Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Soil and Environment

# Challenges and incentives for sustainable manure management in Russia

Johanna Lindgren

BALTIC COMPASS

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

Baltic Sea Region
Programme 2007–2013

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

Examensarbeten, Institutionen för mark och miljö, SLU
2013:03

Uppsala 2013

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

Johanna Lindgren

Challenges and incentives for sustainable manure management in Russia

Supervisor: Helena Aronsson, Department of Soil and Environment, SLU
Assistant supervisor: Ola Palm, JTI & Nina Geladze-Ekstedth, JTI
Examiner: Barbro Ulén, Department of Soil and Environment, SLU

EX0728, Independent project/degree project in Soil Science, 30 credits, Advanced level, A1E
Agriculture Programme – Soil and Plant Sciences 270 credits (Agronomprogrammet – inriktning mark/växt 270 hp)

Series title: Examensarbeten, Institutionen för mark och miljö, SLU
2013:03

Uppsala 2013

Keywords: manure management, Russia, sustainable, eutrophication, agricultural policies, Baltic Sea

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

## Abstract

The Baltic Sea is threatened by eutrophication that largely is due to nutrient leaching from farmland within the catchment area. To solve this problem the surrounding countries cooperate within various configurations such as HELCOM and the EU-financed project Baltic Compass. Poor manure management in Russia has been discussed frequently the last couple of years.

A literature review of different types of reports and legal acts is the core of this degree project which has been performed in connection to two ongoing research projects financed by EU (Baltic Compass) and SIDA. It is supplemented with interviews with Swedish agricultural consultants and travel reports from two occasions when I had the opportunity to discuss with Russians active within the agricultural sector. Different hypotheses were investigated and discussed.

The environmental debate in Russia is quiet and there is a widespread approach that economic profit always trumps environmental concern – a Soviet heritage that influence the Russian agriculture considerably.

The Russian legal acts on stable manure management focus mainly on sanitary questions and only secondary on nutrient leaching.  If the legislation was fully implemented, the nutrient leaching would decrease significantly. The incentives for obeying the law are low due to corruption and the fact that it is cheaper and easier to pay the fees than fixing the primary cause. Farmers can receive financial support for increased production, but there are no economic instruments to encourage environmental measures. The economic situation on the farms is usually poor and the possibilities to make large investments low, partly due to the difficulties to receive credits on beneficial terms.

The common attitude to manure is that is not a resource, but rather a problem to get rid off. In order to improve the situation it is important to increase the knowledge on manure nutrient value and the soil conditioning organic matter. The subsidy on mineral fertilizers is though an important contributing factor to bad manure usage.

The development of biogas production in Russia may seem tempting, looking at the amounts of produced manure. But in reality, this is a too big investment for most farmers and the production surplus of gas or electricity cannot be connected to the existing grid. Separation of manure would on the other hand enable longer transports of the P-rich solid fraction, which would improve the nutrient balance on a farm level. Composting of manure is the most common way to treat manure today. If this is done as to minimize nutrient leaching, it could be a good alternative if combined with mineral fertilizers.

The manure is used as fertilizers to some extent, but it commonly ends up as a waste in the forests where the risk of nutrient leaching is huge. The concentration of animals in large livestock units is a problem as the spreading area is either too small or too remote from the farm centre.The spreading is further complicated by insufficient drainage systems.

I found that the farmers' incentive for improved manure management and utilization is better economy through increased production rather than environmental issues. In order to enable this, a shift in state priorities is needed as is the development of extention services for increased awareness and knowledge level among farmers.

## Sammanfattning

Östersjön är hotad av eutrofiering som till stor del beror på näringsläckage från jordbruksmark i tillrinningsområdet. För att lösa detta problem samarbetar de omkringliggande länderna genom bland annat HELCOM och det EU-finansierade projektet Baltic Compass. Bristande stallgödselhantering i Ryssland har uppmärksammats mycket de senaste åren.

Grunden till detta examensarbete bygger på en litteraturstudie av bland annat vetenskapliga rapporter och lagtexter. Den har sedan kompletterats med intervjuer av svenska lantbruksrådgivare samt reserapporter från två tillfällen i Sverige respektive Ryssland då det givits möjlighet till diskussioner med ryssar som arbetar inom lantbrukssektorn. Arbetet utfördes inom två pågående forskningsprojekt finansierade av SIDA respektive EU (Baltic Compass).

Miljödebatten i Ryssland är lågmäld och det finns ett allmänt spritt synsätt att ekonomisk vinning alltid går före miljöhänsyn – ett arv från Sovjettiden som i högsta grad påverkar dagens ryska lantbruk.

Det lagverk som omfattar stallgödselhanteringen fokuserar huvudsakligen på sanitära frågor och endast i liten utsträckning på näringsläckage. Om lagarna implementerades skulle dock växtnäringsläckaget minska markant. Incitamenten att följa lagen är låga på grund av korruption och för att det är billigare och enklare att böta för förseelser än att åtgärda grundorsaken. Gårdar kan erhålla stöd för att öka sin produktion, men det finns inga ekonomiska styrmedel för främjande av miljöåtgärder. Överlag är den ekonomiska situationen på ryska lantbruk dålig och det finns sällan möjlighet till några större investeringar, särskilt inte då det är svårt att få banklån till bra villkor.

Den generella attityden till stallgödsel är inte att det är en resurs, snarare att det är ett kvittblivningsproblem. För att få till stånd en förbättring är det viktigt att öka kunskapen om stallgödselns näringsvärde och jordförbättrande organiska material. Subventionen på handelsgödsel är dock en viktig bidragande faktor till att stallgödseln inte utnyttjas bättre.

En utbyggnad av biogasproduktion i Ryssland är lockande om man ser till de producerade gödselmängderna. Men i realiteten är detta en alltför stor investering för de flesta lantbrukarna och överskottsproduktion av gas och el är dessutom svår att sälja till det allmänna nätet. Separation av gödsel skulle kunna möjliggöra längre transporter av den fasta fosforrika fraktionen, vilket skulle förbättra växtnäringsbalansen på gårdsnivå. Kompostering är idag det vanligaste sättet att behandla gödsel. Om denna sköts så att läckage minimeras kan det vara ett bra alternativ i kombination med mineralkväve.

Stallgödsel sprids till viss del som gödselmedel på fälten men det är inte ovanligt att den dumpas i skogen där risken för växtnäringsläckage är stor. Koncentrationen av djur på större anläggningar är ett problem då spridningsarealen antingen är för liten eller belägen långt från gårdscentrum. Spridningen försvåras av eftersatt dränering.

En viktig slutsats var att de ryska lantbrukarnas incitament till bättre stallgödselhantering är bättre ekonomi genom ökad produktion, snarare än miljöhänsyn. För att detta ska bli möjligt måste de statliga prioriteringarna förändras och rådgivningsverksamheten byggas ut.

# Table of Contents

# 1. Introduction

Pollution and eutrophication have troubled the Baltic Sea for several decades and all surrounding countries are part of the problem and will, if they have not yet, eventually suffer from the consequences. Even though much has already been done, much work still remains and there are large differences between the countries. In Russia the work is still focused on battling the pollution from point sources such as sewage treatment plants. In Sweden on the other hand the work has progressed and after improving the standards of point sources, the work now mainly focuses on diffuse sources such as nutrient leaching from agricultural land.

Livestock manure is a valuable source of nutrients for growing crops and through good practices the nutrients can be recycled within the farming system without major losses to the surrounding environment. Several practical issues are though counteracting the return of nutrients to the field; lack of spreading area, lack of economic incentives or lack of knowledge. As for the latter, not all farmers recognize manure as a complete fertilizer and inadequate handling may actually reduce the nutrient value considerably.

As well as all surrounding countries are part of the problem, they are also part of the solution. But in order to achieve a healthy Baltic Sea the need to understand the challenges and difficulties that farmers in the different countries face is crucial. This report tries to embrace the dilemmas that hinder Russian farmers from handling their manure in an environmentally safe way and to identify possible solutions. The study was performed in connection to two different ongoing projects in the Baltic Sea Region, financed by EU (Baltic Compass) and SIDA.

# 2. Objectives and hypotheses

The overall objective of this thesis was to describe the manure management and environmental work related to livestock production in North-west Russia (Kaliningrad and Leningrad oblasts), where Sweden was used for comparisons. The policies, legislation and challenges facing the farmers were investigated, as well as the incentives and willingness to implement environmental measures. Moreover, specific objectives were to evaluate different approaches for increasing the use efficiency of manure and for reducing nutrient losses. The following hypotheses were investigated using literature studies, travel reports and interviews.

**Environmental debate in society**

The environmental movement has for many years been weaker in Russia than in Sweden, where the farmers are more influenced by the public debate on environmental issues.

**Instruments for environmental measures**

The risk of legal sanctions when violating environmental regulations are lower in Russia than in Sweden and thus the legislation is less efficient.

**Manure as a nutrient resource – knowledge & attitudes**

Russian farmers are not aware of the fact that manure is a valuable nutrient resource and have less insight into how manure management affects the environment.

**Manure treatment**

Anaerobic digestion and biogas production would increase bio-security as well as farm income. It would be possible to implement since Russia already has a developed pipeline system for natural gas.

**Manure spreading**
Concentration of animals in big livestock complexes is a major problem in North-west Russia since lack of spreading area hinders farmers to spread their manure.

# 3. Material and methods

The thesis is divided into three connected parts; a literature review, travel reports and interviews.

## 3.1 Literature review

The literature review constitutes the background for evaluation of results from travel reports and interviews and for suggestions of possible solutions. It includes a description of the environmental problems of the Baltic Sea and some of the numerous institutions battling these. The review continues with a short introduction of agriculture and environmental movements in Russia and Sweden. Thereafter, the agricultural policies and legislation of EU, Sweden and Russia are presented. The literature review finally describes techniques and methods for storage, treatment and spreading of manure. The material is gathered from scientific reports, authorities and Russian and Swedish legal acts.

## 3.2 Travel reports

The travel reports were collected during two different occasions; a week's study visit for Russian agricultural practitioners and institute officials in Skåne, Sweden in the beginning of October; and a three day study visit to different farms in Kaliningrad Oblast, Russia in the middle of November. The original planning was to make qualitative interviews with the participants, but unfortunately this was not possible. Time was being too short and the surroundings did not fulfill requirements of peace and privacy. A questionnaire survey could have been a possibility but would not capture attitudes and non-verbal suggestions that can be identified during a conversation. The method is limited by the not randomized selection. The Russian respondents were contacted through JTI, Swedish Institute of Agricultural and Environmental Engineering. They were first invited to Sweden for a study visit on manure management and sewage sludge, and then received visits from JTI, the organizer of the Swedish visit.

Statements and quotations are from participating Russians, whose identity has been diminished to farmer, institute official and so on, in order to maintain their anonymity. The participating agronomist has worked as head adviser for crop production on different farms over the past 30 years and is now stationed in the Kaliningrad oblast. The farmer runs a small cattle production with approximately 150 heads in Kaliningrad oblast. No chemical pesticides or mineral fertilizers are used in his certified production. He is the head of a meat processing cooperative. Institute official is working at an economic research institute in Leningrad oblast addressing the economic development of the agricultural sector in north-west Russia. He has participated in several international projects on the health of the Baltic Sea.

## 3.3 Interviews

The interviews were conducted with three Swedish agricultural consultants. The interview method was qualitative and semi-structured. The purpose of the interviews was to obtain a clearer insight into Swedish farmers' opinions on manure management and environmental work.The method was chosen to somewhat correspond to the travel reports. These three persons who have been in contact with several Swedish farmers, discussing manure management and environmental work can give a summed view of their opinions.

Hans Nilsson works at the County Administrative Board in Skåne and is responsible for the program Focus on Nutrients in Sweden. Ida Lindell is an agronomist and works as agricultural consultant at Hushållningssällskapet, the Swedish Rural Economy and Agricultural Society, in Kristianstad. Emelie Svensson is also an agronomist and works within Focus on Nutrients and as an agricultural consultant at the County Administrative Board of Västra Götaland.

# 4. Results

## 4.1 Literature review

### 4.1.1 The Baltic Sea – a sea troubled with eutrophication

The Baltic Sea is a rather small sea, almost landlocked, connected to the Atlantic only through a narrow passage between Sweden and Denmark. The exchange of the water mass is slow, up to several decades, and dependant on inflow from the West (Naturskyddsföreningen, 2008). The water is brackish by the mix of salty sea water from the Atlantic and the fresh water from in-flowing rivers. Since salt water is heavier than fresh water, layers of fresh water lie by the surface whereas the salt water lies at the bottom. These layers are seldom disturbed (havet.nu, 2012). By this, any input of nutrients or hazardous substances has a long-lasting effect on the entire sea (EUSBSR, 2012b). About 85 million people in the nine countries surrounding the Baltic Sea live in the catchment area. All these reasons make the sea very sensitive to nutrient enrichment and eutrophication (HELCOM, 2009). Drainage from agricultural land and discharges from sewage plants and industry causes inappropriate nutrient loading in rivers, lakes and, eventually, the sea. This leads to overproduction of biomass, such as heavy summer bloom of photosynthetic cyano-bacteria (blue green algae), which eventually will be digested by microorganisms in an oxygen demanding process. The marine system of the Baltic Sea is not designated to recycle this large amount of organic matter; hence the process is consuming the oxygen to the extent of depletion. Oxygen-free life-less sea beds are created and if the depletion of oxygen goes all the way up to the surface, fish and other aerobic organisms are caused to suffocate. Phosphorus and nitrogen are the nutrients most prone to cause eutrophication (Ricklefs, 2007). Especially the south and the eastern parts of the sea are acutely affected by eutrophication (EUSBSR, 2012b).


*Fig. 1 The Baltic Sea catchment area (Coalition Clean Baltic, 2012)*

During the last century the loads of nitrogen and phosphorus to the Baltic Sea have increased several times (EUSBSR, 2012a). The agriculture in the region is intensive, each year loading the sea with approximately 30 000 tones of phosphorus and 1 million tones of nitrogen. 50 % of the eutrophication in the region is calculated to be caused by agriculture (HaV, 2012). In a climate with a precipitation surplus, the land is naturally leaching nutrients when the rainfall or melting snow is percolating through the soil (SJV, 2011a). Agriculture is the main source for nitrogen pollution in the Baltic, whereas urban wastewater is the main phosphorus source (Aertebjerg & Nixon, 2004).

Poland, Russia and Sweden are together responsible for 64% of the total phosphorus input to the Baltic Sea and 56% of the nitrogen input, see figure 2 and 3 (HELCOM, 2012a).

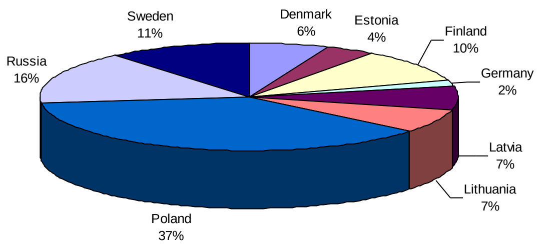


*Fig. 2 Total P input to the Baltic Sea in 1994-2008. The waterborne inputs include trans-boundary loads (recreated from HELCOM, 2012a)*

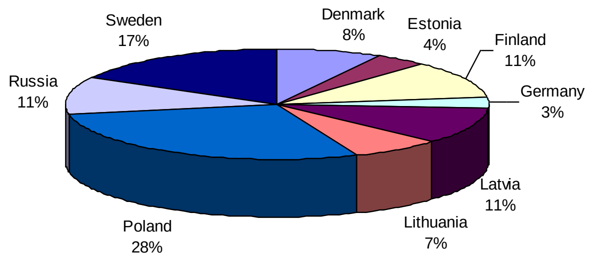


*Fig. 3 Total N input (including waterborne & airborne loads) to the Baltic Sea in 1994-2008. The waterborne inputs include trans-boundary loads (recreated from HELCOM, 2012a)*

The amount of nutrients leaching from agricultural land depends on a wide range of factors, such as amount and time of precipitation, amount of fertilizers or manure applied, time of application, type of crop, soil cultivation, surface runoff, field topography and soil type (Strandmark, 2011).

The emissions of phosphorus and nitrogen started to increase during the 50's and reached a peak in the 80's. According to Gustafsson et al (2012) the emissions have since decreased and are now at the same level as in the 50's. This progress has been achieved mainly through the development of efficient sewage plants. A remaining problem though, is that the stocks of phosphorus last high and hence counteract the recovery of the Baltic Sea (Gustafsson et al, 2012).

**4.1.2 Joint forces and national efforts help saving the Baltic Sea**

The countries in the Baltic Sea catchment area together with several organizations implement actions and projects helping to deliver benefits to the Baltic Sea. A few out of numerous institutions are described in this chapter.

***HELCOM and the Baltic Sea Action Plan***

The task of saving the Baltic Sea cannot be accomplished effectively by national efforts only; co-operation in the region needs to be close. For this appropriate international measures have to be taken; the fundamental idea of the Helsinki Convention, governed by HELCOM (HELCOM, 2008). In 1974 the first steps towards an integrated approach on all environmental questions regarding the Baltic Sea were taken. The 1974 Convention were signed by the, by then, seven countries around the Baltic Sea and it entered into force in 1980. By 1992, after the political transformation of the Soviet Union and the fall of the Berlin Wall, it was time for a new convention to be signed – now by nine countries but also by the European Community. It entered into force in 2000 and is covering all of the Baltic Sea area, which includes inland water as well as the actual sea water and sea bed. Furthermore, measures are taken within the whole catchment area in order to prevent land-based pollution (HELCOM, 2012b).

In 2007 HELCOM adopted the ambitious program Baltic Sea Action Plan based on ecological objectives and with the aim to restore the good ecological status of the Baltic marine environment by 2012 (EUSBSR, 2012b). Instead of, as had been done until now, focusing on what different sectors could do to ease the burden of the environment, focus shifted to the actual ecosystem and a jointly agreed vision of a healthy sea with a good ecological status. Emphasis lies on the active participation of the major stakeholder groups in the region in order to make the plan truly relevant and achievable (HELCOM, 2012b).

