Agricultural phosphorus losses and eutrophication in Nordic-Baltic countries

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Review of indexing tools for identifying high risk areas of phosphorus loss in Nordic catchments

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KEYWORDS
Regulation;
P index;
Nordic countries;
Agriculture;
Water quality

Summary Compliance with the Water Framework Directive (WFD) will require substantial reductions in agricultural phosphorus (P) losses in the Nordic countries Denmark, Norway, Sweden and Finland. Falling P surpluses in agriculture for more than a decade and voluntary programmes of good agricultural practice have not reduced P losses to surface waters, while general regulatory measures have primarily focused on nitrogen. Without addressing the role of critical source areas for P loss, policy measures to abate diffuse P losses are likely to be ineffective. This has created a demand by environmental authorities for instruments that assess the risk of P losses from agricultural land and facilitate the planning of mitigation measures. In Nordic countries index-type risk assessment tools for diffuse P losses are under development inspired by experiences with P indexing in the USA. A common feature is that they are empirical, risk-based, user-friendly decision tools with low data requirements. Phosphorus indices vary between the four Nordic countries in response to different agriculture, soil and climate. These differences also result in different recent average annual agricultural P load estimates to the sea of 0.3, 0.5, 0.5 and 1.1 kg total P ha^{-1} in Denmark, Norway, Sweden and Finland, respectively. In initial evaluations, Nordic P indices explained a large degree of variance in P losses at the field or catchment scale, but comparative data are still limited. To gain acceptance amongst stakeholders and inform river basin

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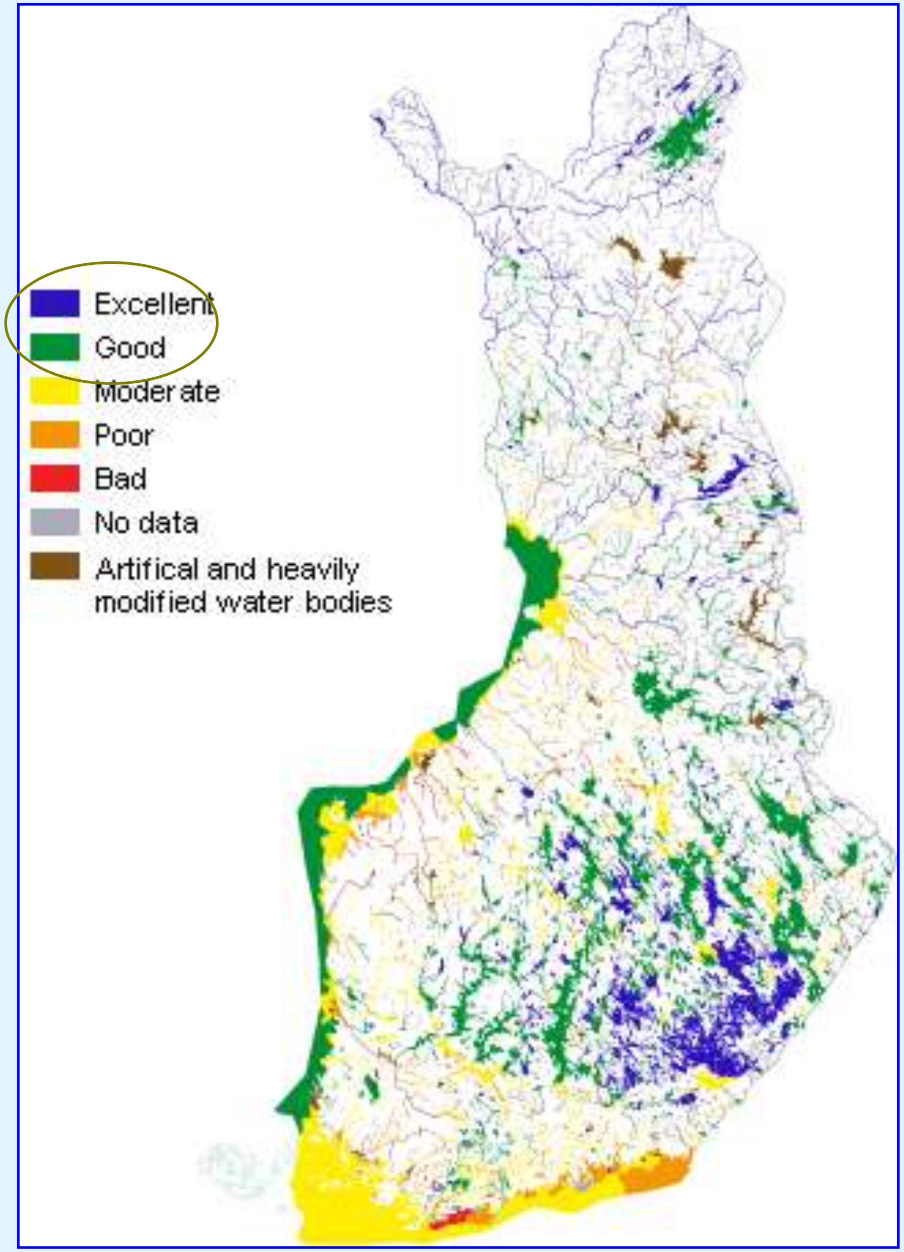
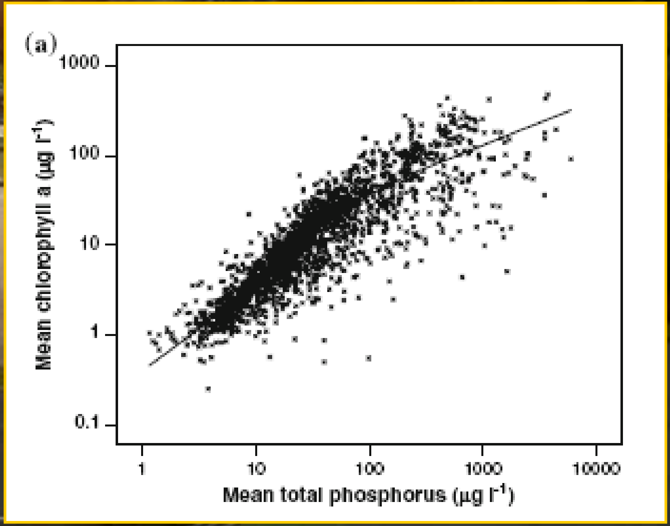
Photos: Petri Ekholm, Seppo Knuuttila, Jouni Lehtoranta/SYKE



Ecological status of surface water in Finland

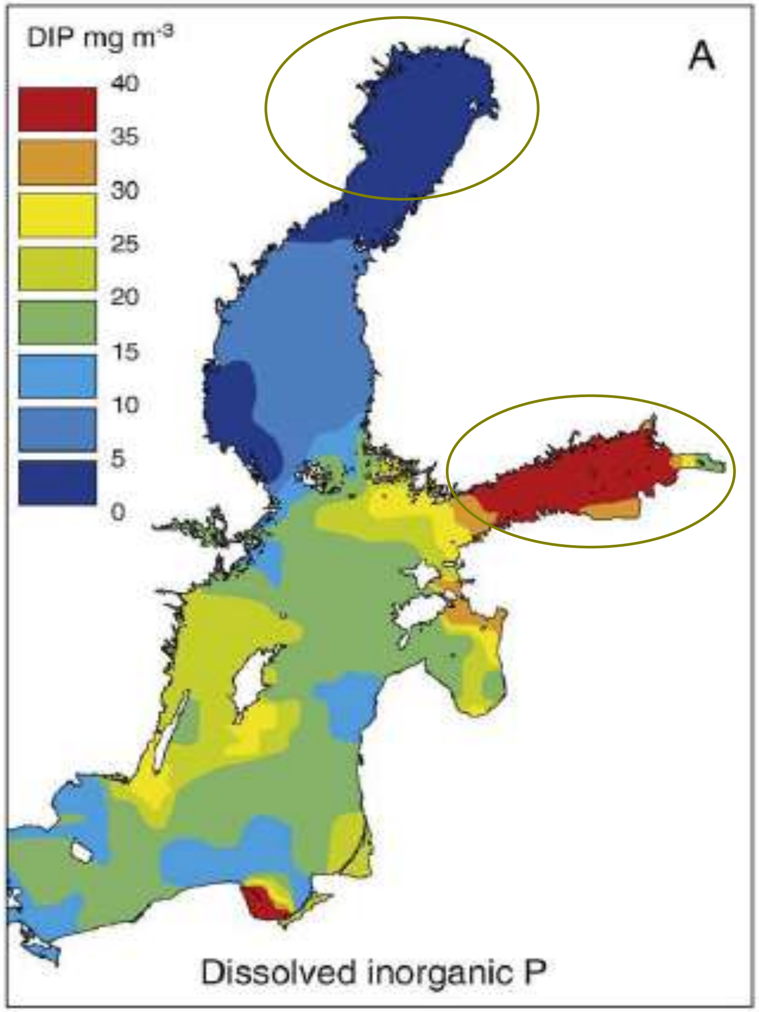
Has P a role in aquatic eutrophication?

