is exported from Brazil to the Netherlands, by multiplying the amount of soybean products exported with the percentage of phosphorus present in these soybean products. Table 24 shows the amount of soybean cake, soybean oil and soybeans exported to the Netherlands and the amount of phosphorus that is present in each of them. The total amount of phosphorus exported from Brazil to the Netherlands is equal to 59,560 tonnes P/y. This is 14.0% of the total phosphorus incorporated in soybeans and 15.9% of the total amount of phosphorus exported out of Brazil in 2011.

Table 24: The amount of phosphorus exported from Brazil to the Netherlands in 2011

	Export from Brazil to the Netherlands (tonnes/y)	% of phosphorus present in the soybean products	Amount of phosphorus exported (tonnes P/y)
Soybean cake	3,914,624	1.3	50,890
Soybean oil	2,961	0.05	2
Soybeans	1,520,683	0.57	8,668
Total exported	-	-	59,560

Phosphorus fertiliser use

The total export of soybeans to the Netherlands is 6,818,085 tonnes/y, as determined in section 4.2.1, which is 9% of the total production. The amount of phosphorus used as fertiliser for the production of all soybeans in Brazil is equal to 690,800 tonnes P/y. The phosphorus fertiliser use for the production of soybeans for export to the Netherlands is therefore equal to 62,954 tonnes P/y. This is more than the amount of nitrogen exported to the Netherlands. It can therefore be concluded that the environment in Brazil is experiencing enrichment of phosphorus due to the production of soybeans for export to the Netherlands.

To determine the size of this enrichment the use of other sources of phosphorus fertiliser need to be taken into account. The only other fertiliser source of phosphorus is the amount of crop residues of 13 kg P/ha. To determine the total amount of residues used on soybean production for export to the Netherlands in 2011 the amount of hectares of 2,184,313 determined in section 4.2.1. will be used. This brings the total use of fertiliser from crop residues to 27,570 tonnes of phosphorus. This is already 46.3% of the total amount of phosphorus exported to the Netherlands. With 62,954 and 25,570 tonnes of phosphorus being added to the soybeans and only 59,560 tonnes being exported 30,964 tonnes of phosphorus is added to the environment. This is almost half of the fertiliser use and 34.2% of the total inputs. This means that only 65.8% of the total inputs is actually exported and incorporated in the soybean products.

Phosphorus in feed

In section 4.2.1. the share of Brazilian soybean products in animal and pig feed has been determined. With the percentage of phosphorus present in all three soybean products the total amount of phosphorus in animal and pig feed originating from Brazil can be determined. The result is given in table 25. In total an amount of 24,672 and 1,907 tonnes of phosphorus is present in animal feed and pig feed due to import of soybean products from Brazil in 2011. Out of the total amount of phosphorus imported 41.4% is incorporated in animal feed and 3.2% is incorporated in pig feed. Out of the total fertiliser inputs this is 27.3% and 2.1% respectively.

Table 25: The amount of phosphorus in pig feed, as a result of the import of soybean products from Brazil in 2011

	The amount of soybeans present in animal feed due to trade (tonnes/y)	The amount of soybeans present in pig feed due to trade (tonnes/y)	% of phosphorus present in soybean products	Total amount of phosphorus in animal feed (tonnes P/y)	Total amount of phosphorus in pig feed (tonnes P/y)
Soybean cake	1,866,390	145,373	1.3	24,263	1,890
Soybean oil	1,054	59	0.05	1	0
Soybeans	71,627	3,020	0.57	408	17
Total in feed		-	-	24,672	1,907

Phosphorus in manure

The last value that is important to know is the amount of phosphorus present in pig manure as a result of trade. The total amount of phosphorus in pig manure is equal to 3,545 tonnes P/y. With Brazilian soybean products accounting for 31% of the feed, it can be expected that the soybean products also account for 30.6% of the phosphorus in the manure. This results in a value of 1,088 tonnes P/y, which is equal to 1.8% of the total amount of phosphorus imported and 1.2% of the total phosphorus inputs.

Looking at all inputs into the Dutch soil, pig manure accounts for 5.6% of the phosphorus inputs. If only the phosphorus originating from Brazil is taken into account this value drops to 1.8%. Due to agriculture in the Netherlands the Dutch soil experiences enrichment with phosphorus. In 2011 this enrichment is equal to 3,100 tonnes of phosphorus. Since phosphorus originating from Brazil accounts for 1.8% of the total inputs, it can be concluded that trade in soybeans is influencing the environment of the Netherlands by adding 1.8% of the total phosphorus enrichment.

In both Brazil and the Netherlands the trade in soybeans in causing an enrichment of the soil with phosphorus. In Brazil this is equal to 34.2% of the total inputs and in the Netherlands this is equal to 1.7% of the total enrichment due to agriculture. Especially in Brazil this influence is quite big. It is important to determine if the nutrient cycle which arises from trade can be changed so the influence of trade on the environment in both countries is reduced. Even though in the end only 1.7% of the phosphorus from soybean products reaches the environment through pig manure, more could reach the surface water through the use in other animal feed like cattle and poultry. If the cycle for pigs can be changed, perhaps the influence of phosphorus of manure of these animals can be reduced as well.

5. MEASURES TO REDUCE THE INFLUENCE OF TRADE ON THE ENVIRONMENT

In the previous three chapters it has been determined how many nutrients are present in the production of soybeans in Brazil and the production of pork meat in the Netherlands and how trade influences these nutrient flows. Now, with this quantification, measures can be discussed that affect one or more of these processes, in order to improve the environment in one or both countries.

Figure 21 gives a schematic overview of the processes in and between Brazil and the Netherlands. The different measures that will be discussed in this chapter are shown with their number at the process they influence. The measures focus on either closing the production cycles on a smaller scale or reducing the scale of the production. All measures will be discussed separately to give a good overview of possible ways to change the flow of nutrients. The purpose of discussing these measures is to see if the measure can actually help improve the environment. This could either be in a direct way, in the case of measures 5 and 6, or in an indirect way, in the case of measures 1 to 4. In the last case the production processes would be optimized separately, reducing the strain on the environment in either Brazil or the Netherlands as a whole. As a consequence, the influence of trade on the environment would decrease as well. The measures will be partly quantified to give an estimate about the influence of the measure. The actual feasibility of the measure will not be determined. This could be done in future research when the measure seems like a reasonable solution for the environmental problems influenced by trade.

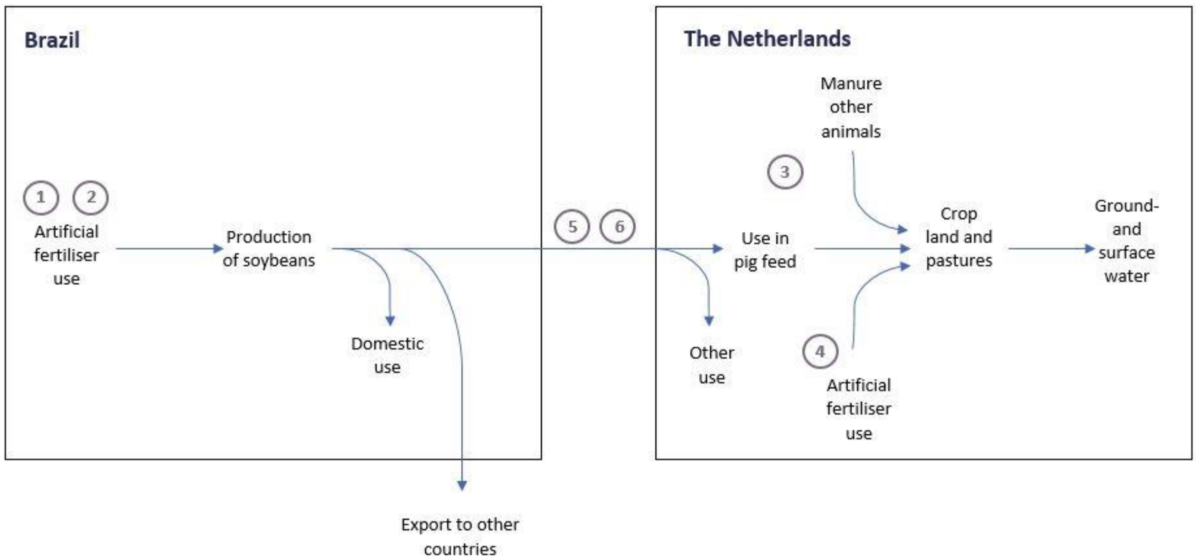

Figure 21: A schematic overview of nutrient flows in soybean production, trade and use between Brazil and the Netherlands with measures that can change the flow of nutrients to obtain a more sustainable production

The measures that will be discussed are:

1) Optimizing the fertiliser use on soybeans in Brazil to make the production of soybeans more efficient and reduce the influence of the production on the environment
2) Substituting artificial fertiliser use in Brazil with manure to reduce the use of artificial fertiliser and make the application of manure in Brazil more effective
3) Reducing the manure surplus in the Netherlands by changing the diet of pigs and processing the manure in a different way
4) Substituting artificial fertiliser use in the Netherlands with manure
5) Exporting pig manure from the Netherlands to Brazil to be used as fertiliser on soybeans to reverse the nutrient flow
6) Replacing soybeans in pig feed in the Netherlands with a local produced protein source to reduce the import of soybeans from Brazil

5.1. OPTIMUM FERTILISER USE SOYBEANS

With the current fertiliser management in Brazil, the soil is being depleted. More nutrients are withdrawn from the soil than that are being added to the soil through fertiliser use and other sources, like crop residues and deposition. For the case of soybeans too little nitrogen and too much phosphorus is added to the soil (chapter 2), causing several environmental problems. By determining an optimum fertiliser use for soybeans this imbalance between nutrient demand and nutrient supply could be reduced.

The optimum fertiliser use is the fertiliser use for which the highest revenues are obtained and the loss of nutrients to the environment is the least. It should be the amount that is equal to the crops demand, subtracting other sources of nutrients. For the production of soybeans in Brazil an optimum nitrogen fertiliser amount and an optimum phosphorus fertiliser amount can be determined using the data from chapter 2.

5.1.1. NITROGEN

In chapter 2 it has been determined that the soybean plant withdraws 94 kg N/ha from the soil each year. With 9 kg N/ha being added to the soil through deposition and 64 kg N/ha being left in the soil through residues, an amount of 21 kg N/ha needs to be added to the soil through nitrogen fertiliser use each year to bring the change in nitrogen soil balance to zero (see figure 6 in chapter 2). This amount is 13 kg N/ha more than the current fertiliser use of 8 kg N/ha.

In the study by Morshed et al. (2008) the same type of soybean plant was given six different amounts of nitrogen fertiliser. They discovered that, for gifts larger than 26.45 kg N/ha, the soybean yield of the plant would no longer increase, instead it would decrease. So the optimum nitrogen fertiliser amount for their cultivar was 26.45 kg N/ha. This is 25% higher than the recommended nitrogen rate for this specific cultivar as given by the BARC (Bangladesh Agricultural Research Council). The value of 26.45 kg N/ha lies close the value of 21 kg N/ha determined based on the results of figure 6.

In the review by Salvagiotti et al. (2008) no significance difference was found in grain yield response to different nitrogen fertiliser treatments. But looking at low application rates (lower than 50 kg N/ha) added after the R3 stage the grain yield was somewhat higher. Appendix I gives an overview of the different growth stages of the soybean plant. The R3 stage consists of the beginning of the development of the pods, right after the soybean plant has been in bloom (Department of Agronomy, 2015). Salvagiotti et al. (2008) did not study the effects of nitrogen fertiliser timing, due to the lack of enough field data of experiments with high nitrogen fertiliser rates (more than 100 kg N/ha). Looking at the agronomic efficiency, the ability of the plant to increase yield in response to added nitrogen, the difference between the studied data differed more. The agronomic efficiency was the highest for fertiliser rates of less than 50 kg N/ha after the R3 stage, the same result as for grain yield.

From the review of Salvagiotti et al. (2008) it can be concluded that nitrogen application rates of less than 50 kg N/ha give the best result. However the timing of adding fertiliser should be taken into account. Shigaki et al. (2006) discovered that, when fertiliser is added just before heavy rainfall, the risk of leaching of nutrients is higher. Therefore, besides the amount of fertiliser, the timing of fertiliser should also be taken into account. Because soybeans are being produced during the rainy season it will be difficult to fertilise the soil when no heavy rain is expected, but the timing of the fertiliser amounts during the growth stages of the soybean plant can be arranged.

Both the optimum value determined above and the value by Morshed et al. (2008) are lower than 50 kg N/ha. Looking at the denitrification rate in figure 6 of 44 kg N/ha the optimum fertiliser should be less than 65 kg N/ha to ensure no loss of nitrogen in the soil. This value lies higher than the determined 50 kg N/ha by Salvagiotti et al. (2008). The denitrification value for Brazil determined in chapter 2 is quite high. Looking at the denitrification determined for the Netherlands the value in Brazil is almost twice this amount. The actual denitrification depends on the amount of nitrogen in the soil, as well as the humidity and the temperature. Soybeans in Brazil are produced during the wet season in high temperatures so the denitrification value of 44 kg N/ha is not an unlikely value. However, it does depend on the amount of nitrogen available. With the soil in Brazil currently being depleted the denitrification might actually be lower. If the nitrogen fertiliser use increases, the denitrification might increase as well.

It is not possible to prevent denitrification from occurring and some of the nitrogen added as fertiliser will leach to the environment. However, by changing the fertiliser use to a more optimum value a more sustainable production can be reached. By changing the nitrogen fertiliser use in Brazil to the optimum nitrogen fertiliser value of 26.45 kg N/ha determined by Morshed et al. (2008), the depletion of nitrogen in Brazil will decrease. The change in soil balance will rise to 5.45 kg N/ha and the total loss will be reduced to 38.55 kg N/ha (see figure 6). By changing the nitrogen fertiliser use from 8 kg N/ha to 26.45 kg N/ha, the nitrogen fertiliser use in Brazil is expanded with 18.45 kg N/ha each year, bringing the total nitrogen fertiliser use to 633,971 tonnes/y. This is an increase of 230%. It needs to be taken into account that these are the average values during the whole growing season of the soybeans. Looking at the results from other studies it might be better to add more or less fertiliser during certain growth stages and wheather conditions.

