# Processes in the Baltic Sea catchment area and eutrophication

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and staff from

Baltic Sea Centre, Stockholm University

- **Eutrophication**

  *-> Current management approach*

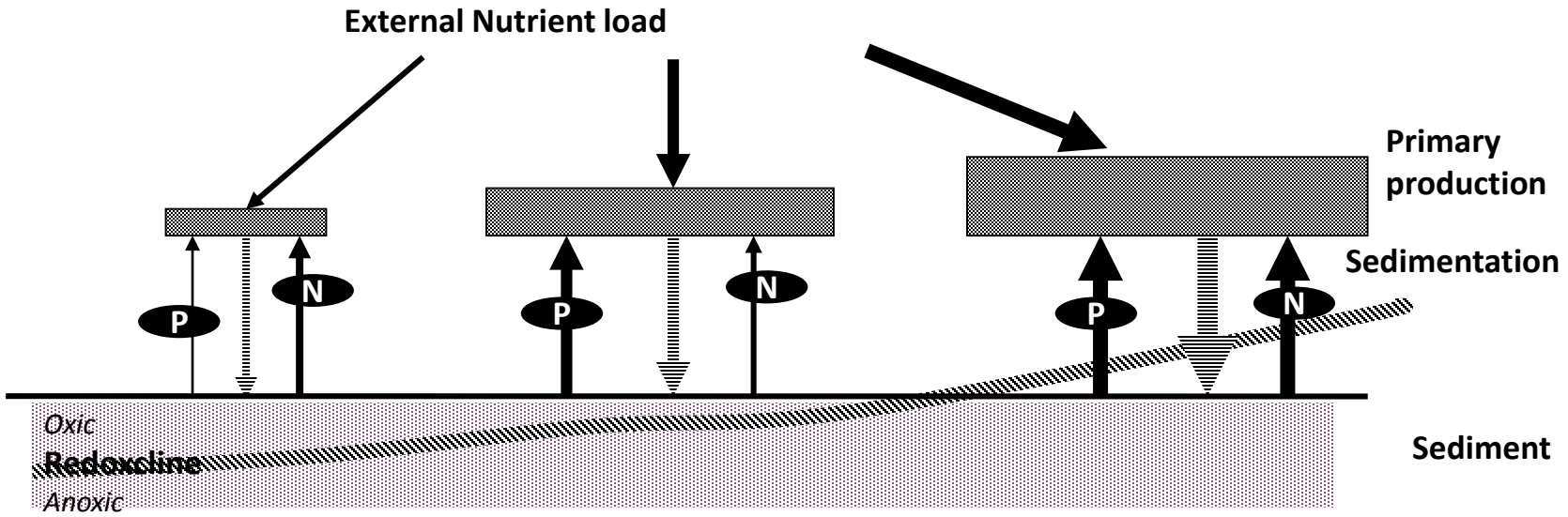
  *-> Recent trends*

  *-> Recommendation for future management*

