SHORT VERSION
OF FINAL REPORT

Circular NP

Better nutrient cycle for animal manure

Is it possible to support the transition of Swedish agriculture to better recycling of plant nutrients in animal manure to reduce eutrophication of aquatic environments, reduce the need for mineral fertilizers, and increase self-sufficiency?

A large-scale demonstration project carried out in 2021-2025 by

Baltic Waters

SLU

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The problem

Around the Baltic Sea, agriculture has become more specialized, with some regions focusing on crop production while others focus on large-scale animal husbandry. Crop farming requires nutrients (nitrogen (N) and phosphorus (P)), while areas with intensive livestock farming have a surplus of phosphorus. Animal manure is wet and heavy and therefore cannot be transported over long distances, and crop farms usually purchase mineral fertilizers for their crops. There is great interest among Swedish farmers in recycling nutrients from animal manure, but there is still no functioning market for circular fertilizers due to a lack of incentives, knowledge, and technology.

An improved recirculation – for the environment and agricultural profitability

By recycling nutrients from animal manure, the risk of nutrient leakage into the Baltic Sea is reduced, while the need for mining to extract phosphorus is reduced and Sweden's self-sufficiency and preparedness are strengthened. The main objective of the Circular NP project has been to develop techniques for extracting phosphorus from animal manure and manufacturing new fertilizer products that are easier to transport over longer distances, from areas with a surplus of phosphorus to areas with a deficit. The researchers involved in the project have evaluated several separation and processing technologies to develop attractive organic fertilizer products, which have then been evaluated in cultivation trials to determine which processing chain and fertilizer product is best from both an agronomic and economic perspective.

Nitrogen and phosphorus in nature
In the sea, phytoplankton need the nutrients nitrogen and phosphorus for their growth and, in the next stage, they constitute an important food source for other organisms such as zooplankton. However, when there is too much nitrogen and phosphorus, it can lead to eutrophication, resulting in algal blooms and oxygen-depleted bottoms.

Approximately 50% of all nitrogen and phosphorus entering the Baltic Sea comes from agriculture. A more circular agriculture would contribute to reduced nutrient leakage and more efficient resource utilization.

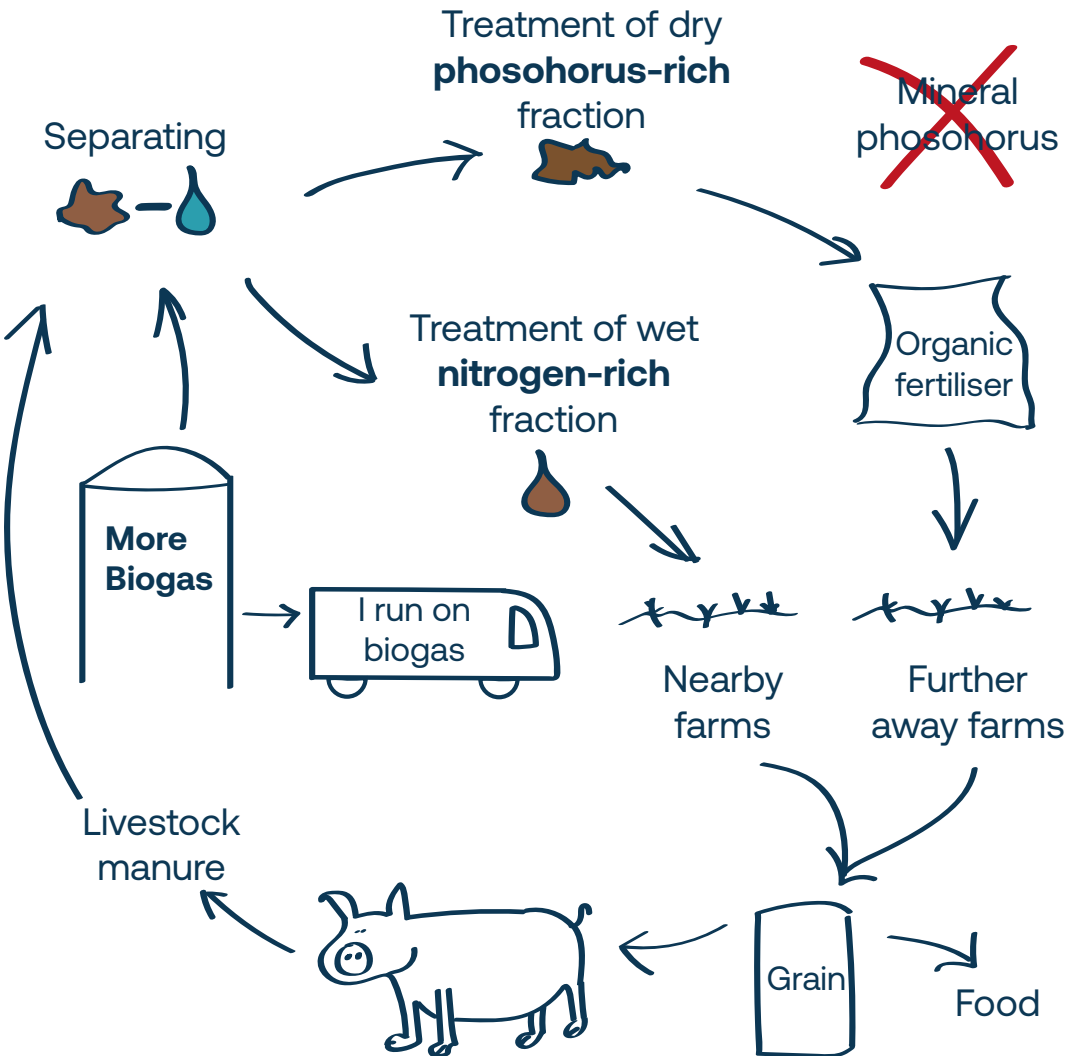
Case studies have been conducted at More Biogas in Kalmar, an agricultural biogas plant that processes manure from around 20 farms in the area. Both digestate from More Biogas and separated animal manure directly from the farms have been used in the trials.

