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Experiences on economic incentives in the Baltic Sea region to enhance nutrient recycling and reduce nutrient losses

Nutrient inputs

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1. Introduction

The goal of the eutrophication segment of the 2021 HELCOM Baltic Sea Action Plan (BSAP) is “Baltic Sea unaffected by eutrophication” and the management objective to “minimize inputs of nutrients from human activities”. Agriculture is one of the major sources of nutrient inputs to the Baltic Sea.

Financial instruments such as taxes or payments can be utilized to incentivize making better use of nutrients available in manure and other organic fertilizers, thus reducing mineral fertilizer use, enhancing nutrient recycling and reducing nutrient losses. As part of the 2021 BSAP the Baltic Sea region countries agreed to “Investigate opportunities for taxation of mineral fertilizer and/or taxation of nitrogen surplus and/or payments for agri-environment measures by 2024 and implement them building on the experiences available in various countries” (BSAP action E18). As criteria for achievement of the action the countries agreed to publish by 2024 a HELCOM report on experiences in the Baltic Sea region countries and the effects of financial instruments such as taxation of mineral fertilizer and/or taxation of nitrogen surplus and/or payments for agri-environment measures to enhance nutrient recycling and reduce nutrient losses and to implement suitable measures nationally building on the experiences available in various countries.

This report gathers experiences on the use of economic incentives in the Baltic Sea region from Denmark, Estonia, Finland, Poland and Sweden to enhance nutrient recycling and reduce nutrient losses. Germany has so far not introduced any taxation of mineral fertilizer and/or taxation of nitrogen surplus and therefore no examples from Germany are included in the report. Agri-environmental measures are financed through the 2nd pillar of the CAP in Germany following EU regulation No 1305/2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and the national Act on the Joint Task "Improvement of Agricultural Structures and Coastal Protection" (GAK Act - GAKG).

The report is divided into two parts: one part focusing on country case examples on taxes and the other part on agri-environmental payments.

2. Taxation

2.1 Country example: Taxation of mineral fertilizers in Sweden

From July 1995 to December 2009, Sweden had a tax on nitrogen and cadmium in mineral fertilizers. The tax level for nitrogen was 1,80 SEK per kg nitrogen. Before that (from 1984), there was a fee based on the nitrogen and phosphorus content in mineral fertilizers. The aim was to reduce eutrophication of rivers, lakes and the sea. The money from the tax/fee financed measures and research aiming to reduce eutrophication. Since 1995, the total tax on fertilizer was equivalent to approximately 20% of the fertilizer price (SOU, 2003; Söderholm & Christiernsson, 2008).

The Swedish government revoked the tax on nitrogen in mineral fertilizers in 2009 (Finansdepartementet, 2009). Finansdepartementet (2009) concluded that the tax had a small effect on the consumption of mineral nitrogen fertilizers in agriculture and that the tax reduced the competitiveness for Swedish farmers. The decision to revoke the tax became known in the autumn 2009 and fertilizer retailers reduced the price of fertilizers with the same proportion that corresponded to the tax. Shortly afterwards, the price of fertilizers in general increased on the world market, which meant that the price of nitrogen fertilizers remained approximately the same for farmers even though the tax was removed (Statskontoret, 2011; Konjunkturinstitutet, 2014). The effect of the tax and if the tax affected consumption of mineral nitrogen fertilizers was debated.

It is difficult to estimate the effect of the nitrogen tax on nitrogen loads to the Baltic Sea because many factors affect the nitrogen load. SOU 2003:9 concludes that the tax contributed to reduced nitrogen leaching from agricultural land, even though the tax had a small effect on the consumption of nitrogen fertilizers. Konjunkturinstitutet (2014) and Weckman (2015) estimated that a tax level at 1,80 SEK per kg nitrogen is cost efficient, but a tax level over 2 SEK per kg nitrogen is not recommended according to Weckman (2015).

Reintroduction of the tax on mineral fertilizers was on the political agenda in 2014-2015, but the government decided not to reintroduce the tax (Swedish government, 2014 and 2015).

Statistics on nitrogen consumption and nitrogen balance in Swedish agriculture is shown in figures 1 and 2.