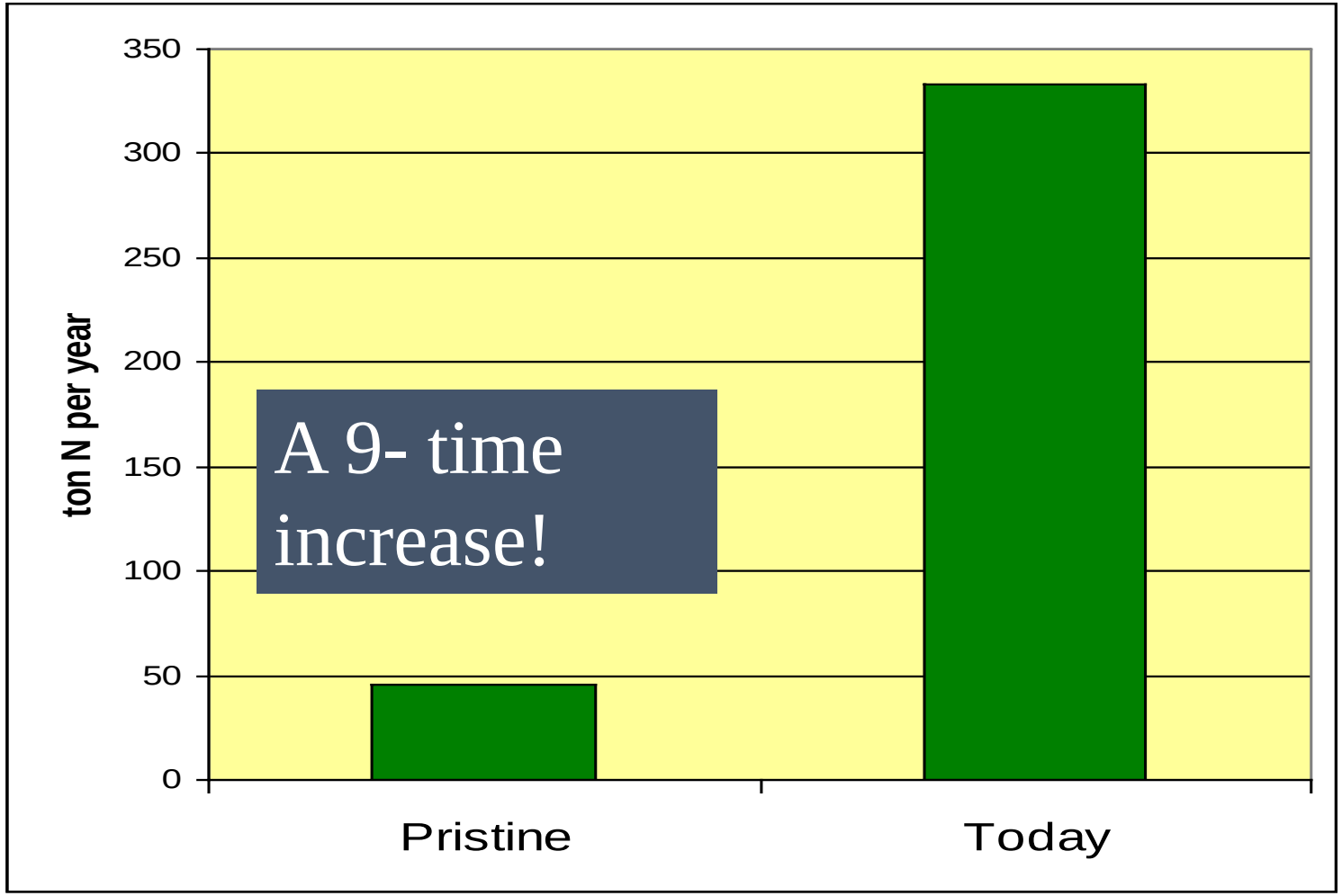
Eutrophication - an increase in the rate of supply of organic matter to an ecosystem

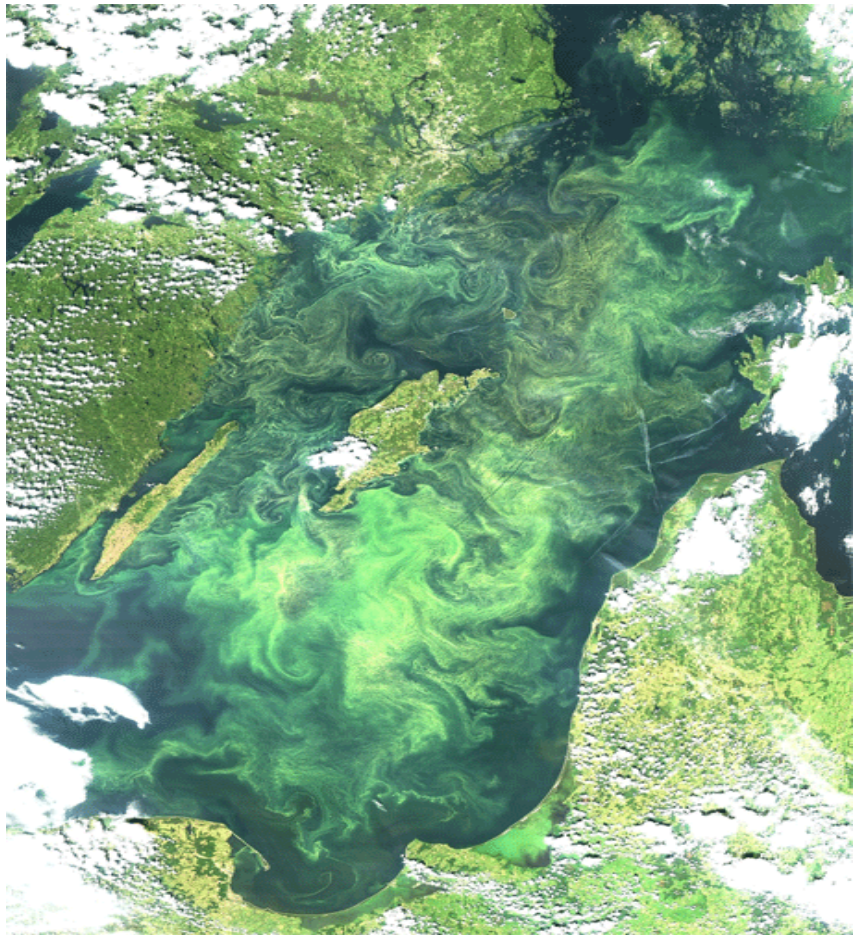
| | Organic Carbon Supply $[gCm^{-2}y^{-1}]$ |
|---|---|
| oligotrophic | < 100 |
| mesotrophic | 100 - 300 |
| eutrophic | 301 - 500 |
| hypertrophic | > 500 |

