DRIVERS AND CONSTRAINTS FOR IMPLEMENTATION BY POLISH FARMERS OF MEASURES TO REMEDIATE NUTRIENT LEACHING TO WATERS

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Abstract: *Against the background of ongoing eutrophication of the Baltic Sea, this study examined drivers and constraints for implementation by farmers of measures to minimise nutrient losses to waters. The research was conducted in two Polish regions (Mazovia and Pomerania) and included 28 agricultural farms. Four remediation tools were tested and the results evaluated. The study clearly demonstrates the need for greater awareness among farmers of nutrient flows and management on their farms, especially in a changing world requiring them to be better prepared to show flexibility in their production.*

Keywords: FARMERS, PERCEPTIONS, NUTRIENT FLOWS, NUTRIENT LEACHING, SOIL, WATER, NUTRIENT MANAGEMENT

1. Introduction

There are about 1.35 million farms managed by full-time farmers in Poland. Average farm size is 11 hectares (ha) and small farms dominate, with 50% of Polish farms being smaller than 5 ha and only 8% larger than 20 ha [www.arimr.gov.pl]. However, farms larger than 100 hectares occupy 22% of utilised agricultural area (UAA), although they represent only 1% of total number of farms (Figure 1). In general, the smallest farms are situated in southern Poland and the largest in northern and western Poland.

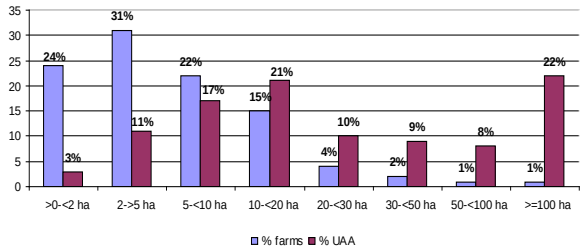

Figure 1: *Percentage of farms in different size classes (blue) and corresponding total utilised area (UAA) in agricultural production in Poland, 2010.* Source: Agricultural Census, Eurostat 2010.

The large number of small farms in Poland is a result of historical circumstances from when Poland was under foreign rule and had a tradition of family farms. However, the topography, soil type and climate are characterised by large regional variations (diversity).

The quality of the soil is another important reason for the large diversity of farm structure. Six quality classes have been distinguished in Poland, based on morphological characteristics, soil properties, location, soil profile construction, soil structure, colour, water relations, pH level, and calcium, phosphorus, magnesium and potassium content (Figure 2).

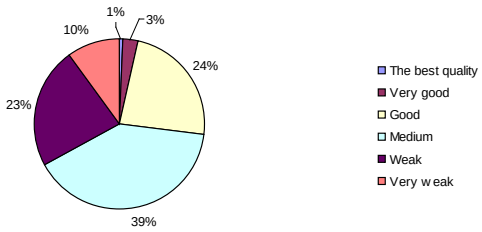

Figure 2: *Agricultural land in Poland (%), divided into six different soil quality classes.* Source: Agriculture in 2015, Central Statistical Office of Poland, 2015.

Farm size, soil quality, region and topography are also factors that significantly affect farm productivity (efficiency and effectiveness). A fragmented agrarian structure compromises farm management, as well as fertilisation and implementation of sustainable agricultural practices.

Some measures can be implemented on-farm to reduce nutrient leaching to waters. These measures primarily relate to rational fertilisation and soil protection, but also concern general farm management, including use of fertiliser, manure and seed and soil tillage (ploughing and soil cultivation) (Pietrzak 2012). To prevent losses of nitrogen (N) and phosphorus (P), farmers can apply a number of methods relating to farm management. For example, they can (Ulén, Pietrzak, Tonderski 2013):

- Store animal manure on concrete pads or in slurry tanks during winter
- Apply fertilisers in a balanced way and in appropriate doses (less than 170 kg N per ha and year, P in relation to soil P status)
- Choose the right time for fertiliser and manure application so that nutrients are available when the crop requires them.

Farmers can also use agro-technical methods to minimise or avoid nutrient leaching, such as:

- Using modern, precise and efficient application equipment for spreading mineral fertilisers, manure and slurry than enables good contact between manure/ fertiliser and soil
- Taking into account weather conditions during application of fertilisers, by avoiding application shortly before heavy rain. Slurry should not be applied on warm days to avoid loss of N to the atmosphere
- Keeping a plant cover on arable land during autumn and winter, e.g. growing a catch crop
- Leaving buffer strips of grass along open ditches and streams
- Limiting soil tillage
- Ploughing in spring instead of autumn, before sowing of spring crops
- Incorporating manure into the soil as soon as possible and applying mineral fertilisers in bands close to the seed
- Applying lime to optimise the pH level of the soil and specialist lime to improve the structure of certain soils.