- P controls the growth of phytoplankton in many lakes and estuaries
- P triggers the blooms of blue-green algae
- Both oligotrophic and eutrophic lakes may show N limitation of phytoplankton growth
- There are differences among phytoplankton species (e.g. Si limitation of diatoms)
- Aquatic rooted vegetation may be N-limited
- Complex ecosystem effects



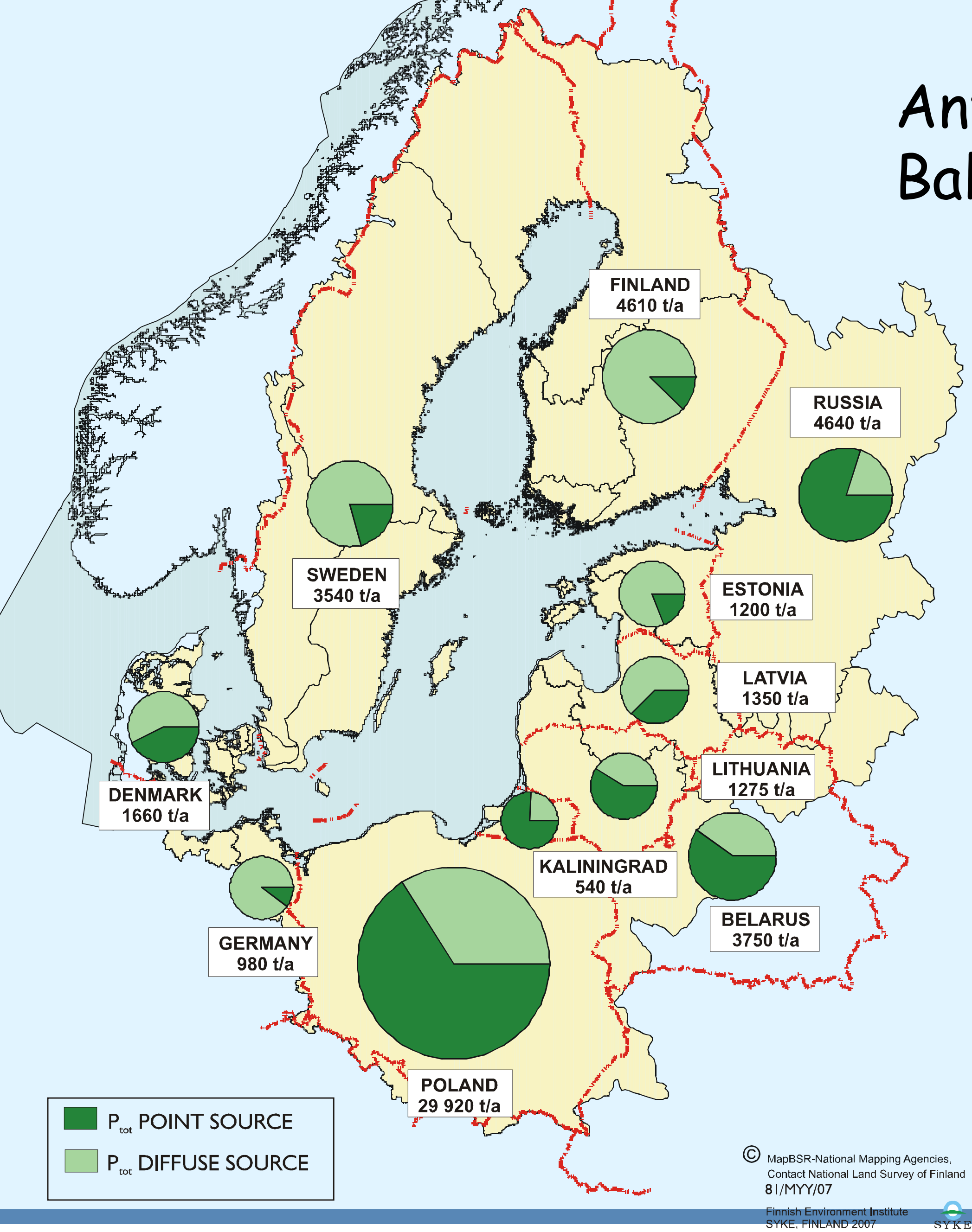
Phillips G, Pietiläinen O-P, Carvalho L, Solimini A, Lyche Solheim A, Cardoso AC. 2008. Chlorophyll–nutrient relationships of different lake types using a large European dataset. Aquat Ecol 42:213–226.

Phosphate in the surface water in winter



Graph: Kiirikki (2002)

Anthropogenic P load to the Baltic Sea in 2000 ($t\ yr^{-1}$)



≈ 50% of the P flux (incl. natural background) originates from diffuses sources

Map: Seppo Knuuttila, SYKE, HELCOM

In Nordic-Baltic countries there are differences in

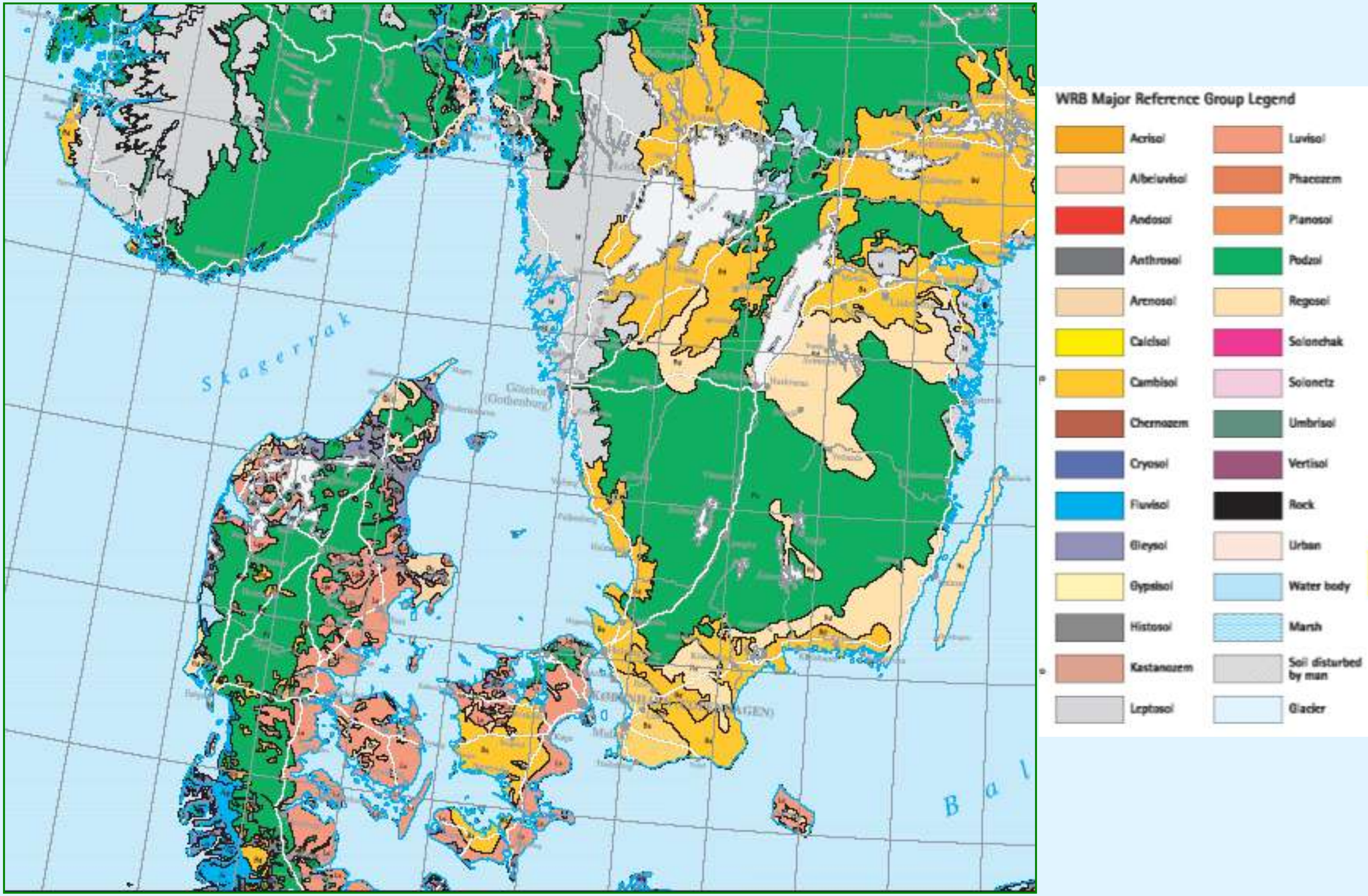
Agriculture

- P use
  - Baltic countries
- Animal density
  - Large P surpluses associated with livestock production
- Set-aside
- Special features
  - 90% watercourses widened or canalized in Denmark
  - Land levelling in Norway
- Regulation/incent-ves/advice…

