Project „GreenAgri (Environmentally-friendly Management of Organic Fertilizers in Agriculture)"

Final Report of Pilot Programme

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Content

Introduction

The project GreenAgri was aimed at reducing nutrient losses from agriculture in Baltic States by introducing and testing environmentally-friendly management of organic fertilizers. As agriculture is one of the sources of nutrients eventually entering from surface waters to Baltic Sea the project's idea was to amend the situation.

During the project period 22 farmers from Estonian and Latvian pilot areas implemented appropriate manure management methods in real life using their own financial resources or support from research institutions.

First phase of the GreenAgri project was selecting the farms and carrying out an environmental audit in each of them to find out the main problems. In second phase selected farms composed action plans using the support of agri-environmental experts/advisors and implemented measures most appropriate for each farm. Experts and researchers gathered and analysed nutrient runoff data and provided the farmers with information about the efficiency and environmental impact of different solutions.

The main goals of pilot farms were how to increase the efficiency of organic fertilizers (solid and liquid manure) also considering influence on surrounding environment. In big dairy farms where mainly liquid manure produced, the best available technology (BAT) is already used in the farm for manure spreading, as well as complying with all requirements for water protection, the GreenAgri project focused on more efficient manure utilization. In farms where solid or deep litter manure were produced, the problems were related also with the manure heaping and action plans addressed following questions: What are the best ways to heap? How to protect environment and avoid leaching during heap composting? How to increase the composting speed? Do they have to increase this?

The highest aim of this project was the increasing awareness of farmers especially who don't have an overview of the quality of manure produced in their farm and don't have experiences to prepare the fertilization plan which is the basis for environmentally sustainable and friendly fertilization.

1 Overview of pilot farms

One of the project tasks was to evaluate the nutrient leaching from agricultural land and to suggest potential measures. The aim was to involve different farms (different in size, production type, location, landscape, nature conditions etc), so that the results are applicable for wider range of farms.

11 Estonian and 11 Latvian farmers were selected to take part in GreenAgri pilot project.

All of the selected farms are very different and specific according to the number of parameters - farm size, specialization, organic fertilizer type and farm location. Dairy farms, pig farms, beef cattle and sheep breeders were represented in the project. The selection of farms included farms with more than 1000 animals in total as well as farms with less than 100 animals. Several of selected farms are located in hilly territories with many slopes on the fields, which may increase the potential risks of nutrient leaching.

Pilot farms selected in Estonia for implementation of project activities:

- Dairy farms (5 in total)

There were 1 farm with more than 2000 dairy cows and ca 4000 ha arable land, 3 farms with more than 500 dairy cows and ca 900-2600 ha arable land and 1 farm with ca 200 dairy cows and ca 500 ha arable land.

All farms are active in both production systems - dairy farming and crop production. Their land also includes some permanent grasslands.

Farms produce mainly liquid manure (4 farms) or semi-liquid manure (1 farm), but also solid manure. Manure produced in livestock housings is used as fertilizer in the crop fields.

- Beef cattle and sheep farms (5 in total)

5 small or medium-sized beef cattle breeders, one of them breeding both cattle and sheep, were selected in the project in Estonia. 2 farms have less than 100 animals, 3 farms have 150-300 animals (including calves or lambs). Farms operate according to organic farming principles.

All farms graze their cattle and/or sheep on permanent grasslands. Deep-littered manure produced in livestock buildings and sheds is used in crop production as fertilizers and/or in grassland renewal. Average agricultural land (including permanent grassland) area of cattle farms in the pilot project is ca 200 ha.

- Pig farm

There was one pig farm with more than 3000 animals in total (including piglets). The farm is also active in crop production (ca 700 ha of arable land) and liquid manure from livestock housing is used as fertilizer in the fields.

The concrete solid manure storages, concrete liquid manure storages, lagoons, lined with geotextile were used for manure storage in big farms. In farms engaged with beef cattle and sheep mainly heaping deep litter manure on the field.

Location of Estonian pilot farms is shown in the figure 1. Selected farms cover most of Estonia, including the islands. 5 Estonian farms are located in Pandivere and Adavere-

Põltsamaa Nitrate Vulnerable Zone. There are some stricter requirements for fertilization with manure in Nitrate Vulnerable Zone compared to the rest of Estonia established with Water Act and its implementing act (protection rules of nitrate vulnerable zone) – for example reduced allowed nitrogen spread with mineral fertilisers (100 kg per hectare) in areas of unprotected groundwater and prohibition of fertiliser use and keeping manure in manure stack in areas surrounding springs and sinkholes.

