Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Soil and Environment

Self-evaluation of the Risk of Enhanced Nutrient Leaching by Polish Farmers
– Nutrient balances, Soil maps, Farm walks and other tools

Beatrice Ramnerö

Master's Thesis in Soil Science
Agriculture Programme – Soil and Plant Sciences

Examensarbeten, Institutionen för mark och miljö, SLU
2015:07

Uppsala 2015

SLU, Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Soil and Environment

Beatrice Ramnerö

Self-evaluation of the Risk of Enhanced Nutrient Leaching by Polish Farmers - Nutrient balances, Soil maps, Farm walks and other tools

Supervisor: Barbro Ulén, Department of Soil and Environment, SLU
Examiner: Lars Bergström, Department of Soil and Environment, SLU

EX0430, Independent project/degree project in Soil Science - Master´s thesis, 30 credits, Advanced level, A2E
Agriculture Programme – Soil and Plant Sciences 270 credits (Agronomprogrammet – inriktning mark/växt 270 hp)

Series title: Examensarbeten, Institutionen för mark och miljö, SLU
2015:07

Uppsala 2015

Keywords: nitrogen, phosphorus, potassium, nutrient use efficiency, soil status, liming, loss to water

Online publication: http://stud.epsilon.slu.se

Cover: Water course running through an agricultural landscape in Poland, 2015, photo by author

Abbreviations

EU15 - the EU number states in 31 December 2003

EU27 - EU15 plus 12 members joined until 1.1. 2007

EU28 - EU27 plus Croatia (joined 1/7 2013)

FGB – Farm gate balance. Balance illustrating nutrient input and outputs at farm level.

K – Potassium, plant nutrient.

LSU – Livestock unit. Number of animals per hectare.

N – Nitrogen, plant nutrient.

NPK- Nitrogen, phosphorus and potassium. Common combination of plant nutrients in mineral fertilizers.

NS – Nutrient surplus

NUE – Nutrient use efficiency

P – Phosphorus, plant nutrient.

Department of Soil and Environment, SLU
Box 7050, SE-750 07 Uppsala, Sweden
Org.nr 202100-2817
tel: +46 (0)18-67 10 00
www.slu.se

Abstract

Nutrient emissions from Poland are the most important sources of both nitrogen (N) and phosphorus (P) to the Baltic Sea. For this reason it is important to reduce nutrient leaching from Polish agriculture and make farmers aware of how they can act to reduce the risk for nutrient leaching. One way to create awareness of nutrient flow on farm scale among the farmers is to make quantifications of nutrient flows (for example farm gate balances). This can help the farmers to re-evaluate the management of nutrient on their farm and may help to reduce nutrient losses. Nutrient balances are a useful tool to compare farms and farm systems, but also to identify hotspots for nutrient emissions.

In this report data from the BalticSea 2020- financed project ‘Self- evaluation concerning nutrients by farmers in Poland’ is assessed. Data in form of farm gate balances, calculations of the risk for N-leaching, soil maps and farm walking protocols are gathered from 50 farms. The project focus is to increase the knowledge and awareness of environmental issues in agriculture among the involved farmers which lives in the Pomeranian and Mazovian provinces. The overall aim with this thesis was to evaluate if the farm balances, estimates of nitrogen leaching and other activities seemed to have been successful or not and if they can be expected to have any effect on the farm management.

From the farm gate balances it can be concluded that the most nutrient surpluses are found on animal farms. Most farms involved have a surplus of nitrogen, but at the same time it is common with deficits of phosphorus and potassium at farm level. The soil analysis indicates a great need for additional phosphorus and potassium fertilization, but since deficits are common the soil can be expected to be depleted. Also the need for liming is large in both Mazovia and Pomerania and due to urgent need for liming it can be assumed that liming of the soils would improve farm conditions.

The advisors involved in this project estimated appropriate farm gate balances but they had greater problems estimating nitrogen leaching from single fields. The errors commonly made indicated that the advisors did not completely understand how these rough estimates should have been done and how the results could be interpreted. However, the measures performed in this project can be assumed to give a positive effect on nutrient management on the farms involved. This since the knowledge on environmental questions in the agriculture is presently low and a project like this can be assumed to increase the knowledge among farmers. To achieve improved results further education of advisors should be prioritized to make them more confident in how to use these tools to help farmers improve their nutrient management.

Sammanfattning

Näringsläckage från Polen är den mest betydande källan av både kväve och fosfor till Östersjön. Av denna anledning är det viktigt att reducera näringsläckaget från polskt lantbruk och göra lantbrukarna mer medvetna om hur de själva kan agera för att minska risken för näringsläckage. Ett sätt att skapa en större medvetenhet bland lantbrukare är att kvantifiera de näringsflöden som sker på gårdsnivå, genom att göra näringsbalanser. Detta är verktyg som kan hjälpa lantbrukare att utvärdera hur näringseffektiv deras verksamhet är och hjälpa dem att minska risken för läckage. Gårdsbalanser är även användbara för att identifiera skillnader mellan gårdar, brukningssystem och för att identifiera högriskområden för näringsläckage.

I denna rapport analyseras data från projektet ” Utvärdering och riskbedömning gällande näringsförluster i småjordbruk i Polen”, ett projekt finansierat av BalticSea 2020. Data i form av gårdsbalanser, beräkningar av kväveläckagerisk, markkarteringar samt gårdsvandringar har samlats in från 50 gårdar i de polska regionerna Pommern och Mazovien. Projektet fokuserar på att öka de deltagande lantbrukarnas kunskap och medvetenhet om miljöfrågor kopplade till jordbruket. Det övergripande syftet med denna rapport är att analysera om gårdsbalanserna, läckageberäkningarna, markanalyserna och gårdsvandringarna verkar ha varit lyckade eller inte och om de kan förväntas ge någon effekt på hur lantbrukarna driver sina gårdar.

Från gårdsbalanserna går det att dra slutsatsen att de flesta näringsöverskott återfinns på djurgårdar. De flesta gårdar som är med i studien uppvisar ett överskott av kväve på gårdsnivå, men samtidigt visar balanserna att det är vanligt att det är brist på fosfor och kalium. Markkarteringen visar att det finns ett stort behov av att tillföra fosfor och kalium till de flesta fält, men eftersom näringsbalanserna ofta visar ett underskott av fosfor och kalium på gårdsnivå kan jordarna antas bli allt mer utarmade. Det finns även ett stort behov av att höja pH-värdet i jordarna, och regelbunden kalkning kan antas förbättra förutsättningarna för växtodling på de studerade gårdarna.

Rådgivarna som deltog i projektet har lyckats mycket väl med att göra gårdsbalanser, men de har haft större problem med att beräkna kväveläckagerisken. De fel som gjorts i en stor del av beräkningarna indikerar att rådgivarna har haft svårt att förstå hur excelarket som beräknar läckagerisk fungerar och hur resultaten från uträkningarna kan användas. Trots det kan de aktiviteter som genomförts i detta projekt antas ge en positiv effekt på näringshanteringen på gårdsnivå. Detta eftersom kunskapen kring miljöfrågor kopplade till jordbruk är relativt låg bland polska lantbrukare. Ett projekt som detta kan antas öka kunskapen bland lantbrukarna. För att nå än bättre resultat bör utbildning av rådgivare prioriteras för att göra dem mer bekväma i hur de ska använda de verktyg de fått för att hjälpa lantbrukare att förbättra sin verksamhet.

Popular science summary

The Baltic Sea is heavily affected by algae blooms due to eutrophication caused by leaching of the plant nutrients nitrogen and phosphorus from adjacent land areas. Nutrient leaching from Polish agriculture is the largest source of nutrients to the Baltic, since Poland is the country with the largest share of agriculture within the catchment area of the sea. Therefore, it is of great importance that the nutrient leaching from Polish agriculture is reduces and that the Polish farmers become aware of how they can act to reduce the risk of nutrient leaching.

One way to create a greater awareness among farmers is to illustrate the nutrient flow at farm gate level by calculating the amount of nutrient imported and exported to the farm. The information gathered is later compiled to what is called a farm gate nutrient balance. The result from the balance can help the farmer to evaluate their nutrient management to see if the nutrient is used in an efficient way. Farm gate balances can also show differences among farms and can be used to identify high-risk areas where a lot of nutrient is gathered.

In this report data from the BalticSea 2020- financed project ‘Self- evaluation concerning nutrients by farmers in Poland’ is assessed. In the first step of the project local advisors were educated. They later visited the 50 farms included in this study to give advice on how to improve their businesses from an environmental point a view. Besides making farm gate balances, calculations of the risk for nitrogen leaching were made and soil maps describing the quality of the soil were created. Also, the advisors walked over the farm together with the farmer to identify simple and cost efficient measures to improve nutrient handling. All of these actions focus on improving the awareness among farmers for environmental questions connected to the agriculture. The overall aim with this report is to analyze how far this work, to increase the awareness among farmers, have come and if the farmers will change their farm management as a consequence. The knowledge about environmental issues is rather low among Polish farmers. Therefore, advisory visits with environmental focus can be expected to increase their knowledge and as a consequence reduce the risk for nutrient leaching. Especially if the visits are combined with creating crop- and fertilizer plans for the farm. To achieve a greater effect the education of the advisors should be prioritized and further developed. The advisors wished to have more time for this project and to be able to return to each farm more often. It is clear that it is not the making of the farm balances and the leaching estimations that can be expected to have the greatest effect, but the understanding generated from the follow-up counselling.

Table of content

1 Introduction

Due to eutrophication, the Baltic Sea is suffering from algal blooms, dead zones and reduced biodiversity. Eutrophication is caused by delivery of nutrients from land (agriculture, sewage treatment plants, and individual waste water systems), from internal loading from sea sediment and transport through inlets from other seas (BalticSea 2020 (a), 2014). The Baltic Sea is a shallow enclosed sea with brackish water and due to its long turnover rate (25 y) it is vulnerable to eutrophication (Steineck et al 2000).

Nutrient leaching from agriculture is one of the main sources of nutrient loads to the Baltic Sea and therefore this needs to be reduced (HELCOM, 2009). Agriculture contributes with about one third of the total external load of P and about the half of the total load of N that ends up in the Baltic Sea (HELCOM, 2009). Except from nutrient leaching that reaches the Baltic with water streams, ammonia emissions from manure may deposit directly in the Baltic Sea or in waters that ends up in the Baltic. The direct deposition of ammonia is the main impact of agriculture at the Baltic Sea (27% of the total impact) (Gren et al 1995). Nutrient emissions from Poland are the most important source of both N and P to the Baltic Sea. The emissions from Poland accounts for 27 % of the total nitrogen load to the Baltic and 34% of the phosphorus load (HELCOM, 2009).

One way to create awareness of nutrient flows on farm scale among the farmers is to quantify nutrient flows (for example farm gate balances). This can help the farmers to re-evaluate the management of nutrient on their farm and may help to reduce nutrient losses. Nutrient balances are useful tools for comparing different farms and farm systems, but also to identify hotspots for nutrient emissions (Schröder et al., 2003, Dalgaard et al., 2012). From the farm nutrient balance the nutrient surplus for each specific farm is estimated. A positive correlation is generally found between nutrient (nitrogen in this case) surpluses and concentrations of nitrates in soil and groundwater, as well as concentration of ammonia in the surrounding air (Dalgaard et al., 2012).

In this report data from the BalticSea 2020- financed project ‘Self- evaluation concerning nutrients by farmers in Poland’ is assessed. The project focus is to increase the knowledge and awareness of environmental issues in agriculture among the involved farmers who live in the provinces Pomerania (in the north of Poland) and Mazovia (in the middle of Poland). On every farms included in this study a farm gate balance was made to illustrate farm nutrient management. An estimation of risk for nitrogen leaching from different fields or plots, a farm walk to identify risk areas and soil analysis resulting in maps were also made on every farm. This was done to have a material to discuss around with the involved farmers and if possible identify simple and cost-efficient measures that can be performed at the specific farm (Ulén et al, 2013).

1.1 Purpose and aim

The purpose of this thesis is to compile the information gathered on the farms included in this study. Information were available in form of farm gate nutrient balances (nitrogen, phosphorus and potassium), farm walks which included both farmyard buildings and fields, simple estimates of nitrogen leaching as depending on crop and management preceding and present year, and soil analysis to identify areas with high risk for phosphorus leaching based on soil maps. This information was analyzed to identify differences between farm types, farm locations etc. The overall aim was to evaluate if the estimates of farm balances, nitrogen leaching and other activities seemed to have been successful or not.

Specific questions that should be answered are:

- Have the advisors managed to perform proper farm gate balances and nitrogen leaching estimations?
- What effect can be expected from these measures that are taken and what can be done to achieve improved results?
- What conclusions can be made about different farm types from the collected data?
    - Are there differences between farm types?
    - Are there differences between farms in Pomerania and Mazovia?
    - Can liming of the soil be assumed to improve production and help to reduce leaching?
- Measures that could be taken as a first step to improve farm management and reduce the risk for nutrient leaching should be proposed.

1.2 Background to the project

The BalticSea 2020- financed project 'Self-evaluation concerning nutrients by farmers in Poland' aims to reduce nutrient leaching from Polish farms through advisory services and network build up. The focus is not measures that are driven by law and ordinance, but to encourage farmers to take their own initiatives to reduce nutrient leaching from their own farm. It is assumed that an increased level of knowledge among the farmers will help to reduce the nutrient load from these farms to the surrounding waters (BalticSea 2020 (b), 2014).

The project includes several steps and as a first step Polish farming advisors were educated. The advisors were trained in how to perform soil analyses, nutrient balances and how to estimate expected nutrient leaching from a specific field in particular circumstances (BalticSea 2020 (b), 2014). The education was based on Swedish experience of reducing nutrient leaching from agriculture. Other presentations covered principals of constructed wetlands, perform nutrient balances and fertilization plans, rough estimation of the effect of different measures to reduce nutrient leaching. In total 60 farm advisors participated in this educational part.

Thirty farm advisors from Masovian province (from the east, north and south part of the province) and 30 farm advisors from all 16 districts of the province of Pomerania (BalticSea 2020, 2013).

After the advisors had been educated they visited the farms in this project to discuss which measures that can lead to reduced pollution from the specific farm. The farmers have a lot of experience and knowledge about their own farm and together with the knowledge the advisors contribute with, cheap and simple measures that reduce nutrient leaching and that suit the farm may be identified (BalticSea 2020(b), 2014). Before training the advisors a pre-intervention interview study was made with 30 of the involved farmers to hear their concerns on losses of plant nutrients. The interviewed farmers were selected by the Pomeranian Agricultural Advisory Board and the Board in the Mazovian region. The result from this pre-intervention study will be followed up with new interviews at the end of the project- in 2015, an after-intervention study (Vatema, 2014).

Information material, a ‘Handbook’ and a ‘Manual’ was produced and distributed to the participating advisors. The material covered how to perform a farm gate balance, how to estimate N leaching etc. (Ulén et al, 2013, in Polish and 2014 in English).

During the second advisory visit the advisors brought with them soil maps of the farm and in some cases analyze protocols with the nutrient content of the farmer’s own manure. The risk of nitrogen leaching on each field was evaluated in a simplified way with an excel sheet and NPK farm-gate balances were developed for the entire farm. Based on a general low soil pH, liming was recommended and subsidized to 50% of the cost. Subsidized seed for catch crops was also offered. The advisors walked over the farm together with the farmers and discussed measures that could be done to reduce nutrient leaching. Measures that were recommended were adjustment of the doses of phosphorus fertilization or manure related to the soil content and manure content to use appropriate mineral nitrogen and phosphorus with the background of nutrient content in the manure. Appropriate storage and spreading of manure were other measures identified by advisors, as well as adjustment of soil cultivation to soil type and sowing date. Also, cultivating catch crops, maintenance of wetlands, buffer zones, and ponds were recommended to decrease the risk of nutrient leaching (Raport PODR, 2013).

1.2.1 Polish agriculture and conditions for the farmers

Forty-seven percent of the EU territory is covered by agriculture and Poland is one of the larger agricultural nations. Poland is the third largest producer of cereals in EU28. Like for EU in general, common wheat is the most important cereal crop in Poland. The second most important cereal crop is triticale, in fact Poland is the single largest producer of triticale in EU28 with 37.3% of the total production. After Germany, Poland is the second largest producer of rye in EU28, holding about 33% of the total production. Other important crops in Poland are barley, maize, sugar beet, carrots and apples. Poland is the largest producer of apples in

EU28, with 32 % of the share. Poland is also a large producer of animal products, the most important animal products in EU28; milk 7%, pigs 8 % and poultry 13% of total production in EU28 (EUROSTAT, 2015).

The conditions for farming in the focused areas (Pomerania and Mazovia) have changed considerably over the last decades. One of the more important changes is the size of the farm that has been enlarged for all but three of the farms included in the pre-intervention interview study (Vatema, 2014). The major part of the farmers owns their land, purchased with cheap loans. Only 30 percent of the farmers interviewed are leasing a smaller part of their farm land (Vatema, 2014). Further expansion of farm size is possible since there is land available for purchase. A constraint for the farmers is access to farm employees, which partly have been circumvented by heavy mechanization of the agriculture in the area (Vatema, 2014). Another change seen is a large increase in the number of livestock, motivated by the areal expansion. The farmers now focus on one kind of animal to a greater extent that earlier (Vatema, 2014).

Poland is one of the most water-poor countries in Europe and the agriculture is mainly rain-fed. The total fresh water resource is 1 700 m^3 per capita, of the EU-27 countries only the Czech republic, Cyprus and Malta have water resources that are more scarce (EUROSTAT,2010). Water supply for household purposes and farm needs are predominantly arranged by connection to a water supply network. This water is used both for human and animal need, however it is not allowed to use this tap water for irrigation. For that purpose river water is used and permission for doing that is needed (Vatema, 2014).

The maintaining of ditches is organized in a collective way and the farmers pay a monthly fee for this service. The reason for doing this in a collective way is due to the earlier system for draining watersheds which was run by the regional authorities. This collective maintaining of ditches causes many concerns for the farmers (Vatema, 2014). There are great needs for liming the soil at the farms included in the project. In a project in the Pomeranian vovoidship including 23 farms and 405 soil samples, liming was advised on fields at 72 % of the farms. In 35% of the farms liming was necessary on some fields, and in 24 % it was needed (Report PODR, 2013).

Most of the farmers in the pre-interviews experienced that they have problems of water-logging, wet fields and floods on their farms during certain periods of the year. The farmers claim it is caused by poor management of the open ditches in the area and blame the company engaged to dredge the ditches for not doing it properly (Vatema, 2014). There are no big concerns of the water quality of the rivers among the farmers. One farmer mentioned that no one cares about the quality of the river water. All but one of the farmers answered that you get better yields from irrigating with ground water compared to river water. Despite that, and the fact that all the fish have disappeared from the river, the farmers in Mazovia seem to agree that the quality of the river water is good (Vatema, 2014).

Acidification of soil is a question that most of the farmers are aware of and a large part of the farmers apply lime to their soils to improve the yields. The awareness of reasons for soil acidification (especially removal of plant material) is low and so is also the awareness of the connection between acid soil and liming for higher yields. Only one farmer motivates the use of lime by a need to increase pH in the acid soil (Vatema, 2014). When it comes to discussions about loss of soil fertility and nutrient leaching only one of the pre-interviewed farmers mention that soil nutrients might leak to surrounding waters. However, several of the farmers discussed measures to keep losses of nutrients small. Common measures brought up are immediate mixing soil or covering the manure and applying fertilizers when it is cloudy but not raining. Since no farmer mention anything about adapted manure application depending on type of manure, the awareness of differences in nutrient content etc. among different types of manure are presumed to be low (Vatema, 2014).

1.2.2 Farm characteristics in Mazovia and Pomerania

In the Mazovian district 25 farms were visited by the advisors. The average selected farm in this region was characterized by an agricultural area of 21 to 44 hectares, the average characteristics are presented in table 1. To enable comparison, the farms were divided in different subgroups depending on their main production and the major export of the farm. In Mazovia these subgroups consists of farms that only produce plant products (crop production farms), farms that mainly produce milk (dairy farms), farms that mainly produce pigs and the last group that is called “Specialized”. In the “specialized”-group only one farm was placed, a horse farm that did not fit in any of the other groups. Almost 50% of the selected farms only produce crop products, mainly grain but also rapeseed, potatoes, maize, grass etc.

Table 1 Farm characteristics of Mazovian farms. Standard deviation in brackets. Letters indicate significant differences.

Farm type	**Crop production**	**Milk production**	**Pig production**	**Specialized**
N:o of farms	12	8	4	1
Share	0,48	*0,32*	*0,16*	*0,04*
Farm area	41 (26)	44 (25)	42 (29)	21 (0)
Stocking rate				
LSU/ha	0 (0) *a*	1,31 (0.58) *b*	2,25 (0,59) *c*	0,62 (0) *ab*
Soil				
Dominating soil type	Loamy sand	Loamy sand	Loamy sand	Clayay soil
Dominating P-class	IV	IV	IV	V
Dominating K-class	III	III	III	IV
Dominating Mg-class	IV	IV	IV	V

The average dairy farm had the largest agricultural area of the different farm types (44 ha) and a stocking rate of 1.3 LSU ha^{-1}. The average pig farm was a bit smaller than the dairy farm (42 ha) but had remarkably higher stocking rate, of 2.3 LSU ha^{-1}. The group "specialized farm"- is hard to compare with since it only contains one farm that differs a lot from the other animal farms. That farm is a horse farm and it is an extensive animal farm with a low stocking rate (0.6 LSU ha^{-1}). No significant difference in farm size was found among the groups, but the stocking rate shows significant differences with highest animal density at the pig farms. Most of the animal farms do not only export animal products like milk and meat, but also plant products (can be seen in appendix 4). Some of the farms export almost as much plant products as animal products, and that might affect the data since the characteristics of these farms will be somewhere in between animal- and crop producing farms.

The selected farms in Mazovia were larger and more specialized compared to those in Pomerania. Therefore the grouping of farms differs between Mazovia and Pomerania (table 2). Of the selected farms in Pomerania many of them have several business branches and are grouped as 'Mixed'. A representative farm for these groups could have some hectares with cash crops, a dozen pigs, a few cattle or dairy cows and also a group of ducks. The farms were divided into subgroups depending on the major nutrient export from the farm. At the farms in the "Crop production"-group more than 80 % of the nutrient export was in the form of plant products. At the milk and pig production farms more than 80 % of the nutrient export comes from milk (and cows, calves etc.) and pigs (sows, porkers, piglets etc.) respectively. The farms called "Mixed farms" have two or more major nutrient outputs, for example both crop products, milk, pork and eggs.

