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NutriTrade
Nutrient Offsetting for the Baltic Sea

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Gypsum amendment of fields: a cost-efficient measure for the Baltic Sea
Water quality benefits and feasibility for large scale use in agriculture

The Baltic Sea Action Plan aims to reduce 15 200 tonnes of phosphorus load and 118 000 tonnes of nitrogen load to the Baltic Sea. These reductions can be realized in agriculture or from point sources, industry or waste water treatment plants. Nitrogen loads can be cost-efficiently reduced in all countries. In contrast, many countries' possibilities to further reduce phosphorus at point sources are limited thanks to already high abatement rates. Furthermore, the expansion and regional concentration of livestock production tends to increase phosphorus loads from agriculture. This highlights the need to reduce phosphorus in agriculture in those countries. Unfortunately, the current measures to reduce phosphorus runoff from arable fields are quite ineffective, especially in the short-run.

Gypsum amendment and water quality

Gypsum ($CaSO_4 \cdot 2H_2O$) application to the surface of soil provides a new measure that can effectively reduce phosphorus runoff from agricultural fields. Gypsum application increases the ionic strength of soil pore water. It creates larger aggregates of soil particles, calcium bridges and affects phosphorus binding, which reduces erosion and phosphorus losses to waterways. Importantly, phosphorus remains fully available to plants. A vital additional benefit is reduction in the loss of dissolved organic carbon. These beneficial effects occur immediately after the dissolution of gypsum, last for about five years and are achieved without any loss of crop yields or taking land out of cultivation.

Reduction potential of phosphorus for the Baltic Sea

Previous research, and the recent large-scale gypsum pilot in the River Savijoki catchment in southwestern Finland, have demonstrated that gypsum amendment of fields reduces both dissolved reactive phosphorus and particulate phosphorus. In total, gypsum reduces phosphorus loads from fields by 50%. To our knowledge, no other measure in agriculture can provide a reduction this large. Gypsum amendment of clay fields, for instance in southern Finland, would reduce phosphorus load to the Baltic Sea by 200–300 tonnes (almost 100% of Finland's phosphorus reduction target). The estimated cost of this reduction would be one third of the costs of achieving the target by currently available measures. The Finnish gypsum pilot suggests that the unit cost for gypsum amendment is about 70 €/kg P reduced. This figure is based on measured phosphorus reduction and the actual gypsum amendment costs (gypsum, its transportation and spreading) of 220 €/ha. With other measures, the costs rise to 220 €/kg P reduced.

Gypsum amendment can provide a promising solution to agricultural phosphorus loads for the entire Baltic Sea. Gypsum amendment may be suitable for agricultural soils especially in Denmark, Estonia, Finland, Poland and Sweden,

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which all have clay soils. Agricultural phosphorus runoff to the Baltic Sea from these five countries amounts to 8000 tonnes annually. By preliminary estimates, gypsum amendment of arable fields could reduce the load by up to 1500–2000 tonnes from these countries alone. So far, gypsum has been tested for water protection only in Finland and the United States.

Gypsum amendment in practise

Gypsum amendment is an easy measure and farmers perceive it positively, which is evidenced by the high participation rate. Gypsum is well-suited to clay soils and all crops. In the Finnish gypsum pilot in the River Savijoki catchment, the applied amount was 4 tonnes/ha. Gypsum can be easily spread by ordinary lime- or manure-spreading machinery. The best time for spreading is after the harvest. Gypsum can safely be used with conservation tillage, no-till and land ploughed with mouldboards. Gypsum includes sulfur, which is beneficial for crops. Previous trials in Finland suggest that impacts of one treatment last for about five years.

Availability and quality of gypsum in the Baltic Sea region

Gypsum is globally available both as a mined mineral and as a side product of manufacturing other commodities. Natural gypsum is extracted from rock, and the nearest mines are found in Latvia. Large amounts of synthetic gypsum are obtained as a by-product, especially from phosphorus acid production (phosphogypsum) and flue-gas desulfurization at coal energy plants (FGD gypsum). Other sources of synthetic gypsum are, among others, the sugar industry. Almost all countries in the Baltic Sea region possess some of these gypsum sources. In addition, gypsum is an easily recyclable material.