The project was carried out by BalticWaters, the Swedish University of Agricultural Sciences (SLU), and Research Institutes of Sweden (RISE), in collaboration with producers, potential customers, and authorities.

Implementation

The researchers based their work on the pilot plant built at More Biogas for the separation of digestate. This in turn was based on experiences from the BalticSea2020 project at a Polish farm where pig manure was separated using a screw press in combination with a decanter centrifuge. The material extracted from the digestate was used for further processing into dry products, compost and biochar, which were then used for studies of plant nutrition efficiency in laboratories and greenhouse cultivation, as well as for demonstrations and field trials. The economic analysis of redistribution and production of various dry products was based on the

results of the separation, together with in-depth analyses on farms of current and possible fertilisation strategies. This also applied to the life cycle analysis, where the system was evaluated in terms of climate and eutrophication. As part of the project, a survey was also conducted on farmers' interest in organic fertilizers. Researchers with different areas of expertise, farmers, consultants, and the company More Biogas participated in the work.



The project uses digestate from the biogas plant More Biogas, and separated animal manure directly from the farms. Nitrogen circulates in the immediate area, while the phosphorus becomes a resource for farms further away that experience a need in phosphorus. The plant nutrients efficiency increases and the risk of eutrophication of the Baltic Sea decreases. Illustration: Madeleine Kullenbo, BalticWaters

Biofertilizer that can be transported varying distances

The test bed at More Biogas investigated various separation techniques for digestate into a wet nitrogen-rich fraction and a dry, transportable fraction with a high phosphorus content. The researchers calculated how targeted return of different fractions to farms could reduce phosphorus surpluses on livestock farms in the surrounding area and replace mineral phosphorus on crop farms. By using all the wet fraction and 35% of the solid fraction locally, and transporting 65% of the solid fraction to other farms in need, P utilization in the digestate could increase from 54 to 100% and the need for mineral phosphorus could be reduced. According to the project's calculations, the cost of digestate separation (50–55% of phosphorus to solid fraction) would be offset by the increased value of the fertilizer. However, drying and pelletizing

the solid fraction is costly. This would enable long-distance transport and significantly reduce the system's climate impact according to the life cycle analysis, but the economic analysis shows that it is not economically viable with today's plant nutrient prices. The researchers tested various product concepts, which they then investigated in the laboratory and in cultivation trials. The trials showed that further processing of the solid phase can lead to better phosphorus availability for crops. The researchers found that there were additional benefits to the solid phase - biochar, which increases carbon storage in the soil, can make it economically attractive to produce a product for long-distance transport.