The average Pomeranian farm included in this study was characterized by an agricultural area of 20 to 35 hectares. A significant difference ($p < 0.05$) in farm size was found between the farms with mixed production and the dairy farms. In Pomerania only four farm focus on just producing crops, with an average agricultural area of 25 ha. Thus, these farms only sold crop products, and due to that were classified as crop farms, several of these farms had only a few animals (and a low LSU). The dairy farms had the largest agricultural area (36 ha) and also the highest stocking rate in this group of farms (1.3 LSU ha^{-1}). A significant difference was found in LSU ha^{-1} between the milk farms compared to all of the other farms. The pig farms in Pomerania differed a lot from each other. Three of the four farms were pretty similar, with a quite low stocking rate and quite similar input and output values. However, the fourth farm (here called P23) differed a lot and had a high stocking rate (10 LSU ha^{-1}). In contrast, the other pig farms had a stocking rate of 0.2-0.6 LSU ha^{-1}. The inputs and especially the output of nutrient differed a lot between P23 and the other farms. Therefore, P23 was excluded from the calculations.

Table 2 Farm characteristics of Pomeranian farms. Standard deviation in brackets. Dominating K- and Mg-class cannot be calculated since only a few analyzed K and Mg status in the soil samples. *Letters indicate significant differences.*

Farm type	**Crop production**	**Milk production**	**Pig production**	**Mixed farms**
N:o of farms	4	8	4	9
Share	0,16	*0,32*	*0,16*	*0,36*
Farm area	25,4 (8,9) *ab*	35,5 (12,0) *b*	22,2 (12,1) *ab*	19,6 (3,7) *b*
Stocking rate				
LSU/ha	0,01 (0,02) *bc*	1,25 (0,57) *a*	0,41 (0,18)[1] *b*	0,59 (0,24) *b*
Soil				
Dominating soil type	Clayay soil	Loamy sand	Loamy sand	Loamy sand
Dominating P-class	II	III	IV	I
Dominating K-class	n.a.	n.a.	n.a.	n.a.
Dominating Mg-class	n.a.	n.a.	n.a.	n.a.

1.3 Methods

Information has been gathered by local advisors in the provinces of Mazovia and Pomerania. How the information was gathered is described in the following sections. The data was compiled and analyzed to enable comparison between farm types etc. and to answer the questions stressed in the “purpose”-section.

A field trip to Poland was made to discuss this project with some of the involved advisors and their respective involved farmers. The meeting with the advisors and farmers was made to get an idea of what they thought of the project, what was useful and what they think should be the next step to follow up the project.

Selection of farms was made by the local advisory companies. They advertised that this project should be carried out and interested farmers could apply for taking part in the project. There was no problem finding interested farmers, rather the opposite. The farmers were very interested to be a part in this project, according to the advisors. However, several of the farms were larger than first intended.

1.3.1 Farm gate nutrient balance

A farm gate nutrient balance gives an overview of nutrient flow at the farm (Schröder et al, 2003). In the balance the plant nutrients nitrogen (N), phosphorus (P) and potassium (K) are included. Potassium is not an environmental problem but has a limiting effect for crop production and is consequently included in the farm-gate balances (FGB). A farm nutrient balance consists of inputs to and outputs from the farm and can be calculated in different ways; here a detailed method was used described in the Handbook (Ulén et. al., 2013b). FGS:s commonly include fertilizers, seed, feed, exported products etc. This also includes estimates of N fixation by legumes, microorganisms and free-living microbes. The protocol used to collect this data is presented in Appendix 1.

The amount of inputs in mineral fertilizers were calculated by multiplying the mass of each purchased mineral fertilizer with its nutrient content (N:P:K ratio). Amount of inputs in purchased feedstuffs and amount of inputs in purchased animals were calculated in the same way by multiplying the mass of each feedstuff purchased and the mass of animals purchased with its content of N, P and K. Amount of inputs in organic fertilizers and in other purchased materials was calculated in the same way as earlier. Nutrient contents in different organic fertilizers were based on a large number of different organic fertilizers. Nutrient inputs with atmospheric deposition are estimated by multiplying the agricultural area of the farm by the expected atmospheric deposition (based on data from Poland). Amount of crop-fixed nitrogen was estimated by multiplying the area of each legume crop cultivated, the above-ground yield of this crop and a certain factor for symbiotic nitrogen fixation depending on which crop was cultivated on what type of soil. When calculating the amount of nitrogen introduced in soil organisms, estimated values for different soils in Poland were used (Pietrzak in Ulén et al, 2013).

The amount of exported nutrient was calculated by multiplying the mass of each sold product with its content of nutrients from experimental data. The last step was to calculate changes in nutrient stock at the farm over the year. The stock in this case can be mineral and organic fertilizers, feedstuffs and livestock. These changes were calculated by comparing the difference between the amount of nutrients accumulated in the farm stock at the start and then at the end of the year. First the difference in mass of these stock products were calculated and later multiplied by the content of N, P and K. If the calculated value is negative it means a decrease in amount of nutrients in the stock and if it positive, an increase.

All these data and estimated values were summed up in a table like the one in Appendix 1 and used to calculate if there was a surplus of deficit of nutrients at farm level. The nutrient use efficiency (NUE) at farm level was finally calculated by taking the ratio of each nutrient (N, P and K); i.e. amount nutrient leaving the farm/amount of nutrient entering the farm and multiplied by 100%.

1.3.2 Estimation of nutrient leaching

Nitrogen leaching was estimated in a simplified way by using coefficients in an excel sheet taking into consideration e.g. the crop and tillage preceding year. For phosphorus the risk of high leaching was based on soil P content, soil texture and topography. The leachate for each field could not be estimated in a corresponding way as for N since P leaching is usually more complex and reliable models are missing. A basic leaching always occurs when cultivating crops and for that reason a value for basic leaching (A) depending on soil type and precipitation was used, but the value was based on experiences from the south of Sweden and not from Poland. The key factors when estimating N leaching is to consider the preceding crop and if the soil is covered with crop during autumn and winter, the time of tillage, if manure or compost is added (quantity and time) the former expressed as the factor for intensity of fertilization (Ulén et al, 2013).

For estimation of nitrogen leaching, the table presented in Appendix 2 was used. For each field the four key factors were considered. First the basic value (A) was estimated by classifying the field after which soil type that is the most representative at the field and how much precipitation that can be expected. Nitrogen leaching occurs mainly during late autumn and winter; therefore the preceding crop is affecting the risk of leaching in several ways. Different crops contain different amounts of nutrients and leave different amounts of residues at the soil surface. If the preceding crop is followed by a winter sown crop the risk for leaching will decrease since the crop will be able to take up some mineral N when growing in autumn and, additionally the soil will be covered and thus protected (Ulén et. al., 2013). A certain crop factor used in the calculation is based on experimental data from Hoffmann et al. (1999) and Aronsson and Torstensson (2004). The effect of soil tillage was also represented by a factor that considers time for ploughing or other tillage (in the autumn or if no tillage is done during autumn). The soil tillage factor was based on experimental data from Hoffman et al. (1999) and Aronsson and Torstensson (2004). The effect of applying manure on the risk for leaching was also represented by a factor taking into consideration what type of manure that is used (slurry or solid manure) and time for spreading (autumn or spring). Type of animal the manure origins from or amount of manure was not considered in this estimation, instead an application rate of 20-40 t/ha was assumed. The last factor (F) describes the effect when too much fertilization is applied. This extra leaching was estimated by summing up the amount of N applied the current year with the amount of N left in the soil from the preceding year. This value was compared with the recommended nitrogen application dose. How much extra leaching that can be expected depends on if the actual amount of nitrogen applied is higher than the recommended dose, how much higher it is and it also depends on the soil type of the field (Ulén et al, 2013).

1.3.3 Farm walk

The aim with the farm walk was to systematically go through the farmyard and individual fields of the farm and evaluate the level of risk for nutrient leaching. During the walk a protocol with questions about manure storage, water management, tillage practices etc. was filled in. Results from soil mapping were available during the walk to enable discussion around the soil nutrient status (P, K and Mg). The farm walk also aimed at initiating a discussion about possible simple measures at low costs and in the right place (Ulén et al. 2013(b))

The protocol used in the farm walk can be found in appendix 2. Data gathered from the walking protocol are presented under chapter 2.7 "Agri-environmental indicators".

1.3.4 Soil analysis

Soil samples were taken by the advisors at their first visit to the farm and analyzed for soil pH and content of P, K and Mg. The results were presented as soil maps with different colors to indicate the soil status. Green color means no need for fertilization or liming but simultaneously a risk for high P leaching (but also depending on soil texture and many other factors) as described in table 3.

Table 3 Color codes used on farm maps to present the results from the soil analysis

Color code	pH – need for liming	P/K/Mg – content in soil
	Necessary	Very low
	Needed	Low
	Indicated	Average
	Limited	High
	Unecessary	Very high

1.3.5 Liming of the soil

In the project subsidizes were offered for liming equal to 50% of the costs for buying lime The fields with the most urgent need were identified from the soil analysis and lime was applied to those fields in the Pomeranian province. In Mazovia these subsidizes were evenly spread between the different farms according to the advisors.

1.3.6 Analysis of data and statistical methods

Microsoft Excel has been used to sort the data and calculate mean values and standard deviation of the values of interest.

The data was also analyzed in Excel to see if any significant differences were present among the different farm types (the data groups). The groups with data were arranged in columns and analyzed by the add-in Data analysis. The statistical report showed if there was a significant difference between any of the data groups. In the cases where a significant difference was found, further statistical tests were performed in MiniTab. In MiniTab the one-way ANOVA test (ANOVA: single factor) was used to see if the means of the data sets differed from each other. Where significant differences were found, different letters are used to show this in the tables. Equal letters indicate that the means are not completely separated and thus there is no significant difference.

1.3.6.1 Errors made in data collection

In the farm gate balances few errors were made, and no farm was excluded from these calculations due to errors. Some advisors had troubles with calculating the stock change and skipped this part of the FGB for that reason.

In the calculation of nitrogen leaching several larger errors have been made (that affects the result considerably) and these results have all been excluded from the calculations.

1.3.6.2 Outliers

Some farms were obviously very distinguished from the other farms and therefore excluded from the calculations of mean and standard deviation. This since the mean was affected in a considerable way when these farms were included in the calculations. Here the farm data of these farms are presented and reasons for why they are so different are discussed later in this report.

Mazovian outliers

Table 4 presents three farms from Mazovia not included in the FGB calculations. Farm numbers RM21 and RM 23 differ considerably from the other farms since they are very extensive and specialized. No mineral fertilizers, feed or other inputs are bought. The only input of nutrients in RM 23 is deposition and mineralization, resulting in a very low flow of nutrients. A small amount of nutrient is exported in sold plant products. RM 21 also only has inputs from deposition and soil microbial interaction, but also a very large input of N from N fixation. The estimated input of N from N fixation is more than seven times bigger on RM21 compared to the farm with the second biggest N fixation. That results in a high mean and a very high standard deviation of the N fixation when RM21 is included. Farm RM18 has a relatively low input and very high output resulting in a large deficit of both N and P. When RM18 was included in the calculations it resulted in a much lower mean of the nutrient surplus for crop farms and a much larger standard deviation.

Table 4 Mazovian farms excluded from FGB calculations.

Farm	Ha	Input N/P/K (kg)			Output N/P/K (kg)			Surplus		
RM18	50	1516	268	2531	12794	1015	1335	-81	-15	24
RM21	16	13835	6	33	966	99	276	797	-6	-15
RM23	11	226	4	22	261	40	162	-3	-3	-13

Regarding P, these farms had very high NUE (from 370% to 1000 %), which is caused by large deficits of P at farm-gate scale. When including these farms the mean NUE was calculated to 320, with a standard deviation of 497, which is a deceptive value that does not reflect the general farms studied.

Pomeranian outliers

Of the Pomeranian farms the one called P23 was the one that stood out the most. According to the FGB established for P23 the input is more than 8000 kg N meanwhile the outputs are as much as 32000 kg N. Due to the large output, and the fact that the farm was according to the FGB only 6.20 ha, it was calculated to be a deficit of -3900 kg N/ha. P23 was the only farm in this province that was excluded from the calculations based on farm characteristics and input and output of N and P. In the calculations of input/output of K, farm n:o P14 was also excluded since the deficit was so big so it affected the mean considerably. The figures of the excluded farms are presented in table 5.

Table 5 Farms excluded in FGB calculations due to figures that differs so much from the other farms.

Farm	Ha	Input N/P/K (kg/ha)			Output N/P/K (kg/ha)			Surplus		
P23	6,20	8115	1771	1858	31865	5634	2792	-3902	-659	-217
P14	29	7841	281	587	786	152	0	110	-19	-117

P23 was visited during the field trip to Poland. The figures presented in the FGB were not correct for the farm. In total the farm have over 140 ha of agricultural fields. The 6.20 ha presented in the FGB was only one of the old estates that had been inherited. Due to that the figures in the FGB did not represent the farm in a proper way. The advisor responsible for that FGB was no longer working as an advisor and could not be consulted on why they chose to only include farm land from one estate, but put all of the animal production into that small area in the FGB.

2 Literature review

2.1 Farm Gate Balances as a tool to reduce nutrient leaching

FGB:s with varying level of details have been used in several research projects to evaluate the usage of nutrients on farm level and to identify measures that can be taken to improve nutrient efficiency (Fanguerio et al. (2008), Bassanino et al., (2007), Nevens et al. (2006) etc.) . In all studies reviewed the FGB was calculated in a similar way by first estimating inputs and outputs, than calculating the difference and divide it by the farm area to get the surplus of nutrients per hectare. The largest differences found between the FGBs are what components that are included in the input and the output part (table 6).

Table 6 Inputs and outputs included in reviewed articles about nitrogen and phosphorus balances

Inputs*	**Studies that include this input**	**Outputs***	**Studies that include this output**
Mineral fertilizers	1, 2, 3, 4, 5, 6, 7	Milk, animals, eggs, meat, wool etc.	1, 2, 3, 4, 5, 6, 7
Feedstuffs	1, 2, 3, 4. 5, 6, 7	Manure/slurry	1, 2, 3, 4, 5, 6, 7
Bought animals	1, 2, 3, 5, 6, 7	Other animal products	5, 7
Bought organic fertilizers	1, 2, 3, 4, 5, 6, 7	Crop	1, 2, 3, 4, 5, 6, 7
Seed	1, 4, 5, 6, 7	Straw	4, 5, 7
Forage/byproducts	1, 3, 4, 7	Immobilization	
N-fixation	2, 3, 4, 5, 6, 7	Erosion	
Atmospheric deposition	1, 2, 3, 4, 5, 6, 7		
Soil microbial fixation	7		
Mineralization			
Sedimentation	1, 4		

* Parameters generally included (Schröder et al., 2003).
Parameters included in (1)Fanguerio et al. 2008, (2) Bassanino et al., 2007, (3) Nevens et al. (2006), (4) Nielsen and Kristensen (2005), (5) D'Haene et al. (2007), (6) Daalsgard et al. (2012), (7) parameters included in this study.

At farms that only produce crop products (crop farms) mineral fertilizers normally is the most dominating nutrient input (and in some cases N fixation) and crop products, like cash crops, silage and straw, are the major outputs (D'Haene et al., 2007). At animal farms feed and mineral fertilizers are the dominating inputs and animal products like meat, milk and manure are the major nutrient outputs. It is common that the animal farms also have cash crops as an incoming source, which makes it an important nutrient output even at many animal farms (table 7) (D'Haene et al., 2007, Nielsen and Kristensen, 2005, Fanguerio et al., 2008, Neves et al., 2006).

On average 83 % of the nitrogen input in the EU-28 was nitrogen from mineral fertilizers and manure (feed is not included as an input in this data, but subtracted from the animal outputs instead) (EUROSTAT, 2015). Compared to the EU-28, mineral fertilizers stand for a larger share of the total N and P inputs in Poland, while the manure input is smaller.

Table 7 Major inputs and outputs on farms in literature reviewed.

Farm type	Country	Source	LSU (per ha)	Major input N(P)	Major output N(P)
Crop farms					
Arable farms n=?	Hungary	D'Haene et al. (2007)	0	Mineral fertiliz-er	Cash crops
Dairy farms					
Conventional Dairy farm, n=25	Denmark	Nielsen and Kristensen (2005)	1,14	Feed, mineral fertilizer (P in feed, manure)	Milk, manure
Organic Dairy farm, n=13	Denmark	Nielsen and Kristensen (2005)	1,54	N fixation (P in feed, manure)	Milk
Flemish dairy farms, n=120	Belgium	Neves et al. (2006)	2,98[1]	Mineral fertiliz-er (feed)	Milk
Medium dairy farm, n=8	Portugal	Fanguerio et al. (2008)	4,7	Feed, mineral fertilizers	Milk
Intensive dairy farm, n=7	Portugal	Fanguerio et al. (2008)	6,4	Feed, mineral fertilizers	Milk
Very intensive dairy farm, n=5	Portugal	Fanguerio et al. (2008)	7,5	Feed, mineral fertilizers	Milk, slurry
Pig farms					
Pig indoors, n=19	Denmark	Nielsen and Kristensen (2005)	1,54	Feed	Meat, manure, cash crops
Pig, sows out-doors, n=6	Denmark	Nielsen and Kristensen (2005)	1,69	Feed	Meat, cash crops
Other					
Mixed farms, n=100	Poland	Daalsgard et al. (2012)	0,7	Fertilizers, feed	Meat, milk
Mixed farms	Hungary	D'Haene et al. (2007),		Mineral fertiliz-ers	Cash crops

1) In year 2001.

The countries in Europe with the largest N surpluses are Cyprus (195 kg N ha^{-1} yr^{-1}), followed by the Netherlands (166 kg N ha^{-1} yr^{-1}), Belgium, (119 kg N ha^{-1} yr^{-1}), Malta (114 kg N ha^{-1} yr^{-1}) and Norway (97 kg N ha^{-1} yr^{-1}). The countries with the smallest N surpluses are Latvia (8 kg N ha^{-1} yr^{-1}), Lithuania (14 kg N ha^{-1} yr^{-1}) and Bulgaria (14 kg N ha^{-1} yr^{-1}). The estimated gross nitrogen surplus in Poland is somewhere in the middle with 43 kg N ha^{-1} yr^{-1}. The highest P surplus is found in the same countries which also have the highest N surplus (Norway, Netherlands, Malta and Cyprus) and the largest gross P deficits are found in the countries with the lowest N surplus (Estonia, with -8 kg P h a^{-1} yr^{-1}, and Bulgaria with -5 kg N ha^{-1}

yr^{-1}) (EUROSTAT, 2015). The overall nitrogen use efficiency in EU-28 increased by 12 % between 2000 and 2011, and the phosphorus use efficiency increased during the same period by 27%. Most of this increase in efficiency was linked to improvements in crop and soil management practices, especially fertilizer application techniques (EUROSTAT, 2015).

Nutrient surpluses from farm gate balances performed at different places and at different farm types in Europe are compiled in table 8. According to EUROSTAT (2015) the mean N surplus for the EU28 countries is 47 kg N ha^{-1} yr^{-1}. EU15-countries have a larger surplus, 94 kg N ha^{-1} yr^{-1}, indicating that the "new" EU-nations have smaller nutrient surpluses (Leip et al., 2011). In the literature reviewed the largest surpluses were found on intensive dairy farms and on pig farms, but the differences among farms are large as can be seen in table 8. Livestock unit per hectare cannot explain all differences in nutrient surpluses among animal farms. Farm type has been shown to affect the nutrient surpluses significantly. Nielsen and Kristensen (2005) showed that conventional dairy farms have significantly larger nutrient surpluses than organic dairy farms with equal numbers of livestock units per hectare. N and P surpluses per hectare are significantly affected by both the type of the farm and the year (due weather and other conditions affecting the yield) and significant differences have also been seen between different farms in the same farm type (Nielsen and Kristensen, 2005, Swensson, 2003). In the Nielsen and Kristensens (2005) study of dairy and pig farms in Denmark, farm type was the major reason for variation in both N surpluses and P surpluses at the studied farms.

Table 8 Compilation of farm nutrient surpluses calculated in studies looking at farm gate balances at European farms. Standard deviation in brackets.

Farm type	Country	Source	LSU (ha^{-1})	Nutrient surplus kg ha^{-1}	
				N	P
Average Europe	EU 28	EUROSTAT (2015)		47	1
Average Poland	Poland	EUROSTAT (2015)		43	1
Crop farms					
Arable farms n=12	Hungary	D'Haene et al. (2007)	0	84 (73)	7 (11)
Dairy farms					
Average EU		Swensson (2003)		114	
Conventional Dairy farm, n=25	Denmark	Nielsen and Kristensen (2005)	1,14	175 (16)	16 (4)
Organic Dairy farm, n=13	Denmark	Nielsen and Kristensen (2005)	1,54	113 (25)	7 (6)
Flemish dairy farms, n=120	Belgium	Neves et al. (2006),	2,98[1]	238 (74)	Not calculated
Medium dairy farm, n=8	Portugal	Fanguerio et al. (2008)	4,7	413 (129)	31 (16)
Intensive dairy farm, n=7	Portugal	Fanguerio et al. (2008)	6,4	574 (92)	44 (22)
Very intensive dairy farm, n=5	Portugal	Fanguerio et al. (2008)	7,5	778 (114)	38 (22)
Dairy farm, n=9	Italy	Bassanino et al. (2007)	7,0	173 (120)	Not calculated
Dairy farm, n=138	Sweden	Swensson (2003)	Not mentioned	167-187 (57)	5-7 (std not calculated)
Pig farms					
Pig indoors, n=19	Denmark	Nielsen and Kristensen (2005)	1,54	123 (22)	13 (5)
Pig, sows outdoors, n=6	Denmark	Nielsen and Kristensen (2005)	1,69	251 (35)	42 (8)
Pig, n=11	Italy	Bassanino et al. (2007)	6,9	213 (69)	Not calculated
Other					
Mixed farms, n=100	Poland	Daalsgard et al. (2012)	0,7	122 (20)	Not calculated

Mixed farms	Hungary	D'Haene et al. (2007),		
Suckling cows, n=16	Italy	Bassanino et al. 2,3 (2007)	92 (62)	Not calculated
Beef breeding, n=5	Italy	Bassanino et al. 3,6 (2007)	161 (59)	Not calculated

3 Results

3.1 Farm nutrient balances

3.1.1 Farm-gate balances (FGB)

Inputs and outputs considered in the farm gate balances performed are shown in figure 1. Nutrient content in inputs and outputs are based on experimental data

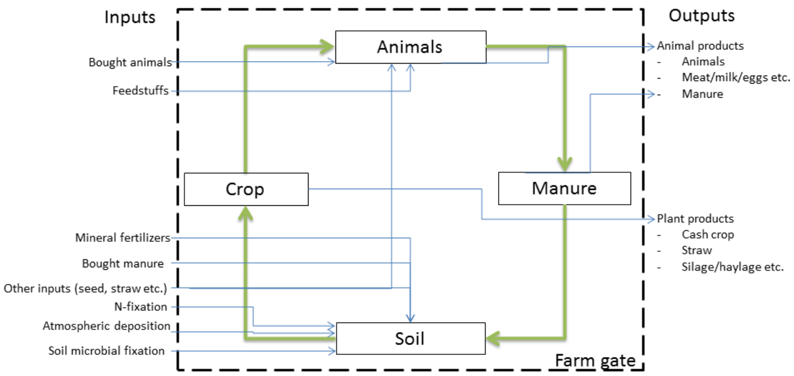

Figure 1. Farm gate balance. Inputs and outputs considered. Own figure inspired by Nevens et al. (2006).

from Poland (Pietrzak in Ulén et al. 2013). For each of the farm type in Mazovia and Pomerania mean values of input, output and surpluses for N, P and K are presented in appendix 4 and 5.

