

## Description of measures on priority list

### 1. Promoting long-term grass cultivation of arable land

**Cultivation of grass or legume/grass crops** on arable land with high/low inputs of nitrogen (N) and phosphorus (P) and high/low outputs of feed, food or other services can reduce nitrogen and phosphorus leaching and surface run-off losses as well as soil erosion, compared with annual crops on arable land.

Crop rotations including **permanent grass or legume/grass crops** can decrease N leaching with 50%, compared with crop rotations dominated by annual crops.

### 2. Vegetative cover in autumn and winter of arable land

**Annual winter crops**, such as winter wheat or winter rape, can provide a vegetative cover that actively takes up available nitrogen and phosphorus from the soil more efficient than annual spring crops at a seasonal period with high precipitation and cool climate.

**Catch crops** can be under-sown in the main crop, simultaneously with, or just after the sowing of this crop. When the main crop is harvested, the catch crop has an established root system ready to take up nitrogen from the soil during late summer and autumn. Nitrogen that otherwise could have been leached is then taken up and incorporated into plant material. The catch crop is then ploughed-in as late as possible in autumn or in spring. Perennial ryegrass (*Lolium perenne* L.) as a catch crop is an effective measure to reduce N leaching in spring cereal crop production. The use of catch crops has reduced N leaching by 50% or more in several studies. The effect of the catch crop on N leaching depends on precipitation and drainage conditions, available N amounts in soil and how successful the establishment of the catch crop was.

### 3. Soil tillage management

**3.1. Reducing soil tillage** by conversion from ploughing to minimal or no cultivation management systems or conversion from deep ploughing to shallow ploughing can reduce mineralization of organic matter in soil. Type of techniques can be, i.e. using discs or tines to cultivate the soil, or direct drill into stubbles (no-till).

**3.2 Time-of the year effects.** By postpone tillage actions from autumn to spring, the mineralized nitrogen will be available for uptake by the established spring crops, which also will provide surface cover.

### 4. Fertilisation management.

#### 4.1. Adapting amounts applied for both chemical and organic fertilisers.

Animal density is a tool to express the number and type of animals kept at the farm in relation to the arable area available for spreading their manure. The tool is used to balance amounts of produced N and P in manure to available spreading area at the farm in order to avoid surplus application of N and P with manure.

Considering crop requirements of N and P in the fertilising plan is a prerequisite for avoiding excessive applications. Nitrogen and P content in manure shall be considered in the fertiliser plan in order to adapt the need of chemical fertilizers and avoid excessive applications.

Sampling and analysing N and P in manure gives information of the N and P concentration and the distribution of plant available-N and organic-N. Then the effect of the manure can be valued in the fertilising plan. Manure characteristics can vary a lot. Liquid manure is a general term that denotes any manure from housed livestock that flows under gravity and can be pumped. Liquid manure can have a high proportion of plant available N ( $\text{NH}_4\text{-N} + \text{NH}_3\text{-N}$ ) of total-N content. Solid manure is a general term that denotes any manure from housed livestock with large amounts of bedding that does not flow under gravity, cannot be pumped but can be stacked in a heap. Solid manure can have a high proportion of organic-N of total-N content.

Sampling and analysing N and P in arable soil gives information of soil fertility concerning these nutrients, which should be considered in the fertilising plan in order to avoid excessive fertilizer applications or deteriorated soil fertility.

#### **4.2. Calculating nutrient balances on farm- and/or field level**

Calculating N and P inputs/outputs and balances on farm and/or field level is a performance tool and a policy tool for assessing the environmental impact. The tool can also be used to monitor and evaluate the impacts of alternative manure and chemical fertilizer management practices and technologies on N and P use at the farm. When farm N and P balances can be linked to within-farm N and P sources and flows, there is a good possibility to identify the weakest link and possible improvements on the farm. The tool can be used to assess the risk of ammonia losses from manure management and the risk of N leaching losses to water.

