



Photo: Mats Pettersson

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Agriculture's contribution to eutrophication

Lakes, seas and watercourses exposed to an excessive amount of nitrogen and phosphorus can be affected by eutrophication. Today, eutrophication is common in lakes and coastal waters in southern Sweden. Especially the Baltic Sea is severely affected by algal bloom and oxygen depletion of the seabed. Plant nutrient losses from agricultural land to water are a major contributor to eutrophication. About half of the anthropogenic nitrogen and phosphorus in Sweden that reaches the sea originates from agriculture. Agriculture also contributes with close to 85 % of the Swedish ammonia emissions.

Sweden's actions against plant nutrient losses and eutrophication

Actions against eutrophication have been conducted for a long period of time. The first Swedish plan of action for reduced plant nutrient losses from agricultural land was established as early as towards the end of the 1980s. Changes have been made based on new knowledge and new legislation. Today, the work is based on EU directives, international commitments and the environmental quality objectives adopted by Sweden.

The measures to reduce plant nutrient losses from agriculture are carried out via:

- legislation
- financial instruments (Agri-Environmental payments, Non-productive investments)
- extension services and information, for example through Focus on Nutrients

The most far-reaching or extensive measures are taken in areas appointed as particularly vulnerable to nitrate pollution. A map of the Swedish nitrate vulnerable zones can be found on the Board of Agriculture's webpage www.jordbruksverket.se.

Results from implemented measures

So far, implemented measures have led to positive results. Losses of nitrogen and phosphorus, as well as ammonia emissions from agriculture have decreased. Despite this, eutrophication is still a problem in lakes, seas and watercourses. Further actions are needed to continue the positive trend of reduced nutrient losses from agriculture.



International and Swedish agreements about reduced plant nutrient losses and eutrophication

Measures to reduce plant nutrient losses from agriculture are based on EU directives, international commitments and the Swedish environmental quality objectives. These aim at reducing eutrophication and improving the environmental condition in fresh- and seawater.

EU directives and international commitments

Efforts to limit and reduce losses to air and water have been going on for quite some time. Emissions from other countries can be transported to Sweden by air- or water currents. International cooperation is therefore important to reduce negative environmental impact. Several international agreements have been adopted in recent decades, with the aim of limiting the emission of substances harmful to the environment.

The Helsinki Commission's (HELCOM's) Baltic Sea Action Plan (BSAP) is of importance regarding nutrient losses from agriculture. The goal of HELCOM is to protect the Baltic Sea from all kinds of pollutions from land, shipping and aviation. With its action plan HELCOM aims at restoring a good ecological status of the Baltic marine environment by 2021. Eutrophication is one of the prioritized problems within the action plan.

Within the EU, there is common legislation since 1991, often referred to as the Nitrates Directive (91/676/EEC), which states minimum requirements for reducing nitrogen losses (nitrate losses) from agriculture to surface and ground water, as well as to coastal and sea water. According to the Directive, each Member State shall identify areas vulnerable to nitrate pollution, and establish a plan of action with the aim of reducing nutrient leaching from agriculture.

Another Directive within the EU is the Water Framework Directive (2000/60/EG). Its overall goal is to achieve a good ecological and chemical status in all lakes, watercourses, coastal waters and ground waters in the EU countries by 2015 or at the latest by 2027.

The Marine Strategy Framework Directive (2008/56/EG) aims to achieve a good environmental status in all marine areas within the EU by 2020. The Directive requires all Member States to assess the environmental status in its marine waters, and from this develop a marine strategy with programmes of measures and monitoring programmes.

The aim for another EU Directive, the so called IED Directive (2010/75/EU) is, by coordinated efforts, to prevent and reduce pollution from a number of activities, including large installations holding pigs or poultry which can cause large losses in the form of nitrate and ammonia.

The National Emission Ceilings Directive (2001/81/EG) sets national emission ceilings for a number of air pollutants. Among other things this directive states the allowed emission of ammonia.