Nature

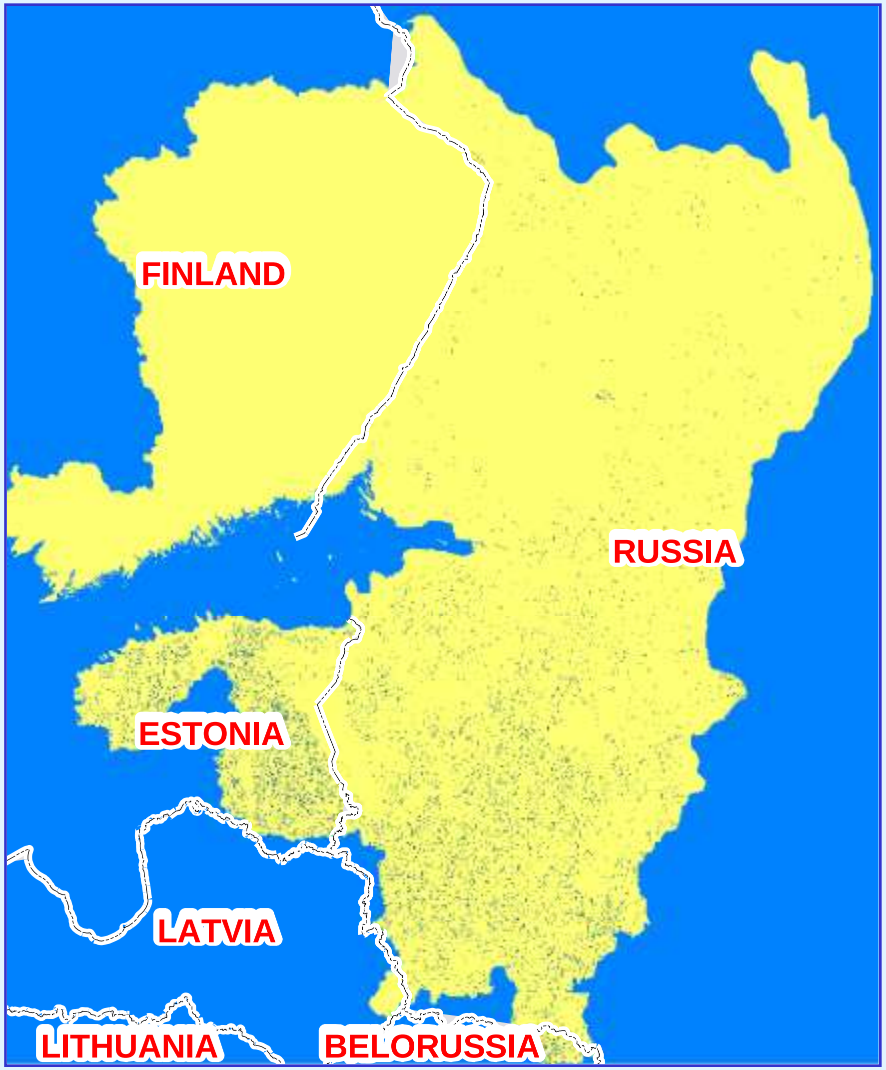
- Climate
  - Temperature
    - Crop yield
    - Rain/snow
    - Frost
  - Precipitation
- Hydrology/transport pathway
  - Runoff: 100–1300 mm
  - Denmark: subsurface losses important
  - Finland: surface runoff and erosion important
  - Streambank erosion
  - Ground water flow
- Soil type

S Y K E



IES, EU/JRC, Land Management & Natural Hazards Unit

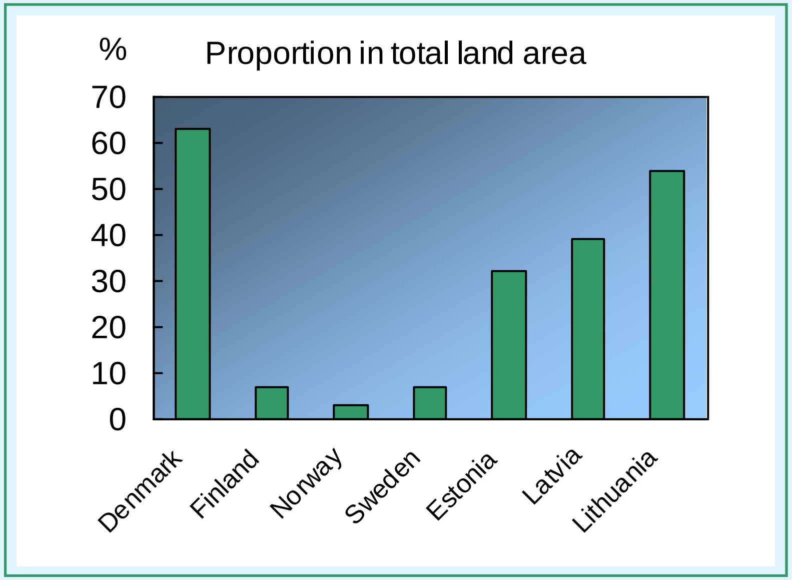
Change in use of agricultural land in the catchment of the Gulf of Finland in 1989–2004

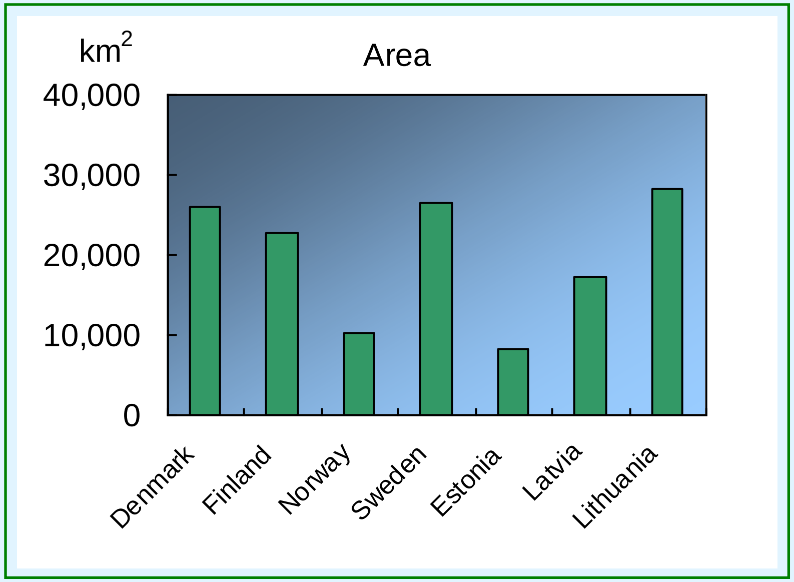


abandoned land

Piirimäe K, Ekholm P, Porvari M. 2007. Application of a catchment model in predicting changes in agricultural nutrient load. Pitkänen H, Tallberg P. (eds.). Searching efficient protection strategies for the eutrophied Gulf of Finland: the integrated use of experimental and modelling tools (SEGUE). Finnish Environment 15/2007.