# Cycles of N and P in response to increased external loads

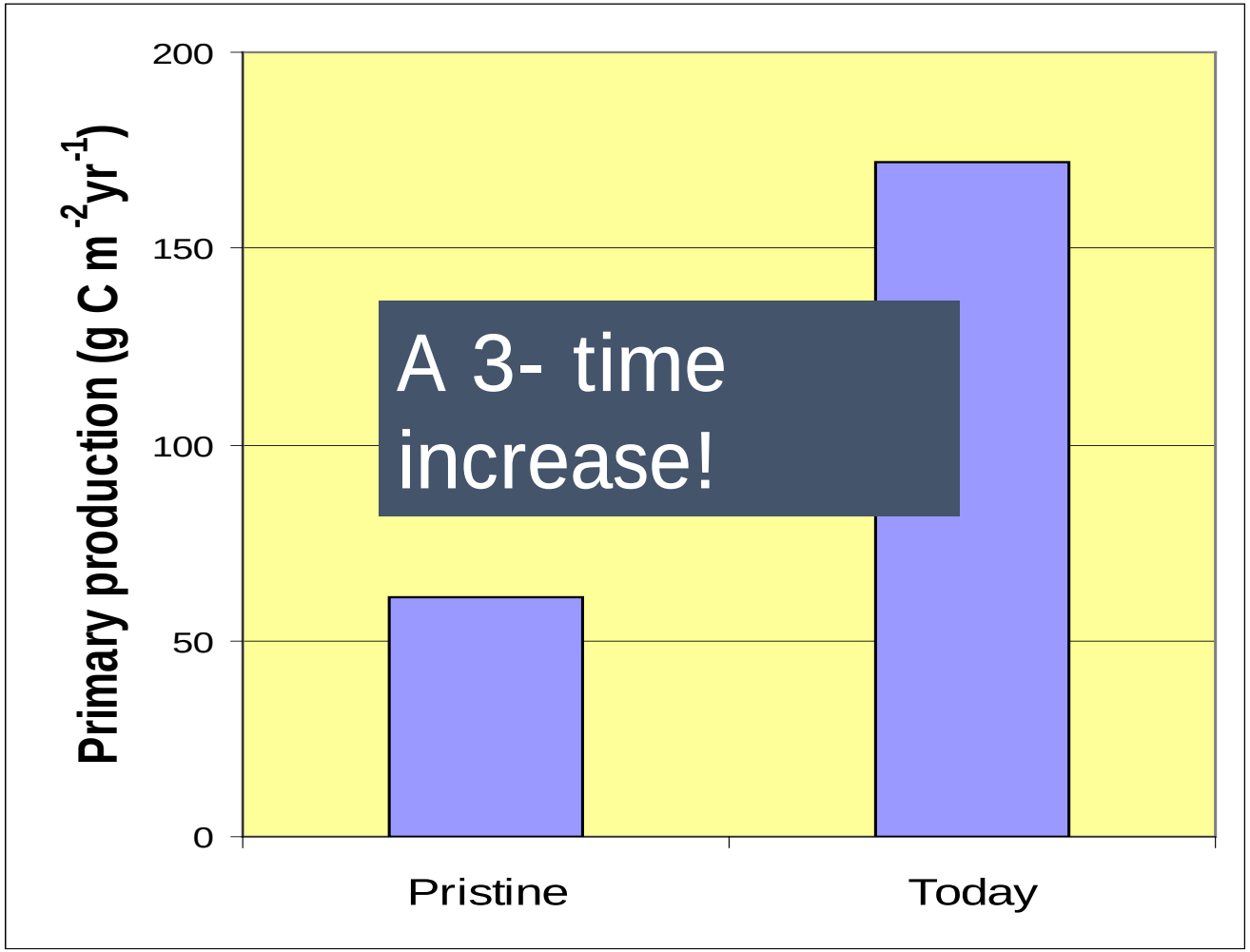


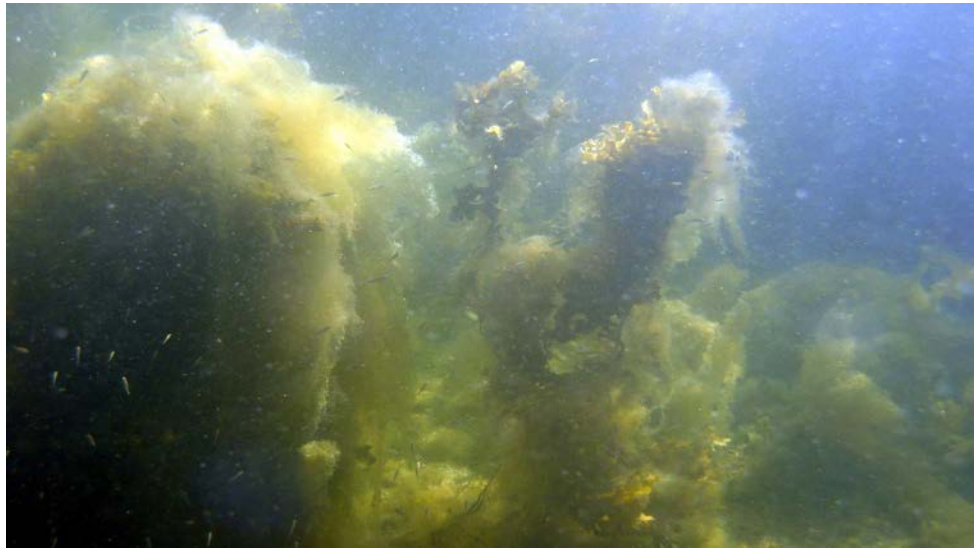
# Bluegreen algal blooms today