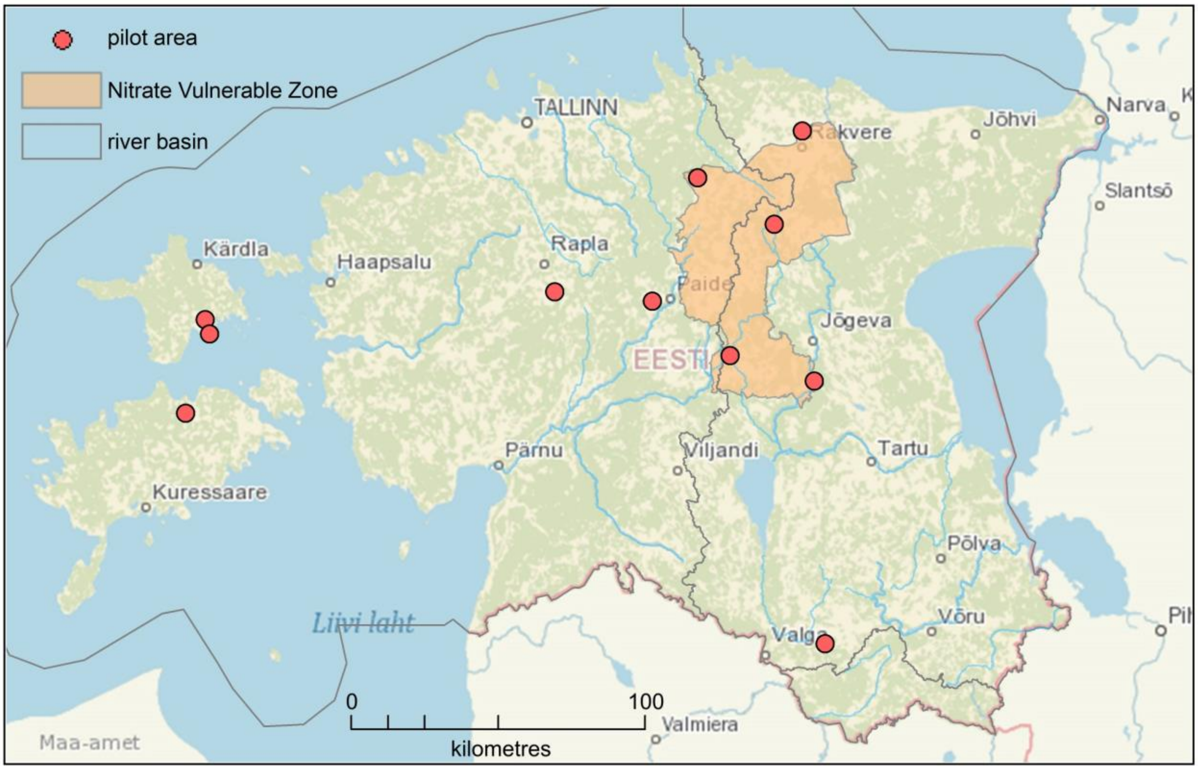

Figure 1. Location of Estonian pilot areas

Pilot farms selected in Latvia for implementation of project demonstration activities:

- Dairy farms (5 in total)

2 intensive dairy farms (200 and 600 dairy cows), both equipped with biogas plants. Therefore, the fertilisation is carried out by using end product of biogas production - digestate. Both farms are situated in Nitrate Vulnerable Zone. Apart from these farms, 1 intensive dairy farm, located in Northern part of Latvia. Farm has 100 dairy cows, fields are fertilized using liquid manure.

In addition to liquid manure and digestate, all three farms have also solid manure, from young stock housing. All three farms practice both production systems - dairy farming and crop production.

There were two less intensive dairy farms selected for demo activities. In these two farms both liquid manure and solid manure is produced. For fertilization of fields, semi-liquid organic fertilizer mixture of liquid manure and solid manure from calf and dry cows housing is used. Mixing of materials is done in lagoon or liquid manure storage tank. Both of these farms have 50 cows, and they are cultivating only permanent grasslands in area around 200 hectares.

- Crop farms using pig manure (3 in total)

This group consists of 3 farms, which are mainly focused on crop production. For fields fertilization pig manure is applied. Two of these farms operate own pig farms (2500 and 2000 pigs). The third farm is fertilizing crops by liquid manure from pig-farm nearby. All three farms use similar manure spreading machinery and cropping technologies. The size of the farms in hectares ranges from 500 to 1000 ha. All three farms are mainly focusing on winter crops.

- Sheep farm, beef farm (2 in total)

In this project also a sheep farm with 600 mother-sheep and beef farm with 60 suckling cows were involved. These farms are cultivating grasslands in area around 150 hectares. Only solid manure is used.

- Crop farm using untraditional organic fertilizer

There was also a very special farm selected, which is practicing crop production (450 hectares), and fertilizing its fields with untraditional organic fertilizer collected from horse, rabbit and mink farms.

For manure storage selected farms use concrete solid manure storages, concrete liquid manure storages, lagoons, lined with geotextile as well as special stainless steel and plastic liquid manure storages. None of the manure storage facilities is equipped with a roof as its requirements were not raised during the construction period.

The selected farms are covering all territory of Latvia, except for Latgale (eastern region), which is not part of program territory. Four of the farms are located in Nitrate Vulnerable Zone (Zemgale region). Particular farms are supposed to follow specific stringent rules and restrictions in regard of handling and spreading of organic fertilizers (in accordance to legislative act ”*MK noteikumi Nr.834 Prasības ūdens, augsnes un gaisa aizsardzībai no lauksaimnieciskās darbības izraisītā piesārņojum*a” Regulation Regarding Protection of Water and Soil from Pollution with Nitrates Caused by Agricultural Activity), which is developed in relation to Nitrate Directive.