3.1.2 Mazovian farm gate balances

As can be seen in figure 2 and appendix 4, mineral fertilizers were the major N input on crop farms and dairy farms, also on pig farms it was an important nutrient input. At the dairy farms feedstuffs was another important input besides the mineral fertilizers. The major nutrient output (figure 3) on crop farms was export of plant products, like cash crops, straw and silage. Major outputs at the dairy farms were predominantly milk and animals, but an almost as big share of the nutrient output was from export of cash crops. At the pig farms, import of feedstuffs was the most important input of nitrogen. Sold animals was the single most important nutrient output, but also export of manure and plant products were significant. Crop farms were the only farms that buy manure. Of the 12 crop farms in Mazovia five imported manure, resulting in a mean input of 19 kg N/ha, which is equal to 8 % of the total N input. Corresponding figure for P was 12 kg P/ha, which is equal to 30% of the total P input. The standard deviation was large since most crop farms did not import any manure at all, while the five farms import quite much manure. If only considering the five farms that import manure their mean N input from manure, was 34kg N/ ha which is equal to 20 % of their nitrogen input and 50 % of their phosphorus input. There were four farms that sell manure, three dairy farms and one pig farm. The pig farm only sells a very small amount of slurry (negligible compared to other outputs at that specific farm); in the dairy farms, however, the export of manure stands for 15-45 % of the total output. In contrast, deal with manure was of no importance for the Pomeranian farms studied here; only one farm (one of the crop farms) bought manure and not a very large amount, 3 kg N/ha, which was 3 % of the N input on that farm. None of the Pomeranian farms exported manure.

Pig production farms have the highest total input of N of the farms studied ($p < 0.05$), but also the highest total output. Despite the high output at the pig farms, the surplus of N was still highest at these farms. Inputs of N at pig farms were 418 kg N/ha (mean value) and outputs were 189 kg N/ha which gives a surplus of 242 kg N/ha. The lowest surplus was found at the single horse farm 49 kg N/ha. The mean surplus at crop farms was 4 kg N/ha and at dairy farms 139 kg N/ha.

There was a significant difference found in total input among the Mazovian farm types. The inputs of pig farms are significantly larger compared to inputs of the other farm types studied ($p < 0.05$). The only input categories where statistical significant differences were found were the category feed, where the input of feed was significantly higher on the pig farms. Also the output of animal products on pig farms was high compared to on the other farm types. Regarding output of plant products, a significant difference was found between crop and dairy farms. However, no significant differences were found in the total output of N.

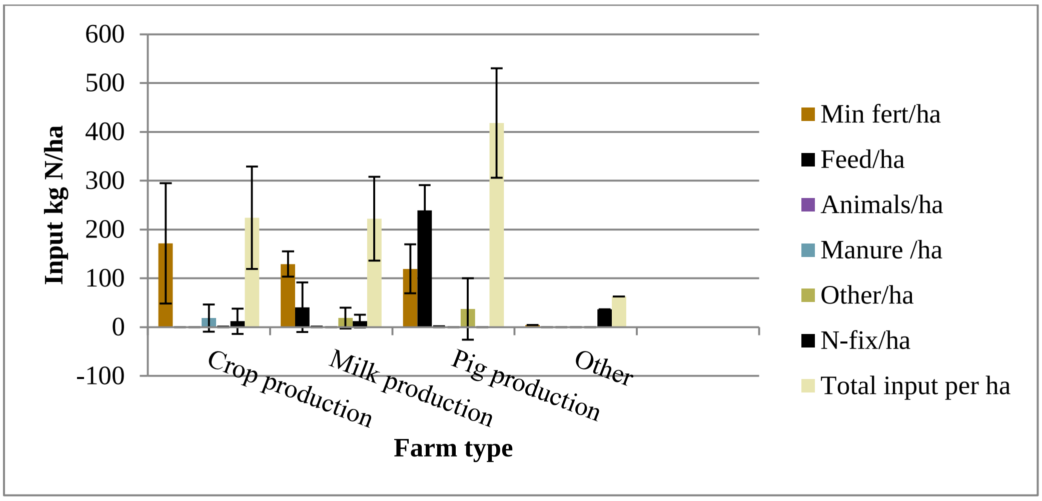

Figure 2 Mean inputs of nitrogen in farm gate balances of Mazovian farms (bars) including standard deviations. Only the main parameters are included in this figure while more complete balance may be found in Appendix 4.

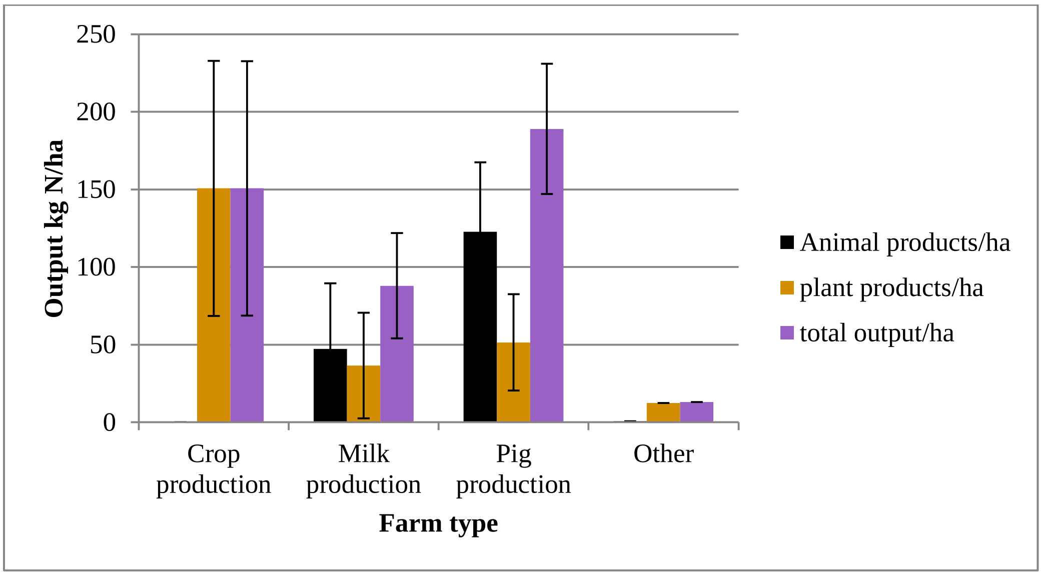

Figure 3 Outputs of nitrogen in farm gate balances of Mazovian farms. The bars represent the mean values also found in Appendix 4 and the error bars represent the standard deviation.

The stock change is not involved in the table since only 3 farms out of the 25 calculated the stock change. Many farms facilitated the FGB by estimating the stock in the beginning of the year to be equal to the stock in the end of the year. Note from the farm gate balance that the total N inputs in Mazovian farms were about two times higher than the outputs at all farm types. That leads to a nutrient efficiency of more or less 50%, meaning that about half of the nutrient input was converted to outputs.

Farm gate balances for nitrogen, but also for phosphorus and potassium are presented in Appendix 4. The highest input of P was found on pig farms (62 kg P/ha), followed by crop farms (43 kg P/ha) and dairy farms (31 kg P/ha). The lowest P input was found on the horse farm, with an input of only 4 kg P/ha. On the pig farms most of the P input was in form of feed, but mineral fertilizers also accounted for a large share. Mineral fertilizers were the single largest input of P on crop and dairy farms. Also the output is largest on the pig farms (31 kg P/ha), but the output from the crop farms was almost as large (28 kg P/ha). However, the surplus of P was largest on pig farms due to the higher input. The surplus of pig farms (31 kg P/ha) was about twice as high as the P surplus of the crop and dairy farm (around 14 kg P/ha). The NUE was highest on the crop farms with 78 %, compared to around 50 % on the dairy and pig farms. Like the N balance, inputs of P were about twice as high as the outputs, except for the crop production farms where the input was about 1.4 times higher, resulting in the higher value of NUE.

The input of K did not differ much between crop production (113 kg K/ha), dairy production (110 kg K/ha) and pig production (112 kg K/ha). Mineral fertilizers were the major input of K at all farms except the pig farms. On the pig farms feed was the most important source. At the dairy farms "other inputs" were of a great importance for the K input that is mainly straw. The outputs of K were largest on crop farms (66 kg K/ha), followed by pig farms (51 kg K/ha). The outputs were lower on dairy farms (34 kg K/ha) and on the horse farm (16 kg K/ha). The largest surplus of K was found on the animal farms, with the highest surplus on dairy farms (76 kg K/ha) and pig farms (61 kg K/ha). The difference between the inputs and outputs were smallest at the crop farms and at the horse farm (less than 1.5 times higher), leading to a much smaller surplus. At the dairy farms, inputs were about three times as high as the outputs and at pig farms about twice as high as the outputs. This is reflected in the values of K use efficiency, where dairy farms had much lower efficiency compared to the other farm types. The highest efficiency could be found at the horse farm, but since that was a very extensive farm type and since the group consists of only one horse farm, no conclusions can be made.

3.1.3 Pomeranian farm gate balances

Mineral fertilizers were the dominating source of imported N at all farm types (figure 4 and appendix 5). Feed and N fixation were other sources of N input, especially at the dairy farms. Other material (predominantly straw) is an important input at the mixed farms. Dairy farms had the highest total input (181 kg N/ha), followed by crop production farms (167 kg N/ha).

One of the four pig farms (P23) was excluded in the calculations since it differed so much from the other farms in the group. The remaining pig farms in Pomerania have a rather low N input (136 kg N/ha) compared to pig farms in other parts of Poland and Europe which commonly is 300-400 kg N/ha (Nielsen and Kristensen 2005).

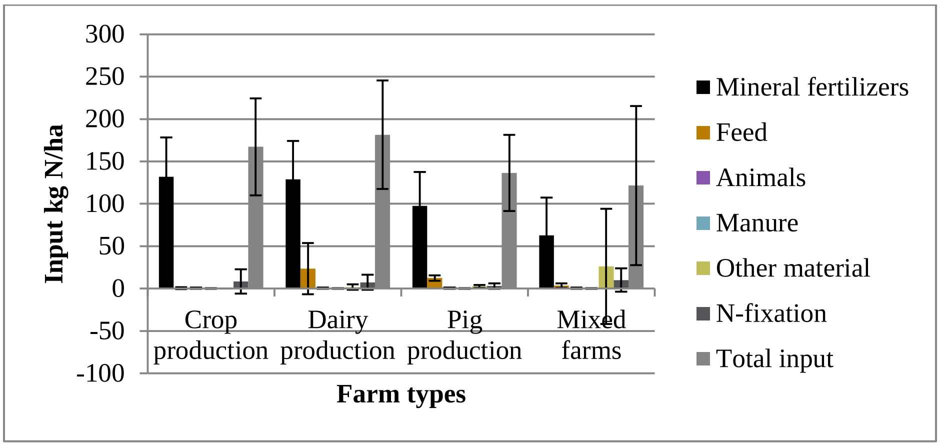

Figure 4 Mean inputs of nitrogen in farm gate balances of Pomeranian farms (bars) including standard deviations. Only the main parameters are included in this figure while more complete balance may be found in appendix 5.

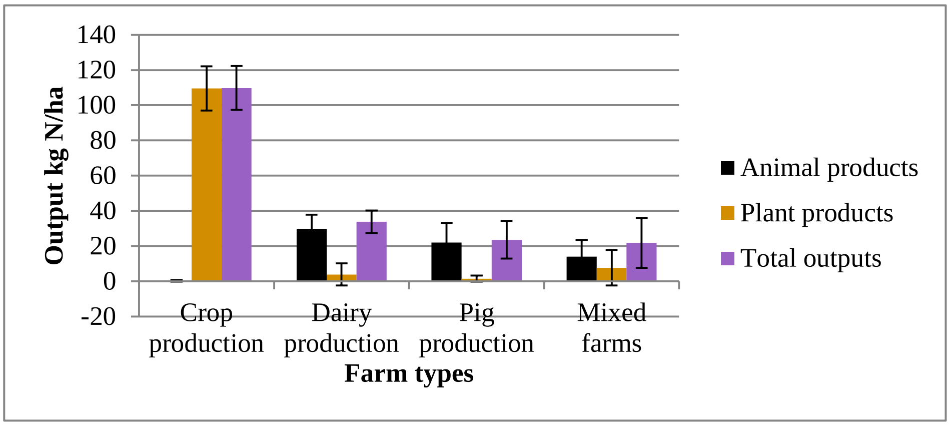

Figure 5 Outputs of nitrogen in farm gate balances of Pomeranian farms. The bars represent the mean values also found in appendix 5 and the error bars represent the standard deviation.

The smallest input of N was found on mixed farms, 122 kg N/ha (appendix 5). The outputs from the Pomeranian farms were small, especially outputs from the animal farms as can be seen in figure 5. No significant differences in output between dairy, pig and mixed farms can be seen. The largest surplus and the lowest nitrogen use efficiency were found at the dairy farms in Pomerania. The dairy farms had a mean N surplus of 147 kg N/ha. The second largest surplus could be found on the other animal farms, pig farms have a mean surplus of 109 kg N/ha and mixed farms a mean surplus of 89 kg N/ha. The smallest surplus, and the highest nutrient use efficiency, was found on the crop farms with a mean surplus of 22 kg N/ha.

Farm gate balances for N, but also for P and K, are presented in appendix 5. The flow of P was very low at the Pomeranian farms. Both inputs and outputs are very small. The major P input at all farm types was mineral fertilizers. Feed is another important input at dairy and pig farms. Largest P inputs were found at the mixed farms (27 kg P/ha), followed by dairy farms (19 kg P/ha), crop farms (13 kg P/ha) and pig farms (12 kg P/ha). The largest mean output was found on crop farms (19 kg P/ha), while the animal farms had considerably smaller P outputs (mean between 4-7 kg P/ha). Due to the large P outputs a P deficit of -7 kg P/ha could be seen on crop farms, while the animal farms had a surplus of P and the largest surplus was found at the mixed farms (22 kg P/ha).

The flows of K are also low. The largest input of K is found at the mixed farms (43 kg K/ha), followed by dairy farms (32 kg K/ha), crop farms (26 kg K/ha) and the smallest K inputs are seen on pig farms (13 kg K/ha). The output of K is largest at crop farms (32 kg K/ha) and since the output is higher than the input there is a deficit of K on the crop farms (-9 kg K/ha). The output from the animal farms are smaller (3-6 kg K/ha) resulting in a surplus of K on these farms, though the surplus is very small (10-31 kg K/ha). The figures calculated for the NUE of K has a very large standard deviation since they differed much, from a very low NUE to 1250%. A NUE over 100% does not say much but indicates a large deficits on the farm

3.2 Surpluses or deficits at farm level

A persistent surplus of plant nutrients indicates that there is a potential environmental problem in the risk for nutrient leaching. At the same time, a persistent deficit indicates that there is a risk for a decline in soil nutrient status (EUROSTAT, 2010). Figure 6 shows the great variety in nutrient surpluses among different farms. The crop farms (1-12) seem to have the smallest surpluses, or even in some cases deficits, except for farm number 11 in Mazovia that stands out (farm 11 is similar to RM21, one of the farms that was excluded from the FGB calculations). A surplus of 797 kg N ha^{-1} yr^{-1} is very large, even compared to intensive animal farms (for example those described by Fanguerio et al. 2008). It can be assumed that an error has been made in the calculations of the input or likewise. The variation in surpluses or deficits of N, P and K are largest among the crop farms. No deficit can be seen on the animal farms.

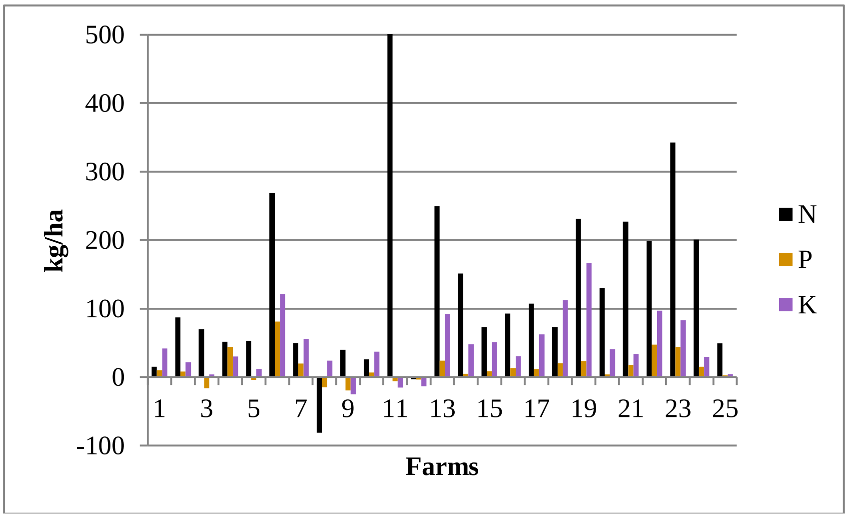

Figure 6 N,P and K surpluses and deficits at farm level of Mazovian farms. Farm n:o 1-12 are crop farms, 13-20 are dairy farms, 21-24 pig farms and n:o 25 is the horse farm. Farm n:o 11 has a N surplus of 797 kg N/ha, but the axis was cut at 500.

In the circle diagrams (figure 7) the surpluses and deficits are presented to get an overview, the surpluses are divided in moderate surplus (1-100 kg/ha) and large surplus (>100 kg/ha), for N and K. For P a high surplus is over 20 kg/ha. A large surplus of N can be seen at 44% of the farms in Mazovia. Most of the farms with a large surplus of N are farms with animals; all of the four pig farms (farm n:o 21-24 in figure 6) have a large surplus of N (over 100 kg N/ha). Of the animal farms in this study, 70 % have a N surplus of 100 kg N ha-1 yr-1 or more. At the farms that only produce crop products 17 % have a large surplus. All the deficits found (of N, P or K) occur on crop farms.

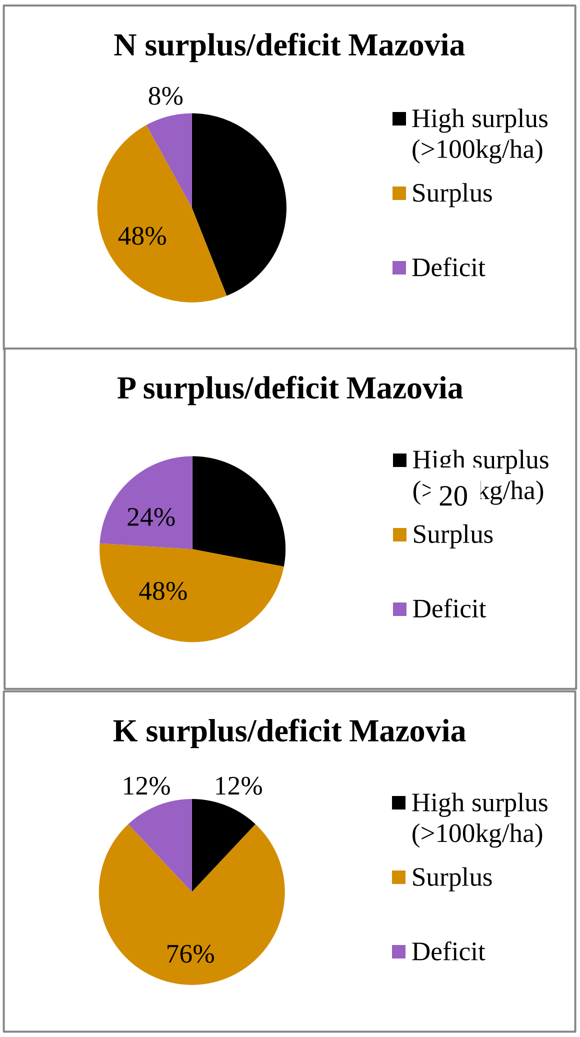

Figure 7 Circle diagrams over the share of farms with deficit/surplus or high surplus of N, P and K in Mazovia

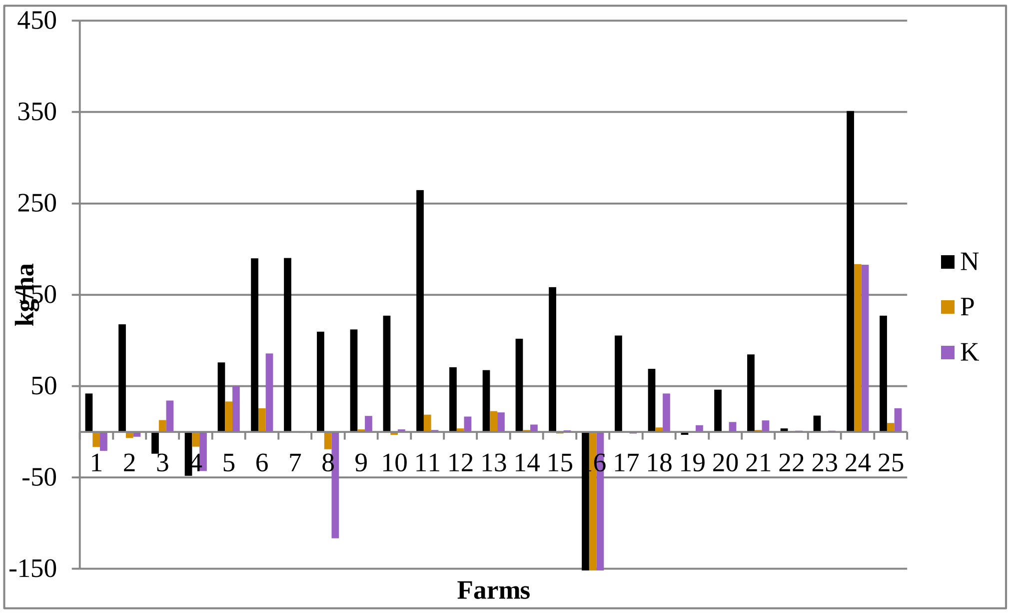

Figure 8 N, P and K surpluses and deficits at farm level of Pomeranian farms. Farm n:o 1-4 are crop farms, 5-12 are dairy farms, 13-16 pig farms and 17-25 are mixed farms. Farm n:o 16 has a very large deficit of both N, P and K that cannot be seen here since the minimum of the axis was set to -150 kg/ha. The actual deficit at farm n:o 16 was -3902 kg N/ha, -660 kg P/ha and -217 kg K/ha.