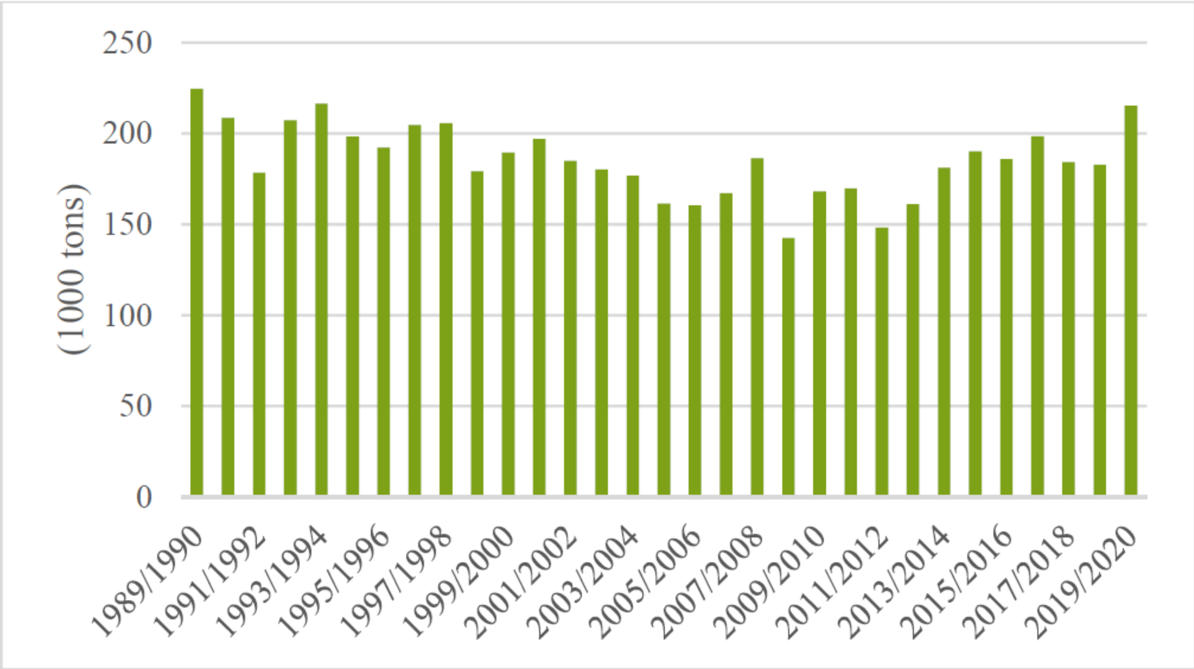

Figure 1. Amount of nitrogen in mineral fertilizers sold in Sweden (Source: Statistics Sweden).

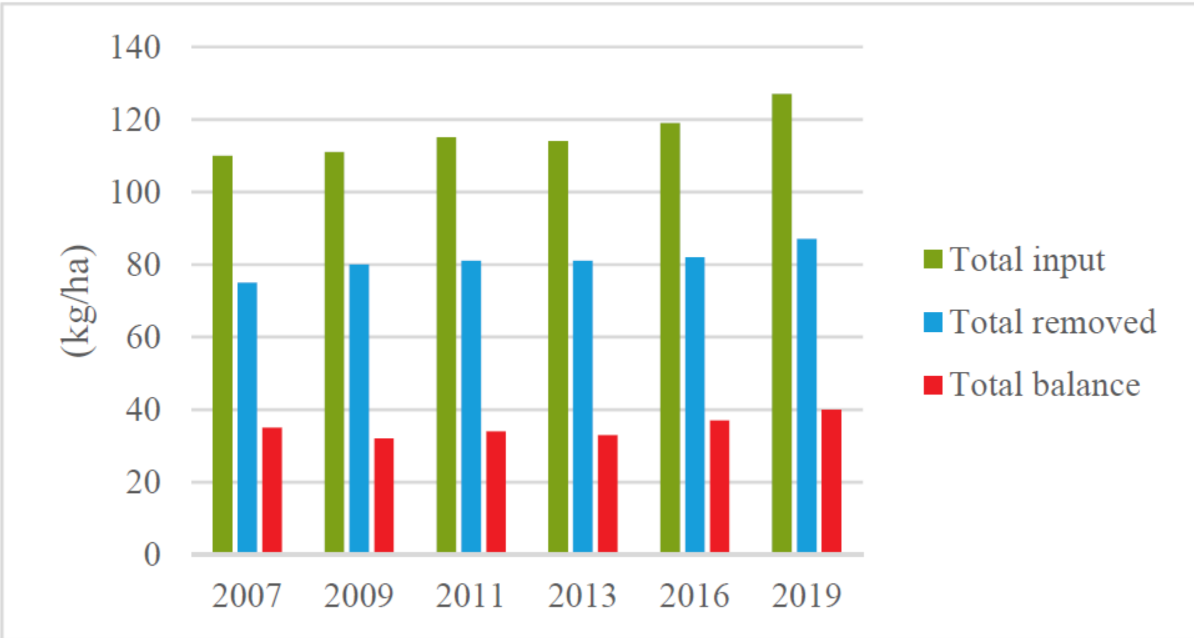

Figure 2. Average nitrogen balance for Swedish agricultural soils (Source: Statistics Sweden).

The price of fertilizers is one factor considered in the recommendations for fertilization from the Swedish Board of Agriculture (Jordbruksverket, 2020). The recommendations give information that economically optimal fertilization planning can be based on. Fertilization adapted to crop need and harvest potential is necessary to reach economically optimal crop production. Factors at the specific field are important, such as previous crop, earlier fertilization, weather and the development of the crop during the season. Advice on how to assess crop need and information on techniques for fertilization application is included in the recommendations. Prices of mineral fertilizers have increased considerably during 2021.