Sweden has also signed up for the UN Convention on Long Range Transboundary Air Pollution. The Convention contains eight protocols with aims and measures to reduce emissions of several air pollutants, including ammonia, and is a co-operation between Europe, North America and the countries in Caucasus and Central Asia.

National environmental quality objectives

Sweden has adopted 16 Environmental Quality Objectives describing the state of the Swedish environment which environmental action is to result in. One of the

objectives, *Zero Eutrophication*, attacks the problem of losses of nutrients to land and water. The environmental objective has been defined by the Swedish Parliament as:

“Nutrient levels in soil and water must not be such that they adversely affect human health, the conditions for biological diversity or the possibility of varied use of land and water.”

The objective *Zero Eutrophication* has four specifications, explaining what is to be achieved and how the objectives are to be followed up:

- **Pressure on the marine environment.** Swedish and total inputs of nitrogen and phosphorus compounds into the seas surrounding Sweden are less than the maximum loads established within the framework of international agreements.
- **Pressure on the terrestrial environment.** Atmospheric deposition and land use do not result in ecosystems showing any substantial long-term harmful effects of eutrophying substances in any part of Sweden.
- **Status of lakes, watercourses, coastal waters and groundwater.** Lakes, watercourses, coastal waters and groundwater achieve at least good status for nutrients in accordance with the Water Quality Management Ordinance (2004:660).
- **Status of the marine environment.** Sea areas achieve at least good environmental status as regards eutrophication in accordance with the Marine Environment Ordinance (2010:134).

Milestone targets are used to identify a desired social change and specify steps towards achieving the environmental quality objectives. The measures aimed at reducing plant nutrients losses from agriculture are primarily based on the objective *Zero Eutrophication*. Other environmental objectives of relevance are *Thriving Wetlands*, *Reduced Climate Impact* and *Good-Quality Groundwater*.

More information about the environmental quality objectives and updates on the progress of environmental action can be found at www.miljomal.se.



Legislation

Some of the measures to reduce plant nutrient losses from agriculture are carried out via legislation. Regulations regarding the environment are gathered in the Environmental Code, and in its ordinances and regulations.

Many activities in agriculture and forestry risk harming or disturbing the environment, so particular consideration is necessary in such activities. For certain activities and measures, there are clear rules in the legislation, and for others the rules are of a more general nature. Whether or not there is detailed legislation concerning a certain measure, the Environmental Code's general rules about consideration always apply. Briefly put, they state that every person who carries out, or intends to carry out, activities must obtain the knowledge and take the measures necessary for protecting human health and the environment against damage or inconvenience.

More detailed rules about the handling of plant nutrients are available in the Ordinance (1998:915) on environmental concern in agriculture, and in the Swedish Board of Agriculture rules and general guidance (SJVFS 2004:62) on environmental concern in agriculture as regards plant nutrients.

The Ordinance on environmental concern in agriculture includes rules on manure storage capacity. It also includes minimum shares of land under vegetative cover during autumn or winter (so called green land).

The Swedish Board of Agriculture rules and general guidance on environmental concern in agriculture includes rules on covering of slurry stores and filling of stores under a cover, rules on spreading area and other aspects of spreading, restrictions on applied quantities of manure, as well as detailed rules on green land.

Storage of manure

If manure is to be spread at times during the year when the fertilization effect is high and the risk of plant nutrient losses is low, it must be possible to store it properly. Manure shall be stored in a way that minimises the risk of contamination of surface and ground water. This means that the storage must be designed in a way that prevents runoff or leaching to surrounding areas. Rainwater that runs off from manure facilities counts as manure or as contaminated water, and must be collected and stored.

For all agricultural enterprises with more than ten livestock units, there are requirements regarding manure storage capacity. In the nitrate vulnerable zones, storage capacity requirements apply to all enterprises with more than two livestock units. An enterprise shall be able to store manure for at least six to ten months before spreading, depending on which part of the country is concerned and what species the manure comes from.