Gypsum is a common soil amendment material and is obtainable nearly everywhere as a commercial agricultural commodity. For agricultural purposes, the purity of gypsum must be ensured, as the quality of gypsum varies depending on its source. Gypsum applied on arable fields must not contain uranium, cadmium, radioactivity or other harmful substances. For instance in Finland, synthetic gypsum produced by Yara from locally mined volcanic apatite is free of these substances, as is the natural gypsum exported from Latvia. Current EU legislation dictates that organic farms are allowed to use only mineral gypsum. In conventional farms, both synthetic and mineral gypsum can be applied.

Ecological criteria for selection of gypsum amendment areas

Gypsum contains sulfate, which after spreading on soils is gradually released to nearby waterways. It is safe to use gypsum in arable fields along waterways running into the sea, since sea water naturally contains sulfate. In contrast, its use is not recommended in catchments with freshwater lakes. In rivers, gypsum does not cause any harm to aquatic biota, as demonstrated by using multiple indicators of aquatic biota in the gypsum pilot in the River Savijoki. Also, the pilot demonstrated that the increase in river sulfate levels is minor and temporary peaks do not last long.

Figure 1 illustrates a GIS-based assessment of feasible land areas for gypsum amendment in the basins of the Gulf of Finland, Archipelago Sea and Bothnian Sea. Yellow colour indicates the areas wherein gypsum amendment could be feasible in agriculture. In total, there is approximately 540 000 hectares of potential field area.

Logistics for large scale use

Gypsum is mainly transported as a bulk product. In large-scale use, the total amount of gypsum generates a logistical challenge, especially if the time frame is narrow. In the pilot organized in the River Savijoki catchment, gypsum was transported by large trucks (40–50 tonnes per truckload) directly from the factory to farms. Alternatively, train and shipping could be used for transport (especially) of large amounts. Although the growing season in Finland is short, the time frame and logistics were manageable thanks to good cooperation between farms, agricultural retailers and gypsum suppliers.