2.2 Country example: Taxation of mineral phosphorus in commercial animal feed phosphate and taxation of nitrogen fertilizer in Denmark

A tax on mineral phosphorus in commercial animal feed phosphate came into effect in Denmark on 1 April 2005. Since then the tax rate remained at DKK 4 (EUR 0.53) per kg of phosphorus. The aim of the tax was to reduce the saturation of agricultural soil with phosphorus and to curb the leaching of phosphorus to surface waters, as most lakes in Denmark suffer from poor water quality caused by eutrophication, conditioned mainly by accumulated phosphorus-leaching. (Skou Andersen 2016)

The tax applied to imported and domestically produced animal feed phosphates used for feeding agricultural livestock. All other purposes (e.g. pet food) were exempt. The tax base was the weight of mineral phosphorus in animal feed phosphates. The tax applied at the point of sale and was administered in line with the value-added tax. Own production of animal feed was exempt. (Skou Andersen 2016)

The tax arose from efforts to identify the most cost-effective means for reducing nutrient losses and was part of a broader package of measures to reduce nutrient leaching and pollution of surface waters. Farmer organisations did not oppose the tax and accepted it as part of a broader package deal while environmental NGOs voiced concerns about impacts on organic farms and were not strong advocates of the tax. (Skou Andersen 2016)

Between 2005 and 2015 the consumption of mineral phosphate in animal feeds reduced by about 2,000 tonnes (or 15%) although the tax rate was not adjusted with inflation. The tax is believed to have improved overall efficiency in the use of animal feed. Phosphorus uptake in animals can be increased by adding enzymes (‘phytase’), a practice that was introduced in 2002 by wholesale companies. Following the decision to tax mineral phosphorus, the additive doses were doubled and expanded to all farm animal feed. (Skou Andersen 2016).

In 2019 the tax on mineral phosphorus in commercial animal feed phosphate was abolished. The reason for this was the introduction of a new direct regulation of phosphorus – the phosphorus ceilings – that limits the application of phosphorus with fertilizers to agricultural land. The phosphorus ceilings will be gradually tightened up to 2025.

The phosphorus ceilings determine the amount of phosphorus that can be applied per hectare for different types of fertilizers, including different types of livestock manure. The phosphorus regulation also includes a mechanism that encourages adding phytase enzymes to fodder in order to increase phosphorus uptake in animals. This is due to taking documented effective feeding into account in the calculation of the phosphorus content in livestock manure. By adding phytase rather than fodder phosphate, the phosphorus content in the livestock manure is reduced below the standard values in the Danish normative system, which makes it possible to apply more livestock manure per hectare within the phosphorus ceiling.

The environmental purpose of the former tax on mineral phosphorus in commercial animal feed phosphate is thus fulfilled by the phosphorus ceilings.

In Denmark, there is a tax on nitrogen in fertilizer of DKK 5 per kg of nitrogen. This applies to fertilizers where the nitrogen content is more than 2 % of the total weight of the fertilizer. In this regard, companies that are included in the Danish Agricultural Agency's Register for Fertilizer Accounting are exempt from this tax. That exception creates an incentive in regard to getting companies to register with the Register for Fertilizer Accounting.

3. Agri-environmental payments

3.1 Country example: Payments for agri-environment measures to enhance nutrient recycling and reduce nutrient losses in Sweden

The Swedish Rural Development Program 2014-2020 included several payments to improve water quality. These include support for cover crops and/or spring tillage to reduce nitrogen losses, buffer zones and locally adapted buffer zones, maintenance of wetlands and ponds, and growing lay crops.

Edström & Grigoryan (2020) evaluated investment measures within the Rural Development Programme 2014-2020 that contributed to reduced plant nutrient leakage from agricultural land. The focus of the evaluation was effects on reduced losses of nitrogen and phosphorus from investment measures for wetlands and phosphorus ponds, improved water quality (e.g. lime filter ditches), two-stage ditches, structural liming and controlled drainage. The construction of wetlands and phosphorus ponds was the type of investment measure with most applications granted, and the measure that covered the largest area, and had the highest granted support. Construction and restoration of wetlands and phosphorus ponds was the measure that had most effect on the Swedish environmental goal of reduced eutrophication. Furthermore, it was the most cost-effective one. The lime filter ditch appeared to be the least cost-effective measure in the evaluation, regarding reduced nutrient leakage from agricultural land. The measure for wetlands is well known among farmers, advisors and consultants. For this measure, the limiting factors for applications were mainly support levels and regulations. For other measures that were included in the evaluation, it seemed that a lack of knowledge among farmers, advisors and administrators had a major impact on the outcome. However, low support levels may also have contributed to the lack of applications, especially in the areas of controlled drainage and two-stage ditches. Edström & Grigoryan (2020) recommend strengthening the knowledge and support of measures that are currently less known, not least among administrators. They also highlight that it is important to increase research on the effects of measures.

Smith et. al. (2016) evaluated agri-environment measures in the Swedish Rural Development Programme 2007-2013. Payments for spring tillage and/or cover crops to reduce nitrogen losses were highlighted as cost efficient. The cost efficiency of buffer zones varied greatly between regions since payment per area was the same while reduction of nutrient losses varied in different regions.

Weisner et. al. (2015) evaluated nitrogen and phosphorus removal in constructed wetlands in agricultural landscapes in Sweden, as well as the effect of creation of wetlands within the Rural Development Programme. They found that creation of wetlands within the Rural Development Programme resulted in significant decreases of transports of phosphorus and nitrogen to inland waters and the coastal sea, but also suggested that the effect could be substantially increased with a better location and design of wetlands.

The county administrative boards administer Local water conservation funding (LOVA). It has been possible to apply for support for structural liming to improve soil structure and reduce phosphorus losses since 2010. Approximately 41 900 ha of agricultural land was structural limed with LOVA-support during 2010-2016 (Geranmayeh, 2017). Most structural liming has been made in clay soil areas relatively close to the coast.