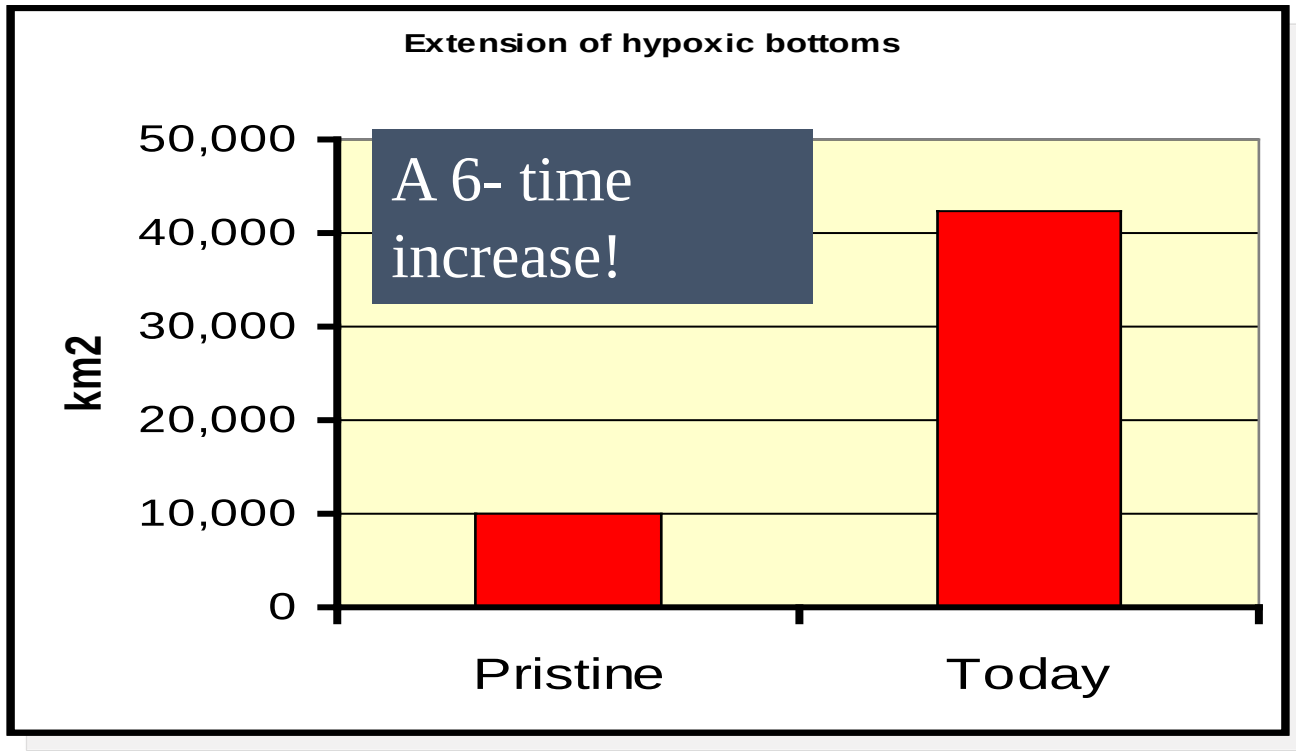



# Algal production

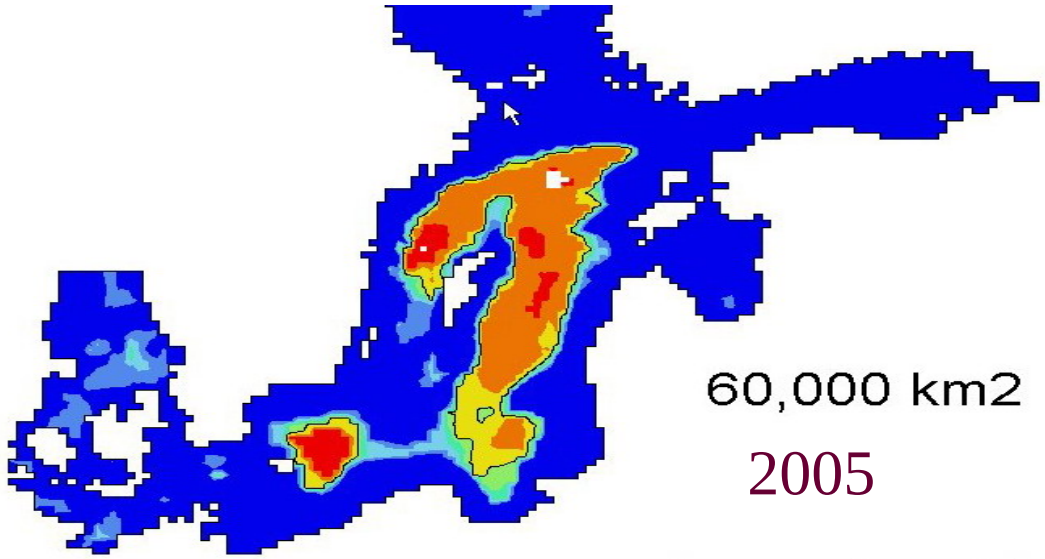


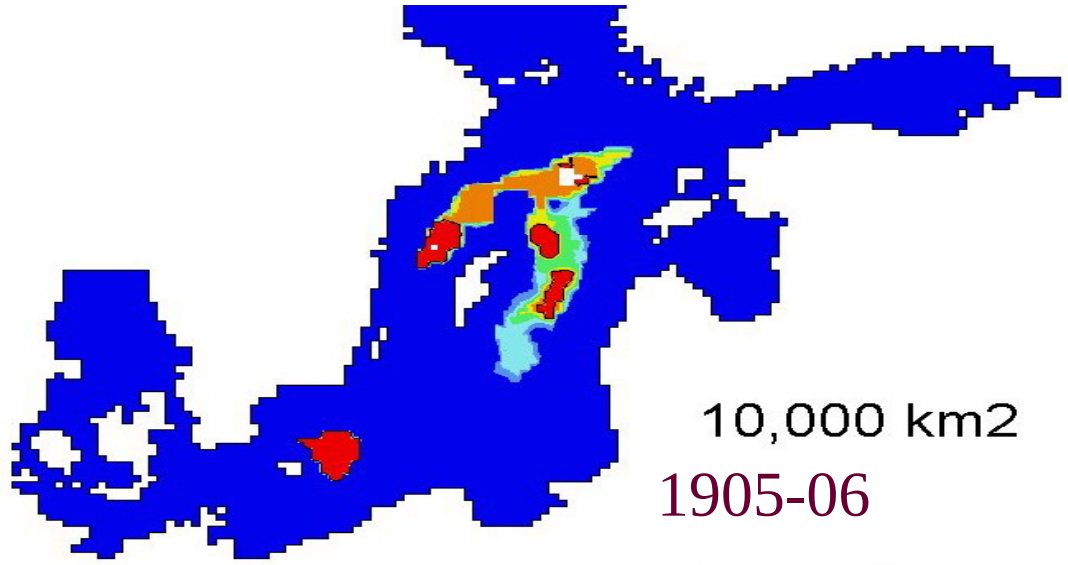



# Low oxygen levels