The ecological objectives of Baltic Sea Action Plan are as follows:

- A Baltic Sea undisturbed by excessive inputs of nutrients
- Concentrations of hazardous substances close to natural levels
- Maritime traffic and offshore activities carried out in an environmentally friendly way
- Favorable conservation status of biodiversity

In order to achieve these objectives specific actions are stated:

- Reduce the amount of nutrients entering rivers from diffuse sources, especially farmland
- Reduce nutrient pollution from the remaining "hot spots", such as waste water treatment plants
- Reduce airborne nutrient pollution

Such hot spots, or main problems, might as well be large scale animal production units with inadequate manure handling (Greppa Näringen, 2012a).

***EU strategy for the Baltic Sea Region***

In 2009 the European Council approved a multi-regional strategy for the Baltic Sea region, the first of its kind in Europe. The strategy aims at "*enabling the Baltic Sea Region to enjoy a sustainable environment and optimal economic and social development (...) through co-ordination of appropriate policies"* (EUSBSR, 2012c). The strategy is divided into three objectives; save the sea, connect the region and increase prosperity. 15 different priorities are connected to these objectives, ranging from keeping agriculture, forestry and fisheries sustainable and profitable, to education and cross-border crime. The first priority area is *Nutrients input to the sea*, which by a set of actions and Flagship Projects strives to reduce the nutrient load into the sea (EUSBSR, 2012b).

The actions are divided into strategic actions; such as *Implement actions to reduce nutrients* and *Promote measures and practices which reduce nutrient losses from farming and address eutrophication*; and cooperative actions such as; *Establish and restore more wetlands* and *Facilitate cross-sectoral policy-oriented dialogue.* The goal is to achieve this through the implementation of e.g. Baltic Sea Action Plan, the Nitrate Directive or the Common Agricultural Policy, but it might as well be through the National Rural Development Plans (EUSBSR, 2012b).

An example of a Flagship Project is Baltic Deal - putting best agricultural practices into work. It started as a voluntary initiative by farmers' federations and advisory services since the farmers around the Baltic Sea had recognized the eutrophication problem and their part in it (EUSBSR, 2012b). The aim is to reduce nutrient losses from agriculture without losing productivity or competiveness. This is achieved by providing advisory organizations with tools and methods that are improved and cost-effective, in order to support the farmers to reduce nutrient losses. Knowledge exchange, demonstration farms and pilot activities are used in this joint effort that runs from 2010 until 2013 (Baltic Deal, 2012).

Another Flagship Project, initiated in 2009, is Baltic Manure which aims to improve the common perception of manure, as to be a resource for nutrients and energy rather than waste. Business innovations are encouraged through research and development of renewable energy and nutrient recycling to achieve a sustainable agriculture, prosperity and jobs in the Baltic Sea Region (Baltic Manure, 2012).

Even though the strategy is a European Union strategy, including the external partners are of outmost importance to be able to address many issues regarding the Baltic Sea Region. Russia´s cooperation is particularly valuable. A problem that has been recognized when the member states are developing their national implementation is that the progress and achievements are held back because of the lack of mandatory commitments (EUSBSR, 2012b).

***Baltic Compass – connecting efforts***

Baltic Compass is a project partly funded by the EU aiming to find ways for the agriculture in the Baltic Sea Region to provide food for its inhabitants and at the same time protect the Baltic Sea. Baltic Compass contributes to the implementation of the EU Strategy for the Baltic Sea Region as well as the HELCOM Baltic Sea Action Plan. Further, National Rural Development Plans are included in the framework.

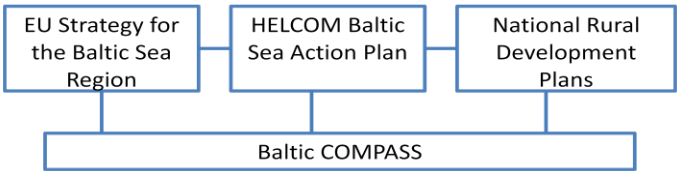


*Fig.4 Framework of Baltic Compass (recreated from Baltic Compass, 2012).*

The strategic objective of Baltic Compass is to help reduce eutrophication of the Baltic Sea by promoting best possible solutions for the agriculture, public and environmental sectors. The problem definitions strive to be relevant for stakeholders within the whole catchment area. The project period is from December 2009 to December 2012. The partners in the project represent authorities, institutions and interest organizations in nine riparian countries; Belarus, Estonia, Latvia, Lithuania, Poland, Germany, Denmark, Sweden and Finland. To secure an all-Baltic coverage Russia is included as associate partner (Baltic Compass, 2012).

### 4.1.3 A Short Introduction to Agriculture in Russia and Sweden

This chapter gives a short, mainly historical introduction to agriculture in Russia and Sweden.

***Agriculture in Russia***

In 1861 serfdom was abolished in Russia and in the beginning of the 20th century the Tsar regime made it possible for farmers to separate their part of land from the village's common. A quite small group of wealthy farmers called kulaks emerged (Alm, 2010). After the 1917 Russian revolution all land accrued to the State and in 1927 the collectivization of the agriculture started. A kolkhoz consisted of farmers that had to put all their land and equipment into a collective agriculture where they also had to work. The sovkhozes were big State owned farms with employed labor that had no rights to land or part in the company. Both the kolkhozes and the sovkhozes had a yearly production plan and a five year plan with delivery obligation to the State (Hedman, 2001). The centralized control resulted in lack of inputs such as mineral fertilizers, which made the agricultural production decrease and millions of people starved in the 1932-1933 famine (Hedman, 2001 and Alm, 2010).

The decrease in production continued and in 1954 the annual cereal production per capita was lower than during the Tsar period (Hedman, 2001). From the mid-60´s the USSR agriculture had obvious problems to maintain sufficient production and the country became dependent on import to feed the population (Samuelson, 2011). In 1965 the average cereal yield was 950 kg/ha in Russia (Hedman, 2001), compared to 3800 kg of winter wheat per hectare in Sweden (SCB, 2012b). The agricultural units were big; the average sovkhoz had 8500 ha of arable land, a fact that contributed to the low efficiency. Another problem was the collective work form; the connection between individual labor input and wage was too diffuse (Hedman, 2001).

In 1989-90 formation of non-state owned companies were allowed and this would be the basis for family-owned farms. By the collapse of the Soviet Union in 1991 the agriculture was mainly characterized by two types; the large scale agriculture and subsidiary plots. The latter accounted for 2% of the land, but 26% of the production. When the land was privatized some of the old sovkhozes and kolkhozes turned into joint stock companies, but continued to be operated as before (Hedman, 2001).

During the chaotic 90's, when politics and economics were reformed, so were the agricultural enterprises. For the agro-holdings, the farms that were transformed into joint stock companies, the main objective was to survive the unfavorable economic conditions. Machinery and equipment got out of condition and hardly anyone could afford required environmental measures (SLU, 2009a).

The majority of Russia´s agricultural land got initially environmentally damaged between 1950 and 1970. The ecological degradation and decline in land fertility has continued ever since now resulting in soil erosion and increased chemical and radioactive contamination. About 40% of the agricultural land is today subject to wind erosion, approximately 18% to water erosion (Yablokov, 2010).

In 2009 the average yield of wheat in Russia was 2300kg/ha and in 2010 1900kg/ha (OECD, 2012). In Leningrad oblast the average size of a farm enterprise is 1880 ha, whereas the average family farm is 7, 4 ha. In addition to these types of farms, personal subsidiary plots are still abundant (SLU, 2009a).

*Fig. 5 Map of Russia; Leningrad and Kaliningrad oblasts starred (CIA, 2012)*

Two Russian regions border the Baltic Sea; Leningrad and Kaliningrad oblast, which were the regions in focus for this study. Leningrad oblast is situated between Finland and Estonia. Historically the region has developed following the necessity to provide St. Petersburg with products that could not stand long transports; fresh milk, meat, eggs and vegetables. The climate is characterized by moderately warm summers and relatively mild winters with frequent thaws. The soil is mainly podsolic and the natural fertility is low. The input of mineral and organic fertilizers is large in order to receive competitive products (SLU, 2009a). The exclave region Kaliningrad is situated between Poland and Latvia. The loamy soils are mainly podsolic, but there are also peat soils. About 20% of the agricultural lands are sensitive to erosion. On about 50% of the total area the content of organic matter is below 3%. The climate is charactarized by mild winters, often without persisting snow cover; warm and rainy springs; and relatively warm summers (Kaliningrad oblast, 2012).

***Agriculture in Sweden***

From mid-19$^{th}$ century until mid-20$^{th}$ crop production and animal husbandry in Sweden were a well integrated production system characterized by biological balance. But the production was not enough to feed the population and especially the years of famine 1865-1867 triggered mass-emigrations to America. Soon after this, major agricultural improvements such as tile drainage and land reclamation were made. The drainage increased crop safety and later enabled mechanization of the agriculture, allowing heavy machines to operate in the fields (Steineck et al, 2000a).

Starting from the 50's the Swedish agriculture changed rapidly. People moving to the cities led to a decrease in recycling of nutrients, which was compensated by the use of mineral fertilizers. The mineral fertilizers allowed for crop production and animal husbandry to be separated and specialized farms were established. This often led to amounts of manure excessive for the accessible spreading area. The nutrient value of the manure was often underestimated which led to significant surpluses of especially phosphorus in the soil. This trend changed during the 90's due to increased awareness from advisors and farmers (Steineck et al, 2000a).

Considering the latitude, the Swedish winter climate is very mild and the summers relatively warm. In the regions Mälardalen and Östergötland the soils are mainly clay soils with more than 40% clay while towards the North the clay content decreases. The soils in the south-west are also clayey but with elements of sand. In the south of Sweden the dominating soils have clay contents below 25% (Eriksson et al, 2005). In 2011 the average yield of winter wheat in Sweden was 5630 kg/ha. The average yield of spring wheat was 3980kg/ha (SCB, 2012).

#### 4.1.4 Environmental movements in Sweden and Russia

The modern environmental movement rose as a response to the industrialization (UN, 2012). In this chapter environmental movements in Russia and Sweden are addressed briefly.

***Russian environmental movement***

In the beginning of the Soviet era, Lenin imposed environmental legislation aiming to protect land, forests and water. Even though he sought to increase the productivity of the USSR, he considered nature worth respecting. Huge land areas were protected through the creation of nature sanctuaries (Weiner, 1988).

In 1928 Stalin launched the first Soviet five-year plan. The view of nature then radically changed; from nature being in harmony with society to a “utilitarian” view, nature being the antagonist of man. Many sanctuaries were closed (Weiner, 1988).

Some degree of political liberalization during the mid-50’s made it possible for environmental groups to protest against the anthropogenic eradication of nature. Some of the most militant and durable environmental groups were student groups; Students’ Nature Protection Corps started in Estonia in 1958 and spread to other universities in USSR (Emelianova & Starik, 2004).

During the 1980’s civic groups campaigns were mostly anti-nuclear. Not only because of the Chernobyl catastrophe, but also because of areas in the Urals and Siberia that had been radio-actively contaminated by weapons production and waste dumping (Emelianova & Starik, 2004). The rising concern linking public health and polluted environment gave the sphere of environmental protection high political priority during the perestroika (Robinson, 1988).

When building the big agricultural complexes during the Soviet era, storage and utilization of manure was not prioritized. This led to the habit of dumping manure in open field disposals, which is still abundant. Further, application of high doses of mineral as well as organic fertilizers was recommended, without any environmental consideration (HELCOM, 2010).

The economic chaos and uncertain social conditions after the breakup of the Soviet Union made environmental issues seem less important to the public. But these issues became part of the political platform of the opposition (Emelianova & Starik, 2004). To be noted is that the opposition in principal was loyal to the political elite during the 90’s and was virtually extincted when Putin became president in 1999 (Gelman, 2004).

In 2000 the Environmental Protection Agency of Russia was dissolved and the environmental legislation and state environmental control has been weakened ever since. Environmental activists are being persecuted and environmental NGO’s obstructed (Yablokov, 2010).

The political attitude is a serious problem for a Russia that faces severe environmental problems threatening peoples’ health. Economic gain frequently trumps environmental costs; an approach known as “de-environmentalism”. This started under Yeltsin and has continued under Putin and Medvedev. The problem lies both in the power-structure and the wider society (Yablokov, 2010).

The environmental priorities differ between Sweden and Russia. Whereas Sweden focuses on a whole range of issues such as biodiversity and nutrient leaching, Russia prioritizes only a few environmental issues like nuclear power and the risks connected to increased transports of oil. Swedish project proposals are therefore met with skepticism and the willingness to contribute with local resources and funding may be low. Environmental work initially has to focus on acute problems and only in the long run on Swedish priorities (Greppa Näringen, 2011f).

***Swedish environmental movement***

After the Second World War the industry recovered in Europe and the economy grew stronger as production and consumption increased. But in the early 60's the industry's environmental impact came to public notice (WWF, 2011a) and in 1962 Rachel Carson's book *Silent Spring* was released, in which she warns for the use of chemical pesticides in agriculture.

During the 60's and 70's the environmental movement grew stronger in Sweden, as in many other countries at this time. Voluntary organizations, state and municipalities as well as the industry got involved in the work of reducing environmental impact (Ekonomifakta, 2012).

In 1987 the Brundtland Commission published its report *Our Common Future* which made the concept of sustainable development known to the public; "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (UN, 2012).

Thanks to the implementation of political and technical solutions and innovations the trend of negative environmental impact in Sweden has been reversed since the 70's. The emissions of heavy metals and chemical substances such as PCB and DDT are now close to zero. According to the economist Simon Kuznets there is a connection between a society´s economic wealth and its environmental impact, derived from Maslow's hierarchy of needs. When the mean wage gets high enough, the public opinion begin to give environment a higher value. The demand for environmentally friendly products raises and stricter legislation is introduced, which in turn reduces the environmental impact (Ekonomifakta, 2012).

**4.1.5 Legislation, economy & information – instruments in environmental policy**

Authorities are using different instruments to achieve objectives stated in environmental policies. Farmers in Sweden are, unlike Russian farmers, controlled by measures imposed by the European Union.

***Instruments in environmental policy***

There are different kinds of instruments controlling the environmental aspects of agricultural business; legal, economic and informative instruments. The purpose and impact differ and usually a combination is required to achieve set goals (Naturvårdsverket, 2012).

Legal instruments are laws and regulations, such as administratively set limitations for use of fertilizers or allowed storage technique (Johansson, 2010). This instrument is mandatory which gives a possibility to impose sanctions such as charges or fines (Naturvårdsverket, 2012). Regulations may put a limit for emissions or may prohibit the emissions of certain substances. The disadvantage of regulations is the lack of incentives for continuing reducing the emissions once set limits are achieved (Naturvårdsverket & Energimyndigheten, 2006).

The economic instruments are taxes, subsidies, investment grants and emission trade. Taxes can be put on the emissions or on certain production inputs if the source of emission is diffuse. When the polluter-pays-principle applies for all emissions, the incentives for technical development will remain even though some reductions have already been done (Naturvårdsverket & Energimyndigheten, 2006). Subsidies can be seen as negative taxation and should mainly be given for activities that create a positive external value. An example of this is the cultivation of catch crops to reduce nutrient leaching. Subsidies affect the rate of development and implementation of new techniques (Johansson, 2010). The emission trade is mainly used for setting a price on carbon dioxide but as Lindahl (2005) writes, it has been used locally for nutrients as well. In a pilot project in Lysekil, on the west coast of Sweden, a sewage plant paid for cultivation of mussels that filtrated the water for nutrients close to the plant, instead of making costly investments for nutrient reduction at the plant.

Informative instruments such as information and education have been used by authorities and NGO's for a long time. The aim is to change a behavior on a voluntary basis or to gain public acceptance for a decision. An example of information that has reduced the nutrient leaching is the Swedish program Focus on Nutrient. The efficiency of informative instruments can be hard to quantify, but if the voluntary change comes with economic incentives the conditions for improvements are good (Johansson, 2010).

***Russian policies and legislation***

When Russia in 1991 went into the transition period from planned economy to market economy, the system of environmental management was poorly developed. The system developed steadily and addressed social, economic and political challenges until the late 1990´s, but since then the process has slowed down (OECD, 2006). The main objective of state support in Russia is to increase the agricultural out-put (SLU, 2009).

***Russian Agricultural and Food Policy***

The Russian Federation has 5-year programs for the rural areas including the agricultural production. The objectives of the plan 2008-2012 are:

- Sustainable development of rural areas, less unemployment and higher living standards for the rural population.
- Higher competiveness of Russian agricultural production
- Conservation of natural resources such as land used in agricultural production

To achieve these objectives, several subprograms are developed; one of these aims to conserve and improve soil fertility (Ministry of Agriculture RF, 2012a). One of the goal indicators for this is increased use of mineral fertilizers (Ministry of Agriculture RF, 2012b).

In 2008 a financing rate was adopted by the Order of the Committee for Agro-industrial and Fishery Complex of Leningrad oblast for purchase of mineral fertilizers and plant protecting agents. Rise in price is compensated by federal budget and the expenses for purchase of mineral fertilizers can be reimbursed. This reimbursement is different depending on which crop the fertilizer is applied and only available if the applied amount of mineral N exceeds 30 kg per ha. For some fertilizers the reimbursement can be more than 50%. This has led to a clear tendency of increased use of mineral fertilizers (SLU, 2009b).

***Federal Law on Environmental Protection***

In 2002 the federal law on Environmental Protection replaced a similar law that had been in force since the Soviet period. The instruments for the Russian environmental policies are found in this law, which tries to balance environmental, economic and social needs (OECD, 2006).

Concerning agriculture, it is stated in article 42: "Agricultural objects management should include strict observance of environmental requirements, and implementation of the measures to protect the land, soils, water bodies, plants, animals and other organisms against the adverse effect of economic and other activity on the environment" (Semenov et al, 2006). Further, the agricultural objects need to take sanitary measures in order to eliminate pollution of soil, surface and groundwater as well as the air (Law on Environmental Protection RF, 2001).