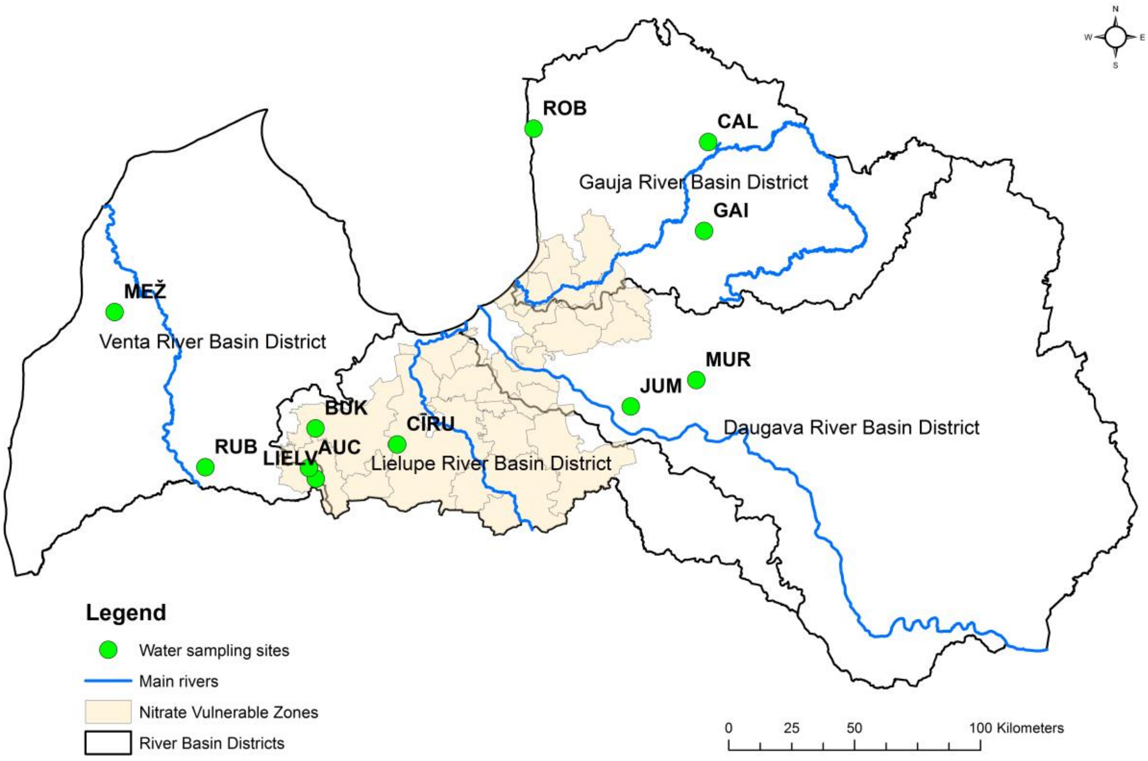

Figure 2. Location of Latvian pilot areas

The farms can be divided in 8 groups based on practical activities implemented in the farms:

- increasing efficiency of the use of manure as an organic fertilizer using nitrogen inhibitor (Vizura);
- reducing fertilization load of arable land and nutrient runoff by including cultural grasslands to the manure spreading plan;
- environmental advice on transition from spreading solid manure to the spread of liquid manure and determination of nitrogen leaching;
- site-specific and variable manure application spreading rate on diversified field in a hilly area;
- prevention of nutrient leakage from organic fertilizer by creating a fertilization plan, which is based on soil and organic fertilizer analysis;
- acceleration of composting of deep litter manure to reduce the possibility of nitrogen leaching during composting;
- increasing efficiency of manure and semi-liquid manure by spreading it before seeding of grasslands;
- improving manure management of year-round grazed animals.

2 Activities: their objectives, actions and results

2.1 Group of activities 1: Increasing efficiency of the use of manure as an organic fertilizer using nitrogen inhibitor (Vizura)

In dairy farms where BAT is already used for manure spreading, as well as complying with all requirements for water protection, the GreenAgri project focused on more efficient manure utilization.

The main objective of this action plan was to increase the efficiency of the use of liquid manure as an organic fertilizer. In liquid manure, a large proportion of nitrogen (N) is dissolved as ammonium nitrogen (NH_4-N), which under certain conditions is released as a volatile ammonia, reducing the impact of liquid manure as fertilizer. In addition, during nitrification process the NH_4-N is converted to nitrate N (NO_3-N) which easily will leach to the lower soil layers (including groundwater) causing potential water pollution.

As the company wanted to find ways to reduce nutrient losses and to increase productivity and economic profitability when fertilizing with manure without environment pollution, the nitrogen inhibitor (Vizura) was tested. The active ingredient in Vizura, DMPP, acts as a stabilizer for ammonium nitrogen (NH_4-N) in liquid manure, keeping the N in form of NH_4-N, ensuring its slow release during the growing season. By slowing down the nitrification process, the efficiency and availability of N with Vizura should increase, plants can use more N over a longer period. It is therefore possible to reduce the leaching of NO_3-N to the lower soil layers and to increase productivity.

Two Estonian dairy farms were selected for this study. In the first farm the action plan started in August 2016 on the arable land (winter rape) and in the second farm in June 2017 on short-time grassland. The test fields were divided in two parts: manure treatments with and without inhibitor Vizura. Immediately prior to spreading the manure, Vizura was added to the liquid manure. Vizura was mixed with liquid manure during soil transfer using a special BASF Dosistar closed dose dispenser system. On the short-term grassland the effect of Vizura was studied after the first and second cuts (June and July 2017, respectively), the liquid manure was directly injected into soil. In both fields the spreading load was calculated based on soil nutrient map of the field and manure samples.

At the start of the experiment liquid manure was analysed. Water and soil samples were taken at the start of action plan and during the monitoring period (until October 2018). Both treatments (with and without Vizura) in both farms had own drainage collectors enabling to collect and analyse water samples to test Vizura effect directly.

In the rape field the expected positive effect of Vizura (decreasing NO_3-N concentration in soil and drainage water) appeared only after a month but it continued until spring of 2018. The missing effect at the start was caused by the rainy 10 day period after the manure spreading.

In short-term grassland the effect of Vizura in the drainage water was not detectable: there were no major differences in the concentrations of NH_4-N and NO_3-N in the drainage water. In the Vizura-treated manure treatment, the NH_4-N content in the soil was slightly lower compared to the treatment without Vizura and was lower until the end of the monitoring period (until October 2018). The effect of Vizura on NO_3-N content in soil was only reported after the first cut, when contrary to expectations, treatment with Vizura had a higher NO_3-N, but later there were no differences.

The addition of Vizura to liquid manure did not affect the yield of the winter rape based on the results of the harvester monitor. Also the effect of Vizura on grassland yield of cuts was missing.

In conclusion, the results indicate that the use of a N inhibitor gave good results, and Vizura kept the N in the form of NH_4-N. We assume that although the test did not produce the expected results and profitability (yield was not profitable), at least the farmer's awareness and experimentation were achieved: how production would be more efficient, but at the same time environmental protection would be ensured.

2.2 Group of activities 2: Reducing fertilization load of arable land and nutrient runoff by including cultural grasslands to the manure spreading plan

Like the first group, the second group of activities is related to big dairy farms where all water protection requirements are already implemented and the farms are using BAT’s in manure storing and spreading.

The main remaining challenge in these farms is efficient management of liquid manure. The amount of liquid manure generated in the farm is large. Most of the agricultural land is short-term grassland used for feed production but these grasslands are not used for manure spreading, mainly due to feed quality considerations. As a result, the cereal fields in the vicinity of livestock complex are usually under intensive fertilization because manure transportation over long distances is not economically feasible. These practices do not allow to reduce the fertilization rate per hectare, which could be both environmentally and economically more beneficial. It also limits the manure spreading time.

