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Revised Palette of measures for reducing phosphorus and nitrogen losses from agriculture

This document is a part of the

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and was endorsed by the 2013 HELCOM Ministerial Meeting

HELCOM

Baltic Marine Environment Protection Commission

REVISED LIST OF EXAMPLES (PALETTE) OF MEASURES
FOR REDUCING PHOSPHORUS AND NITROGEN LOSSES FROM AGRICULTURE

The document is based on the original "Examples of measures for reducing phosphorus and nitrogen losses from agriculture" adopted by the HELCOM Ministerial Meeting held in Krakow, Poland on 15 November 2007 and is updated with relevant regional and European experience and knowledge on application of agri-environmental measures the Baltic Sea catchment.

It is intended to support implementation of part II Annex III of the 1992 Helsinki Convention Helsinki Convention "Criteria and measures concerning the prevention of pollution from land-based sources".

The Palette contains technical, managerial and legislative measures, based on best available knowledge and sought to help in implementation of the aforementioned provisions through e.g. review and further implementation of programmes for river basin management.

Application of measures and their relative cost-efficiency is often case-specific and is subject to national considerations when selecting specific measures for application.

The Palette will be reviewed by the expert community within HELCOM Baltic Agriculture and Environment Forum to reflect changes and development of those measures, including new knowledge when it becomes available.

The Palette was compiled on the basis of the following main materials:

1. *EU JRC Report on Pilot River Basins Network On Agricultural Issues (2008-2009): Sharing experiences and views*
2. *Comparative Study of Pressures and Measures in the Major River Basin Management Plans*
3. *Practical Experiences and Knowledge Exchange in Support of the WFD Implementation (2010-2012), River Basin Network on Water Framework Directive and Agriculture, JRC Scientific and Policy Reports, Report EUR25790EN (2013)*
4. *Guidance for administrations on making WFD agricultural measures clear and transparent at farm level, DG ENV, D.1 - Water (adopted by EU Water Directors in 2011)*
5. *Implementation and status of priority measures to reduce nitrogen and phosphorus leakage – Summary of country reports, Baltic COMPASS Report, 2012*
6. *Agri-environmental measures in the Baltic Sea Region: Advisory services, legislation & best practices, Baltic DEAL Project, 2011*

Relevant pages of the above major references will be referred to under specific measures

The full list of reference is included at the end of the document

Briefs of application/effectiveness of measures

A. Soil management

a. Plant cover in winter

Plant cover in winter will reduce nitrogen and phosphorus leaching and soil erosion.

Effectiveness and applicability/suitability

Without the plant cover in winter, nitrate can be lost through leaching by excess winter rainfall and phosphorus through sediment transport in surface runoff. Plant cover in winter protects the topsoil of the fields against the erosive forces of rain, melt and runoff waters during winter. Furthermore, it helps to improve the soil structure by increasing the amount of organic matter in the topsoil of the fields which decreases the topsoil's susceptibility to silting. Plant cover in winter can reduce erosion 10-40% and nitrate leaching 10-70%. However, in areas where water is less abundant it has to be taken into account that a winter cover may reduce the soil water available for the main crop.

The method is relatively easy to implement. The costs of this method depend on the chosen plant, area, local climatic water balance and the possibility to use the farmer's own machinery or contractor.

Reference

- European: (43), pp.22-23, 211-225
- Baltic: (40), p.24

b. Minimal cultivation systems

Using discs or tines to cultivate the soil or direct drill into stubbles (no-till) will maintain organic matter and preserve good soil structure. This will improve infiltration and retention of water and thereby decrease total phosphorus concentrations in surface runoff.

Effectiveness and applicability/suitability

Conversion from ploughing to minimal or no cultivation systems will decrease phosphorus in surface runoff. When using minimal cultivation systems the phosphorus storage concentrates in the shallow topsoil and that can in the long term increase the amount of dissolved phosphorus especially on the steep slopes with high phosphorus content. Buffer zones and more accurate phosphorus fertilisation should be used there. Nitrate leaching is generally decreased to a small extent through reduced mineralisation of organic matter in soil in the autumn.

The costs of this method depend on how it suits to the farm's crop rotation, how suitable the soils are for this method and whether it is profitable to use a contractor or purchase the machinery for the farm.