5.1.2. PHOSPHORUS

The phosphorus cycle of the soybean production in Brazil in chapter 2 shows that currently 29 kg P/ha of phosphorus fertiliser is used and 30 kg P/ha is taken up by the soybean plant from the soil. This looks like a good balance between fertiliser use and plant growth, but it does not take into account the phosphorus from residues. The residues supply 13 kg P/ha to the soil. The fertiliser use could therefore be reduced to 17 kg P/ha, leaving enough phosphorus for the soybean plant to grow (see figure 7 in chapter 2).

In literature several studies can be found that investigated the response of soybeans on phosphorus fertiliser, with different outcomes. Aulakh et al. (2003) conducted field experiments to evaluate the fertiliser P requirement of soybeans and wheat in India for four years between 1992 and 1996. They used several amounts of P fertiliser on both soybeans and wheat separately as well as in a crop-rotation setting to determine the highest seed yield. The results show that, when crop rotation is not taken into account, soybeans have the highest yield when 80 kg P_2O_5/ha is applied. When crop-rotation is taken into account this value reduces to 60 kg P_2O_5/ha, because they found that the soybean plant is able to take up residues from the wheat production. In Brazil soybeans are often used in crop rotation with maize and cotton (Foreign Agricultural Service, 2012; Hunke et al., 2015). Especially cotton has a high phosphorus fertiliser use (see table 26), so it is likely that in Brazil soybeans are also able to take up residues from the crop-rotation, making 60 kg P_2O_5/ha a reasonable phosphorus requirement. It is 6 kg P_2O_5/ha lower than the current fertiliser use (see chapter 2). As a result the optimum phosphorus application rate is equal to 26 kg P/ha.

Salvagiotti et al. (2003) studied the effect of two different fertilisers at different application rates on soybeans in Argentina in the 2005-2006 and 2006-2007 growing seasons. They determined that phosphorus fertiliser only increased soybean seed yield in areas where the soil phosphorus content was less than 12 mg P/kg. The maximum seed yield response on these locations was found for fertiliser application rates between 5 – 7 kg P/ha. This is lower than the expected values for the phosphorus use on soybean plants in Brazil. The soil in Argentina on which soybeans are being produced has the same characteristics as the soil in the South of Brazil (Schnepf et al., 2011). The Cerrado however, has a different structure and is much more P deficient. The optimum phosphorus use in Brazil can therefore be expected to be higher.

Damodar Reddy et al. (1999) investigated the effects of integrated use of manure and P fertiliser on soybeans in India between 1992 and 1997. The yield of the soybean plant was the highest when a combination of 16 Mg manure/ha (22.4 kg P/ha) and 44 kg P/ha fertiliser was added to the soil. Together this resulted in an amount of 66.4 kg P/ha, which is almost three times as much as the current phosphorus fertiliser use in Brazil. The soils in the studied region of Damodar Reddy et al. (1999) are known for being extremely deficient in nutrients. Part of their study was therefore also looking if it was possible to enrich the soil with nutrients, for a more sustainable soybean production. It can be expected that the soils in this part of India are more nutrient deficient than the Cerrado in Brazil, leaving the optimum amount of phosphorus fertiliser in Brazil lower than the value calculated by Damodar Reddy et al. (1999).

Looking at the values described above, the research by Aulakh et al. (2003) resembles the situation in Brazil the best. The climatic characteristics of both regions differ slightly, but in both regions soybeans are being produced in the rainy season with enough precipitation available. Without taking into account the residues, the amount of 60 kg P_2O_5/ha is a good estimate of the optimum phosphorus fertiliser use. If the phosphorus in the residues is mobile and easily accessible for the soybean plants, less fertiliser can be added (as stated in the first paragraph of this section). Assuming that all phosphorus in the residues can be taken up by the soybean plants, a value of

17 kg P/ha can be used as the optimum phosphorus fertiliser amount. This will bring the total optimum phosphorus fertiliser use for soybeans to 426,448 tonnes/y, a decrease in phosphorus fertiliser use of 40%.

5.2. REPLACE ARTIFICIAL FERTILISER WITH MANURE IN BRAZIL

For the commercial production of crops in Brazil, and soybeans in particular, mainly artificial fertiliser is used (FAO, 2004). This is a problem because of two reasons. The first reason is the production of artificial fertiliser, because the process of nitrogen fixation from the air is energy intensive (Jenkinson, 2001), and phosphorus is a non-renewable resource (Cordell et al., 2009). The second reason is the production of manure. Because manure is hardly used as fertiliser in Brazil, it needs to have another destination. It is usually applied locally as organic fertiliser, causing a surplus of nutrients around livestock farms (Segat et al., 2015). This can cause a whole range of different environmental problems, like eutrophication.

To see if the fertiliser use in Brazil can be adapted to create a more sustainable practise, both the fertiliser use and the manure production in Brazil will be investigated. First, the fertiliser use on all crops will be examined. Second, the manure production in Brazil and its current use will be estimated. With both factors known it can be determined if the manure production can change the fertiliser use to achieve a more sustainable practise.

5.2.1. FERTILISER USE BRAZIL

Artificial fertilisers consist of the nutrients nitrogen and phosphorus, together with other important minerals like potassium. The nitrogen in artificial fertiliser is being created through nitrogen fixation. In this process the nitrogen gas (N_2) is chemically transformed into more reactive forms like ammonia (NH_3) and nitrate (NO_3^-) which can be taken up from the soil by plants (White, 2000). N_2 is a gas that is present in the atmosphere together with other forms like NO_x and NH_2. Nitrogen is returned to the air through volatilization of nitrogen gasses like ammonia and denitrification. It is therefore a renewable resource.

Phosphorus is a mineral that can only be mined in specific areas of the world. It can be taken up by plants from the soil through the soil moisture in which it occurs as phosphate (PO_4^{3-}). The mineral phosphorus was formed 10 to 15 million years ago (White, 2000). The mined phosphorus is gone, because these deposits take a very long time to form. Therefore phosphorus is a non-renewable resource. With the current fertiliser practises the phosphorus stock will run out (Cordell et al., 2009).

The FAO (2004) has determined the artificial fertiliser use per crop for Brazil for nitrogen, phosphorus and potassium. Table 26 shows the values for all crops in Brazil for the whole country for the year 2011. It shows that, overall, the use of phosphorus fertiliser is larger than the use of nitrogen fertiliser, which corresponds to the fertiliser use given by the International Plant Nutrition Institute (IPNI) (2015). The high phosphorus fertiliser use can be explained by the P deficient soils in the Cerrado in the Center-West of Brazil (FAO, 2006).

The highest rates of nitrogen are applied to potato and coffee, with soybeans and beans being the two crops with the lowest nitrogen fertiliser use. For soybeans the nitrogen use is low due to its capacity to take up nitrogen from the air (FAO, 2004). The highest phosphorus rates are applied to potato and cotton with beans, coffee and citrus being the lowest three crops. Almost all crops have a higher phosphorus application rate than nitrogen application rate, except for coffee, citrus fruits, maize and sugar cane, although the difference between both fertilisers for the last two crops is small. This could be explained by a difference in crop demand or the production on soils that are less P deficient.

Looking at the total fertiliser amounts applied, soybeans use by far the most phosphorus fertiliser, followed by potatoes. The highest nitrogen amount is consumed by sugar cane and maize, with only a small difference between their total phosphorus amounts applied. For the production of soybeans, the most hectares are used, which results in more fertiliser use, even though sugar cane is the crop with the highest total production (FAOSTAT, 2011l). Soybeans are therefore a land and fertiliser intensive crop to produce. Due to its high fertiliser use, it is a good crop to determine if the artificial fertiliser use can be replaced with manure, especially for phosphorus.

Table 26: The artificial fertiliser use in Brazil per crop for the whole country as given by the FAO (2004) for the year 2011 (FAOSTAT, 2011b; 2011c)

Crop	Nitrogen applied (kg/ha)	P_2O_5 applied (kg/ha)	Phosphorus applied (kg/ha)	Area harvested (ha)	Total amount of nitrogen applied (tonnes N/y)	Total amount of phosphorus applied (tonnes P/y)
Cotton	83	130	57	1,405,135	116,626	79,767
Rice	27	35	15	2,752,891	74,328	42,075
Potato	121	362	158	1,951,631	236,147	308,511
Coffee	114	24	10	2,148,775	244,960	22,520
Sugar cane	55	51	22	9,601,316	528,072	213,828
Beans	8	13	6	3,710,294	29,682	21,063
Citrus	55	24	10	922,083	50,715	9,664
Maize	40	35	15	13,218,892	528,756	202,035
Soybeans	8	66	29	23,968,663	191,749	690,800
Wheat	12	49	21	2,138,916	25,667	45,767
Other crops	43	45	20	-	-	-
All crops	31	48	21	79,373,000	2,460,563	1,663,714

5.2.2. MANURE PRODUCTION IN BRAZIL

Animals produce manure in which nutrients are present. The production of nitrogen and phosphorus in animal manure depends on many different factors, but feed is one of the most important ones. Depending on the type of feed there can be a different amount of nitrogen and phosphorus present. Because every animal is fed a different blend of feed, the nutrients in the manure as well as the manure production itself, is different for every animal.

To estimate the amount of nutrients in manure, it needs to be determined how many nutrients each animal produces. To make this estimate the mineral excretion factors given by the CBS (2014) are used. These numbers are an estimate of the nutrient production of different livestock in the Netherlands. These values will differ from the nutrient production in Brazil, due to a difference in feed. However, it is expected that the nutrient production is similar in both countries, due to the nutritional demand of the animals.

In order to use the manure as fertiliser, the animals need to be kept in a stable so the manure can be collected. The manure that is left by the animals on the land is assumed to be lost and not suited for reuse as fertiliser. Both Da Silveira Nicoloso et al. (2012) and Costa Junior et al. (2013) show in their research that pigs and cattle are kept in Brazil in a similar way as they are kept in the Netherlands. These animals are the two largest groups in Brazil and are the main producers of nutrients originating from manure. It is therefore assumed that the estimation below is somewhat similar to the manure production in Brazil. The values will only be used as a crude estimate to determine if the artificial fertiliser use in Brazil could potentially be replaced by organic fertiliser.

Table 27 gives an overview of the amount of nutrients in the manure of animals of Brazil as estimated with the data provided by the CBS (2014). Appendix II explains how the nutrient excretion values used for Brazil have been determined. The amount of animals in Brazil is determined using data by the FAOSTAT (2011k). By multiplying the amount of animals in Brazil with the nutrient production per animal the total amount of nutrients in animal manure can be determined.

The FAOSTAT (2011h) has also made an estimate for the production of nitrogen in animal manure in Brazil. They have divided the manure production in manure that is applied to the soil and manure that is left on the pasture. The results are similar to the estimation made in table 27 based on values of the CBS (2014). The difference is that the nitrogen content calculated here is 5% higher than the nitrogen content given by the FAOSTAT (2011h). However, both sources do differ on the nitrogen production of specific animals. In the estimated values based on the CBS (2014), the nitrogen produced by cattle is higher than the nitrogen production given by the FAOSTAT (2011h), and the nitrogen production of poultry is much lower. For this research the specific nitrogen production per animal is not of importance. The FAOSTAT (2011h) unfortunately does not give values for the amount of phosphorus in manure.

In literature data can be found about the phosphorus content in manure of specific animals in Brazil. Shigaki et al. (2006) determined a value of 72 kg P per animal per year for pigs and 0.24 kg P per animal per year for chickens. The values for chickens based on data from the CBS (2014), is similar to the value of Shigaki et al. (2006), but the value for pigs is lower. However, Costa et al. (2014) measured a value of 3.7 g P/kg in pig manure, which can be translated to 6.6 kg phosphorus per animal per year. This value lies close to the value given by the CBS (2014). Based on diet, different types of phosphorus content in animal manure can be found. The values determined based on the CBS (2014) will be used to estimate if artificial fertiliser can be substituted by manure. Data from literature does support the found values based on the CBS (2014), so it is assumed they give a good estimate of the phosphorus content in animal manure in Brazil.

Comparing the amount of animals in Brazil with the amount of animals in the Netherlands, there are some clear differences. The number of poultry in the Netherlands is much higher than the number of poultry in Brazil. The amount of poultry in the Netherlands is almost a 100% bigger than the production in Brazil. The amount of pigs on the other hand is larger in Brazil with a difference of almost 70%. For cattle, as well as goats, sheep and horses Brazil's livestock outnumbers the livestock in the Netherlands. This can be explained by the difference in size of both countries, with the Netherlands being 205 times smaller than Brazil. The production of poultry takes less space than the production of grazing animals. With more grazing animals than stable animals, the manure production in Brazil will have a different distribution. The manure of grazing animals is more difficult to use as a substitute for artificial fertiliser, because it is already deposited on land. Therefore the nutrient production in manure of the Netherlands would probably be more effective to use, due to a larger amount of stable animals. With the use of nutrient excretion values of the Netherlands for Brazil the actual nutrients that could be used in Brazil could differ from the estimation made in table 27.

Table 27: The amount of nutrients present in manure produced by animals in Brazil for the year 2011 (see appendix II)

Type of animal	**Number of animals**	**Nitrogen present in the manure**		**P_2O_5 present in the manure**		**Phosphorus present in the manure (tonnes P/y)**
		(kg N/ anim./y)	**(tonnes N/y)**	**(kg P_2O_5/ anim./y)**	**(tonnes P_2O_5/y)**	
Cattle	212,815,311	47.1	10,023,601	14.6	3,107,104	1,356,814
Buffaloes	1,278,075	47.1	60,197	14.6	18,660	8,148
Sheep	17,668,063	1.2	21,202	0.5	8,834	3,858
Goats	9,386,316	17.6	165,199	6.9	64,766	28,282
Pigs	39,307,336	21.7	852,969	9.9	389,143	169,931
Horses	5,510,601	30.3	166,971	12.0	66,127	28,877
Assess	974,688	30.3	29,533	12.0	11,696	5,108
Mules	1,269,403	30.3	38,463	12.0	15,233	6,652
Chickens	1,268,209	0.65	824	0.29	368	161
Ducks	3,750	0.79	3	0.37	1	1
Turkeys	27,100	1.85	50	0.93	25	11
Rabbits and hares	234	7.8	2	3.5	1	0
Total			11,359,015		3,681,957	1,607,842

Looking at the total fertiliser use in Brazil 2,460,563 tonnes of nitrogen and 1,663,714 tonnes of phosphorus are used on crop land in the entire country. Fertiliser use on pastures is not taken into account. These pastures are supplied by manure from grazing animals (Costa Junior et al., 2013; Shigaki et al., 2006). Comparing these values to the nutrient production as a result of manure, there is a surplus of nitrogen and a shortage of phosphorus, if all nutrients from the manure can be used as fertiliser. Out of the total 11,359,015 tonnes of nitrogen produced by animals 22% can be used as fertiliser, the remaining 78% needs to be disposed of in a different manner. Out of the 1,663,714 tonnes of phosphorus needed as fertiliser, 97% can be replaced by phosphorus produced by animals. The remaining 3% still needs to originate from artificial fertiliser. Looking at only the fertiliser use of soybeans there is enough phosphorus in the manure to substitute all fertiliser use.