It is harder to see any pattern in the surpluses at the Pomeranian farms. There are great varieties, but they do not seem to depend on farm type. The mean surplus is pretty similar for the farm types (appendix 5). Almost half of the farms showed a deficit of P (figure 8), a deficit which could be seen both at animal- and at crop farms.

From figure 9 it looks like the largest surpluses can be found on dairy farms (also concluded in appendix 5). All of the dairy farms (farm n:o 5-12) have relatively large surpluses of N. There are farms of the other farm types that have large surpluses as well, but the variations are larger.

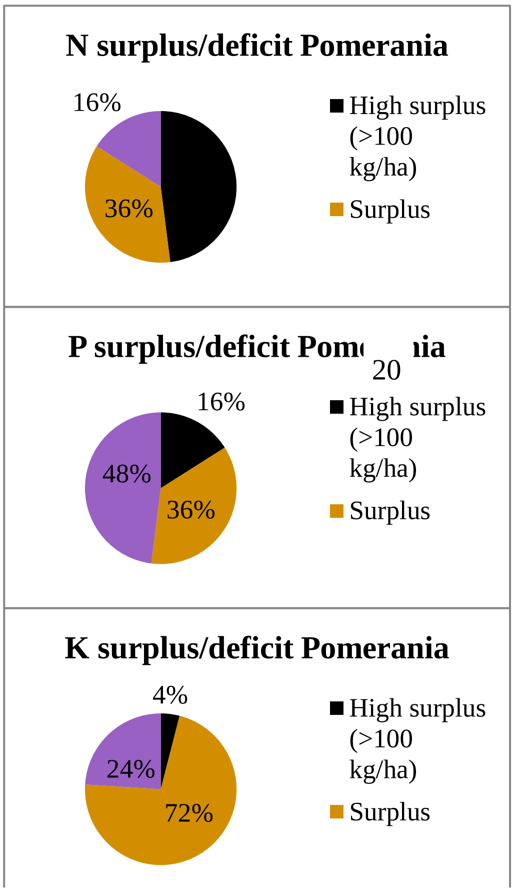

Figure 9 Circle diagrams over the share of farms with deficit/surplus or high surplus of N, P and K in Pomerania

3.3 Nutrient use efficiency

Overall nitrogen use efficiency in Pomerania is 41 % and in Mazovia 51 %. Overall P use efficiency is 64 % in Mazovia and 67 % in Pomerania. Overall K use efficiency is 48 % in Pomerania and 52 % in Mazovia. In Mazovia the highest nutrient use efficiencies can be found at crop farms (figure 10). The farms with animals have a lower NUE compared to the farms with no animals.

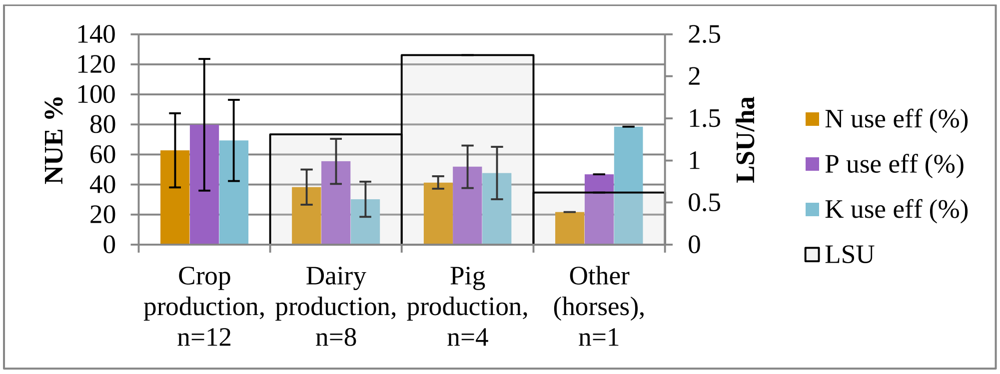

Figure 10 Nutrient use efficiency and livestock unit for the different farm types in the region of Mazovia. Standard deviation as error bars.

Also in Pomerania the nitrogen use efficiency is highest at the farms without animals. Reasons for the high efficiency at the crop farms in Pomerania can be the relatively large output of nutrients through crop products. The farms with animals had a rather small nitrogen output that is reflected here in the low values of the nitrogen use efficiency. The animal farms seem to have a very high P use efficiency, but as can be seen in figure 11 the standard deviation is large. A fourth of the farms in Mazovia and almost half of the farms in Pomerania, have a deficit of P (as can be seen in figure 9), causing the high values of the P use efficiency. When farms have deficits of nutrients it will give a misleading value of the nutrient use efficiency. A persistent deficit in a plant nutrient indicates that there is a risk for a decline in soil fertility over time (EUROSTAT, 2015). In the case of high soil P status however, a ‘phytomining’ of this nutrient may take place with a negative balance (Ulén, oral).

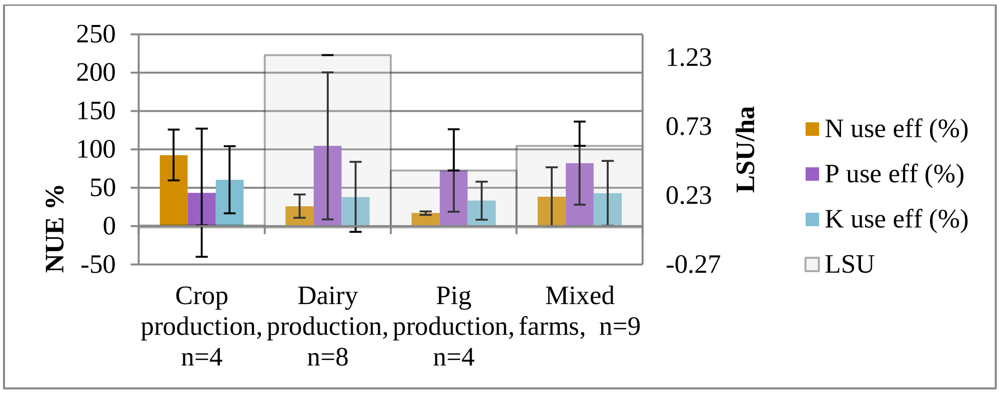

Figure 11Nutrient use efficiency and livestock unit for the different farm types in the region of Pomerania. Standard deviation as error bars.

3.4 N leaching

3.4.1 Surpluses and N leaching

The excel sheet with simplified coefficients used to estimate the N leaching is described in the method-part of this report. Factors included in the calculations of the basic leaching, which is based on generalized Swedish experiences mainly from Scania and Halland (Ulén et al., 2013). Only 68% of the farms used the excel sheet for N leaching. Therefore, these values might be misleading due to a not representative selection.

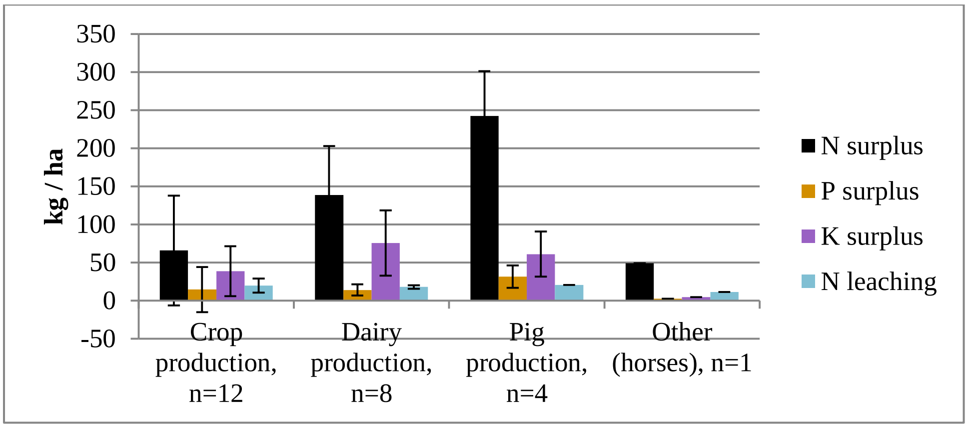

Figure 12 Calculated nutrient surpluses and estimated nutrient leaching for Mazovian farms. Standard deviation is shown as error bars

The pig farms have the largest N and P surpluses (figure 12) of the Mazovian farms (the N surplus is significantly larger compared to crop farms, $p < 0.05$). K surplus is larger at dairy farms but the difference between farm types are smaller compared to the N and P surpluses. No significant differences in estimated N leaching can be seen between farm types. Crop production farms were suggested to have larger N leaching than the other farm types. No correlation between N surplus and N leaching could be found. No such correlations have been seen in advanced scientific studies either (Salo and Turtola, 2006). Accordingly, a large surplus is not equal to a higher value of the estimated N leaching.

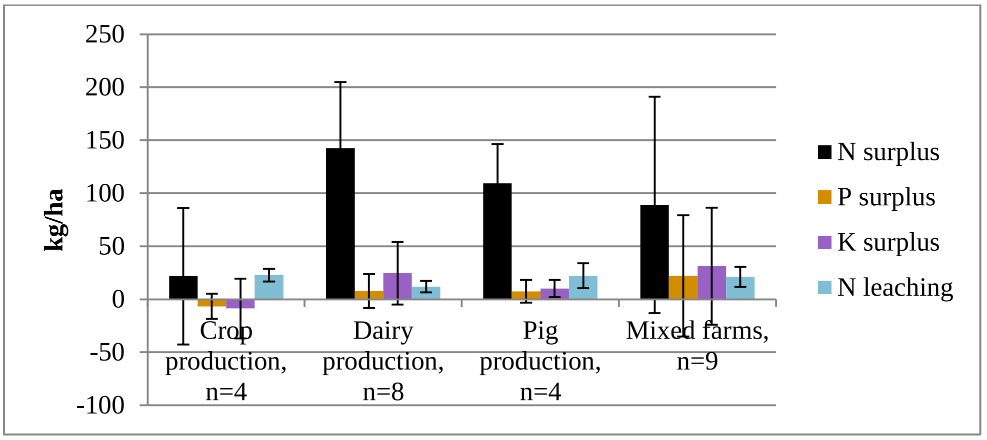

Figure 13 Calculated nutrient surpluses and estimated nutrient leaching for Pomeranian farms. Standard deviation is shown as error bars.

No significant differences were found in nutrient surplus between the farm types in Pomerania. Standard deviations are very high for the values of surpluses and leaching on these farms due to the large variation among farms. Some farms of the same farm type have large deficits and some have large surpluses.

Table 9 Mean values of estimated N leaching depending on farm type. No statistical significance was found.

	Crop farms	Dairy farms	Pig farms	Other[1]
Mazovia	20 (4)	18 (2)	21 (0) [2]	11 (0)[2]
Pomerania	23 (6)	12 (5)	22 (11)	21 (10)

1. Specialized farms (Mazovia) and mixed farms (Pomerania).
2. Standard deviation is zero since n=0, all farms did not calculate N-leaching.

From table 9 it seems like the expected leaching was larger at Pomeranian farms, but the difference were not statistically significant. When analyzing the data it seems like the larger estimated leaching on Pomeranian farms were due to a larger inevitable leaching. A relatively large basic leaching was adopted in Pomerania due to the sandy soils and heavy precipitation.

3.4.2 N leaching depending on soil type

In figure 14 the N leaching calculated on Mazovian farms are divided after soil type. At all soil type a precipitation of 500-700 mm per year is assumed. The advisors got to choose between two different ranges of precipitation; 500-700 mm per year or 700-1000mm. In the data only 4 of 140 fields were estimated to have an average precipitation of 700-1000 mm, the rest had a precipitation of 500-700 mm and for that reason the first fields are excluded in this figure. The highest values of the risk for nitrogen leaching are calculated on fields with sandy or organic soil. The calculated leaching is significantly larger on sandy soils compared to loamy or clayey soils, and the calculated leaching from loamy soils is significantly larger than from clayey soil. As can be seen in figure 14 the mean estimated leaching follow the values of the basic leaching. The mean leaching (and also the estimated basic leaching) was found to be largest on organic and on sandy soils and smallest on clay soils.

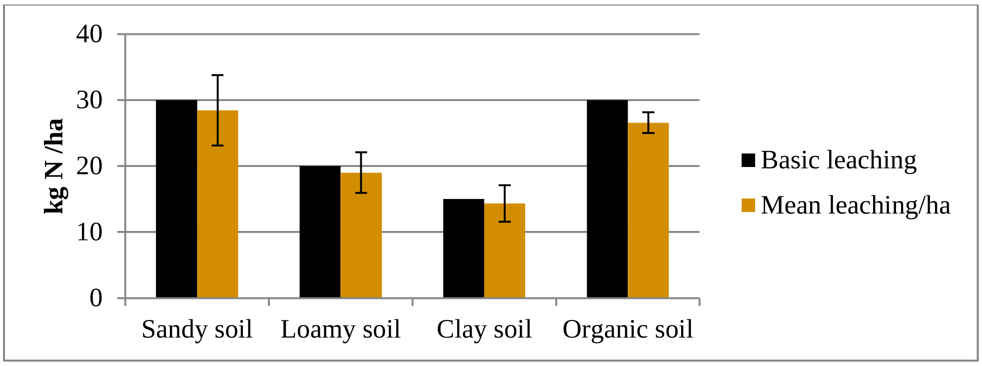

Figure 14 Calculated N leaching on Mazovian farms divided after soil type. Basic leaching is based on Swedish experiences from a spring crop (barley) and conventional tillage in autumn,

In figure 15 the estimated N leaching on Pomeranian farms is presented. The data are classified depending on the basic leaching (assuming a corresponding leaching as in Sweden), which means that this is classified depending on soil type and precipitation. In this case, precipitation was included since it varied much between farms (more farms were in the range of a precipitation of 700-1000 mm compared to Mazovia). However, organic soils are not included in the figure since only seven out of 243 fields had organic soil. Also, many errors were made in the calculations of the fields with organic soil, see next section. The dominating soil type was loamy soils (134 of 243 fields), followed by clay (66 of 243 fields) and sand (35 of 243 fields). The highest estimated risk for N leaching is found on sandy soils.

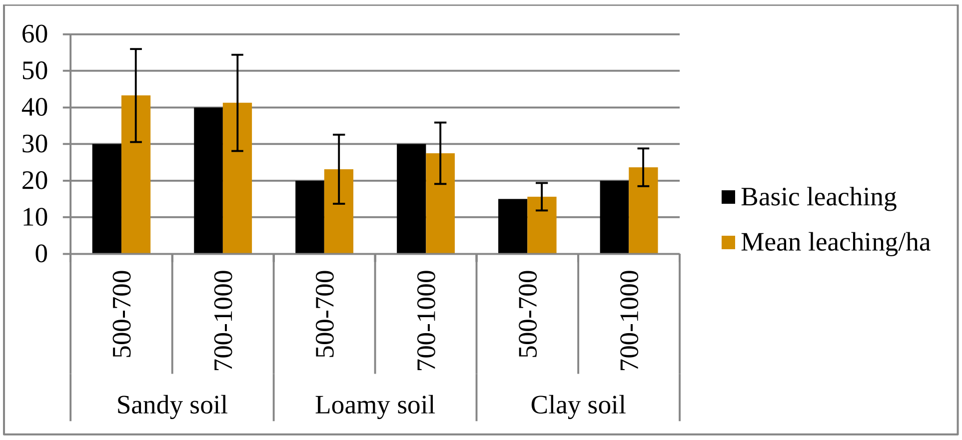

Figure 15 Calculated N leaching on Pomeranian farms divided after soil type and precipitation (mm/year).

3.4.3 Calculations of N leaching

In Mazovia, N-leaching was calculated on 18 out of 25 farms and in Pomerania N-leaching was calculated on all farms that participated in the study. Of the farms in Mazovia where they managed to calculate the N leaching, 11 managed to do it without any bigger problems while 7 have one or several larger errors in the calculation, i.e. errors that have a considerable effect on the calculated leaching. The most common error is that the wrong tillage factor is used (4 farms had this error). Other errors are that wrong manure factor is used (3 farms), or as in some cases; 0 is put as a manure factor when no manure is spread. That leads to a calculated leaching much lower than what it should be calculated to. Three farms have also used wrong figures of the basic leaching and all these have been excluded from figures 12-15. Only one farm has reported that a surplus of N is added on the farm, even though many farms have a quite large input of N. Of the 18 farms that more or less managed to calculate the N leaching, 10 had a problem with the crop factor. Not in the means that they have made errors, but crops that are not included in the tables attached to the instruction are cultivated (most commonly corn).

In Pomerania calculations of N leaching have been made on all farms, but not without problems. Ten calculations have been made without any noticeable errors while the remaining 15 have at least one large error. The most frequent error, made in almost all cases, is that 0, instead of 1, is put in the protocol in the excel sheet when something is not done. For example when no manure is applied or when the soil is not ploughed, zero is used as a factor instead of one, which led to a wrong value of the calculated leaching. Another error made several times in the Pomeranian calculations is that the factors have been misunderstood and added to a much higher factor. For example if manure is only spread in autumn, and no manure during the spring, some advisors have added the factor for slurry spread in the autumn (1.3) with the factor "no manure used" (1), and used the factor 2.3 in the calculations. That lead to a much higher value of the calculated leaching compared to what it should have been. It also seems to be an error in the excel sheet for the factor that gives the basic leaching, all fields that have organic soil have been given a basic leaching of 0.

Problems with the crop factor could not be identified in Pomerania since it is not reported what crop they cultivate. The most suitable option in the excel sheet is just marked with a X. There might still have been problems with crops that are not included in the tables. A surplus of N is calculated on 10 of the Pomeranian farms (the calculations have been made on all farms), but on none of the farms in Mazovia.

3.5 Results from soil analysis

3.5.1 Phosphorus content in soil

The Mazovian farms have relatively high phosphorus status in their soils (figure 16). The majority of the fields have a P-class of III or higher. No significant differences in P-class can be seen between the crop, dairy or pig farms. It is only the horse farm that stands out with a significantly higher P-class compared to the crop and pig farm (table 10). However, since that farm is the only one in its group it is hard to make any conclusions. In Pomerania many more fields have a lower P-status than in Mazovia; almost 50 % of the fields have a P-class of I or II. Not even a third of the Pomeranian fields have a P-class of IV or V, compared to about 60 % of the Mazovian fields. In Pomerania there are more significant differences in P-class between farm types. Pig farms have a significantly higher P-class compared to the other farm types (table 10), and dairy farms have a significantly higher P-class compared to the mixed farms.

Table 10 Mean P-class in Mazovian and Pomeranian farms. Letters indicate statistical significance between farm types in the same region.

	Crop farm	**Dairy farm**	**Pig farm**	**Specialized/mixed**
Mean Mazovian farms	3,7 *a*	3,9 *ab*	3,5 *a*	5 *bc*
Mean Pomeranian farms	2,5 *ab*	3,0 *b*	3,8 *c*	2,5 *a*

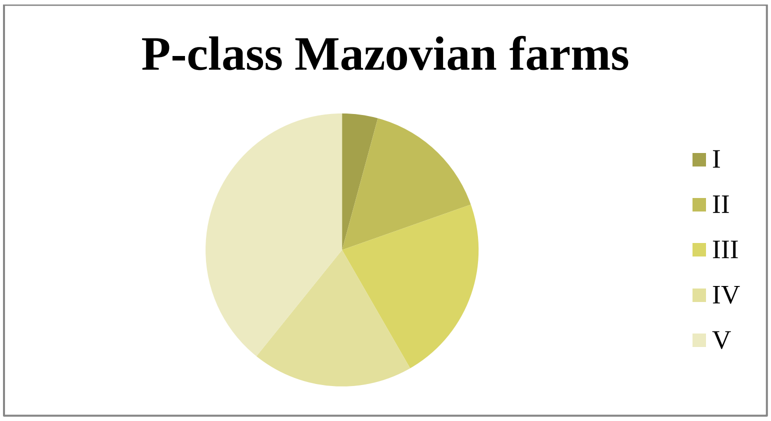

Figure 16 P-class of the analyzed soil samples in Mazovia. In total 404 soil samples were analyzed.

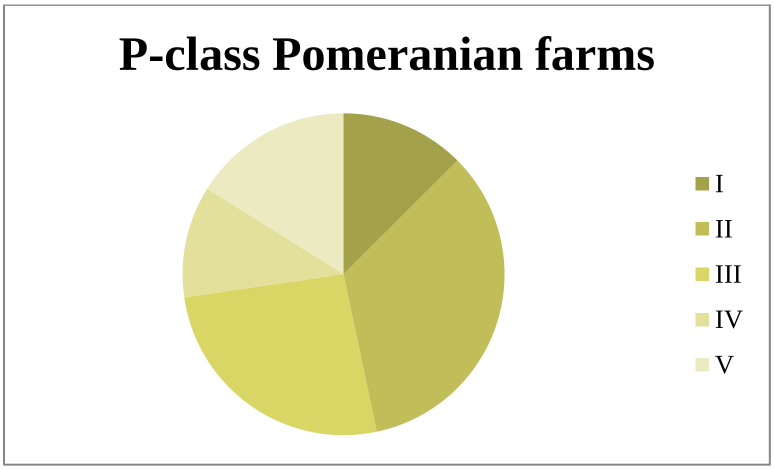

Figure 17 P-class of the analyzed soil samples in Pomerania. In total 392 soil samples were analyzed

From figure 16 and 17 it seems like Mazovian farms have a higher P-class, and the statistical analysis of the data tells the same thing. A highly significant difference in P-class is found between Mazovian and Pomeranian farms ($p<0.00001$). Significant differences are also found between Mazovian and Pomeranian crop and dairy farms, but not between pig farms (table 11). The mixed and the specialized farms cannot be compared since the groups are not similar in any way.

Table 11 A comparison of mean P-class between Mazovia and Pomerania. The fourth farm category (specialized respectively mixed farms) cannot be compared and is therefore not included in this table.

Mean P-class	**Mazovia**	**Pomerania**	**p-value**
Total farm area	3,7 *b*	2,8 *a*	1,2E-22
Crop farms	3,7 *b*	2,5 *a*	1,2E-11
Milk farms	3,9 *b*	3,0 *a*	4,3E-09
Pig farms	3,5	3,8	0,2 Not significant

3.5.2 Potassium content in soil

The K-status was generally low in both regions. In Mazovia, most of the fields have a moderate K-status (figure 18). In Pomerania the K-status is much lower and majority of the field have a K-class of I or II (figure 19). There is an obvious lack of K on the dominating part of the farms involved in this study. In Mazovia the lowest K-values are found on dairy farms ($p < 0.05$) and the K-values of the pig farms are significantly higher compared to crop and dairy farms (table 12). In Mazovia the mixed farms show a significantly higher value of the soil K-status compared to the other farm types.