Liquid manure is a valuable fertilizer, but when used, strong attention should be paid to water protection. Studies carried out in Estonia[1] show that nitrogen runoff to waterbodies is relatively higher from cereal fields compared to grasslands. This can be explained by the more intensive land use and increased use of fertilisers in arable land. In addition, grassland biomass and the permanent root systems help to minimize the runoff. One of the factors contributing to potential nitrogen and phosphorus runoff is also using organic fertilizers in crop fields in autumn period which can lead to higher nutrient leaching in winter and spring when there is no vegetation in the field.

[1] Eesti Keskkonnauuringute Keskus, 2017. Vee põllumajanduslike koormusallikate ja nende mõju informatsiooni ajakohastamine, nende mõju vähendamise meetmete määratlemine Peipsi alamvesikonna näitel. https://www.envir.ee/sites/default/files/aruanne_peipsi_pollumajanduskoormused.pdf
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Based on these considerations it was decided to test the use of liquid manure on short-term grasslands using the BAT's and appropriate manure spreading times. The objective of the action plans was reduced nutrient runoff from arable land. It would be achieved through enlarged manure spreading area and avoidance of high application rates per unit of land, as well as through shifting part of the autumn manure spreading to late spring or first half of summer (active growth period). The expected results of the action plan were improved crop yields with minimal nutrient losses and without compromising the feed quality.

Two Estonian farms were selected for this case study. Both are active in dairy farming and crop production and their arable land is located in complex area in terms of surface water and groundwater protection (partly in Nitrate Vulnerable Zone, surface water bodies close to fields, areas with unprotected groundwater, etc).

Two short-term grasslands were chosen as pilot areas. Both grasslands were fertilized with liquid manure from dairy farms using BAT's (in compliance with Estonian BAT-notes for intensive rearing of cattle). The spreading load was calculated based on soil nutrient map of the field and manure samples. To avoid the potential nutrient runoff in autumn and winter period, the spreading took place in summer – in June after the first cut. All relevant water protection restrictions were followed.

One of the pilot areas was divided in two sectors where different spreading systems where compared – trailing hose spreading (farm's usual practice) and direct injection to the soil (used for the pilot project).

The second pilot area was also divided in two sectors. In this case, one of the sectors was left as reference area where "business-as-usual" continued (no fertilization) to compare the results.

The action plans were implemented in 2017. One of the farms continued with the same actions in 2018. Second farm in the group could not repeat the action plan due to extreme drought.

In one of the fields water samples were taken from a waterbody (ditch) directly adjacent to the field to monitor possible nutrient runoff to surface water. The water samples were taken before, during and after the actions. In the second pilot area it was not possible to take water samples (there were no water bodies or drainage systems near the field).

Based on the water sample analysis, it can be concluded that there was no significant nutrient leaching from the field to the ditch. During the rainy period following the manure spreading, the nitrogen content (NO_3-N and NH_4-N) of the waterbody next to test field was low. Nitrogen concentrations remained low also in spring high water period.

In addition, monitoring of the soil and silage quality took place in both pilot areas. Soil samples were taken before (both pilot areas, autumn), during (one area, after spreading) and after (both areas, autumn) implementation of the action plan to evaluate the changes in nutrient levels in the soil and compare the sectors of pilot areas. The monitoring results indicated that the phosphorus loss in the soil was smaller with injector spreader, but it did not cause differences in the yields. Also, there were no significant differences in the soil or yields of two field sectors in the pilot area where one of the sectors was left as reference area.

The main positive result of this action plan for the farmers was that the spreading of manure according to decided action plan did not lead to a reduction in the quality of the silage. Both farmers expressed strong willingness to continue fertilizing grasslands with organic fertilizers after the pilot project as it will considerably facilitate their manure management.

This is expected to reduce the intensive fertilization of cereal fields with liquid manure in the future and thereby reduce nutrient leaching to groundwater and surface water in the area. Grassland fertilization gives the farms also greater choice over spreading time and helps to meet new more strict water protection requirements of Estonian Water Act (shorter spreading period in autumn).

2.3 Group of activities 3: Environmental advice on transition from spreading solid manure to the spread of liquid manure and determination of nitrogen leaching

In livestock farming, less solid manure has been produced in recent years, as the litter use to bind solid and liquid faeces is decreasing. As a result, farms produce more liquid manure, which differs from the properties of solid manure due to the lower dry matter content. In solid manure, nutrients are generally not readily available for plants but become available during the decomposition of organic matter in manure over an extended period of time. In liquid manure, nutrients are in dissolved form and in a higher proportion immediately available for plants, but there is a risk of nutrient leaching when liquid manure is introduced into the soil when nutrient consumers (for example growing plants) are absent.

The future plan of one Estonian dairy farm was to start to spread liquid manure instead of solid manure but the earlier experiences and knowledge of effect on the surrounding environment were missing.

As a result, the aim of this case study was to test suitable liquid manure spreading rate and technology, in parallel with monitoring leaching of N. The output of the monitoring was to analyse whether the selected techniques could be sufficient to prevent negative effects on the aquatic environment and to give feedback to the farmer about his activities and choices.

In view of the forthcoming legislative changes in Estonian Water Act, the aim was to spread liquid manure before 1 November.

1 November, 2017 at the semi-liquid manure was spread into soil with disc spreader system. In the previous growing season, summer wheat was grown in this field. The spreading load was calculated based on soil nutrient map of the field and manure samples . Next spring the short-term grassland with clover-grasses mixture established. The application of manure to the test field did not affect the NO_3-N and NH_4-N content in the drainage water and soil because during the monitoring period (from November 2017 to October 2018) the results of the water and soil analyses were similar to the samples taken before the liquid manure was applied.