3.2 Country example: Agri-environment support in Estonia

Estonia implemented the following agri-environment support under the Estonian Rural Development Programme (ERDP) 2014-2020:

1. Agri-environment-climate measure M10
1.1 Support for environmentally friendly management *(KSM)* M10.1
1.2. Regional water protection support *(VESI)* M10.2
1.3. Regional soil protection support *(MULD)* M10.3
1.4. Support for environmentally friendly horticulture M10.4
1.5. Support for growing local plant varieties M10.5
1.6. Support for keeping animals of endangered breeds M10.6
1.7. Support for the maintenance of semi-natural habitats *(PLK) M10.7*
2. Support for conversion to organic farming and support for maintenance of organic farming *(MAHE)* M11 (M11.1, M11.2)
3. Natura 2000 payments *(NAT)* M12
3.1. Natura 2000 support for agricultural land M12.1
3.2. Natura 2000 support for private forest M12.2

In addition, support was provided for green investment, animal welfare M14, environmental training and advice for producers. The measures were also implemented in the transition years 2021 and 2022.

Ex ante, mid-term and ex-post evaluations are carried out to assess the effectiveness and impact of the measures of the ERDP. In order to further assess the environmental impact of the implemented measures, the Agricultural Research Centre conducts permanent assessment, monitoring and supporting studies of area-based agri-environmental measures and animal welfare measures and submits annual reports.

Farm gate balances

According to the farm gate nutrient studies, the RDP 2014-2020 measures had a positive impact on both the N and P balances and the use of mineral fertilizers. The nitrogen balance of 291 farm gates (N) was 34.56 kg/ha in areas with RDP measures (KSM+MAHE) and 43.84 kg/ha in the control group (covered with single area payment scheme - SAPS). The difference between the proportions of the nitrogen balance sheet of the measure and the control group before- after was -119.37 %, by which the proportion of N's balance in the option with the RDP measure was smaller than in the control group. Therefore, it could be argued that the change in the balance sheet of N showed a positive impact of the RDP's measures.

As an average for the years 2015-2016, phosphorus (P) balance sheet was slightly negative both in the areas of the RDP measure and in the control group. By 2017, P's balance sheet increased to 0.22 kg/ha in areas with RDP measure and 1.54 kg/ha in the control group areas. The difference between the P's balance of the areas covered by the measure and the balance sheet of the control group was 50.47 %. Thus, as a result of the RDP measures, the value of P's balance sheet increased, but the minimally positive balance of P does not endanger the aquatic environment.

The majority of the input to the farm gate balance is mineral fertilizers, the use of which has an impact on the aquatic environment. In 2017, N mineral fertilizers accounted for 57.06 % of the input of the N balance sheet in areas with RDP measure and 56.18 % in the control group. In the same year, P inorganic fertilizers accounted for 69.21 % of P's input and 78.49 % in the control group. As the difference in NP mineral fertilizer inputs from NP inputs in the areas covered by the RDP measure and in the control group after-time was small (-0.44 % and -3.63 %, respectively), the positive impact of the RDP measures remained small.

A new study conducted in 2021 showed that in 2020, the nitrogen balance varied between 7,4-37.5 kg/ha, the phosphorus balance of 1.8-(-1.9) kg/ha and the potassium balance of 11.0-(51.1) kg/ha (Agricultural Research Centre, 2021). The difference was due to the different production levels and characteristics of the monitoring holdings, the use of agricultural land, type of production, soil, size class, regional characteristics, year, general economic situation, compliance with the requirements for receiving support, etc.

The nitrogen balance was low in 2020 for MAHE (7.6 kg/ha) and SAPS (7.4 kg/ha). The average N balance between KSM and Estonia (37.5 kg/ha, 34.7 kg/ha) can also be considered to pose a negligible risk to the environment. In 2020, the phosphorus balance was positive in Estonia (1.8 kg/ha) and KSM (1.2 kg/ha), in the SAPS and MAHE the balance sheet was negative (-0.6) kg/ha and (-1.9) kg/ha respectively. The problem is the worsening P deficit in MAHE companies.

In 2020, the main share of total nitrogen, phosphorus, potassium inputs in KSM, SAPS and Estonia was mineral fertilizers (56-92 %), the largest share of NPK inputs in SAPS enterprises (78-92 %).

Drainage water quality monitoring

Drainage water quality monitoring showed that both nitrate ion concentration in drainage water and nitrogen leaching increased as an average over the period 2015-2018 both in the groups affected by RDP measures (KSM, MAHE) and in the control group (CAP) compared to 2007-2013. As both nitrogen concentration and leaching were higher in the control group, the harmful effects of nitrogen on the environment were reduced by RDP measures. The implementation of RDP measures had no impact on phosphorus leaching. As this was a pilot study, the number of monitoring points was low and therefore it was not possible to extend the results to the macro level.

In a new study conducted in 2021, the average annual concentration of nitrate ion in drainage water in 2021 was 0.9 mg/l in non-fertilised organic field (MAHE), 45.5 mg/l in KSM fields and 46.9 mg/l in the SAPS field (Agricultural Research Centre, 2021).

The average concentration of nitrate ion over the support period (2014-2021) was below the limit value for the KSM support type and exceeded it for the SAPS fields. Compared to the reference period (2007-2013), the average concentration increased in fields with both KSM and SAP support types.

In terms of nitrate nitrogen, all samples of drainage water collected from fields T1, J28, K1 and KH during the period 09.2020-09.2021 were in poor status class. The quality of the organic fields (MAHE) drainage water was good throughout the monitoring period. In the new monitoring area of the nitrate-vulnerable zone (NVZ), where grass was grown on permanent grassland, 91 % of the collected water samples were poor and only 9 % of the average status class.