Reference

- European: (43), pp. 30-31, 253-259
- Baltic: (40), p.24

c. Cultivate land for crop establishment in spring rather than autumn

Autumn cultivation of land stimulates the mineralisation of nitrogen from organic matter reserves at a time when there is little nitrogen uptake by the crop, which will increase the potential for over-winter leaching losses. By cultivating in spring, there will be less opportunity for mineralised nitrogen to be leached and the nitrogen will be available for uptake by the established spring crops.

Effectiveness and applicability/suitability

Cultivation of soils results in mineralisation of organic nitrogen and increases the risk of nitrate leaching. The amount of mineralisation is strongly affected by soil temperature, moisture and nitrogen balance under the previous crop. Cultivation in spring is better, because bare soil is not exposed over the winter period and actively growing crop is established soon after cultivation to take up nitrogen and provide surface cover.

Land for spring crops, ploughed late in the autumn, has the winter for frost action and wetting and drying cycles to break down soil clods. Ploughing in the autumn also allows early establishment of the following spring crop. On medium to heavy soils if ploughing is not carried out in late autumn, the delayed cultivation may result in the spring crop being drilled into a drying seedbed. This may impact on establishment and yield.

Reference

- see above

d. Catch crops

Catch crops are fast-growing crops that are grown simultaneously with or between successive plantings of a main crop.

Effectiveness and applicability/suitability

Catch crops protect the surface of the soil and catch the extra nutrients. The longer the soil is covered with vegetation, the smaller is the nitrate leaching. Catch crops can also improve the soil structure and increase the amount of organic matter in the soil. According to a Finnish study undersowing of ryegrass with barley reduced nitrate leaching 27-68% depending on soil.

This method is relatively easy to implement. The costs of this method consist of buying the seeds, sowing and finishing the catch crop.

Reference

- European: (43), pp. 24-25, 226-234
- Baltic: (40), p.24

e. Ploughing of ley on sandy soils in autumn

The time for ploughing a ley is very important to nitrogen leaching. From a leaching point of view, it should be ploughed late in autumn instead of early in autumn. Spring ploughing is also good but nitrogen release from the large amounts of organic-N is often too late for crop demand and might instead be leached in the following autumn. However, ploughing in late autumn or in spring is not possible on many clay soils so this is a method for sandy soils.

Effectiveness and applicability/suitability

Because a lot of organic nitrogen is turned over into nitrate when ploughing a ley, leaching from ley ploughed early in autumn can be considerable, especially if the ley contains clover or if there is a lot of above-ground biomass. In such cases, an effective way to reduce leaching is to delay the ploughing of ley from early to late autumn. On clay soils effectiveness decreases as the clay content in the soil increases up to a limit where the clay content does not make it possible to employ late ploughing or ploughing in spring.

Costs

The single largest cost arises if ploughing is done so late in autumn that sowing of winterwheat is no longer possible. Ley is a good crop before winterwheat and often gives a larger yield of winterwheat compared to when cereals are cultivated before winterwheat. If this situation occurs, costs can be of importance but if the timing of ploughing of ley does not influence the choice of the next crop in the crop-rotation the cost is small.

Reference

- (35)

f. Controlled sub-surface drainage

In controlled sub-surface drainage, control structures are installed at the outlet of sub-surface drainage pipes at appropriate intervals depending on i.e. field slope. The control structures are used to regulate the water table in the field allowing both optimal lowering of the water level during spring tillage operations and planting and maintaining an optimal level in the root zone for the growing plants uptake of nutrients and water.

Controlled sub-surface drainage intensifies the drainage systems so that drainage waters from the arable areas can be efficiently utilised by the plants. If runoff of drainage waters is controlled and recirculated back to the arable area for irrigation, it enhances the effect of the measure.

Effectiveness and applicability/suitability

Controlled drainage has many potential benefits including reduction in water- and airborne nutrient losses (both N & P), improvement of soil condition and increase in yield, as well as enhance carbon storage capacity. The drainage waters can be recycled used for sub-surface irrigation which enhances the effect of the measure and enables optimal provision of water for the plants during the whole growing season even in less favourable soils.