***Water Code of the Russian Federation***

The use and protection of water resources are regulated in the Water Code which came into force in 1995 (OECD, 2006). In 2007 a new version of the law entered into force after signing by President Vladimir Putin (IRC, 2006).

The management of water bodies for use and protection is divided into 20 basin districts all over Russia. Each basin consists of river basins and hereto associated groundwater and seas. In order to ensure the protection of the water bodies, a basin council which formulates recommendations is established in each basin district (Water Code, 2006).

Article 65 in the Water Code addresses water protection zones and near-shore, riparian protective belts. These zones and belts are territories next to seas, rivers, water reservoirs etc., within which special rules complies for economic and other activity in order to prevent contamination, erosion and depletion (Water Code, 2006). The width of the protection zones is established on the basis of maximum tidal level, mean annual water level during summer and the rim of water reservoirs. The width is between 50 and 500 meters. Within this zone it is prohibited to apply liquid manure and to store manure. Further, within the riparian zones it is prohibited to plow the lands and apply any fertilizers what so ever (Semenov et al, 2006).

It is prohibited to construct cattle-breeding farms and other agro-industrial complexes without waste treatment facilities and sanitary protection zones (HELCOM, 2010).

***Federal Law on Production and Consumption Waste***

Animal waste is classified as hazardous and hence complies with the federal law on production and consumption waste (HELCOM, 2010).

***Federal Law on State Regulation of Fertility of Lands of Agricultural Designation***
Since soil fertility is crucial for higher yields and increased production, the use of agricultural land as well as management and restoration of soil fertility are addressed at a national level in the federal law on state regulation of fertility of lands of agricultural designation. Land owners and users are obliged to use their land "…in such a way that fertility restoration (…) is guaranteed" (Semenov et al, 2006).

***Russian Environmental Control***
Since the 90´s the Russian environmental administration has changed constantly and the controlling system has been reconstructed several times. For the time being the Ministry of Natural Resources and Ecology controls all matters concerning state ecological monitoring and supervision, wildlife management, ecological, nuclear and technical safety. The ministry is hence responsible for both the utilization and the protection of natural resources (HELCOM, 2010). The Russian Agricultural Inspection is responsible for controlling that fertilizers and manure are treated in a safe way (Skorupski, 2007). Agricultural enterprises violating the ecological legislation requirements are obliged to pay a fee for environmentally and sanitarily harmful actions every three months (HELCOM, 2010).

***Criticism of Russian Environmental Work***
The environmental policy in Russia has been ambitious, but unfortunately not fully implemented because of lack of realistic objectives, coherent environmental legislation and effective financing mechanisms. The economic development has benefited in favor of the environmental work and the non-compliance with environmental legislation is wide-spread. Environmental management in Russia is hindered by problems on a systemic level, such as low political interest and priority of environmental issues (OECD, 2006).

Nutrient run-off and leaching has not been of high priority in the Russian environmental legislation; the focus has instead been on health-related standards. There is no environmental legislation addressing agricultural production in specific, but general environmental and sanitary regulations for the industry also apply for agricultural enterprises (HELCOM, 2010).

Some Russian environmental regulation, such as maximum allowable concentrations of certain substances, is much stricter than their EU or WHO counterpart, making it hard or impossible to achieve the standards. This leaves room for compromises between controlling authorities and the polluter and the effectiveness of the regulation is thus undermined (HELCOM, 2010).

There are almost no incentive instruments such as subsidies, credits, compensations, loans or tax incentives, in the environmental policy. Instead only taxes, pollution charges and penalties are applied (HELCOM, 2010).

## ***EU policies and legislation***

***Common Agricultural Policy***
The Common Agricultural Policy, CAP, is one of the oldest policies in the European Union and has its roots in the 50´s post-war Western Europe. The initial aim of the CAP was to improve food security by increasing productivity, ensure the living standards of farmers, stabilize the market and provide the population with food at affordable prices. The policy was successful in increasing the production and the 80´s saw an overproduction of almost all major commodities that had to be exported with the help of subsidies or stored and disposed within the community. The policy became unpopular with the public because of the high budgetary costs, the distortion of markets and, increasingly, concern for the environmental sustainability of agriculture. The 1992 MacSharry reform aimed at improving the agricultural

competiveness, stabilize the agricultural market as well as the EU expenditures and agro-environmental programs were introduced. The Agenda 2000 further reformed the CAP with the objectives to increase market orientation and competiveness, simplify and decentralize and incorporate environmental concern into the agricultural policy. The 2003 reform continued this work and the 2008 Health Check aimed to reduce the regulatory burden and enable the farmers to catch up market signals and to respond to challenges such as climate change, water management and bio-energy (European Commission, 2012a).

CAP is divided into two pillars; the first containing market measures and production support and the second containing the rural development policy. The first pillar shall support all farmers providing good quality products with high animal welfare and environment standards. At the same time it shall reconstruct the balance between the EU market and the markets in developing countries. The second pillar constitutes of targeted supports for environmental work and rural development. This pillar is partly financed with national or regional funds and it is up to the Member States to decide on which measures that is most important to their region (WWF, 2011b).

The different policy areas within the both pillars of CAP, such as direct support, organic farming, bio-energy and environment, are interlinked through the cross-compliances. By this mechanism the EU support to the farmer will be reduce if he does not obey the EU laws on environment, public or animal health, animal welfare or land management. The size of the reduction depends on the severity of the infringement. The direct support as well as rural development payments can be reduced if the cross-compliances are not fulfilled (European Commission, 2012a).

***The EU IPPC Directive – Integrated Pollution Prevention and Control***

Since 2008 industrial and agricultural activities are obliged to have a permit if their pollution potential is high. The permit will only be given to companies that meet certain environmental conditions and they will be responsible for preventing and reducing any pollution that they may cause (Europa, 2011). The permit is needed for intensive rearing of poultry and pigs if the production site has more than 40 000 places for poultry, 2 000 places for production pigs (>30 kg) or 750 places for sows (IPPC, 2008).

***The EU Water Framework Directive***

The EU Water Framework Directive, WFD, entered into force in December 2000. It originated in the early European water legislation that during the 80's addressed drinking water and waters for fish, shellfish and bathing. The aim of the WFD is to protect the surface and ground waters in Europe by establishing community legislation. The demands for enough quantity of good quality water were increasing and at the same time the public awareness was rising. Instead of dividing the work into administrative or political regions, the system is based on management by river basin which means that sometimes the work transcends national borders (European Commission, 2012b).

***The EU Nitrate Directive***

An integral part within the Water Framework Directive is the Nitrate Directive (1991) which aims at protecting the quality of ground and surface waters by preventing pollution from agriculture through promoting of good practices. The implementation has been done in five steps; starting with the identification of polluted and threatened waters. Secondly, Nitrate Vulnerable Zones were designated as land area that drained into threatened or polluted waters and which contributed to N pollution. Thirdly, Codes of good agricultural practices were established to be implemented by farmers on a voluntary basis. These Codes consisted of:

- Measures limiting the time when fertilizers can be spread in field, to assure that the nutrients would be available only when the crops need them.
- Measures limiting fertilizer application during certain field conditions. The fertilizers should not be applied in steep slopes, on frozen land or snow or close to water courses.
- Minimum storage capacity for livestock manure.
- Catch crops, soil winter cover and crop rotations to prevent leaching during season with high precipitation.

The fourth step in the implementation was to establish Action Plans making it compulsory for farmers within Nitrate Vulnerable Zones to implement the Codes of good agricultural practices. Further, the amounts of fertilizers applied had to correspond to the need of the crop, the total N input and soil supply. The amount of applied livestock manure is not to exceed 170 kg N per ha and year. The fifth step is the national monitoring and reporting in every fourth years (European Commission, 2012c).

***The EU Marine Strategy Framework Directive***
The aim of the program is to achieve good environmental status of the EU´s marine waters by 2020. This should be achieved at the same time as the oceans and seas are used to its full economic potential. The directive was adopted in 2008 and is the vital environmental part of the future Marine Policy in the EU. Member States and non-EU countries are to cooperate and develop strategies for their common marine environment. The directive should strengthen the international agreements already decided on which in the case of the Baltic Sea refers to the work of HELCOM (European Commission, 2008).

***Criticism of the EU Environmental Work***
The environmental benefits of the Common Agricultural Policy are increasing. Of the different financial supports in CAP, the targeted support within the Rural Development Programs is the best in order to achieve positive environmental benefits. The main part of the agricultural policy budget is though spent on general supports that cannot be directed and hence are less easily operated and give lower environmental benefits. The environmental benefits would increase in case a larger proportion of the budget was targeted, but this kind of support is not cost efficient since the administrative costs for this are considerably higher (Naturvårdsverket, 2011). If the EU legislation was fully implemented and enforced, agricultural hot spot pollution from intensive pig rearing would be hindered according to Foged (2010).

***<u>Swedish policies and legislation</u>***
In Sweden the first actions against nutrient losses were launched in the late 80´s when the debate about eutrophication started. In the beginning focus was on nitrogen losses, but has since then widened to include measures for reduced phosphorus and ammonia losses as well. The efforts are part of international commitments and Swedish Environmental Objectives (SJV, 2009a).

Ever since the entry into the European Union in 1995, Sweden has to obey to the EU legislation. If Swedish law contradicts an EU law, the latter applies. There are two types of EU laws; regulations and directives. The regulations apply directly as law in the Member States, whereas the directives include common objectives that the individual Member State can implement as they find best. Both regulations and directives are binding (EU-upplysningen, 2012).

***Swedish Environmental Code***

*Miljöbalken*

The Swedish Environmental Code should be applied as for soil, water and environment otherwise to be used in a sustainable way for ecological, social, cultural and socio-economical purposes. Recycling and reuse of materials, primary products and energy should be encouraged.

In chapter 2 of the Swedish Environmental Code, the Rules of Consideration, it is specified that anyone that conducts an activity or measure has to obtain enough knowledge to protect the human health and the environment. If the activities are of professional art, best known practices should be used (Sveriges Riksdag, 2012a).

Concerning manure storage, the Board of Agriculture recommends that its location should risk minimum negative environmental impact if leaching occurs. Further, to decrease the risk of leaching and run-off, the storage facilities should be inspected regularly as for defects to be discovered and fixed (SJV, 2009c).

***Decree on Environmental Consideration in Agriculture***

*Förordning 1998:915 om miljöhänsyn i jordbruket*

In the decree on environmental consideration in agriculture the nitrate vulnerable zones in Sweden are defined which are, except a few regions, most of the south and central parts of Sweden. In these areas, the manure storage capacity for farms keeping more than 10 animal units has to correspond to eight months of manure production for cattle, horses and sheep; and ten months for other animal types. Outside of these areas the restriction is six months for cattle, horses and sheep; but still ten months for other animal types. The storage facilities should be designed to prevent run-off and leaching (Sveriges Riksdag, 2012b). The general advice of the Swedish Board of Agriculture is that the size of the manure storage facilities should enable storage during periods and weather conditions when spreading is forbidden or inappropriate (SJV, 2009c).

***Swedish Agricultural Board Regulation on Environmental Consideration in Agriculture concerning Plant Nutrients***

*Statens jordbruksverks föreskrifter SJVFS 2004:62 om miljöhänsyn i jordbruket vad avser växtnäring*

The applied manure or other organic fertilizer cannot exceed the amount that equals to 22kg of total P per hectare spreading area and year. This is calculated as an average of the entire spreading area per year throughout a five-year period. Within this period manure should have been applied to the entire minimum spreading area. If the available spreading area is larger than that, manure only has to be applied to the minimum spreading area (SJV, 2004).

Within nitrate vulnerable zones the input of nitrogen should not exceed the crop need. The nitrogen need for the expected yield should be calculated considering the long-term effects of the fertilizer, preceding crop effect, if the soil is rich in humus and application of manure or other organic fertilizers to this year’s crop (SJV, 2009c).

Manure or other organic fertilizers spread should be incorporated into the soil within 12 hours; within 4 hours in the nitrate vulnerable zones (Greppa Näringen, 2011g). Further within the nitrate vulnerable zones, fertilizers may not be spread on water-saturated or flooded soils or on frozen or snow-covered ground. The recommendation outside of these zones is to consider surface erosion and leaching when spreading during above mentioned conditions (SJV, 2009c).

Within nitrate vulnerable zones it is not allowed to spread fertilizers closer than two meters from the field edge adjacent to rivers or lakes. It is also forbidden to spread fertilizers on agricultural land adjacent to rivers and lakes if the slope < 10%. Mineral fertilizers and manure cannot be spread during the period of 1 November – 28 February if within nitrate vulnerable zones. The total amount of nitrogen from manure added may not exceed 170 kg total N/ha/year. There are also additional regional differences concerning the allowed spreading periods (SJV, 2009c).

***The Swedish Rural Development Program***
*Landsbygdsprogrammet*
The Rural Development Program is a tool for accomplishing the common rural development policies in EU and is financed both by Sweden and EU. The program has three main objectives; improving competitiveness of agriculture and forestry; improving environment and landscapes; and improving life quality, business and rural economy. About three quarters of the budget goes to environmental support which is more than 26 billion SEK. Farmers can receive support for organic farming, for preventing pastures and meadows from overgrowing, for keeping endangered species of domestic animals and preserving cultural and natural heritage values. Further, protective zones next to water courses and measures such as growing catch crops during winter and only plough during spring, can make a farmer liable for support. In order to receive the financial support for environmental measures, the ordinary as well as additional environmental cross compliances have to be fulfilled. If the farmer complies with the law concerning environmental issues, he also fulfills the cross compliance conditions (SJV, 2012c).

***Swedish Environmental Quality Objectives***
*Sveriges miljömål*
In 1999 the Swedish Riksdag launched the idea of a limited number of national environmental objectives in order to organize the environmental work. The overall goal of the Government's policy, the so called Generation Goal, aims at handing over to the next generation a society that has taken care of the major environmental problems facing Sweden. This will be done by 2020 for a majority of the objectives and by 2050 for the objective No Climate Impact. While achieving this, the problems are not to be exported to other countries where environment and health could be affected. There are 16 Environmental Quality Objectives, describing what the actions should result in for the Swedish environment. Agriculture is somewhat connected to almost every objective. Manure handling in specific is connected to Zero Eutrophication, Good-Quality Groundwater and Reduced Climate Impact (Miljömål, 2012).

***Focus on Nutrients***
*Greppa Näringen*
The project Focus on Nutrients started in the southern parts of Sweden in 2001 to help farmers fulfill the national environmental objectives; Zero Eutrophication, Good-Quality Groundwater and Thriving Wetlands. In 2003 the project was expanded geographically and now also including the national environmental objective A Non-Toxic Environment. In the project farmers are offered free consultation that he as well as the environment benefits of. The Swedish Board of Agriculture is responsible for the project and it is funded by the Rural Development Program and return from environmental taxes. It is administrated by the Swedish Board of Agriculture, County Administrative Boards, Federation of Swedish Farmers and several companies in the agricultural sector. Consultations are mainly carried out individually; the advisor makes farm visits and shows the farmer which measures that can increase the utilization of resources, hence contribute to lowered costs, increased profitability and reduced nutrient losses to the environment (Greppa Näringen, 2011). Even though

consultation is voluntarily, the reductions of nitrogen and phosphorus losses from the agriculture have been significant (LRF, 2012).

***Swedish Environmental Control***

The County Administrative Board is responsible for supervision of management of agricultural land. It receives supervision guidance from the Swedish Agricultural Board on questions concerning animal husbandry and agricultural production (Sveriges Riksdag, 2012c).

In order to receive full EU financial support all conditions have to be fulfilled. It is mainly the County Administrative Board that controls if the farmer's application is correct and that all conditions for the single payment scheme and the cross-compliances are fulfilled. The control includes visits to the farm; it can be announced shortly in advance or be unannounced. If the conditions are not fulfilled, the financial support may be reduced; partly or completely depending on how severe the error is (SJV, 2012b).

***Criticism of the Swedish Environmental Work***

In 2009 Sweden got criticized by the EU Commission because of lacking implementation on some points of the Nitrate Directive. The criticism mainly focused on spreading of manure in nitrate vulnerable zones during autumn and winter, but also on maximum slope towards water courses restricting spreading of manure (SJV, 2010).

During the 80´s Sweden introduced a fee, which transformed into taxation during the 90´s, on nitrogen in mineral fertilizers; an economic instrument with the intention to restrict the use (SJV, 2010). As Sweden was the only country in EU with this taxation, it was a competitive disadvantage and in 2010 it was removed (LRF, 2009). The removal of the tax was assumed to increase the use and hence the leaching (SJV, 2010).

#### 4.1.6 Manure management

Manure management includes several continuous steps in order to return organic material and plant nutrients to the field; feed management, collection, transport, storage, handling, treatment, disposal and utilization (Alberta, 2005).

***<u>Manure as a fertilizer</u>***

Manure is the generic term for dung, urine, water and bedding material, such as straw, in various proportions. It is divided into urine, slurry, semi-liquid manure, solid manure and deep litter bedding depending on the dry matter content, consistency and origin. Slurry and urine may be pumped, as opposed to the other categories (SJV, 2009b). The manure on many cattle farms in Russia can be classified as semi-liquid; nearly without washing waters and usually mixed with peat, straw or sawdust (HELCOM, 2010). The pig manure is mostly liquid (Venglovsky & Greserova, 2002). The main part of the stable manure in Sweden is liquid and the solid part is decreasing (Rodhe, 2006).

Manure contains nitrogen, phosphorus, potassium, micronutrients and organic matter (SJV, 2009b). The nitrogen in manure occurs as ammonia and organic nitrogen. Ammonia is available for instant plant uptake. Organic nitrogen on the other hand, has more of a long-term effect and has to mineralize before it is plant available (Malgeryd et al, 2002).