The trend of change in the mean concentration of nitrate ion coincides with the trend of filtration. Therefore, an increase in concentration during periods of high filtration amplifies nitrogen leaching. Both concentration and filtration maximums remain in the non-vegetation period.

17,6 and 21.8 kg/ha of nitrogen leached from KSM fields and SAPS fields respectively. In comparison with the support periods, nitrogen leaching increased in fields with both KSM and SAPS types of support.

Spring 2021 was favorable for plant growth, but summer with two periods of drought. As a result, the yields of summer fruits remained relatively low. In cereal fields where organic fertilizers were used, the total balance of nitrogen and also phosphorus had a large surplus. Although the total nitrogen balance of the monitoring field K1 in Raplamaa was significantly smaller (55 kg/ha) compared to the monitoring fields in Läänemaa, the nitrogen leaching from this field was relatively high (21.8 kg/ha). This was due to both land use (black fallow) and heavy rainfall in August after sowing and fertilization of winter rape.

Organic farming, grasslands, Natura 2000, winter vegetation

The expansion of organic farming contributes to improving the aquatic environment. The use of mineral fertilizers and manure from organic animals is very low. Thus, leaching and spillage of plant nutrients into both surface and groundwater is low on the entire surface area used in organic cultivation. The area under organic farming grew by 46.6 % compared to 2013, reaching 175 749 hectares in 2018.

The grasslands are not ploughed annually, which increases the mineralisation and erosion of organic matter in the ploughing layer. Due to vegetation cover, nutrient leaching from grasslands is less than annual crops. The grassland supporting measures contribute to the preservation of grassland surface and thereby improve the quality of surface water, reduce soil erosion and improve the efficiency of soil management. The area of permanent grassland managed by RDP measure “MAHE” applicants increased by 37.9 % compared to the reference period in 2018.

The regional soil protection support fulfils the same objective, where permanent grassland or long-term grassland is considered eligible land. The area under this support has increased from 8 842 ha in 2015 to 11 819 ha in 2018.

Natura2000 support (NAT) also contributes to maintaining permanent grasslands and thus improving water quality. An analysis of the land use under the NAT-support showed that in 2018, permanent grassland accounted for 62.7 % of total NAT land use, which remained at the same level as in the reference period.

Seminatural grassland support (PLK) can be applied for permanent seminatural grasslands. In 2018, the area supported by PLK increased by 39.2 % compared to the reference period 2007-2013, covering 29 679 ha. Thus, the entire area supported by PLK measure supports also the good water status.

The obligation of winter vegetation (*water protection measure*) contributes to reducing leaching and erosion of nutrients and improving soil structure. In the case of KSM support, the winter 2018 vegetation cover amounted to 219 262 ha, which is slight increase compared to the reference period.

Leguminous plants are not, as a rule, fertilised with nitrogen fertilizers. Therefore, the requirement for the cultivation of leguminous crops for KSM and MAHE aid applicants contributes to reducing the use of mineral nitrogen fertilizer and also the risks for the water environment. In 2018, these applicants had an increase of legumes area by 18.3 % compared to the reference period.

Bare fallows are considered to be one of the biggest contributors to nutrient leaching and erosion in the fields, as the soil is uncovered and organic matter is more intensively decomposed and soil structure is broken down when it is cultivated. The bare fallow area decreased from 6 010 ha in the reference period to 2 350.2 ha in 2018 under the KSM and MAHE subsidies.

3.3 Country example: Agri-environment payments in Poland

As part of the Polish Rural Development Program 2014-2020 (RDP), a number of measures were implemented to reach pro-environmental goals, including protection of soils against erosion, surface runoff of nutrients and loss of organic matter and aimed at increasing the level of humus in the soil.

One of such activities in line with the environmental objectives of the CAP was the Agri-environment-climate measure (AECM). Its essence was to promote practices contributing to sustainable land management (to protect soil, water, climate) and to protect biodiversity by: protecting valuable natural habitats and endangered species of birds, protecting endangered genetic resources of crops and farm animals, and protecting biodiversity landscape.

The aim of “Package 1. Sustainable agriculture” is to promote a sustainable management system and to prevent the loss of organic matter in the soil. The beneficiary is obliged, inter alia, to perform a double soil analysis (at the beginning and end of the commitment period), in which the content of phosphorus, potassium, magnesium, organic carbon (humus) and soil pH are determined in order to determine the need for liming and the application of optimal fertilizer doses. Based on this analysis, and based on the nitrogen balance, a fertilization plan is prepared. In addition, in order to increase the level of humus in the soil, appropriate crop rotation should be applied, involving the use of a minimum of 3 groups of crops within 5 years, and additionally practices increasing the content of organic matter in the soil, such as: catch crops, plowing in straw or adding manure. As part of this package, there is also an obligation to diversify crops (at least 4 crops in the main crop each year).

The aim of “Package 2. Soil and water protection” is the appropriate use of soils, protection against water erosion, counteracting the loss of organic matter in the soil and protection of water against pollution. This package promotes agrotechnical practices that counteract water soil erosion, loss of organic matter and water contamination with components leached from soil. Package 2 includes two variants:

- Variant 2.1. Catch crops;
- Variant 2.2. Protective strips on slopes with a slope of more than 20%.