Based on the above, the farm could continue to spread the liquid manure. Doing so they have to consider that when spreading manure, it is important to find a way that as many nutrients as possible remain in the top layer of soil (root zone of plant) and as little as possible leach to groundwater. If possible, they should avoid spreading manure on the bare land without plants. In this case study the NO_3-N did not leach into the drainage water because the liquid manure was spread on a field where spring wheat was previously grown and where residues of harvest (stubble and root) remained on the field. Residues of wheat are hardly decomposable by microorganisms caused by high carbon and low N content but N rich liquid manure facilitating decomposition of these kind of material. During decomposition process microorganisms bound N in their cells and prevent N leaching. The company's arable land is located in an extremely complex area for the protection of surface and groundwater, as most of the spreading areas remain in nitrate-sensitive and partly unprotected groundwater areas, therefore, it is important that the amounts of nutrients with liquid manure are not exceeded.

2.4 Group of activities 4: Site-specific and variable manure application spreading rate on diversified field in a hilly area

One of the farms participating in GreenAgri project was a pig farm in Estonia with manure spreading fields in a hilly area. Complex terrain is accompanied by diversified soil conditions. Topography of the region contributes to erosion, nutrient leaching from the highest areas and accumulation of nutrients in the lower areas. Even gently sloping fields can produce considerable runoff, especially in periods without vegetation. As land slope increases, the risk of runoff and erosion also increases. As a result, there can be significant variability in soil types and nutrient concentration across one field.

Diversified terrain and soil provide a challenge for the farmer. It is difficult to find fertilization rates and techniques, which would ensure a good yield throughout the field, while preventing nutrient leaching to surface water or groundwater.

Water protection aspect is particularly important since arable land of the farm is located in Nitrate Vulnerable Zone and there are areas with unprotected groundwater, springs and karstic forms. Part of the arable land is also located next to surface water bodies.

The objective of the pilot project was to develop and implement economically and environmentally beneficial fertilization plan in the agricultural parcel with variable conditions. It was decided to adapt fertilizer rate according to the variations in terrain, soil nutrients and soil type. Thus, instead of applying a uniform amount of manure on one field, the aim was to apply the optimum type and amount of organic and/or mineral fertilizers in a specific area of the field. Basing organic and inorganic fertiliser application rates on nutrient balance in the soil and field terrain helps to avoid over-fertilizing, reduce nutrient losses and enable best possible yields across the field.

A field with complex soil types was selected as a pilot area. The field is located next to a surface water body (a ditch) and has a land improvement drainage system.

The action plan involved assessment of fertilization needs of different field sectors and varying fertilization rates to be applied. The pilot field was divided into three sections based on the differences in terrain (higher and lower areas) and soil (nutrient and organic matter content). Site-specific fertilization plan was compiled for each sector based on precision agriculture principles. Previously analysed soil and yield data from different parts of the field were taken into account for that.

The use of pig liquid manure from the farm combined with additional mineral fertilizers were included in the fertilization plan. In 2017, all sectors were fertilized with mineral fertilizers in spring and only the higher part of the field was additionally fertilized with pig liquid manure in summer. The farmer repeated the actions in 2018.

To avoid the potential nutrient runoff in the autumn and winter period, the spreading of liquid manure took place in the active growth period (in July). All relevant water protection restrictions were followed.

To monitor possible nutrient runoff to surface water, water samples were taken from drainage water of the field. There were two monitoring points – drainage water collector in the higher field sector and drainage water collector in the lower field sector. Nitrate (NO_3-N) and ammonium (NH_4-N) content was analysed in drainage water. Water samples were taken in April (before and after implemented actions to monitor and compare nitrogen leaching after winter), July (during the rainy period following manure spreading to monitor nitrogen leaching after spreading) and in October (before and after implemented actions to monitor and compare nitrogen leaching after harvesting).

Based on the water sample analysis, there was usually higher nitrogen runoff from the lower sector of the field than from the higher sector.

However, after spreading liquid manure according to the site-specific fertilization plan the nitrogen content in the drainage water remained relatively low in the higher area and it was of about the same level in lower area (< 1 mg NO_3-N/l; < 0,1 mg NH_4-N mg/). Thus, there was no higher nitrogen runoff from lower areas after spreading. It can be concluded that using varying fertilization rates and avoiding liquid manure spreading in more vulnerable areas (using liquid manure only in the higher sector of the field) helps to avoid significant nutrient leaching from the field to drainage water and to the ditch and is in line with the water protection principles.

Monitoring of the soil quality and the yield took place as a parallel process. Soil samples were taken to evaluate the changes in nutrient levels in the soil, including comparing the three sectors. Based on the results of the soil samples, the phosphorus runoff of the field has decreased significantly and the total phosphorus content in the soil across the field has increased by the end of the monitoring period. Soil structure in the lower parts of the field has also improved.

Both, the monitoring and the visual observation of the field indicated that the distributed fertilization had a positive effect, improving the condition of the soil and reducing environmental impacts.

On the basis of the results, it can be concluded that using elements of precision agriculture management practices (gathering information regarding the site-specific soil and crop condition and varying the fertilization dose) in areas with complex terrain can reduce the amount of nutrient inputs used while increasing yields and benefitting surface water and groundwater protection.

It is particularly beneficial for water protection to apply this approach in spreading with liquid manure. In manure, some nitrogen may become mobile during the winter, when plants do not use it, and nitrogen and phosphorous are flushed out of soil to the lower parts of field and to the water bodies.

As the pilot project provided the expected results, the advisers' recommendation was to continue with precision agriculture practices in fields with complex terrain and soil conditions. The awareness of the farmer and his interest in applying the principles of precision agriculture practices was high even before the pilot project started. The advisory project played mainly a supporting role in the implementation of these activities in the pilot field. Thus, it can be assumed that the farm will continue to study and implement precision agriculture practices.

2.5 Group of activities 5: Prevention of nutrient leakage from organic fertilizer by creating a fertilization plan, which is based on soil and organic fertilizer analysis

Three Estonian and seven Latvian pilot farms during individual consultations and situation evaluation phase expressed their main interest to improve nutrients efficiency through better, more accurate and targeted fertilization planning. Estonian farms were engaged in beef cattle breeding and were organic farms. Latvian farms were engaged in dairy farming and pig farming. All these farmers had no overview of quality of manure produced and used for fertilization in their farms. Also the knowledge of effect of manure spreading on the surrounding environment was missing.