By adding organic fertilizers to the soil, the nutrient availability is affected through immobilization and mineralization both in short and long term. The short term effect might vary depending on the composition of the substrate, where the carbon content and quality largely affects if there will be a net mineralization or immobilization of other nutrients, especially nitrogen. Substrates with high content of carbon such as peat or straw initially lower the soil content of plant available nitrogen because of immobilization, while those with high N content in relation to C will result in an immediate increased mineralization. In the long run, on the other hand, the build-up of soil organic matter will always increase the fertility and mineralization potential of the soil. Higher yields when using organic fertilizers can be explained not only by increased nutrient availability but also by a better soil structure which is due to the higher content of soil organic matter (Kätterer et al, 2011). Soil fertility is crucial for obtaining high yields, and high yields also provide means for maintained or increased soil fertility. Management practices that increases soil organic matter content is worthwhile in the long run (Kätterer et al, 2012). Even a slight increase in soil organic matter can reduce the risk of soil compaction from heavy machinery (Soane, 1990). Soils with higher infiltration rate, higher levels of organic matter and good soil structure are usually more resistant to water erosion than others (Wall et al, 1987).

After the financial crisis in 2008 in Russia farms and cooperatives had a harder time paying for chemical fertilizers and hence the demand for organic manure increased, especially from those situated close to animal farms and where the manure is supplied free-of-charge. But the regional excess of manure in Leningrad region is approximately 70% or higher (NEFCO, 2011).

Swedish farmers buy nutrients in mineral fertilizers and nutrients in feed for approximately 3 billion Swedish kronor each year. Looking at it that way manure from animals has thus an economic value, which makes it a resource worth using (Greppa Näringen, 2012b).

***Nutrient content in livestock manure***

The amount of nutrients in the manure depends on type of animal, feeding, animal housing, manure management system, amount and type of bedding material, water and other additives. It also depends on manure treatment, such as digestion or composting (SJV, 2009b). As the nutrient content may vary considerably depending on these factors, it is important to analyze the manure in order to evaluate the fertilizer value, especially for liquid manure which has high nitrogen content. By doing this, the risk of applying too much or not enough nutrients is decreased. Table 1 shows standard values of nutrient content in different kinds of livestock manure, though these values are fairly uncertain (Greppa Näringen, 2011c).

The advisory computer program STANK in MIND can be used for calculations of manure nutrient value. It considers the economic benefits of nutrient value prior to application, long term effect of nitrogen and increase in soil fertility, and the costs of transportation and application. Soil type, spreading technique, spreading date and volume of manure to be spread are also considered since they affect soil compaction and effect of applied nutrients, and hence the value of the manure (Greppa Näringen, 2011d).

*Table 1 Nutrient content in different types of manure, kg/ton manure (Greppa Näringen, 2011c)*

| Type of manure | N | $NH_4$ | P | K | S |
|---|---|---|---|---|---|
| Cattle, deep litter bedding | 5,5 | 0,6 | 1,5 | 10 | 0,9 |
| Cattle, solid manure | 5 | 1,3 | 1,3 | 4 | 0,8 |
| Cattle, liquid manure (10% dry matter) | 4,4 | 2,6 | 0,7 | 4 | 0,6 |
| Cattle, urine | 3 | 2,7 | 0,1 | 5,5 | |
| Pigs, deep litter bedding | 5 | 0,5 | 2,5 | 4,5 | 1,1 |
| Pigs, solid manure | 6 | 1,5 | 3,5 | 2,5 | 1,4 |
| Pigs, liquid manure (6% dry matter) | 3,5 | 2,5 | 1 | 1,6 | 0,6 |
| Pigs, urine | 1,5 | 1,4 | 0,2 | 1,2 | |
| Broiler chicken, deep litter manure | 30 | 6 | 7 | 15 | |
| Egg-laying hens, semi-liquid manure | 12 | 7,2 | 4,5 | 5 | |
| Egg-laying hens, liquid manure | 5 | 3,8 | 1,7 | 1,8 | |
| Sheep, deep litter manure | 10 | 1 | 2 | 20 | |
| Horses, solid manure | 5 | 0,5 | 1,5 | 10 | |

***Nutrient management plans***

Plant nutrient management plans reveal surplus and deficits of nutrients on farm or field level, hence being an important tool for the farmer in planning and decision-making. Deficits can be detected even before the crop shows any deficit symptoms, which gives the opportunity to take measures before it is too late (Malgeryd et al, 2002). On a farm level the flow to the farm constitutes of mineral fertilizers, animal feed, seeds, nitrogen deposition and nitrogen fixation. Sold products are the output from the farm, see figure 6 (Greppa Näringen, 2011b).

Even though the nutrient balance not necessarily equals the environmental impact of the farm, it makes it possible in a long term view to see the effects of environmental measures as a trend of higher nutrient use efficiency (Greppa, 2011b).

Within the Focus on Nutrients-program in Sweden, the dataprogramme STANK in MIND is used for calculations of nutrient balances. It can be used for livestock farms as well as for farms solely with crop production. The program can also be used for calculations of storage capacity needs and required spreading area, economical comparison of different machinery for manure management and calculations of energy balances (SJV, 2011d).

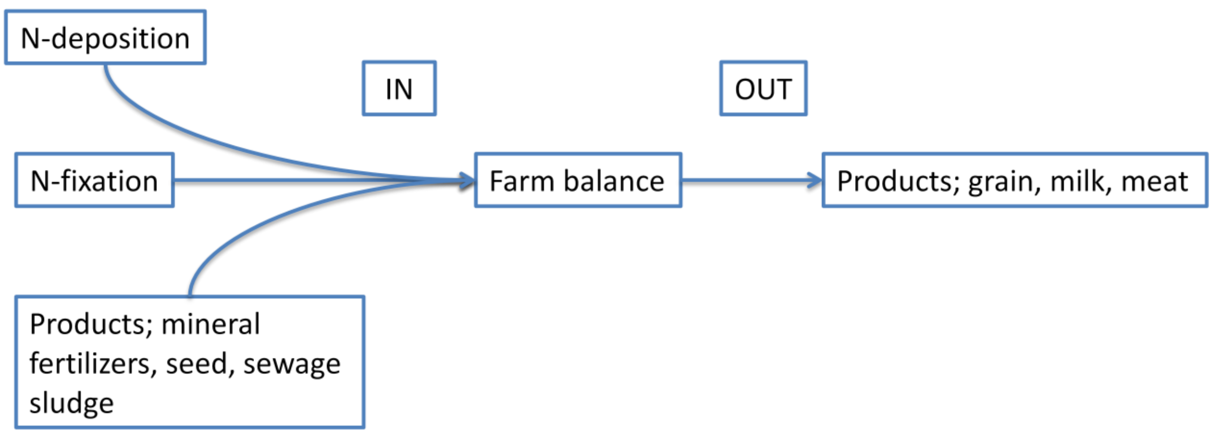


*Fig. 6 Overview of nutrient management plan on farm level (recreated from Greppa Näringen, 2011b)*

***Storage***

The storage facilities largely influence the risk of plant nutrient losses to the soil and through ammonia volatilization. A higher storage capacity gives greater flexibility when it comes to timing of spreading (SJV, 2011c). This means that the application to the field can be avoided during inappropriate times, hence utilizing the nitrogen better and avoiding soil compaction (Malgeryd et al, 2002). The amount of livestock manure produced in a year is dependent on several factors; productivity level, amount of bedding material, yearly precipitation if the storage is uncovered, waste and rinse water (Steineck et al, 2000).

There is no required storage capacity for manure in Russia (Skorupski, 2007) but in Leningrad region it is though recommended to have eight months storage for cattle that are kept on pasture during summer, and twelve months if they are kept indoor all year round (Semenov et al, 2006). However, the storage system in Russia is out-dated and works unsatisfactory due to constant overloading (Kalyuzhnyi et al, 2003).The common practice is to store solid manure in the fields (HELCOM, 2010). In the nitrate vulnerable zones in Sweden, the minimum storage capacity for cattle is eight months and for pigs ten. Outside of these zones the minimum capacity is six and ten months respectively (Sveriges Riksdag, 2012b).

***Preventing ammonia emissions***

There are several methods of preventing ammonia emissions from storage facilities. One way is to change from a system that generates solid manure to a system that gives liquid manure. The ammonia emissions can be decreased since liquid manure is stored under anaerobic conditions. If the bedding material in a deep litter bedding system is straw, it can be mixed with peat in order to bind ammonia and ammonia nitrogen (HS, 2005).

By having an efficient cover over slurries and urine storages and by filling new material from beneath, the ammonia emissions can be decreased by 50-95%. In cattle slurry the natural floating crust that occurs may alone prevent 65% of the ammonia losses, whereas in manure from other animals the formation of a natural crust is poorer. The formation of crust can be supported by adding peat, solid manure, straw, vegetable oil or bark, but this type of additives might need maintenance during the storage period. It is important that the floating crust regenerates fast after filling, if this is done from above (HS, 2005).

Slurry tanks should be protected from wind and air flow in order to reduce ammonia losses. If this cannot be done by a floating crust it is possible to equip the tank with either a solid roof or with a floating plastic cover. In order to be efficient, the roof needs to be fitted tight to the tank (Steineck et al, 2000).

In the central and southern parts of Sweden the slurry storages must be covered with a floating crust or by some kind of roof that prevents ammonia emissions efficiently (SJV, 2011c).

***Preventing nitrate and phosphorus leaching during storage***

There are several solutions to prevent nitrate leaching; most importantly the storage tanks and stacking slabs should be sealed to avoid leaching, run-off and seepage. Stacking slabs can either drain seepage for collection in a separate urine tank, or it can slope slightly towards a supporting wall and hence keep liquids and rain water to accelerate the composting process in dry manure types (HS, 2005).

In Leningrad region only a small amount of the nutrients from manure is recycled to the fields, the rest is accumulated in disposal sites close to the farms. This practice leaves room for improvements in order to reduce nutrient loading to the Baltic Sea (NEFCO, 2011). On poultry farms the common practice for manure management is to dispose the manure in heaps in lagoons, fields or landfills. The fields on the farm are usually not enough to utilize the manure reasonably in the fodder production. Co-operation with other farms is hard or impossible due to long distances (HELCOM, 2010).

***Manure treatment***

Manure can be treated by different techniques such as composting, anaerobic digestion, separation or additives, before spreading. The reasons might be to obtain a more liquid manure, better transport economy if the manure contains less water, less odor problems when spreading, higher amount of plant available nutrients or to decrease the risk of spreading pathogens (Bergström Nilsson, 2009).

***Composting***

There are several advantages of composting solid manure; reduced mass and volume, pathogens and weed seeds are destroyed, odor is reduced and it is a good soil conditioner from which the nutrients are released slowly and steadily when applied in field. The disadvantages include loss of ammonia, time and labor, cost of equipment and land required for composting (Steineck et al, 2000b).

The composting process consists of two phases; the active stage and the curing stage. In the active stage microorganisms degrade the organic matter using oxygen. They produce heat, water vapor, $CO_2$, $NO_x$ and other gases. To ensure that the process is entirely completed it is important with turning, keeping the right moisture content (50-60%) and aeration. In the curing stage microbial activity decreases since the organic material is decomposed and the temperature decreases to that of the surrounding air. The active stage is approximately 21-40 days and the curing stage about 30 days (Alberta, 2005).

According to Kirchmann and Lundvall (1998) the loss of ammonia during composting can be significant depending on type of manure. The emissions from poultry manure can be 76% and from pig manure 23%, whereas from cattle manure below 1%. Kirchmann and Lundvall consider composting of manure appropriate only if the purpose is hygienization.

When selecting site for composting enough distance to floodways, springs and wells is important, in order to minimize the risk of contamination. The soil on the location should be compacted or have an impervious surface to reduce the risk of nutrient leakage. Surface runoff should also be kept away from the composting site (Alberta, 2005).

Composting is already common practice in the parts of Russia neighboring the Baltic Sea, but is usually not optimized as it occurs spontaneously in manure heaps if the access to air is sufficient (HELCOM, 2010).

***Separation***

Liquid manure can be separated into solid and liquid fraction with the use of different techniques; mechanical, chemical or vacuum evaporation. The phosphorus is mainly concentrated to the solid fraction, whereas nitrogen and potassium mostly accumulates in the liquid fraction.

When applied in field the liquid fraction will penetrate the soil faster than slurry and hence lower the odor and the risk of ammonia emissions. Using the separated solid fraction for anaerobic digestion will generate a higher amount of biogas than ordinary slurry would give, since it contains less excess water. Because of the lower water content the transportation costs for the solid fraction decrease, making it possible to spread further away or to sell (HS, 2006).

There are two different mechanical techniques; dewatering screw press and decanter centrifuge. The construction of the first is simple; it mechanically presses the liquid out of the solid fraction. The screw press is relatively cheap, but not very effective. In the decanter centrifuge the manure is separated by centrifugal force in a high-speed rotating barrel. The separation of P to the solid fraction is efficient and the capacity of the machine is high, but it is quite expensive (HS, 2006).

The chemical technique is efficient, with a high proportion of P in the solid fraction. A chemical substance, often containing iron, is mixed into the slurry in order to precipitate the phosphorus. The more of the chemical used, the more P goes to the solid fraction. Then a polymer is added to the manure, which makes the tiniest particles of the manure glue together. Finally, the liquid fraction is separated through filtration and by the use of a screw press. The machine is easy to handle, but is quite expensive (HS, 2006).

During evaporation, water is boiled from manure or biogas digestate. The first step is to dewater the manure with a decanter centrifuge to separate the liquid and solid fractions. Sulphuric acid is added to the liquid fraction to lower pH and hence hinder ammonia from emitting. The evaporation process gives two end products; condensed pure water and concentrated liquid fertilizer rich in nitrogen (Norin, 2008). This process is consuming lots of energy, but vacuum can be used to lower the boiling point temperature and hence reduce the energy demand. The separation is very efficient, but also very expensive. Possibly, the technique can be cost-efficient if placed next to a biogas plant using the waste heat from the anaerobic digestion (HS, 2006).

In Denmark different separation techniques are currently being established. In Sweden the development has not come so far, but it could be interesting especially for pig farms with the fields for crop cultivation remotely situated (Bergström Nilsson, 2010). The large pig breeding complexes in Russia often produce manure wastewater with only 2-2,5% solid materials, due to cleaning by flushing. The use of separation techniques could be a solution for such diluted manure (Kalyuzhnyi et al, 2003).

***Acidification of slurry***

By lowering the manure pH it is possible to save nitrogen through decreased ammonia emissions. The acidifying additive can be lactic acid, phosphoric acid or, as is used in Denmark, sulfuric acid (Rodhe et al, 2012). In Denmark, two diffent techniques are used for acidification of slurry; directly in the stable or during spreading. Another, newly developed technique acidifyes the slurry while in the lagoon, one day before spreading. The aim is to lower pH to 5,5 - 6,0 which displaces the ammonium – ammonia equilibrium to the left, hence reducing ammonia emissions. The nitrogen fertilizer value increases (Foged, 2010) and the sulphur contribute to the fertilizing effect. 2-3 liters of sulphuric acid is added per ton slurry (Greppa Näringen, 2011e). Acidification of the manure can increase the nitrogen effect in field.

***Anaerobic digestion***

During anaerobic digestion, naturally occurring micro-organisms digest organic matter such as slurry, manure or plant residues under anoxic conditions which results in formation of biogas. The biogas produced in sealed tanks consists of about 60% methane that can be combusted to provide heat or electricity or that can be upgraded to pure methane to be injected into gas grids or to be used as road fuel. The remaining digestate, which consists of indigestible material and micro-organisms, can be used as fertilizer (Biogas Info, 2012). The nutrient content of the digestate is about the same as for the inserted manure. Though, a larger share of the total N-amount occurs as ammonia which makes the fertilizer more readily accessible for plant uptake (Rodhe et al, 2012). The properties of the digestate resemble pig slurry and it can be applied to the field in the same way. The dry matter content is though a bit lower and it is important to stir the digestate in the storage container and in the application tank in order to prevent sedimentation which otherwise would leave the organically bound nutrients, such as phosphorus (Baky et al, 2006). The pH of the digestate is slightly higher than in raw, non-digested manure. This leads to higher risk of ammonia emissions (Frandsen et al, 2011).

Some substances may have an inhibitory effect on the biogas production. It can be any typically used substrate added in a too high concentration; the optimal ratio between carbon and nitrogen is 10-30:1. Other substances such as antibiotics, herbicides, disinfectant agents and heavy metals can disturb the process even when added in small concentrations (Ek, 2007).

There is no market for upgraded biogas in Russia, which might be due to the production of natural gas. For the time being there are no subsidies or grants for building of biogas plants or for production of renewable electricity. In addition to this, the process of receiving permits for biogas plants suffers from bureaucracy (Foged & Mortensen, 2011).

Financed by the Rural Development Program (SJV, 2010) the current investment grant for building of biogas plants in Sweden is 30% of the total cost. In the northern parts of the country it is 50%. Despite this, Foged & Mortensen (2011) consider the public economic support schemes for investments in agro-environmental techniques too low and that the process of receiving permits to some extent suffers from bureaucracy.

***Drying, combustion and thermal gasification***

After separation of the liquid fraction from the manure, drying and pelletizing of the fiber fraction is possible and the technique is in practice in for example Spain. It is not a stand-alone technology, but rather part of a complex manure treatment plant. Because of its complexity and the heavy investment it is not an alternative for farm-based manure treatment. The fiber fraction can be also be combusted or thermally gasified, possibly after the process of drying and pelletizing. The remaining product is charcoal or ash, which can be used as fertilizers. The economic performance for general use of these techniques has not yet been proven (Foged, 2010).

***Field application***

The last step when handling manure is the field application. Through the choice of technique, dosage and timing the crop demand for nutrients shall be met to a reasonable cost at the same time as the negative impact on the environment is minimized (Malgeryd, 2003). The economic return from manure is affected by income and expenditure. Factors contributing to income are nutrient value the year of spreading, later effects of nitrogen and increased soil fertility. Expenditure is costs for transportation, cost of spreading and soil compaction and damage by heavy machines (Greppa Näringen, 2004).

