How changes in farm structure could help reduce nutrient leakage to the Baltic Sea

In this policy brief, we discuss farm structure from the perspective of specialisation and separation between crop and livestock production.

The specialisation and spatial separation of crop and livestock production is a strong driver of nutrient surpluses, which increase the risk of eutrophication. To address this well-acknowledged problem, we found scientific support for at least three pathways: moving nutrients, moving livestock, and changing our diets.

In this policy brief, we discuss farm structure from the perspective of specialisation and separation between crop and livestock production. These variables characterise agriculture in most of the Western world.

It is important to consider the potential contributions of farm structure to eutrophication, because agriculture is the single largest source of human-related nutrients to the Baltic Sea, contributing about 40% of total waterborne nitrogen inputs and 30% of total phosphorus inputs (HELCOM 2018). In the catchment, most nutrients cycle through livestock; the majority of mineral fertiliser and livestock feed that is imported to the catchment is transformed into manure (Hong et al. 2017).

Regions with large numbers of livestock in relation to agricultural land often rely on imported feed because there is not enough local production. In these areas, proper manure management can be difficult because the amount of nutrients in livestock manure exceeds what local crops require. This situation can lead to over-fertilisation and nutrient surpluses, which increase the risk of nutrient leakage to the environment.

The problems linked to the present farm structure are well-acknowledged and can occur at both national and regional levels, but potential solutions are not widely discussed. As a result, farm structure has become the “elephant in the room” when it comes to identifying opportunities to reduce impacts of agriculture on eutrophication.

How did we get here?

Over the past century, agriculture changed dramatically, not just in the Baltic Sea region, but globally. Intensification, specialisation, and segregation have been enabled and driven by technological advances, such as synthetic and mineral fertilisers, pesticides, and fossil fuel-driven equipment. Additionally, governments have often actively encouraged this trend through agricultural subsidies and trade policies aiming specifically to intensify and expand industrial agricultural enterprises.

This structural development of the agricultural systems mirrors broader technological shifts in society and is producing more food for more people at relatively lower prices.

No quick or easy solutions

In the last three decades or so, environmental policy has tried to address nutrient leakage in agriculture and has influenced management practices (van Grinsven et al. 2012, Dalgaard et al. 2014, Willems et al. 2016). The Nitrates Directive, for example, is credited with reducing nitrogen leakage from agricultural land while maintaining or even increasing agricultural production. (Hutchings et al. 2014, Lassaletta et al. 2014). But so far, environmental policy has not led to reduced nutrient surpluses adequately enough to protect or restore water bodies.

After examining scientific literature, we identified three major pathways to address nutrient surpluses associated with the present separation between crop and livestock production. These pathways are not mutually exclusive and could produce other benefits as well, such as reducing greenhouse gas emissions and improving human health.

1. Redistribute manure nutrients. Transport manure from areas with high livestock density and more nutrients than what the crops need to areas that focus on crop production.

<u>Current barriers to redistributing manure nutrients</u>

- Manure is bulky and expensive to transport due to high water content. It is possible to process in various ways to make it more transportable and easier to handle, but it is typically cheaper to use mineral fertiliser in manure-poor regions (Hjorth et al. 2010, Flotats et al. 2011, ten Hoeve et al. 2016)
- Mineral fertiliser is often easier to apply and nutrients in manure are not necessarily in the optimal ratios or form to meet plant needs. Investments in specialised equipment for collection, handling, storage, processing, and spreading manure are needed (Buckwell and Nadeu 2016).
- Proposed EU legislation aims to create common quality standards for recycled fertilisers that are currently lacking in order to promote trade (EC 2016).

<u>Added benefits of redistributing manure nutrients</u>

- Better recycling of manure that reduces imports of inorganic nitrogen and phosphorus fertilisers would also reduce the energy use and greenhouse gas emissions from synthesis, mining, and transport.
- Better recycling of manure that reduces imports of inorganic phosphorus fertilisers would:
    - reduce dependence on mined phosphate rock, a finite resource with geo-political risks because reserves are concentrated in a handful of countries (Cordell et al. 2009).
    - reduce the inputs of cadmium to the environment. Fertilisers deriving from phosphate rock from certain regions, such as in Morocco and the West Sahara, naturally contain high concentrations of cadmium and are the largest source of cadmium to soils
      (link: http://www.europarl.europa.eu/sides/getAllAnswers.do?reference=P-2017-001120&language=EN)

2. Redistribute livestock. Move livestock from areas with high livestock density and relatively low crop production, to areas that focus on crop production and have few or no livestock.