There are also several recommendations relating to animal production, such as providing appropriate animal nutrient-balanced feed and ensuring adequate construction and equipment in buildings for animals. Other measures relate to the farm surroundings and managing other fields, such as constructing wetlands and sedimentation ponds to reduce N and P losses via water leaving the field. There are also recommendations to keep the farmyard in order and according to pro-environment rules (Ulén, Pietrzak, Ramnerö, Strand 2016).

2. Materials and methods

This study was conducted as part of the pilot project "Baltic Sea 2020: Self-evaluation and risk analysis by farmers concerning losses of nutrients and low-cost remedial measures". The project lasted three years and involved a total of 50 farmers and 26 agricultural advisors from two Polish administrative regions, Pomerania and Mazovia.

Farmers and advisors were introduced to four relatively recent approaches to modifying agricultural practices and management, and reducing P and N losses to waters: 1) Surveys with soil analyses of all fields on the farm, 2) calculation of farm-gate P and N balances, 3) a calculation tool for estimating N leaching risk in individual fields, and 4) a farm walk with an advisor to discuss ways to reduce nutrient losses from small hotspots, such as farmyards, stream banks and erosion-prone areas.

The aim of the present study was to analyse and assess factors influencing implementation of measures to mitigate losses of N and P to waters. The study encompassed 28 agricultural farms from among the 50 included in the project.

Two rounds of interviews (in 2013 and 2015) were conducted using semi-structured questions. The farmers were interviewed in their farmhouse and audio-recorded with their consent. The interview protocol contained 25 questions about each farmer's perception of environmental protection issues and fertiliser management, and about some measures to reduce nutrient leaching to waters. The questions focused primarily on subjective assessments and the farmer's opinion about implementing remediation measures to counter nutrient losses. The second round of interviews also sought to trace changes in the farmer's perceptions compared with the first interview.

3. Results

The average farm size was 45 hectares (range 13-130 ha). Most farmers (72%) did not change their production from 2013 to 2015, so their crop rotation, or main type of agricultural production, remained basically the same. However, eight farmers (28%) had expanded their acreage by leasing land. These farmers tried to manage the leased fields in the same way as their own fields, but in practice this depended on the duration of the lease and its terms. When farmers were asked about improved methods of soil tillage (own fields as well as leased), most responded that it would be possible to manage the soil more efficiently than at present. Only four farmers responded in the negative, and another four were unsure. The latter farmers usually argued that timing their measures was impossible, since the weather is difficult to predict. The positive answers were often supported by mention of measures that the farmer had already adopted. Most farmers were open-minded regarding (in favour of) changes and claimed that something can always be improved or changed.

Soil testing performed by accredited regional laboratories provided data and maps on pH levels and plant-available potassium (K) and P in the soil. All farmers (28) reported that the soil surveys were very useful, and 22 farmers claimed that they now did soil tests regularly (every 1-2 or every 5 years). Four farmers had done a soil survey for the first time, while two farmers stated that it was a long time since they had their soil tested. Twenty farmers now tested their soil for pH and liming requirement and assessed the fertiliser requirement in order to decide the doses of manure and mineral fertiliser to apply.

All farmers confirmed that each crop needs a specific composition of nutrients in the soil or when adding commercial mineral fertilisers. Some farmers gave the following examples: "For each plant the NPK ratio is different", "You have to monitor the soil and take plant observations into account when you calculate the dosage, otherwise the yield will be lower", "I cultivate grass, cereals and maize for silage; cereals and maize take up all the nutrients they need from the soil, a mixture of grass and legumes can fertilise the soil" (Drangert, Kiełbasa 2016). Three farmers agreed about differences in crop requirements, but claimed that it is difficult to monitor this in practice owing to lack of knowledge or external factors such as weather or soil quality that influence the nutrient content in the soil.

Knowledge of nutrient flows on the farm is essential in managing soil and fertilisation. However, the farmers interviewed had rather vague ideas about nutrient flows on their farm, as evidenced by their difficulties in estimating farm-gate nutrient balance. The farmers were assisted by their advisor in completing the sheets and estimating the surplus/deficit of nutrients on their farm. In addition, the Excel spreadsheet was designed to allow them to roughly estimate N leaching in a simplified way, based on factors such as previous year's crop and soil tillage method. Of the 28 farmers interviewed, 23 remembered the idea of farm-gate balance more or less well by the second interview and described it in various ways. They were able to specify the inputs and outputs of nutrients on their farm. Two farmers did not trust the results and therefore relied on own experience to identify amount of nutrients on the farm. Five farmers did not recall the farm-gate balance at all and complained that it was too "academic" and detailed.