Variant 2.1 is particularly advantageous from the point of view of increasing the level of humus in the soil. Catch crops, which consists in sowing a mixture of catch crops by September 15 and keeping them at a minimum until March 1 of the following year. Then, the catch crop should be plowed in (except for soil cultivation in a no-till system).

Implementation of variant 2.2 consists in establishing a strip of grass with a width of not less than 6 meters across the slope. The grass strips are established by sowing a mixture of grasses in the first year of the agri-environment-climate commitment by April 15 or in the period from August 15 to September 10.

According to the Polish Paying Agency data, from the beginning of RDP implementation to April 24, 2022, final payments were made under AECM to 111,519 beneficiaries for a total amount of 5 895,74 million PLN. In total, on the basis of the issued decisions granting payment for 2021, the support covered an area of 2 265 658 hectares of agricultural land, while the size of the physical area covered by support was 1 692 984 hectares, including:

- Package 1. Sustainable agriculture, RDP 2014-2020 and RDP 2007-2013, payments for the amount of 1 091 663 223 PLN were made for 25 451 farms. The support covered an area of 937 807 hectares,
- Package 2. Soil and water protection, RDP 2014-2020 and Package 8. Soil and water protection, RDP 2007-2013, payments for the amount of 586 670 827 PLN were made for 32 662 farms. The support covered an area of 385 246 hectares.

The above packages will be continued from 2023 under the new Strategic Plan for the CAP for 2023-2027 as eco-schemes (1-year commitments), i.e.: winter catch crops/undersown crops, developing and respecting the fertilization plan and diversified crop structure.

The implementation of the requirements under these AECM packages enables rational and effective management of minerals and the reduction of their losses, which in turn reduces the pressure of nitrogen and phosphorus pollution of surface waters (runoff) and groundwater, which in turn is of great importance in maintaining the appropriate proportions of nutrients. Moreover, an important goal of the above-mentioned packages is the rational use of fertilizers, taking into account the needs of individual plants and the content of P, K and Mg in the soil. Rational use of fertilizers prevents the components contained in fertilizers, especially nitrogen and phosphorus, from entering surface and groundwater. The conducted soil testing (chemical analysis) enables the use of optimal amounts of fertilizers, which avoids introducing too much of them into the soil and limits their leaching and penetration into groundwater. Maintaining vegetation especially under Package 2 in the periods between two main harvests limits contamination of water and erosion. Above mentioned AECM packages therefore undoubtedly have a positive impact on water quality and water management.

Another activity in line with the environmental objectives of the CAP is the Organic farming measure under RDP 2014-2020. This measure (area-related support) is implemented in Poland since 2015. This kind of support will be continued from 2023 as one of the interventions of the Strategic Plan for the CAP for 2023-2027. Due to restriction in organic farming methods of production (concerning external inputs, fertilizers, pesticides) pressure on the environment is limited. Thus the organic farming system has a positive impact on valuable elements of environment such as water, soil and air. Sustainable and rational use of plant protection products and fertilizers, excluding the use of synthetic plant protection products and fertilizers limits the inflow of nutrients from agricultural sources, and thus reducing the sources of groundwater and surface water pollution.

In the framework of the Rural Development Programme the support is granted for the afforestation and the creation of woodland on agricultural land and non-agricultural land. These measures contribute to the sequestration of carbon dioxide and have a beneficial effect on soils, e.g. threatened by erosion. Furthermore, the afforested land contributes significantly to water retention. Additionally, as from 2022, support for the creation of mid-field trees will be implemented. This support will contribute to increasing water retention, constituting an important element against the effects of drought and will reduce the amount of pollutants entering the waters. Naturally, mid-field trees prevent water and wind erosion and increase the absorption of carbon dioxide. Finally, as from 2023, in the framework of the Strategic Plan for 2023-2027, in addition to the above-mentioned measures and interventions, it is planned to implement agroforestry systems. Agro-forestry systems similarly prevent erosion and increase the content of organic matter in the soil. They also contribute to environmental and climatic benefits due to increased infiltration and protection of surface waters.

3.4 Country example: Agri-environmental payments in Finland

In Finland, a study was carried out on the effectiveness of agri-environmental measures in the implementation of different environmental objectives, including water protection objectives (Hyvönen et al. 2020). The latest research and information on the state of the environment were utilized in the work. The measures were assessed from the perspectives of water protection, soil growth status, climate protection and the promotion of biodiversity.

Regarding water protection targets, the impacts of different agri-environmental measures were assessed separately in relation to five nutrient loading components: nitrogen load, the load of soluble phosphorus, erosion, soil structure and soil organic matter. The specific impact of each measure and the surface area of its implementation in Finland were assessed separately. Based on these, the overall effectiveness was assessed. The underlying idea was that the measure has affected the situation in which a typical autumn-ploughed cereal field would have been in the absence of these measures. The effectiveness of the measures on environmental objectives was also assessed at regional level (target area, not the target area) and by a production sector (plant, pig, poultry and cattle). Estimates were also made of the cost-effectiveness of the measures and assessed according to whether they contributed to one or several environmental objectives.