Agricultural land in Nordic-Baltic countries



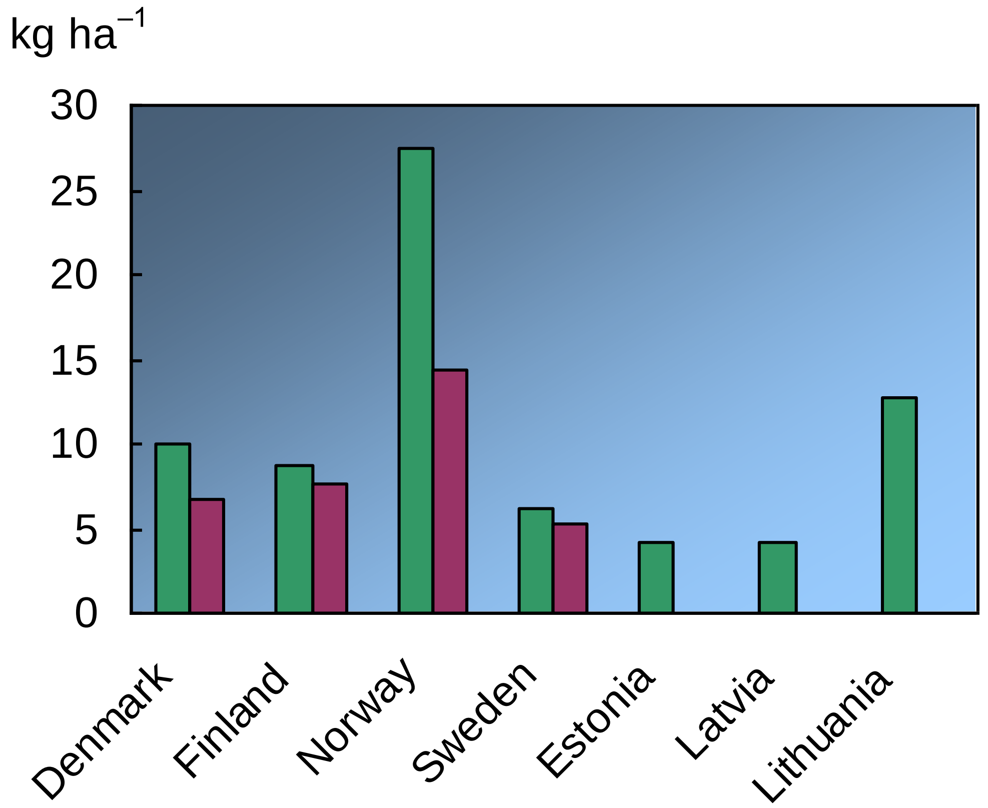


The proportion of arable land in total area in the Nordic countries 18.8% (USA 18%)

FAOSTAT

SYKE

Use of P in fertilizers



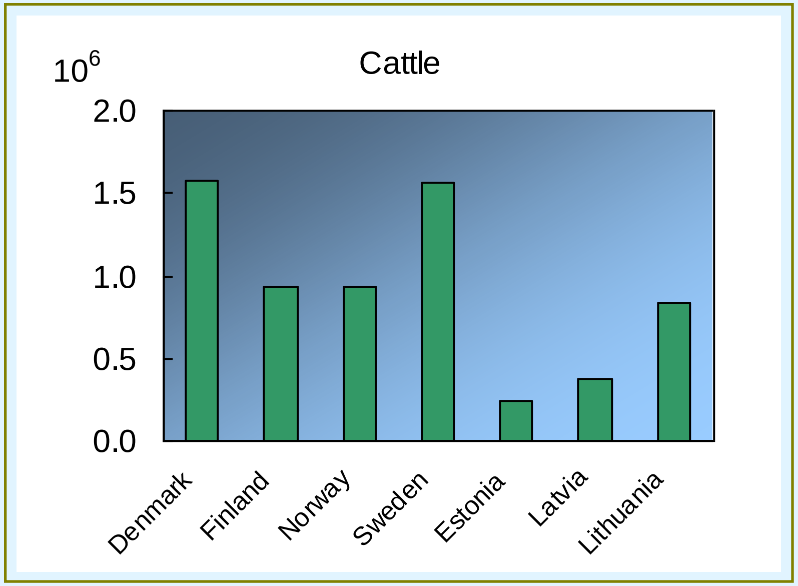
Accumulation of P in soil kg ha^{-1}

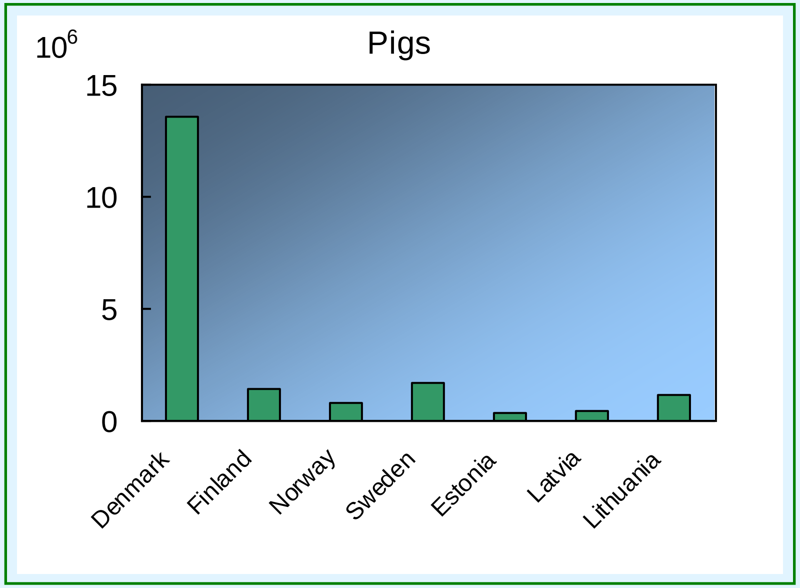
Denmark 1400

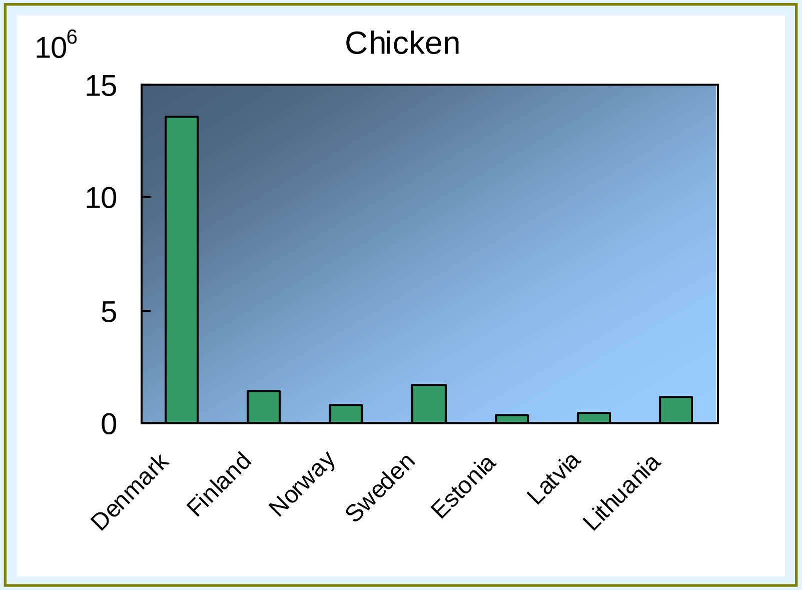
Finland 1000

Sweden 600–700

FAOSTAT, Nordic Statistical Yearbook, Heckrath et al. (2007)