Covering and filling of slurry stores

There may be large losses of ammonia when manure is stored. Such losses can be minimised if the air directly above the slurry store is prevented from circulating. A method that efficiently reduces ammonia losses is to cover the slurry stores with, for instance, a roof, a floating plastic cover or a stable natural crust. If the slurry store is filled underneath the cover, this can be kept intact even during filling, which reduces the risk of ammonia emission. In the south of Sweden, and in parts of the plains in central Sweden, special requirements regarding the filling and covering of slurry stores apply to agricultural enterprises that keep livestock.

Restrictions on applied quantities of manure and fertiliser

For environmental reasons, there are restrictions on how much manure and fertiliser that may be applied per hectare land. The requirement regarding land available for spreading manure is there in order to avoid plant nutrient losses to lakes, watercourses and the sea from excessive spreading.

The spreading of manure and other organic fertilisers is limited by its content of phosphorus. The supply of phosphorus from manure and organic fertilisers may not exceed 22 kg per hectare available land, counted as a five-year average.

Within nitrate vulnerable zones, there are also regulations limiting the application of manure based on its content of nitrogen. Within these areas, manure may not be applied in quantities larger than the equivalent of 170 kg nitrogen per hectare available land and year. Within areas identified as vulnerable, the supply of nitrogen via manure and fertilisers may not exceed the quantities considered necessary for the crop in the site in question.

Spreading of fertilisers

The rules on precautionary measures when spreading fertilisers are not the same in all parts of Sweden. In the nitrate vulnerable zones, the rules are more far-reaching than in the rest of the country. There are also specific rules which only apply in the counties of Blekinge, Skåne and Halland.

Mineral fertilisers based on urea that is spread on bare soil shall always be incorporated into the soil within four hours of the spreading. The purpose of this rule is to minimise ammonia losses during spreading, and applies in all of Sweden.

Outside the areas identified as vulnerable, manure and organic fertilisers that are spread during the period 1 December – 28 February, shall be incorporated into the soil within 12 hours.

In the counties of Blekinge, Skåne and Halland, manure that are spread on bare soil shall be incorporated into the soil within four hours. This applies during the entire year.

As regards the nitrate vulnerable zones, the following precautionary measures apply:

- Fertilisers may not be spread on water-saturated or flooded ground.
- Fertilisers may not be spread on frozen or snow-covered ground.
- Fertilisers may not be spread on agricultural land closer than two meters from an edge adjacent to a watercourse or a lake. Fertilisers may not be spread on agricultural land adjacent to a watercourse or a lake where the slope exceeds 10 %. Manure provided from animals themselves when outdoors should not be counted in the term spreading.
- No fertilisers may be spread during the period 1 November – 28 February.
- During the period 1 August – 31 October, manure and other organic fertilisers may only be spread on growing crops or before autumn sowing. Spreading in catch crops is not allowed.
- Solid manure (except from poultry) may however be spread on bare soil during the period 1 October – 31 October, even if the land is not about to be sown.
- Solid manure spread on bare soil during the period 1 October – 31 October shall be incorporated into the soil within four hours in the areas identified as vulnerable within the counties of Blekinge, Skåne and Halland. For other areas identified as vulnerable, rules apply that solid manure spread on bare soil shall be incorporated into the soil within 12 hours during this time period.



Photo: Per G Norén

Spreading liquid manure in growing crops

The largest part of ammonia losses due to the spreading of manure takes place in the first hours after spreading. This means that if the manure is quickly incorporated into the soil or placed directly into the ground, the losses are efficiently reduced.

However, when spreading takes place in growing crops, it is not always possible to incorporate the manure into the soil. In the counties of Blekinge, Skåne and Halland, the spreading of liquid manure in growing crops shall be carried out using a technology that efficiently reduces ammonia losses. Spreading in growing crops shall be carried out using one of the following options:

- A method that places the manure directly on the ground underneath the green cover, for instance band spreading.
- Liquid manure drill or a similar method that places the manure directly into the ground.
- Any method that dilutes the manure with water before spreading (1 part manure and at least 1/2 part water).
- Spreading followed by irrigation supplying at least 10 mm of water. The supply of water shall begin no later than four hours, and be completed within 12 hours, after the spreading began. Rain counts towards fulfilment of the 10 mm requirement.