#### **4.3. Avoiding the spreading of chemical fertilizers and manure during high-risk periods.**

The timing of chemical fertilizer and manure application is a key factor to have a high plant nutrient use efficiency. Poor timing is one of the most important sources of large N leaching loads.

#### **4.4. No or reduced P-fertiliser for high soil P fields or part of fields.**

When the soil P values increase beyond agronomical optimum ranges, there is a reasonable consistence pattern whereby P leaching increase significantly. However, P leaching has large spatial and temporal variations and can be influenced by several factors interacting with each other. It is therefore important to consider site-specific factors to be able to find measures to reduce P leaching.

### **5. Improved spreading technology of manure and chemical fertiliser**

**5.1 Site-specific dosage.** In all fertiliser application, the use of **Global Positioning System** (GPS) signals for the purpose of determining the device's current location on earth can improve the possibilities for a controlled and proper distribution. GPS devices provide latitude and longitude information, and some may also calculate altitude. GPS in combination with **steering aid systems** means that the fertiliser can be spread with a minimum of bare spots and overlaps. The simpler variant of the steering aid system is called **guidance**, where a ramp with a series of LEDs shows

whether the driver is located right on line or if he should adjust to the right or left.

**Auto steer** is an automated steering system where the driver does not need to actively steer the vehicle except perhaps in curves or when turning. With the use of GPS technology, it is also possible to map different properties in the field, and later on use this information e.g. for **site specific spreading** of fertilisers.

**5.2 Combined drilling** is when seeding and fertilisation is done with one and the same machine in one working operation. A drilling machine with normal distance between the drill coulters is equipped with coulters for chemical fertilisers placed in front of the drill coulters between every other row. Fertiliser coulters are placing chemical fertiliser a few centimetres deeper than the seeds.

Chemical fertiliser placed at this depth, provides good conditions for the crop to take up the added nutrients. This procedure is, in addition to time savings and a better nutrient utilization, reducing competition for plant nutrients from weeds and reduces the risk of nutrient surface runoff. Phosphorus in fertilizers binds quickly to soil particles and is thus less exposed to leaching.

The recommended nitrogen ration at a given harvest level can be reduced by 10 kg N / ha, if combined drilling is applied (Albertsson, 2010). Leaching will probably be reduced by 1-2 kg N/ha compared with other fertilization techniques.

**5.3 Incorporation** of manure and chemical fertiliser may be achieved with equipments such as discs or cultivators depending on soil type and soil conditions. Usually the incorporation is done in a separate working operation. The manure/ chemical fertiliser must be completely incorporated within the soil to achieve maximum efficiency. As regards liquid manure, incorporation should be made quickly after spreading as ammonia losses takes place immediately after spreading.

This method will help to prevent the exposure of manure to the surface runoff and drain-flow losses. It will also increase the utilisation of manure nutrients compared with surface application.

**5.4 Liquid manure.** Distribution uniformity of liquid manure has improved significantly with the introduction of **band spreading** technology, where the manure is discharged just above ground level in strips or bands through a series of hanging or trailing pipes attached to a boom. As the liquid manure is distributed laterally via a ramp, good lateral distribution uniformity is achieved. The spread in the longitudinal direction can also be kept at a constant level by means of the pumping equipment which is part of the equipage. Some newer spreaders are also equipped with a **control system** that automatically adjusts the output to the driving speed, which will keep the application rate to the desired level.

**Injection** of liquid manure means that it is applied directly into the active layer of soil, either in open or in closed slots. In the latter case manure is fully covered after injection, by closing the slots with press wheels or rollers fitted behind the injection tines. Closed-slot injection is more efficient than open-slot for decreasing the ammonia emission. To obtain this added benefit, soil type and conditions must allow effective closure of the slot.

**5.5 Solid manure.** In solid manure handling, **disintegration equipment** has been developed that breaks the manure better and gives greater working width and more

uniform spreading laterally. Distribution of solid manure in the longitudinal direction and opportunities to set the intended application rate still leaves much to be desired.