Because Brazil is a country in which phosphorus fertiliser use is high (FAO, 2004), the excess amount of nitrogen and the shortage of phosphorus is not a surprising outcome. In section 5.1 it has been estimated that for soybeans the use of nitrogen fertiliser should increase and the use of phosphorus fertiliser should decrease. If this change in fertiliser use could also be applied to other crops, the nutrients in the manure production and the nutrients in the fertiliser use might lie closer together. The nitrogen surplus would therefore decrease and less artificial phosphorus fertiliser is needed. Changing the fertiliser use of soybeans to the optimum values determined in section 5.1, the total fertiliser use changes to 2,902,785 tonnes of nitrogen, an increase of 18%, and 1,399,362 tonnes of phosphorus, a decrease of 16%. Instead of a shortage there is now also an excess amount of phosphorus of 13% and the surplus of nitrogen is reduced to 74%. This shows that, even though Brazil is a country with a large agricultural production, the amount of livestock is probably too large in comparison to the amount of agricultural land, not taking into account pastures. But substituting the fertiliser use with manure, will help decrease the nutrient surplus close to animal farms.

5.2.3. CURRENT DESTINATION MANURE BRAZIL

According to the FAO (2004), Brazil uses very little manure as fertiliser on commercially grown crops. This means that the manure is used for other purposes. Shigaki et al. (2006) investigated the manure use of intensive pig and poultry farms in the South of Brazil, where 43% of the pig production and 49% of the poultry production is located. The farms that were investigated are generally small farms. This means that they do not have the necessary facilities to store, treat or redistribute the manure (Shigaki et al., 2006). The manure is usually applied to land very close to the farms which, due to farms being small with little land coverage, could lead quickly to a nutrient surplus. Even though the manure is now used in an inefficient way, Shigaki et al. (2006) did determine that the manure could have real benefits for crop production when used as fertiliser. They do point out that the ratio of N : P in manure (typically 4:1) compared to the ratio of N : P needed by the plants (typically 8:1) is different and should be taken into account when applying manure, preventing an excess amount of phosphorus in the ground.

For the Brazilian Agricultural Research Corporation (EMBRAPA) Da Silveira Nicoloso et al. (2012) have written a report about strategies for pig manure management in Brazil. They discuss the consequences of the expanding pig production in Brazil. Most pig farms are still located in the South of Brazil, but there is a growing trend of pig farms in the Center-West. As with the soybean production the location of the pig farms has consequences for their size and their manure management. Several manure management strategies are discussed, taking into account the differences between the two regions. The main manure management technique applied in Brazil for pigs is the storage of liquid manure after which it is applied to the soil. With this type of manure processing it is important to have cropland close to the farm, because it is not economically sound to transport the manure over long distances (Da Silveira Nicoloso et al.2012). Other manure management strategies have been developed to reduce the influence on the environment. One of those strategies is the use of biodigestors (Da Silveira Nicoloso et al. 2012). These tanks produce biogas from the manure that can be used as an energy source. However nitrogen and phosphorus are not removed from the manure in this process and this rest product is still applied to soil in the surrounding areas. A final manure management strategy discussed is composting, in which the water is evaporated leaving solid material. This material still has to be applied to land for disposal (Da Silveira Nicoloso et al., 2012).

Costa Junior et al. (2013) did a survey of 73 cattle feedlots in Brazil, located mainly in the Center-West and South-East, to obtain information about manure management. The interviews took place in 2011 to acquire information about 2010. The feedlots are places where the cattle are fed for slaughter. The manure in the feedlots was stored in pens, heaps, or on a field (Costa Junior et al., 2013). Out of the 73 feedlots 10% did not remove any manure from the pens the animals were kept in, in 58% of the feedlots the manure was removed after the end of the feeding period and in 33% of the feedlots the manure was cleaned out more often. The manure is either stored in heaps, applied directly on a field or sold to a third party for fertiliser use. Out of the total amount of manure 78% is applied to cropland and pastures as fertiliser (Costa Junior et al., 2013).The quantity of manure that was applied on crop land and pastures, was not always monitored. In 42% of the feedlots it was unclear how much manure was actually applied on the soil each time. One of the aspects that was also taken into account during the survey was the use of manure on crops that were later used for the feed of the cattle. This was the case in 51% of the feedlots. The reasons given to use manure as fertiliser were savings on artificial fertiliser (74% of the feedlots) and an improvement of the organic content of the soil (41% of the feedlots) (Costa Junior et al., 2013).

The three papers discussed above show that manure is applied on crop land and on pastures. This is not specifically done as fertiliser, but also to dispose the manure. When the soil surrounding the farms reaches its nutrient capacity an excess amount of nutrients arises, which can cause environmental problems. It is therefore important to adjust both the manure management and the fertiliser management to prevent a surplus of nutrients in the soil.

5.3. CHANGE THE MANURE SURPLUS OF THE NETHERLANDS

The Netherlands is a country with a manure surplus. A manure surplus occurs when more nutrients are produced in the manure of animals, than are allowed to be applied on the land of the farm. Even though the quantity of the manure is important, this is not the reason why a manure surplus arises. A manure surplus arises because of the nutrients that are present in the manure. It is therefore better to speak of a nitrogen surplus or a phosphorus surplus (Schoumans et al., 2008).

With the import of soybeans to be used in pig feed, the Netherlands is importing nutrients. These nutrients are added to the nutrient balance, which has a negative influence on the manure surplus. By estimating the manure surplus in the Netherlands and determining if it could be possible to reduce this manure surplus, potentially the influence of trade in soybeans could be reduced indirectly.

5.3.1. MANURE SURPLUS OF PIG FARMS

As explained before the amount of nutrients present in the manure of animals depends on the type and quantity of the feed. The amount of nutrients that is present in the manure of animals can be determined using the mineral excretion factors. The mineral excretion factors show the amount of nitrogen and phosphorus that is present in the manure of one animal. In appendix II an estimation is made of the manure production of all animals in the Netherlands. The found values for finishing pigs correspond to the values found by Luesink et al. (2011). However, the values determined in chapter 3 are a factor three lower. The values determined in chapter 3 were based on a specific blend of feed for the year 2002 (Jongbloed & Kemme, 2005). The mineral excretion factors used here are for 2013. It could be possible that the blend of feed was changed in those 10 years, and that as a result the nutrient excretion of the animals differs.

Besides the manure production, the size of the nutrient surplus depends on the "plaatsingsruimte", the amount of nutrients that can be added to the soil before it has an impact on the environment, as determined by the government. In the Netherlands for each type of nutrient, fertiliser and crop an application threshold has been established. For nitrogen the application thresholds depend on the type of soil on which a crop is grown and in 2014 these values differed between 140 and 320 kg/ha active nitrogen, with the values for crop land being lower than the values for pastures (Compendium voor de Leefomgeving, 2014). With the active nitrogen the difference in fertiliser use is indicated, with artificial fertiliser containing 100% active nitrogen whereas the active nitrogen in manure varies from 30-80% depending on the type of manure (liquid or solid). The manure of finishing pigs can both be liquid or solid, depending on the type of stable (Bokhorst & Ter Berg, 2001).

For phosphorus the application threshold depends on the amount of phosphorus which is already present in the soil. For both crop land and pastures this amount of phosphorus in the soil is determined in a different way. For crops the amount of phosphorus in the soil is given by the Pw-number which expresses the amount of phosphorus in the soil in mg P_2O_5 per litre soil (Compendium voor de Leefomgeving, 2014). In 2015 the phosphorus application threshold for crops lie between 75 kg P_2O_5/ha/y for low phosphorus concentrations in the ground and 50 kg P_2O_5/ha/y for high phosphorus concentrations in the ground (Compendium voor de Leefomgeving, 2014). For pastures the amount of phosphorus in the soil is given by the PAL-number, which expresses the amount of phosphorus in the soil in mg P_2O_5 per 100 g dry soil (Compendium voor de Leefomgeving, 2014). In 2015 the phosphorus application thresholds for pastures lie between 100 kg P_2O_5/ha/y for low level phosphorus and 80 kg P_2O_5/ha/y for high level phosphorus in the ground (Compendium voor de Leefomgeving, 2014).

When a farmer produces more nutrients in the manure of its animals, than that it can apply on its land, a manure surplus arises. Luesink et al. (2011) have investigated the manure surplus in the Netherlands in 2010. Tables 28 and 29 show the manure surplus of pig farms in the Netherlands in 2010. The manure surplus is the amount of manure which is offered at the manure market. This is the manure that farmers cannot apply on their own land. Figure 22 shows the supply of manure on the manure market in the Netherlands in 2010. Most manure offered at the manure market originates from poultry and pigs. Poultry and pig farms generally have less land, so their available nutrient placement capacity is smaller.

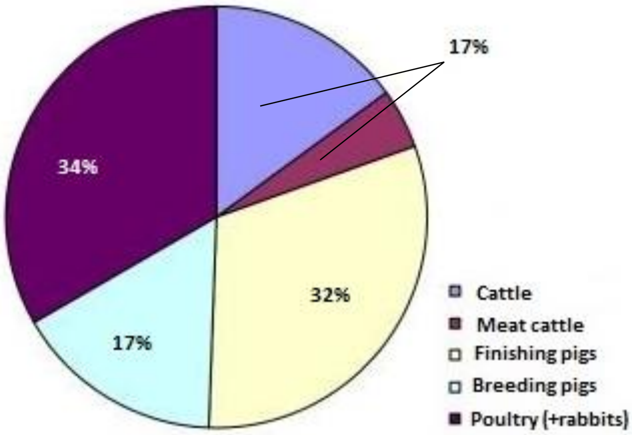

Figure 22: An overview of the types of animal manure offered at the manure market in the Netherlands in 2010 (De Koeijer et al., 2011)

Table 28: The amount of nitrogen in pig manure, the amount of nitrogen that is used at the farm itself and the amount of nitrogen of manure that is offered at the manure market in the Netherlands in 2010 (Luesink et al., 2011)

	Nitrogen produced in pig manure (tonnes N/y)	Nitrogen placed at own company (tonnes N/y)		Nitrogen offered at the manure market (tonnes N/y)	
Finishing pigs	59,000	11,000	19%	48,000	81%
Breading pigs	26,000	3,000	12%	23,000	88%
Total	85,000	14,000	16%	71,000	84%

Table 29: The amount phosphate produced in pig manure, offered at the manure market and used at pig farms in the Netherlands in 2010 (Luesink et al., 2011)

	Phosphate produced in pig manure (tonnes P_2O_5/y)	Phosphate placed at own company (tonnes P_2O_5/y)		Phosphate offered at the manure market (tonnes P_2O_5/y)	
Finishing pigs	30,000	3,000	10%	27,000	90%
Breading pigs	16,000	2,000	12%	14,000	88%
Total	46,000	5,000	11%	41,000	89%

5.3.2. POSSIBLE CHANGES TO REDUCE MANURE SURPLUS

It has been established that there is both a nitrogen and a phosphorus surplus at pig farms in the Netherlands. There are two ways in which the manure surplus of pig farms in the Netherlands can be adapted: By reducing the amount of nutrients in pig manure and by making the application of manure more effective.

Reducing nutrients pig manure

By changing the diet of finishing pigs in the Netherlands, both the nitrogen and the phosphorus content of the manure could be reduced. In 2013 the Dutch government has presented new measures to reduce the manure surplus in the Netherlands. One of the most important ones was reducing the amount of phosphate in pig feed (Rijksoverheid, 2013). But also reducing the amount of nitrogen in pig feed could have benefits for the environment.

Nitrogen
Van Vuuren et al. (2015) investigated the effect of low nitrogen feeding strategies on the feed production costs. They also give an estimate of the effect of these strategies on the nitrogen excretion. There are two low-feeding strategies discussed: reducing the urea concentration and excretion and reducing the ammonia production and volatilization during storage and application. For reducing urea concentration and excretion two feeding strategies have been tested: reducing the total urinary and faecal N excretion and shifting the N excretion in urine towards N excretion in faeces (Van Vuuren et al., 2015).

The total urinary and faecal N excretion can be reduced by reducing the crude protein intake. This can be done by replacing high-protein feed materials like soybean cake with a carbohydrate source (Van Vuuren et al., 2015). With this strategy the dietary demands of pigs need to be taken into account, to maintain growth and health of the pigs (Van Vuuren et al., 2015). An example of a carbohydrate source is wheat. Wheat however is a resource which is already high in demand for food and ethanol production, which could result in higher production costs (Van Vuuren et al., 2015). The shifting of N excretion can be done by using fibres from plant cell walls which will not be digested in the small intestine. The downside of this type of method is that the quantity of manure increases (Aarnink et al., 2010).

Aarnink et al. (2010) have investigated the effect of the measures described above on the nitrogen excretion of pigs. Changing the protein content in the feed of finishing pigs can reduce the emission of ammonia with 10 to 12.5%, when reducing the protein level by 10 g protein/kg feed. For finishing pigs a reduction of 10-20 g protein/kg feed is possible, leading to a change in ammonia emission of 10-25% (Aarnink et al., 2010). Shifting the excretion of nitrogen from urine towards faeces can reduce the emission of ammonia by 12% when changing 100 g non-starch carbohydrates/kg feed (Aarnink et al., 2010).