The farmers interviewed usually decided the amount and proportions of manure and mineral fertiliser to use on the basis of soil test results. They also relied on their own experience and usually decided how much to use for each field depending on the amount of manure available. They commonly applied as much manure as was produced on the farm, with only a few exporting manure to neighbours. Most farmers examined the content of nutrients in the soil (using the soil test results) and took into account the specific needs of the planned crop. Farmers usually bought mineral N fertilisers to supplement P in the manure or mineral P (K and trace elements) to improve soil fertility. Thus we concluded that they considered the composition of mineral fertilisers. As regards the composition of manure, the farmers usually relied on their experience, since the nutrient composition in manure varies.

Most farmers wanted to extend their farms and improve productivity. Fertilisation is a major factor in such improvement. Farmers' understanding of the intricate interplay between soil, plant and nutrients was assessed already in the first set of interviews. Their views on the composition of cow manure and pig slurry differed significantly. Sixteen farmers claimed that there is a great difference and 13 stated that cow manure is better than pig slurry because, according to them, it contains more P and K than pig slurry. Only two farmers claimed the opposite, stating that pig slurry contains more nutrients which plants can also take up more easily than those in cow manure. Seven farmers (25%) stated there is no major difference in nutrient content between the two types of manure. According to four farmers from this group, pig slurry and cow manure have a very similar content of nitrogen (N) and differ in terms of other nutrients. A further two farmers claimed that the composition of nutrients is almost the same, except for the acidic nature of pig manure. One farmer said that all manure and slurry cause acidification, but cow manure to a lesser extent. Six farmers said that they did not know whether there was any difference or could not decide.

In general, the farmers' understanding and perception of the nutrient content and accessibility of nutrients in manure improved between the two rounds of interviews, conducted in 2013 and 2015.

Nineteen farmers (68%) confirmed that their views on the nutrient content and accessibility of nutrients in manure had changed in recent years. They mentioned several attitudes that had changed (some farmers listed more than one change). The most important change was their attitude to using soil maps and evaluating soil fertility. The second most important change was in mineral fertiliser dosage, as they applied less fertiliser but obtained the same or similar yields. They also mentioned changes in farm management methods in general, and confirmed that it helped to change the whole farm management and to become more effective. The responses were as follows:

- Seven farmers (25%) confirmed the importance of soil mapping for familiarising themselves with soil type and soil fertility
- Seven farmers had realised that they can apply less fertiliser and get the same yield; now they know it is important not to apply too much fertiliser, because this can harm the soil (over-fertilisation),
- Three farmers said that they had learned that different crops and different stages of development need different fertilisers
- Two (7%) farmers had changed mineral fertiliser type and now used better balanced and more expensive fertilisers because these gave higher yield
- Two (7%) farmers applied fertilisers at appropriate times and in appropriate amounts and used a good application technique ("Now I apply fertiliser early in the season to ensure the fertiliser gets into the soil and that plants can take it up through the root system because that's a long process", "I have learned that it's not good to apply lime and phosphorus at the same time")
- Two farmers now use manure more effectively, by using only as much manure as is needed; previously they applied all the manure available, but now they match the amount of N and P to the crops and the soil mapping data.

However, seven farmers (25%) claimed that nothing had changed in recent years. Their view on manure nutrient content and accessibility had not changed in recent years and they managed the soil and nutrients in the same way as in the past. This could be the result of low awareness of the importance of knowledge or reluctance to gain new knowledge. Three of them claimed that they already had all the necessary knowledge and did not want to change their attitude. One farmer cited financial reasons as the main obstacle, claiming that money is the main driver for any change. In addition, two farmers said "I can't say", as if they did not know a simple answer to that question.

Measures to prevent nutrient leaching to waters are usually readily available and simple to apply. Some measures do not require large expenditure, as confirmed by the interviewees. However, implementation of some other measures involves additional costs or workload. Eleven farmers (39%) stated that they did not incur any costs in implementing measures to reduce nutrient losses or they could not specify any costs. Most farmers had already constructed manure pads and/or slurry tanks, usually with the support of EU funds as 82% of the farms concerned were subsidised by the Rural Development Programme for Poland. These funds were allocated for farm modernisation. Purchase of necessary equipment such as spreaders for manure and fertilisers and seed drills had also been subsidised by EU funds or direct payments received by all farmers. Some farmers reported extra costs linked to reducing nutrient losses in the previous three years. These costs were:

- Six farmers had bought a new type of fertiliser that also included e.g. micro-nutrients
- One farmer had renovated a manure pad
- One farmer had prepared a fertiliser plan and ordered soil tests
- One farmer was spending more on soil cultivation because he had started to apply lime on his farm
- Two farmers had spent their own time learning new things (nutrient flows on the farm, difference in crop nutrient requirements, the importance of soil testing) and found it very inspiring.

In addition, one farmer claimed that he did not incur any costs through implementation of pro-environment measures, but rather gained benefits from new knowledge.

