# How does gypsum work to mitigate eutrophication?

Photos: Eliisa Punttila and a local farmer

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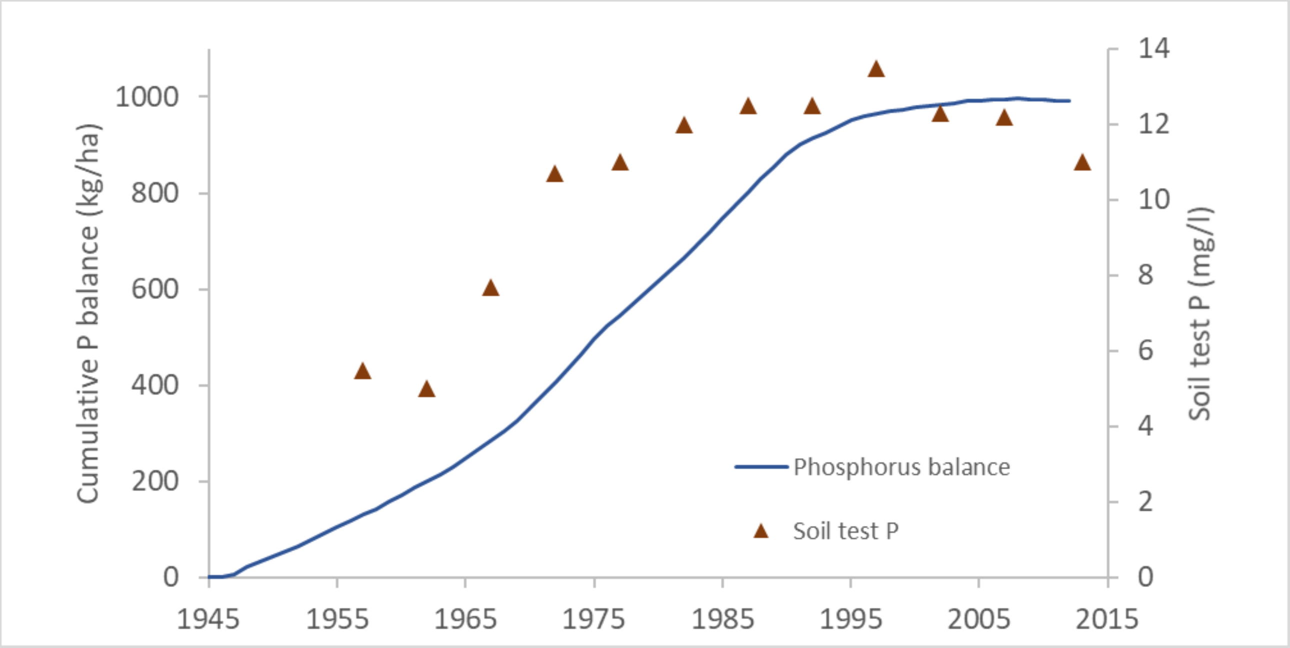
# Contents

- Why gypsum for reducing agricultural phosphorus load
- What is gypsum and how it works
- Pros and cons of gypsum
- Research needs
- How to study whether gypsum works in your country