If the feed of finishing pigs in the Netherlands would be adapted according to the measures described above, it might be possible to reduce the nitrogen content in the manure with 25%. This would reduce the amount of nitrogen in pig manure from 20,695 tonnes N/y to 15,521 tonnes N/y. In total the amount of organic nitrogen fertiliser would be reduced to 319,826 tonnes N/y, bringing the total nitrogen fertiliser use to 521,826 tonnes N/y. As a result the nitrogen surplus in chapter 3 would decrease to 253,167 tonnes N/y, a reduction of 2%. This shows that, changing only the feed of finishing pigs would not lead to a high enough reduction to solve the nitrogen surplus. If the feed of other animals would be adapted as well, taking into account their nutritional demands, it might be possible to reduce the nitrogen surplus further.

Looking at the manure surplus in table 28, decreasing the nitrogen content with 25% would lead to a total production of 44,250 tonnes N/y. Assuming that the amount of nitrogen which can be placed at the own farm remains the same, the manure surplus reduces to 33,250 tonnes N/y, a reduction of 31%. This means that less nitrogen reaches the manure market.

Phosphorus
Van Krimpen et al. (2009) investigated the effect of reducing phosphorus in animal feed in the Netherlands. They determined that by changing the feeding strategy of pigs, the phosphorus excretion could drop by approximately 25%. This change can be reached by applying feeding in phases (-5%), adding phytase to the feed (-5%) and by using raw materials with a higher P-digestibility (-15%) (Van Krimpen et al., 2009). Phytase is an enzyme which helps improve the digestibility of phosphorus (Veldkamp, 2012). Feeding in phases means that during the life span of a pig it gets fed different types of feed. For finishing pigs a reduction of 65% can be reached by supplying highly concentrated feed, feed that contains materials with a high P-digestibility (Van Krimpen et al., 2009).

In the discussion Van Krimpen et al. (2009) mention the development of genome crops that have a much lower content of the difficult digestible phytate-P. The total P-digestibility of these crops has almost doubled. Developers have managed to improve the P-digestibility of several crops, like maize, wheat and soybeans. The crops are currently not used in Western Europe in animal feed. It will depend on the market and the policies if these raw materials will become available in the Netherlands (Van Krimpen et al., 2009). If they do, it could reduce the phosphorus excretion as well.

If the phosphorus excretion of finishing pigs in the Netherlands would reduce by 65% the total phosphorus excretion of these animals will become 1,241 tonnes P/y. As a consequence the total organic fertiliser use would be reduced to 52,696 tonnes P/y, bringing the total phosphorus fertiliser use to 57,696 tonnes. The phosphorus surplus would decrease by 26% to 6,696 tonnes P/y. This shows that, changing the diet of pigs could result in a change of the phosphorus surplus. With changing the feed of other animals as well, it might be possible to reduce the phosphorus surplus to a minimum. It should be taken into account that changing the feed to decrease the nitrogen or phosphorus content would also have consequences for the other nutrient. It might not be possible to reduce both.

Looking at the manure surplus in table 29, decreasing the phosphorus content with 65% would lead to a total production of 13,500 tonnes P_2O_5/y. Assuming that the placement capacity of the own farm does not change, the amount of phosphorus offered at the manure market will reduce to 10,500 tonnes P_2O_5/y, a reduction of 61%. So less phosphorus has to be offered at the manure market.

Figure 23 shows the destination of phosphorus originating from pig manure offered at the manure market. It shows that currently 58% is used as fertiliser on farms in the Netherlands, 9% is exported, 1% is processed, 23% is stored at the transporter, and another 9% has another destination. Other destinations can include the use of manure as fertiliser on nature, or private fertiliser use (Luesink et al., 2011).

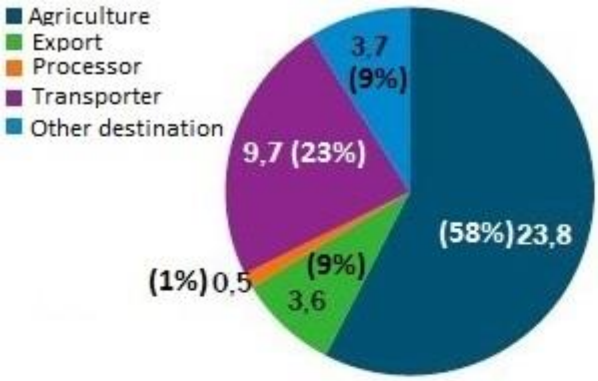

Figure 23: The destination of phosphorus (P_2O_5) originating pig manure offered at the manure market in the Netherlands in 2010 in million kg (Luesink et al., 2011)

If the diet of finishing pigs would be adapted, the total supply to the manure market would decrease. Instead of 41 million kg P_2O_5, an amount of 24,500 tonnes of P_2O_5 would be offered at the manure market. As a whole this almost covers the use of pig manure as fertiliser. Only a small part would be left for either processing, export, transporting or other destinations.

Making the use of manure as fertiliser more effective

The use of manure as fertiliser can be made more effective, by processing manure in a different way. Hoeksma & de Buisonjé (2012) recently studied a new manure processing method: the reversed osmosis of the liquid manure fraction. In this process a mineral concentrate arises which has a high nitrogen concentration and a low phosphorus concentration. The remaining solid manure fraction has a high phosphorus content (Lesschen et al., 2011). As a result the application of manure to the soil can be monitored more closely. Farmers would be able to apply both a nitrogen content and a phosphorus content of there choice, instead of being able to only add one until their threshold is met and applying artificial fertiliser to accomplish the demand of the other nutrient. De Koeijer et al. (2011) for example determined that for pastures the phosphorus placement capacity is not met, because the nitrogen placement capacity is already reached. If the nitrogen and phosphorus content of the manure can be partly separated, more phosphorus can be added. As a result the manure surplus would reduce. Processing the manure with reversed osmosis on a large scale will not have significant negative effects on the ammonium emission (Lesschen et al., 2011).

Looking at figure 23 it can be concluded that the placement of manure at the transporter is an important destination for pig manure (Luesink et al., 2011). Manure is placed at the transporter for temporary storage. Storage can be necessary due to the restrictions of fertiliser use by the Dutch government. There are for example specific times in the Netherlands at which manure is allowed to be applied to soils (RVO, 2014). When the use of manure is not allowed, manure needs to be temporarily stored, because manure is produced all year long. If the application of manure would become more efficient, less manure will have to be stored at the transporter. The manure which is stored at the transporter will probably also have to stay there shorter.

In 2012 the Netherlands exported 2,758,000 tonnes of manure, which contained 46,900 tonnes N and 28,800 tonnes P_2O_5 (CBS, 2015a). As shown by figure 23 the Netherlands exported 3.6 million kg phosphorus originating from pig manure in 2010. Pig manure is supplying 12.5% of the total phosphorus exported. With the export of nutrients the Netherlands can balance its import of nutrients. However the countries that receive the nutrients are sometimes another country than the country from which nutrients are received. This could result in problems for both the nutrient exporting countries and the nutrient importing countries.

As shown in chapter 4, Brazil is exporting nutrients with the export of soybeans. In order to compensate for this export Brazil could import nutrients. However in section 5.2 it was estimated that Brazil produces enough nutrients in the manure of animals to replace its total artificial fertiliser use. If Brazil would import nutrients they would only increase their nutrient surplus. The export of nutrients should therefore only go to a country with a nutrient deficit, which cannot produce enough nutrients itself. Otherwise the Netherlands would be moving the nutrient surplus problem instead of solving it.

5.3.3. CURRENT SITUATION PIG FARMERS

The Dutch government has strict regulations for pig farms, and farming in general. It has one of the strictest regulations in Europe (Nieuwsuur, 2015). Due to these strict regulations the production of pork meat in the Netherlands is cost intensive. According to an article written by Nieuwsuur (2015), this results in an unfair competition between Dutch pig farmers and pig farmers of other European countries. The trade union NVV (Dutch Union for pig farmers) is therefore pleading for uniform laws in whole of Europe (Nieuwsuur, 2015).

The NVV has started the discussion about laws due to the declining prices of pork meat. The prices of pork meat in Europe have declined due to two reasons. In 2014 in Poland two wild boars were diagnosed with the African swine fever (NOS, 2014a). This is a highly contagious disease, for which pigs cannot be vaccinated (NOS, 2014a). After this disease was diagnosed in Belarus, Russia stopped importing pork meat from Europe (NOS, 2014c). With the exported to Russia being blocked by the government, the demand in pork meat decreased. As a result, farmers decided to store the meat temporarily to sell it at a later stage (NOS, 2014b). However, due to the civil war in Ukraine, they never got the chance. As of this day, Russia still has a boycot on Dutch tomatoes, peppers, cucumbers, meat and cheese (NOS, 2015c).

With the export of meat to Russia coming to a halt, Europe is producing too much pork meat. With the supply of pork meat being higher than the demand of pork meat the prices have dropped tremendously (NOS, 2014b). Not only Dutch farmers are affected by the Russian boycott. In the summer of 2015 French farmers have protested against their bad situation with success (NOS, 2015e). The French government promised to support the farmers to reach a minimum price for pork meat (NOS, 2015e). Due to the success of the French, Dutch farmers have started protesting as well, since many farmers are having financial problems (NOS, 2015d).

In September 2015 the European Commission has agreed on a 500 million euro aid package for the farmers. Out of this 500 million euros the Dutch government has received 30 million euros, to be divided among the farmers (NOS, 2015a). Pig farmers will receive 10 million euros. Another 10 million euros will be given to dairy farmers and the remaining 10 million will be used for improving manure treatment (NOS, 2015b). This means that there is money to investigate the implementation of the measures described in section 5.3.2.

Many Dutch pig farmers are having financial difficulties (NOS, 2015d). As a cause, the farmers point to the decreasing meat prices in combination with the strict Dutch environmental laws. But in fact the problems can be traced back to the size of the meat production. Figure 24 shows the pork meat production in 2013. Europe is producing 24% of the world pork production. Out of this 24%, 40% is produced by Western Europe of which 12% is produced by the Netherlands (FAOSTAT, 2013). The Netherlands is the third largest producer of pork meat in Western Europe, after Germany and France. Looking at these numbers the Dutch pork meat production seems large, taking into account that France is a bigger country. With the supply of pork meat being higher than the demand, it can be concluded that the Netherlands is producing too much. By decreasing the pork production the prices for meat could increase, giving the Dutch farmers a better financial state without changing the legislation.

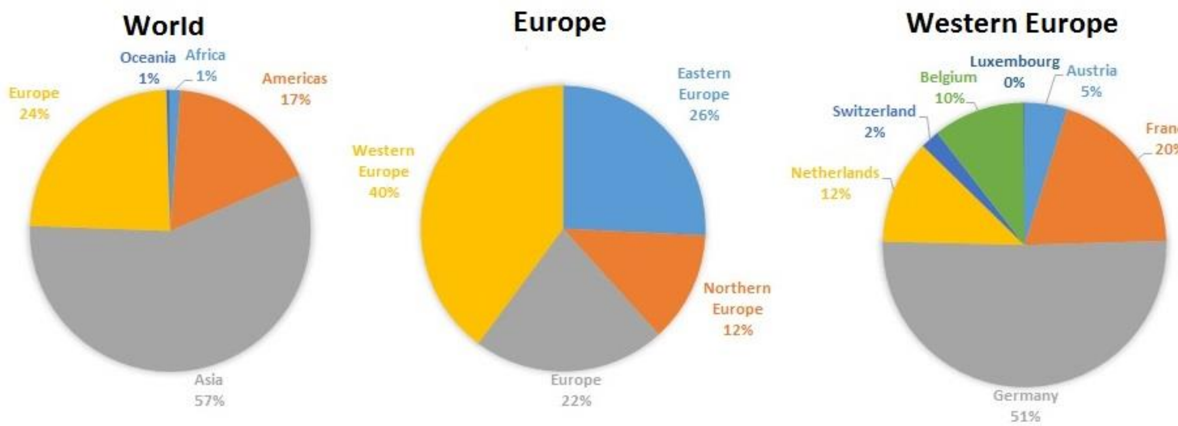

Figure 24: The pork production of the World, Europe and Western Europe in percentages in 2013 (FAOSTAT, 2013)

5.4. REPLACE ARTIFICIAL FERTILISER WITH MANURE IN THE NETHERLANDS

Even though the Netherlands is a country in which the use of manure as fertiliser is highly developed, the Netherlands still also uses large amounts of artificial fertiliser for the production of crops. If this artificial fertiliser use could be substituted by manure or other organic fertilisers, the imbalance in nutrient use and nutrient production caused by trade could be reduced. By estimating the nutrient production in manure of animals in the Netherlands and comparing this with the current use of manure as fertiliser and the artificial fertiliser use, it can be determined if the artificial fertiliser could be substituted by manure.

5.4.1. ARTIFICIAL FERTILISER USE

In chapter 3 it has been determined that in 2013 on crop land 202 million kg N and 5 million kg P artificial fertiliser was applied (CBS, 2013). Out of the total fertiliser use, the use of artificial nitrogen was equal to 38% and the use of artificial phosphorus was equal to 8%. It shows that the replacement of artificial phosphorus fertiliser has been important for the Dutch government. This could be the result of phosphorus being a non-renewable resource (Cordell et al., 2009).

In appendix II an estimation is made of the nutrients in the manure of animals in the Netherlands. Table 30 shows the results. The Netherlands produces approximately 528,935 tonnes N/y and approximately 91,934 tonnes P/y in the manure of animals. These estimations are in the same range as the calculated nitrogen and phosphorus production of Luesink et al. (2011), but their nitrogen production is slightly lower and their phosphorus production slightly higher.

The total artificial fertiliser use in the Netherlands in 2013 was equal to 527,000 tonnes N/y and 60,000 tonnes P/y (chapter 3). The estimated values below show that there should be enough nutrients in the manure of animals in the Netherlands to substitute all artificial fertiliser use. It is therefore important to look at reasons why artificial fertiliser is still applied in the Netherlands.