Precise or accurate nutrient calculation is crucially important for reducing the risks of nutrients leaching and negative impact on the environment, additionally involving economic impacts on the farm.

Thus the main objective of GreenAgri demo activities was to raise farmers' awareness through the prepare and implementation of fertilization plans using the results of soil and organic fertilizers (manure or digestate) analyses and taking into account the planned yields. Due to reason that many farms had not done any soil analysis before, this was a significant contribution in a long-term environment-friendliness and profitability of farms.

The second aim was to identify possible nutrient leaching as a result of prepared and implemented fertilization plans. Expected additional effect was prevention/reduction of nutrient leakage from organic fertilizer when crops and grasslands are being fertilized.

In 2016 organic fertilizers (manure, digestate) samples from all pilot farms where analysed in order to have precise information about nutrients content in the material. Each pilot farm had individual approach in sense of fertilization plan and necessary amounts of nutrients, taking in account the planned yields.

In two Estonian farms the activity started in 2016 autumn when solid manure was incorporated into soil and soil and water samples were collected before and after manure spreading till autumn 2018. The amounts of N and P per hectare allowed by the Water Act calculated based on manure samples were not exceeded in both test fields. After one month of manure plowing into soil, the nitrate content of the drainage water increased a little compared to condition before manure spreading but nitrate concentration stayed at the low level. From one farm in the following years, no water samples were collected, because there was no drainage water. In the other company, the nitrate content in drainage water remained low also in the next spring and further decreased 1,5 years after the manure spreading.

In the third Estonian farm of this group the results of chemical analysis of manure indicated that the manure produced in farm had higher than average N and P content. Thus farmer should reduce significantly their usual spreading load to not exceed legal limit. Actual nutrient leaching in the drainage water could not be determined because there was no drainage water during this year.

For Latvian farms the activity started in 2017 when pilot fields were selected and fertilization plans were calculated and elaborated. Plans based on three basic parameters: freshly gathered information – soil analysis and manure analysis, as well as expected yield. According to calculations necessary amounts of nutrients to reach planned yields exceeded maximum legally allowed limits of organic fertilizer. Therefore, additional N mineral fertilizer amount was included in the fertilization plan, to reach the needed balance. These fertilization plans were made according to necessities of particular crops, but it was strongly emphasized that the N of organic fertilizer cannot exceed 170 kg N/ha as defined by the Nitrates Directive.

From start of activities till the end of 2018 from each pilot field drainage system water samples were collected.

The yields, harvested in 2017 approved that the fertilization plans were correct. In other words, farms were able to acquire the crop yields according to planned levels. The water samples collected for the monitoring of the measure efficiency at the fall of 2017 indicated higher NO_3-N concentrations than the average value, obtained by multiannual results of water monitoring in Latvia. After consultations with project partners from Environment and Water Management Faculty of Latvia University of Life Sciences and Technologies and other experts, it was concluded, that particular anomaly was caused by extremely heavy rainfall in summer-autumn period of 2017. If average yearly precipitation in Latvia is around 650 mm then in 2017 it exceeded 800 mm. In some areas of country it almost reached 1000 mm. In such conditions it is very hard to monitor the pilot fields and indicate clear effect of our actions on nitrate leaching reduction.

Accordingly, it was decided to continue the cooperation with pilot farms, and to proceed with water sampling also in 2018. Also, in following year, there were some corrections made in the fertilization plans. For example, the overall amount of organic fertilizer was decreased, and a bigger emphasis was put on fertilization during the spring period, when the plants are consuming the nutrients more rapidly. Additional positive factor is that environmental responsibility of few pilot farms in this period increased and some farmers included in GreenAgri project decided to invest in liquid manure spreading machinery, particularly, buying a trailing hose systems. New systems replaced outdated and environmentally unfriendly, unprecise broadcast spreading technology. The first monitoring water samples in the spring of 2018 indicated major improvement in nutrient leakage reduction, but since an unprecedented drought occurred, it was not possible to collect water samples throughout all season. Water did not run in drainage systems. Therefore, project partners were unable to make final clear indications, proving by clear figures, that the improvements in fertilization planning are efficient not only for farm economy, but what is more essential – for nutrients leakage reduction and overall environment protection.

It was concluded that in farms where organic fertilizer is being used, it is vitally important to use precise real data when creating a fertilization plan. Accurate calculations will help to avoid over-fertilization risks and accordingly, will reduce nutrient leaching risks as well. Moreover, analysis-based fertilization gives an economic benefit to farmers, since organic fertilizer is used more efficiently, and the need for mineral fertilizers is decreased. The results of the first activity implementation year approved that if the overall amount of fertilizer is decreased, it is still possible to harvest the planned yields, with condition, that fertilization is done in the right time, according to the plan and taking into account real climatic conditions.

Additional conclusion, which was acquired by analysing the demo results is that spreading of organic fertilizer has to mainly be done in spring – time when the vegetation is on its peak. If rainfall is experienced, the most intense nutrient leaching is during the period when there is no vegetation on the fields. Spreading of fertilizers during this period is a potential threat to environment, since there are no plants that would use the available nutrients, and majority of elements are leaching. In pilot fields with winter crop cover, or catch-crop cover, amount of nutrients in water sample was significantly lower than from the fields with plant residues or no residues at all.

A creation of correct and precise fertilization plan is major leap towards sustainable farming, where high yields are harvested, and leaching of nutrients is decreased due to reason that plants consume most of the available elements.

2.6 Group of activities 6: Acceleration of composting of deep litter manure to reduce the possibility of nitrogen leaching during composting

In farms which main activity is beef cattle breeding and are an organic can use only organic fertilizer (for example deep litter manure produced in the company) for fertilization of grasslands. Permanent grasslands can only be fertilized by top fertilization which would be most effective if composted manure could be used, the physical composition of which allows better contact between the compost and the soil, thereby improving the movement of the nutrients from manure to the plants. Usually, in this kind of farms, the deep litter manure is heaped on the field to compost. During composting possible leaching is expected to be greater the longer the time manure is stored on the soil. Therefore shorter time is preferred for getting mature compost to decrease the risk of leaching.