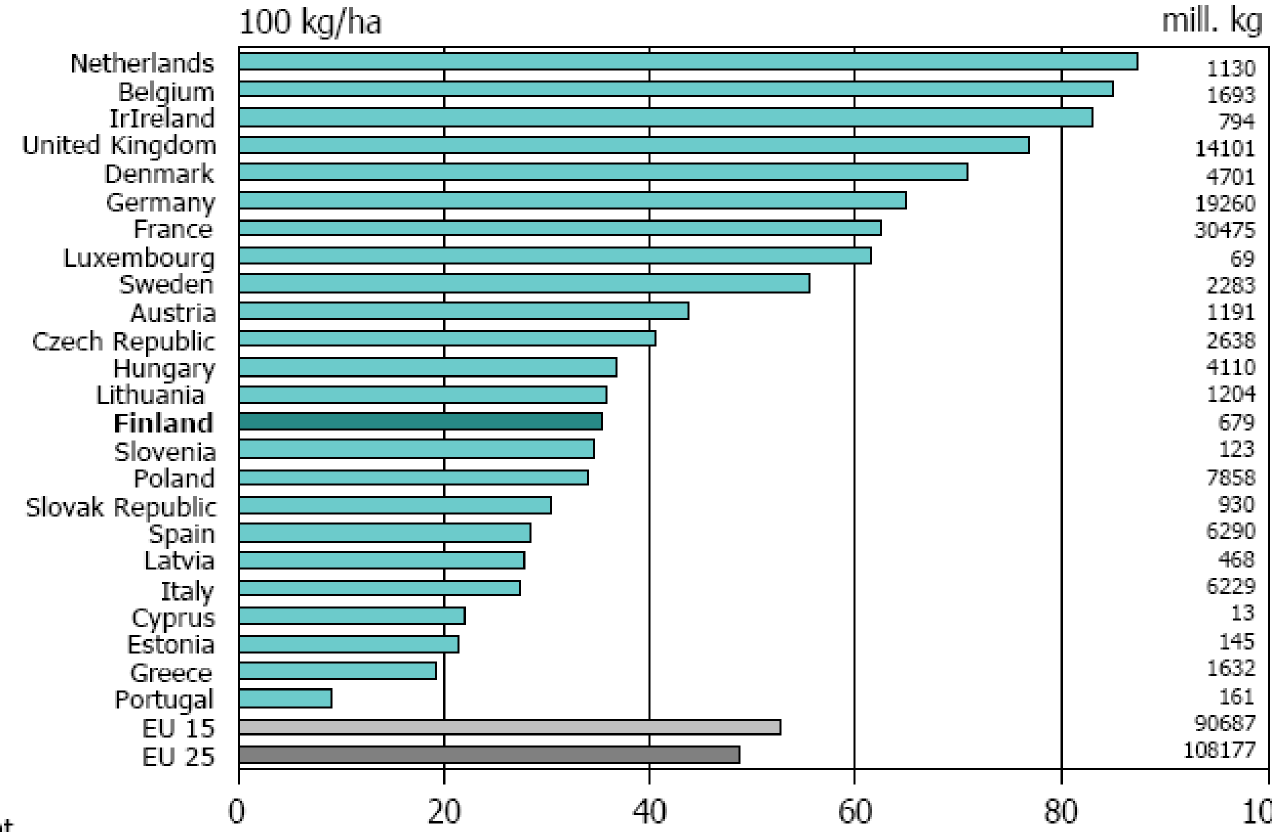




FAOSTAT, Nordic Statistical Yearbook 2007

Statistics Finland

Crop yields of wheat in the EU countries in 2003



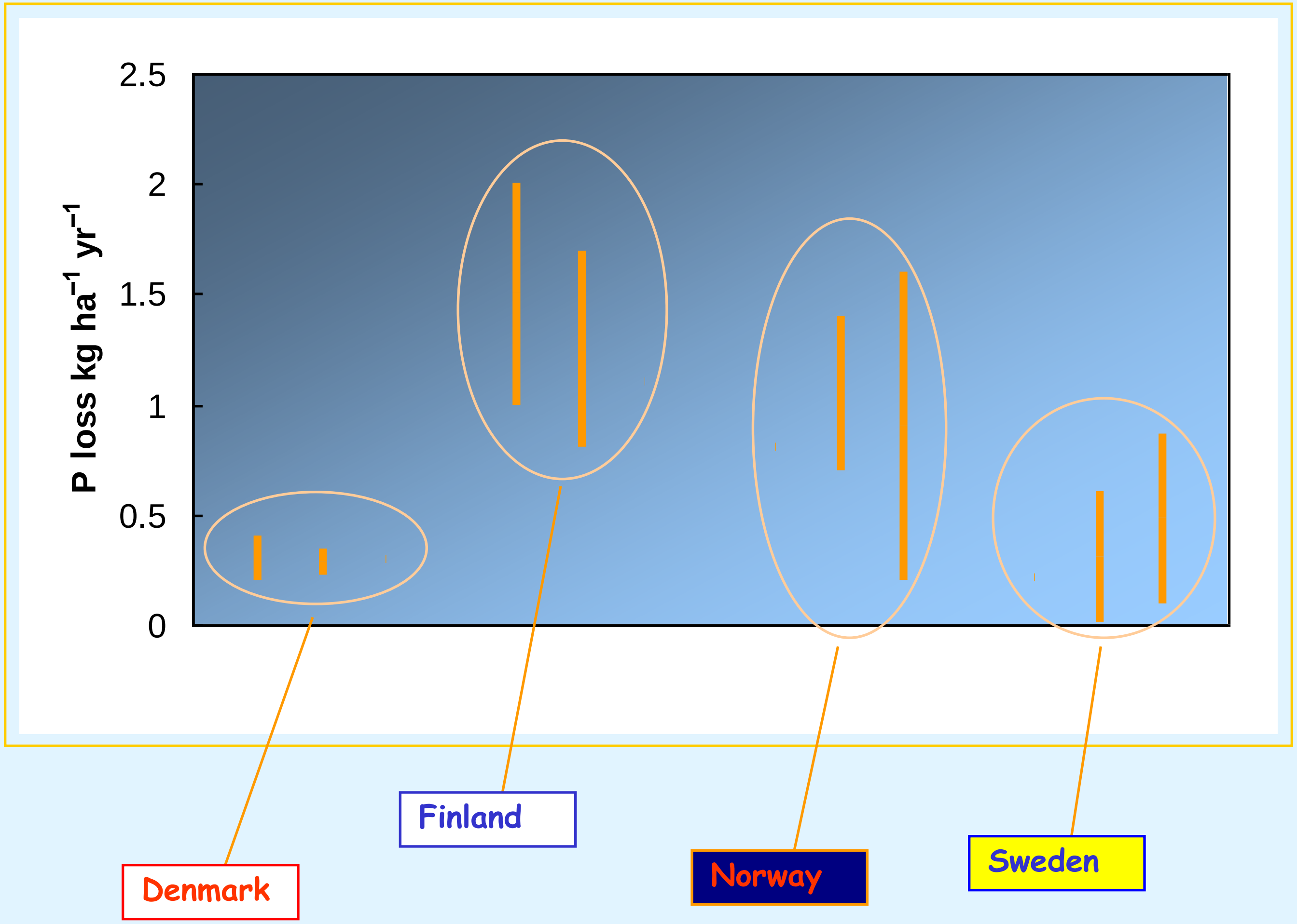
Source: Eurostat

Environment Statistics 2005

Estimation of agricultural P loss to waters

- Monitoring of water flow and P concentration in agricultural catchments
- Manual sampling -> automatic sampling -> on-line sensors
  - (Especially older) estimates are more or less uncertain
- Source apportionment methods vary
  - Natural background loss?
- Extrapolation to a regional and national scale?

Loss of P from arable land in Nordic countries



Baltic countries:

0.1–5.4 kg ha^{-1} yr^{-1}

Svendsen LM, Kronvang B (1991), Rekolainen et al. (1997), Vagstad et al. (2000, 2001), Ulén et al. (2007), Heckrath et al. (2008)

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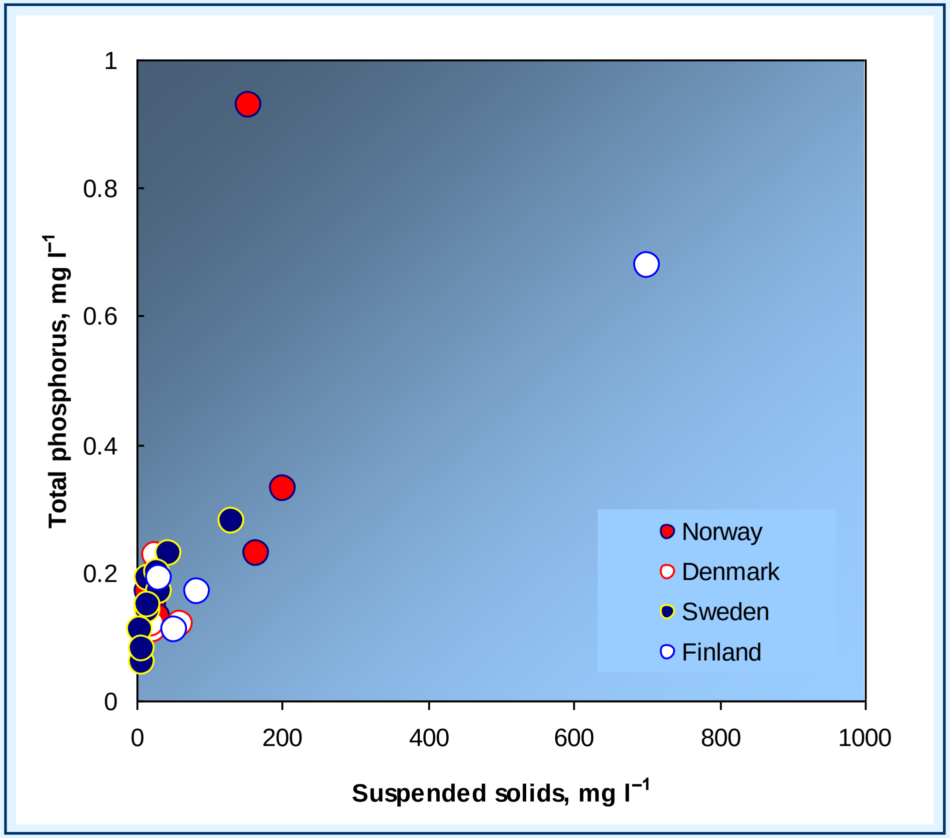
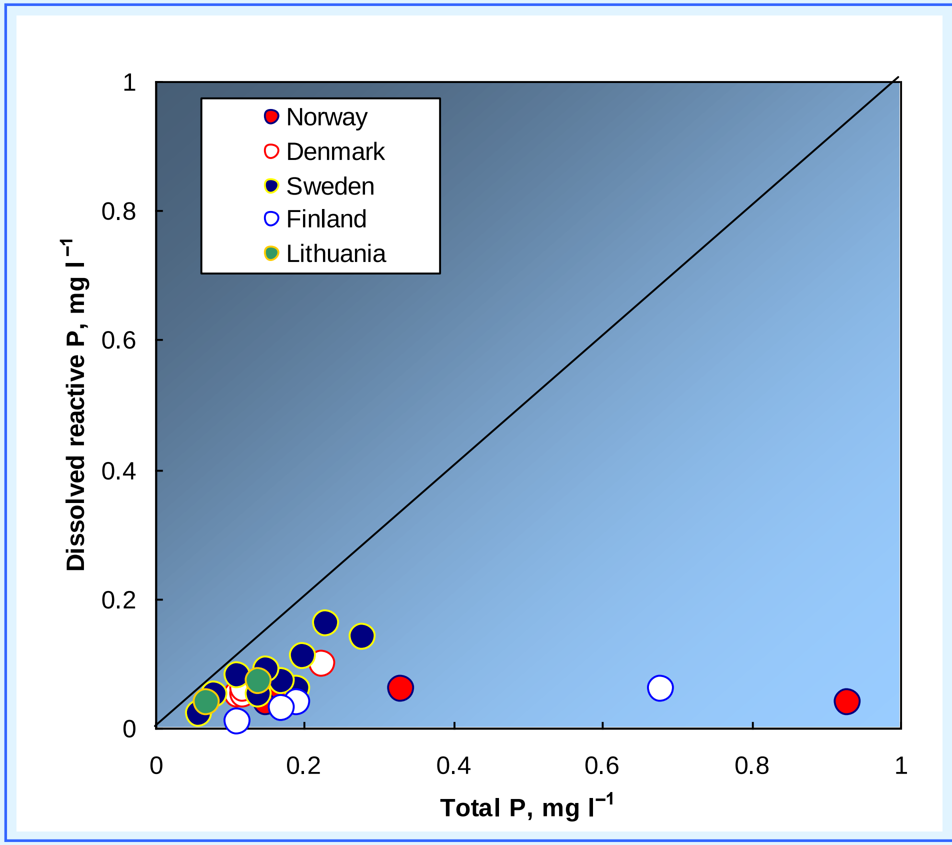
Phosphorus losses in Nordic-Baltic countries