Rules concerning land under vegetative cover in the autumn and winter

An efficient way of reducing plant nutrient losses from arable land during the autumn and winter is to keep the land under vegetative cover (green land) during this period, particularly in areas with light soils and gentle climate. In the counties of Blekinge, Skåne and Halland, the rules state that 60 per cent of arable land shall be under vegetative cover during the autumn and winter. In the rest of southern Sweden, the requirement is 50 per cent.

There are rules about when certain crops must be sown and ploughed up in order for the area to be considered as being under vegetative cover during the autumn and winter.

Financial instruments

Within the Swedish Rural Development Programme it is possible to get financial support for measures reducing plant nutrient losses from agriculture. The current Rural Development Programme applies for the period 2007-2013 and establishment of the 2014-2020 programme is in progress. Agri-Environmental payments in the Rural Development Programme 2007-2013 to reduce plant nutrient losses apply to:

- environment protection measures (crop production plan, nutrient balance, soil mapping, determination of nitrogen content in liquid manure),
- reduced nitrogen leaching (catch crops, spring tillage),
- riparian strips,
- wetlands,
- cultivated grasslands.

It is also possible to get financial support for measures within what is called selected environment, consisting of custom riparian strips, controlled drainage, phosphorus retaining ponds and establishment/restoration of wetlands.

Environment protection measures, such as nutrient balances and determination of nitrogen content in liquid manure, help to adjust application of fertilisers after crop need and reduce the risk of plant nutrient losses.

In order to reduce nitrogen leaching during the period from October to March, support is granted for the sowing of catch crops, and for spring tillage. A catch crop has its main growing period between two main crops, and is grown so that it can take up the plant nutrients left in the soil after harvest, that may otherwise be lost by leaching. Farmers can also receive support if they chose to till their fields in the spring, when the risk of nutrient leaching is lower than in the autumn.

The purpose of riparian strips is to reduce the erosion of plant nutrients, primarily phosphorus, from arable land to water. The riparian strip shall be sown with grass and be at least six meters wide counted from the watercourse.

Custom riparian strips, sown with grass, can be created around wells or in depressions on the arable land. The purpose is to reduce surface runoff of phosphorus.



Wetlands and ponds may act as nitrogen and phosphorus traps, and are important for the reduction of the negative effects associated with plant nutrient leaching. They may also be significant for biodiversity in the landscape.

Controlled drainage makes it possible for the farmer to raise or lower the ground water level on the arable land, by the use of installed wells. By this, the runoff from the arable land can be controlled, which helps to reduce the amount of nitrogen lost to lakes, seas and watercourses.

Establishment of ponds adjacent to watercourses or ditches in the agricultural landscape can retain phosphorus and thereby improve the water quality. The idea is that sediment from the ponds is to be collected to recirculate phosphorus back to arable land.

Cultivated grasslands contribute to reduced plant nutrient losses and erosion from arable land.

Extension services and information

Extension services

Extension services and information are important tools for achieving an improved plant nutrient management and to reduce the negative impact on environment. An advantage with extension services is that the measures brought up can be adapted to local conditions and circumstances on the individual farm.

The Board of Agriculture employs plant nutrient advisors in Alnarp, Skara, Linköping and Uppsala. The regional offices coordinate advisory service in their respective parts of Sweden. They work to ensure that actions to reduce plant nutrient losses from agriculture are implemented efficiently. This means that regional activities in the area of plant nutrients shall be run in a way that:

- adapts the use of plant nutrients to need, as regards cultivation,
- adapts feeding to needs,
- ensures that mineral fertilisers and manure are spread in a way that makes optimal use of the plant nutrients and avoids negative effects on the environment,
- stimulates the use of cropping systems and cropping techniques that combine financial profitability with minimal environmental effects,
- minimises ammonia losses from agriculture.