Table 30: An estimation of the production of nutrient in animal manure in the Netherlands in 2013, based on the calculation in appendix II

	Nitrogen produced in manure (tonnes N/y)	P_2O_5 produced in manure (tonnes P_2O_5/y)	Phosphorus produced in manure (tonnes P/y)
Grazing animals			
Cattle	180,809	56,747	24,780
Sheep	1,240	517	226
Goats	6,972	2,847	1,243
Horses	3,247	1,242	542
Total	192,268	61,353	26,792
Housed animals			
Pigs	268,238	117,598	51,353
Chickens	61,547	27,830	12,153
Turkeys	1,463	824	360
Ducks	600	308	134
Rabbits	2,550	1,275	557
Fur-bearing animals	2,269	1,341	586
Total	336,667	149,176	65,142
Total	528,935	210,529	91,934

5.4.2. REASONS FOR ARTIFICIAL FERTILISER USE

One of the reasons why artificial fertiliser is still used has been discussed in section 5.3. The Dutch government is regulating the application of both nitrogen and phosphorus fertilisers. On both crop land and pastures only a certain amount of nitrogen and phosphorus can be applied. With the ratio of nitrogen and phosphorus in manure depending on the feed and the type of animal, it is difficult to apply both nutrients at the allowed rate. Especially for crops it could therefore be necessary to apply artificial fertiliser besides manure use, to reach the nutrient demand of the crop.

Depending on the crop or manure either nutrient can be limiting. With phosphorus being a non-renewable resource the Dutch government is promoting the re-use of phosphorus and is investing in new ways of extracting phosphorus from manure and other sources. This would decrease the use of mineral phosphorus. It could explain the difference in percentage of artificial fertiliser use between nitrogen and phosphorus. If the use of phosphorus is subsidised even further, it is more likely that farmers will apply manure until the phosphorus threshold is met, and applying artificial nitrogen to reach the crops demand, depending on the composition of artificial fertilisers.

Another reason is the availability of manure. Figure 25 shows the amount of hectares used per province for the production of crops. Looking at the location of pig farms in figure 9 in chapter 3, the production of crops takes place in different provinces than the production of pork meat, and as a result the production of manure. It can therefore be difficult for some farmers to obtain manure for the use as fertiliser. It could be easier and perhaps cheaper to use artificial fertiliser instead. If this is the case the government should stimulate the use of manure instead of artificial fertiliser. Manure could be made more available through for example processing or it can be made cheaper than the use of artificial fertiliser.

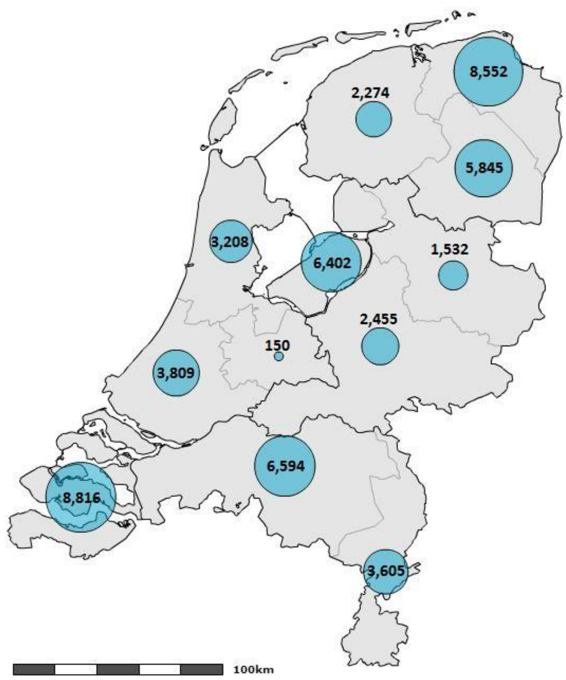

Figure 25: The location of crop land in the Netherlands in 2013 in ha (CBS, 2014c)

5.5. TRANSPORT EXCESS MANURE FROM THE NETHERLANDS TO BRAZIL

In chapter 4 it has been established that the trade in soybeans from Brazil to the Netherlands is depleting the soil in Brazil. With the export of soybeans nutrients are exported from Brazil to Netherlands. In order to prevent the soil from depletion, it might be possible to transport manure from the Netherlands to Brazil to be used as fertiliser on soybeans. In order to determine if this could be an effective measure, the fertiliser use of the soybeans which are exported to the Netherlands needs to be compared to the manure production of finishing pigs as a result of eating these soybeans.

To produce soybeans in Brazil for export to the Netherlands 17,475 tonnes of nitrogen fertiliser and 62,954 tonnes of phosphorus fertiliser is used in 2011 (see chapter 4). Finishing pigs in the Netherlands produce 20,695 tonnes of nitrogen and 3,545 tonnes of phosphorus annually (see chapter 3). Of these nutrients 7,379 tonnes of nitrogen and 1,088 tonnes of phosphorus can be traced back to be originating from soybeans in the feed imported from Brazil (see figure 19 and 20 in chapter 4).

Comparing these numbers to each other, it does not seem sustainable to export manure from the Netherlands to Brazil to be used as fertiliser. Finishing pigs in the Netherlands alone do produce enough nitrogen for the imported soybeans to be fertilised, but for phosphorus there is a huge shortage. Only 6% of the fertiliser use can be substituted by pig manure. Looking at only the nutrients that can be traced back to the soybeans both values are too low. For nitrogen 42% of the fertiliser use could be substituted and for phosphorus the value drops to 2%. It seems that simply exporting what is imported does not work.

As established before, Brazil uses more phosphorus fertiliser than nitrogen fertiliser. The nutrient surplus in the Netherlands is exactly the other way around. The surplus of nitrogen is higher than the surplus of phosphorus. It is therefore difficult to obtain enough phosphorus in the manure of pigs for export to Brazil to be used on soybeans that are produced there for export to the Netherlands. Looking at the total manure surplus in the Netherlands of all pigs, there is a surplus of 71,000 tonnes of nitrogen and 41,000 tonnes of P_2O_5 (see section 5.3.). Even this manure surplus does not supply enough phosphorus for fertiliser use in Brazil. And it should also be taken into account that a part of this surplus is used as organic fertiliser in the Netherlands. Exporting all manure could therefore lead to an increase of artificial fertiliser use in the Netherlands.

Looking at only the amount of fertiliser needed for the export of soybeans to the Netherlands that are used in the feed of finishing pigs, the fertiliser use drops to 513 tonnes of nitrogen and 1,847 tonnes of phosphorus.

Comparing this with the excretion of finishing pigs as a result of eating these soybeans of 7,379 tonnes nitrogen and 1,088 tonnes of phosphorus, there is still a lack of phosphorus in the manure of finishing pigs to substitute all fertiliser use.

With the optimum fertiliser values in section 5.1 the total fertiliser use of soybeans in Brazil could be adapted to 633,971 tonnes N/y and 426,448 tonnes P/y. In chapter 4 it has been established that out of all the fertiliser used on soybeans, 9% is used for export to the Netherlands. This would change the fertiliser use values to 57,057 tonnes N/y and 38,380 tonnes of P/y. Even with this change there is still not enough phosphorus in pig manure to substitute the fertiliser use for the production of soybeans in Brazil for export to the Netherlands.

Exporting manure from the Netherlands to Brazil does not only effect the environment in the Netherlands. In section 5.2 it was estimated that currently animals in Brazil are producing more nitrogen than is used as fertiliser and the produced and applied phosphorus values are almost equal. Of course this is only an estimation, but it can be expected that Brazil is already producing most of its needed nutrients themselves, even though they are currently not used in an effective way. Importing manure will therefore only increase the amount of nutrients in the country, affecting the environment in a negative way.

Looking at the discussion above, exporting manure from the Netherlands to Brazil is not an effective way to reduce the influence of trade on the flow of nutrients. Pigs in the Netherlands do not produce enough nutrients for the use as fertiliser on soybeans in Brazil and Brazil itself probably already produces enough nutrients to replace the artificial fertiliser use. Exporting the surplus of the Netherlands to Brazil would therefore only lead to a shift of the problem. Taking into account the transport of the manure as well, the export of manure is not a sustainable solution.

5.6. CHANGE SOYBEANS IN PIG FEED WITH A LOCALLY PRODUCED PROTEIN

Due to the trade in soybeans nutrients are withdrawn from the Brazilian soil and added to the Dutch soil. By changing the soybean products in pig feed, with other protein sources that are produced in the Netherlands, the influence from trade on the nutrient balance in both countries could be reduced. There are two ways to replace soybeans in pig feed: By changing soybeans into a locally grown crop in the Netherlands and by changing soybeans for a non-crop protein.

5.6.1. LOCALLY GROWN CROP

If soybeans are being replaced by a crop which is grown in the Netherlands, the Netherlands would be recycling its nutrients. The nitrogen and phosphorus in pig manure could be used as fertiliser on these crops and, as a consequence, the nutrients in the manure would also be originating from the Netherlands. So no external nutrients would be added to the nitrogen and phosphorus balance.

In order to estimate if soybeans could be replaced by a locally grown crop, the crops grown in the Netherlands need to be determined. Of these crops, only the crops that are used in animal feed are of importance. To see if the crops are an alternative for soybeans, their crude protein content is determined. Based on this percentage the crops can be compared to soybeans.

Table 31 shows the crops grown in the Netherlands that are used in animal feed, together with their protein content. The crops grown in the Netherlands are determined using the table 'Akkerbouwgewassen' of the CBS (2014a). This table gives the planted area in hectares, together with the revenue per hectare for all crops grown in the Netherlands for 2014. By cross referencing this information with the crops used in animal feed as given by the CVB (2011) the selection in table 31 was made. The protein content was determined using the characteristics given by the CVB (2011).

According to the CVB (2011), soybeans have a crude protein content between 49% and 56%. Looking at table 31 the only two crops that have similar values are maize and starch potatoes. Starch potatoes have a wide range of crude protein content. The crude protein content of starch potatoes depends on the usage, processing and size of the potatoes. Besides the protein content also other nutritional values need to be taken into account, like amino acids. Soybeans contain many important amino acids that starch potatoes do not (CVB, 2011). Therefore starch potatoes would only be a suitable alternative for soybeans if extra additives would be used. Otherwise the nutritional value of the feed would not comply with the pigs demands. Also more potatoes need to be added to the feed, than the amount of soybeans to obtain the same protein content. This would result in a completely different diet. As a result starch potatoes do not seem like a suitable alternative for soybeans.

Table 31: The crops grown in the Netherlands which are currently used in animal feed, together with their protein content (CBS, 2014a; CVB, 2011)

Crop	Area planted (ha)	Revenue (kg/ha)	Protein content
Wheat	142,212	9,200	13%
Barley	27,613	15,400	12%
Rye	1,720	4,100	11%
Oats	1,751	5,700	12%
Triticale	1,520	6,200	13%
Corn	12,594	13,700	9%
Maize	226,151	47,700	24-42%
Corn Cob Mix	4,930	13,500	16-19%
Linseed	1,983	700	23%
Chicory	3,555	43,600	9%
Hemp	1,633	8,000	21%
Potatoes	74,068	52,300	10%
Starch potatoes	42,310	42,200	1-93%
Sugar beets	75,094	90,800	16%

The other alternative for soybeans is maize. Compared to starch potatoes maize resembles soybeans more, but it still misses important characteristics that soybeans do have. And even though the percentage of crude protein is similar to each other, in order to obtain the same amount of protein from maize the intake needs to be three times larger than the intake of soybeans (CVB, 2011).This would lead to an increase in maize production and currently maize is already the crop which is produced the most (CBS, 2014a).

In the Netherlands 200,658 tonnes of soybean cake, 1,731 tonnes of soybean oil and 6,156 tonnes of soybeans is used in the feed of finishing pigs each year. In order to replace these amounts with maize the triple of these numbers is necessary. The Netherlands produced 10,787,403 tonnes of maize in 2014. This production would have to be increased with approximately 620,000 tonnes. As a result the amount of hectares would need to increase with approximately 13,000 ha. In total the Netherlands used an area of 2,000,900 ha to produce crops in 2014 (CBS, 2014b). Extending this with 13,000 ha would mean an increase of 1%. This does not seem like a lot, but looking at the production areas in table 31, it is more than the area on which most of the crops are grown.

With the Netherlands only being 4 million ha, most of the land already has a destination. In order to produce the extra maize, 13,000 ha will have to change destinations. This means either not producing a certain crop, producing less of a crop, or changing nature into crop land. With the Netherlands having many legislations protecting their environment this last option could be difficult. Changing the production of a crop would have consequences for the economy and it could result in the reduction of the production of other crops. Taken into account the difference in composition of maize and soybeans and the disadvantages of increasing the maize production, maize does not seem like a good alternative for the use of soybeans in pig feed.

5.6.2. OTHER PROTEIN SOURCES

According to the International Feed Industry Federation (2015), the global meat production is expected to double by 2050. This will increase the demand for animal protein. With the production of meat increasing the demand for soybean products to be used in animal feed will increase as well. Due to soybeans being a crop which is best grown in (sub-)tropical climate regions, the possible production of this crop is limited to certain parts of the world (Taelman et al., 2015).

In order to ensure the increase in the production of meat, it can be important to look at other protein sources, non-crop based, which could be produced within Europe. Therefore Veldkamp & Bosch (2015) have investigated the use of insects as a protein source in animal feed. Taelman et al. (2015) raised the question whether the production and import of soybeans for animal feed is environmentally sustainable. Therefore they have investigated the use of algae meal as a substitute for soybean cake.

Insects
Veldkamp & Bosch (2015) have identified three types of insects which are promising for industrial production in the Western World and could work as a possible protein source. These three types of insects are: the black soldier fly, the common housefly and the yellow mealworm (Veldkamp & Bosch, 2015). Of these three insects the protein content was determined and it was compared to the protein content of soybean cake. The protein content differed between the species and growth phase, but the highest median crude protein content was observed for the common housefly pupae (62.5% of dry matter), and the lowest value was found for the black soldier fly larvae (42.3% of dry matter) and pupae (38.1% of dry matter) (Veldkamp & Bosch, 2015). According to the CVB (2011) the crude protein content of soybean cake lies between 49% and 56%. Looking at these values the protein content is similar, however soybean cake contains less crude fat and it is important to look at the different amino acids in both the insects and the soybean cake (Veldkamp & Bosch, 2015).

After determining the characteristics of the different insects, Veldkamp & Bosch (2015) determined the influence of insect as feed ingredients on finishing pigs. The use of black soldier larvae meal was found to be a suitable ingredient in pig feed (Veldkamp & Bosch, 2015). When 50% of the original protein source was replaced, the results were slightly better than replacing 100% of the original ingredient (Veldkamp & Bosch, 2015).