Current barriers to redistributing livestock

- Current locations of livestock depend on infrastructure, such as closeness to feed suppliers, slaughter houses, and other specialised facilities. Relocation of infrastructure would lead to additional costs (van Grinsven et al. 2018).
- Natural pre-conditions set the enterprises' direction; e.g. livestock are historically reared in areas with land that is less suitable for crop production.
- Intensive, large-scale livestock production generally lowers production costs, at least when the environmental impacts or livestock welfare are not internalized in the economic system (van Grinsven et al. 2018).
- Political difficulties to limit livestock numbers or infringe on land-owner rights.

Despite difficulties there are examples of policies that have reduced livestock densities. These include the EU Industrial Emissions Directive and the Swedish national regulation that requires enough manure-spreading area so that a certain phosphorus application rate is not exceeded.

Added benefits of redistributing livestock (Oomen et al. 1998, Clark 2004, Sulc and Tracy 2007, Hilimire 2011, Peyraud et al. 2014, Soussana and Lemaire 2014, Sulc and Franzluebbers 2014, Willems et al. 2016)

- Introducing ruminants in areas with mostly annual crops (such as cereals) leads to more diversified crop rotations including fodder crops (such as grass-clover mixes).
- Diversified crop rotations can improve soil fertility and yields.
- Application of manure and changed crop rotations can increase organic matter in soils, and thereby improve yields and nutrient use efficiency. Grazing of natural pastures can be beneficial for biodiversity.

3. Produce and consume fewer livestock-based products.
Here, we provide a brief overview of a complex issue; for more information, see the separate fact sheet: Can changing our diets help the Baltic Sea?

Because food is a global business, it is not obvious that changed consumption in the Baltic Sea catchment would help the Baltic Sea. In other words, through international trade in food and feed, the environmental impacts of consumption may be far removed to other countries or continents (Westhoek et al. 2011, MacDonald et al. 2015, Wiedmann and Lenzen 2018).

First, what if people in the Baltic Sea catchment consumed fewer livestock products that were produced in the catchment?

This only reduces imports of livestock products and would have no direct effect on the risk of nutrient leakage to the Baltic Sea.

Second, what if people in the Baltic Sea catchment consumed fewer livestock products that were produced outside the catchment?

In this case, farmers could keep producing as much and under the same systems as today and just sell it elsewhere because of strong global demand. In this situation, reduced consumption of livestock products would not reduce in the risk of nutrient leakage to the Baltic Sea.

Third, what If the consumption of livestock products from the Baltic Sea catchment was reduced *and* farmers cut back on their livestock production?

Over time, this could reduce the risk of nutrient losses to the sea, but it depends on how former livestock-production land is used.

Fourth, what If the production and consumption of livestock products from the Baltic Sea catchment was reduced *and* agricultural land used for feed is taken out from production?

Over time, this could reduce the risk of nutrient losses to the sea.

<u>Current barriers to reducing the production and consumption of livestock products</u>

- Trade deals encourage the export of livestock products (see example here: http://trade.ec.europa.eu/doclib/docs/2017/july/tradoc_155684.pdf).
- Strong and growing global demand for livestock products (FAOSTAT 2016).
- Low awareness of environmental and health issues associated with consumption of certain livestock products, such as processed meats (Wellesley et al. 2015, Macdiarmid et al. 2016).

<u>Other benefits of reducing the production and consumption of livestock products</u>

- Improved human health by reducing over-consumption of livestock protein in processed or high fat meats (Westhoek et al. 2011, Wellesley et al. 2015).
- Fewer ruminants and reduced fertiliser use and nitrogen leakage could reduce greenhouse gas emissions (Tukker et al. 2011, Wolf et al. 2011).
- Consuming less protein could have a minor effect on the nutrient content in sewage, because excretion of nitrogen and phosphorus would be reduced (Cease et al. 2015).

What can we do about today's farm structure?

There is no easy or one size fits all solution to the problem of farm structure and nutrient leakage to the Baltic Sea. A combination of the presented pathways will likely be needed to address the problems resulting from the present farm structure.

Given the global nature of today's markets for food products, balancing consumer demand and rural livelihoods with environmental consequences will require action at both national and international levels. Policies aimed at relocating livestock or nutrients and reducing farming pressure in sensitive areas can be implemented at national and sub-national scales, depending on conditions.

We need to consider all pathways to reduce nutrient leakage simultaneously and not put all our eggs in one basket. Regardless of farm structure or type of farming, however, fertiliser should be applied according to crop needs (thus avoiding over-fertilisation) and farming pressure should be limited in ecologically sensitive areas.