Controlled subsurface drainage will prevent nutrient leaching with ditch waters from the arable areas into watercourses and return the nutrients dissolved in the water back to the plants' root zone. Controlling drainage waters has a potential to result in significant reductions in nutrient losses to the sea as by estimate half of the agricultural land in the Baltic Sea Region is drained and typically 50% of nitrogen and up to ~20% of phosphorus losses happen via drainage. Therefore controlled subsurface drainage can result in ca. 40% nitrate reduction or even higher if drainage waters are both controlled and recirculated

The cost will be covered best in the cultivation of special plants e.g. potato.

Reference

- (28), (58)

B. FERTILISER AND MANURE MANAGEMENT

a. Fertilization plans and Nutrient balances

A fertilization-plan is a tool to optimize the utilization of plant nutrients in manure at the farm. It will help the farmer to minimize the purchase of mineral fertilizer and reduce losses of nutrients to air and water and therefore benefit both the environment and the crop production economy. The fertilizer plan calculates the proper dosing of manure and mineral fertilizer for each farm field, as well as timing for fertilization to ensure maximum uptake of the nutrients by the different plants. The calculations are based on results from soil analyses for P, K and pH and comparison with optimum soil supply status derived from regionalized experimental calibration plots, analysis of nutrient concentrations in manure and norms for nutrient requirements of plants in the farm crop rotation plan. In the case of nitrogen deficits of mineral N in spring have to be filled up as well as an insufficient N-mineralization (which must be estimated according to moisture and temperature) during the vegetation period.

Nutrient balances at farm level will evaluate the efficiency of nutrient utilisation at the farm. The balance is the difference between all nutrients imported to the farm (e.g. seed, fertilizer, feed, livestock and nitrogen fixation by crops such as clover and peas) and all nutrients leaving the farm (e.g. livestock, meat, manure, crop products). It is important that nutrient balances are transparent (like a standard farmgate balance) and contain no hidden losses.

Various computerised tools are available for calculation of fertilization plans and nutrient balances (on farm or field level).

Effectiveness and applicability/suitability

Using nutrient balances, fertilization- and crop-rotation plans, as well as soil maps and N-mineralization assessments helps to reduce the excess nutrient application. It also ensures that the soil fertile state is known and additional fertilization can be adapted to it in order to maximise the efficient use of nutrients already in the soil. Improving the accuracy of the use of fertilisers on the basis of the crop, the yield and the characteristics of the parcel to the economic optimum will ensure that the necessary quantities of the essential crop nutrients are only available when required for uptake by the crop.

The nutrient balance will never be zero as nutrient losses are inevitable in farming, but repeated balances and comparison between years helps to evaluate and understand where in the farming practices and processes losses may occur. The balancing is a visualization of the nutrient efficiency at the farm and the improved nutrient efficiency resulting from measures taken. Farm nutrient balances can be used as a benchmarking to identify most efficiently managed farms and hence promote improvements at other farms.

This method is cost-effective. Nutrient losses are a direct measure of the principal problem, namely excessive nutrients in the environment. Farmers have the freedom to determine the most economical method of nutrient loss reduction. The use of this method will require standard data (NPK-values) for input and output factors (seed, feed, fertilizer, manure, and harvested products) investment in (preferably) on-line tools as well as education and guidance. Soil-mapping of P and K, as well as pH should be done at established intervals e.g. every 10 years or more frequently if farming practices change a lot. N-mineralization prognosis/monitoring should be made available at level of agro-regions with similar climatic conditions , e.g. by state agencies or farm-advisor organisations.

Reference

- Baltic: (40), p.26, (27), (42), (22)

b. Conversion from conventional to organic production

Minimum standards of organic production within the European Union are regulated by Council Regulation (EEC) No. 834/2007 and starting by 1 January 2009 by the Commission Regulation (EC) No 889/2008.

Effectiveness and applicability/suitability

Nutrient input in organic production aims at promoting and maintaining soil fertility rather than crop yield. Organic production aims at closed nutrient cycles. The need for efficient nutrient use is regularly higher, as no additional chemical fertilizers are allowed. Nutrient inputs in organic production are often lower than in conventional production, as well as crop yields. This requires a maximum adaptation of e.g. input manure-P to crop demands and soil-P-status, as well as the clever use of N-fixation crops in order to supply following crops with sufficient N levels. Timely manure spreading and ploughing of ley-crops is crucial to insure maximum nutrient efficiency and minimize nutrient losses to the environment.