In the Rural development programme for Mainland Finland 2014-2020 all farms that received agri-environmental payments had to commit to a measure called balanced use of nutrients in all their field parcels. This meant maximum limits on the use of nitrogen and phosphorus fertilization depending on the cultivated crop and soil properties (soil type, humus and phosphorus content), parcel-specific record keeping and buffer strips along water courses and main ditches. In addition, farms could choose measures to be implemented in certain field parcels only. Measures related to increasing plant cover in winter, buffer zones and grasslands were geographically targeted so that the payment was higher in areas where the measures were deemed to be the most effective. (Hyvönen et al. 2020)

Based on river monitoring data, nutrient runoff from agriculture slightly decreased, except in the catchment areas of the Archipelago Sea and Bothnian Bay. This indicates that the most important agri-environment payment measures aiming at fertilizing according to crop need and enhancement of plant cover in winter have been effective. It was estimated that the measures that most reduced the leakage of dissolved phosphorus were balanced use of nutrients and recycling of nutrients and organic matter while grasslands were the most effective in reducing erosion and nitrogen leakage. Although grasslands prevent erosion, they do not usually reduce the leakage of dissolved phosphorus, but this can rather be achieved by adjusting fertilization (Hyvönen et al. 2020).

The measure on balanced use of nutrients was correctly targeted at regional and local level. It reduced the phosphorus content of arable soils, leading to a permanent reduction of phosphorus loading. Recycling nutrients and organic matter was found to be the most beneficial in southern Finland and Ostrobothnia, where manure-based phosphorus may exceed plant phosphorus need.

Slurry injection reduced the risk of dissolved phosphorus run-off reducing the direct leakage and stratification of phosphorus on the soil surface, but it did not enhance nutrient recycling effectively. (Hyvönen et al. 2020)

It was deemed cost-effective to reduce nitrogen loading and erosion, especially for erosion-prone soil types, if at least 40 % of the field area had plant cover in winter. Most cost-effective measures to reduce dissolved phosphorus leakage were recycling nutrients and organic matter and slurry injection. The third most cost-effective measure is balanced nutrient use in field crops. Targeting buffer zones to fields that slope towards water courses is important. Buffer zones placed in flat fields were deemed expensive and ineffective (Hyvönen et al. 2020).

A conclusion of the study was that the measure on balanced use of nutrients will be necessary throughout Finland, but the maximum amounts of phosphorus fertilization should be updated to correspond to the latest research on the fertilization needs of different crops. The exception that manure phosphorus could have been spread more than mineral fertilizer phosphorus was also proposed to be removed, as it weakens the effectiveness of the measure.

At the beginning of 2023, phosphorus fertilization limits were introduced as a legislative requirement, which means that they apply to all farms. The fertilization limits were revised on the basis of most recent research results, and the above-mentioned derogation concerning manure use will be abolished after a transition period of two years. Environmental support scheme no longer includes nitrogen fertilization limits stricter than those laid down in the directive on the use of nitrates, which means that farms can use nitrogen fertilization slightly more than before.

The recycling of nutrients and organic matter was found to be the most necessary in southern Finland and Ostrobothnia, regions where animal production is intensive and manure-based phosphorus may exceed plant needs at municipality, farm or field parcel level. The measure supports phosphorus fertilization according to plant need by promoting the receiving of manure-based phosphorus to fields where phosphorus fertilization can be expected to increase crop yield (low soil phosphorus status). Currently, it belongs to a measure called circular economy. The main improvement to the previous scheme is that lower application rates will be eligible for compensation. It was found that the maximum permitted rates of phosphorus fertilization limited the rates of application to a lower level than was required for compensation. This was particularly the case for phosphorus-rich materials. The change is expected to increase commitment to the measure and promote nutrient recycling.

Buffer zones and strips were found to have an effect on all studied environmental objectives in addition to reducing erosion. A geographical target area of buffer zones with higher compensation was considered largely successful limiting its implementation to southern Finland where erosion prone clay soils and annual crop cultivation are common. In addition, the ecological status of the surface waters is largely weaker than being at a good state. Compared with the previous agri-environmental scheme, the criteria for establishing buffer zones were significantly changed from an application-based specific aid to a field parcel specific measure which was available to be selected on whole field parcels along watercourses and main ditches. The effectiveness of buffer zones to reduce erosion per area was found to have decreased because buffer zones were not always spatially located in the most effective way to prevent erosion. The study recommended better targeting of buffer zones to the field parcels that have the steepest slope towards watercourses in southern Finland in accordance with the verified buffer zone plans, and on regularly flooded field parcels.

In the current agri-environmental scheme, the target area has been removed and buffer zones receive the same compensation throughout the country. As before, commitment to the buffer zone measure is available for arable fields vulnerable to erosion and field parcels along watercourses, in Natura 2000 areas and groundwater areas, and arable field parcels bordering on a wetland that is managed under an environmental contract. Buffer zones along watercourses are required at minimum 30 m and maximum 50 m width. The entire field parcel must be converted to a buffer zone if it is located within 50 m of a watercourse. Efforts are being made to improve local targeting of buffer zones to the fields most vulnerable to erosion with erosion risk assessment with the RUSLE2015 (Revised Universal Soil Loss Equation). Since 2024 maps of the most erosion-prone areas eligible for a buffer zone commitment are aimed to be available in Vipu (e-service for farmers).