Photos: Eliisa Punttila

# Basic problem: legacy phosphorus

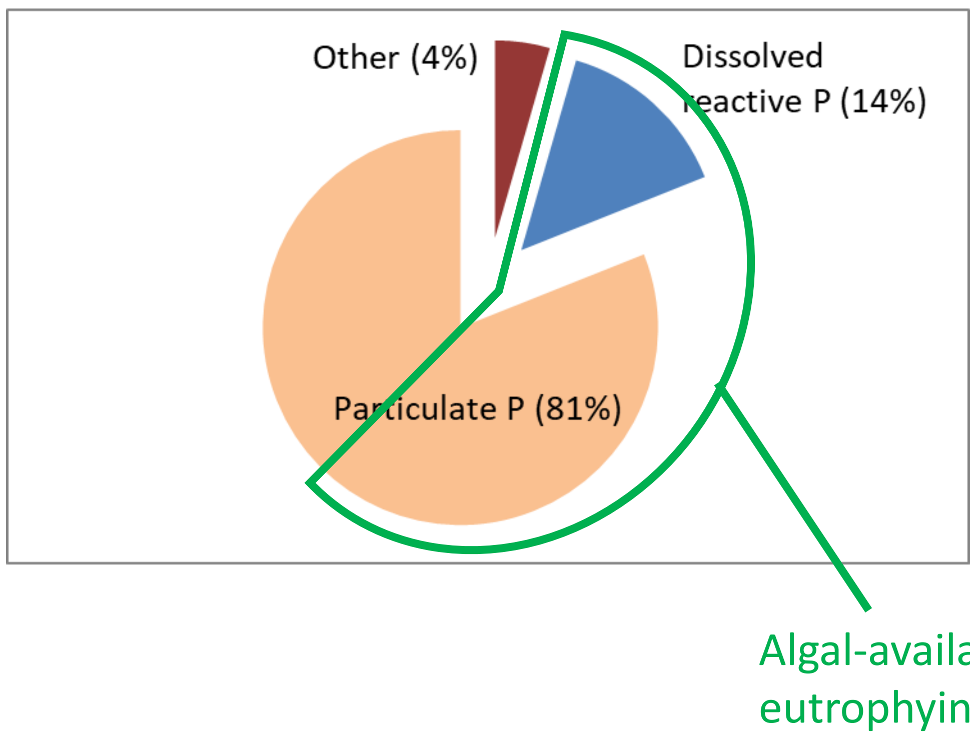



Lowering of (too high) soil P status takes decades, other measures needed for the transition period

# Phosphorus forms in agricultural rivers in Finland

The River Paimionjoki

- Total phosphorus concentration 250 µg/l



# Motivation

- A need for measures that
  - Give a quick response
  - Can be applied to a large field area
  - Reduce bioavailable phosphorus

# What is gypsum $CaSO_4 \cdot 2\ H_2O$?

## Some uses of gypsum

- Construction: cement, concrete, wallboards, land stabilization, mine reclamation
    - An American house contains an average of 7 tons of gypsum
- Agriculture: fertilizer (S, Ca), remediation of soil chemical and physical problems, erosion control
- Environmental: reducing the losses of P and organic C
    - Finland, USA (Australia, China, Ireland, South Korea)

## Types of gypsum

- Phosphogypsum
    - Residues of P
- Flue-gas desulfurization gypsum
    - Free from P
- Recycled gypsum
- Natural gypsum
    - Regulations for organic farming restrict the use of industrial-based gypsum

# Phosphogypsum

Apatite + sulphuric acid = ortophosphoric acid + **gypsum**

$Ca_5(PO_4)_3X + 5\ H_2SO_4 + 10\ H_2O \rightarrow 3\ H_3PO_4 + 5\ \mathbf{CaSO_4 \cdot 2\ H_2O} + HX$
X = OH, F, Cl or Br