***Manure application rates***

The harvested yield determines the amount of nutrients withdrawn from the field; a higher average yield demands higher access to plant nutrients than a lower yield (SJV, 2011e). One of the most important factors for low nutrient leaching losses is to adjust the amount of fertilizer to the crop demand. On a farm with animal production, the fertilizer management plan should be based on the nutrient content in the manure, the crop demand and the soil nitrogen delivery capacity. The remaining demand can be covered by mineral fertilizers. In general recommended rates for manure applications are 20-30 tonnes/ha (Malgeryd et al., 2002). The fertilizing effect of manure is dependent on the amount of $NH_4$ and the mineralization of nitrogen, but also on the N-emissions (Greppa Näringen, 2011d). Table 2 shows the nutrient content in different crops given a certain yield.

*Table 2 Approximated content of nitrogen, phosphorus and potassium in a selection of crops (SJV, 2011e)*

| | | Nutrient content(kg/ha) | | |
|---|---|---|---|---|
| Crop | Yield(ton/ha) | N | P | K |
| Fodder wheat, kernel, 11% protein | 6 | 100 | 19 | 26 |
| Bread wheat, kernel, 12% protein | 6 | 110 | 19 | 26 |
| Barley, kernel | 5 | 80 | 17 | 22 |
| Straw from cereals | 4 | 30 | 4 | 40 |
| Oilseed crops | 2,5 | 90 | 15 | 20 |
| Peas | 3,5 | 120 | 13 | 35 |
| Potato, tubers | 30 | 105 | 15 | 150 |
| Ley, 25% clover | 6 (dry matter) | 140 | 14 | 150 |
| Sugar beets, beets | 45 | 90 | 18 | 90 |
| Sugar beets, tops | 30 | 100 | 15 | 150 |

Swedish animal farms that produce their own fodder and manure are recycling most of the nitrogen, phosphorus and potassium within the farm. Pig manure has a composition of nutrients well suited for cereals, whereas cattle manure contains higher amounts of potassium which suits the ley demand (Malgeryd et al., 2002).

If the risk of leaching losses or surface run-off and erosion is significant, the amounts of applied manure should be restricted, e.g. during wet periods with low plant nutrient uptake. Long-term high supply of phosphorus, which increases the phosphorus saturation of the soil, should be avoided according to Swedish recommendations in order to limit leaching (SJV, 2011e). By applying slurry in the spring instead of in the autumn, both phosphorus and nitrogen losses can be decreased (Naturvårdsverket, 2003).

The most common manure management practice in Russia is to spread it on fields as fertilizer, if not disposed. The Swedish norm of 22 kg P/ha /year has no Russian equivalent. The maximum allowed amount of manure is equal to 200kg N/ha/year (Skorupski, 2007). In Sweden, according to the Nitrate Directive the maximum allowed amount is 170 kg N/ha (European Commission, 2012c). By the implementation and mandatory use of official P fertilizer norms the risk of overdosing livestock manure is decreased compared to when limited only by N fertilization norms (Foged & Mortensen, 2011).

Currently less than one third of the feed needed in Leningrad region is produced within the region. The import of feed thus results in substantial nutrient surplus (NEFCO, 2011). The typical application rate of manure in Russia is 20-30 tonnes/ha (Venglovsky & Greserova, 2002). The fields to be fertilized are often remote from the farms and the amount of produced manure far exceeds the needs of the available arable land (HELCOM, 2012c).

***The impact of timing***

A potential problem when spreading manure is that the mineralization and release of organic nitrogen not always corresponds to the most intensive crop growth (Ekbladh, 1999).

Precipitation surplus, type of soil, geographic location and presence of winter crops are factors that influence the nitrogen use efficiency of autumn-spread manure. Slurry and urine have the highest nitrogen use efficiency when spread during spring or when spread in growing crops. Solid manure with low content of ammonia nitrogen has as good effect when spread during spring as autumn (SJV, 2011e).

When manure is spread during dry and windy conditions the ammonia losses may be significant, as when spread on frozen soil (SJV, 2011e). By choosing to apply the manure during the coolest time of the day or prior to rainfall, the ammonia emissions may be reduced. The farmer's flexibility decides whether this knowledge can be used in practice. Factors that influence the flexibility include total amount of manure to be applied and the length of the period available for application. This period might be determined by legislation, but also by soil conditions (Sommer & Hutchings, 2001).With a well functioning drainage system soil compaction and damage by heavy machines will decrease and it will be possible to operate the fields earlier in the spring and sooner after rainfall (Kvarnemo, 1983).

In Russia as well as in Sweden it is not allowed to spread manure on flooded, frozen or snow covered ground, but in Russia there are no regulations restricting spreading of manure during winter time (Skorupski, 2007). As frozen soil can carry heavy machinery, manure on many cattle farms in Russia is also spread during winters, despite the legislation. Further, the capacity of both storage and machinery is usually too low and the fields too distant for responsible spreading during spring and summer (HELCOM, 2010). Most of the drainage system in Leningrad region was constructed in the 70's and 80's and about half of the arable land area is currently drained (Foged and Mortensen, 2011).

***Different techniques for spreading of manure***

<u>Slurry transportation</u>

The most commonly used equipment for transport of slurry is spreading tankers (Steineck et al, 2000a), which unload the manure either by vacuum or by varying types of pumps. Other means of transportation from lagoon to field include umbilical hose and irrigator. With the umbilical hose the manure is fed through a drag hose to a tractor or other machine with a distribution system. The positive aspect of this system is less damage and soil compaction by heavy machines in field, but crops might be damaged by the dragged hose. The hose might also wear out, especially on rough or flinty ground. If the manure is to be spread by irrigator the dry matter content has to be below 3%, which means that separation is required (Chambers et al, 2001). Biogas residues can also be transported with this system (Norin, 2008).

<u>Slurry distribution</u>

Broadcast spreaders usually force the slurry under pressure through a nozzle and onto a splash plate, which is often inclined in order to increase sideways spray. The main benefits of broadcast spreading is the uncomplicated technique and low cost. But the contact surface between manure and air is large which favors ammonia emissions as well as odor and the technique is not suitable for spreading of slurry in leys since the crop might be vastly contaminated (Steineck et al., 2000a). Incorporation of the manure into the soil, directly or soon after application, has proven to be the best way of reducing ammonia losses. Compared to broadcast spreading the ammonia emissions can be reduced by 90% (Malgeryd et al., 2002).

Band spreaders have a number of hoses hanging close to the ground from a boom, distributing slurry in strips from a single central pipe. This technique has several benefits compared to the broadcast spreader; lower ammonia emissions, less sensitive to wind, fixed spreading width and better for spreading in growing crops (Steineck et al, 2000a). A disadvantage is that the uniformity across the spreading width might be poor since the system relies on the pressure in each hose outlet. This problem can be overcome by using a more advanced system with a rotary distributor that proportions the slurry evenly to each outlet. The maximum dry matter content is 6% which might demand separation (Chambers et al, 2001).

The trailing shoe spreader is a variant of the band spreader, with a shoe added to each hose which allows for the slurry to be placed below the crop canopy. If the soil is bare and loose the shoes might be able to incorporate the slurry into the surface (Steineck et al, 2000a). As with the band spreader the dry matter content should not exceed 6%. The equipment is though a bit more expensive than the band spreader (Chambers et al, 2001).

With an injector the slurry is injected into the soil surface. The injection can be either shallow, approximately up to 50mm deep, placing slurry in shallow open slots; or deep, about 150mm deep. Compared to other techniques the ammonia emissions are considerably lower. Odor also decreases and it is not at all sensitive to the wind. But, especially for the deep injection, the tractive force demand is high (Steineck et al, 2000a) and the cost for the equipment is relatively high (Chambers et al, 2001). According to Velthof and Mosquera (2011) the problem with spores if spread on grassland will also decrease since the grass avoids contact with the manure. But on the other hand, when the slurry is injected into the soil the emissions of nitrous oxide is increased. A reason for this is simply that a higher amount of nitrogen that is applied to the soil can be lost as nitrous oxide when less is lost through ammonia emissions (Velthof & Mosquera, 2011). As Hoffman (2012) points out, some practical aspects have to be taken into consideration when deciding what technique to use. Stony soils for example are not suitable for injection and the damages done to the crop could be considerable if all slurry applications during the season were done by injection. The common Swedish practice to surface-apply the slurry is justified since it may be more applicable under varying circumstances.

With modern technique for spreading slurry the precision can be almost as high as when mineral fertilizers are applied. Today several manure spreaders on the market can be equipped with automatic control engineering which allows for controlled dosage (Malgeryd, 2003).

The most common technique for spreading of liquid manure in Russia is surface application with splash plate equipment. Low emission spreading techniques is predominant only in countries that demand it by legislation, such as Denmark, Netherlands and southern Sweden (Venglovsky & Greserova, 2002). According to Swedish law manure and other organic fertilizers have to be incorporated into the soil within 12 hours; and within 4 hours in the nitrate vulnerable zones (Greppa Näringen, 2011g).

Solid manure spreading

Broadcast spreading is still the only available way to spread solid and semi-solid manure. Regardless of equipment utilized the manure is more or less thrown in clods and the discharge rate is varying considerably over the field due to turning and changes in speed (Steineck et al, 2000a). The machinery is heavy, which might cause soil compaction during unfavorable conditions (Chambers et al, 2001). When spreading solid and semi-liquid manures the only measure to reduce ammonia emissions is to incorporate the manure into the soil after application. This can be done with a plough, harrow or other tillage equipment (Malgeryd et al., 2002).

The rear discharge spreader is the traditional spreader for solid manure. It is a trailer body with a moving floor or other mechanism that moves the manure to the rear to the beaters that shred and distribute the manure (Steineck et al, 2000a).

The equipment for spreading solid and semi-liquid manure is less developed than for spreading slurry, which means that the right dosage and even distribution will be harder to achieve (Malgeryd, 2003).

***Bio-security issues***

Manure might contain contagious disease agents, some of which can be transmitted from animals to humans, for example *Salmonella*, *Campylobacter*, *Cryptosporidium* and VTEC/EHEC (Tattari et al, 2012). When a livestock population is infected, large quantities of contaminated manure are produced and sometimes spread in the field. For some diseases, such as VTEC in cattle herds, the manure can be spread in the fields as long as it is incorporated into the soil, preferably by ploughing. But this is not always possible, especially not in cattle production where the share of grassland usually is large (SVA, 2009).

Many micro-organisms can survive a long time in soil and water and hence risk spreading. Non-disinfected manure has showed to be a major reason for pathogen presence in livestock populations. To avoid this, the manure can be hygienically treated before spreading. The most common practices of hygienizing manure are storage, composting, anaerobic digestion or chemical disinfection. In situations of disease outbreak the manure is usually treated with lime for rapid, but temporary increase of pH, to about 12. The pathogens die off, but the handling is complicated since the working environment is hazardous and the incorporation of lime difficult. This kind of treatment also lowers the nitrogen content of the manure, which decreases its agronomic value (Ottoson et al, 2006). Another way to hygienize the manure is to add ammonia or urea. The cost for the ammonia is also partly covered by the increased fertilizer value since the nitrogen content increases (SVA, 2009).

The risk of pathogens spreading to the environment is related to poor animal health, high animal density, poor storage and risk of erosion and run-off. Areas with high animal density and high risk of surface run-off and erosion might be at risk for bio-security issues as well as nutrient leaching (Tattari et al, 2012). The major part of liquid manure in Russia is spread on grassland and a minor part to arable crops (Venglovsky & Greserova, 2002). The Russian agro-environmental legislation has a clear focus on health-related standards and sanitary issues rather than prevention of nutrient leaching (HELCOM, 2010).

## 4.2 Travel reports

This chapter is arranged according to the hypotheses and includes comments from Russian farmers and municipality employees as well as my own impressions.

**Environmental debate in society**

Farmer: Even though it has become increasingly popular with ecologically clean products among the wellsituated in St. Petersburg and Moscow, the trend has not reached the ordinary consumer, who is only looking at the price when choosing products. There is a certification system for food stuffs produced without chemicals or mineral fertilizers, but people in general do not find it trustworthy.

**Instruments for environmental measures**

Agronomist: There is legislation prohibiting inadequate manure management, but it is not obeyed. It is easier and more profitable to pay the fees for violating the law than to do the necessary investments. Even though the fees are said to be raised, they are still low and hence affordable. It is common practice to dump the manure in the forest instead of spreading it on the fields.

**Manure as a nutrient resource – knowledge & attitudes**

Farmer: The nutrients will leach from my manure storage since I have no walls on the stacking slab. I'm aware of the risk of leaching but I have no financial means to invest in manure storage since my business is basicly going breakeven. I will spread the manure on the fields as soon as the soil freezes. The drainage is so bad that the only possibility to spread manure is to do so when the frost carries the weight of the tractor and spreader. It is just too bad that the crops cannot benefit from the manure since the nutrients leach.

Agronomist: Farmers' unions exist but their influence on governing administration is close to zero. There are no extension services except from the advice given by dealers trying to sell their own products.

The overall impression from both the study visit in Sweden and the visit to Kaliningrad is that the farmers and the institute officials have a great knowledge about nutrient leaching and ammonia emissions, and insight into techniques preventing this from happening. But they all consider it a big problem to find competent people to work on a practical level within the agricultural sector. The wages are low and so is the status of agricultural work.

**Manure treatment**

Agronomist*:* Do not even talk about biogas – it's cosmos for us. It is very hard for agricultural businesses to receive loans on favourable terms. If the business cannot fulfill a wide range of conditions, such as high wages, the interest rate will be from 16 to 20%. To take a big and long-term loan with such an interest rate is impossible. It is hard to sell produced biogas or electricity to the regional pipeline system or grid. The few biogas plants that exist are state owned or owned by someone close to the power. Electricity is quite expensive in Russia, but the gas is still rather cheap.

Farmer*:* I'm wondering whether you have found out a way yet to make mineral fertilizers out of manure?

The farmers have no financial means whatsoever to invest in biogas equipment. They wish for a way to compress or concentrate the manure in order to make it more cost-efficient to transport and easier to spread.

**Manure spreading**

Institute official: Actually, there is usually enough area for spreading the produced manure on the farm's fields. The problem is rather that the fields are remote or that the farmers do not have access to adequate technique for storage and spreading.

Farmer: For every head I add to my heard, I receive a production support from the State.

Agronomist: The majority of the fields in Kaliningrad oblast are currently under fallow since it is not profitable to put them into production.

Farmer: The drainage system was built during the Soviet era and now needs to be either rinsed and repaired or completely rebuilt. The ditches are to be rinsed within a regional program but it takes time to cover the whole oblast. I rinsed the ditches surrounding my fields myself, but since my neighbour could not afford to, the fields closest to him have now been flooded for several months.

Most of the respondents lift field remoteness from the farm as a problem for spreading the manure. The autumn has been rainy in Kaliningrad and many fields have small lakes of standing water that the drainage system cannot empty. In some fields the maize is still not harvested in November, but the deep tracks from machines reveal that someone has tried to but given up.

## 4.3 Interview results

This chapter is based on the interviews with Swedish agricultural consultants.

**Environmental debate in society**

Nilsson: It is hard for the farmers to be pointed out in the environmental debate, especially in the climate discussion. There are high demands on farmers considering environmental measures and animal welfare; in the grocery store the consumers chose to buy cheap imported meat produced under worse conditions than in Sweden. People find the world safe and do not consider the fact that the degree of self-sufficiency is only about 50% in Sweden. It is troublesome to promote Swedish products.

Lindell: Farmers find it tiresome to be seen as environmental criminals rather than producers of food.

**Instruments for environmental measures**

Svensson: Some farmers have only the regulations before their eyes and they do not understand its environmental benefits. The support schemes are very important for the implementation of environmental measures.

Lindell: The legislation is one of several incentives for good manure management practices.

**Manure as a nutrient resource – knowledge & attitudes**

Lindell: Manure is considered both a soil fertility resource and a burden to get rid of, depending on the animal density in the area. It is a question of economy to save as much nitrogen as possible in order to reduce the need for mineral fertilizers.

Nilsson: The attitude to manure has clearly changed for the farmers that have been part of the Focus on Nutrients program. The share of farmers that considered timing for manure spreading was initially 20-30%. After a few extension sessions within Focus on Nutrients the number was 70-80%. The foremost reason for adopting an improved manure management is to save money through better N and P efficiency. To some extent soil compaction influence the timing for spreading.

Svensson: Organic farmers are dependent on manure and other organic fertilizers and if they do not have enough animals they have to buy manure. Saving money is the main motive for good manure management. The interest for manure usually increases when the farmers learn about its economic value.

**Manure treatment**

Svensson: A way of concentrating the manure in order to avoid transporting water would save fuel, decrease soil compaction and save time. At the same time it would be easier to apply the right amount of nutrients to the crop.

Lindell: On animal producing farms, especially on those with pigs, the interest for separation of manure is big. But it is considered hard to achieve high efficiency on small-scale, farm-based biogas plants. It might be an option for the producers with many animals. The Swedish farmers are interested in how to manage the manure more efficiently and turn their eyes to Denmark where acidification of manure has become increasingly popular in order to save nitrogen from ammonia emissions.

Nilsson: The interest for manure treatment is quite low in Sweden as it usually is hard to achieve profitability. Biogas is much discussed, but comparably few farm-based biogas plants are built since the energy price is low. The higher nutrient availability does not pay off with the nitrogen prices of today. Acidification has not had a break-through in Sweden, but is rather popular in Denmark as it suits their manure handling systems with storage beneath the stables. Again, there is an interest but the profitability is low.

**Manure spreading**

Lindell: In areas where the animal production is concentrated it might be hard to find enough fields for spreading of the manure. Since it is difficult to transport manure for longer distances, the manure is hence concentrated to these areas. The spreading is not always optimal, but due to limited storage capacity the farmers have to empty the slabs and lagoons whenever it is allowed.