These basic practices are necessary first steps to reduce nutrient surpluses and protect the environment, but are not always used. Further examination is needed to find the best policy tool at EU, national, and local scales.

Policy recommendations

- Limit phosphorus fertilisation by setting maximum application rates or maximum surpluses.
- Account for phosphorus status in the soil. Limit livestock densities under the EU Industrial Emissions Directive.
- Expand current zones that are deemed as environmentally sensitive or vulnerable to nutrient losses to include livestock density limits.
- Establish minimum proportions of locally grown feed at farm- or regional scale (similar to rules for organic labelling).
- Provide seed funding for the development of innovative recycled nutrient fertiliser products.
- Establish common quality standards for recycled nutrient fertiliser products.

References:

Buckwell, A., and E. Nadeu. 2016. Nutrient recovery and reuse in European agriculture. A review of the issues, opportunities, and actions. RISE Foundation, Brussels, Belgium.

Cease, A. J., K. A. Capps, K. K. Gates, M. L. McCrackin, and D. A. Nidzgorski. 2015. Consumer-driven nutrient dynamics in urban environments: the stoichiometry of human diets and waste management. Oikos **124**:931-948.10.1111/oik.02391

Clark, E. A. 2004. Benefits of Re-Integrating Livestock and Forages in Crop Production Systems. Journal of Crop Improvement **12**:405-436.10.1300/J411v12n01_06

Cordell, D., J. O. Drangert, and S. White. 2009. The story of phosphorus: Global food security and food for thought. Global Environmental Change-Human and Policy Dimensions **19**:292-305.10.1016/j.gloenvcha.2008.10.009

Dalgaard, T., B. Hansen, B. Hasler, O. Hertel, N. J. Hutchings, B. H. Jacobsen, L. Stoumann Jensen, B. Kronvang, J. E. Olesen, J. K. Schjørring, I. Sillebak Kristensen, M. Graversgaard, M. Termansen, and H. Vejre. 2014. Policies for agricultural nitrogen management—trends, challenges and prospects for improved efficiency in Denmark. Environmental Research Letters **9**:115002.10.1088/1748-9326/9/11/115002

EC. 2016. Procedure 2016/0084/COD. COM (2016) 157: Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL laying down rules on the making available on the market of CE marked fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009. http://eur-lex.europa.eu/procedure/EN/2016_84.

FAOSTAT. 2016. Food and Agriculture Organization of the United Nations, FAOSTAT Database Collections. http://faostat.fao.org/.

Flotats, X., H. Lyngso Foged, A. Bonmati Blasi, J. Palatasi, A. Magri, and K. Schelde. 2011. Manure processing technologies. Technical Report No. II concerning "Manure Processing Activities in Europe" to the European Commission, Directorate-General Environment.".

HELCOM. 2018. Sources and pathways of nutrients to the Baltic Sea. Baltic Sea Environment Proceedings No. 153.

Hilimire, K. 2011. Integrated Crop/Livestock Agriculture in the United States: A Review. Journal of Sustainable Agriculture **35**:376-393.10.1080/10440046.2011.562042

Hjorth, M., K. V. Christensen, M. L. Christensen, and S. G. Sommer. 2010. Solid-liquid separation of animal slurry in theory and practice. A review. Agronomy for Sustainable Development **30**:153-180.10.1051/agro/2009010

Hong, B., D. P. Swaney, M. McCrackin, A. Svanbäck, C. Humborg, B. Gustafsson, A. Yershova, and A. Pakhomau. 2017. Advances in NANI and NAPI accounting for the Baltic drainage basin: spatial and temporal trends and relationships to watershed TN and TP fluxes. Biogeochemistry **133**:245-261.10.1007/s10533-017-0330-0

Hutchings, N. J., O. K. Nielsen, T. Dalgaard, M. H. Mikkelsen, C. D. Børgesen, M. Thomsen, T. Ellermann, A. L. Højberg, L. Mogensen, and M. Winther. 2014. A nitrogen budget for Denmark; developments between 1990 and 2010, and prospects for the future. Environmental Research Letters **9**:115012

Lassaletta, L., G. Billen, B. Grizzetti, J. Anglade, and J. Garnier. 2014. 50 year trends in nitrogen use efficiency of world cropping systems: the relationship between yield and nitrogen input to cropland. Environmental Research Letters **9**:105011.10.1088/1748-9326/9/10/105011