Regional advisors shall spread information about results from research and trials in the area of plant nutrients to the operators in the region, as well as other important information (like legislation). Furthermore, they shall support other advisors in their work, and take part in various regional projects and studies within their special fields.



Focus on Nutrients

Focus on Nutrients (Greppa Näringen) offers advice, free of charge for farmers, and is a joint venture between The Swedish Board of Agriculture, The Federation of Swedish Farmers and The County Administration Boards. The purpose with Focus on Nutrients is to provide farmers and advisors with inspiration and motivation to improve profitability on the farm, and reduce its negative impact on the environment. Through Focus on Nutrients, agriculture is to contribute to the fulfilment of the Environmental Quality Objectives *Zero Eutrophication, A Non-Toxic Environment, and Reduced Climate Impact*.

Advisory service within Focus on Nutrients is procured by The County Administration Boards and provided by a variety of advisory firms. Farmers can choose between about 30 different advisory visits, which are divided by theme into “advice modules”.

At the initial advisory visit on the farm, the farmer and the advisor discuss the need of additional counselling and establish a nutrient balance for the farm. The nutrient balance shows the farm’s starting position, and it is followed up one or several times during future visits. The farmer also receives a plan for the continuation of advisory visits, based on his or hers own interests and the needs of the individual farm.

After seven advisory visits it is time for a follow-up, where the farmer and the advisor establish a new nutrient balance and evaluate actions carried out in different areas on the farm. If needed, a plan for a continuation of advisory visits is established. Focus on Nutrients emphasises that the advisor should make repeated farm visits and return to follow up changes and the progress on each farm

More information can be found on the webpage www.greppa.nu. The webpage contains several interactive services where farmers and other interested can use a tool for valuation of manure and calculate the optimal application of nitrogen. Members can also calculate a plant nutrient balance for the own farm.



Photo: Ingela Toth

Information material

On a regular basis, the Board of Agriculture produces brochures and other information material concerning plant nutrients and manure. Several reports are published that are used as a basis for extension services and for monitoring compliance with the environmental legislation. Brochures and reports can be ordered from the Board of Agriculture's webpage www.jordbruksverket.se. Some of the material is available as pdf-files directly on the webpage.

Furthermore, the Board of Agriculture has designed computer software as an aid for plant nutrient extension services focused on environmental issues. This software is called Cofoten (previously STANK in MIND), and can for instance be used for evaluating how various ways of handling manure affect the use of the plant nutrient content, or for calculating plant nutrient balances at the farm.

Research and development

The Board of Agriculture allocates funds to research and development (R&D) for reduced plant nutrient losses. These activities include both cropping and technical development within the fields of agriculture and horticulture. The purpose is to reduce plant nutrient losses from agricultural land to surrounding water, as well as to reduce ammonia losses from agriculture through improved handling of manure.

Results from research and development form an important basis for the design and selection of measures and instruments for reduced plant nutrient losses.



Are the measures effective?

Evaluations and follow-ups are important tools to see if measures to reduce plant nutrient losses are effective.

Many factors influence the size of plant nutrient losses from agricultural land. Soil type and slope, choice of crops, the number of animals on the farm, the amount of fertiliser applied on the fields and cultivation of catch crops are some examples. Because of this, data used in follow-ups and evaluations includes i.e. cropped area, livestock numbers, fertiliser sales and participation rates in environmental schemes.

This makes it possible to see if changes in plant nutrient losses from agricultural land are caused by changes in influencing factors, or if it is a result of specific measures directly targeted at reducing the nutrient losses.

Statistics Sweden provides a lot of information about agriculture. Every other year, they carry out a survey about the handling of fertilisers in agriculture. The study presents data on spreading and storing of manure, and the use of mineral fertilisers. The report can be found at the webpage www.scb.se.