Svensson: Farmers quite often find it time-consuming to spread manure. If the autumn is rainy the risk of soil compaction is considerable. In general large farms find it worse to spread manure than farms with shorter distances to the fields. Some farmers complain about the change in legislation that manure no longer can be spread on frozen soil, which used to be a way of reducing soil compaction.

## 5. Discussion

In this chapter the questions posed in the objectives and hypotheses are discussed based on facts collected in literature review, travel reports and interviews.

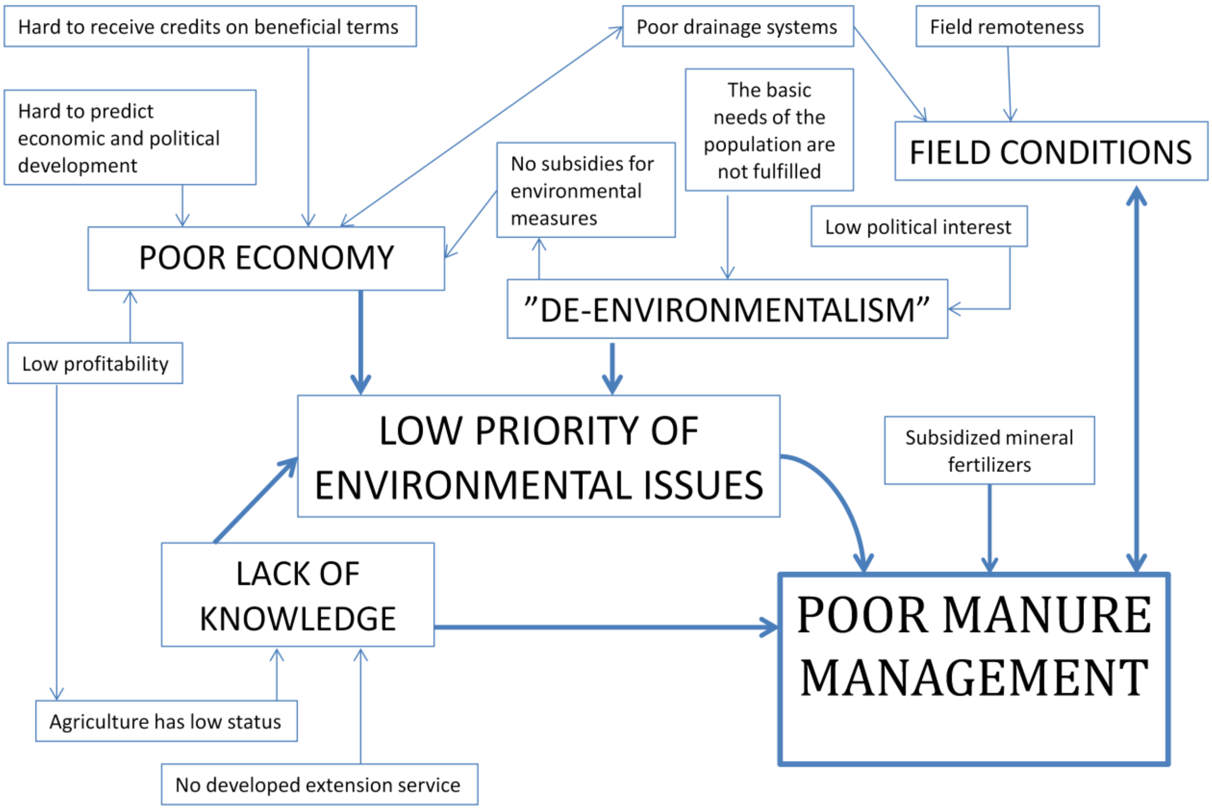


*Fig. 7 Reasons for poor manure management in Russia*

There are several interacting reasons for poor manure management in Russia, see fig. 7. The poor economy is due to difficulties to predict the economic and political development, but also low profitability and problems of receiving credits on benefical terms. The low profitability gives agriculture a low status, which together with poorly developed extension service make the agricultural sector suffer from lack of knowledge. “De-environmentalism” originates from the living standards of the population as well as the power structure; a reason for the fact that no subsidies are given for environmental measures. The field conditions are bad, partly due to neglected drainage systems, partly due to field remoteness hindering manure spreading. These reasons, combined with the subsidized mineral fertilizers, contribute to the poor manure management in Russia.

**Environmental debate in society**

*The environmental movement has, for many years, been weaker in Russia than in Sweden, where the farmers are more influenced by the public debate on environmental issues.*

The environmental debate in Russia mainly focuses on safety connected to nuclear activity and oil transports; barely at all on nutrient leaching. "De-environmentalism" is an attitude among politicians as well as the public, which means that economic interests always trump environmental concern. I find the first hypothesis to be true; the time for widespread environmental concern has not yet come for Russia.

In Sweden, environmental issues are given more space in the media and public debate than the food production and degree of self-sufficiency, which can be a reason why farmers may feel that they are seen as environmental criminals rather than producers of food. This is a dull attitude to agriculture. Russia, on the other hand, faces quite the opposite situation with de-environmentalism and focus on production growth. This is not a very sustainable approach to farming or even to food-security.

The last century of Russian history differs quite a lot from the Swedish when it comes to political stability and revolutionary transformations. The Russians have experienced a huge shift as the planned economy was turned into market economy through shock therapy. Even though the country is regaining political stability, the confidence in the legal system is low, as is the general security in society. The Swedish prosperity has enabled protection of the environment. Russia on the other hand has not fulfilled its basic needs of security and the mean wage has not yet reached the level when the public get engaged in environmental protection. Given the historical and present perspectives, Russia is understandably well behind Sweden when it comes to environmental awareness and protection. This is made worse by the de-environmentalism that permeats power-structure as well as the wider society.

Probably a lot of environmental issues in Russia could be solved by introducing agro-environmental policies with subsidary schemes, analogue to that of the European Union. Sweden would not have come as far in its environmental work if it was not for state intervention in terms of legal, economic and informative instruments. It has been made clear though, that the persons in power in Russia have no interest in this and the question is wheater it would gain public acceptance before the living standards have increased for a broader middle class.

Due to several aforementioned reasons the care for common resources is low in Russia compared to Sweden. In order to gain environmental benefits without encouragement or demands from the State, the farmer needs a personal profit motive. Individuals almost always see to their own needs before they see to the common best, even though it might be a harmful strategy when everybody thinks in the same way. The incentive for the Russian farmers would be the economic advantage of handling manure sustainably. But to cross the first threshold, external input is propably needed, such as information campaigns or development of the market for agricultural products which would raise the interest of production increases.

The development of environmentally safe products has started in Russia and could be a good way to increase environmental awareness, but also for the farmers to earn more money. But the trend is still excluded to the well-situated in Moscow and St. Petersburg, which is quite a limited market. For people in general, the price is the most important when chosing products in the grocery store. This can be seen in Sweden as well even though the environmental awareness is rather high in the population. This double standard is an expression of the personal profit motive; people want the animals to be treated well and the environment to be considered, but they are not ready to pay for it themselves.

**Instruments for environmental measures**
*The risk of legal sanctions when violating environmental regulations are lower in Russia than in Sweden and thus the legislation is less efficient.*

The Russian legislation regulates manure management, but the objective is not mainly to reduce nutrient leaching and eutrophication; the sanitary standards are the driving force. It is not lack of policies and legislation that is the problem, but rather lack of implementation. The respondents state that they find it easier and less expensive to pay the fee for violating the law than to do the necessary improvements.The widespread system of bribes in Russia is also likely to make it possible for the farmers to pay the inspector to pass him at the control. This hypothesis can thus be rejected; the risk of legal sanctions is not lower in Russia, it is merely more affordable than in Sweden, which makes the legislation less efficient.

There are only negative economic instruments for environmental issues in Russia; no subsidies, tax reliefs or credits. This means that the farmers are punished when violating regulations, but they are not encouraged by financial means to improve their manure management. Farm economy and environmental measures need to go hand in hand, it is the best way of gaining acceptance and thereby it is more likely that the measures actually are implemented. Development of policies and subsidies with environmental objectives could help farmers invest in new techniques. The incentives for environmental measures would increase if the Russian farmers could connect to a system of subsidies as is done in the European Union. When the subsidies are large enough to attract farmers, it will be an economic set-back to violate the legal conditions and lose the support. The harsh reality is that no investments in manure management facilities will be made as long as the farmers barely go break-even. Poor finances hinder many much needed investments and especially those that do not directly increase production or lower the costs. The economic incentive to invest in manure storages and spreading techniques is low and will remain so until the subsidiary on mineral fertilizers is repealed.

Information as a way of changing attitudes has proven successful among farmers in the Swedish Focus on Nutrients. If voluntary change comes with economic incentives the conditions for improvements are good. There is no such information campaign or other informative instruments in Russia with the objective to decrease nutrient leaching from the agriculture. The Russian authorities have other priorities; a fact that is reflected in the behavior of the farmers.

As it seems, the instruments of environmental measures in Russia contain neither carrot nor whip. The problem of poor manure management is mainly systemic and even though some progress can be made on a volontary basis or if the farmers find economic possibilities that also gain the environment, the real breaktrough will not come until the State changes its priorities. In this, HELCOM and other organisation working with the health of the Baltic Sea need to influence Russian authorities to change their attitudes towards environmental work. It is also important that the European Union raise the pressure on a higher level. Both bottom-up and top-down efforts have to be done in order to get a change in environmental issues and ultimately in manure management.

**Manure as a nutrient resource – knowledge & attitudes**

*Russian farmers are not aware of the fact that manure is a valuable nutrient resource and have less insight into how manure management affects the environment.*

There is no built out extension service in Russia and the farmers depend on information from dealers selling products. Manure is seen as a sanitary issue rather than a nutrient resource. But the hypothesis is only partly true; poor profitability and lack of technical equipment are equally important, as is the subsidies on mineral fertilizers.

All Russian respondents taking part in the study visits showed a thorough understanding for the nutrient value of manure and had a clear insight into how manure management might affect the environment. These persons are though probably not representative for all Russian farmers. The difficulty of finding competent personnel is a problem for many farmers. The status of agricultural work is low, as is the wages. Young and driven people turn agriculture down for other, better paid businesses. This is a vicious circle that in the end hampers economic development of the agricultural sector. In order to create a change in attitudes it is important to inform and educate. The Swedish campaign Focus on Nutrients has been successful in this. It has been a win-win situation for the environment and the Swedish farmers; they have been taught how to save money by saving nutrients.

In Russia no equivalent program as Focus on Nutrients exists. Overall independent extension service is lacking. The main way for farmers to gain information is through Internet and from dealers trying to sell their own products. Internet is a great source of all kinds of information, as long as you have a basic understanding in the subject in order to analyze and apply it to your own conditions. The language might also pose a problem as much of the research is published in English; many Russians have poor English skills. Many of the dealers selling agricultural technique might be skilled, but their advice can never be trusted to be independent; they do not have the farmers best for their eyes, rather the expectation to sell more. There is an existing farmers union in Russia but it is weak and does not make its voice heard.

In the meanwhile, the manure management will stay poor due to lack of knowledge of good practices for storage and spreading; without knowledge about the problems and how you can solve them, you cannot be expected to take any active measures to reduce environmental impact.

The fact that mineral fertilizers are subsidized up to 40% decreases the incentives for using manure as fertilizer. Even though the farmer might be aware of the manure nutrient value and other beneficial effects, the use will be discouraged as mineral fertilizers are cheap and convenient to apply, and the results are easier to predict. Even though many soils in Russia are depleted, manure is rather considered waste than a resource. Better use of manure would be more efficient in increasing soil fertility than to subsidize the use of mineral fertilizers. In the long run soil organic matter would increase and hence improve soil structure. This would allow for machines to traffic the fields with less soil compaction and the conditions for crop root development would be better. Mineralization would give a long-term nutrient supply. The yields, which today are much below their potential, could increase which in turn would boost profitability. Climate change that might give more extreme weather with heavier rainfall and dryer summers is also an incentive to increase soil organic matter. A better soil structure enables faster infiltration of rainfall and the organic matter will increase the water holding capacity.

The influence of soil organic matter on soil fertility is still a minor issue for many famers in Sweden and possibly also in Russia. For Russian farmers bio-security issues pose a more serious, and not as abstract, threat as nutrient losses; a reflection of the legislation. This is valuable knowledge when approaching changes in manure handling since there are win-win solutions for animal health and reduction of nutrient losses.

With education to illustrate this and to show the direct and long-term effects of manure more farmers might understand that manure is, right managed, a nutrient resource. The change in attitudes would propably be faster if the cost for mineral fertilizers increased.

**Manure treatment**
*Anaerobic digestion and biogas production would increase bio-security as well as farm income. It would be possible to implement since Russia already has a developed pipeline system for natural gas.*

Several of the manure treatment techniques available are expensive and the return on investment is doubtful. Excess production of biogas or electricity cannot be connected to the existing pipeline system. This hypothesis is unfortunately rejected. Continued composting and especially separation techniques seem to be the best solution today.

Composting of manure is common practice in Russia even though as it is not performed in a controlled way but rather spontaneously in manure heaps. The conditions cannot be expected to fulfill the standards for minimum seepage and leaching. Even under optimal settings, a majority of the nitrogen is lost as ammonia and other gases and the compost can hence never serve as a complete nitrogen fertilizer. But soil fertility is about more than just nitrogen and the compost improves soil fertiliy thanks to the content of organic matter, phosphorus and other nutrients. It is also an easy practice for reducing volumes and water content, which makes the manure easier to handle and spread. Given the Russian policy of subsidizing mineral fertilizers, composting can be economically viable. The treatment is feasible and waste of manure N is compensated by cheap mineral N. Composting is not optimal from a climate perspective, but if the heaps are situated as to minimize seepage it is a preferable alternative to manure dumping in the forest.

Separation of manure into a liquid and a solid fraction enables the P rich solid fraction to be transported to more remote fields, while the liquid fraction can be spread nearby. This technique, especially in combination with P norms or nutrient balances, could reduce the phosphorus losses from Russian agriculture. The mechanical screw press might not be the most efficient choice, but is simple and stable. The investment is not so big and it would pay off sooner than the other separation alternatives.

Acidification of slurry and urine could be a way of reducing ammonia emissions and saving nitrogen. It is common in Denmark, but has not yet had its break-through in Sweden since the stable systems differ. The technique of acidifying the slurry during spreading could though easily be implemented in Russia as well as in Sweden. But the price of the equipment is high, about 100 000 Euro according to Foged (2010). If the higher effect of nitrogen in field will pay for the equipment depends on the price of nitrogen. The combination of subsidized mineral fertilizers and the difficulties of receiving credits on beneficial terms ruin the potential of acidification in Russia.

Foged (2010) consider anaerobic digestion to be a good solution for higher nitrogen use efficiency and reduced leaching in the European countries surrounding the Baltic Sea and it is considered a way to enhance manure management in Russia. However, several factors actually diminish the potential for biogas in Russia.The development of farm-based biogas production is hindered by the State through bureaucracy and lack of willingness to adopt techniques for renewable energy production. The already built out system for distrubution of natural gas could have been a huge advantage for selling and distribution of biogas. But as long as the excess production of biogas cannot be connected to the pipelines – it makes no diffence for the incentives of investing in biogas production plants. Another problem for the development of biogas production is the poor economy of agricultural businesses. If the farmer barely reaches breakeven and cannot afford to invest in proper storage and spreading techniques, he is not likely to invest in a biogas facility. Without long-term loans with an acceptable interest rate it is impossible to make such a large investment. But even in Sweden, the interest for biogas is limited because of the low profitability. The low energy price and efficiency difficulties hinder the expansion. After the anaerobic digestion a larger proportion of nitrogen occurs as ammonia which makes it more accessible for plant uptake. But if the digestate is spread during unfavorable conditions or not during growing season, the ammonia emissions will increase and thus leaving even less nitrogen for the crops. The actual nutrient value might accordingly decrease and the negative environmental impact increase. Considering profitability and nutrient availability, the development of biogas cannot be recommended for the time being.

Drying and pelletizing of manure as well as combustion and thermal gasification of manure are promising techniques that, if implemented on a large scale, could be very benefical for the recycling of nutrients on a regional, national as well as global level. This could be the solution to the biggest problem with manure; its inability to be transported for longer distances. The animal units would not have to be located nearby the fields where the fodder is cultivated; a sustainable way of disconnecting animal and fodder production. But unfortunately, these techniques will not be a viable economic option in the nearby future, at least not on a farm-based or small-scale level.

**Manure spreading**

*Concentration of animals in big livestock complexes is a major problem in North-west Russia since lack of spreading area hinders farmers to spread their manure adequately.*

The lack of spreading area might be true for some farms in Russia, but more commonly the problem is that some of the fields are too remote from the farm centre to be profitable, or even possible, for transport and spreading of manure. This hypothesis is partly true; the concentration of animals is problematic, but the logistics seems equally important.

Too large amounts of manure can, as is done in Sweden; be solved by establishing spreading agreements with neighbors which increase the total spreading area. But the larger the animal production, the larger the amounts of manure get; and when avoiding excess dosage close to the farm, the transport distance increase accordingly. The problem is built into the system and in order to solve it, animal husbandry and crop production need to be tied closer together. But for example the large animal complexes built to support St. Petersburg with food will probably not be taken out of production because of environmental issues merely. Rather the opposite since the production support aimed at increasing Russian meat production only focuses on the increased amount of animals, excluding environmental issues. The economy of scale that influences animal production and enlarges the units in Russia as well as in Sweden is not ecologically sustainable if the manure management is to remain unchanged. But on the other hand, processing of manure such as separation, drying and pelletizing and anaerobic digestion is more likely to become economically attractive when the animal units are large.

The application rates stated by Venglovsky and Greserova (2002), 20-30tonnes/ha are within the normal range even considering Swedish standards. It is likely though, that some fields receive much more than that, whereas others do not get anything depending on remoteness from the farm centre or other field conditions. Broadcast spreading is the common practice in Russia for solid as well as for liquid manure. Band spreading or injection is not likely to be common since it requires investment in new spreaders and since it is not stipulated by law. In order to reduce ammonia emissions without replacing existing technique incorporation by harrow or plough could be done directly after spreading. This might unfortunately be problematic if the manure is spread on frozen ground or on grassland.