Organic production systems have potentially increased costs due to more labour because of new management practices, mechanical or manual control of weeds, pests, and diseases (because chemical control is banned), as well as the generally lower production/yields level. Lower crop production levels and/or longer intervals for animal production means higher costs per unit produced. . The production costs from increased labour requirements and lower production intensity varies a lot and must be assessed in relation to other factors, particularly yield and price changes.

Reference

- (15), (19), (20), (44)

c. Reduced fertilisation

Reducing the amounts of nitrogen and phosphorus fertilisers by a certain percentage below the economic optimum will reduce the residual nitrate in the soil after harvest and in the short term the amount of soluble phosphorus. In the long term reducing phosphorus fertilisers can reduce the soil P-status and thereby the amount lost as particulate phosphorus. Recommendations for optimum fertilization each year are often released country-wise, based on regionalized standardizing field trials as well as economic optimum in relation to climatic conditions.

Effectiveness and applicability/suitability

There will be a reduction of residual soil nitrate available for leaching in the autumn but there will be no effect on the nitrate mineralised from soil organic matter. In the long run, when soil phosphorus reserves will be decreased there will be a reduction in soluble phosphorus loss.

This method will have an impact on crop yields and crop quality and therefore there could be a considerable resistance to the method. Reducing phosphorus fertilisers would impact immediately crops that are particularly responsive to phosphorus (e.g. potatoes and some vegetable crops). Reduction of nitrate fertilisers would have an immediate impact on all crops other than legumes.

Reference

- European: (43), pp. 18-19, 179-191
- Baltic: (40), p.26

d. Application techniques of manure

Decreasing of manure surface application and promoting new techniques which improve manure – soil - contact (e.g. injection techniques, acidification and mulching) will decrease leaching into the watercourses immediately. These methods will help to prevent reduce ammonia losses, as well as exposure of manure to the surface runoff and drain flow losses.

Effectiveness and applicability/suitability

By injecting the slurry it is possible to apply it directly into the active layer of soil. The slurry can be released into slots cut in the soil and then closing them after application. There are also direct ground injection systems in operation which work by the direct injection of pressurised slurry into the ground. The injection of slurry effectively increases the utilisation of manure nutrients compared with surface application. Acidification should be applied with precaution, as along with ammonia losses reduction it may lead to increased release of hydrogen sulphide (H_2S).

The additional cost is the biggest in the small farms. In the big farms the fixed costs will be divided by a bigger amount of manure and additional costs per tonne are smaller.

Reference

- European: (43), pp. 26-27, 235-244
- Baltic: (40), pp.27-29

e. Integration of fertiliser and manure nutrient supply

Using manure standards and analysis to calculate the amount of nutrients supplied by manure applications will help to determine the amount and ideal timing of additional fertilisers required by the crop. Taking better account of the nutrients in manure can reduce the fertiliser inputs and nitrate and phosphorus losses. Analysis of manure can be difficult for certain types of manure. There are new analysing techniques which can be installed on the slurry spreading tank for in-field analysis.However, manure nutrient content standards are a good alternative, already available in many countries (e.g. for EU Member States, in action programmes and codes of good agricultural practice developed under the EU Nitrates Directive.

Effectiveness and applicability/suitability

The method is effective when mineral fertilisers are used to top-up the nutrients supplied in manure. Mineral fertiliser applications should be used as a complement to utilization of manure nutrients as fertilizer. The adapted NPK-levels in mineral fertilizer can provide optimum economic production level and maintain adequate nutrient levels in the soils.

This method achieves savings rather than increasing costs. The use of this method will require regional or national manure standards available for farmers, and investment in education and guidance on how to calculate adequate rates. Application of specialised equipment, e.g. N-sensor will be also of help to calculate N fertilization to the plants needs and supply status and hence reduce overfertilisation.

Reference

- Baltic: (40), p.25, (11)

f. Liming

Both too acidic or too calcareous soils make plant nutrient uptake difficult. The optimal pH for phosphorus availability is around pH 6.5, while for sandy soils can be ranging between 5 and 6.With lower or higher pH, phosphorus is bound tightly to the soil particles and it will drift from the fields with runoff waters to the watercourses. On acid soils (low pH) it is possible to add lime in order to improve phosphorus availability and uptake by plants. Structural liming, and liming in new tile-drainage-systems has been used in recent years in both Sweden and Finland, in order to improve soil structure, and thereby root development and water infiltration, to increase crop-nutrient-uptake and prevent surface-runoff, and also to bind phosphorus to soil-particles in tile-drain-systems and avoid leaching.