**5.6 Manure spreading and NH<sub>3</sub> emissions – general measures.** Variables significantly affecting NH<sub>3</sub> emissions after spreading of manure are soil water content, air temperature, wind speed, manure type, dry matter content of manure, total ammoniacal nitrogen content of manure (TAN=NH<sub>3</sub>-N+NH<sub>4</sub>-N), application method and rate and manure incorporation. Losses of NH<sub>3</sub> can vary between 3 to 90% of the NH<sub>4</sub>-N applied with manure.

## **6. Avoiding the application of chemical fertilisers and manure to high-risk areas**

Examples of high risk areas on arable land are those: with a significant slope, with flushes draining to a nearby watercourse, soils with cracks over field drains, fields adjacent to water or fields with phosphorus values beyond agronomical optimum ranges.

## **7. Measures to optimize soil pH and improve soil structure**

Measures to improve soil fertility and soil structure can increase the crop's plant nutrient use efficiency and decrease the risk of N and P leaching and surface run-off. Such measures can be liming for improved soil structure or liming for optimizing soil pH.

## **8. Adapted feeding**

### **8.1 Adopting phase feeding of livestock**

Livestock at different growth stages or stages of the reproductive cycle have different optimum nutritional requirements. Greater division and grouping of livestock on the basis of their feed requirements allows more precise formulation of individual rations. This increases the animal's nutrient use efficiency and results in reduced excreted amounts of nitrogen and phosphorus in fresh animal faeces and urine.

### **8.2 Reducing dietary nitrogen and phosphorus intakes**

Farm animals are often fed diets with higher than recommended contents of nitrogen and phosphorus as a safeguard against a loss of production arising from a deficit of these nutrients. A surplus intake of nitrogen and phosphorus is not utilised by the animal and is excreted with faeces and urine, leading to a larger N and P content in the manure. Therefore a ratio balancing of nutrients in feed is a key factor to both ensure animal health and production requirements and minimizing adverse environmental impacts. To improve nutrient use efficiency purchased as well as home-produced feed components need careful management and analysis of nutrient content and dietary value.

### **8.3 Phytase supplementation**

Supplementation of synthetic phytase to pig feed reduces the need for the addition of mineral phosphate. Phytase increases the availability of phosphorus in the feed and allows total phosphorus contents to be reduced without affecting productivity. With the addition of phytase the phosphorus content of the feed can be reduced by up to 30% for pig feed.

## 8.4 Wet feed and fermentation

Endogenous phytase in grain can be activated by wetting the pig feed some time before feeding thereby reducing or even eliminating the need for mineral phosphorus supplementation. This means that pig production with wet feed systems should be able to utilise feed with lower phosphorus content than normally recommended.

Fermentation of the feed can reduce the need for mineral phosphate supplementation. Fermentation occurs naturally in wet feed after a certain amount of time. The fermentation process is difficult to manage and the method is still to be developed.

## 9. Reducing ammonia losses in stable

Key emissions to air from animal housing emissions are ammonia (NH<sub>3</sub>), odor and dust. The level and variation of ammonia emissions from animal housing are determined by many factors, which also interact. Factors influencing ammonia emissions from animal housing are:

- Increased nitrogen use efficiency.
- Decreased emitting areas with manure in the stable.
- Avoiding high temperature in stable and manure
- Adapting airflows along manure surfaces.
- Use and choice of bedding material.

## 10. Storage of manures

Adequate collection and storage facilities provide the possibility to choose a time to apply manure to fields when the crops can utilize N and P and there will be fewer occasions when lack of capacity forces the farmer to spread manure at unsuitable times.

Manure storage must be of such a quality that it prevents N, P and manure losses. The main influencing factors on the ammonia losses from storages are manure properties (pH, dry matter content) temperature and wind conditions, filling technology, storage time, and for liquid manure storage ratio surface: volume, crust formation and mixing methodology.