The environmental quality objectives are also evaluated, and follow-ups are carried out to examine the effects of different measures. The objective *Zero Eutrophication* is followed up with the help of seven different indicators, such as total area of catch crop cultivation, spring tillage and riparian strips. Model calculations are an important part of the evaluation and are also used to obtain data for reporting to HELCOM. Model calculations are made concerning total nitrogen and phosphorus load from all sources to the sea, and total nutrient loss from agriculture is calculated.

The past few years have seen a reduction in plant nutrient losses from agriculture. Part of this reduction is due to changes in influencing factors. The total cropped area has decreased which have led to reduced plant nutrient losses. The total livestock number has also decreased which have contributed to reduced ammonia emissions from agriculture.

The reduction in plant nutrient losses from agriculture can also be attributed to effects of actions to reduce nitrogen leaching and phosphorus losses. Examples of contributing actions are results from the advisory service Focus on Nutrients and the establishment of wetlands. Cultivation of catch crops and the practice of spring tillage have led to reduced plant nutrient losses from agricultural land. The establishment of riparian strips with grass covered ground next to watercourses has increased during the past few years and this measure reduces the transport of plant nutrients to water. Measures to improve handling of manure have contributed to reduced ammonia emissions.

Can any improvement be seen in the state of the environment?

The state of the environment and changes to it are monitored within national monitoring programmes. There are monitoring programmes for groundwater, lakes, watercourses and seas. To a certain extent, these programmes can be used for obtaining information about the effects of measures taken within agriculture.

Within the environmental monitoring programme, there are special programmes directly aimed at monitoring agriculture's effect on water quality. These programmes are called "typical areas" and "observation fields". Typical areas consist of small catchment areas dominated by agriculture, where samples are taken from run-off water and in groundwater close to the surface. Observation fields consist of arable land in the ordinary crop rotation of individual farmers. Samples are taken of drainage water and groundwater close to the surface. The Swedish University of Agricultural Sciences is responsible for coordinating and presenting the results of the programmes. More information can be found at www.slu.se.

Deposition of airborne nitrogen compounds is monitored within the national environmental monitoring programme. Assessments of air chemistry are made through monitoring stations that are part of the so-called Swedish Precipitation Chemistry Network, and through stations that are part of a European network. The IVL Swedish Environmental Research Institute is responsible, and the result can be found on their webpage www.ivl.se.

Follow-ups and evaluations show that the measures to reduce plant nutrient losses so far implemented in agriculture have had the intended effect. Plant nutrient losses from agriculture have decreased and it is possible to detect the result in the environment. A study ¹ from the Swedish University of Agricultural Sciences show significant downward trends in both concentration and transport of nitrogen and phosphorus in a sample of 65 small watercourses in the southern and central Sweden. The watercourses are situated in predominantly agricultural areas with minimal impact from other human sources. The decrease of nutrients has been greatest in regions where the measures against plant nutrient losses from agriculture have been most extensive. It is however not possible to see any real improvements in the state of the environment when it comes to eutrophication of our surrounding coasts and seas.



A reduction in plant nutrient losses from agriculture is detectable at an earlier state in watercourses surrounded by agricultural land. As the water is transported towards the sea, nutrients released from the ground, lakes and watercourses are added. The natural background leaching of nutrients occurring from all land contributes to a large part of the total amount of nutrients transported with water through the landscape. In addition to this, the sea also receives nutrients from other anthropogenic sources, such as industries and sewage plants. The levels of nutrients in the sea are also influenced by the amount of nitrogen fixated by cyanobacteria (blue-green algae) and release of phosphorus from oxygen depleted seabeds. As a consequence of this, changes in nutrient losses from land based sources, such as agriculture, are less distinct in coastal and sea water than in watercourses on land.

The decreased levels of nitrogen and phosphorus in watercourses demonstrate that efforts within agriculture aiming to reduce nutrient losses are effective. Further actions within agriculture are needed to ensure that the positive trend with reduced plant nutrient losses continues.

¹ Fölster, Kyllmar, Wallin, Hellgren (2012) Käve- och fosfortrender i jordbruksvattendrag. Har åtgärderna gett effekt? Institutionen för vatten och miljö, SLU. Rapport 2012:1.



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