The research conducted by Veldkamp & Bosch (2015) shows that insects could be a good alternative protein source for soybean cake. Insects can be produced in a way which will make them have similar characteristics as soybean cake, but the costs of production are still high. Unfortunately little research has been done about the use of insects in animal feed. The digestibility of insect protein of animals was only investigated by three studies, and also the functional properties of insect meal have not yet been investigated (Veldkamp & Bosch, 2015). Therefore, for insect meal to be a sustainable replacement for soybean cake more research needs to be carried out.

Algae
To reduce the demand in soybean products and make the production of meat a more sustainable process, Taelman et al. (2015) believe that Europe should become more self-sufficient. If Europe can produce its own protein source, they could decrease their import. Because land area is scarce in Europe Taelman et al. (2015) see algae production as a good alternative. Algae are a rich source of biomass, whit a protein content of 6-52% (Taelman et al., 2015).

Taelman et al. (2015) carried out a sustainability analysis of the production of algae meal in the Netherlands, in comparison to the production of soybean cake in Brazil. They discovered that currently it is still more sustainable to feed livestock in the Netherlands soybean cake instead of algae meal. This is due to the fact that the production of algae meal is energy intensive. However, a sensitivity analysis showed that it could be possible to produce algae meal in a way which will make the resource footprint lie in the same order as the resource footprint of soybean cake when other sustainable energy sources are used (Taelman et al., 2015).

In order for algae meal to be a good substitute for soybean cake further research needs to be carried out. It has been determined that algae meal contains more protein than soybean cake, but it is unclear which type of protein is more digestible or if livestock can tolerate the replacement of soybean cake with algae meal (Taelman et al., 2015). With more information known and with the production process of algae meal being optimized, algae meal could be used as a suitable replacement of soybean cake to make the production of pork meat in the Netherlands more sustainable.

5.7. CONCLUSION

Above 6 different measures have been discussed, which could reduce the influence of trade on the environment during the production of soybeans in Brazil or the production of pork meat in the Netherlands. Table 32 gives an overview of the results of the measures. It shows that almost all measures can be effective in reducing the influence of trade. Only the export of manure to Brazil and the substitution of soybeans with another protein source are not effective measures. Even though most measures give good results in decreasing the influence of trade, all measures only influence the problem partly. It is therefore necessary to combine the measures in order to reduce the problem completely.

Table 32: The results of the measures that could be implemented to reduce the influence of trade on the environment in both Brazil and the Netherlands, by either changing the production processes or changing the trade relationship (- = influence unknown)

Measures	Is the measure effective?	Possible change in nitrogen (%)	Possible change in phosphorus (%)
1. Optimum fertiliser use Brazil	Yes		
Change in fertiliser use on soybeans in Brazil		+230%	-40%
2. Replacing artificial fertiliser with manure in Brazil	Yes		
Possible replacement of artificial fertiliser with manure		100%	97% (100%)
3. Reduce manure surplus the Netherlands	Yes		
Possible reduction in nutrients in manure of pigs by changing the feed	*Yes*	-2%/-31%	-26%/-61%
Processing pig manure with reversed osmosis	*Yes*	-	-
4. Replacing artificial fertiliser with manure in the Netherlands	Yes		
Amount of artificial fertiliser still used in the Netherlands which could be replaced with manure		38%	8%
5. Export manure from the Netherlands to Brazil	No		
Possible artificial fertiliser use in Brazil which could be replacement by manure from the Netherlands		100% (42%)	6% (2%)
6. Replacing soybeans with a locally produced protein source	No		
Starch potatoes	*No*	-	-
Maize	*No*	-	-
Insects	*No*	-	-
Algae	*No*	-	-

By changing the fertiliser use in Brazil on soybeans to an optimum fertiliser use, the depletion of nitrogen and the enrichment of phosphorus of the soil could be reduced. An optimum fertiliser use for the production of soybeans in Brazil can be reached by increasing the nitrogen fertiliser use with 230% and decreasing the phosphorus fertiliser use with 40%. Changing the fertiliser use on soybeans will also change Brazil's unlikely fertiliser use. Currently the ratio between nitrogen and phosphorus use in Brazil differs from the international standards (FAO, 2004). By changing the fertiliser use the ratio of Brazil will become more in line with the rest of the world.

It has been estimated that Brazil produces enough nutrients in the manure of animals to replace the use of artificial fertiliser. For nitrogen all fertiliser need can be satisfied by the produced manure. 78% of the nitrogen produced in the manure would be left unused. For phosphorus 97% of the artificial fertiliser use could be replaced. Looking at only the fertiliser use of soybeans, there is enough manure to replace all artificial fertiliser. Manure is produced in the same location as the production of soybeans so transportation should not be an issue. With replacing artificial fertiliser with manure the difference in ratio between nitrogen and phosphorus should be taken into account, to prevent adding an excess amount of one of the nutrients.

It has been established that the Netherlands has both a nitrogen and a phosphorus surplus. These surpluses are partly caused by the import of nutrients. By changing the diet of pigs it could be possible to reduce the excretion of nutrients in pig manure, therefore reducing the manure surplus. For nitrogen a reduction of 25% could be reached, resulting in a change of 2% in the nitrogen soil surplus and 31% in the nitrogen manure surplus. For phosphorus for finishing pigs a reduction of 65% can be reached resulting in a change in the phosphorus soil balance of 26% and the phosphorus manure surplus of 61%.

By processing manure with reversed osmosis there are two different manure outputs, one being high in phosphorus and the other being high in nitrogen. With this processing methods it would become possible to monitor the application of nutrients of manure on the soil. It will become easier to apply the required amount of nutrients, without adding too little or too much of the other nutrient. This could reduce both the need of storage of manure as well as the export of manure. Even though both the reduction of nutrients in the manure and the processing of manure could help reduce the manure surplus, the low prices for pork meat will not change unless the size of the pork meat production in the Netherlands decreases.

Looking at the fertiliser use in the Netherlands, currently still 38% of the nitrogen use and 8% of the phosphorus use originates from artificial fertiliser. The manure production in the Netherlands shows there should be enough nutrients available to substitute all artificial fertiliser use. Due to the placement thresholds and the different locations of crop production and manure production the use of artificial fertiliser could be easier for some farmers. By producing the manure in a different way or making the application of artificial fertiliser more expensive the government could stimulate the use of organic fertiliser more.

Because the import of nutrients is causing problems in the Netherlands it was chosen to look at the possibility of transporting excess manure from the Netherlands back to Brazil. Comparing the fertiliser use in Brazil to the nutrient production in the Netherlands, showed that the Netherlands is producing too little nutrients to substitute the fertiliser use in Brazil. For nitrogen the production was sufficient, but for phosphorus only 6% can be replaced by imported manure. Looking only at the nutrients originating from soybeans in the feed the percentage drop to 42% for nitrogen and 2% for phosphorus. The export of manure from the Netherlands to Brazil to reduce the influence of trade is therefore not an effective measure.

The last measure which was investigated was the use of alternative protein sources. Looking at crops grown in the Netherlands, only starch potatoes and maize contain enough protein. However they both lack the nutritional values soybeans do have and the intake of both would be higher than the intake of soybeans. Therefore these crops do not seem a suitable alternative for soybeans. There are also two non-crop protein sources that could replace soybeans, insects and algae meal. They both contain the necessary protein content as well as other nutritional values that could benefit pigs. Unfortunately still little research has been carried out about the use of these two protein sources and for them to be a suitable alternative more research needs to be carried out ant the production process needs to be optimized.

6. DISCUSSION

In this paper research has been done about the influence of trade on the nutrient balance in both Brazil and the Netherlands related to the production of soybeans and pork meat. This specific case study was chosen due to the high import of soybeans from Brazil by the Netherlands and the availability of information. Even though the trade in soybeans from Brazil to the Netherlands affects many different sectors, the only processes taken into account were the production (growth) of soybeans in Brazil and the use of soybeans in pig feed for finishing pigs in the Netherlands. By looking at only these two processes in detail, a good overview could be made of the influence of trade on the environment in these two countries. If other processes would have been taken into account as well the research would have become too complex.

The production of soybeans in Brazil for export to the Netherlands has been a discussion point for years, which recently lead to a debate in the Dutch newspaper the Volkskrant among others. A discussion arose after an article of Hidde Boersma (2015), who stated that in the western civilization the environmental pollution is decreasing and that intensification of livestock farming and urbanisation is a good thing (Boersma, 2015). In a response to this article Jacomijn Pluimers (2015) stated that, even though the environmental pollution is decreasing in the Netherlands, we are polluting the environment due to import: Instead of growing food in our own country we are contributing to deforestation in South-America due to our import of for example soybeans (Pluimers, 2015). As a reply to this response Henk Flipsen (2015) stated that the import of soybeans by the Netherlands is very small, especially when looking at China who is importing 60% of the world´s soybean production whereas the Netherlands imports less than 1% (Flipsen, 2015). He also stated that one third of the imported soybeans of the Netherlands is responsible soy, i.e. soy which has been produced on land which has been agricultural land for at least 12 years (Olthuis, 2015). This is confirmed in the article of Loethe Olthuis (2015) who pointed out that the responsible soy is only used in the feed of cattle. Poultry and pig farmers find this is too expensive and they are still importing soybeans from recently deforested land (Olthuis, 2015). The discussion above shows that it is unclear how importing soybeans from Brazil to the Netherlands influences the environment. Especially the contribution of the Netherlands to environmental pollution in Brazil is unclear. With this specific case study the influence of the Netherlands on the Brazilian environment was actually estimated for the first time and it did show that the import of agricultural commodities by a western country can have negative consequences for the environment in the producing country. This includes the enrichment and depletion of the soil with nutrients, as well as other environmental impacts like deforestation and pollution with pesticides.

For this research no measurements were carried out. The research consists of a literature review in combination with existing and publically accessible data from databases. The results are therefore relying on the information of other people. The data can be considered reliable, but there is always the possibility of uncertainties, which can influence the outcome.

The research showed that the export of soybeans from Brazil to the Netherlands does in fact impact the environment in both countries, but the influence of this trade on the environment in the Netherlands is small. This can be related back to the choices made for the case study. It was chosen to only investigate the use of soybeans in the feed of finishing pigs, but also other pigs and livestock are fed with soybeans imported from Brazil. The total influence of the trade in soybeans between Brazil and the Netherlands on the Dutch environment will therefore be bigger than estimated here.

There is a difference in data between Brazil and the Netherlands. Due to the use of different databases for both countries it was difficult to use data from the same year for both countries. It has therefore been chosen to use two different years for the quantification of both countries. When looking at the traded quantities the numbers for 2011 were used, the year of quantification of Brazil, even though the specific data for the Netherlands originated from 2013. Nevertheless it is assumed that the quantification gives a good indication of the influence of trade on both nitrogen and phosphorus in 2011.

Several measures have been discussed which could reduce the impact of trade on the nutrient balance in Brazil and the Netherlands. With the quantification of the production processes, an estimation could be made about the effect of the measures. It has not been determined what this effect would be if the measure was actually implemented. The results show that there are four possible measures that could have a positive influence on the nutrient balance of Brazil and the Netherlands. These measures could further be investigated with more specific data to determine if they could be implemented.

In this research only the effect of exporting soybeans from Brazil to the Netherlands has been investigated. But there are more trade relationships and commodities exported all over the world. This research shows that, with looking at only one product line, a clear estimation can be made of the influences of one of these production lines on the involved nutrient balances. It should therefore be possible to carry out a similar research for different crops, processes, livestock and countries.

A final discussion point is the relation of this research to the water footprint. In this paper only the trade in nutrients has been taken into account. However, with the production and trade of soybeans also water is (vitually) imported and exported. In his article in the Volkskrant Peter de Waard (2015) states that, for the production of one litre milk, 225 litres water is necessary. This is not taking into account the 250 litres of water that is necessary for the production of soybeans of which only 3% actually makes it into the milk. For the production of pork meat a similar calculation can be made. Brazil is known as the 'Saudi-Arabia of water' due to 12% of the freshwater supply of the world being located here (Bessems, 2015). But currently Brazil is experiencing a water shortage with many people not having water for several parts of the day. This has been going on for years (Bessems, 2015). And even though climate change has an influence on the situation, most problems can be traced back to human actions. With Brazil being one of the leading exporting countries a part of this water shortage can be traced back to trade.

7. CONCLUSION

The objective of this research was to investigate the influence of trade on the flow of nutrients by the production of soybeans in Brazil and the production of pork meat in the Netherlands. In order to achieve this goal three research questions were defined. The research questions will be answered below.

How much fertiliser is used to produce soybeans in Brazil for export to the Netherlands?

In Brazil a total of 191,749 tonnes N/y and 690,800 tonnes P/y was used as fertiliser in 2011 to produce an amount of 74,815,448 tonnes of soybeans. Out of this 75 million tonnes of soybeans 6,818,402 tonnes of soybeans were used for export to the Netherlands. This is equal to 9% of the total production, resulting in a fertiliser use of 17,475 tonnes N/y and 62,954 tonnes P/y for the production of soybeans for export to the Netherlands. This is equal to 4.7% of the total nitrogen demand and 69.5% of the total phosphorus demand for the production of soybeans by the soybean plant. Other fertiliser sources were residues from the soil and nitrogen fixation from the air by the soybean plant itself.

With the current fertiliser scheme Brazil is adding too little nitrogen to the soil. As a result the soil is being depleted of nitrogen with an amount of 51,203 tonnes N/y, 13.6% of the total nitrogen demand of the soybean plant. For phosphorus the result is the other way around, too much phosphorus is added to the soil resulting in an enrichment of 30,964 tonnes P/y, equal to 34.2% of the total phosphorus demand of the soybean plant. These results show that the import of soybeans by the Netherlands has negative effects on the environment in Brazil.

How many nutrients are present in the manure of pigs, as a result of eating soybeans that originate from Brazil?

The Netherlands is importing whole soybeans as well as soybean oil and soybean cake out of Brazil. These three products together contain an amount of 375,133 tonnes N/y and 59,560 tonnes P/y. In the Netherlands the soybean products are mainly used in animal feed, but can also be found in food and other products. Approximately 11,821 tonnes of the imported nitrogen and approximately 1,907 tonnes of the imported phosphorus end up in the feed of finishing pigs. As a result of eating the imported soybeans, the pigs excrete an amount of 7,379 tonnes N/y and 1,088 tonnes P/y. This is equal to 2% of the total nitrogen imported from Brazil and 1.8% of the imported phosphorus.