Ammonia losses can be sharply reduced if the air directly above the liquid manure store is prevented from circulating. A method that efficiently reduces NH<sub>3</sub> losses is to cover the liquid manure stores with, for instance, a roof, a floating plastic cover or a stable natural crust. If the liquid manure storage is filled underneath the cover, this can be kept intact even during filling, which reduces the risk of NH<sub>3</sub> losses.

From storages with solid manure, especially if composting take place with high temperatures, NH<sub>3</sub> losses could be high. Peat included in the bedding material will reduce NH<sub>3</sub> losses during storage. Roofs on solid manure storages could be an effective measure to reduce ammonia losses from solid manure storages. Additionally, a roof keeps rainwater away, which could prevent nutrient leakage from the manure pad if it has insufficient or lacking drainage leading to a collection pit.

## 11. Constructed wetlands for nutrient reduction/retention

### 11.1 Sedimentation ponds

Small surface flow wetlands designed primarily to retain phosphorous. This is achieved by retaining eroded phosphorous bound to aggregates and particulate

materials in the run-off water by optimizing the conditions for sedimentation processes. To some extent phosphorous and other nutrients are reduced due to biological and chemical decomposition and transformation processes as well as plant uptake.

A sedimentation pond is suitable for establishment in highly intensive small-scale agricultural areas. The ponds are relatively small representing approximately 0.1 – 0.5 % of the run-off area. The sedimentation pond is constructed for instance by widening a section in a ditch into a sedimentation pond slowing down the speed of the run-off water hence increasing sedimentation.

A sedimentation pond is often designed as a serial combination of (i) a sedimentation basin with a water depth of 1-1.5 m representing 20-30% of the total area of the sedimentation pond where the main sedimentation of larger particles takes place, followed by (ii) a wetland filter covered with typical wetland plants providing good conditions for sedimentation of smaller particles. In case the area is highly sloped it is suitable to include an overflow area followed by a second wetland filter prior to the outlet to further induce the sedimentation efficiency.

The accumulated sediments in the sedimentation basin need to be removed on regular basis for maintenance.

## **11.2 Constructed wetlands**

Large free water surface wetlands are designed and constructed primarily for removal of nutrients, e.g. nitrogen and phosphorous and other pollutants from run-off water through sedimentation, biological and chemical transformation and degradation and plant uptake. Constructed wetlands have additional benefits, i.e. improved biodiversity, water storage capacity, resource recovery, irrigation possibilities and production of crop biomass.

Constructed wetlands are established, or re-established, to receive water from large run-off areas in arable as well as agricultural areas. The run-off area should be represented by at least 50 percent intensive agricultural land use with the constructed wetland covering approximately 0.5–4 % of the total run-off area.

An important characteristic is the establishment of typical emerges and submerges wetland vegetation. A constructed wetland provides heterogenic water regimes and environments. It is common with a mixture of areas with (i) permanently high water level, more or less covered with typical wetland vegetation, as well as (ii) periodically waterlogged areas with low water level. The water regime can also vary over the year.

## **12. Buffer-zones along water areas and erosion sensitive field areas**

Buffer zones are uncultivated areas between fields and water courses, main ditches, ponds, lakes or gulfs. Buffer zones are also to be implemented in erosion sensitive field areas such as around surface water wells or surrounding field areas with high ground water levels.

Buffer zones reduce the speed of water surface run-off mitigating losses of eroded aggregates, soil particles, and particulate phosphorous and other soil borne pollutants. They also decrease the risk of freshly spread manure and pesticides to reach the water environment. Buffer zones are an especially important measure in

areas with eroding problems. Buffer zones also provide conditions for biological and chemical transformation of pollutions as well as plant uptake.

The buffer zones are under permanent plant cover of dense grass or vegetation. Buffer zones are situated on former agricultural land and have a width of 5-20 m. They are not allowed to be cultivated, fertilized or sprayed with herbicides or pesticides. The vegetation should be kept dense and plants should be established if needed for maintenance.