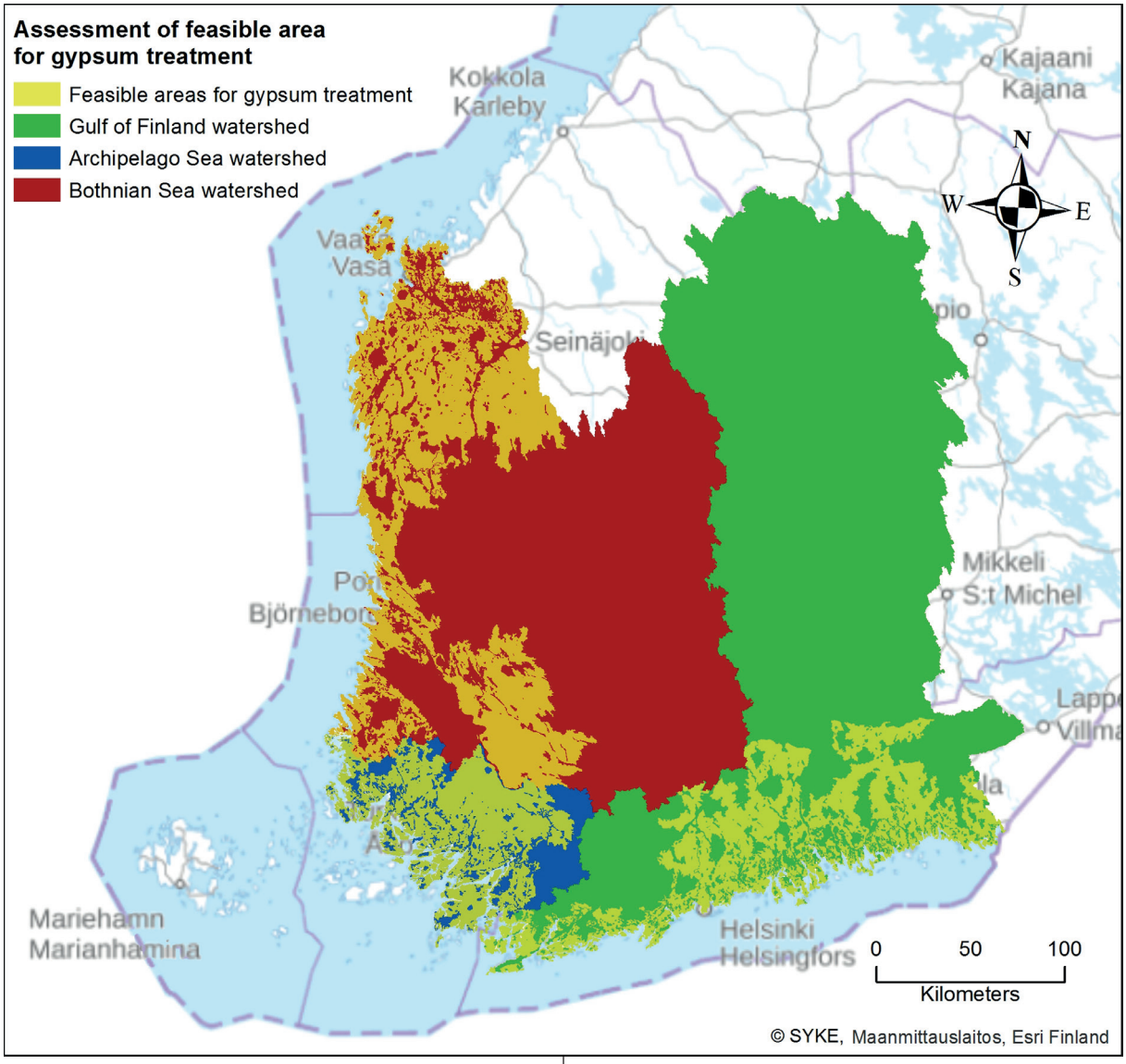

Figure 1. Basins of the Gulf of Finland, Archipelago Sea and Bothnian Sea and land areas favourable for gypsum amendment.
(Source: Juha Riihimäki, SYKE)

The feasible land areas in Figure 1 are defined using the following procedure:

1. GIS-based information of the chosen sea basins.
2. All sub-basins of lakes that are larger than 1 ha and in which water delay/water detention time exceeds 10 days are excluded.
3. All acid sulfate soils are excluded.
4. Sensitive ground water areas and Natura 2000 sites are excluded.

Key criteria for the use of gypsum in arable lands

Drawing on the experiences from Finland, we suggest that the following aspects should be taken into account when planning gypsum amendment.

1. Basic requirements
- The gypsum must be free of harmful substances and safe to use in agriculture
- Gypsum amendment is recommended only in river basins which discharge into the sea

2. Regionally important
- Gypsum is not suitable for acid sulfate soils
- Gypsum cannot be used in Nature 2000 areas
- If sulfate leakage risk is present, gypsum amendment is not recommended in groundwater areas

3. Important at farm level
- In organic farms, only natural gypsum can be applied
- Simultaneous gypsum amendment and seeding under no-till cultivation technology is not recommended

Recommendations for the Baltic Sea countries

We recommend starting soil tests and larger experiments in the Baltic Sea states, and based on the results defining ways by which gypsum can be included in national agri-environmental policies.

- **Soil tests**: Simple laboratory tests reveal whether gypsum works on the soil in question, or not. The testing may include amending pot-sized units of soil with gypsum. After dissolution of gypsum in moistened soils, the soils are irrigated and monitored, e.g. for the turbidity of water running through the soil. Gypsum has a potential to reduce phosphorus losses, if percolating water from gypsum amended soils is less turbid and has a lower concentration of dissolved phosphorus than the unamended controls.

- **A larger pilot:** A pilot is useful to examine how well farmers adopt gypsum, how gypsum logistics can be organized and how a society accepts the new measure. The design of the pilot should facilitate water quality measurements.

- **National conservation programmes:** These programmes draw on the experience developed from domestic pilots and international experience. The key part is designing a support scheme that fits EU regulation norms, is flexible for farmers and provides guidelines for efficient gypsum logistics.

Further information

Markku Ollikainen, Professor, University of Helsinki, p. +385 2941 58065, markku.ollikainen@helsinki.fi
Petri Ekholm, Senior Researcher, Finnish Environment Institute, p. +385 2952 51102, petri.ekholm@environment.fi
Eliisa Punttila, Project Manager, University of Helsinki, p. +385 2941 58061, eliisa.punttila@helsinki.fi

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