- 35 catchments (<30 km^2) in
  - Denmark, Estonia, Finland, Latvia, Lithuania, Norway, Sweden
  - Proportion of agricultural land usually >50%
  - Years 1993–1997
- P losses ranged from 0.1 to 4.7 kg ha^{-1} yr^{-1}
  - The highest loss in Norway
    - A catchment with organic soils, relatively high animal density and high runoff
  - Generally high in Norway and Finland
    - Hilly erosion-prone areas in Norway
    - Clayey soils in Finland
  - Lowest in Estonia and Sweden
  - Variation within a country

Vagstad et al. (2001). Nutrient losses from agriculture in the Nordic and Baltic countries. Tema Nord 591,
Kronvang et al. (2007)

Concentrations of P and suspended solids in runoff from the 35 catchments





Data from: Vagstad et al. (2001). Nutrient losses from agriculture in the Nordic and Baltic countries. Tema Nord 591

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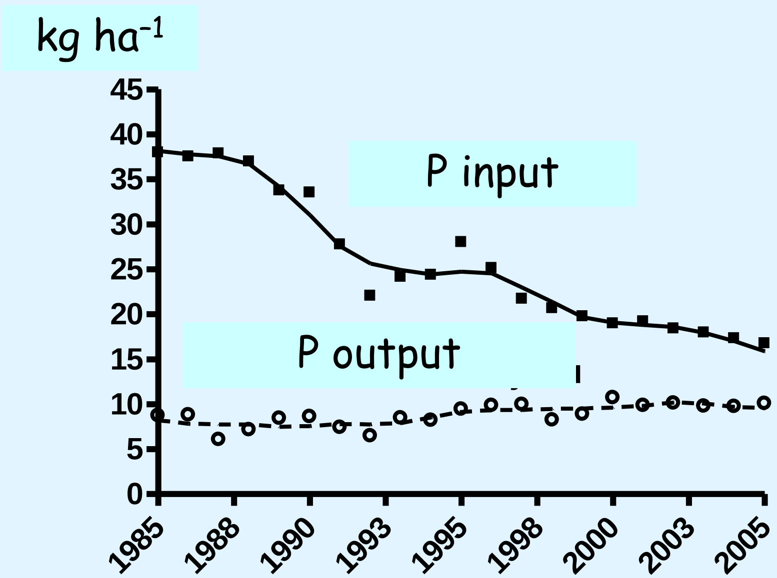
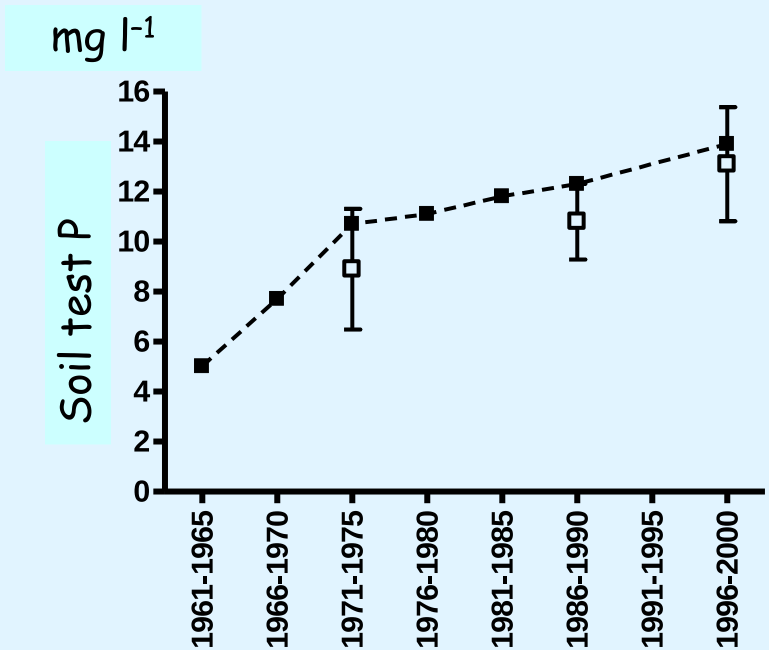
Trend in P balance and soil test P in Finland





- Soil test P is often at a level at which annual P fertilization no more gives clear yield responses
- Farms specialized in non-cereal plant production and animal production have highest soil test P
- An imbalance in P cycling between plant (feed) and animal production

Uusitalo R, Turtola E, Grönroos J, Kivistö J, Mäntylahti V, Turtola A, Lemola R, Salo T. 2007. Finnish trends in phosphorus balances and soil test phosphorus. Agricultural and food science 16:301-316.