Effectiveness and applicability/suitability

Liming helps to attain reasonable yields in acid soils with lower phosphorus fertiliser rates. Liming aims to ensure that phosphorus is utilised efficiently and thus to prevent nutrients from leaching into watercourses.

It may take 5 to 10 years after application to recover the cost of lime. The economics of lime use on rented land need special consideration. Profitability of liming on rented land is decreased and depends on the period of the rental agreement.

Reference

- European: (43), pp. 26-27, 235-244
- Baltic: (40), p.29, (38)

g. Avoiding the application of fertilisers and manure to high-risk areas

Not applying mineral fertilisers and manure at any time to high-risk areas helps to prevent the mobilisation and transfer of nitrate and phosphorus to the watercourses. Risk areas can be, for example, areas with flushes draining to a nearby watercourse, cracked soils over field drains or fields with high phosphorus values. Phosphorus risk areas can be estimated by using the phosphorus risk index or certain specified risk elements making in-field observations.

Effectiveness and applicability/suitability

Losses of phosphorus on eroded soil particles and by leaching are greatest on high phosphorus index soils. Applying manure to these areas will increase the excessive phosphorus content of the soil and increase the amounts lost. This method is most effective against losses of phosphorus where the primary mechanism of transport is surface runoff.

The cost of not applying fertilisers to high-risk areas would be in terms of avoiding a drop in production proportional to the lost yield. Not applying manure to high-risk areas will have no costs if land is available elsewhere on the farm. If there is a need for increased manure storage, there would be additional costs. The use of this method will entail costs related to development of P-index as well as education and guidance of farmers on how to identify high-risk areas by in-field observations.

Reference

- European: (43), pp. 20-21, 192-210
- Baltic: (40), p.29, (46)

h. Avoiding the spreading of fertilisers and manure during high-risk periods

Avoiding spreading mineral fertilisers or manure during high-risk periods reduces the availability of nitrate for loss through leaching and of phosphorus for loss in surface runoff. High-risk periods can be, for example, when there is a high risk of surface flow, rapid movement to field drains from wet soils or when there is little or no crop uptake.

Effectiveness and applicability/suitability

Surface runoff risk is the greatest when rain falls onto sloping ground with saturated (or packed), frozen or snow-covered soils. Rapid flow of nutrients through the soil is most likely to occur from drained (or cracked) soils when they are wet and rainfall follows soon after applying fertilisers. Avoiding the addition of nitrogen in the autumn reduces the amount of nitrates available for leaching by over-winter rainfall.

This method needs investments in storage facilities for all kinds of manure (slurry, farm-yard, urine etc.) to enable timely spreading and avoid high-risk periods. However there may be indirect opportunity cost if the high-risk periods coincide with crop development in spring.

Reference

- European: (43), pp. 20-21, 192-210
- Baltic: (40), p.27

i. Increasing the capacity of manure storage

Adequate collection and storage facilities provide first of all reduced leaching and evaporation of nutrients during manure storage, but also the possibility to choose when to apply manure to fields.

With enough capacity of the storage tank there will be few occasions when lack of capacity forces the farmer to spread manure at unsuitable times. Manure should be spread at times when there is an actively growing crop to maximize the nutrient uptake of plants from the manure, and when there is a low risk of runoff.

Effectiveness and applicability/suitability

If there is not enough storage capacity for manure the farmer has to spread it as it is produced. This will inevitably result in applications at times when uptake of the nutrients is not efficient and when there is a risk of nitrate leaching and phosphorus being transported to watercourses in surface runoff.

Safe storage facilities is fundamental to reduce nutrients leaching from all kind of manure, slurry and urine tanks, grounds for farm-yard manure etc. Costs for storage tanks, especially for liquid or mixed fractions, are usually high and should be facilitated through investment support to the farms. Promotion of new techniques, standards and developments, as well as adaptation to stricter environmental regulations should be prioritised.

Reference

- European: (43), pp. 28-29, 245-252
- Baltic: (40), p.31-32

j. Transporting manure to neighbouring farms

When a farm has a surplus of manure nutrients, additional spreading areas need to be found, or manure needs to be processed to other products. Export and use of excess manure at neighbouring farmland is a way to use the nutrient recourse in the manure to its full potential and at the same time reduce losses to water.