The main objective of this action plan was to find a way to accelerate the composting of deep litter manure. One possibility was to use a preparation EM or "Effective Microorganisms" that accelerates the composting of manure. Preparation EM or "Effective Microorganisms" is a bioactivator consisting of different types of beneficial microorganisms. The main components of EM are lactic acid bacteria, photosynthetic bacteria, yeasts and other useful microorganisms that support each other and promote each other's development and coexistence. The addition of EM therefore accelerates the decomposition of organic matter and therefore is permitted for organic farming. The recommended spray rate was 1 litre per m^3 manure.

One Estonian beef cattle organic farm was selected for this case study. The land fund of farm contained only permanent grasslands. These soils are nutrient-poor, so getting high-quality and mature compost for fertilization was important.

The preparation EM was tested in 2016 and 2017, heaping the deep litter manure in August in both years. In 2016 the preparation was sprayed directly after the heaping on the manure pile and in 2017 formulation was sprayed on the manure in the manure storage directly before heaping.

The adding of formulation did not increase the composting speed and maturing process of compost but at the end of monitoring period the quality of compost in treatment with formulation was better, having higher organic matter and total nitrogen content and lower dry matter content compared to compost without formulation. Results showed that 14 months were not enough for getting mature compost but after 22 month the deep litter manure was sufficiently composted and had similar properties to the soil: a smell of soil, no unpleasant smell, and almost black color.

At the time the project started, the composting time allowed in Estonia by law (Water Act) was maximum 8 months, but this time was not enough to get mature and well composted compost. Now the allowed composting time has been prolonged to 24 month which is sufficient time for composting and there is no need to spend money to the different formulation for acceleration of composting process. Still, the shorter time to get mature compost is advisable because then the N leaching risk decreases. But the leaching risk can be minimised, for example using layer of straw under the heap. Also, the dry matter content of the manure should not be less than 25% for deep litter manure.

2.7 Group of activities 7: Increasing efficiency of manure and semi liquid manure by spreading it before seeding of grasslands

There are four Latvian farms included under this activity. Two of them are extensive dairy farms with large proportion of grassland. These farms are using semi-liquid manure as fertilizer which is obtained by mixing the liquid manure in lagoons or storage-tanks, and adding of solid material (with straw bedding) from cattle housing. This type of manure has a higher over than 10% content of dry matter, therefore it cannot be spread by trailing hose systems. Broadcast spreading of manure is being used instead. The usage of this spreading technology in grasslands and pastures leads to significant nutrient losses. The straw material does not degrade fast enough, and creates a dense layer on grassland, which then causes a lack of oxygen for plants. Finally, this requires additional soil cultivation. Overall, this spreading method is expensive and harmful both from crop and environmental perspectives.

The other two farms are using manure with particularly high level of dry matter. This type of manure does not degrade fast. If it is spread relatively fresh on grassland, it adds unnecessary amount of straw on top of the grass, and it also increases the surface nutrient leaching. Fresh manure application can also promote spreading of *Clostridium* bacteria, which can be highly harmful for animals. Taking into account the fact that these two farms have a rather low farm mechanization level, it is not possible to spread the necessary amounts of fertilizer in optimum timeframe.

In all four farms the priority was to optimise the spreading technologies in order to prevent any surface nutrient leaching as well as to increase the yield of grasslands.

For demonstration activities, taking background factors into account, several improvement actions for manure management process where offered to the farms. It was recommended to spread and incorporate the manure and liquid manure during the spring period and establish first-year grasslands in these area. It was also recommended to use a mix of various plant species within the grassland, which would lead to various different root systems. This would ensure that plants obtain nutrients from different depths of soil, which would again reduce the leaching of nutrients. In the past, farms have incorporated their manure into the soil in late autumn, exposing the fields to surface runoff unless frost occurred. One of four farms additionally to recommended grasslands management, also used this method by incorporating the semi-liquid manure in spring time for maize.

In order to fulfil the aim of this project and implement actions related to the fertilization plans, in all four farms precise information was gathered about the used organic fertilizer in 2016. Even though there are average values available for different sorts of fertilizers in guidelines and regulations, the aim was to understand whether the values are in compliance with the situation in farms.

The analysis showed that the quality of organic fertilizers is very different, and, even though the manure is stored with compliance to good farming practices, there are still some N emissions observed.

The second task was to make a full agrochemical analysis of the soil, in order to have a sufficient amount of information about soil pH, granulometric composition, organic matter, and amount of macro and micro nutrients. Due to reason that many farms hadn't done any soil analysis before, this was a significant contribution in a long-term profitability and environment-friendliness of farms.

In 2017, by selecting the pilot fields, a fertilization plan was made, taking in consideration the freshly gathered information – soil samples, fertilizer analysis, crops, and expected yield. Also, since the necessary amounts of nutrients did not exceed the maximum allowed norm of organic fertilizer, additional N mineral fertilizer was included in the fertilization plan. These fertilization plans were made according to necessities of particular crops, but it was strongly emphasized that the N of organic fertilizer cannot exceed 170 kg N/ha.

From 2017 till the end of 2018 from each pilot field drainage system, water samples were collected and analysed. Since it wasn't possible to take samples from pilot fields during the period of drought, together with researchers from Latvia University of Life Sciences and Technologies, drillings were made, in order to acknowledge if these spreading technologies could negatively impact the groundwater.

The water samples clearly indicate that implementation of recommended manure-handling system in chosen farms had a significantly positive effect. Groundwater meets all the requirements, and did not contain any pollution neither in 2017 or 2018. Positive effect is that the productiveness of grasslands and the quality of harvested material has improved. It was visible after analysis of the quality of the fodder and the owners estimates of the total amount of grass harvested. Unfortunately, because of severe drought in 2018 it was not possible to approve this tendency again due to lack of moisture.