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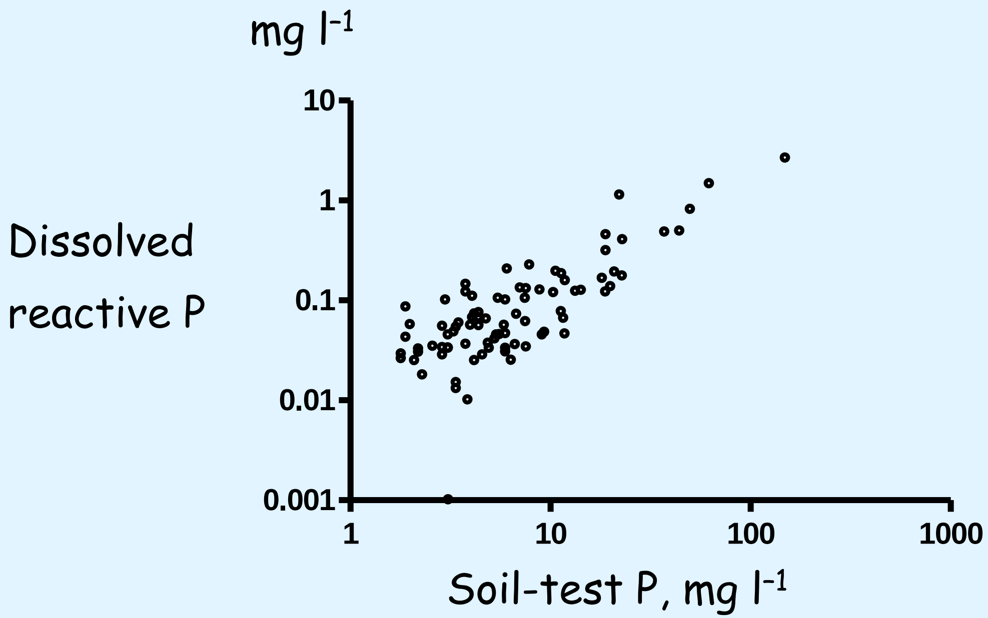
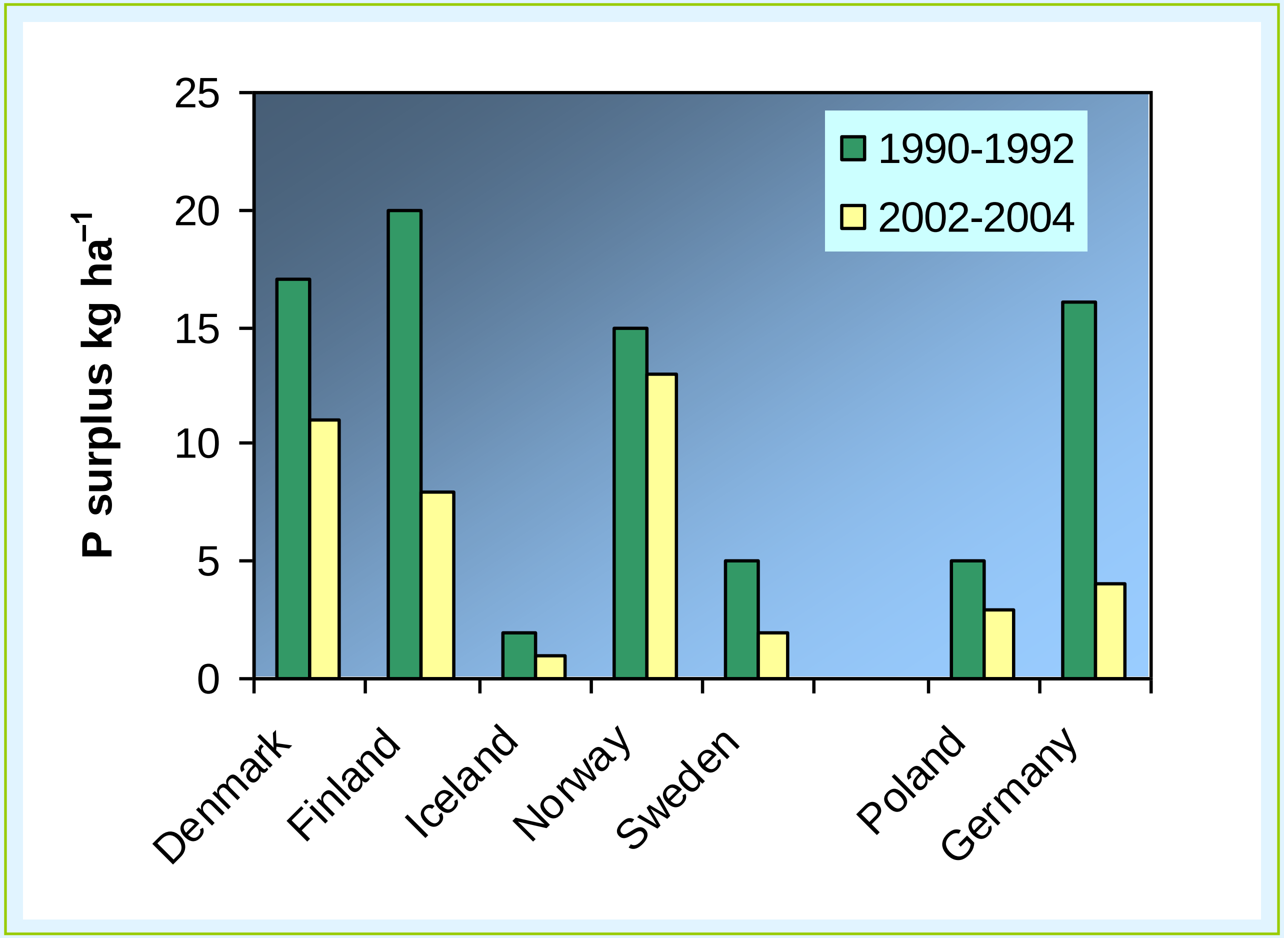
Dissolved reactive P in runoff correlates with soil test P



Soil test P is lowered most on reducing P surpluses in plots that have a high soil test P

Uusitalo R, Turtola E, Grönroos J, Kivistö J., Mäntylahti V, Turtola A., Lemola R, Salo T. 2007. Finnish trends in phosphorus balances and soil test phosphorus. Agricultural and food science 16:301-316.

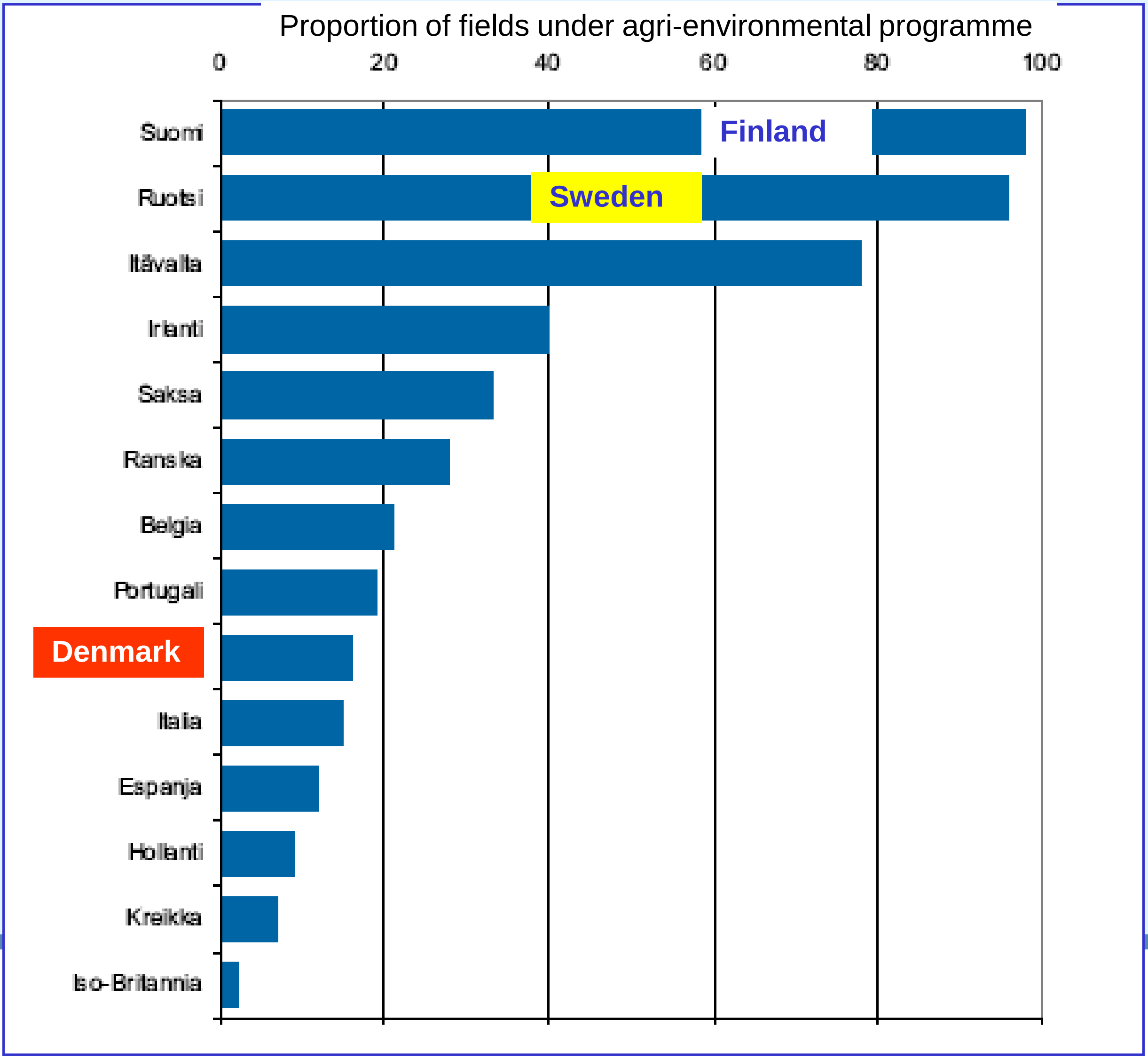
Phosphorus balances in OECD countries around the Baltic Sea