Russian and Swedish farmers face the same difficulty to recycle the nutrients. The one-way direction of bought feed, excess manure production and thus nutrient, especially phosphorus, accumulation could only be broken if the nutrients, in any form, were recycled.  For the transports not to be increadibly expensive when doing this, the water content in the manure has to be decreased. The technique is already available; it only has to be profitable.

The timing of manure application is crucial for high nutrient use efficiency. A big problem in North-west Russia is the poor condition of the drainage system which hinders optimal spreading time. The fields dry slowly after snowmelt, which prevents spreading of the manure in the spring without delaying sowing; and after rainfall, which makes autumn spreading and incorporation troublesome. Spreading when the soil is frozen allows for heavy machinery to work without risking soil compaction; but the nutrient use efficiency will be low due to run-off, leaching and gaseous emissions. The importance of repairing and rebuilding old drainage systems, but also constructing new must be considered when addressing reduced nutrient leaching to the Baltic Sea.

## 6. Conclusions

It seems that the hypothesis of environmental debate in society is true; environmental concern has low priority in Russia. The hypothesis stating that the Russian legislation is less efficient than the Swedish is not true; it is merely poorly implemented. Concerning the hypothesis that knowledge and attitudes to manure as a nutrient resource is low in Russia, it is only partly true. Equally important is the subsidies of mineral fertilizers, poor profitability and poor technical equipment. The hypothesis that anaerobic digestion of manure for biogas production would be possible in Russia was rejected due to the large investments needed and the fact that the amount of manure is not reduced. The last hypothesis, that lack of spreading area is a problem for adequate manure management, is partly true but the logistics of transporting the manure from large animal units to remote fields is equally important.

The main challenges for environmentally sustainable manure management in Russia are the poor economy of agricultural businesses and the public attitude to environmental concern, which is interacting with the state priorities. The main incentive to improve the manure management is to make it profitable. The awareness of manure as a nutrient resource has to be raised and connected to increased production and enhanced farm economy.

A shift in state priorities would the best way of improving manure management; getting rid of the subsidies on mineral fertilizers and instead introducing new ones for environmental measures. An alternative would be to promote the technical development, which would be interesting from an increased production point of view, but would also gain the environment. Enforcement of existing legislation is also important. Development of an independent extension service would benefit the farmers as would demonstration farms, showing how to save plant nutrients easily and costefficient.

It is still written in the stars how the Russian WTO accession will affect the agricultural sector. Lower tariffs will facilitate import of foreign goods which in turn might decrease the cost of farm equipment. If the threat from imported food stuffs can be averted, export to the world market might help develop Russian agricultural production. An open market can possibly also allow for new influences, such as new attitudes to environmental protection, and in the long run fulfilled committments concerning the Baltic Sea.

## 7. Acknowledgements

I would like to thank Ola Palm, JTI, and Staffan Lund, SLU Grants Office, for their essential input during the initial stage of this degree project. They are both involved in the Baltic Compass project, which financed part of my working hours. I would also like to thank Dr. Fredrik Fogelberg, JTI, for bringing me on his study visits and for enabling my contact with the Russian respondents. Further, I would also like to thank my supervisor Ass. Prof. Helena Aronsson, SLU, for her time and valueable support. I would like to thank the Russian respondents for sharing their thoughts about agricultural production in general and the Russian situation in particular. Finally, I would like to thank Ida Lindell at Hushållningssällskapet Kristianstad, Hans Nilsson at Länsstyrelsen Skåne and Emelie Svensson at Länsstyrelsen Västra Götaland for their time and valueable input.

# 8. Bibliography

**Publications**

Aertebjerg, G. & Nixon, S. (2004). *(WEU7) Source apportionment and loads (riverine and direct) of nutrients to coastal waters*. [online]. Copenhagen: European Environment Agency. [fact sheet]. Available from: http://www.eea.europa.eu/data-and-maps/indicators/source-apportionment-and-loads-riverine/weu7_loads_n_p_final_version.pdf [2012-10-22]

Alberta. (2005). *Manure Composting Manual 2005*. Edmonton: Livestock Engineering Unit & Environmental Practices Unit Technical Services Division, Alberta Agriculture, Food and Rural Development. [online]. Available from: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/agdex8875/$file/400_27-1.pdf?OpenElement [2012-10-19].

Baky, A., Nordberg, Å., Palm, O., Rodhe, L., Salomon, E. (2006). *Rötrest från biogasanläggningar – användning i lantbruket*. Uppsala: JTI (JTI informerar nr 115).

Bergström Nilsson, S. (2009). Behandling av gödsel påverkar förlusterna av ammoniak och växthusgaser. *Skånska Lantbruk,* nr 4 2009. [online]. Available from: http://www.vaxteko.nu/html/sll/hs_m_lan/skanskt_lantbruk/SLB09-04/SLB09-04B.PDF [2012-10-24]

Bergström Nilsson, S. (2010). Gödselseparering ett sätt att optimera gödseln. *Jordbruksaktuellt*, 2010-04-05. [online]. Available from: http://www.ja.se/?p=33892&pt=105&m=3433 [2012-12-03]

Chambers, B., Nicholson, N., Smith, K., Pain, B., Cumby, T. & Scotford, I. (2001). *Spreading systems for slurry and solid manures*. [online]. Mansfield: ADAS Gleadthorpe Research Centre (Managing Livestock Manures). [booklet]. Available from: http://archive.defra.gov.uk/foodfarm/landmanage/land-soil/nutrient/documents/manure/livemanure3pt1.pdf [2012-10-29]

Semenov, V.A., Minin, V.B. & Huhta, H. (2006). *The Codes of Good Agricultural Practices for the Leningrad Region, Rules and Recommendations*. St. Petersburg: HELCOM (Part 1 Animal Husbandry and Fodder Production). [online]. Available from: http://www.ymparisto.fi/download.asp?contentid=75323 [2012-10-17]

Ek, F. (2007). *Biogasframställning på gården*. Helsingfors: ProAgria Svenska Lantbrukssällskapens förbund.

Ekbladh, G. (1999). *Ekologisk grönsaksodling. Kvävetillgång och kvävebehov under odlingssäsongen*. [online]. Färjestaden: Torslunda försöksstation. [booklet]. Available from: http://www.vaxteko.nu/html/sll/slu/utan_serietitel_slu/UST99-16/UST99-16.PDF [2012-09-06]

Emelianova, E. & Starik, M. (2004). Russian Environmental Values and Strategies: Historical Development and Role of NGOs. *Environmental Issues in Eurasia*, vol. 3, No. 2 winter 2004. [online]. Available from: http://www.americancouncils.org/JER/ [2012-10-22]

Eriksson, J., Nilsson, I., Simonsson, M. (2005). *Wiklanders marklära*. Lund: Studentlitteratur.

European Commission. Directive 2008/56/EC of the European Parliament and the Council of 17 June 2008 establishing a framework for community action in the field of the marine environmental policy (Marine Strategy Framework Directive). (2008). [online]. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:164:0019:0040:SV:PDF [2012-09-13]

EUSBSR (2012b). *European Union Strategy for the Baltic Sea Region, Action Plan: Commission staff working document*. Brussels: Commission of the European Communities (January 2012 version). [online]. Available from: http://www.balticsea-region-strategy.eu/ [2012-09-15]

Foged, H.L. (2010). *Best Available Technologies for Manure Treatment – for Intensive Rearing of Pigs in Baltic Sea Region EU Member States*. Stockholm:Baltic Sea 2020. [online]. Available from: http://www.balticsea2020.org/english/images/Bilagor/ippp%2020100201%20best_practice_manure_handling_final.pdf [2012-11-29]

Foged, H.L. & Mortensen, C.G.E. (2011). *Sector Study - Prioritized innovative agro-environmental technologies for sustainable food production in the Baltic Sea Region*. Tjele: Agro Business Park A/S. [online]. Available from: http://www.agro-technology-atlas.eu/docs/repo20905_Baltic_Compass_Sector_Study.pdf [2012-10-23]

Frandsen, T. Q., Rodhe, L., Baky, A., Edström, M., Sipilä, I., Petersen, S.L., Tybirk, K.. (2011). *Best Available Technologies for pig Manure Biogas Plants in the Baltic Sea Region*. Stockholm: Baltic Sea 2020. [online]. Available from: http://www.bioenergiportalen.se/attachments/42/580.pdf [2012-11-29]

Gelman, V. (2004). *The Extinction of Political Opposition in Russia*. St Petersburg: European University (PONARS Policy Memo 340). [online]. Available from: http://www.gwu.edu/~ieresgwu/assets/docs/ponars/pm_0340.pdf [2012-10-22]

Greppa Näringen. (2004). *Din stallgödsel är värdefull, sprid den vid rätt tidpunkt och med god teknik*. [online]. Jönköping: Greppa Näringen. [booklet]. Available from: http://www.greppa.nu/download/18.1c0ae76117773233f780002553/Stallgodsel_broschyr.pdf [2012-10-23]

Greppa Näringen. (2012b). *Goda Råd om Stallgödsel och Gödsling*. [online]. Malmö: Greppa Näringen. [booklet]. Available from: http://www.greppa.nu/skrifter/godarad.4.32b12c7f12940112a7c800021169.html [2012-10-25]

Gustafsson, BG., Schenk, F., Blenckner, T., Eilola, K., Meier, HE., Müller-Karulis, B., Neumann, T., Ruoho-Airola, T., Savchuk, OP., Zorita, E. (2012). Reconstructing the Development of Baltic Sea Eutrophication 1850-2006. *Ambio A Journal of the Human Environment*, vol. 41, no. 6, 534-48.

Hedman, K. (2001). *Ryskt jordbruk – nuläge och framtidsutsikter*. Lund: Livsmedelsekonomiska Institutet ( rapport 2001:5). [online]. Available from: http://www.agrifood.se/Files/SLI_rapport_20015.pdf [2012-10-26]

HELCOM, 2008: *Convention on the protection of the marine environment of the Baltic Sea area, 1992 (Helsinki Convention)*. Helsinki: Helsinki Commission. [online]. Available from: http://www.helcom.fi/stc/files/Convention/Conv1108.pdf [2012-09-24]

HELCOM (2009). *Eutrophication in the Baltic Sea – an integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea Region*. Helsinki: Helsinki Commission (Baltic Sea Environment Proceedings no. 115B). [online]. Available from: http://meeting.helcom.fi/c/document_library/get_file?p_l_id=79889&folderId=377779&name=DLFE-36818.pdf [2012-09-24]

HELCOM (2010). *Reducing nutrient loading from large scale animal farming in Russia - BALTHAZAR project 2009-2010*. Helsinki: Helsinki Commission. [online]. Available from: http://www.helcom.fi/stc/files/Publications/OtherPublications/agricultural_full_english.pdf [2012-10-24]

HELCOM (2012a). *HELCOM Activities 2011 Overview*. Helsinki: Helsinki Commission (Baltic Sea Environment Proceedings No. 132). [online]. Available from: http://www.helcom.fi/stc/files/Publications/Proceedings/BSEP132%20FINAL.pdf [2012-09-20]

HS (2005). *Lagra utan läckor*. Uppsala: Hushållningssällskapet Mitt (Miljöartikel 3 (5) 2005). [online]. Available from: http://www.hush.se/attachments/64/1048.pdf [2012-10-30]

HS (2006). *Gödselseparering, framtiden eller en dagslända?*. Halmstad: Hushållningssällskapet Halland (Miljöartikel 7 (9) 2006). [online]. Available from: http://www.hush.se/attachments/64/1057.pdf [2012-10-19]

IPPC. Directive 2008/1/EC of the European Parliament and the Council of 15 January 2008 concerning integrated pollution prevention and control. (2008). [online]. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:024:0008:0029:SV:PDF [2012-09-12]

Johansson, S. (2010). *Styrmedel för minskade utsläpp*. Jönköping: Jordbruksverket (bilaga 1 till rapport 2010:10). [online]. Available from: http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra10_10_bilaga_1.pdf [2012-09-10]

Kaliningrad oblast, (2012). *Доклад об экологической обстановке в Калининградской области в 2011 году (Report on the ecological situation in Kaliningrad oblast 2011)*. Kaliningrad: Правительство Калининградской области (Kaliningrad regional government).

Kalyuzhnyi, S., Sklyar, V., Epov, A., Arkhipchenko, I., Barboulina, I., Orlova, O., Kovalev, A., Nozhevnikova, A. & Klapwijk, A. (2003). *Sustainable Treatment and Reuse of Diluted Pig Manure Streams in Russia, From Laboratory Trials to Full-Scale Implementation*. Moscow: Department of Chemical Enzymology, Moscow State University. [online]. Available from: http://www.researchgate.net/publication/10719446_Sustainable_treatment_and_reuse_of_diluted_pig_manure_streams_in_Russia_from_laboratory_trials_to_full-scale_implementation [2012-10-29]

Kirchmann, H. & Lundvall, A. (1998). *Treatment of solid animal manures: identification of low NH3 emission practices*. Uppsala: Department of Soil Sciences, Swedish University of Agricultural Sciences.

Kvarnemo, L. (1983). *Täckdikning*. Stockholm: LT.

Kätterer, T., Kirchmann, H. & Börjesson, G. (2012). Hög bördighet ger hög skörd som ger… *Arvensis,* vol. 01 2012, 14-15.

Law on Environmental Protection. Федеральный закон от 10 января 2002 г. N 7-ФЗ "Об охране окружающей среды (Federal Law of 10 January 2002, N 7-FZ, on environmental protection). (2001). [online]. Available from: http://www.icfinternational.ru/doc_files/oops.pdf [2012-10-17]

Lindahl, O. (2005). Musselodling – nytt verktyg mot övergödning. *HavsUtsikt*, vol. 3 2005. [online]. Available from: http://www.miljoportalen.se/vatten/havet/musselodling-nytt-verktyg-mot-oevergoedningen [2012-09-10]

Malgeryd, J., Karlsson, S., Rodhe, L. & Salomon, E. (2002). *Lönsam stallgödselhantering - teknik, växtnäringshushållning, kvalitet och ekonomi*. Uppsala: JTI (Teknik för lantbruket 99). [online]. Available from: http://www.jti.se/uploads/jti/t99.pdf [2012-09-04]

Malgeryd, J. (2003). *Spridning av gödsel i ekologisk odling*. Jönköping: Jordbruksverket (Ekologisk odling av grönsaker påfriland, Ekologiskt lantbruk). [online]. Available from: http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_ovrigt/p7_11.pdf [2012-09-06]

Ministry of Agriculture RF. Государственная программа развития сельского хозяйства и регулирования рынков сельскохозяйственной продукции, сырья и продовольствия на 2013-2020 годы (State program of agricultural development and regulation of agricultural products, raw materials and food 2013-2020). (2012b). [online]. Available from: http://www.garant.ru/hotlaw/federal/412981/ [2012-10-16]

Naturvårdsverket (2003). *Åtgärder och kostnader för minskad fosforutlakning från jordbruksmark till sjön Glan*. Stockholm: Naturvårdsverket (Underlagsrapport (3) till Miljökvalitetsnormer för fosfor i sjöar – redovisning av ett regeringsuppdrag, NV rapport 5288). [online]. Available from: http://www.naturvardsverket.se/Documents/publikationer/620-5291-8.pdf [2012-10-31]

Naturvårdsverket (2011). *Miljöeffekter av EU's jordbrukspolitik*. Stockholm: Naturvårdsverket. [online]. Available from: http://www.naturvardsverket.se/978-91-620-6461-7 [2012-11-02]

Naturvårdsverket & Energimyndigheten (2006). *Ekonomiska styrmedel i miljöpolitiken*. Stockholm: Naturvårdsverket & Energimyndigheten (Rapport 2006-10). [online]. Available from: http://www.naturvardsverket.se/Documents/publikationer/620-5616-6.pdf [2012-11-02]

NEFCO (2011). *Preparation of a business plan for improving manure management in poultry factories in the Leningrad region, Russia*. Helsinki: NEFCO (Summary Report 16WWE0731). [online]. Available from: http://www.nefco.org/sites/nefco.viestinta.org/files/BPs%20for%20Manure%20Mgmt_%20Summary%20Report_Volume%20I_Eng_20111018.pdf [2012-10-24]

Norin, E. (2008). *Översikt över metoder för biogödselhantering*. Malmö: Avfall Sverige Utveckling (Rapport B2008:02). [online). Available from: http://www.energigjenvinningsetaten.oslo.kommune.no/getfile.php/energigjenvinningsetaten%20(EGE)/Internett%20(EGE)/Sentrale%20dokumenter/Oversikt%20over%20metoder%20for%20biogj%C3%B8dselh%C3%A5ndtering.pdf [2012-11-29]

OECD (2006). *Environmental Policy and Regulation in Russia, the Implementation Challenge*. Paris: OECD. [online]. Available from: http://www.oecd.org/env/environmentinemergingandtransitioneconomies/38118149.pdf [2012-10-16]

Ottoson, J., Nordin, A. & Vinnerås, B. (2006). *Ammonia and urea manure hygienisation*, Uppsala: Department of Biometry and Engineering, Swedish University of Agricultural Sciences (Rapport – miljö, teknik och lantbruk 2006:02). [online]. Available from: http://pub.epsilon.slu.se/3805/1/ottoson_et_al_090930.pdf [2012-09-04]

Ricklefs, R. (2007). *The Economy of Nature*. 5 ed. New York: W.H Freeman & company.