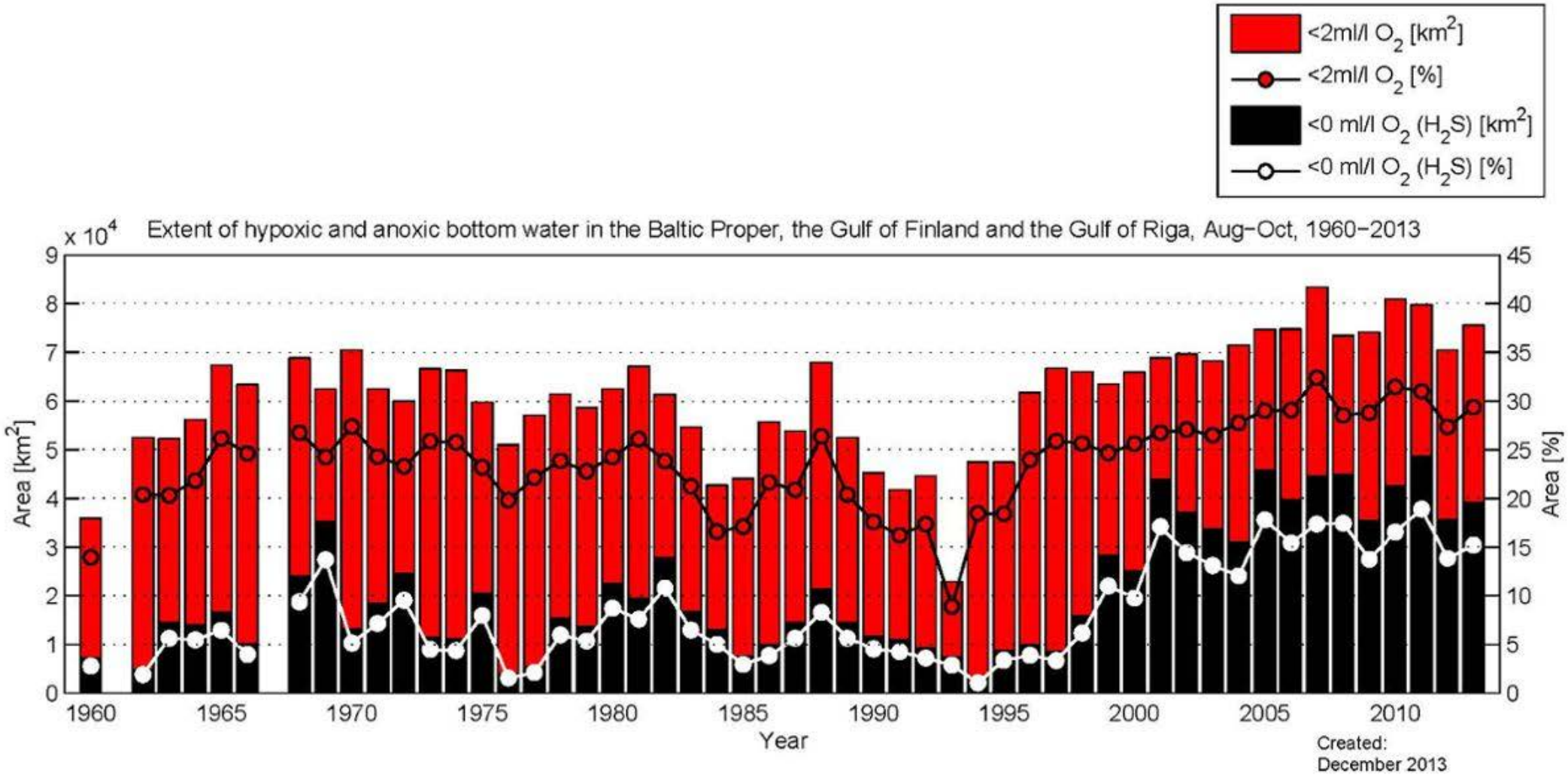



Savchuk et al. 2008



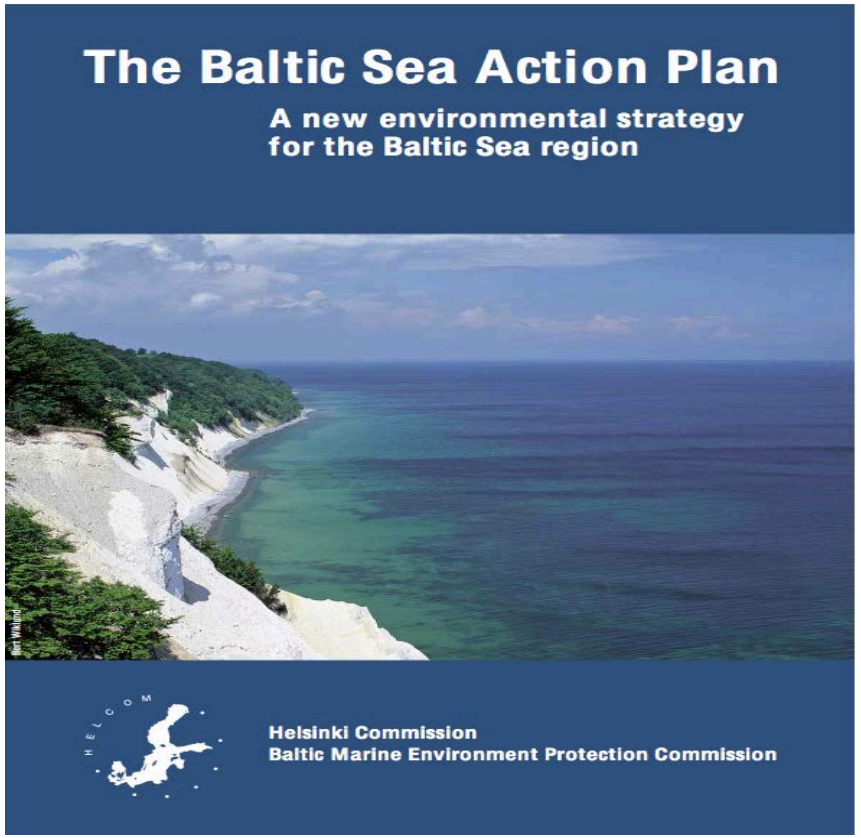



# Anoxic bottoms




SMHI

# Current status of eutrophication management