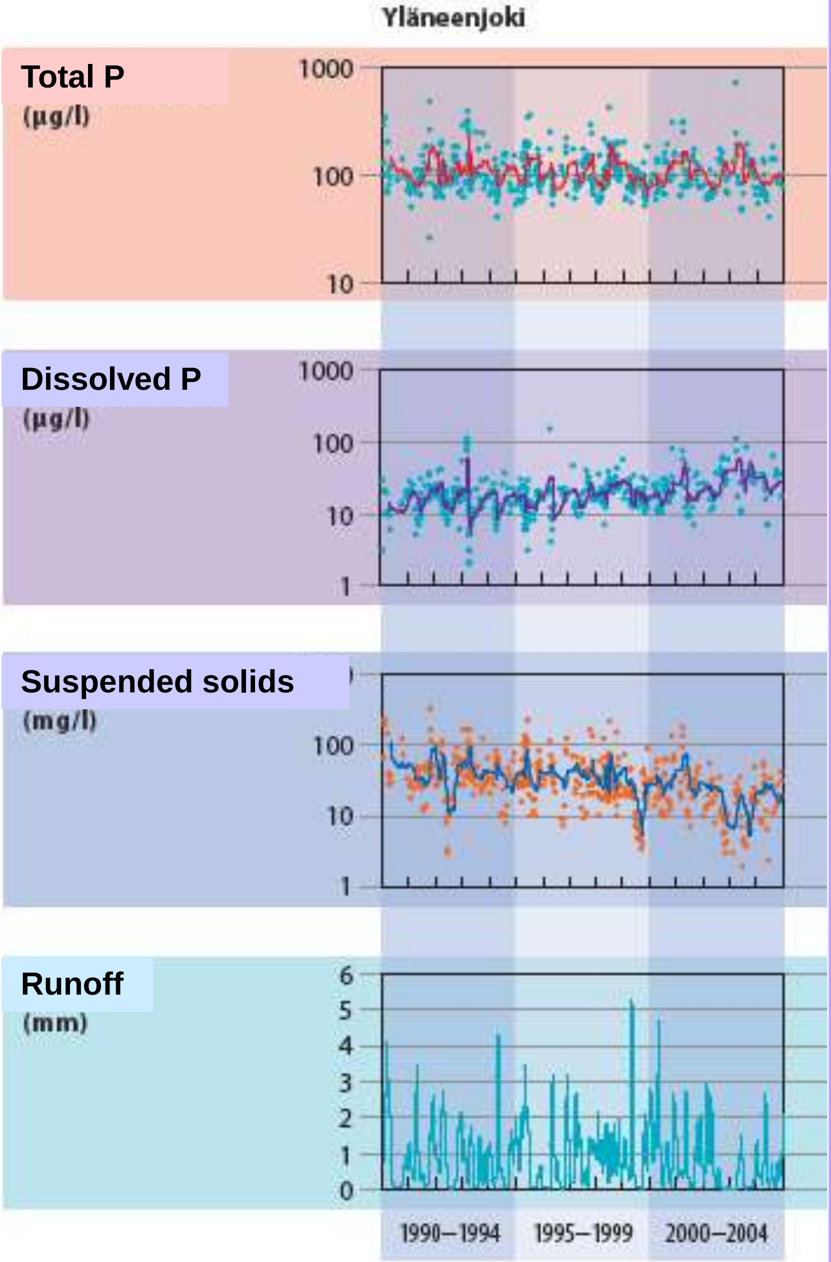
OECD

1. There is a decreasing trend in the use of P in all Nordic-Baltic countries
2. There has been a tendency to stricter regulation

-> The P load from agriculture should go down



Valtiontalouden tarkastusviraston toiminnantarkastuskertomus 175/2008



No clear decrease in agricultural P losses in Finland

<u>National Audit Office of Finland</u>

Released a report in September 2008 on the inefficiency of the Finnish agri-environmental programme

Ekholm P, Granlund K, Kauppila P, Mitikka S, Niemi J, Rankinen K, Räike A, Räsänen J. 2007. Influence of EU policy on agricultural nutrient losses and the state of receiving waters in Finland. Agricultural and Food Science 16: 282–300.

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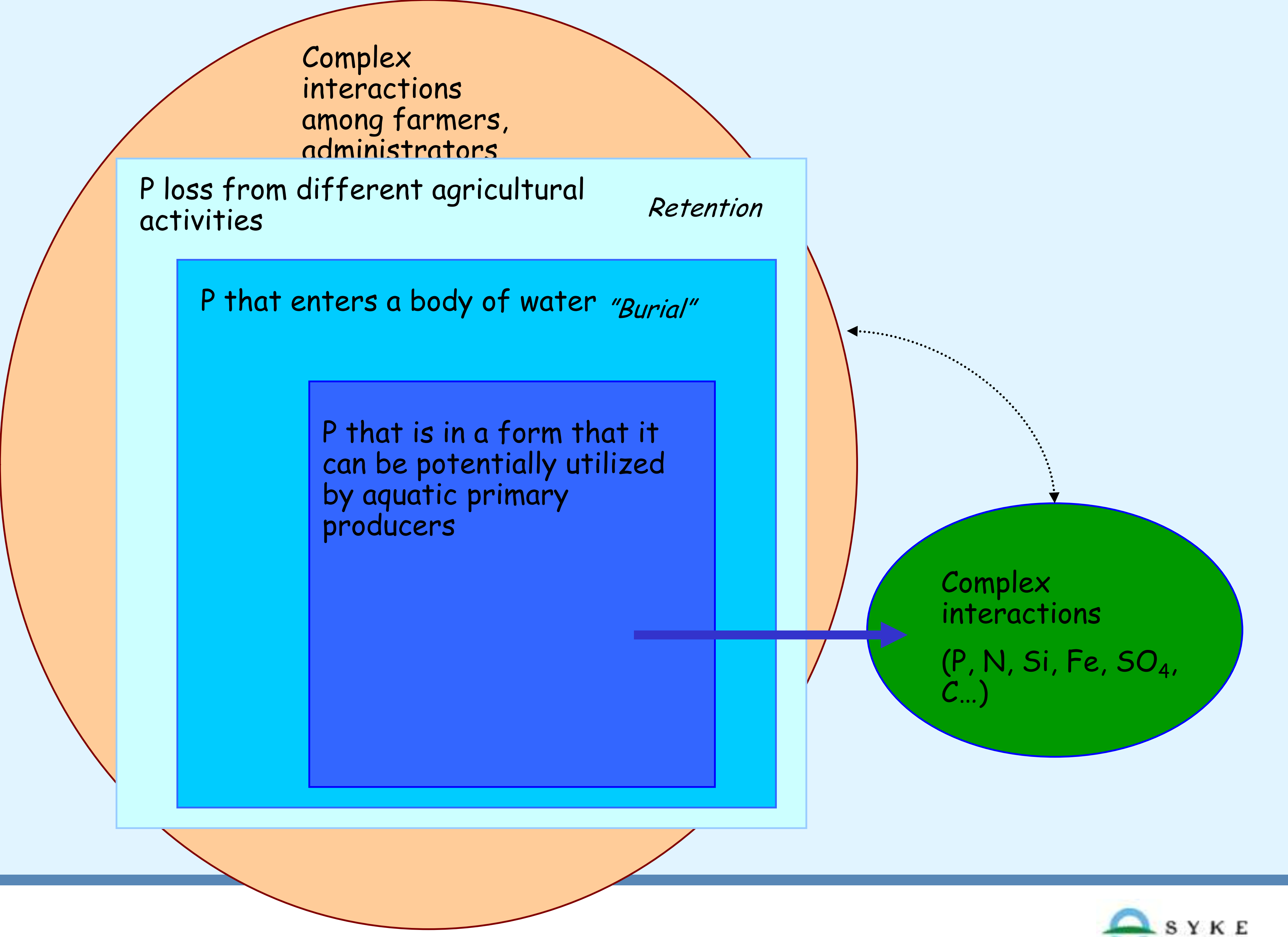
Management of P

Management actions have to be environmentally sustainable, economically viable, technologically feasible, socially desirable (or at least tolerable), legally permissible, administratively achievable and politically expedient (Ducrotoy & Elliott, 2008)

Ducrotoy JP & Elliott M. 2008. The science and management of the North Sea and the Baltic Sea. Natural history, present threats and future challenges. Marine Pollution Bulletin 57:8–21.


Complex interactions among farmers, administrators
P loss from different agricultural activities
Retention
P that enters a body of water
"Burial"
P that is in a form that it can be potentially utilized by aquatic primary producers
Complex interactions
(P, N, Si, Fe, SO_4, C…)
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