Robinson, N. A. (1988). *Perestroika and Priroda: Environmental Protection in the USSR*. Pace: Pace Law Faculty Publications (Paper 385). [online]. Available from: http://digitalcommons.pace.edu/lawfaculty/385 [2012-10-26]

Rodhe, L. (2006). Konsten att: Minska växthusgaserna från gödseln. *Miljöforskning*, vol. 4/2006. [online]. Available from: http://miljoforskning.formas.se/sv/Nummer/September-2006/Innehall/Ovriga-artiklar/Minska-vaxthusgaserna-fran-godseln/ [2012-10-20]

Rodhe, L., Baky, A., Olsson, J. & Nordberg, Å. (2012). *Växthusgaser från stallgödsel*. Uppsala: JTI (JTI-rapport 2012, Lantbruk & Industri nr 402). [online]. Available from: http://www.jti.se/uploads/jti/R-402%20LR%20m.fl.pdf [2012-10-20]

Samuelson, L. (2011). Därför föll Sovjetunionen. *Forskning & Framsteg*, vol. 10/2011. [online]. Available from: http://fof.se/tidning/2011/10/darfor-foll-sovjetunionen [2012-10-26]

SCB (2012a). *Historisk statistik, Jordbruket i siffror åren 1866-2007*. Stockholm: SCB. [online]. Available from: http://www.ssd.scb.se/databaser/makro/SaveShow.asp [2012-10-26]

SCB (2012b). *Jordbruksstatistisk årsbok 2012 med data om livsmedel*. Stockholm: SCB. [online]. Available from: http://www.scb.se/statistik/_publikationer/JO1901_2012A01_BR_10_JO01BR1201.pdf [2012-10-23]

SJV (2004). SJVFS 2004:62, Statens jordbruksverks föreskrifter om miljöhänsyn i jordbruket vad avser växtnäring. [online]. Available from: http://www.jordbruksverket.se/download/18.26424bf71212ecc74b080001478/2004-062.pdf [2012-11-01]

SJV (2009c). SJVFS 2009:82 Föreskrifter om ändring i Statens jordbruksverks föreskrifter (SJVFS 2004:62) om miljöhänsyn i jordbruket vad avser växtnäring samt beslut om Statens jordbruksverks allmänna råd (2005:1) om lagring och spridning av gödsel m.m. [online]. Available from: http://www.jordbruksverket.se/download/18.72e5f95412548d58c2c80002182/2009-082.pdf [2012-11-01]

SJV (2010). *Bilaga 2 Åtgärder för minskade utsläpp*. Jönköping: Jordbruksverket. [online]. Available from: http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_rapporter/ra10_10_bilaga_2.pdf [2012-11-02]

Strandmark, M. (2011). *Gödsel och miljö 2011*. Jönköping: Växt- och miljöavdelningen, Jordbruksverket (version 3, januari 2011). [online]. Available from: http://www2.jordbruksverket.se/webdav/files/SJV/trycksaker/Pdf_ovrigt/ovr206.pdf [2012-10-20]

SJV (2011e). *Riktlinjer för gödsling och kalkning 2012.* Skara: Jordbruksverket (Jordbruksinformation 21 – 2011).

Skorupski, J.(ed.), Balcere, A., Norén, G., Holmgren, S., Hrytsyshyn, P., Lobanov, E., Marttila, J., Merisaar, M., Rimavicius, R. & Roggenbuck, A. (2007). *Report on Industrial Swine and Cattle Farming in the Baltic Sea Catchment Area*. Uppsala: Coalition Clean Baltic. [online]. Available from: http://www.ccb.se/documents/indfarmencorr_000.pdf [2012-10-24]

SLU (2009a). *Agricultural Production in Leningrad Oblast, Present State and Prospects for Development*. Uppsala: Swedish University of Agricultural Sciences.

SLU (2009b). *Agricultural development in Leningrad Oblast under conditions of transitions*. Uppsala: Swedish University of Agricultural Sciences.

Soane, B. D. (1990). The role of organic matter in soil compactibility:  A review of some practical aspects. *Soil and Tillage research*, vol. 16, Issues 1–2, April 1990, 179–201.

Sommer, S. G. & Hutchings, N. J. (2001). Ammonia emissions from field applied manure and its reduction – invited paper, *European Journal of Agronomy*, vol.15 2001, 1-15. [online]. Available from: http://www.chesapeake.org/stac/presentations/63_Sommer%20S%20and%20H%20Hutchinson_2001_Ammonia%20emission%20from%20field%20applied%20manure%20and%20its%20reduction.pdf [2012-11-16]

Steineck, S., Gustafson, A., Richert Stintzing, A., Salomon, E., Myrbeck, Å., Albihn, A. & Sundberg, M. (2000a). *Växtnäring i kretslopp*. Uppsala: Swedish University of Agricultural Sciences.

Steineck, S., Svensson, L., Jakobsson, C., Karlsson, S. & Tersmeden, M. (2000b). *Hästar – gödselhantering.* Uppsala: JTI (Teknik för lantbruket 82). [online]. Available from: http://www.jti.se/uploads/jti/t82.pdf [2012-12-05]

Sveriges Riksdag (2012a). Miljöbalk (1998:808). [online]. Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Miljobalk-1998808_sfs-1998-808/#K12 [2012-11-01]

Sveriges Riksdag (2012b). Förordning (1998:915) om miljöhänsyn i jordbruket. [online]. Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Forordning-1998915-om-miljo_sfs-1998-915/?bet=1998:915 [2012-11-01]

Sveriges Riksdag (2012c). Miljötillsynsförordning (2011:13). [online]. Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Miljotillsynsforordning-2011_sfs-2011-13/ [2012-11-02]

Sveriges Riksdag (2012d). Förordning (2012:259) om miljösanktionsavgifter. [online]. Available from: http://www.riksdagen.se/sv/Dokument-Lagar/Lagar/Svenskforfattningssamling/Forordning-2012259-om-miljo_sfs-2012-259/#K5 [2012-11-02]

Tattari, S., Jaakola, E., Koskiaho, J., Räsänen, A., Huitu, H., Lilja, H., Salo, T., Ojanen, H., Norman Haldén, A., Djodjic, F., Collentine, D., Norrgren, L., Boqvist, S., Rydh Ottoson, J., Sternberg Lewerin, S., Pakhomau, A., Duus Borgeson, C., Rubaeck, G. & Krisciukaitieneet, I. (2012). *Mapping erosion- and phosphorus vulnerable areas in the Baltic Sea Region – data availability, methods and biosecurity aspects*. Jokioinen: MTT Agrifood Research Finland (Raportti 65).

Velthof, G.L. & Mosquera, J. (2011). The impact of slurry application technique on nitrous oxide emission from agricultural soils. *Agriculture, Ecosystems and Environment*, vol. 140, issues 1-2, 30 January 2011, 298-308. [online]. Available from: http://www.sciencedirect.com/science/article/pii/S0167880910003440 [2012-09-04]

Venglovsky, J. (ed.) & Greserova, G. (ed.) (2002). *Recycling of agricultural, municipal and industrial residues in agriculture.* Strbské Pleso: RAMIRAN.

Wall, G., Baldwin C.S. & Shelton, I.J. (1987). *Soil erosion – causes and effects*. Guelph: Queen's printer for Ontario (Factsheet). [online]. Available from: http://www.omafra.gov.on.ca/english/engineer/facts/87-040.htm [2012-10-30]

Wallén, G. (1993). *Vetenskapsteori och forskningsmetodik.* Lund: Studentlitteratur.

Water Code. Federal Law Water Code of the Russian Federation. (2006). [online]. Available from: http://dinrac.nowpap.org/documents/law/Russia/Water_Code_Russia.pdf [2012-10-17]

Weiner, D.R. (1988). *Models of Nature: Ecology, Conservation, and Cultural Revolution in Soviet Union*. Bloomington: Indiana University.

Yablokov, A. (2010). The Environment and Politics in Russia. *Russian Analytical Digest*, no 79, 24 May 2010. [online]. Available from: http://www.isn.ethz.ch/isn/Digital-Library/Publications/Detail/?id=116687&lng=en [2012-10-24]

**Internet sources**

Alm, M. (2010). *Den stora svälten*. http://www.levandehistoria.se/node/1758 [2012-10-26]

Baltic Deal (2012). *About Baltic Deal*. http://www.balticdeal.eu/about-baltic-deal/ [2012-08-29]

Baltic Manure (2012). *About the project*. http://www.balticmanure.eu/en/about_the_project/ [2012-08-29]

Baltic Compass (2012). *Project strategy*. http://www.balticcompass.org/Project_strategy.html [2012-08-29]

Biogas Info (2012). *What is AD?*. http://www.biogas-info.co.uk/index.php/ad-basics [2012-09-18]

CIA, 2012: *The World Factbook*. https://www.cia.gov/library/publications/the-world-factbook/geos/rs.html [2012-12-03]

Coalition Clean Baltic (2012). *About CCB*. http://www.ccb.se/about.html [2012-09-19]

Ekonomifakta (2012). *Sverige bröt trenden på 70-talet.* http://www.ekonomifakta.se/sv/Artiklar/2008/Januari/Sverige-brot-trenden-pa-70-talet/ [2012-10-22]

European Commission (2012a). *The CAP*. http://ec.europa.eu/agriculture/index_en.htm [2012-09-13]

European Commission (2012b). *Introduction to the new EU Water Framework Directive*. http://ec.europa.eu/environment/water/water-framework/info/intro_en.htm [2012-09-12]

European Commission (2012c). *The Nitrates Directive*. http://ec.europa.eu/environment/water/water-nitrates/index_en.html [2012-09-12]

Europa (2011). *Att förebygga och begränsa föroreningar (fram till 2013)*. http://europa.eu/legislation_summaries/environment/waste_management/l28045_sv.htm [2012-09-12]

EUSBSR (2012a). *Priority Area 1 – Nutrient input to the sea*. http://groupspaces.com/eusbsr-nutrient-inputs/ [2012-08-29]

EUSBSR (2012c). *What is the EUSBSR*. http://www.balticsea-region-strategy.eu/pages/what-is-the-eusbsr [2012-08-29]

EU-upplysningen (2012). *EU-lagar gäller framför svenska lagar*. http://www.eu-upplysningen.se/Sverige-i-EU/EU-lagar-galler-framfor-svenska-lagar/ [2012-09-13]

Greppa Näringen (2011a). *Projektbeskrivning*. http://www.greppa.nu/omgreppa/projektbeskrivning.4.32b12c7f12940112a7c800018407.html [2012-09-05]

Greppa Näringen (2011b). *Vad är en växtnäringsbalans*. http://www.greppa.nu/vaxtnaringsbalans/vadarenvaxtnaringsbalans.4.1c0ae76117773233f780001965.html [2012-09-05]

Greppa Näringen (2011c). *Analysera gödseln*. http://www.greppa.nu/stallgodsel/stallgodselinformation/analyserastallgodsel.4.1c0ae76117773233f780006822.html [2012-10-29]

Greppa Näringen (2011d). *Beräkningsinstruktioner*. http://www.greppa.nu/stallgodsel/varderadinstallgodsel/berakningsintruktioner.4.1c0ae76117773233f780006217.html [2012-10-29]

Greppa Näringen (2011e). *Surgörning av gödsel på bred front i Danmark*. http://www.greppa.nu/omgreppa/nyheter/surgorningavgodselpabredfrontidanmark.5.6ba76eeb12e25d1f02b8000825.html [2012-11-29]

Greppa Näringen (2011f). *Nordiska Ministerrådets miljöarbete kring Östersjön*. http://www.greppa.nu/omgreppa/omwebbplatsen/artikelarkiv/aldreartiklar/nyhetsarkiv/tidigarear/nyhetsarkivet20012005/nordiskaministerradetsmiljoarbetekringostersjon.5.1c0ae76117773233f780002326.html [2012-11-30]

Greppa Näringen (2011g). *Internationell jämförelse av ammoniakregler för lantbruk*. http://www.greppa.nu/omgreppa/omwebbplatsen/artikelarkiv/aldreartiklar/nyhetsarkiv/stallgodsel2006/internationelljamforelseavammoniakreglerforlantbruk.5.4ef62786124a59a20bf8000101.html [2012-12-03]

Greppa Näringen (2012a). *Lösningar för stora ryska djuranläggningar på gång*. http://www.greppa.nu/omgreppa/nyheter/losningarforstoraryskadjuranlaggningarpagang.5.6c98fa0413952587b5d80001517.html [2012-08-28]

HaV (2012). *Några fakta om övergödning och Östersjön*. http://www.havochvatten.se/kunskap-om-vara-vatten/miljohot/overgodning/nagra-fakta-om-overgodning-och-ostersjon.html [2012-08-27]

Havet.nu (2012). *Egentliga Östersjön*. http://www.havet.nu/?d=43 [2012-09-17]

HELCOM (2012b). *About HELCOM*. http://www.helcom.fi/helcom/en_GB/aboutus/ [2012-08-28]

HELCOM (2012c). *Proper Manure Management in Russian Farms to Reduce Threat of Nutrients Leaching to the Baltic Sea*. http://www.helcom.fi/press_office/Newsletters/Newsletter_2-2012/en_GB/manure_composting_story/ [2012-10-24]

Hoffman, M. (2012). *Lustgasavgång vid olika sätt att sprida flytgödsel*. http://www.greppa.nu/omgreppa/nyheter/lustgasavgangvidolikasattattspridaflytgodsel.5.42c619a8136b9f2109d8000517.html [2012-09-04]

IRC (2006). *Putin signs Water Code into law*. http://www.source.irc.nl/page/29793 [2012-10-17]

LRF (2009). *Välkommet besked om slopad kväveskatt*. http://www.lrf.se/Om-LRF/Kontakta-LRF/Press/Pressmeddelanden/2009/Vlkommet-besked-om-slopad-kvveskatt [2012-11-02]

LRF (2012). *Greppa Näringen har gett resultat*. http://www.lrf.se/Om-LRF/Mer-om-LRF/Verksamhetsberattelse-2011/Konkurrensvillkor/Greppa-Naringen-har-gett-resultat/ [2012-09-05]

Miljömål (2012).*Miljömål.se – den svenska miljömålsportalen*. http://www.miljomal.se/sv/ [2012-09-07]

Ministry of Agriculture RF (2012a). *II. Цели Программы и прогноз развития сельского хозяйства на 2008 - 2012 годы (II. Program objectives and prediction of the agricultural development 2008-2012)*. http://www.mcx.ru/documents/document/v7_show/1350.145.htm [2012-10-16]

Naturskyddsföreningen (2008). *Övergödningen i Östersjön*. http://www.naturskyddsforeningen.se/natur-och-miljo/hav-och-fiske/ostersjon/overgodningen-i-ostersjon/ [2012-08-27]

Naturvårdsverket (2012). *Styrmedel för miljövänliga val*. http://www.naturvardsverket.se/Start/Lagar-och-styrning/Styrmedel-for-miljovanliga-val/ [2012-09-11]

OECD (2012). *OECD-FAO Agricultural outlook 1970-2012 / Russia / Wheat*. http://stats.oecd.org/ [2012-10-23]

SJV (2009a). *Plan of action against nutrient losses*. http://www.jordbruksverket.se/swedishboardofagriculture/engelskasidor/crops/plantnutrients/plantnutrientlosses.4.6621c2fb1231eb917e680003252.html [2012-09-04]

SJV (2009b). *Stallgödsel i kornodling*. http://www.jordbruksverket.se/amnesomraden/odling/spannmalsgrodor/korn/vaxtnaring/stallgodsel.4.3229365112c8a099bd980003232.html [2012-09-04]

SJV (2011a). *Jordbruket och övergödningen*. http://www.jordbruksverket.se/amnesomraden/miljoochklimat/ingenovergodning/jordbruketochovergodningen.4.4b00b7db11efe58e66b80001608.html [2012-08-27]

SJV (2011c). *När du lagrar stallgödsel*. http://www.jordbruksverket.se/amnesomraden/odling/vaxtnaring/lagrastallgodsel.4.1a4c164c11dcdaebe12800084.html [2012-08-31]

SJV (2011d). *Programmet STANK in MIND*. http://www.jordbruksverket.se/amnesomraden/odling/vaxtnaring/stankinmind/omstankinmind.4.6beab0f111fb74e78a78000102.html [2012-10-25]

SJV (2012a). *När du sprider gödsel – bestämmelser som gäller hela landet*. http://www.jordbruksverket.se/amnesomraden/odling/vaxtnaring/spridagodselmedel/spridagodselmedelhelalandet.4.207049b811dd8a513dc80002742.html [2012-11-01]

SJV (2012b). *Kontroller och avdrag på gårdsstödet*. http://www.jordbruksverket.se/amnesomraden/stod/gardsstod/kontrollerochavdrag.4.14121bbd12def92a91780004523.html [2012-11-02]

SJV (2012c). *Miljöersättningar*. http://www.jordbruksverket.se/amnesomraden/stod/miljoersattningar.4.7850716f11cd786b52d8000485.html [2012-11-03]

SVA (2009). *Gödselhantering*. http://www.sva.se/sv/Mer-om-SVA1/Mijlo-och-klimat/Halsorelaterad-miljomikrobiologi/Godselhantering/ [2012-09-04]

UN (2012). *Environment*. http://www.un.org/en/globalissues/environment/ [2012-10-22]

WWF (2011a). *WWFs historia – hur det hela började*. http://www.wwf.se/om-wwf/historik/1122850-ww-fs-historia [2012-10-22]

WWF (2011b). *EUs gemensamma jordbrukspolitik (CAP)*. http://www.wwf.se/vrt-arbete/jordbrukslandskap/jordbrukspolitik/1127774-eus-gemensamma-jordbrukspolitik [2012-09-13]

**Oral presentations & personal messages**

Kätterer, T., Kirchmann, H. & Börjesson, G. (2011). *Fosfor- och kväveinteraktioner samt mulluppbyggnad i svenska långliggande försök*. Oral presentation by Kätterer presented at Regional Växtodlings- och Växtskyddskonferens i Uddevalla 12-13 jan. 2012. Extended abstract, 10 pages.

Lindell, I. (2012). Plant production consultant, Hushållningssällskapet Kristianstad. Telephone interview. [2012-11-26]

Nilsson, H. (2012). Head of Greppa Näringen, Länsstyrelsen Skåne. Telephone interview. [2012-11-27]

Svensson, E. (2012). Plant production consultant, Länsstyrelsen Västra Götaland. Telephone interview. [2012-11-28]