Buffer strips were a compulsory farm-specific measure for all farms committed to environmental payments as part of the balanced use of nutrients. A buffer strip of at least 3 m on average and up to 10 m was required along watercourses with the same management requirements as the buffer zone (tillage, fertilization and pesticides prohibited), except for annual moving and removing of vegetation. The area of buffer strips may increase slightly in the current scheme, as all farms receiving CAP support are obliged to establish buffer strips along water courses as part of the mandatory GAEC 4 (Good Agricultural and Environmental Conditions) requirements. On the other hand, a requirement of a one-meter-wide bank of the main ditch was removed.

Plant cover on arable land in winter carried out by having living plants or stubble was found to be the most cost-effective water protection measure when at least 40 % of eligible area of farm was covered by the measure, despite low effectiveness per area. This was due to the low implementation costs and income loss of the measure, as the area was available for crop production during the growing season. More than half of the field area (61%) in 2016 was covered in winter with approved measures ranging from living plants to reduced tillage in autumn. In addition, other agri-environmental measures, such as natural management field grassland, perennial environment grasslands and buffer strips and zones, increased the area of arable land covered by vegetation in winter. Measures' target area with higher compensation was located in southern Finland and the coastal region of the Gulf of Bothnia. Higher compensation was also paid according to the percent of eligible area covered by the measure.

Reduced tillage (cultivation, stubble cultivation) in autumn was assessed to have the most modest effect, while perennial grasslands were assessed to have the most substantial reductions in nitrogen load and erosion. Reduced tillage was suggested to be removed from the implementation options to improve the effectiveness of the measure. The target area was considered successful, but its extension northwards in the coast of the Gulf of Bothnia was recommended. In addition, more detailed recommendations were made to delimit the options for implementing the measure in terms of soil type, catchment area and farm production sector.

In the current scheme, the target areas have been removed and the compensation per hectare is equally irrespective of the proportion of the eligible area committed to the measure. Numerous plant coverings are accepted for the measure. As was recommended, reduced tillage is no longer accepted for compensation, but it meets the GAEC 6 requirements of 33 % compulsory vegetation cover.

4. Discussion and conclusions

This report highlights examples from the Baltic Sea region on the use of economic incentives to reduce nutrient losses and increase nutrient recycling, including taxes and subsidies.

For taxation, there are examples from Sweden and Denmark. It was concluded that the tax on mineral nitrogen fertilizers in Sweden contributed to reduced nitrogen leaching from agricultural land, even though the tax had a small effect on the consumption of nitrogen fertilizers. In Denmark, taxation of mineral phosphorus in commercial animal feed was believed to have improved the overall efficiency in the use of animal feed.

For subsidizing agri-environmental measures, there are examples from Sweden, Estonia, Poland and Finland. In Sweden, investment support for construction and restoration of wetlands and phosphorus ponds was the measure that had most effect on the Swedish environmental goal of reduced eutrophication. Furthermore, it was the most cost-effective one. Payments for spring tillage and/or cover crops to reduce nitrogen losses were also highlighted as cost-efficient.

In Finland, based on river monitoring data, nutrient runoff from agriculture slightly decreased, except in the catchment areas of the Archipelago Sea and Bothnian Bay. This indicates that the most important agri-environment payment measures aiming at fertilizing according to crop need and enhancement of plant cover in winter have been effective. It was estimated that the measures that most reduced the leakage of dissolved phosphorus were balanced use of nutrients and recycling of nutrients and organic matter while grasslands were the most effective in reducing erosion and nitrogen leakage. It was deemed cost-effective to reduce nitrogen loading and erosion, especially for erosion-prone soil types, if at least 40 % of the field area had plant cover in winter. Most cost-effective measures to reduce dissolved phosphorus leakage were recycling nutrients and organic matter and slurry injection.

In Estonia, the effectiveness of implementing agri-environemntal measures was tracked through nutrient balances, which highlight the risk of nutrient losses but do not inform of the actualization of the risk, as well as water quality monitoring. Based on the results of a pilot study comparing implementation of rural devleopment plan measures and a control group, nitrogen concentration and leaching were higher in the control group but the implementation of RDP measures had no impact on phosphorus leaching. The results for nitrogen were the same in a new repeat study.

Poland offers support for the implementation of measures related to sustainable agriculture and soil and water protection similarly to other countries and the measures are assumed to be similarly effective. However, there was no study available on the effectiveness.

Based on the examples, nutrient inputs from agriculture have been reduced in the region by both taxes and subsidies. However, it is another matter whether these instruments have been the most effective or cost-effective ways to reduce nutrient inputs and assessing this is not always easy.

As mentioned in the Swedish example, it is difficult to estimate the effect of the nitrogen tax on nitrogen loads to the Baltic Sea because many factors affect the nitrogen load. There are many different policies and regulations related to the agricultural sector which can have an effect on nutrient loading and sometimes they have contradictory goals. Also, setting a tax at the right level is crucial for it to have the desired effect. From the environmental perspective, setting restrictions or ceilings for fertilization could be more effective, while they might not be as cost-effective.

When subsidizing the implementation of agri-environmental measures it is important to note that the effectiveness and cost-effectiveness of measures can vary greatly depending on the site. For example, the effectiveness of buffer zones and wetlands in reducing nutrient loading is highly site dependent. Such measures implemented in the wrong place can be very expensive and ineffective. Thus, support for measures should be well targeted to be cost-effective. It would also be important to monitor and assess the effectiveness and cost-effectiveness of implemented measures to be able to adjust policies and ensure reaching the agreed nutrient reduction targets.

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