Effectiveness and applicability/suitability

Using fertilizer planning as described above makes it possible to balance the input of nutrients in an effective way so that the dosing of nutrients to the field can be adapted to the need of the plants in farm crop rotation.

Costs

This method is most relevant when the receiving farm is close e.g. within 5-20 km. The costs for transportation increase with distance. Composting of manure allows it to be transported over larger distances relatively easily. Slurry separation as described below reduces the cost of transport because the transport of water is reduced. A system to register manure transportation could be implemented. Hygiene and veterinary considerations should be taken into account as well to prevent potential spreading of animal diseases through manure traffic (for EU Member States cf. Regulation (EC) No 1069/2009).

Reference

- (39)

k. Slurry separation

In slurry separation, slurry is divided into a liquid and a solid fraction. The liquid fraction, which mainly contains mineral N, can be utilised at the production site and the solid fraction which contains most of the P and organic material can be transported to other farms to be used as fertiliser and soil conditioner, or used in biogas production.. There are a number of different types of mechanical separators including rotary screens, roller presses, screw presses, inclined screens and vibrating screens.

Effectiveness and applicability/suitability

Slurry separation does not change the total nutrient content of the slurry but will facilitate proper dosing according to the need of the plants. This is particularly important in livestock intense areas where manure nutrients exceed the need of the farms in the area. It will also decrease the cost for transportation of the excess fertilizer. Slurry separation, as well as enough storage capacities, allows greater flexibility in spreading times and application and thus can optimise the full nutrient potential of slurry.

In order to get maximum return from the investment, a separator should be easily integrated into the existing farm setup with little extra expense and there should be sufficient slurry produced on the farm to justify the outlay. Mobile separators shared by several farms are a possibility to reduce costs.

Reference

- (13), (23), (51)

l. Composting solid manure

Composting is done in order to make livestock manure stable (easier to transport and store without further moulding or fermenting). Furthermore composting is a cheap way to reduce the water content and provides a possibility to kill weed seeds and pathogens (through microbial metabolism which increases temperature).

The readily available nitrate content of manure is typically reduced from 25% to 10% of the total nitrates, and therefore nitrate losses in land spreading are likely to be lower. On the other hand, composting risk N-losses through emissions (N_2, NH_3 and N_2O) and seepage of water, unless it is done in closed containers and using filter and treatment systems.

Effectiveness and applicability/suitability

Composting can be acceptable in case of adequately controlled conditions e.g. in closed containers or alike, i.e. ensuring emissions are captured and that leaching and run-off is effectively collected. Composting is relevant if substantial losses of carbon and nitrogen, that are considered important for the soil fertility, are acceptable. Composting performed under acceptable conditions is rather expensive, and mainly relevant to organise as large-scale installations and not a single farm scale.

Reference

- (2), (17), (51)

m. Biogas production from manure and other agri-waste biomass

Biogas production reduces greenhouse gas emissions, provides a source of renewable energy and generates a *digestate* in which nutrients are more readily available for crop uptake, with reduced odour emissions and pathogen content at land spreading. The risk for ammonia and methane emissions is higher for *digestate* than for raw manure and therefore covered storage and timely spreading of the *digestate* is important.

Effectiveness and applicability/suitability

Biogas production does not change the total nutrient content of the manure but will increase the nutrient availability for plant uptake. The biogas digest is more homogenous and is therefore easier to handle and distribute than raw slurry.

High capital costs discourage investments in biogas plants based solely on manure unless the process is supported by economic incentives or subsidies. Biogas production based on farm manure production is mainly profitable for larger farms or cooperatives. Therefore, biogas feedstocks are often supplemented (or even dominated) by dedicated energy crops, which have a much higher energy content than manure and offer a higher efficiency of operations. The favoured energy crop for biogas in the EU is silage maize (about 80% of feedstock), a high-input crop. It should be stressed that using such dedicated crops offer none of the advantages that apply to the use of manure, and can even be counter-productive if biogas leads to the increase or intensification of cropping. Small farms can get the biogas production to be profitable by handling agro-waste materials from other farms or from food production industry. Economy is also improved if surplus energy/gas can be sold, or if the energy consumption on a farm is very big.