Macdiarmid, J. I., F. Douglas, and J. Campbell. 2016. Eating like there's no tomorrow: Public awareness of the environmental impact of food and reluctance to eat less meat as part of a sustainable diet. Appetite **96**:487-493.10.1016/j.appet.2015.10.011

MacDonald, G. K., K. A. Brauman, S. Sun, K. M. Carlson, E. S. Cassidy, J. S. Gerber, and P. C. West. 2015. Rethinking Agricultural Trade Relationships in an Era of Globalization. BioScience **65**:275-289.10.1093/biosci/biu225

Oomen, G. J. M., E. A. Lantinga, E. A. Goewie, and K. W. Van der Hoek. 1998. Mixed farming systems as a way towards a more efficient use of nitrogen in European Union agriculture. Environmental Pollution **102**:697-704.10.1016/s0269-7491(98)80101-2

Peyraud, J.-L., M. Taboada, and L. Delaby. 2014. Integrated crop and livestock systems in Western Europe and South America: A review. European Journal of Agronomy **57**:31-42.10.1016/j.eja.2014.02.005

Soussana, J.-F., and G. Lemaire. 2014. Coupling carbon and nitrogen cycles for environmentally sustainable intensification of grasslands and crop-livestock systems. Agriculture, Ecosystems & Environment **190**:9-17.10.1016/j.agee.2013.10.012

Sulc, R. M., and A. J. Franzluebbers. 2014. Exploring integrated crop–livestock systems in different ecoregions of the United States. European Journal of Agronomy **57**:21-30.10.1016/j.eja.2013.10.007

Sulc, R. M., and B. F. Tracy. 2007. Integrated Crop–Livestock Systems in the U.S. Corn Belt. Agronomy Journal **99**.10.2134/agronj2006.0086

ten Hoeve, M., B. Gomez-Munoz, L. S. Jensen, and S. Bruun. 2016. Environmental impacts of combining pig slurry acidification and separation under different regulatory regimes

- A life cycle assessment. J Environ Manage **181**:710-720.10.1016/j.jenvman.2016.08.028

Tukker, A., R. A. Goldbohm, A. de Koning, M. Verheijden, R. Kleijn, O. Wolf, I. Pérez-Domínguez, and J. M. Rueda-Cantuche. 2011. Environmental impacts of changes to healthier diets in Europe. Ecological Economics **70**:1776-1788.10.1016/j.ecolecon.2011.05.001

van Grinsven, H. J. M., H. F. M. ten Berge, T. Dalgaard, B. Fraters, P. Durand, A. Hart, G. Hofman, B. H. Jacobsen, S. T. J. Lalor, J. P. Lesschen, B. Osterburg, K. G. Richards, A. K. Techen, F. Vertès, J. Webb, and W. J. Willems. 2012. Management, regulation and environmental impacts of nitrogen fertilization in northwestern Europe under the Nitrates Directive; a benchmark study. Biogeosciences **9**:5143-5160.10.5194/bg-9-5143-2012

van Grinsven, H. J. M., J. D. van Dam, J. P. Lesschen, M. H. G. Timmers, G. L. Velthof, and L. Lassaletta. 2018. Reducing external costs of nitrogen pollution by relocation of pig production between regions in the European Union. Regional Environmental Change.10.1007/s10113-018-1335-5

Wellesley, L., C. Happer, and A. Froggatt. 2015. Changing Climate, Changing Diets. Pathways to Lower Meat Consumption. Chatham House Report.

Westhoek, H., T. Rood, M. van den Berg, J. Janse, D. Nijdam, M. Reudink, and E. Stehfest. 2011. The Protein Puzzle, The Hague: PBL Netherlands Environmental Assessment Agency.

Wiedmann, T., and M. Lenzen. 2018. Environmental and social footprints of international trade. Nature Geoscience **11**:314-321.10.1038/s41561-018-0113-9

Willems, J., H. J. M. van Grinsven, B. H. Jacobsen, T. Jensen, T. Dalgaard, H. Westhoek, and I. S. Kristensen. 2016. Why Danish pig farms have far more land and pigs than Dutch farms? Implications for feed supply, manure recycling and production costs. Agricultural Systems **144**:122-132.10.1016/j.agsy.2016.02.002

Wolf, O., I. Pérez-Domínguez, J. M. Rueda-Cantuche, A. Tukker, R. Kleijn, A. de Koning, S. Bausch-Goldbohm, and M. Verheijden. 2011. Do healthy diets in Europe matter to the environment? A quantitative analysis. Journal of Policy Modeling **33**:8-28.10.1016/j.jpolmod.2010.10.009