Table 12 Mean K-class in Mazovian and Pomeranian farms. Letters indicate statistical significance between farm types in the same region. Notice that only 8 out of 25 Pomeranian farms presented data on K-class of the soil samples. Therefore, these figures might not be representative for all of the 25 Pomeranian farms.

Mean K-class	**Crop farm**	**Dairy farm**	**Pig farm**	**Specialized/mixed**
0Mean Mazovian farms	3,2 *b*	2,8 *a*	3,5 c	4 *bc*
Mean Pomeranian farms	1,7 *ab*	2,0 *b*	1,5 *ab*	2,6 *c*

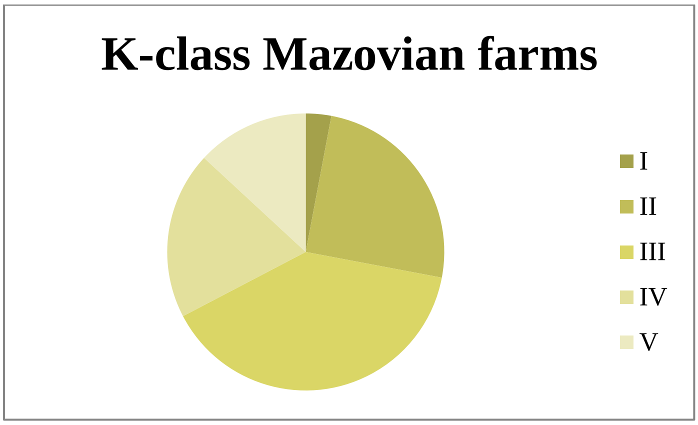

Figure 18 K-class of the analyzed soil samples in Mazovia. In total 404 soil samples were analyzed.

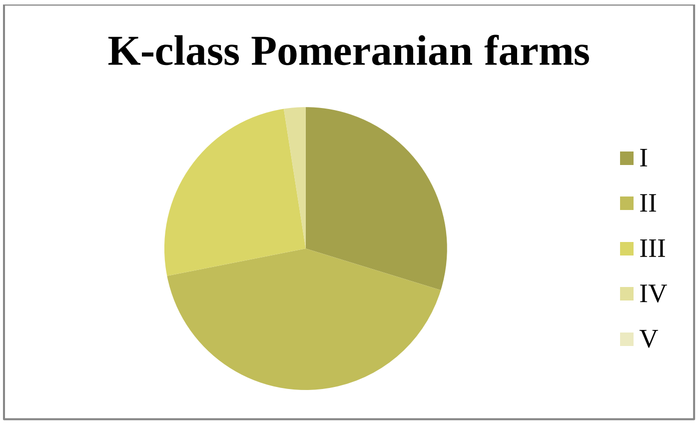

Figure 19 K-class of the analyzed soil samples in Pomerania. Notice that only 8 out of 25 farms presented data on K-class of the soil samples. Therefore, these figures might not be representative for all of the 25 farms.

The K-class is lower on Pomeranian farms, as can be seen in figures 18 and 19 and table 13. There are significant differences between Mazovian and Pomeranian farm in all compared farm types.

Table 13 A comparison of mean K-class between Mazovia and Pomerania. The fourth farm category (specialized respectively mixed farms) cannot be compared and is therefore not included in this table.

Mean K-class	**Mazovia**	**Pomerania**	**p-value**
Total farm area	3,1 *b*	2,0 *a*	3,0E-26
Crop farms	3,2 *b*	1,7 *a*	7,5E-14
Milk farms	2,8 *b*	2,0 *a*	2,9E-07
Pig farms	3,5 *b*	1,5 *a*	1,5E-07

3.5.3 Liming of soil

Liming normally has a positive impact on the soil fertility, soil structure is improved and the availability of macro- and micronutrients, for example phosphorus, is increased. In this project the pH-value of the soil is used, in combination with data of clay and humus content, to decide whether liming is urgently needed or not. The soil pH-value to aim for is normally pH 6.5 for clay soils (humus content < 6%) and pH 6.0 for soils with a higher content of silt and sand. The target value of soil pH is approximately 0.5 units lower for soils with higher humus content (Jordbruksverket, 2014).

3.5.3.1 Liming need Mazovia

The need for liming at the farms in Mazovia was found to be limited (figure 20). Most farms seem to have a good soil status and not an urgent need to increase soil pH. From figure 20 it seems like on more than a third of the fields liming is indicated, needed or necessary.

According to farmers and advisors there were specific plots on the farms where liming was needed. In this project a certain amount of money was used to subsidize liming of the soil. The liming was focused to the most problematic fields with very low pH. Information about the liming: where lime was applied, the amount and type of lime is not collected yet but should be compiled by the advisors.

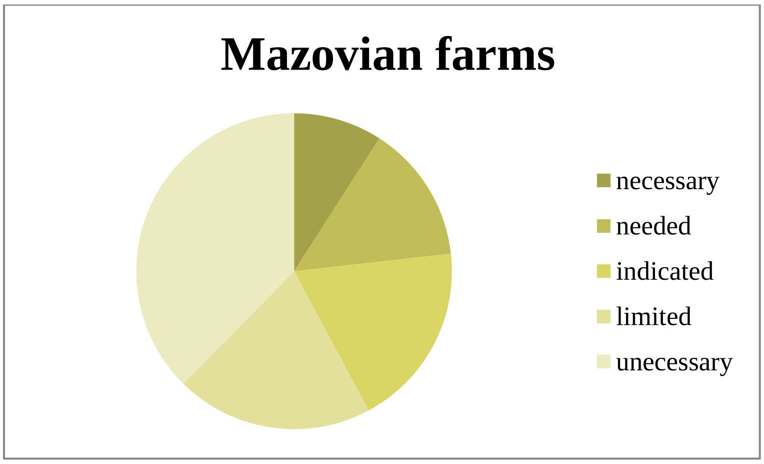

Figure 20 Liming need at Mazovian farms. In total 404 soil samples were analyzed.

In appendix 6 the liming need at different farm types are presented. The need for liming is generally slightly less for the pig farms. In contrast almost every soil sample that indicated that liming was necessary is found on crop farms or dairy farms. The need for liming seems to be largest on dairy farms. A statistical difference ($p < 0.05$) in liming need is found between crop farms and dairy farms, showing that the liming need is greater on dairy farms. Very low soil pH has also been demonstrated for pastures used for grazing (Pietrzak, oral). Between the other farm types no significant differences are found.

3.5.3.2 Liming need Pomerania

In Pomerania a big need for liming the fields can be seen (figure 21). On almost 70 % of the fields in this study liming is necessary, needed or indicated. The need for liming is large on all farm types (appendix 6).

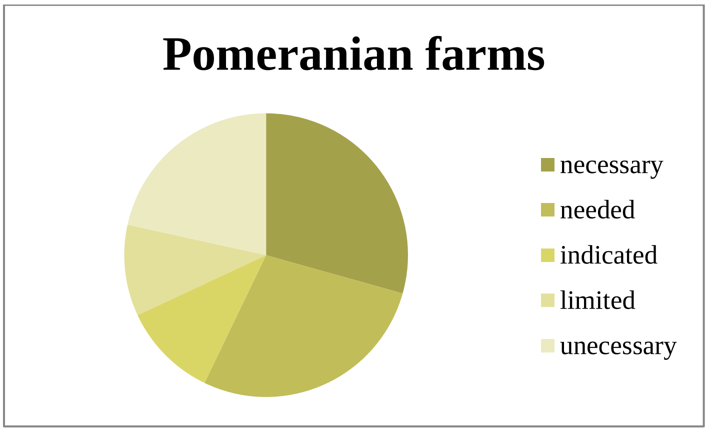

Figure 21 Liming need at Pomeranian farms. In total 392 soil samples were analyzed.

The liming need on different farm types is presented in appendix 6. The farms with mixed production have the largest share of soils where liming is necessary, needed or indicated. A significant difference in liming need is found between the mixed farms and the pig farms, where the mixed farms show a larger need for liming. Between the other farm types no significant differences are found.

Table 14 shows that the need for liming is significantly higher on Pomeranian farms compared with Mazovian farms, both when comparing total farm area and comparing different farm types.

Table 14 A comparison of mean value of liming need between Mazovia and Pomerania. The fourth farm category (specialized respectively mixed farms) cannot be compared and is therefore not included in this table. A lower mean indicates a higher liming need.

Mean liming need	**Mazovia**	**Pomerania**	**p-value**
Total farm area	3,7 *b*	2,7 *a*	5,0E-21
Crop farms	3,8 *b*	2,9 *a*	7,1E-06
Milk farms	3,3 *b*	2,7 *a*	0,005
Pig farms	3,7 *b*	3,2 *a*	0,015

3.6 Agri-environmental indicators

From the data gathered in the walking protocol and in the FGB a lot of data used as environmental indicators by EU (EUROSTAT, 2010) can be found. Compiling this data enables comparison with Poland in general and with other countries in EU-28. Several agri-environmental indicators have been established to explain the relationship between agriculture and environment, to enable comparison farms and countries, to evaluate the result of performed measures etc. (EUROSTAT, 2010). Here selected agri-environmental indicators of the polish farms included in the study are presented and compared with general data for Poland and EU. Gross N balance is also an agri-environmental indicator (EUROSTAT, 2010) that is already presented in the section “Surpluses and leaching”, and therefore not included in this section.

3.6.1 Farmers training level

The educational structure is one of the most important factors that contribute to a more efficient management of agricultural holdings. This since well-educated farmers, that are innovative and aware, find it easier to adapt to environmental considerations, new economic circumstances and social conditions (EUROSTAT, 2010, Hallberg et al., 2005). The interview study performed by Vatema (2014) indicated that the awareness of agricultural impacts on the environment is low among the farmers. The farm walk protocols indicate the same thing with a few exceptions. There were no proposed measures noted in the protocols on how to improve farm management to decrease the environmental impact. More than 50% of the Polish farmers have some kind of agricultural training and about 10 % of the farmers have participated at group training free of charge during the last 12 months. However, this training does not normally focus on environmental issues related to agriculture. The number of Polish farmers that have participated in vocational training devoted to the environment is very low (EUROSTAT 2015-02-23a).

All of the advisors included in this project concluded that the advisory visits they performed increased the farmer’s knowledge about the causes of loss of nitrogen (N) and phosphorus (P) and what measures to be taken to reduce the loss (Report PODR, 2013).

3.6.2 Mineral fertilizer consumption

Data on mineral fertilizer consumption is gathered from the farm gate balance, but since it is an agri-environmental indicator it is presented here. Excessive nutrient application may pose a threat to the environment. For that reason mineral fertilizer consumption is a common agri-environmental indicator to look at. When looking at this indicator it is important to notice that the total application of mineral fertilizers is divided by the utilized agricultural area. However, this area includes not fertilized areas as well. Also higher fertilizer consumption does not necessary mean a larger nutrient leaching, since leaching depends on many other factors. Still, higher fertilizer consumption per hectare of agricultural utilized area gives an indication of the risk for nutrient leaching (EUROSTAT, 2010). Organic fertilizers also provide nutrients, and therefore also pose a risk for nutrient leaching. Regions with a high livestock density access more organic fertilizers and therefore need less mineral fertilizers compared to regions that are dominated by crop production. That needs to be considered when looking into this indicator (EUROSTAT, 2010).

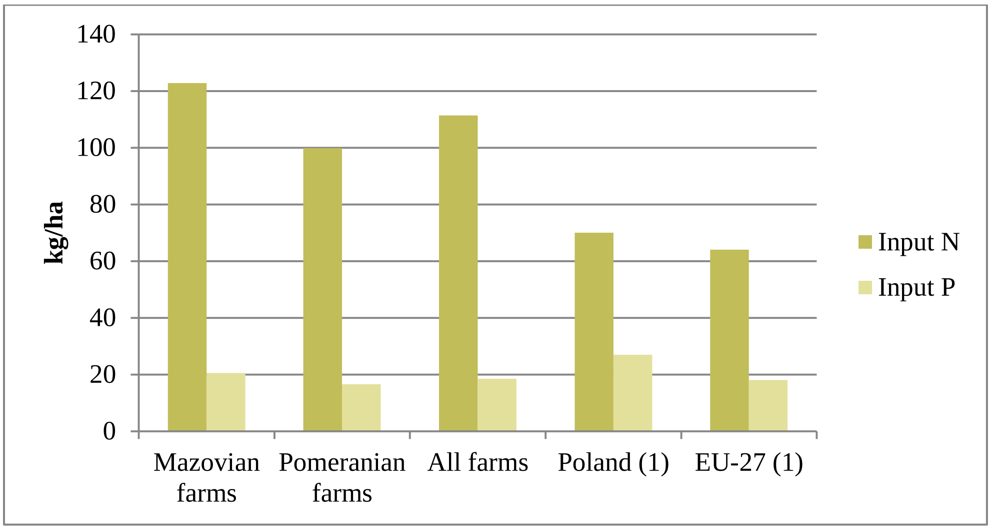

Figure 22 Input of N and P from mineral fertilizers at the farms included in this study (Mazovian, Pomeranian and all of the farms in the study) and general figures from Eurostat. (1) data from EUROSTAT (2010).

On average Poland have a mineral fertilizer consumption of about 70 kg N ha^{-1} and 27 kg P ha^{1}. This is a bit higher that the EU-27 average of 64 kg N ha^{-1} and 18 kg P ha^{-1}(EUROSTAT, 2010). The Mazovian farms have larger input of both N and P, than the Pomeranian farms (figure 22). The farm included in this study have on average larger inputs of mineral N and P compared to the average input in Poland and in EU-27 generally. These results are from the data gathered in the FGB and can be seen in appendix 4 and 5.

3.6.3 Soil cover

Soil cover means the period of the year when the soil is covered by crops; cash crops, ley or cover crops. When the soil is bare and uncovered the risk for nutrient leaching and soil erosion is increased (EUROSTAT, 2010). Soil cover decreases this risk and can also help to improve the soil fertility. When looking at the agri-environmental indicator 'soil cover' one consider the part of the year when the arable land is covered by winter sown crops, perennial crops, annual grass crops etc. (EUROSTAT 2015-02-23b). Fifty percent of the arable area in Poland is covered by normal winter crops, e.g. winter wheat, triticale and winter barley. Five percent of the arable land is covered by cover crops and 2-3% of plant residues (EUROSTAT 2015-02-23b).

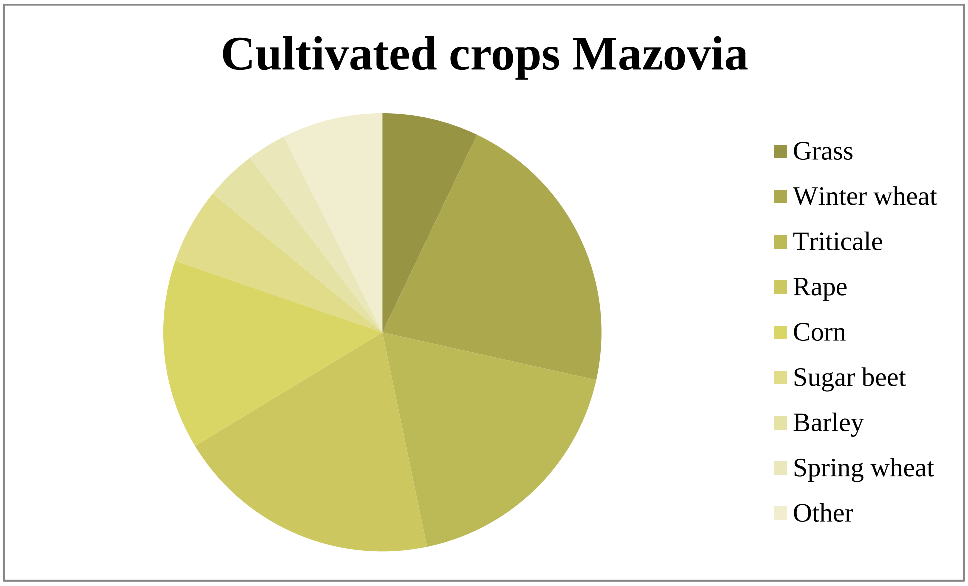

Figure 23 Share of farm land covered with different crops, in Mazovia. The field area is considered.

Figure 23 shows the share of the field area in Mazovia covered with different crops. If it is assumed that all triticale and rape is sown in the autumn, it seems that two thirds of the fields are covered with vegetation during winter. The fields with grass, winter wheat, triticale and rape can be assumed to be covered during winter, those stands for 66 % of the total field area. More recent official data about crops in the year of this study (2013-2014) are not available for Pomerania and cannot be compiled.

It is hard to read from the walking protocols if any of the farms have cover crops. According to advisors asked cover crops are not popular among farmers since the seed is very expensive and the farmers fear that such crops should make the already dry soil even dryer. Neither it is not very common to have buffer zones along water courses, as can be seen in figure 24. Only two farms in Mazovia and three farms in Pomerania state that they have some kind of buffer zone along adjacent water

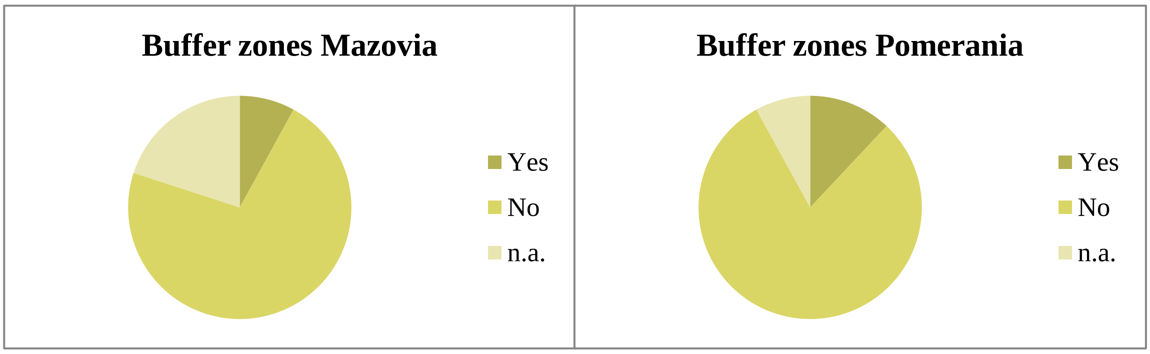

Figure 24 Share of farms that have buffer zones on fields that are adjacent to watercourses. Not applicable (n.a.) are the farms that do not have any adjacent watercourses.

3.6.4 Tillage practices

Changed tillage practices can be an effective measure, both separately and in combination with other measures, to reduce soil and nutrient losses (EUROSTAT, 2010). According to Eurostat (2013-07-09) over 85% of the arable land in Poland was under conventional tillage. The remaining 15 % was divided almost equal between conservation tillage practices, zero-tillage systems and no tillage. Conventional tillage is the most widespread tillage practice in the EU. Conservational tillage is mainly found on farms that are specialized towards cereals, protein crops, olives, and poultry or wine (EUROSTAT 2015-02-23c).

Figure 25 shows tillage practices at the farm included in this study. Most of the farms perform conventional tillage with early autumn tillage before winter crops and late autumn tillage before spring crops. Reduced tillage is not very common among these farms, and only performed at a few farms in Mazovia. Only one farm in Mazovia uses zero-tillage on the whole farm area. The reason for why the farmer chose to practice zero-tillage was according to him that he has a big problem with stones on his field, coming up to the surface when the soil is tilled. A few farms use delayed tillage before spring crops, especially in Pomerania.

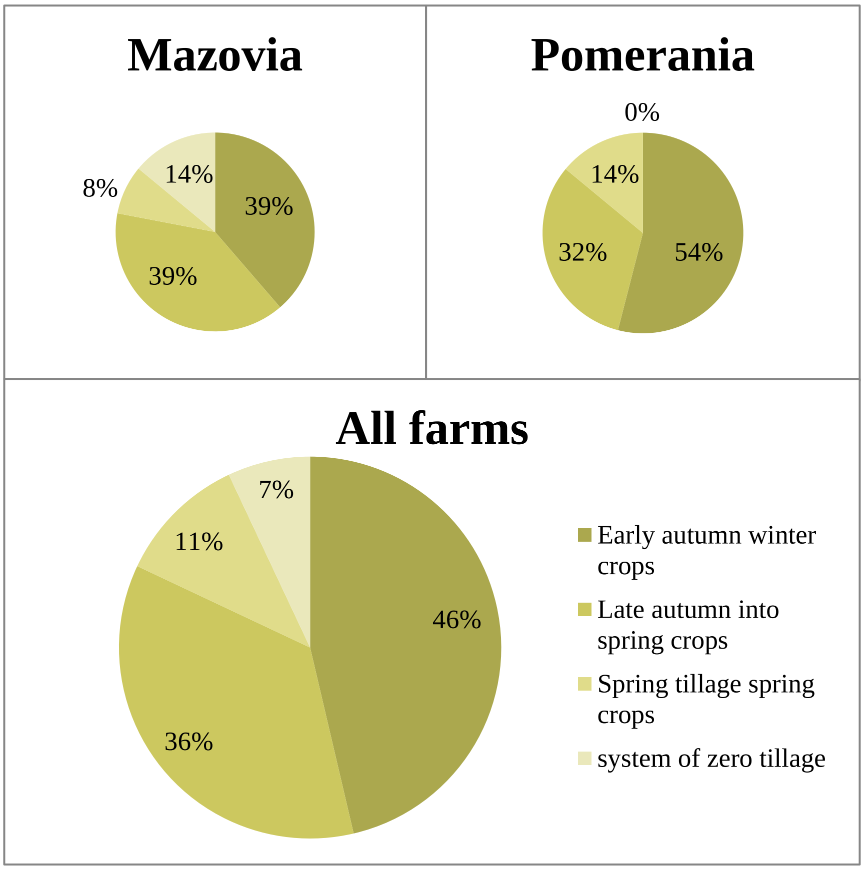

Figure 25 Share of farms that perform conventional, delayed or conservational tillage.

3.6.5 Manure storage

Nitrogen volatilities from manure during several of the steps in the manure handling process; in the animal housing, during the manure storage and spreading of the manure. Factors that affect the emissions are besides the types of manure also manure storage, timing and application technique when spreading the manure (EUROSTAT, 2015). Proper storage of manure is necessary to avoid the harmful effects on the local environment that N emissions and run-off from manure can cause (EUROSTAT, 2010).