- Magmatic apatite (free from cadmium and radioactivity)
- Sedimentary apatite

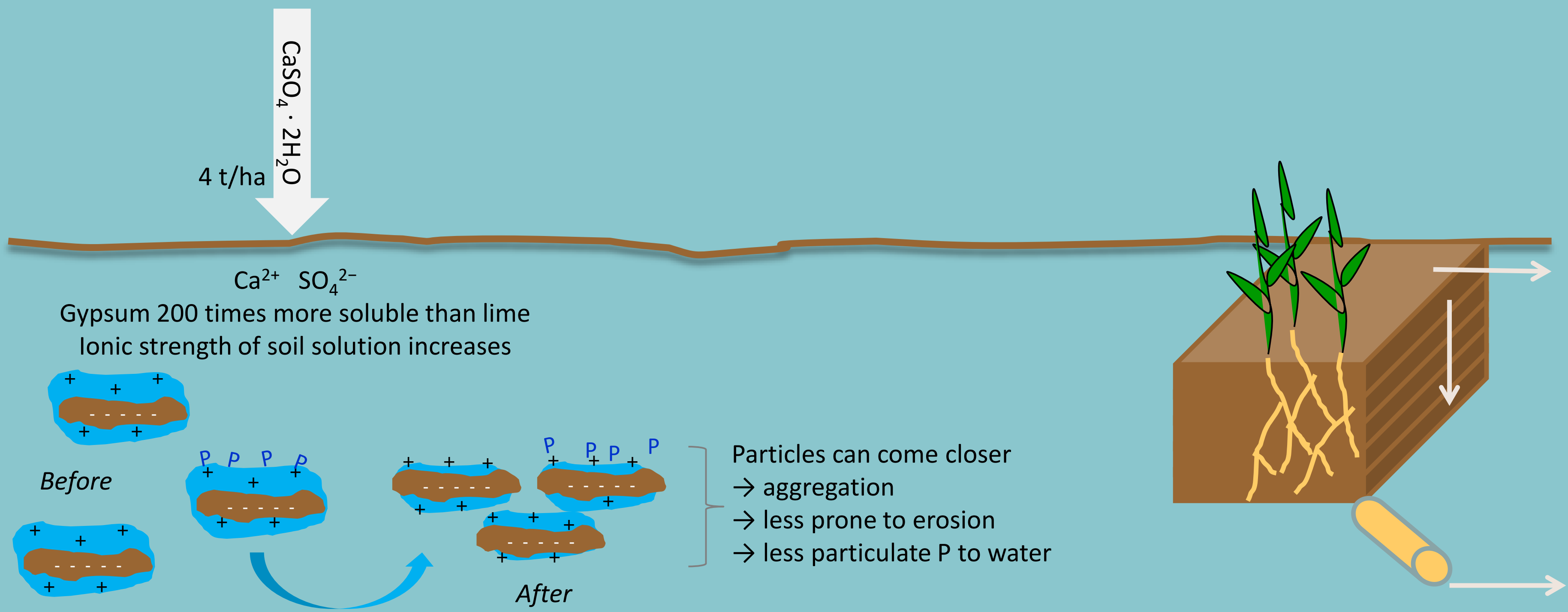
*Apatite mine in Siilinjärvi, Finland*

*Gypsum formed as a side-product*

*Gypsum heap on a field*

Photos: Petri Ekholm, Pasi Valkama

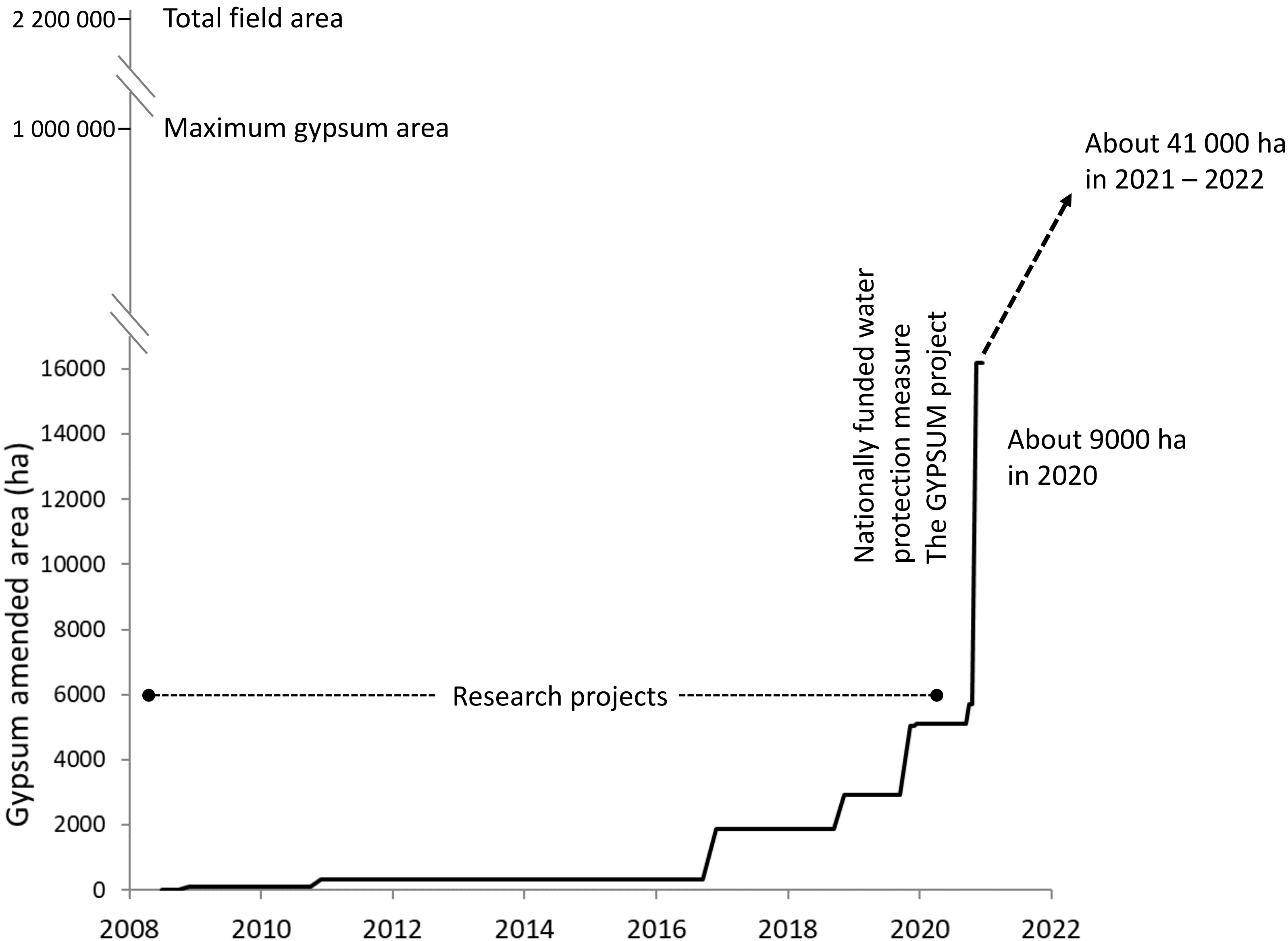
# How gypsum works?