Figure 26 shows the amount of nitrogen needed for the production of soybeans to be used in the pig feed of finishing pigs in the Netherlands. It shows that in total an amount of 513 tonnes nitrogen is applied as fertiliser and the soil is being depleted with 2,719 tonnes of nitrogen. As a result of eating the soybeans the pigs in the Netherlands excrete an amount of 7,379 tonnes of nitrogen. Looking at the absolute values, the influence of trade in soybeans from Brazil to the Netherlands for the use in pig feed is influencing the environment in the Netherlands more. Looking at the percentages, the depletion as a result of soybeans for pig feed is 0.8% of the

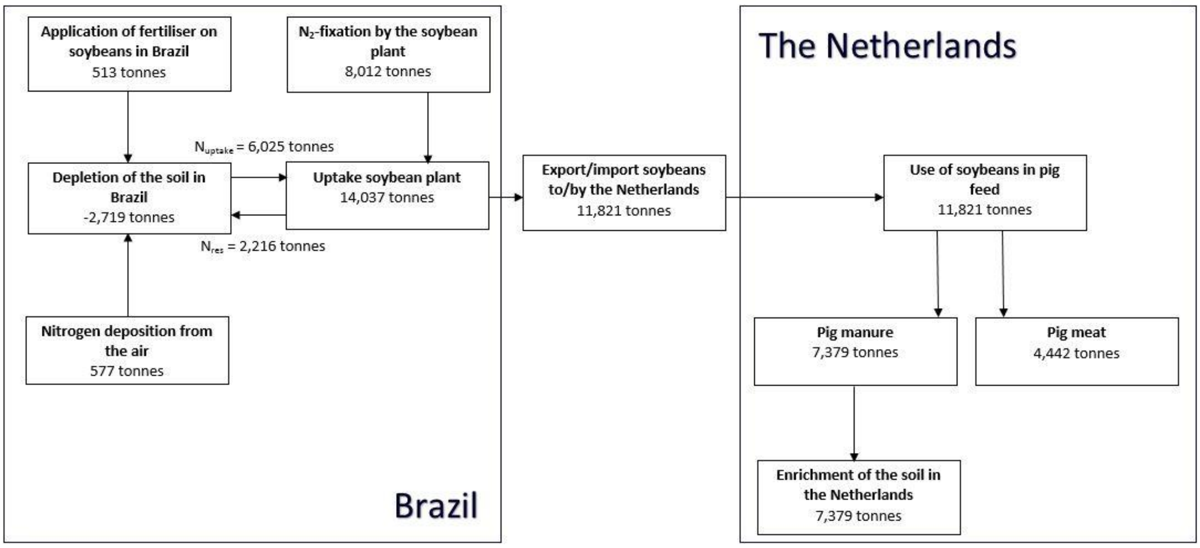

Figure 26: The amount of nitrogen used on 64,095 ha needed for the production of soybeans needed for pig feed of 5,657,191 finishing pigs in the Netherlands

total depletion, whereas the excretion of nitrogen in pig manure is equal to 2.3% of the total manure use in the Netherlands and 1.1% of the total fertiliser inputs into the Dutch soil. It can be assumed that the import of soybeans from Brazil for the use in pig feed of finishing pigs is causing an enrichment of nitrogen of 1.1% in the Dutch soil. This shows that, looking at the scale of the case study, the influence on the environment is small, with the influence in the Netherlands being slightly higher.

The situation for phosphorus is shown in figure 27. For the production of soybeans, used in the feed of finishing pigs in the Netherlands, an amount of 1,847 tonnes of phosphorus is necessary. As a result of eating these soybeans, pigs in the Netherlands excrete an amount of 1,088 tonnes of phosphorus. The quantification in chapter 2 showed an enrichment of phosphorus in the soil in Brazil due to the production of soybeans, this overview shows a depletion. This is due to the fact that the amount of phosphorus exported is determined based on the difference in soybean products, whereas the fertiliser use is determined for only the whole soybeans. The amount of phosphorus in soybean cake is higher than the amount of phosphorus in whole soybeans, resulting in this change. Out of all the phosphorus used in Dutch agriculture originating from manure, 2.0% is originating from soybeans imported out of Brazil and eaten by finishing pigs. Looking at the total fertiliser inputs this value drops to 1.8%. So the import of soybeans from Brazil for the use in feed of finishing pigs, results in an enrichment of phosphorus of the Dutch soil of 1.8%. As a consequence of the production of these soybeans Brazil is experiencing -0.02% enrichment. As for nitrogen the influence of only producing soybeans for the use in pig feed in Brazil is small. The influence on the Dutch environment is slightly higher, but it is still only a small percentage of the total phosphorus enrichment.

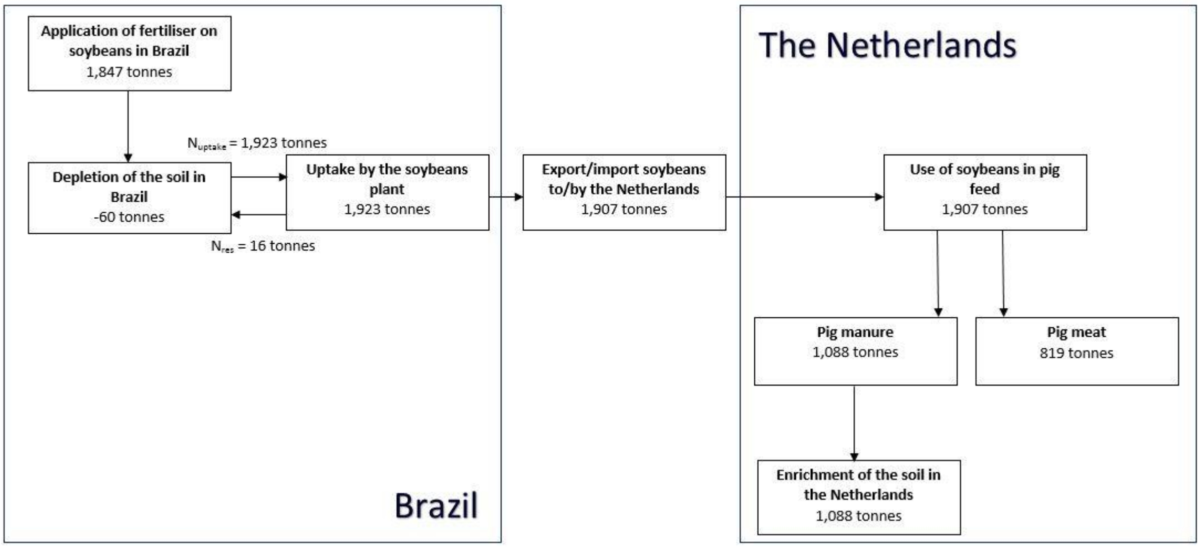

Figure 27: The amount of phosphorus used on 64,095 ha needed for the production of soybeans needed for pig feed of 5,657,191 finishing pigs in the Netherlands

How could the influence of trade on the environment in both Brazil and the Netherlands be reduced?

There are six different measures that can alter the influence of trade in soybeans from Brazil to the Netherlands by either closing the production cycles on a smaller scale, or reducing the scale of the production. Of the six measures only four are effective:

- By adapting the fertiliser use of soybeans in Brazil the depletion and enrichment of the soil can be reduced. In order to reduce the environmental impacts to a minimum the nitrogen fertiliser use should increase with 230%. The phosphorus fertiliser use should decrease by 40%.
- Looking at the manure production in Brazil it should be possible to replace all artificial nitrogen fertiliser use and 97% of all artificial phosphorus fertiliser use. Looking at only the phosphorus fertiliser needed for the production of soybeans, the production of phosphorus in the manure is sufficient to replace all artificial fertiliser use. By replacing artificial fertiliser use with manure the enrichment of the environment in Brazil due to the application of manure on secluded areas will decrease and the demand for artificial fertiliser will decrease resulting in a possible drop in artificial fertiliser production.
- The manure surplus in the Netherlands can be decreased by either changing the diet of the animals to reduce the amount of nutrients present in the manure or by processing the manure in a different way

to make the application of manure more effective. Changing the diet of finishing pigs can lead to a reduction of the nitrogen manure surplus of 31% and a reduction of the phosphorus surplus of 61%.

- Even though the Netherlands is a country in which a lot of the manure is already used as fertiliser, some artificial fertiliser is still used. For nitrogen an amount 38% still originates from artificial fertiliser and for phosphorus this amount is equal to 8%. Looking at the manure production in the Netherlands there should be enough nutrients available to replace this artificial fertiliser use

The two measures that were not effective in altering the influence of the trade relationship between Brazil and the Netherlands was the export of manure from the Netherlands to Brazil and the replacement of soybeans with another protein rich crop. By substituting the protein source in pig feed, the demand in soybeans could drop. In the Netherlands not enough nutrients are produced in pig manure to substitute the fertiliser use of soybeans in Brazil because the surplus in the Netherlands mainly consists of nitrogen whereas the fertiliser use in Brazil mainly consists of phosphorus. Brazil is receiving nutrients, but it would need nutrients from other countries as well to receive sufficient. Also it is expected that Brazil produces enough nutrients itself in their manure. Importing manure to be used as artificial fertiliser could therefore lead to a shift of the problem.

Only two crops which are grown in the Netherlands contain enough protein to substitute soybeans: maize and starch potatoes, but they both lack in nutritional value. Therefore they could only be used if the diet was changed considerably. Looking at other sources of protein there is the possibility of using both insects and algae. Both contain enough protein to substitute soybeans and contain other nutritional values which could benefit pigs. However the production of both protein sources is not yet effective enough to be a sustainable alternative for soybeans, and more research needs to be done about the effect of these two protein sources on the digestibility by pigs.

All measures described above focus on changing a part of the current production cycles. However there is one solution that could reduce the influence of trade all together: reducing the scale of the pork meat production in the Netherlands. If less pigs would be kept in the Netherlands, less manure would be produced. With a fewer number of pigs, the amount of feed needed would also decrease, leading to a lower demand and import of soybeans. This could lead to a reduction in the soybean production in Brazil. However this could have negative consequences for the Brazilian economy. But for the Netherlands it could have a positive economic effect. Due to a decrease in supply of meat the currently low prices for pork meat could increase.

8. RECOMMENDATIONS

Based on the discussion and conclusion several recommendations can be made about influencing the trade relationship between Brazil and the Netherlands. The recommendations can be divided into recommendations for policy changes or recommendations for further research. The recommendations in section 8.1 focus on changing the policies that revolve around the discussed production processes in either the Netherlands or Brazil. The recommendations in section 8.2 focus on possible further research.

8.1. RECOMMENDATIONS FOR POLICY CHANGE

The recommendations for a possible change in policy mainly focus in the production of soybeans in Brazil. This research has shown that the production of soybeans in Brazil currently is not sustainable. By making a few adjustments the impact of the production of soybeans on the environment could be reduced.

1) Changing the fertiliser use in Brazil

It is recommended that the government in Brazil stimulates the use of manure as fertiliser on commercial grown crops. If the government stimulates the use of manure, by for example subsidies, higher prices for artificial fertiliser or awareness, it will become more attractive for farmers to use manure instead of artificial fertiliser. The manure will be used more effectively, instead of being applied to land close to the farm on which it is produced.

2) Optimizing the fertiliser use on soybeans in Brazil

It is recommended that the fertiliser use on soybeans in Brazil is adapted to the demand of the soybean plant. The estimation in this research shows that, with the current fertiliser practise, too little nitrogen and too much phosphorus is added. Adapting the fertiliser use to suit the demand of the soybean plant would decrease the strain of the production of soybeans on the environment without reducing the revenues.

3) Adapting the diet of finishing pigs in the Netherlands

It is recommended that the diet of finishing pigs in the Netherlands is adapted to reduce the amount of nutrients in the manure excreted. Research showed it is possible to decrease both the nitrogen excretion and the phosphorus excretion. However the research discussed in this paper only focusses on decreasing one of the two nutrients. It is therefore recommended to investigate if it is possible to reduce both nutrients at the same time.

4) Making the application of manure in the Netherlands more effective

It is recommended that manure in the Netherlands is processed with reversed osmoses in order to obtain two mineral concentrates, which either contain a high amount of nitrogen or a high amount of phosphorus. Processing manure on a large scale with this method does not have a significant effect on the emission of ammonia and it will make the application of manure on crop land and pastures in the Netherlands more effective, reducing the need for export.

5) Decreasing the pig population in the Netherlands

A part of the environmental problems in both Brazil and the Netherlands are caused by the scale of the production. It is therefore recommended that the production of pork meat in the Netherlands would be decreased. This would result in a decrease in manure production, reducing the manure surplus, a decrease in the demand of soybeans, which could possibly lead to a decrease in soybean production and it could increase the currently low price of pork meat on the European market due to a decrease in supply.

8.2. RECOMMENDATIONS FOR FURTHER RESEARCH

The recommendations for further research focus on the implementation of the measures that have been discussed during this research and the possibility of extending this research into other fields or countries.

1) Carrying out more research about the use of both insect meal and algae meal as a protein source in pig feed

The export of soybeans from Brazil to the Netherlands does not only have negative consequences for the environment in both countries based on nutrients, it also contributes to the drought problem in Brazil. But currently there is no suitable alternative protein source which can be produced within Europe. It is therefore recommended that more research is carried out on the use of both insects and algae in pig feed as a protein source to replace the use of soybeans in pig feed.

2) <u>Extending the research to include all livestock in the Netherlands fed with soybeans in Brazil</u>

In this research only the effect of imported soybeans on the manure of finishing pigs was taken into account. The estimation shows that of the nutrients imported only a small amount reaches the Dutch soil through the manure of pigs. But finishing pigs are not the only animals that get fed soybeans originating from Brazil. Approximately 94% of the total imported soybean products is used in the feed of other animals. To get a complete overview of the influence of the import of soybeans from Brazil on the Dutch environment it is recommended to also investigate the use of soybeans in the feed of other animals.