Photo: Niklas Virsén

The function of nitrogen and phosphorus for plants

Plants need nitrogen to form shoots and leaves. A lack of nitrogen results in pale and weak plants. Plants absorb nitrogen in the form of ammonium and nitrate, but most of the nitrogen in the soil is bound in humus.

Phosphorus is necessary for plant photosynthesis, flowering, seed production, and growth. In order for plants to absorb phosphorus, it must be in the form of phosphate.

Reflection

The goal of Circular NP is to support the transition of Swedish agriculture to a better circulation of plant nutrients in animal manure, in order to reduce eutrophication of aquatic environments, reduce the need for mineral fertilizers, and increase self-sufficiency. The case study in Kalmar shows that a transition is possible. The project has demonstrated that the technology works, that there are realistic scenarios for redistribution, and that there is a demand for circular manure among farmers. There is no functioning market for circular fertilizers today, and the results explain some of the reasons why.

There is considerable interest from the agricultural media and biogas companies, and several large facilities are now being built that focus on separation systems for environmental reasons. At the same time, issues surrounding self-sufficiency and food security have become increasingly important social issues, and plant nutrients is one of the most important inputs in agriculture. The regional imbalance in phosphorus is driven by the long-standing structural rationalization of agriculture with separate plant and animal production. This is not an issue that is solely the responsibility of individual farmers, biogas companies, or fertilizer producers, but is very much a societal issue, where processes other than today's market forces now need to be activated in various ways to bring about change. Circular NP is well positioned to contribute to this.

Policy tools and scaling up for impact

The results from Circular NP have been crucial in scaling up research in two major international projects – CiNURGi and FERTITEC. CiNURGi, funded by Interreg, focuses on analyzing plant

nutrient balances, developing industry standards for recycled fertilizers, and establishing support centres that help companies and farmers test and adopt new technologies. FERTITEC, funded by the EU's Horizon program, develops Best Available Techniques (BATs) for plant nutrient recycling and will lead to policy recommendations that support the circular use of nutrients in Europe. Together, the projects build on the experiences of More Biogas and the work towards more resource-efficient and self-sufficient agriculture. To move forward, research needs to be linked even more clearly to practical solutions and policy instruments that make it profitable to recycle plant nutrients. The technology exists, but the market is lacking. Incentives and policy tools are needed to promote the use of circular fertilizers and investment in new technologies. Cooperation between researchers, authorities, biogas companies, agriculture, and the food industry is crucial to building a functioning cycle throughout the chain. The next step is to develop national and regional strategies for nutrient recycling so that Sweden and the Baltic Sea region can become pioneers in the circular use of plant nutrients.

The way forward

Circular NP has been crucial in driving and further developing research into circular plant nutrient use in Sweden. The project laid the foundation for several parallel initiatives with funding from the Swedish farmers' foundation for agricultural research, the JTI Foundation, and the EU-EIP, and Circular NP became a hub where researchers at RISE and SLU could build their joint expertise, strengthen cooperation with farmers and companies, and develop a common research infrastructure. The experiences from the separation pilot at More Biogas were particularly important. They provided practical knowledge about technical solutions, nutrient flows, and product quality, which was directly crucial in securing new funding and realizing two major international projects (the Interreg BSR project CiNURGi and the Horizon Europe

project FERTITEC), both coordinated by RISE. Together, the projects are driving the issues forward at European level and placing Swedish research at the forefront of circular plant nutrient management, technology and policy development, and collaboration between academia, industry and society.

Full final report

The full final report of the project is available to read and download on our website (in Swedish).

Scientific articles from the project

Björs M. 2023. Separation and acidification of digested animal manure –properties of the future organic fertilizers. Master thesis in soil science, Swedish University of Agricultural Sciences, SLU. https://stud.epsilon.slu.se/18859/

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Åberg A. 2024. Förstudie av småskalig tillverkning av kvävegödsel med plasmateknik. Examensarbete, SLU, Institutionen för energi och teknik, Uppsala, https://stud.epsilon.slu.se/20493/