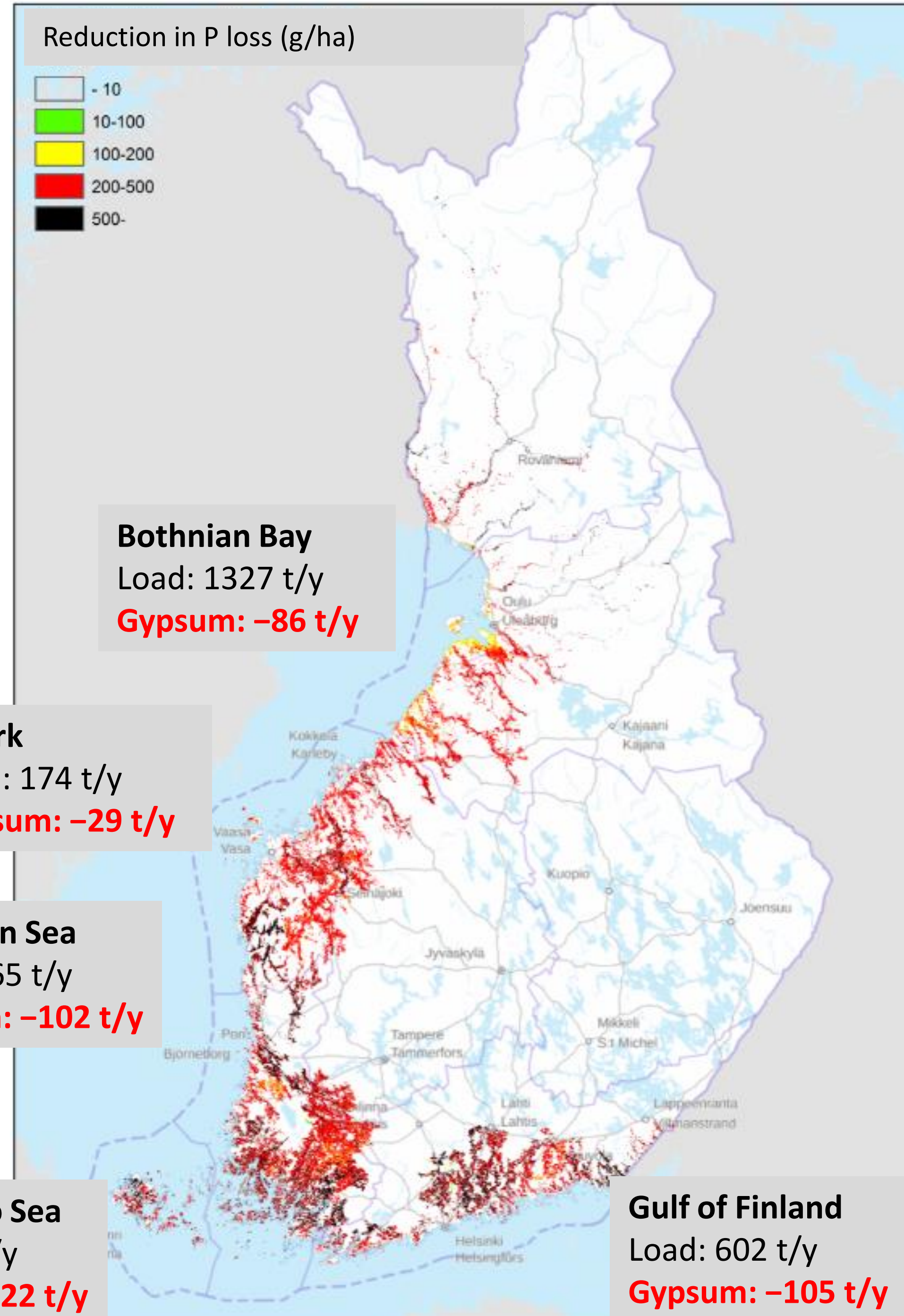

Electrical double layer around particles becomes thinner

- Dissolved P will also be reduced, P being available to plants
  - Increase in ionic strength, precipitation or co-sorption with Ca
- Organic C
  - Ca acts as a bridge linking clay and organic matter (OM), formation of insoluble Ca-OM complexes, flocculation of Ca-OM complexes
- No effect on pH (unlike lime, $CaCO_3$)

# Gypsum use in Finland



# Maximum potential of gypsum in Finland*




**Bothnian Bay**
Load: 1327 t/y
**Gypsum: –86 t/y**

**Quark**
Load: 174 t/y
**Gypsum: –29 t/y**

**Bothnian Sea**
Load: 565 t/y
**Gypsum: –102 t/y**

**Archipelago Sea**
Load: 442 t/y
**Gypsum: –122 t/y**

**Gulf of Finland**
Load: 602 t/y
**Gypsum: –105 t/y**

**Total**
Load: 3109 t/y
**Gypsum: –433 t/y**

*All fields not on lake catchments or organic soils amended with gypsum

Map: Markus Huttunen, SYKE

# Pros and cons of gypsum amendment

☺ **Immediate effect**

- About 50% reduction in
  - Turbidity and the losses of
    - Suspended solids