The overall conclusion is positive – solid and semi-liquid manure incorporation for grasslands before sowing in spring time leaves a positive effect both on reduction of potential pollution and increase of yield, so this technology could be recommended for small sized farms which are not able to invest in advanced farming equipment. Also, by using this technology and by including legumes in their crop rotation, farms can harvest fodder of a higher quality, without using mineral fertilizers. This aspect is crucially important for organic farms.

Another positive factor is that by moving the fertilization to spring season, a risk of rapid nutrient leaching is reduced, which usually happens in autumn and winter period, when the vegetation slows down or stops.

When creating a fertilization plan, it is very important to take samples both from soil and organic fertilizer material, which will prevent the over-fertilization of plants. Also, in many farms the soil had a very low pH level, and fertilizing the soil, without liming done at first, is a useless process. Soil analysis provides an opportunity for livestock farms with high density of grasslands to have an optimum solution – achieve high fodder yields, without over-fertilizing the fields.

2.8 Group of activities 8: Improving manure management of year-round grazed animals

There are two important sources of potential nutrient leaching in typical beef cattle and sheep farms. Firstly, if the farm does not have manure storage facilities, the manure collected from animal shelters is usually heaped on the fields. Secondly, in the case of year-round grazing, there are winter feeding areas in the pastures where feed waste and manure accumulate. If the location of manure heaps or feeding areas is not changed during the year or even from year to year, it can result in enriched soil around these areas and lead to nutrient runoff and leaching.

In addition, collecting manure from such feeding areas is complicated and it means that some of the valuable organic fertilizer is lost for the production process.

Both situations were noted in one of the organic pilot farms. Cattle and sheep were kept in free-range, with the possibility of using animal housing. The sheep had concrete feeding area with the roof, but there was no specially adapted feeding area for cattle. It was not possible to collect manure from winter feeding areas of beef cattle – it was scattered over the winter grazing area.

Deep-litter manure collected from the animal housing and from sheep feeding area was heaped in the field near grazing area. The manure had high dry matter content (up to 25%), but the heaps were not covered and had no special bottom layer. Thus there was no protection against precipitation and nutrient runoff.

During the GreenAgri project soil samples were taken from the cattle feeding area to assess whether there was accumulation of nutrients in the soil over a longer period. Soil samples were taken from the feeding area before the animals were brought to the feed site and after the manure was removed from the area. The samples showed that there was indeed some leaching (although in modest quantity) of nutrients into the soil from the feeding area.

The initial action plan in the farm was to propose a suitable solution for storing manure and to add an absorbing bottom layer to the winter feeding area. The farmer was instructed how to make a straw mat under the feeding area to minimize nutrient leaching into the soil and water.

However, these activities were not carried out as the farm had an opportunity to make even bigger change in its manure management. The farmer built in 2018 a concrete covered feeding area and manure storage facility for beef cattle, meeting relevant water protection requirements. These actions reduce the risk of nutrient pollution in soil and water. It also has direct benefits for the farmer - the new feeding area allows more manure to be collected. In addition, better storage conditions for manure reduce nutrient losses. As a result, the amount of manure that can be used for fertilization of arable land increases significantly.

3 Main conclusions and recommendations

Various farms were involved in the pilot project. In some farms, the farmers had little practical knowledge of using manure environmentally friendly and efficiently, while other farmers were already using the best available techniques. However, in all the farms, some areas with improvement possibilities were found. Implemented activities ranged from better planning of manure spreading to changing spreading technology and use of innovative additives in manure management.

Due to quite difficult weather conditions (both in Estonia and in Latvia) during the implementation years of pilot program activities, measurable changes in nutrient leaching or other environmental impact aspects could not always be clearly monitored. In pilot areas, where it was possible, the results showed that the impact of the GreenAgri activities had neutral or positive effect on the environment.

The most important result was raising the awareness of all farmers through received counselling and testing of new manure management practices in real life. Project experts hope that the experience and knowledge gained from the project will be used throughout the farm. Further implementation of environmentally friendly manure management practices is expected to reduce nutrient leaching from manure storage and spreading. This results in a reduction in nutrient load on surface and groundwater.

In future the principles of good agricultural practice should be respected, which is also the basis for the environmental management of the livestock farm. The environmental requirements imposed by the legislation must be respected and, if possible, recommended guidelines should be applied.

It is important to apply techniques (from thinking to equipment and technologies) that ensure at least the level of environmental protection established. It is recommended for all farms, from planning of (organic) fertilizer spreading perspective to:

- Do regular soil agrochemical analysis in order to determine the level of nutrients in soil,
- Do regular manure analysis in order to determine the level of nutrients in manure,
- Create an accurate balance of plant nutrients in fields,
- Spread the fertilizer in accordance with previously mentioned points.

Creation of objective and accurate fertilization plan, where soil and manure analysis are taken in account, is a significant measure towards balanced and sustainable agriculture. It provides the opportunity for farmers to achieve expected yields not only on farm level, but also individually field by field.

When spreading manure, it is important to find a way that as many nutrients as possible remain in the plants and the soil and as little as possible in the surrounding environment, where no one uses it for purpose (leaching to groundwater, emission to the air).

Organic fertilizer must be spread in by such technologies, which makes very little nutrient losses. The best technological solution is promptly incorporating the manure into the soil.

Reduction of nutrient losses is also achieved by moving fertilization activities from autumn to spring, when the vegetation is on its peak.

In order to reduce nutrient leaching in period when intensive vegetation of plants is not happening, for example, in autumn, it is recommended to seed early winter crops or catchcrops. If it is not possible, then leaving the plant residues during the winter period also reduces the nutrient leaching.

From water management perspective, farms should do full inventory of drainage systems in order to determine the existing problems. For example, drainage collector outflows could be clogged, or could be placed under the water level, which significantly harms the functionality of these systems.

An increased concentration of nitrates in water samples could be reduced by using separate or combined water management tools, from which one of the most effective is buffer strips with intense vegetation.

If there is an interest in testing new technologies, it is recommended contacting research institutions. If there is mutual interest, testing can be carried out in collaboration.

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