Reference

- (18) (cf. handling digestate to avoid ammonia emissions – p.25), (13), (23), (41)

n. Pelletisation

Pelletisation is most appropriate for manures with a high dry matter content, such as poultry litter or manures that have already been treated and separated to give a high dry matter material.

Effectiveness and applicability/suitability

Pelletisation does not change the total nutrient content of the manure but will help to distribute it to greater distances through improved transport economy.

Pelletisation is generally carried out in centralised plants. The costs are high but the end product can command a good price as a fertiliser.

Reference

- (2)

o. Incineration

The incineration process has been identified as one possible method for dealing with poultry litter. The poultry litter is used as a fuel for power plants. The resulting ash can be sold as a phosphate and potash fertiliser.

Effectiveness and applicability/suitability

Incineration allows to utilise remaining nutrient content of excessive poultry manure and allocate it more evenly through distribution to other areas for application .

The investment costs are high. The running costs of incineration are estimated at around one Euro per tonne of dry solids contained in the waste. Although poultry manure is very dry and readily combustible, it may not be economically feasible to establish an incineration plant solely for solid farm wastes and even more so for slurries owing to the large amount of water present.

Reference

- (2)

C. ANIMAL FEEDING

a. Adopting phase feeding of livestock

Livestock at different growth stages or stages of the reproductive cycle have different optimum nutritional requirements. Because of limited labour and housing facilities, livestock with different feed requirements are often grouped together and receive the same ration. As a result some stock will receive higher levels of nitrogen and phosphorus than they can utilise efficiently and will excrete the surplus.

Effectiveness and applicability/suitability

Greater division and grouping of livestock on the basis of their feed requirements allows more precise formulation of individual rations. This will reduce the amount of nitrogen and phosphorus applied in manures and therefore decrease losses in surface runoff and by leaching.

There is a limited scope for improvements in the poultry sector where phase feeding is already widely in use. There is a great potential for phase feeding in the pig sector to reduce nitrogen and phosphorus excretion. However the costs can be considerable without necessarily improving performance.

Reference

- Baltic: (40), p.29, (47)

b. 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. For example, it has been shown that some cows get more protein (nitrogen) in their feed than would be necessary. In practice, however, surplus nitrogen and phosphorus is not utilised by the animal and will be excreted.

Effectiveness and applicability/suitability

Avoiding excess nitrogen and phosphorus in the diet composition of livestock diets can reduce the amount of nitrogen and phosphorus excreted either directly to fields or via manure and thereby minimise additions to the pools of nitrogen and phosphorus that are sources of diffuse pollution.

For example, the protein content in cowfeed can be reduced by one percent unit without decreasing milk yield.

Reference

- Baltic: (40), p.30

c. Animal feed supplementation (phytase and amino acids)

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

Protein in feedstuff often does not contain amino acids in an optimum ratio for the animals. Animals feed according to their need for the minimum amino acid and thus take up an excess of other amino acids ending up in manure and ammonia emissions. This can be avoided by adding synthetic amino acids to the feed giving an optimum ratio between the different amino acids and thus reducing nitrogen in manure and ammonia emissions

Effectiveness and applicability/suitability

With the addition of phytase the phosphorus content of the feed can be reduced by up to 30% for pig feed.

If there is too little phosphorus in the pig feed or the ratio between different minerals is wrong, the condition of pig legs and the ability to move can weaken. This can have an effect on the economic output.

Reference

- Baltic: (40), p.30

d. 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.

Reference

- Baltic: (40), p.30

D. FARM INFRASTRUCTURE

a. Establishment of wetlands

Constructed or established wetlands are used to intercept runoff water from a field or group of fields. Wetlands can be natural or artificial, permanent or temporary, with water that is static or flowing, fresh or brackish. The wetland may be a wet grassland, wet woodland, reed bed, bog, sedimentation pond or lake.

Effectiveness and applicability/suitability

Wetlands act by intercepting nutrient delivery to ditches, streams and lakes on farm arable land. They improve water quality by breaking down, removing, using or retaining nutrients, organic waste and sediment carried to the wetland with runoff from the watershed. They can trap sediment and through the retention of runoff reduce nitrates and phosphorus (soluble and particulate). Wetlands reduce the severity of floods downstream by retaining water and releasing it during drier periods and protect stream banks and shorelines from erosion. According to a Finnish study, wetlands have reduced 25-48% phosphorus and 20-90% nitrogen. Swedish studies show that wetlands can potentially reduce up to 90-100% phosphorus and 76-90% nitrates. The effectiveness depends on the size of the wetland, vegetation, loading and influx.