    - Particulate phosphorus
    - Particulate organic carbon
- Some reduction in the losses of
  - Dissolved phosphorus
  - Dissolved organic carbon

☺ **Suitable for large field areas**

☺ **Several gypsum sources**

- Must be free from harmful substances and not contain too much phosphorus

☺ **No negative effect on the quality or quantity of yield**

- Lots of calcium (777 kg/ha) and sulfur (622 kg/ha)
- Soil structure may improve

☺ **No harmful effects on riverine biota**

- Mussels, mosses, fish tested
- A scientific manuscript on ecotoxicological studies to be submitted soon

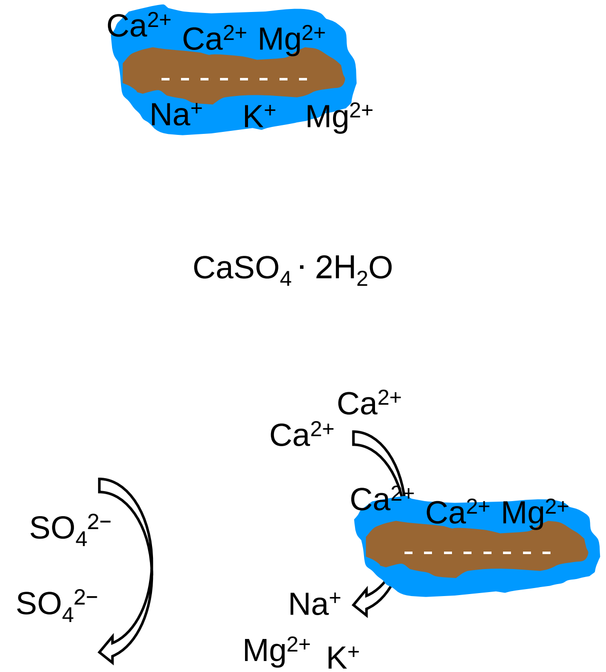
# Pros and cons of gypsum amendment

☹ **Should be used with care in**

- Catchments upstream of lakes
    - Sulfate may accelerate eutrophication of lakes and reservoirs
- Soils low in magnesium or potassium
    - Cation exchange reactions
- Ground-water areas (if leaky soils)
    - Groundwater legislation
    - Moderate increase in sulfate harmless to humans and structures
- Natura 2000 sites