Of the farms included in this study half of them in both Mazovia and Pomerania have some kind of plate on which the manure is stored. The remaining farms store their manure in piles either on the fields on which it is to be applied or somewhere on the yard (figure 26).

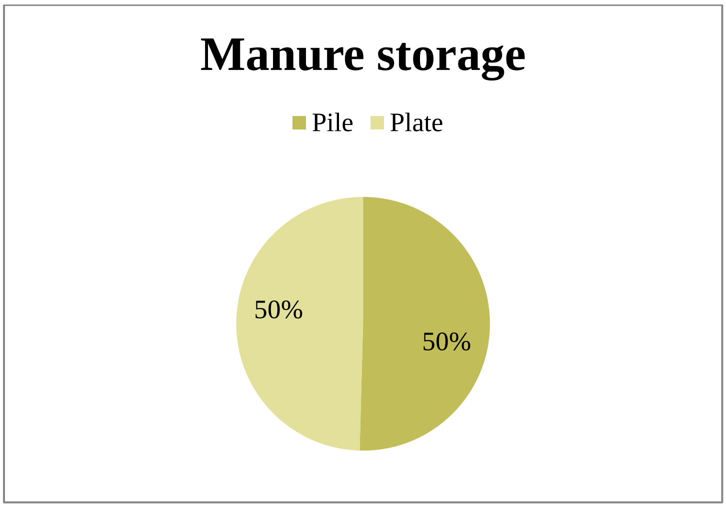

Figure 26 Share of farms (all farms in the study) that store manure on a plate or in a pile on a field or somewhere else on the farm area.

Almost all (89 %) of the manure piles are large, wider than 2.5 m. There are larger difference in the height of the pile, how long the manure is stored in a pile, how often piles are formed and when the manure is applied to the fields. Most common is a storage time of about two months, and the pile is most commonly formed during late autumn or winter. Only one of the farms keeps their pile close to a watercourse, the rest keep their piles more than 150 meters from the closest water. In Pomerania half of the farmers spread manure on the fields during autumn and half spread it during spring. In Mazovia a larger share of the farmers spread the manure during autumn (60%) than during spring (40%).

The farms that produce slurry and urine store it in tanks. The major parts of these tanks are closed or have some kind of cover, like a plastic cover or a stable crust (figure 27). A big difference can be seen between the Mazovian and Pomeranian farms included in this study, since a larger share of the Pomeranian slurry tanks were covered but these tanks were also smaller. The number of farms that produce or buy slurry is larger in Pomerania (20 of 25 farms) than in Mazovia (13 of 25

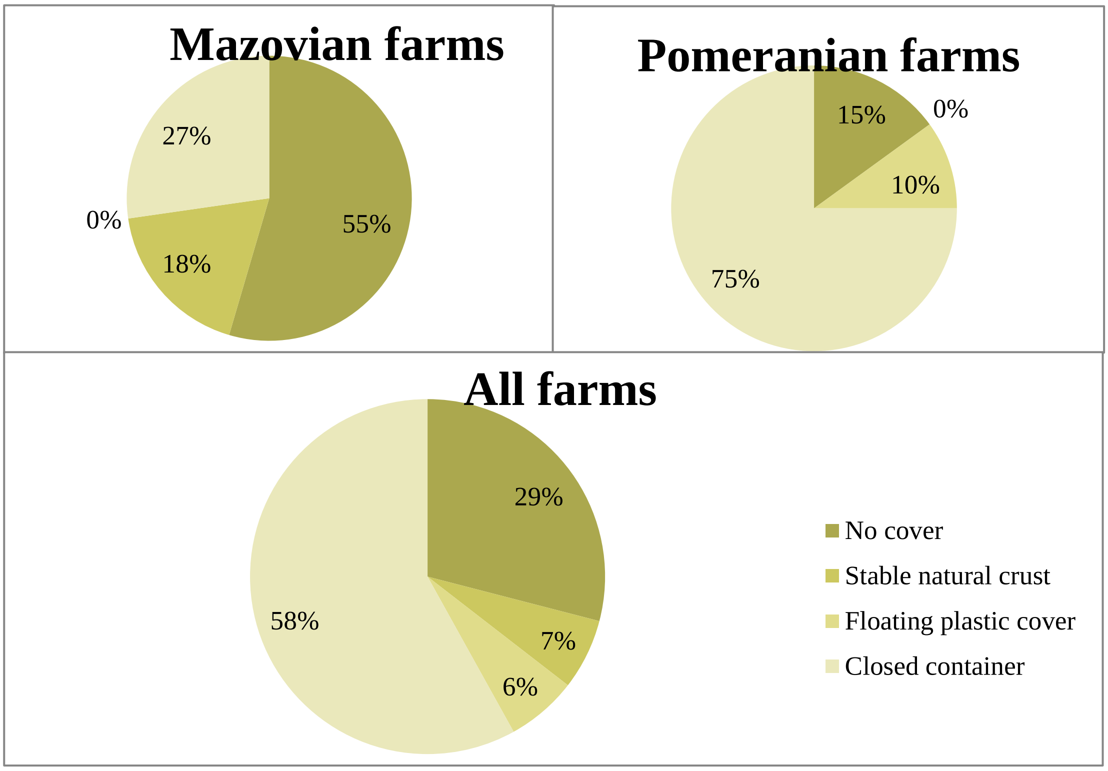

Figure 27 Share of farms in Mazovia, Pomerania and total that lack cover or have some kind of cover on the slurry tanks.

3.6.6 Agri-environmental commitments

Agri-environmental measures were designed to encourage farmers to protect and improve the environment at their farms and on their land. The measures are designed so they can be adapted to the local or regional farming and environmental conditions. Through these measures farmer are no longer only paid for producing food, but also for doing well for the environment (EUROSTAT, 2010).

No measures were proposed in the walking protocols, although measures were discussed between the farmers and the advisors. Some of the farmers have done their own projects to reduce their impact on the environment. Installing small sewage treatment plants is one measure found on some farms and improved wetlands as sediment traps is another measure.

3.6.7 Other results from the farm walk

The farm walk also presented other information that can be useful. Problem areas were identified in the walking protocols. Here these areas where for example fields where depressions emerged at a certain time during the year, where erosion problems were visible or where trampling damages could be seen.

One of the visited farmers told us that the walking protocol made him understand he had erosion problems on a sloping field that he ploughed every year. After identifying this problem area he decided to have grassland on that area instead, to mitigate the erosion problems. The result from the farm walk that most advisors thought was that the most important result from this project was that it made the farmer think about their farming practices and how they can improve.

4 Discussion

4.1 Farm gate balances – how useful are they?

Nutrient balances may play an important role to create awareness among farmers and identify hotspots that might be a risk for nutrient leaching. However, the usefulness of the nutrient balance depends on the completeness of it (Schröder et al, 2003) and the reliability of the FGB depends on the sources and quality of information (Swensson, 2003). Factors like yearly conditions affect the balance significantly. Without additional information about the processes underlying the nutrient fluxes, the nutrient balance does not give much useful information (Schröder et. al., 2003). This farm gate balance contains most components identified as necessary by Schröder et al. (2003) except for immobilization, erosion and sedimentation. Changes in soil organic N can be of great importance for the farm gate nutrient balance (Schröder et al, 2003). Therefore, not considering changes in soil nutrient might affect the reliability of the calculated nutrient surpluses. Compared to the other FGB:s presented in table 6 the FGB made in this project is rather detailed.

What changes that can be expected from the created farm balances are hard to predict. Hallberg et al. (2005) showed that farmers are generally positive to perform farm gate nutrient balances as long as it is not mandatory. Hallberg et al. (2005) experienced that the farmers were interested in understanding more of how to include the environmental aspect in their farm management. The interest from the farmers increased if they understood the environmental issues and how changing their management could be beneficial both from environmental point of view and for their business. Most of the farmers in Hallberg's study changed their management in some way after they had performed some type of input-output accounting system (like a FGB). Advisory campaigns among farmers have been shown to be efficient for reduction of the nutrient surpluses. Most of the farms in a study by Fanguerio et al. (2008) in Northern Portugal improved their nutrient management, improved the nutrient efficiency and reduced the nutrient surpluses. The major reason for the reduction of nutrient surpluses was a decrease of inputs, mainly mineral fertilizers (Fanguerio et. al., 2008). Also Swensson (2003) showed that an education and advisory campaign, which aimed at increasing the awareness among farmers of environmental questions related to farming, reduced the N surplus significantly.

To make any use of the performed farm gate balances, it is not enough to just provide data from the calculations. It needs to be combined with indicators to compare farm data with. Indicators that are either set up by politicians or based on data (or modelled data) from farms follow standards for good agricultural practice or best available practice. This enables benchmarking between the farms to identify possible measures to improve farm management (Hallberg et al., 2005). In the present project soil mapping, visual observation on farm walks, as well as simplified estimates on N leaching was tried as such benchmarking. It is also important to combine performance of nutrient balances, or any other input-output accounting system, with interpretation of the results and advisory services to help the farmers implementing necessary changes. The most successful input-output accounting systems are those which are linked to advisory services and tools for production planning, like fertilizer planning (Hallberg et al., 2005). This was done in a Swedish information campaign where one part of the voluntary campaign was to calculate farm level nutrient balances. Other parts were a 2-day course and a package of rules concerning the farm management that the farmers ought to follow (Swensson, 2003).

Since the farm gate balances are just one tool in a larger campaign, together with a discussion between the farmers and advisors on how to improve nutrient management, estimation of nutrient leaching etc., it can be assumed to have a positive effect and reduce the risk for nutrient leaching. Using some kind of nutrient balance together with advisory work and other tools with the same goal have been proven to work in several cases (Fanguerio et al., 2008, Swensson, 2003). There are few polish farmers that have participated in any kind of training devoted to environmental issues increase (Eurostat, 2015-02-23a). With more farmers trained in environmental issues the awareness and understanding of how agriculture impacts the environment will increase (EUROSTAT, 2010, Hallberg et al., 2005). According to the advisors in Mazovia it was very easy to find farmers willing to participate in this study. The farmers have been positive to the project, interested and willing to improve. The farmers were not so keen on calculating and preferred maps where the situation of the farm was visualized. The farmers also wanted to know more about how to interpret the results since only the figures did not tell so much. According to Hallberg et al. (2005) a better result from an advisory campaign can be expected if the farmers are interested and feel motivated. Education of advisors could improve the knowledge among farmers regarding environmental issues connected to agriculture.

The advisors included in this project thought the next step should be to discuss interpretation of the farm results with the farmers. Like what does the FGB say about the farm and how can the farmers use that information for improvement? The advisors need help with material that advises the farmers on how to interpret the results. The advisors in the Mazovian district propose that information should be given to the farmers on how to interpret the results from the farm gate balances, the soil maps and the information gathered in the walking protocol. This would according to the advisors make the farmers more interested and positive to the project, when they understand how the information they gather can be used for improving their farms.

A limited number of manure samples were analyzed from the Mazovian farms. Generally, the figures of the manure need to be updated according to the advisors involved in this project. The figures available for the moment were collected over 20 years ago and the nutrient content in the manure might have changed considerably due to changed feeding of the animals. If there were updated figures of manure and if the farmers start to test their manure they will probably trust the effect of the manure better and use less mineral fertilizers according to the advisors in this project.

4.2 Nutrient surpluses

Nutrient surpluses per area indicate the environmental impact of the agriculture, if the balances are complete and additional information about the nutrient fluxes are available (Schröder et. al., 2003). Although there are large uncertainties connected to the environmental indicator (N-surplus/ha), it gives important information for assessing the impact of nutrient inputs on the environment (W. de Vries et al., 2011). The N surplus is closely correlated to the nutrient input (Leip et al., 2011). The largest surpluses can be seen at the most intensive farms, the farms with the largest number of livestock unit per hectare. Nitrogen surpluses have been shown in several studies to correlate to farm intensity. Fanguierio et. al. (2008) showed a positive correlation between N surpluses and milk production per hectare and the stocking rate of the farm. Both can be seen as indicators of the farm intensity. Animal farms often have both a larger nutrient surplus and a lower NUE compared to crop farms or mixed farms, since animals only retain little of their N intake in the products (Leip et al., 2011, Swensson, 2003). Also in the farms included in this project the nutrient surpluses are higher on the farms with animals.

4.3 Farm gate balances – a comparison

4.3.1 Comparison with other FGB-studies

When comparing different nutrient budgets it is important to be aware of what factors that are included in different studies and different system boundaries. It is also important to consider the level of the nutrient budget since the calculated nutrient surplus will differ a lot if the budget is calculated on field level compared to on farm level (de Vries et al., 2011). The calculated nutrient surplus is often largest when calculated at farm level, and smaller when looking at field, land or soil level (Leip et al., 2011). The most common method to use is the farm gate balance since it gives an overall picture of the nutrient management (Leip et al., 2011, Schröder et at., 2003).

Mineral fertilizers and feed are the most important sources of imported nutrients to the farms included in this study. Similar results have been found at farms all over Europe (D'Haene et al., 2007, Nielsen and Kristensen, 2005, Fanguerio et al., 2008, Neves et al., 2006). At the farms included in this study a N surplus of 49-242 kg N ha^{-1} yr^{-1} was calculated for the Mazovian farms (an average of 98 kg N ha^{-1} yr^{-1}) and a N surplus of 122-193 kg N ha^{-1} yr^{-1} at the Pomeranian farms (an average of 113 kg N ha^{-1} yr^{-1}). These farms have higher average nitrogen surplus than the EU27 and the EU15 average (67 and 96 kg N ha^{-1} yr^{-1} respectively) (Leip et al., 2011). One important thing to consider is that there are great differences among the farms included in this study. Some farms have great surpluses and some have great deficits, resulting in a relatively high mean value of the surpluses (compared to the EU27 or EU15 average). Compared to the farms included in the nutrient budget studies compiled in table 19, the farms in this study seem to have a rather low nutrient surplus. Especially when comparing with the very intensive dairy farms with surpluses of over 500 kg N ha^{-1} yr^{-1} (Fanguerio et al., 2008). According to Leip et al. (2011) the average N surplus of Polish farms (all farm types in the whole country) is below 50 kg N ha^{-1} yr^{-1}. Daalsgard et al. (2011) calculated a nutrient surplus more similar to the one calculated in this study; a surplus of 122 kg N ha^{-1} yr^{-1} in a nutrient budget study with 100 farms of mixed farm type. When comparing nutrient load from different farms it is also important to notice that similar nutrient loads may produce different effects. The effects are not only related to the nutrient load, but also to regional sensitivities, availability of other elements etc. (de Vries et al., 2011).

4.3.2 Comparison of Pomeranian and Mazovian FGB:s

Regional variations in N fluxes are common and de Vries et al. (2011) showed that these regional variations are mainly determined by N inputs. The variations are highest in areas with intensive crop production and high livestock density, while land and soil characteristics did not contribute that much to the variations in N fluxes. The difference in total N input between the Pomeranian farms is not as big as the difference between the Mazovian farms. The larger differences between

Mazovian farms can be assumed to be due to the more intensive crop production and the higher livestock density in Mazovia, compared to in Pomerania.

The outputs from Pomeranian animal farms are rather small, both compared to the Mazovian farms and farms included in other studies. The outputs from animal farms in Pomerania are much lower compared to the farms in Mazovia. The Pomeranian animal farms have mean outputs of 21-34 kg N/ha (appendix 5). In Mazovia the animal farms have mean outputs of 80-190 kg N/ha (appendix 4). According to the farmers visited in Pomerania it is common for the farmers to sell crops and animal products to family and neighbors. Therefore, all outputs might not be considered in the FGB:s from Pomerania, resulting in a lower value of the output compared to reality. The smallest surplus, and the highest nutrient use efficiency, is found on the crop farms in Pomerania with a mean surplus of 21.8 kg N/ha. Probably due to the considerably larger outputs compared to the other farm types in Pomerania. This since a smaller output will give a larger surplus (surplus = inputs-outputs).

The inputs are larger in Mazovia compared to Pomerania, but despite that the nutrient surpluses are larger in Pomerania. One reason for the larger average surplus in Pomerania compared to Mazovia can be the very small nutrient outputs from Pomeranian animal farms. It is hard to compare Mazovian and Pomeranian farms since they differ much from each other. The Mazovian farms in this study are more specialized, generally larger (but not significantly larger in this study) and have a higher farm intensity compared to the Pomeranian farms. There are also more farms with nutrient deficiencies in Pomerania compared to in Mazovia, but there are also larger shares of farms that have a large surplus of N. One reason for the larger share of farms with nutrient deficiencies can be that the smaller and more extensive farms in Pomerania can be assumed to have a lower profit and therefore might not afford the most suitable fertilizers. Several of the farmers visited in Pomerania said that they would add more phosphorus if they only could afford it.

The output from the crop in Pomerania farms were a bit smaller compared to the crop farms in Mazovia, 109 kg N/ha compared to 150 kg N/ha in Mazovia. The output from animal farms in Pomerania were much smaller compared to the farms in Mazovia and other animal farms studied in Denmark and Portugal (Nielsen and Kristensen, 2005; Bassanino et al.,2007 and Daalsgard et al. 2012). The Pomeranian animal farms have mean outputs of 21-34 kg N/ha (Appendix 5).

No statistical significant differences are found between Mazovia and Pomerania when analyzing the nutrient surpluses, except for the surpluses on pig farms. When P23 is excluded from the calculations there is a significantly larger N surplus on Mazovian pig farms compared with Pomeranian pig farms.

4.3.3 The outlier-farms

Why do these farms differ so much from the other farms of the same farm type? It can of course be due to errors in the calculations. Some parameters are hard to estimate correctly. Why one of the farms was so different was answered when that farm was visited. The figures in the FGB did not give the whole picture of the farm since only a small part of the farm land was included (one small estate that was inherited), but all of the animal production at the farm was included in the FGB. That led to enormous deficits in the FGB calculations. However, those figures are not to be considered since they are completely misleading. It is possible that this is the case on not only this, but also on several of the other farms. The case that the whole farm or the whole production is not included in the FGB, which can make the result not very representative for the farm.

4.3.4 Sources of error

Calculation of the stock in the FGB:s is something that have caused some problems. In Mazovia calculation of the stock change was neglected on almost every farm, it was estimated that the stock in the beginning of the year was similar to the stock in the end of the year. That might be a valid estimation for some cases, but can also be a cause of error. One farmer describes that he bought a lot of mineral fertilizers in one year, having in mind that it would be enough for the next year as well and thought that it had affected the nutrient balance. A case like that can easily be missed if stock changes are not included.

Another identified error is that all of the outputs might not be registered and the farmers might not want to tell about them. Some farmers sell meat, egg etc. to neighbors, on the local market or use it in the family. The outputs might therefore be larger than presented in the FGB:s in some cases. That can have been the reason for the rather low outputs in Pomerania.

Errors due to estimations or miscalculations can also be expected to occur according to the Mazovian advisors. All variables are not very easy to estimate and simplifications always have to be done to some extent. Another error that was discussed among the advisors in Mazovia was that some of the tabled data used was not up to date. That was the case for the data on nutrient content in manure, where all the data was gathered before 1995. The data on the leaching might not be completely accurate since it is based on Swedish experiments and might not reflect the Polish conditions completely.

Another thing that one should bear in mind when studying the FGB:s is that it might be large variations among years. The results from the FGB can be assumed to vary rather much between years depending on yield levels, unexpected events like death of animals, changed price of the inputs etc. To be able to make more reliable conclusions, data from several years would be required.

4.4 Nitrogen leaching

The nitrogen leaching from Polish farms were generally expected to be low based on the Swedish experience. The average farm is rather extensive and therefore does not cause that much nutrient leaching. No significant differences in the calculated risk for N leaching can be seen among farm types or between Mazovia and Pomerania. Pomerania seems to have a slightly higher risk for N leaching and that is due to a higher value of the basic leaching, which is due to more precipitation and a larger share of sandy soils. Significant differences in N leaching could be seen among soil types in each district, and the highest risk for leaching was found on sandy and organic soils.

Many direct errors have been made in the calculation of the risk for N leaching. It is obvious from the many errors made in the calculations that the advisors have not completely understood the excel sheet used to estimate N leaching. If they had understood the excel sheet they would have noticed these errors. From the results it seems like some advisors only have inserted some random figures in the excel sheet, but they have not paid any attention to the results. That really shows the need for more education.

One common error is that zero is put as a factor in the excel sheet when something is not done. For example if manure is not spread on the field, than the basic leaching is multiplied with zero instead of one as it should be. This will give a calculated total leaching from that field much lower that what it should have been if the calculations were correct. Some advisors obviously do not understand what happens when you put zero as a factor in the calculations. Another error commonly made is that the advisors did not understand how to calculate if a surplus of nutrients is added to the field. In many cases that part of the calculations of N leaching is not performed, even though it is obvious that a surplus of N is added to the field. These two errors are probably made due to a lack of understanding of the N leaching calculations. It is obvious that the advisors need more training in using a method like this to get a deeper understanding of what the calculated figures means and how to interpret them. From the discussion with the farmers and advisors visited it was clear that they had not paid much attention to the result from the N leaching. None of the farmers visited have had a discussion about why some fields got a higher value of the risk for N leaching and what could be done to reduce that risk. If the advisors had understood these calculations better they would probably have paid more attention to it and would have focused more on discussing how different management on their own fields might affect N leaching. To get the farmers to have in mind that what they do one year will affect the leaching the following year.

Some errors are made due to lack of tabled values for some crops etc. That caused some confusion and irritation among advisors, that common Polish crops were not included in the tables over the effect of the preceding crop. It is therefore important that the materials distributed are adapted to polish conditions to avoid confusion among advisors and farmers.

The advisors that managed to use the excel sheet in a proper way have calculated reasonable values of the risk for N leaching. But still, more focus should be put on how the result from the calculations can be used in the discussion between the advisor and the farmer. Otherwise the result will be nothing but just figures on a paper.

4.5 Soil analysis

There is a significantly higher soil phosphorus status in Mazovia compared to in Pomerania. It is hard to draw any conclusions between farm types in Mazovia, since the group called specialized farms only contains one farm and it is only that farm that differs significantly from the other types. In Pomerania the pig farms have the significantly highest phosphorus status of the soil. That could be expected since the pig farms also have a lot of manure with a high P content.

Many soils on the studied farms have a rather low P status; there is a great need for applying P. At the same time, many farms show a deficit of P in the FGB, this indicates that the soils are getting depleted. Several farmers visited mentioned that they knew they need to apply more P, but they cannot afford it. This can lead to not only lower yields than possible, but also that the farmers apply too much N, since P is the nutrient that limits the plant growth. To increase the yields one important measure would be to apply more P. Another fact that is important to consider in this context is that the soils are very acid. Due to the acid soils a large share of the P will probably precipitate and become unavailable for the crops. The first step, before increasing the P fertilization, would be to apply lime on the soils to make the soils less acid. There is a large need for liming, especially in Pomerania where the need for liming is significantly higher compared to in Mazovia. Liming was mentioned as the most important measure to improve yields by many farmers visited. Liming should probably be one of the most prioritized measures in future projects. Adding lime could increase soil pH and the fertilizer applied could be utilized in a better way, which can be assumed to reduce the risk for leaching (Ulén et. al., 2008).