3. Discussion

On-farm nutrient flows are determined by a complex system of soil, water, air, chemical reactions and the influence from the crop itself and farming practices. The farmer tries to manipulate this system, mainly to increase crop and animal outputs and make the farm economically viable. Increasing fertiliser prices, environmental regulations and EU subsidies push the management of the farm in one direction, but consideration of nutrient balances on the farm and economic gain may be conflicting. There are general rules of thumb for increasing the efficiency of nutrient management, such as:

- The 'Four R'-rule: fertiliser and manure at *right* dose, *right* place, *right* time and *right* measures
- Keeping manure on pads and slurry in tanks
- Leaving a green strip along water courses and open ditches
- Tillage in spring for spring crops
- Planning fertiliser/manure application considering crop rotation and, especially, the preceding crop
- Minimising the number of passes with heavy equipment on fields, to avoid soil compaction.

Prevention of nutrient losses and implementation of low-cost remedies require certain knowledge. A farmer can use methods that are beneficial in reducing losses without detailed knowledge of each step in nutrient flows. They develop such methods from practical experience or from advice obtained from other farmers, neighbours, agricultural advisors or training courses. From a water quality and Baltic Sea perspective, good practice is what counts, not a detailed understanding by farmers of nutrient flows. However, in a changing world farmers need to be better prepared for flexibility in their production and for introducing changes (searching for new markets, implementing new animal breeds, new cultivation methods, etc.), which may be easier if they are familiar with actual nutrient flows. They may also be more likely to change poor practices if they know the basics of nutrient management.

The farmers interviewed knew most of the general rules for increasing nutrient management and, just like agricultural advisors and researchers, they knew that all measures are site-specific. Therefore, the measures prioritised on their farm may in practice be guided by guesswork and convenience, rather than scientific fact.

The results show different approaches of farmers to improving their farm management and differences in their perceptions of nutrient and fertilisers. These may be related to farm size and type of production. Implementation of pro-environment practices is very often a condition for obtaining subsidies or grants (e.g. from EU funds). Therefore, farmers should start with low-cost measures when it comes to nutrient management optimisation, as well as seeking to avoid nutrient leaching. Other obvious and general limitations are the local climate and soil quality, which determine agricultural practices and dosages.

The main driver for implementation by farmers is that tools are easy to learn and cheap to implement in practice. Farmers can also

be driven by measurable (tangible) results, both in terms of improving the environment and saving money on the farm, for example as a result of reducing mineral fertilisation. The role of agricultural advisors is also very important; if they have the appropriate knowledge, they can encourage farmers to implement suitable measures.

Within the study sample, 28% of farmers had introduced one or more measures directly aimed at reducing nutrient leaching, e.g. growing a catch crop, avoiding soil tillage on steep slopes, preparing a fertiliser plan or improving manure storage on their farm to avoid losses. However, the most important impact of the project seemed to be that farmers had become aware that they sometimes apply too much manure and fertiliser, or apply plant nutrients in very far from optimal proportions.

The present analysis focused on farmers' knowledge and perceptions about nutrient losses. Some interviewees, especially younger farmers (10 farmers were under 40 years of age) showed an interest in learning more about how to improve farming and husbandry practices. These younger farmers were willing to take part in training activities and scientific conferences. Their goal was to become more competitive on the market and achieve higher income, so they were prepared to implement innovations or test new solutions on their farms. Most stated that they would like to be involved in similar projects in the future. In contrast, 25% of the farmers aged 55 and above showed less interest in gaining new knowledge or in developing their farms, due to their age.

All farmers interviewed appreciated the soil mapping in helping them to get to know their own soil and apply fertilisers in a good way. However, most farmers found the farm-gate calculations very difficult and some farmers even said that it was necessary to be very knowledgeable or "academic" in order to complete the tables. On the other hand, a soil test was considered clear and easy by farmers, and therefore they used it more willingly. The graphical form of the soil maps was clearer and the laboratory testing made farmers trust the results and adjust application of manure and fertiliser to the map data more willingly.

It can be concluded that there is a clear need for Polish farmers to identify P and N flows on their farms. Systems thinking using farm-gate data represents a relatively recent approach to nutrient management and must be carefully rolled out to farmers over time to facilitate adoption. Implementing low-cost measures for reducing nutrient losses requires a fair understanding of the nature of losses and what is within reach for farmers. However, nutrient losses are only one part of a more comprehensive systems set-up. Analysis of responses obtained in interviews with farmers revealed possible ways to improve farm practices in order to raise productivity and reduce environmental harm simultaneously. A major challenge seems to be that farmers would benefit from a better (systems) understanding of nutrient behaviour/flow on their farm. Soil surveys, maps showing N leaching from different fields and other ways of showing the risk of leaching through observations (farm walks) are tools that can provide such insights and enhance farm practices, as well as systems understanding.

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