☹ **Selenium in crops decreases at first**

😐 **Temporary impact** (about 4–5 years)



# Gaps in knowledge

- Effect in coarse mineral, organic and calcareous soils
- Dose in different conditions
  - 4 t/ha
- Duration of the effect in different conditions
- Spreading near sowing (effect on germination)
  - Tests under way
- Co-use with lime and manure
- Effect on soil organisms
  - Tests under way

# Can gypsum work in other Baltic Sea countries?

- Soil type
  - Texture
  - Calcium concentration

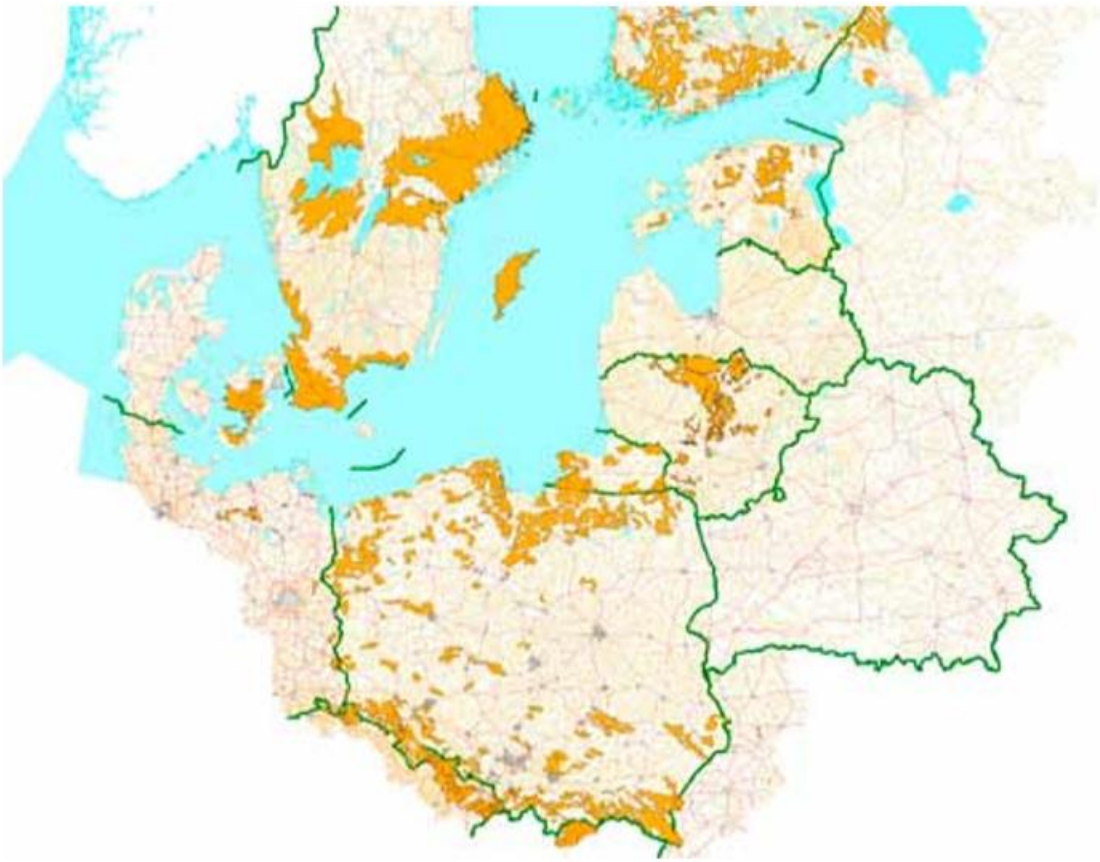
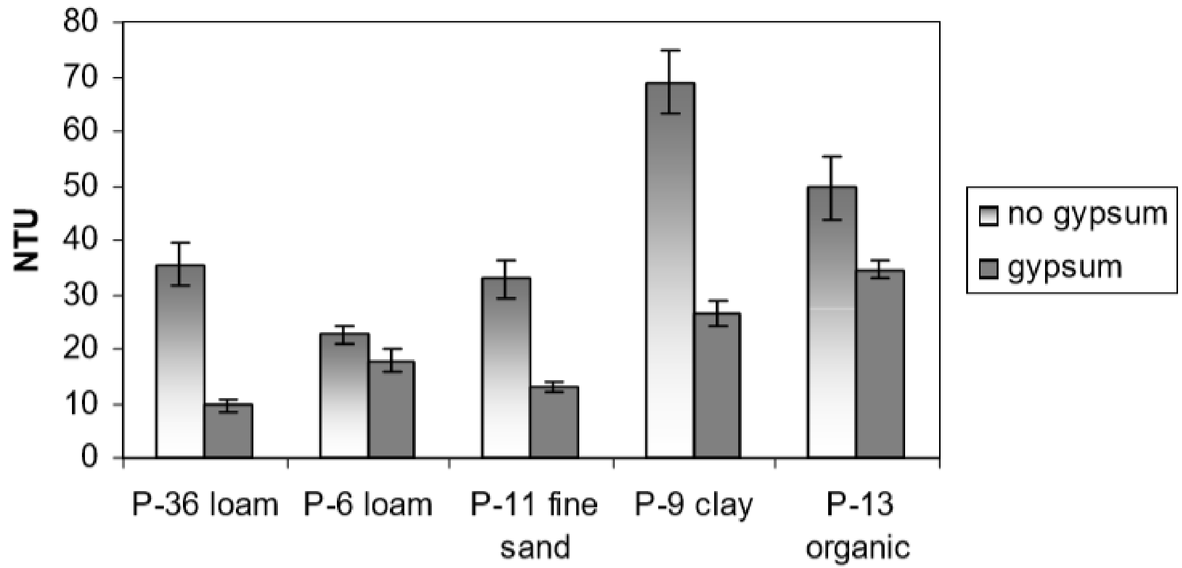