In general the soils have a very low K status, especially in Pomerania (significantly lower compared to in Mazovia). Some of the farmers visited said the low K status was due to cultivation of demanding crops like potatoes and that they have taken away crop residues from the fields for a long time. Many farmers used N34 as the major fertilizer, and only applied K when spreading manure.

The soil analysis and the presentation of the results in form of farm maps were very appreciated among the involved farmers. The farmers felt that they could make the most use of this part and that they understood it. It was good and pedagogical to present the results from the analysis on maps. The soil analyses were performed by Polish accredited laboratories after sampling as composite samples representing a certain area according to Polish praxis. But of course the results might not have been justified for fields with pronounced small-scale variations. One farmer also mentioned that he thought the soil analysis was not done in a proper way that the sampling did not consider natural variations on the fields. This farmer felt that the soil analysis did not give a good picture of the soil and that the variations might not be presented when samples are taken according to a decided pattern.

Farmers also appreciated the liming of the soil that was included in this project. The farmers visited seemed to know it was needed, some did it regularly but thought it was very expensive. They would have done it more often if they had more money. Liming was in fact the measure that most of the farmers mentioned they would invest in if they had more money. The farmers were very interested in a follow up of the liming in the project. A new soil analysis could be interesting to see if the liming gave any effect. Some farmers were skeptical that the lime would give any effect at all; another soil analysis would maybe convince them that liming is necessary and should be prioritized on their fields.

4.6 Farm walk

The results from the farm walk are hard to evaluate especially since the farm walk was performed in different ways depending on the advisor that made it. However, the walking protocol gives a good indication of the farm management and enables identification of problem areas. Some farmers indicated that they appreciated the farm walk since they themselves got ideas on how to improve their farm management when they walked over the farm together with an advisor. A difficulty that was experienced among some advisors was on what level to perform the analysis. In Mazovia they did an average of all fields on the farms, and they thought it was hard to do that since it did not show the whole picture. In Pomerania they did one table for each field and each meadow. It gave a more detailed picture, but was much more demanding and time consuming to do, according to the advisors. To present more observations from the farm walk on a map over the farm instead of in the protocol used was proposed by the Mazovian advisors. To use a farm map, walk over the farm and mark problem areas etc. on the map. That would, according to the advisors, make it more clear for the farmers and make the work easier for the advisors. Doing the farm walk worked in some sense since it made the farmers think about their own farm management and made some farmers change their farm management in some way. The farm walk functioned as an eye opener in some cases, but should have been done in a more pedagogical way to encourage the farmers to use the knowledge and information gained to identify and try new measures on their farms.

From the statements of the advisors it seems that education of the farmers and a continuous consulting work is important in the work to increase awareness of nutrients, how they are lost and how to prevent the loss of nutrients. The shares of farmers that have had advisory services focusing on environmental issues are close to zero (EUROSTAT, 2015). Therefore, it can be assumed that any type of education of and advising to the farmers on how to improve their farm management from an environmental point of view, will have a positive effect on farm nutrient management. Especially with follow-up visits ideally yearly when discussing new fertilizer plans.

The mineral fertilizer consumption is rather high compared to the average figures from Poland in general and EU28 in total. It is important to have in mind that these figures are based on total farm area, not only fertilized area (the figures from EUROSTAT, 2015) and will therefore include pastures and meadows etc. The farms in this study do not have that much meadows and pastures. The largest part of the farm's area is fertilized fields and due to that the higher figure of the mineral fertilizer consumption on the studied farms compared to the general figures found in the EU-statistics are not surprising.

More than half of the soil seems to be covered with crops during winter and mainly of winter sown crops like winter wheat and triticale. According to the Mazovian advisors, the farmers are not interested in cultivating cover crops. Reasons for that are that it is not profitable, the subsidies are not enough to cover the costs of cultivating the cover crop. Another reason is that the soils in Poland are in general rather dry and cultivation of cover crops might, according to the advisors, make the soils even drier. To increase the interest among the farmers it would according to advisors be necessary to find other species that can be used as cover crops that are more profitable or give other benefits, or give higher subsidies to cultivation of cover crops. It would be optimal if the cover crops can be used as hay or other fodder. Regarding tillage practices conventional practices are dominating, only a few farmers practice delayed or zero tillage. It could be good with more information to the farmers about other tillage systems besides the conventional tillage. Delayed tillage or zero tillage is maybe not suitable for all farmers, but it can be an interesting measure to try if the farmers want to increase soil organic matter to improve the soil structure.

Manure is used a lot on the farms and is highly valued by the farmers, but a lot can be done to improve manure management. It is common to store manure in piles on the field or slurry in not covered slurry tanks. If the knowledge among farmers increase on how to save nutrients in the manure they would probably be more motivated to store the manure properly and cover the slurry as far as possible. More knowledge is also needed on how the manure function in the soil and on how to spread the manure in the best way since it is common to spread manure during the autumn. Some farmers visited did not see any benefits with spreading the manure during spring. Also if the farmers knew what amount of nutrients the manure contained they would probably use less mineral N.

4.7 Proposed measures to be taken as a first step

1. A follow up of the farm gate balance should be done with focus on how the advisors and farmers can interpret the results from the FGB.

2. A follow up of the nitrogen leaching estimation is an even more important measure since it was obvious that many advisors and farmers had troubles understanding this tool's meaning to improve the general awareness on how agricultural management may influence the leaching. It is important that the farmers and advisors have a discussion about why some fields stand out in the calculations and some don't. It is important for both farmers and advisors to understand for example why field where manure is spread in the autumn gets a higher value of the calculated N-leaching. If

they would understand these calculations in a better way they would make more use of it.

3. Education of the advisors on how to use the FGB, the N leaching estimation, the soil map and farm walk as tools to help the farmers should be further prioritized. Increasing the knowledge among advisors can be expected to lead to increased knowledge among farmers. If the advisors get more comfortable in how to use the FGB, the result from the leaching calculations and the soil analysis as a tool the farmers will get more use of it.

4. Liming of the soil is an important measure to improve soil fertility. Most farmers highlight that as their most important measure to take to improve their yields. The problem with acid soils is perceived as very serious among farmers and advisors. The farmers seem to know the reasons for the low pH; that they often fertilize with only ammonium sulphate, since it is too expensive to buy other fertilizers plus the fact that the soils are rather acid from the beginning.

5. More knowledge is needed among farmers and advisors about how to store and spread manure in the best possible way and why it is better to do it in this way. The farmers value their manure very much and notice positive differences in the soil after spreading manure. The storage facilities for manure could be improved by storing the manure on a concrete slab or to cover it. If the farmers had more knowledge about their manure, nutrient content etc. they would probably be more motivated in improving the manure storage facilities and to spread the manure at the best time in the best way. Fertilizer plans should be established to help the farmers improve their nutrient management.

6. If the farmers knew how much nutrients their manure contained and if the manure was more evenly spread among the farms the amount of added mineral nitrogen fertilizers could probably be decreased. The figures for manure nutrient content need to be updated. Some farmers analyzed their manure, which should be considered in the fertilization plans.

7. More potassium and phosphorus needs to be applied on many fields to avoid soil depletion. Swedish experiments have demonstrated that totally avoiding P fertilization to a soil with low soil P status is only followed by a poor yield without any reduced P leaching (Svanbäck et al., 2014).

5 Conclusions

From the farm gate balances it can be concluded that the major inputs are mineral fertilizers and on animal farms also feed is a dominating input. In Mazovia the highest inputs of nutrients are found on pig farms, and it is also on the pig farms where the highest number of livestock units and the largest nutrient surpluses are found. In Pomerania the inputs and the livestock unit were higher on the dairy farms. The most nutrient surpluses are found on farms with animals and for that reason the crop farms shows higher nutrient use efficiency. In Pomerania a larger number of farms with nutrient deficiency are found compared to in Mazovia, deficiencies of P and K are most common. At the same time, many farms show a surplus of N of over 100 kg per hectare. In Pomerania the P and K status of the soil are significantly lower compared to Mazovian soils and almost 75% of the Pomeranian soils have a P status of III or lower, indicating a large need for P fertilizers. Almost 100 % of the soils in Pomerania and 70% of the soils in Mazovia needs K fertilizers. Since the farm gate balances show a deficit of P and K on many farms, and the soils show a great need for additional P and K it can be assumed that the soils are depleted. The need for liming is large in both Mazovia and Pomerania, but the liming need is significantly higher in Pomerania. Due to the large liming need it can be assumed that liming of the soils would improve farm conditions. A follow up on the liming performed in this project is important to see the effect from liming, to convince the farmers that liming could be an important measure on their farm.

No correlation is found between the nitrogen surplus and the calculated risk for nitrogen leaching. The calculated leaching is rather low and no significant differences between farm types are found. The only significant differences are found between different soil types, where the estimated leaching is highest on sandy soils in both Mazovia and Pomerania.

The advisors involved in this project have managed to calculate proper farm gate balances but a few had problems with calculating the change in storage. In contrast several advisors had a large problem with the calculations of nitrogen leaching, where several errors were made. The errors commonly made indicated that the advisors did not understand completely how the calculations worked and how the results could be interpreted.

The measures performed in this project can be assumed to give a positive effect on nutrient management on the farms involved. These since few farmers have participated in advisory services focusing on environmental questions and a project like this can be assumed to increase knowledge among farmers on environmental issues regarding agriculture. To achieve greater results it is important to not only do farm gate balances and other protocols, but also to give the farmers advices on how to use the result and to do follow ups. Farmers and advisors found it hard to interpret the results from the gathered data and asked for more guiding on how to interpret the results. Further education of advisors should be prioritized to make them more confident in how to use these tools to help the farmers improve their farm management.

The next steps in this project, and prioritized measures in these areas, are to increase knowledge among advisors on how to improve nutrient management on farm level. If the knowledge is increased among the advisors, they can pass on this knowledge to the farmers. The data included in the instructions needs to be more adapted to polish conditions to avoid confusion among the advisors, and the instructions should include more pedagogical examples on how to perform the measures and how to interpret the results.

Acknowledgement

I would like to thank several people and organizations for helping me in my work with this thesis. First I would like to thank Axel Adlers foundation for funding my excursion to Poland. It was a very important feature in this work that gave me an understanding that could not be achieved by only reading literature and collected data. I also would like to say a big thank to the Polish counselling organizations PODR and MODR for taking us around in Poland. You showed a large hospitality, not only taking us to the farmers that we were supposed to visit, but also to points of interest along the journey. I would like to thank Justyna and Alicia for being perfect guides and for patiently answering all of our questions about Poland and translating everything for us. And I would like to thank Karin Tonderski for being unbearable during the second part of the Poland journey

Of course I would like to thank my supervisor Barbro for guiding me through this work, always answering my emails immediately and making good points on how to improve this thesis

Last but not least I would like to thank my partner Martin, for telling me to stop staring into the statistics late Saturday nights, and forcing me to do other things than working.

References

Aronsson, H., Torstensson, G. (2004) Beräkning av olika odlingsåtgärders inverkan på kväveutlakningen - Beskrivning av ett pedagogiskt verktyg för beräkning av kväveutlakning från enskilda fält och gårdar. Ekohydrologi N:o 28. Department of soil and environment, division of Water Quality Management, Swedish University of Agricultural sciences, Uppsala.

BalticSea 2020 (a) (2014), Eutrophication, Available at: http://www.balticsea2020.org/english/alla-projekt/overgodning. 2014-12-29.

BalticSea 2020 (b) (2014), Self-evaluation concerning nutrients by farmers in Poland, Available at: http://www.balticsea2020.org/english/alla-projekt/overgodning/eutrophication-ongoing-projects/280-self-evaluation-concerning-nutrients-by-farmers-in-poland. 2014-12-29.

BalticSea 2020 (2013), Education for agricultural advisors in Poland, Available at: http://www.balticsea2020.org/english/bibliotek/32-eutrophication/290-education-for-agricultural-advisors-in-poland. Reviewed 2014-12-29.

Bassanino, M., Grignani, C., Sacco, D., Allisiardi, E. (2007) Nitrogen balances at the crop and farm-gate scale in livestock farms in Italy. Agriculture, Ecosystems and Environment 122, 282-294.

Cherry, K., Mooney, S. J., Ramsden, S., Shepherd, M. A. (2011) Using field and farm nitrogen budgets to assess the effectiveness of actions mitigatins N loss to water. Agriculture, Ecosystems and Environment 147, 82-88.

Dalgaard, T., Bienkowski, J. F., Bleeker, A., Dragosits, U., Drouet, J. L., Durand, P., Frumau, A., Hutchings, N. J., Kedziora, A., Magliulo, V., Olesen, J. E., Theobald, M. R., Maury, O., Akkal, N., Cellier, P. (2012) Farm nitrogen balances in six European landscapes as an indicator for nitrogen losses and basis for improved management. Biogeosciences, 9, 5303-5321.

D’Haene, K., Magyar, M., De Neve, S., Pálmai, O., Nagy, J., Német, T., Hofman, G. (2007) Nitrogen and phosphorus balances of Hungarian farms. European Journal of Agronomy, 224-234.

EUROSTAT (2010) Environmental statistics and accounts in Europe 2010 edition. Eurostat Statistical books. ISBN: 987-92-79-15701-1. Publications office of the European Union, Luxembourg.

EUROSTAT (2015) Agriculture, forestry and fishery statistics 2014 edition. ISBN: 978-92-79-43201-9. Publications office of the European Union, Luxembourg.

EUROSTAT (2015-02-23a) Agri-environmental indicator - farmers’ training and environmental farm advisory services. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_farmers%E2%80%99_training_and_environmental_farm_advisory_services [2015-03-17]

EUROSTAT (2015-02-23b) Agri-environmental indicator - soil cover. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_soil_cover [2015-03-17]

EUROSTAT (2015-02-23c) Agri-environmental indicator - tillage practices. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_tillage_practices. [2015-03-18]

EUROSTAT (2015-02-23d) Agri-environmental indicator - ammonia emissions. http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_ammonia_emissions [2015-03-18]

EUROSTAT (2013-07-09) Arable area by tillage practice, EU-27, IS, NO, CH, ME and HR, 2010. http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Arable_area_by_tillage_practice,_EU-27,_IS,_NO,_CH,_ME_and_HR,_2010.png [2015-03-18]

Fanguerio, D., Pereira, J., Coutinho, J., Moreira, N., Trindade, H. (2008) NPK farm-gate nutrient balances in dairy farms from Northwest Portugal. European Journal of Agronomy 28, 625-634.

Halberg, N., Verschuur, G., Goodlass, G. (2005) Farm level environmental indocators; are they useful? An overview of green accounting systems for European farms. Agriculture, Ecosystems and Environment 105, 195-212.

HELCOM (2009) Eutrophication in the Baltic Sea – An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region. Available online: http://www.helcom.fi/Lists/Publications/BSEP115B.pdf Baltic Sea Environment Proceedings No. 115B

Hoffmann, M., Aronsson, H., Aronsson, P., Nilsson, H., Albertsson, B. (1999) Gårdsmodellen – En empirisk modell för kväveutlakning. Teknisk rapport n:o 48. Department of soil and environment, division for Water Quality Managemend. Swedish University of Agricultural Sciences, Uppsala.

Jordbruksverket (2014) Riktlinjer för gödsling och kalkning 2015, Jordbruksinformation 12-2014.

Leip, A., Britz, W., Weiss, F., de Vries, W. (2011) Farm, land and soil nitrogen budgets for agriculture in Europé calculated with CAPRI. Environmental Pollution 159, 3243-3253.

Nevens, F., Verbruggen, I., Reheul, D., Hofman, G. (2006) Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: Evolution of future goals. Agricultural Systems 88, 142-155.

Nielsen, A. H., Kristensen I. S. (2005) Nitrogen and phosphorus surpluses on Danish dairy and pig farms in relation to farm characteristics. Livestock Production Science 96, 97-107.

Raport PODR (2013) PODR/ZO/084/1-26/KR/2013, project report.

Nitrogen balance as an indicator of nitrogen leaching in Finland. Agriculture, Ecosystem and Environment 113, 98-107.

Schröder, J.J., Aarts, H.F.M., ten Berge, H.F.M., van Keulen, H., Neeteson, J.J. (2003) An eveluation of whole-farm nitrogen balances and related indices for efficient nitrogen use. European Journal of Agronomy 20(2003) 33-44

Steineck, S., Gustafson, A., Richert Stintzing, A., Salomon, E., Myrbeck, Å., Albihn, A., Sundberg, M. (2000) Växtnäring I kretslopp, Sveriges Lantbruksuniversitet, Uppsala

Svanbäck, A., Ulén, B., Etana. A. (2014) Mitigation of phosphorus leaching losses via subsurface drains from a cracking marine clay soil. Agricultural Ecosystems and Environment 184:124–134.

Swensson, C. (2003) Analyses of mineral element balances between 1997 and 1999 from dairy farms in the south of Sweden. European Journal of Agronomy 20, 63-69.

Ulén, B., Aronsson, H., Bergström, L. (2008) Åtgärdskatalog – för minskade fosfor- och kväveförluster från jordbruk och vatten, Department of Soil and Environment, Swedish University of Agricultural Sciences, Uppsala.

Ulén, B., Pietrzak, S., Tonderski, K. S. (2013) Self-evaluation of farms for improved nutrient management and minimised environmental impact, Institute of Technology and Life Sciences, Falenty, Poland

Ulén, B., Pietrzak, S., Tonderski, K. S. (2013(b)) Instrukcja samooceny gospodarstw w zakresie – Zarządzania składnikami pokarmowymi I oceny warunków środowiskowych (advisors manual). ISBN 978-83-62416-65-3, Falenty

Vatema (2014) Report 1 – Self-evaluation and risk analysis by farmers concerning losses of nutrients and low cost remedial measures, pre-intervention interview study in July-August 2013. Vatema AB, Stockholm.

de Vries, W., Leip, A., Reinds, G.J., Kros, J., Lesschen, J.P., Bouwman, A.F. (2011) Comparison of land nitrogen budgets for European agriculture by various modeling approaches. Environmental Pollution 159, 3254-3268.

Not published references

Pietzrak, S. Institute of Technology and Life Science, (ITP), Falenty. Poland. Oral communication 2015-03-26.

Ulén, B., Swedish University of Agricultural Science (SLU), Uppsala, Sweden. Oral communication 2015-04-23.

Appendix 1

Table 15 Farm Gate Balance protocol

Calculating overall balance of nitrogen, phosphorus, potassium and their nutrient use efficiency on the farm					
Lp.	Specification	Figures from previous tables	Amount of the component, kg		
			N	P	K
1	2	3	4	5	6
1	**Nutrient inputs**				
2	Amount of inputs in mineral fertilizers	A			
3	Amount of inputs in purchased feeds	B			
4	Amount of inputs in purchased animals (for breeding)	C			
5	Amount of inputs in organic fertilizers	D			
6	Amount of inputs in other purchased materials and resources	E			
7	Amount of inputs in deposition	F			
8	Amount of symbiotically fixed nitrogen	G		X	X
9	Amount of N introduced by soil organisms	H		X	X
10	**Total inputs (2–9)**				
11	**Nutrient outputs**				
12	Outputs in animal products sold	I			
13	Outputs in plant products sold	J			
14	**Total outputs (12–13)**				
15	**Changes in stock**				
16	Changes in nutrient stocks in mineral and organic fertilizers over the year	K			
17	Changes in nutrient stocks in feeds over the year (green fodder, roughage, maize)	L			

18	Changes in nutrient stocks in livestock over the year	Ł			
19	**Total change in nutrient stock (16–18)**				
20	**Inputs corrected for increase in nutrient stocks (difference: 10–19)**				
21	**Outputs corrected for decrease in nutrient stock (difference: 14–19)**				
22	**Surplus/deficit (difference: 20–21)**				
23	**Surplus/deficit in kg/ha (ratio: 22/arable land on the farm)**				
24	**Nutrient use efficiency, % (ratio: 21/20 x 100)**				

Appendix 2

Table 16 Excel sheet used to calculate N-leaching. Described in detail in section 1.3.2

Form to calculate the estimated annual N leaching from agricultural fields									
Field N:o	**Factor**								
	A	B	C	D	E	F	G	H	I
	Basic leaching (kg ha-1)	Crop factor	Soil tillage	Modified leaching (kg ha^{-1}) =A*B*C	Manure application (autumn or spring)	Fertilization intensity	Total leaching (kg ha^{-1}) =(D*E)+F	Field area (ha)	Total leaching (kg)=G*H
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Appendix 3

Table 17 Protocol used to gather data during the farm walk. Some parameters which are marked green in the observation list of the manual may be regarded as low risk factors, while parameters marked red refers to high risk factors.

Farm production	Milk	Meat	Cereal crops	Feeding grains	Others

Cattle	(number in total)	Recalculated to livestock units*
Milk cows		
Bulls		
Heifers for recruitment		
Calves for recruitment		
Young bulls/heifers for beef		
Mother-sow/gilts-pigs		
Boar		
Fattening pigs 0-6 months		
Hens		
Chickens		
Sheep		
Goats		
Lamb		
Kids		

* Adult beef animal, dairy cow = 1, calves (0-6 months) =1/6, sheep, goat = 1/10, lamb, kid = 1/40

Manure form

General manure handling	Deep litter bed	Other solid manure	Slurry
General manure handling			
Approx. amount			
Is all manure kept on the farm?			