Wetlands are quite expensive to implement and their construction will often involve the loss of some agricultural land. Constructed wetlands require maintenance due to deposition of sediment and organic matter.

Reference

- European: (43), pp. 14-15, 136-167
- Baltic: (40), pp.32-33, (3), (6), (25), (26)

b. Buffer zones

Establishing vegetated and unfertilised buffer zones alongside watercourses and in fields where there is risk for surface runoff decreases effects from soil erosion and the movement of nutrients into watercourses. Buffer zones can reduce pollution in two ways. They stop agricultural activity on the area and therefore reduce direct pollution from inorganic fertilisers and organic manure additions. They also intercept overland flow from agricultural areas just before it reaches the watercourse.

Effectiveness and applicability/suitability

Buffer zones should be free-draining and have a good surface porosity to intercept surface runoff. According to a Finnish study, buffer zones of 10 meters have proved to be efficient in reducing the leaching of suspended solids, dissolved phosphorus and total nitrogen. During the four years of research, suspended-solid loads were reduced by 50–60%, leaching of nitrogen by 50% and leaching of phosphorus by 30%. The efficiency of buffer zones in removing suspended solids and nutrients is affected by the width of the zone, gradient of the drained field, soil type and particularly by the variety and density of zone vegetation.

The costs for buffer zones depend mainly on the land price for the area taken out of production and the harvest-income lost. Buffer zones require a certain amount of investment to establishment but once established require little maintenance and could be even utilised as extensive grassland or in some cases as short rotation for energy wood.

Reference

- European: (43), pp. 11-13, 105-135
- Baltic: (40), p. 33, (26)

c. Converting arable land to extensive grassland

Changing from intensive agriculture to extensive grassland will reduce nitrogen and phosphorus losses. This method suits best in areas which were historically kept as grazing areas and have conservation value.

Effectiveness and applicability/suitability

Converting arable land to extensive grassland is very effective in reducing nitrogen because the low inputs ensure that nitrogen does not accumulate in soil. Conversion to ungrazed grassland can reduce nitrate losses by 95%. However, where the phosphorus content in soil is high, significant reductions in the leaching of soluble phosphorus are not achieved in the short term because the elevated levels of phosphorus will continue to be recycled through the soil. The immediate effect is that a permanent vegetative cover will reduce soil erosion and phosphorus losses in surface runoff. Conversion to ungrazed grassland can result in a 50% reduction in phosphorus.

This is an extreme change in land use that is unlikely to be implemented by farmers without incentives.

References

- see above

E. OTHER

a. Effective purification of runoff waters

For the purification of runoff waters, soil particles in the runoff water are precipitated by Al^{3+} -ions or aluminium oxide polymers resulting in a low concentration of soluble phosphorus in runoff waters and negligible amounts of exchangeable phosphorus in the precipitated soil aggregates. This method needs further refinement and testing if it is to be used for quantitative determination of redox-sensitive P in runoff.

b. Ditch Filters and Dams

Phosphorus runoff can be capture by lime-based filters installed in farm ditches, and even more effectively if combined with small ditch dams. This measure has been tested in near full scale field experiments for three years in Sweden by the Swedish Environmental Research Institute, and is now being evaluated for its potential in Poland, Estonia and Lithuania. The first full scale operational installations are being built in Sweden in 2013.

Effectiveness and applicability/suitability.

The measure still needs some evaluation and refinement. The Swedish Environmental Research Institute conclude so far that up to 60 percent of phosphorus leaching from agricultural land and transported in the ditches can be caught, and that the technology is cost effective compared to other measures in Sweden, for example constructed wetlands and buffer zones.

Reference

- (14)

c. Systematic on-farm Advisory Services

Agrotechnical measures are implemented by close co-operation between farmers and agricultural advisors. Advisors give consultations on limited stock density, crop coverage over winter, intercropping, fixed value for nitrogen utilisation of farm manure, limited nutrient budget, fertiliser plans and nutrient balances.

Effectiveness and applicability/suitability

This method can reduce nutrient input by 50% and nutrient losses by 30%.

The method is easy to implement. It requires a dense system of advisors to support farmers.

Reference

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