Figure 4. Clayey areas identified as FAO soil class Cambisol with EU soil map.

Tattari et al. 2012. Mapping erosion- and phosphorus-vulnerable areas in the Baltic Sea Region – data availability, methods and biosecurity aspects. MTT Report 65.

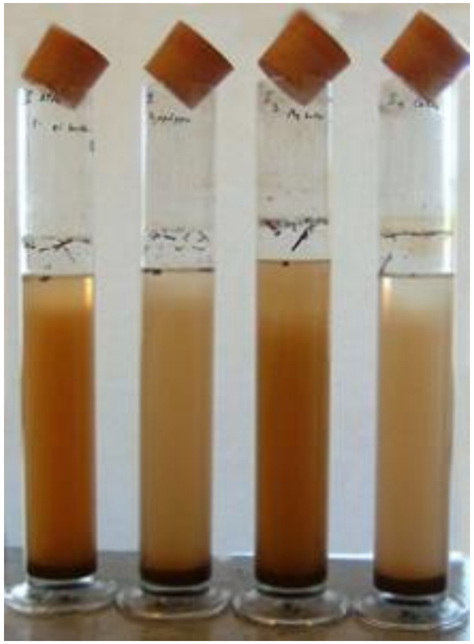
# Gypsum works best on fine-textured soils, but may also work on others




Pietola L, 2008. Gypsum-based management practices to prevent phosphorus transportation. NJF Report, Vol 4, Nr 4.