Composting/storage before applying on the field

Site for storage/composting solid manure[a]	Deep litter bed	Other solid manure
Strip on the field in which it will be spread		
On the field just outside the stable		
Compost heaps on or close to the farmyard*		
Duration for composting close to the yard		
On manure floor		
In container		
Other (on forest/other non-agricultural land)		
Storage of liquid manure	Slurry[b] (*Gnojowica*)	Urine

Slurry tank (size and how old)			
Slurry tank cover (if any)	Roof	Floating plastic cover	Stable natural crust
Slurry tank cover (if any)			
Urine/liquid manure pit (size and design)			

[a] Can by definition be stored to a height of at least 1 metre without a support wall
[b] Pumpable manure

Other farmyard observations

Wastewater from dairy parlour and cow house	Washing agent for glassware, etc.	Other washing agents used
Wastewater from dairy parlour and cow house		
Amount of washing agent used		
Design of water outlets		
Storm-water from the yard		
(amount and how it flows)		
Rainwater from roofs		
(amount and how it flows)		

Composting in windrow/heap

Width of the compost	< 1.5 m		> 1,5 < 2.5 m	> 2.5 m
Width of the compost				
Height of the compost	<1 m		>1 m < 2 m	> 2 m
Height of the compost				
Composting season	Spring	summer	Early autumn	Winter
Composting season				
Duration of composting	A few weeks		> 2 months	> 1 year
Duration of composting				
Distance to stream	< 50 m no buffer strip		< 150 m	> 150 m
Distance to stream				
How often (when composting on the same spot)			< every 5 years	>every 5 years
How often				
Time of incorporation (in the field)			Spring	Autumn (early or late)
Time of incorporation				

Grazed areas

General soil type	Sand	Loam	Silty	Clayey
Soil type				
Topography	Plain	Gentle slope	Undulating	Steep slo
Topography				
Distance to stream downstream	Bordering	0-100 m	100-200 m	>200 m
Distance to stream				

Distance	Bordering	0-100 m	100-200 m	>200 m
Distance to human water supply				
Water supply for cattle	Drinking cups		Water-course/lake	
Water for cattle				
Drinking cup layout (incl. leaching)				
Any buffer strip by water course downstream?				
Fence around stream/buffer zone?				
Vegetation cover close to the water course	Trampled <10%	Trampled >10%	Intact >80%	Intact <8
Vegetation cover				
Surface water on the field (if any)	Ponded (standing) water		Rills	
Surface water				
When	Spring snow-melt	Summer rain-storm	Autumn rainfall	
Where (mark on a map)				
Frequency and duration	Frequency[a]	Duration[b]	Frequency[a]	Duration
*Grazing animal density** per ha	0,1-0,5	0,5-2	2-6	>6
Grazing animal density				
Grazing season (e.g. mid-May-Oct)				

[a] Several times per year or once every year
[b] Hours/days or weeks
* Adult beef animal, dairy cow = 1, calf (0-6 months) =1/6, sheep, goat = 1/10 lamb, kid = 1/40

Cultivated field

General soil type	Sand	Loam	Silty	Clayey
General soil type				
Mean soil P status/P soil class				
Mean soil pH				
Topography	Plain	Gentle slope	Undulat-ing	Steep slope
Topography				
Distance to open ditch/stream	Bordering	0-100 m	100-200 m	>200 m
Distance to ditch/stream				
Any buffer strip adjacent to water courses?				
Tile drainage	No tiles	Single pipe/culvert	Systematic tile drainage	
Tile drainage				
Age and condition (broken pipes etc.)				
Surface water on the field (if any)	Ponded (standing) water		Rills	

When	Spring snowmelt	Summer rainstorm	Autumn rain-fall	
When				
Where (mark also on the map)				
Frequency and duration	Frequency[a]	Duration[b]	Frequency[a]	Duration[b]
Frequency and duration				
Soil surface with visible surface water	Ploughed	Harrowed	Track wheels	Crop cover
Soil surface				
Crop	2012	2013	Planned 2014	
Crop				
Time for ploughing/tillage 2012	Early autumn for winter crop	Late autumn for spring crop	Spring for spring crop	No tillage
Time of tillage				
Time of ploughing/tillage 2013	Early autumn for winter crop	Late autumn for spring crop	Spring for spring crop	No tillage
Time of tillage				

Open ditches and streams

General soil type	Sand	Loam	Silty	Clayey
General soil type				
Topography	Plain	Gentle slope	Undulating	Steep slope
Topography				
Buffer strip, buffer zones? Yes/no				
If buffer strips, state buffer zone:	Length	Grass	Bushes	Grass cut?
Fences to keep out grazing cattle? Yes/no				
Grazing cattle, how frequent?				
Drain pipes opening into the stream				
Pipe opening? Yes/no?				
Loose bottom at pipe outlets? Yes/no				
Stream bank conditions	Steep	Plain	Grass cover	No cover
Soil surface				
Visible erosion on stream banks if any	Straight reach	Curves	Stream bottom	
Stream bank/stream erosion				
Turbid water in the ditch/stream if any	Frequency[a]	Duration[b]	Colour of the particles	
Turbid water				

[a] Several times per year or once every year
[b] Hours/days or weeks

Appendix 4

Farm Gate Balances Mazovia

Table 18 Mean values of N input, N output and N balance for four farm types in Mazovian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written there are no significant differences found.

	Crop production, *n=12* Kg N ha^{-1}	**Dairy production, *n=8* Kg N ha^{-1}**	**Pig production, *n=4* Kg N ha^{-1}**	**Specialized farm (horses), *n=1* Kg N ha^{-1}**
Inputs				
Mineral fertilizers	172 (0-387) [2]	129 (77-164)	119 (74-199)	4,62 (-)
Feed	0 (-) [2] *a*	41 (4-154) *a*	239 (157-294) *b*	0 (-) *a*
Animals	0 (-) [2]	0,3 (0-2)	1 (0-3)	0 (-)
Organic fertilizers	19 (0-91) [2]	0 (-)	0 (-)	0 (-)
Other inputs	0,6 (0-2) [2]	19 (0-62)	37 (0-146)	0 (-)
Deposition	12 (-) [2]	12 (-)	12 (-)	12 (-)
N-fixation	12 (0-84) [2]	12 (0-37)	0 (-)	36 (-)
N introduced by soil microorganisms	9 (9-10) [2]	9 (9-10)	9 (9-10)	9 (-)
Inputs total	**224 (129-408)**[2] *ab*	**222 (128-370)** *ab*	**418 (306-602)** *c*	**63 (-)** *a*
Outputs				
Animal products	0 (-) [2] *b*	47 (12-120) *b*	123 (46-160) *c*	0,71 (-) *ab*
Plant products	151 (80-362) [2] *c*	37 (0-96) *b*	52 (21-100) *bc*	13 (-) *abc*
Outputs total	**151 (80-362)** [2]	**88 (35-130)**	**189 (152-260)**	**13,2 (-)**
Storage change	n.a[1]	n.a	n.a	n.a
Min/org. fertilizers				
Feedstuffs				
Livestock				
Surplus	74 (15-269)[2] *b*	139 (73-231) *bc*	242 (199-343) *c*	49 (-) *abc*
NUE %	69 (34-90)[2] *c*	38 (27-63) *b*	41 (34-45) *b*	22 (-) *ab*

1) Storage change is not applicable since too few have calculated the storage change at farm scale.

2) Farms excluded from calculations: RM 18, RM 21 and RM 23.

Table 19 Mean values of P input, P output and P balance for four farm types in Mazovian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written there are no significant differences found.

	Crop production, *n=12* Kg P ha^{-1}	**Dairy production, *n=8* Kg P ha^{-1}**	**Pig production, *n=4* Kg P ha^{-1}**	**Specialized (horses), *n=1* Kg P ha^{-1}**
Inputs				
Mineral fertilizers	34 (5-102) [2]	17 (7-31)	16 (0-44)	4 (-)
Feed	0 (-) [2] *a*	7 (1-32) *a*	39 (22-47) *b*	0 (-) *a*
Animals	0 (-) [2]	0.1 (0-0.7)	0.2 (0-0.5)	0 (-)
Organic fertilizers	8 (0-9) [2]	0 (-)	0 (0)	0 (-)
Other inputs	0.2 (0-0.8) [2]	3 (0-10)	7 (0-29)	0 (-)
Deposition	0.4 (-) [2]	0.4 (-)	0.4 (-)	0.4 (-)
Inputs total	**43 (22-102)** [2]	**31 (14-52)**	**62 (45-90)**	**4 (-)**
Outputs				
Animal products	0 (-) [2] *a*	10 (2-28) *ab*	22 (8-28) *c*	0.2 (-) *ab*
Plant products	28 (11-62) [2] *c*	6 (0-17) *bc*	9 (4-17) *b*	2 (-) *abc*
Outputs total	**28 (11-62)** [2]	**17 (7-28)**	**31 (20-45)**	**2 (-)**
Storage change	n.a [1]	n.a	n.a	n.a
Min/org. fertilizers				
Feedstuffs				
Livestock				
Surplus	15 ((-19)-85) [2]	14 (4-24)	31 (15-48)	2 (-)
NUE %	80 (20-150) [2]	55 (34-76)	52 (29-66)	47 (-)

1) Storage change is not applicable since too few have calculated the storage change at farm scale.
2) Farms excluded from calculations: RM 18, RM 21 and RM 23.

Table 20 Mean values of K input, K output and K balance for four farm types in Mazovian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written there are no significant differences found.

	Crop production, *n=4* Kg K ha^{-1}	**Dairy production, *n=8* Kg K ha^{-1}**	**Pig production, *n=4* Kg K ha^{-1}**	**Specialized (horses), n=1 Kg K ha^{-1}**
Inputs				
Mineral fertilizers	96 (23-229) [2]	67 (9-110)	40 (0-80)	19 (-)
Feed	0 (-) [2]	11 (1-31)	61 (37-80)	0 (-)
Animals	0 (-) [2]	0.02 (0-0.2)	0.1 (0-0.3)	0 (-)
Organic fertilizers	15 (0-49) [2]	0 (-)	0 (-)	0 (-)
Other inputs	0.2 (0-1) [2]	30 (0-75)	10 (0-37)	0 (-)
Deposition	2 (-) [2]	2 (-)	2 (-)	2 (-)
Inputs total	**113 (71-231)** [2]	**110 (39-244)**	**112 (81-164)**	**21 (-)**
Outputs				
Animal products	0 (-) [2]	22 (6-61)	12 (4-20)	0.05 (-)
Plant products	66 (19-144) [2] *c*	13 (0-44) *b*	38 (19-67) *bc*	16 (-) *abc*
Outputs total	**66 (19-144)** [2]	**34 (9-77)**	**51 (23-81)**	**16 (-)**
Storage change	n.a. [1]	n.a.	n.a.	n.a.
Min/org. fertilizers				
Feedstuffs				
Livestock				
Surplus	33 ((-25)-121) [2]	76 (30-166)	61 (30-97)	4 (-)
NUE	61 (25-120) [2]	29 (13-51)	48 (19-64)	79 (-)

1) Storage change is not applicable since too few have calculated the storage change at farm scale.
2) Farms excluded from calculations: RM 18, RM 21 and RM 23.

Appendix 5

Farm Gate Balances Pomerania

Table 21 Mean values of N input, N output and N balance for four farm types in Pomeranian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written there are no significant differences found.

	Crop production, *n=4* Kg N ha^{-1}	**Dairy production, *n=8*** Kg N ha^{-1}	**Pig production, *n=4*** Kg N ha^{-1}	**Mixed farms, *n=9*** Kg N ha^{-1}
Inputs				
Mineral fertilizers	132 (70-198)	129 (72-204) [1]	98 (50-147) [1]	63 (0-135)
Feed	0.7 (0-3)	22 (0-72) [1]	13 (8-16) [1]	4 (0-8)
Animals	0.03 (0-0.1)	0 (-) [1]	2 (0-3) [1]	0.2 (0-2)
Organic fertilizers	0.8 (0-3)	0 (-) [1]	0 (-) [1]	0 (-)
Other inputs	0 (0)	1,7 (3,5) [1]	2,6 (1,6) [1]	26,2 (68,0)
Deposition	10 (-)	10 (-) [1]	10 (-) [1]	10 (-)
N-fixation	8 (0-33)	8 (0-27) [1]	3 (0-8) [1]	10 (0-45)
N introduced by soil microorganisms	16 (10-35)	11 (10-15) [1]	10 (-) [1]	9 (8-10)
Inputs total	**167 (93-243)**	**181 (104-296)** [1]	**136 (85-195)** [1]	**122 (21-356)**
Outputs				
Animal products	0.3 (0-1) *a*	30 (16-40) [1] *c*	22 (10-37)[1] *bc*	14 (4-30) *ab*
Plant products	110 (92-125) *b*	4 (0-16)[1] *a*	2 (0-4)[1] *a*	8 (0-32) *a*
Outputs total	110 (92-125) *b*	34 (23-43) [1] *a*	24 (11-37) [1] *a*	22 (4-46) *a*
Storage change				
Min/org. fertilizers	-36 ((-143)-0)	0.5 (0-2) [1]	3 (0-5) [1]	-10 (-83-0)
Feedstuffs	2 (0-4)	0 (-) [1]	0 (-) [1]	6 ((-5)-23)
Livestock	0.1 (0-0.3)	0.1 (0-0.7) [1]	1 (0-2) [1]	-1 ((-6)-2)
Surplus	22 ((-48)-118)	147 (71-265) [1]	109 (38-158) [1]	89 ((-3)-127)
NUE	93 (52-126) *b*	21 (10-33) [1] *a*	17 (14-19)[1] *a*	38 (1-116) *a*

1) P14 (dairy) and P23 (pig) excluded since the figures are not representative.

Table 22 Mean values of P input, P output and P balance for four farm types in Pomeranian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written

	Crop production, *n=4* Kg P ha^{-1}	**Dairy production, *n=8* Kg P ha^{-1}**	**Pig production, *n=4* Kg P ha^{-1}**	**Mixed farms, *n=9* Kg P ha^{-1}**
Inputs				
Mineral fertilizers	12 (0-33)	13 (0-38)[1]	8 (0-20)[1]	26 (0-184)
Feed	0 (-)	4 (0-22)[1]	3 (2-4)[1]	0.6 (0-1.8)
Animals	0.01 (0-0.02)	0 (-)[1]	0.3 (0-0.6)[1]	0.07 (0-0.5)
Organic fertilizers	0.2 (0-0.8)	0 (-)[1]	0 (-)[1]	0 (-)
Other inputs	0 (-)	0.4 (0-2)[1]	0.5 (0.2-1)[1]	0.4 (0-2)
Deposition	0.4 (-)	0.4 (-)[1]	0.4 (-)[1]	0.4 (-)
Inputs total	**13 (0.4-34)**	**19 (3-41)**[1]	**12 (5-25)**[1]	**27 (1-185)**
Outputs				
Animal products	0.05 (0-0.1) *a*	6 (3-8)[1] *c*	4 (2-7)[1] *bc*	3 (1-6) *ab*
Plant products	19 (16-22) *b*	1 (0-3)[1] *a*	0.3 (0-0.7)[1] *a*	1 (0-5) *a*
Outputs total	**19 (16-22)** *b*	**7 (5-8)**[1] *a*	**4 (2-7)**[1] *a*	**4 (1-8)** *a*
Storage change				
Min/org. fertilizers	0.01(0-0.3)	0.1(0-0.4)[1]	0.2 (0-0.6)[1]	-1 ((-5)-0.2)
Feedstuffs	0.2 (0-0.6)	0 (-)[1]	0 (-)[1]	1 ((-1)-4)
Livestock	0.01 (0-0.6)	0.04 (0-0.2)[1]	0.2 (0-0.4)[1]	-0.2 ((-2)-0.3)
Total change	**0.2 (0-0.6)**	**0.1 (0-0.7)**[1]	**0.5 (0-1)**[1]	**-0.1 ((-2)-1)**
Surplus	**-7 ((-17)-13)**	**12 ((-3)-33)**[1]	**8 ((-2)-22)**[1]	**22 ((-1)-184)**
NUE	**342 (60-494)**	**77 (24-222)**[1]	**73 (9-339)**[1]	**82 (1-194)**

1) P14 (dairy) and P23 (pig) excluded since the figures are not representative.

Table 23 Mean values of K input, K output and K balance for four farm types in Pomeranian district. Data range is presented in brackets (smallest value – largest value). Significant differences are marked with letters. In categories where no letters are written there are no significant differences found.

	Crop production, *n=4* **Kg K ha^{-1}**	**Dairy production, *n=8*** **Kg K ha^{-1}**	**Pig production, *n=4*** **Kg K ha^{-1}**	**Mixed farms, *n=9*** **Kg K ha^{-1}**
Inputs				
Mineral fertilizers	22 (0-63)	28 (0-93) [1]	9 (1-20) [1]	39 (0-184)
Feed	0 (-)	0.2 (0-0.7) [1]	0.4 (0-1) [1]	0.7 (0-2)
Animals	0.003 (0-0.01)	0 (-) [1]	0.1 (0-0.3) [1]	0.02 (0-0.1)
Organic fertilizers	0.9 (0-4)	0 (-) [1]	0 (-) [1]	0 (-)
Other inputs	0 (-)	0.4 (0-2) [1]	0.7 (0-1) [1]	1 (0-7)
Deposition	3 (-)	3 (-) [1]	3 (-) [1]	3 (-)
Inputs total	**26 (3-69)**	**31 (3-97)** [1]	**13 (5-23)** [1]	**43 (4-187)**
Outputs				
Animal products	0.02 (0-0.08)	5 (0-10) [1]	2 (1-3) [1]	2 (0-7)
Plant products	32 (23-36) *b*	0.5 (0-4) [1] *a*	1 (0-1) [1] *a*	4 (0-18) *a*
Outputs total	32 (23-36) *b*	6 (0-10) [1] *a*	3 (2-3) [1] *a*	6 (0-19) *a*
Storage change				
Min/org. fertilizers	0.2 (0-0.7)	0.3 (0-2) [1]	0.4 (0-1) [1]	-3 ((-15)-0.2)
Feedstuffs	3 (0-9)	0 (-) [1]	0 (-) [1]	5 ((-3)-12)
Livestock	0.006 (-)	0.01 (0-0.05) [1]	0.1 (0-0.1) [1]	-0.1 ((-0.5)-0.1)
Total change	**3 (0-10)**	**0.3 (0-2)** [1]	**0.5 (0-1)** [1]	**2 ((-9)-13)**
Surplus	**-9 ((-42)-34)**	**25 ((-116)-86)** [1]	**10 (1-21)** [1]	**31,26 ((-2)-183)**
NUE	**227 (50-1249)**	**38 (0-676)** [1]	**33 (8-172)** [1]	**43 (2-135)**

1) Farm n:o P23 and P14 excluded.

Appendix 6

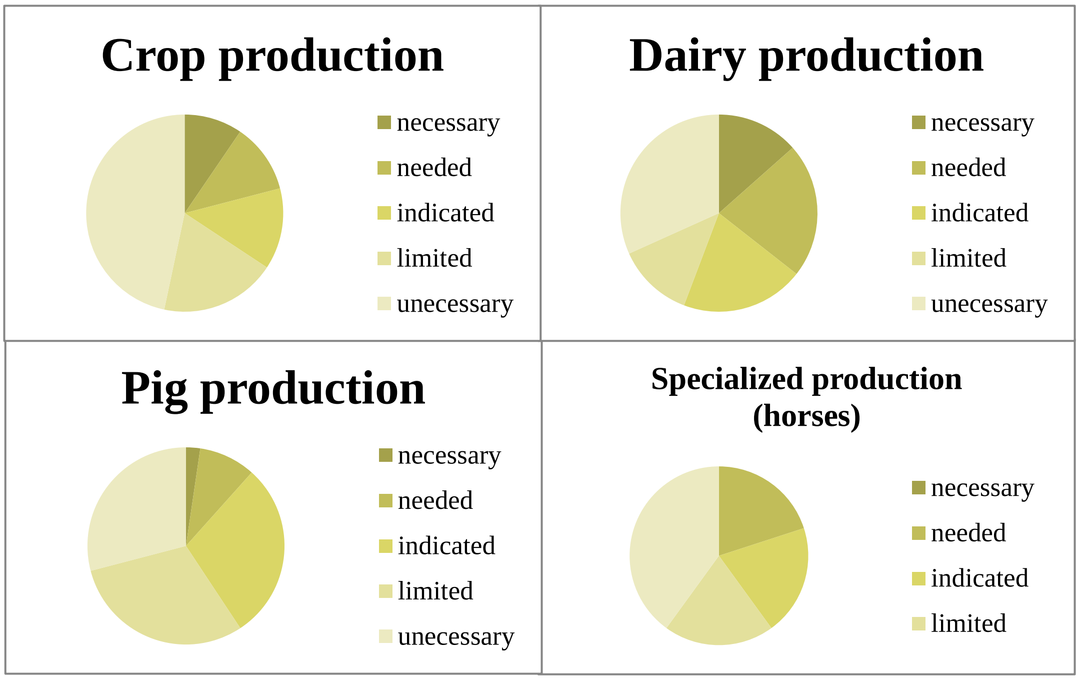

Figure 28 Liming need at Mazovian farms, divided by farm type.

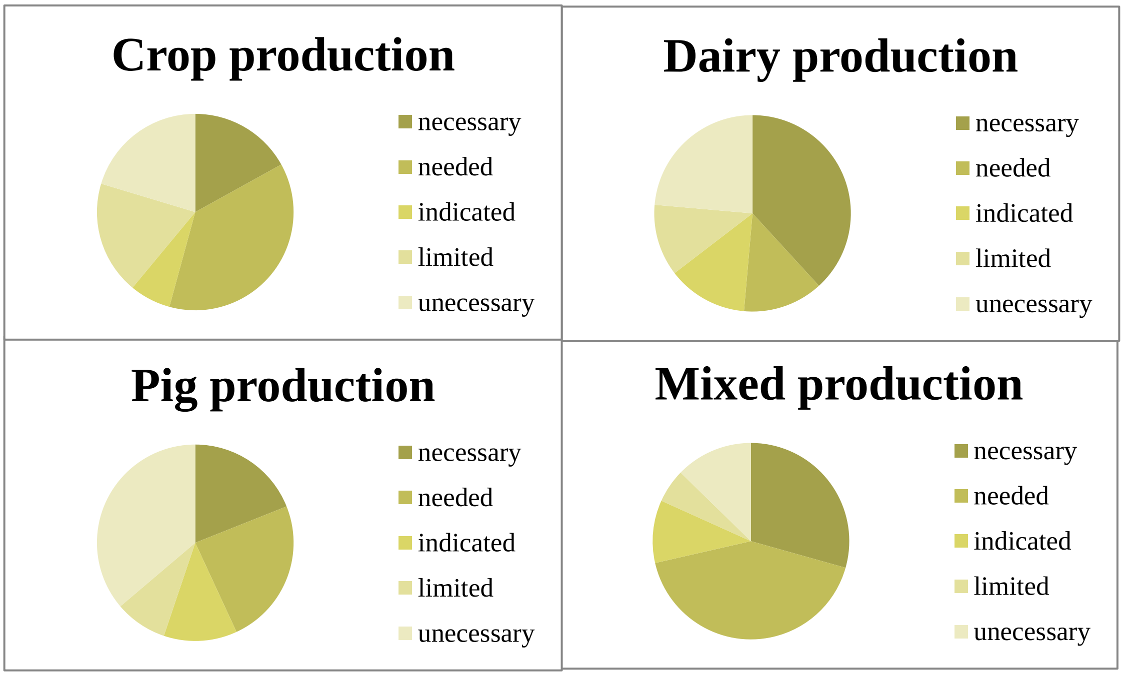

Figure 29 Liming need at Pomeranian farms, divided by farm type