3) <u>Carrying out this research for other crops, processes and countries</u>

This research has shown that, by looking at one specific case study, it is possible to determine how trade is influencing the environment of the countries involved. It is therefore recommended that this research is extended to include other crops, processes and counties. By determining specific case studies it should be possible to estimate the influence of trade on a larger scale.

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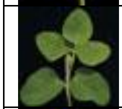
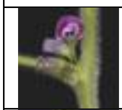
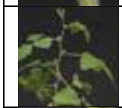
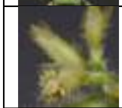
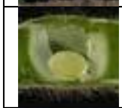
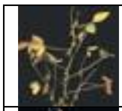
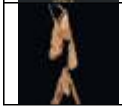
APPENDIX I: GROWTH STAGES OF THE SOYBEAN PLANT

This appendix gives an overview of the soybean growth stages as described by the Department of Agronomy of the Iowa State University (2015). The growth stages can be divided into two parts: the vegetative stages (V) and the reproductive stages (R). The vegetative states are divided based on the number of fully-developed trifoliate leaves that are present. Trifoliate leaves are leaves that consists of three parts, like clovers, which is a typical feature of the soybean plant. The reproductive stages start at the flowering of the plant and end when the plant is fully developed and ready for harvesting.

Table 33 shows the different growth stages as described by Department of Agronomy (2015) with a picture of how the plant looks at that specific state. Not all plants develop in the same past, so growth stages will overlap when producing soybeans. A new growth stage begins when 50% or more of the plants are in or beyond that stage (Department of Agronomy, 2015).

Table 33: An overview of the growth stages of the soybean plant as described by the Department of Agronomy of the Iowa State University (2015)

Vegetative Stages		
	VE	**Emergence** – cotyledons (the first part of the plant after sprouting) have been pulled through the soil surface
	VC	**Unrolled unifoliate leaves** – unfolding of the unifoliate leaves
	V1	**First trifoliate** – one set of unfolded trifoliate leaves
	V2	**Second trifoliate** – two sets of unfolded trifoliate leaves
	V4	**Fourth trifoliate** – four unfolded trifoliate leaves
	V(n)	**n^{th} trifoliate** – the final number of trifoliate leaves depends on cultivar and environmental conditions
Reproductive stages		
	R1	**Beginning flowering** – plants have at least one flower on any node
	R2	**Full flowering** – there is an open flower at one of the two uppermost nodes
	R3	**Beginning pod** – pods are 5 mm at one of the four uppermost nodes
	R4	**Full pod** – pods are 2 cm at one of the four uppermost nodes
	R5	**Beginning seed** – seed is 3 mm long in the pod at one of the four uppermost nodes on the main stem
	R6	**Full seed** – pod containing a green seed that fills the pod capacity at one of the four uppermost nodes on the main stem

	R7	**Beginning maturity** – one normal pod on the main stem has reached its mature pod colour
	R8	**Full maturity** – 95% of the pods have reached their full mature colour

APPENDIX II: CALCULATION MANURE PRODUCTION

The manure production in both Brazil and the Netherlands is based on the mineral excretion factors of the Central Bureau of Statistics of the Netherlands (CBS). For Brazil the mineral excretion factors for 2011 are used (Centraal Bureau voor de Statistiek, 2012), and for the Netherlands the mineral excretions factors of 2013 are used (Centraal Bureau voor de Statistiek, 2014). In the two sections below the calculations for both countries are explained.

II.I. BRAZIL

The nutrients in the manure production in Brazil is calculated based on the mineral excretion factors by the CBS for the Netherlands (Centraal Bureau voor de Statistiek, 2012). These values are given in nitrogen per animal and P_2O_5 per animal. The number of animals in Brazil is obtained through the FAOSTAT database (2011k). The mineral excretion factors are very detailed and specify the excretion for each type of animal making a distinction between animals for meat production, animals for milk production and animals kept on grass or in stables. The number of animals given by the FAOSTAT (2011k) are aggregated per type of animal. Therefore the mineral excretion factors given by the CBS (Centraal Bureau voor de Statistiek, 2012) will first be averaged to determine one value for each animal type.

The average mineral excretion factors will be determined using data about the number of animals in the Netherlands. The CBS (2015b) gives a detailed overview of the number of animals in the Netherlands in 2013. With these numbers the percentage of one type of animal to the total number can be determined and multiplied with this animal's mineral excretion factor. These factors can then all be summed up with each other to obtained one mineral excretion factor for each animal type. The CBS (2015b) does not give a number of animals for 2011. The ratio in animals in Brazil can be expected to be different, but because detailed information is missing this will be used as an estimation.

Table 34 shows the mineral excretion factors for grazing animals in the Netherlands for 2011, together with the total amount of animals in the Netherlands in 2013, necessary to determine one excretion factor for cattle. The percentages are determined by dividing the type of cattle with the total number of cattle. By multiplying with the excretion factors for 2011, the excretion factors for Brazil for grazing animals are determined. These factors have been used to determine the nutrients in the manure production of Brazil in chapter 5. For grazing animals excretion factors are given for the whole year, the time they are on pastures and the time they spend in the stable. For the determination of the amount of manure in Brazil only the factors for manure production in the stable are used. The manure which is left on the pasture while grazing is considered lost and cannot be used as a replacement for artificial fertiliser. Therefore these values will not be taken into account.

Table 35 shows the mineral excretion factors for animals which are only kept in stables for 2011, with the number of animals in the Netherlands in 2013. The percentages are determined by again dividing the types of chickens and pigs with the total amount of chickens and pigs, resulting in one excretion value for pigs and chickens for Brazil for 2011. These values have been used to determine the nutrients in the manure production of animals in Brazil in 2011 in chapter 5.

II.II. THE NETHERLANDS

The nutrients in the manure of animals in the Netherlands has been determined based on the mineral excretion values for 2013 (Centraal Bureau voor de Statistiek, 2014). The mineral excretion factors together with the number of animals in the Netherlands are shown in tables 36 and 37. As for Brazil the values for nutrient excretion for the stables is used for grazing animals. The time these animals spend on pastures and the manure they produce during this time will not be taken into account, because it is assumed that this manure cannot be reused as a replacement for artificial fertiliser on crops. In order to determine the total amount of nutrients produced by these animals the nutrient excretion factors are multiplied with number of animals to obtain the total nutrient production in manure in 2013. The results are shown in chapter 5.

Table 34: The mineral excretion factors for grazing animals for Brazil for the year 2011 as given by the CBS (2012), with the number of animals in the Netherlands in 2013 (CBS, 2015b)

Grazing animals			**Number of animals in 2013**	**% of cattle**	**Nitrogen excretion factor 2011 (kg/animal)**	**P_2O_5 excretion factor 2011 (kg/animal)**	**Nitrogen excretion factor Brazil (kg/animal)**	**P_2O_5 excretion factor Brazil (kg/animal)**
Cattle	Cattle, total		3,999,220	100	-	-	47.1	14.6
	Young cattle for dairy	Young dairy cattle, < 1 year, female	573,130	14	28.9	7.9	4.1	1.1
		Young dairy cattle, < 1 year, male	40,400	1	32.4	8.2	0.3	0.1
		Young dairy cattle, 1-2 year, female	530,870	13	49.2	14.5	6.5	1.9
		Young dairy cattle, 1-2 year, male	13,120	0	82.7	25.5	0.3	0.1
		Young dairy cattle, >= 2 year, female	85,660	2	49.3	14.5	1.1	0.3
	Meat cattle	Meat cattle for pink meat (< 1 year)	337,050	8	14.0	5.6	1.2	0.5
		Meat cattle for white meat (< 1 year)	588,400	15	27.3	8.3	4.0	1.2
	Young cattle for meat production	Young meat cattle, < 1 year, female	34,360	1	28.6	7.9	0.2	0.1
		Young meat cattle, < 1 year, male	43,510	1	23.9	6.5	0.3	0.1
		Young meat cattle, 1-2 year, female	37,570	1	48.6	14.3	0.5	0.1
		Young meat cattle, 1-2 year, male	42,290	1	51.5	16.7	0.5	0.2
		Young meat cattle, >= 2 y, female	22,250	1	48.6	14.3	0.3	0.1
	Milk- and breeding cows (>= 2 year)		1,552,920	39	68.8	21.9	26.7	8.5
	Remaining cows		83,600	2	37.6	12.3	0.8	0.3
	Bulls (>= 2 year)	Bulls for breading (>= 2 year)	7,760	0	82.7	25.5	0.2	0.0
		Bulls for meat production (>= 2 year)	9,460	0	51.1	16.7	0.1	0.0
Sheep			1,033,570		1.2	0.5	1.2	0.5
Goats			412,550		17.6	6.9	17.6	6.9
Horses			88,610		30.3	12.0	30.3	12.0

Table 35: The mineral excretion factors for stable animals for Brazil for the year 2011 as given by the CBS (2012), with the number of animals in the Netherlands in 2013 (CBS, 2015b)

Animals kept in stables			**Number of animals in 2013**	**% of pigs or chickens**	**Nitrogen excretion factor 2011 (kg/animal)**	**P_2O_5 excretion factor 2011 (kg/animal)**	**Nitrogen excretion factor Brazil (kg/animal)**	**P_2O_5 excretion factor Brazil (kg/animal)**
Pigs	Pigs, total		12,212,300	100	-	-	21.7	9.9
	Breading pigs	Sows and boars, 20 till 50 kg	101,370	1	15.9	6.4	0.1	0.1
		All sows (including the piglets)	6,348,500	52	30.1	14.6	15.6	7.6
		Boars, 50 kg or more, not yet sexual mature	2,330	0	15.9	6.4	0.0	0.0
		Boars, 50 kg or more, sexual mature	6,060	0	23.4	12.0	0.0	0.0
	Finishing pigs		5,754,050	47	12.5	4.7	5.9	2.2
Chickens	Chickens, total		97,719,300	100	-	-	0.65	0.29
	Laying hens	Laying hens, younger than 18 weeks	10,128,300	10	0.35	0.17	0.04	0.02
		Laying hens, 18 weeks or older	34,687,500	35	0.78	0.40	0,28	0.14
	Parent chickens		8,661,400	9	1.12	0.57	0.10	0.05
	Broiler chickens		44,242,000	45	0.52	0.18	0.24	0.08
Turkeys			840,800	-	1.85	0.93	1.85	0.93
Ducks			810,400	-	0.79	0.37	0.79	0.37
Rabbits			311,000	-	7.8	3.5	7.80	3.50

Table 36: The number of animals, the mineral excretion factors for grazing animals as given by the CBS (2014) and the total nutrient production for the Netherlands in 2013 (CBS, 2015b)

Grazing animals			**Number of animals in 2013**	**Nitrogen excretion factor 2013 (kg/animal)**	**P_2O_5 excretion factor 2013 (kg/animal)**	**Total nitrogen production (tonnes/y)**	**Total P_2O_5 production (tonnes/y)**
Cattle	Cattle, total		3,999,220	-	-	180,809	56,747
	Young cattle for dairy	Young dairy cattle, < 1 year, female	573,130	29.1	8,1	16,678	4,642
		Young dairy cattle, < 1 year, male	40,400	31.8	8.0	1,285	323
		Young dairy cattle, 1-2 year, female	530,870	49.0	15.2	26,013	8,069
		Young dairy cattle, 1-2 year, male	13,120	81.8	26.4	1,073	346
		Young dairy cattle, >= 2 year, female	85,660	49.0	15.2	4,197	1,302
	Meat cattle	Meat cattle for pink meat (< 1 year)	337,050	14.5	5.2	4,887	1,753
		Meat cattle for white meat (< 1 year)	588,400	23.2	7.0	13,651	4,119
	Young cattle for meat production	Young meat cattle, < 1 year, female	34,360	28.7	8.0	986	275
		Young meat cattle, < 1 year, male	43,510	20.0	5.4	870	235
		Young meat cattle, 1-2 year, female	37,570	48.5	15.1	1,822	567
		Young meat cattle, 1-2 year, male	42,290	44.6	14.9	1,886	630
		Young meat cattle, >= 2 y, female	22,250	48.6	15.1	1,081	336
	Milk- and breeding cows (>= 2 year)		1,552,920	65.9	21.1	102,337	32,767
	Remaining cows		83,600	35.7	12.4	2,985	1,037
	Bulls (>= 2 year)	Bulls for breading (>= 2 year)	7,760	81.8	26.4	635	205
		Bulls for meat production (>= 2 year)	9,460	44.6	14.9	422	141
Sheep			1,033,570	1.2	0.5	1,240	517
Goats			412,550	16.9	6.9	6,972	2,847
Horses and pony's	Horses and pony's, total		130,540	-	-	3,247	1,242
	Horses		88,610	30.4	11.7	2,694	1,037
	Pony's		41,930	13.2	4.9	553	205

Table 37: The number of animals, the mineral excretion factors for stable animals as given by the CBS (2014) and the total nutrient production for the Netherlands in 2013 (CBS, 2015b)

Stable animals			Number of animals in 2013	Nitrogen excretion factor 2013 (kg/animal)	P_2O_5 excretion factor 2013 (kg/animal)	Total nitrogen production (tonnes/y)	Total P_2O_5 production (tonnes/y)
Pigs	Pigs, total		12,212,300	-	-	268,238	117,598
	Breading pigs	Sows and -boars, 20 to 50 kg	101,370	15.5	6.5	1,571	659
		All sows (including the piglets)	6,348,500	31.1	14.6	197,438	92,688
		Boars, 50 kg or more, not yet sexual mature	2,330	15.5	6.5	36	15
		Boars, 50 kg or more, sexual mature	6,060	23.7	11.4	144	69
	Finishing pigs		5,754,050	12.0	4.2	69,049	24,167
Chickens	Chickens, total		97,719,300	-	-	61,547	27,830
	Laying hens	Laying hens, younger than 18 weeks	10,128,300	0.35	0.20	3,545	2,026
		Laying hens, 18 weeks or older	34,687,500	0.77	0.40	26,709	13,875
	Parent chickens		8,661,400	1.11	0.56	9,614	4,850
	Broiler chickens		44,242,000	0.49	0.16	21,679	7,079
Turkeys			840,800	1.74	0.98	1,463	824
Ducks			810,400	0.74	0.38	600	308
Rabbits			311,000	8.2	4.1	2,550	1,275
Fur-bearing animals			1,031,200	2.2	1.3	2,269	1,341