# Studying the performance of gypsum

## Laboratory experiments I

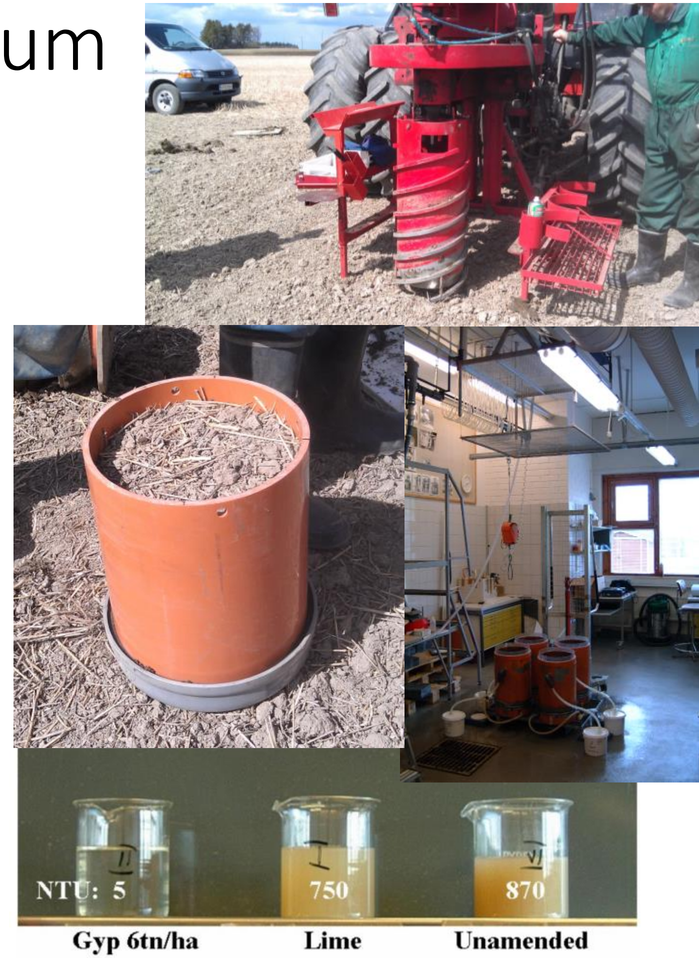


1. Soil, distilled water, gypsum
2. Mixing, left to stand
3. Analysis of overlying water

Aura E, Saarela K, Räty M. 2006. Savimaiden eroosio. MTT:n selvityksiä 118. In Finnish.

1. Soil, gypsum
2. Weekly watering
3. After 2–3 months, soils leached with water
4. Leachate determined for P

Pietola L. 2008. Gypsum-based management practices to prevent phosphorus transportation. NJF Report, Vol 4, Nr 4.




1. Spreading gypsum on a field
2. Taking soil sample each year
3. Artificial rainfall in the lab
4. Analysis of throughflow

Uusitalo R, Ylivainio K, Rasa K, Kaseva J, Pietola L, Turtola E. 2012. Gypsum effects on the movement of phosphorus and other nutrients through undisturbed clay soil monoliths. Agricultural and Food Science 21:260–278.

# Studying the performance of gypsum

## From laboratory experiments II

1. Soil, gypsum
2. Watering, left to stand
3. Several waterings
4. Analysis of throughflows

An ongoing study

Surface runoff simulation

Unpublished


Demonstrating the effect

Photos: Helena Soinne, Johanna Nikama, Natural Resources Institute Finland, Pasi Valkama

# Studying the performance of gypsum

## Catchment pilots

Photos: Petri Ekholm, Janne Artell, John Nurminen foundation

TraP project

100 ha amended


Ekholm P, Jaakkola E, Kiirikki M, Lahti K, Lehtoranta J, Mäkelä V, Näykki T, Pietola L, Tattari S, Valkama P, Vesikko Lj, Väisänen S. 2011. The effect of gypsum on phosphorus losses at the catchment scale. The Finnish Environment 33.

Ekholm P, Valkama P, Jaakkola E, Kiirikki M, Lahti K, Pietola L. 2012. Gypsum amendment of soils reduces phosphorus losses in an agricultural catchment. Agricultural and Food Science 21:279–291.


**SAVE project**

**1550 ha amended**


Iho A, Laukkanen M. 2012. Gypsum amendment as a means to reduce agricultural phosphorus loading: an economic appraisal. Agricultural and Food Science 21:307–324.

Iho A, Lankoski J, Ollikainen M, Puustinen M, Lehtimäki J. 2014. Agri-environmental auctions for phosphorus load reduction: experiences from a Finnish pilot. Agricultural and Resource Economics 58:205–222.


**Vantaanjoki project**

**3615 ha amended**


Kosenius A-K, Ollikainen M. 2018. Drivers of participation in gypsum treatment of fields as an innovation for water protection. Ecological Economics: 157:382-393.

Ollikainen M, Kosenius A-K, Punttila E, Ala-Harja V, Puroila S, Ekholm P. 2019. Gypsum amendment of arable fields – Farmers' experience from a large -scale pilot. Submitted to Agricultural and Food Science.