"BEARING IN MIND that the figures are **based on the NEST model**,

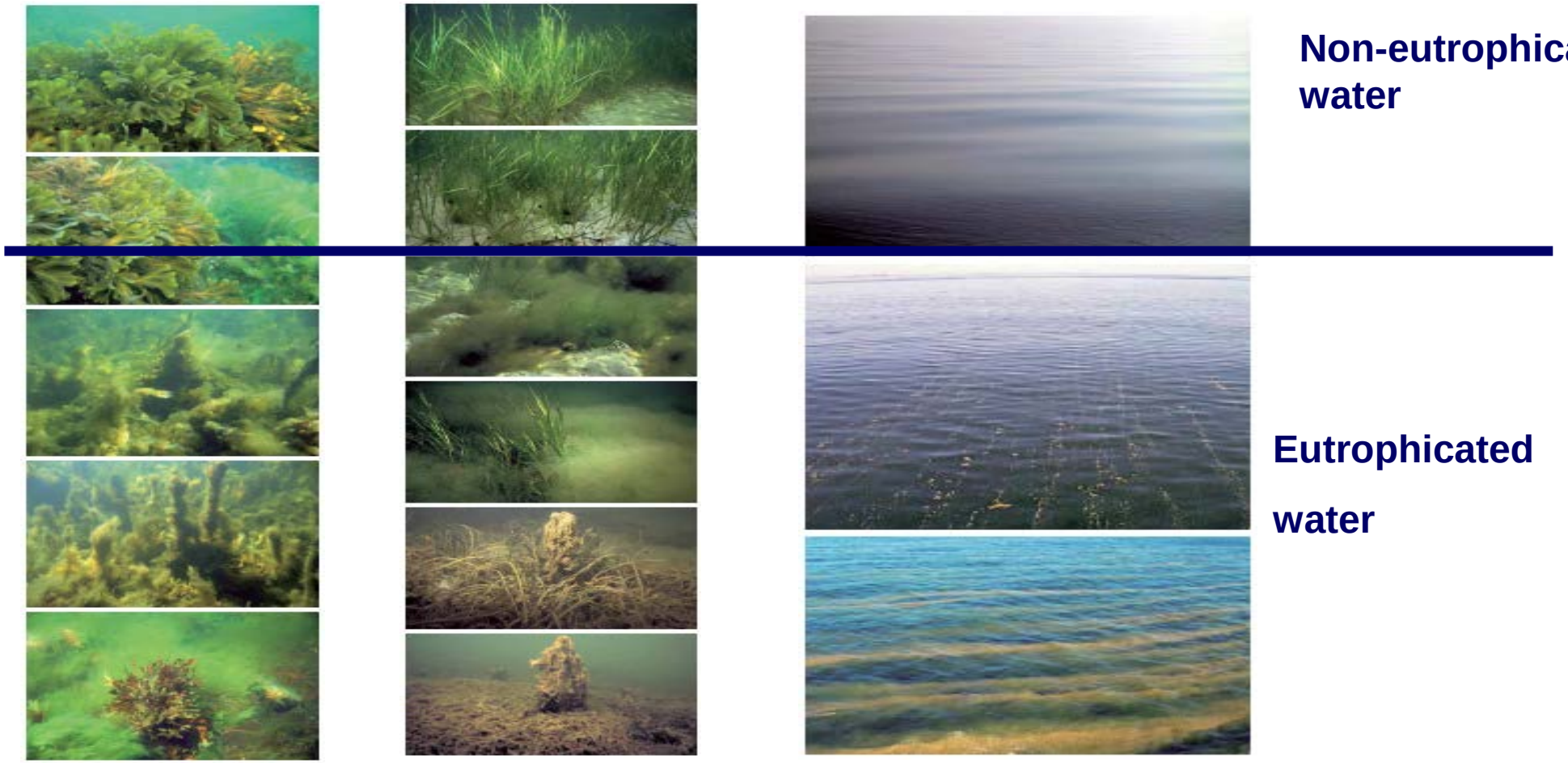
the best available scientific information, and thus stressing the provisional character of the data …

WE ACKNOWLEDGE that the maximum nutrient input to the Baltic Sea that can be allowed and still reach good environmental status with regards to eutrophication is about

- **21,000 tonnes** of phosphorus and
- **600,000 tonnes** of nitrogen…"

*Eutrophication segment of the HELCOM Baltic Sea Action Plan*

# Targets and indicators

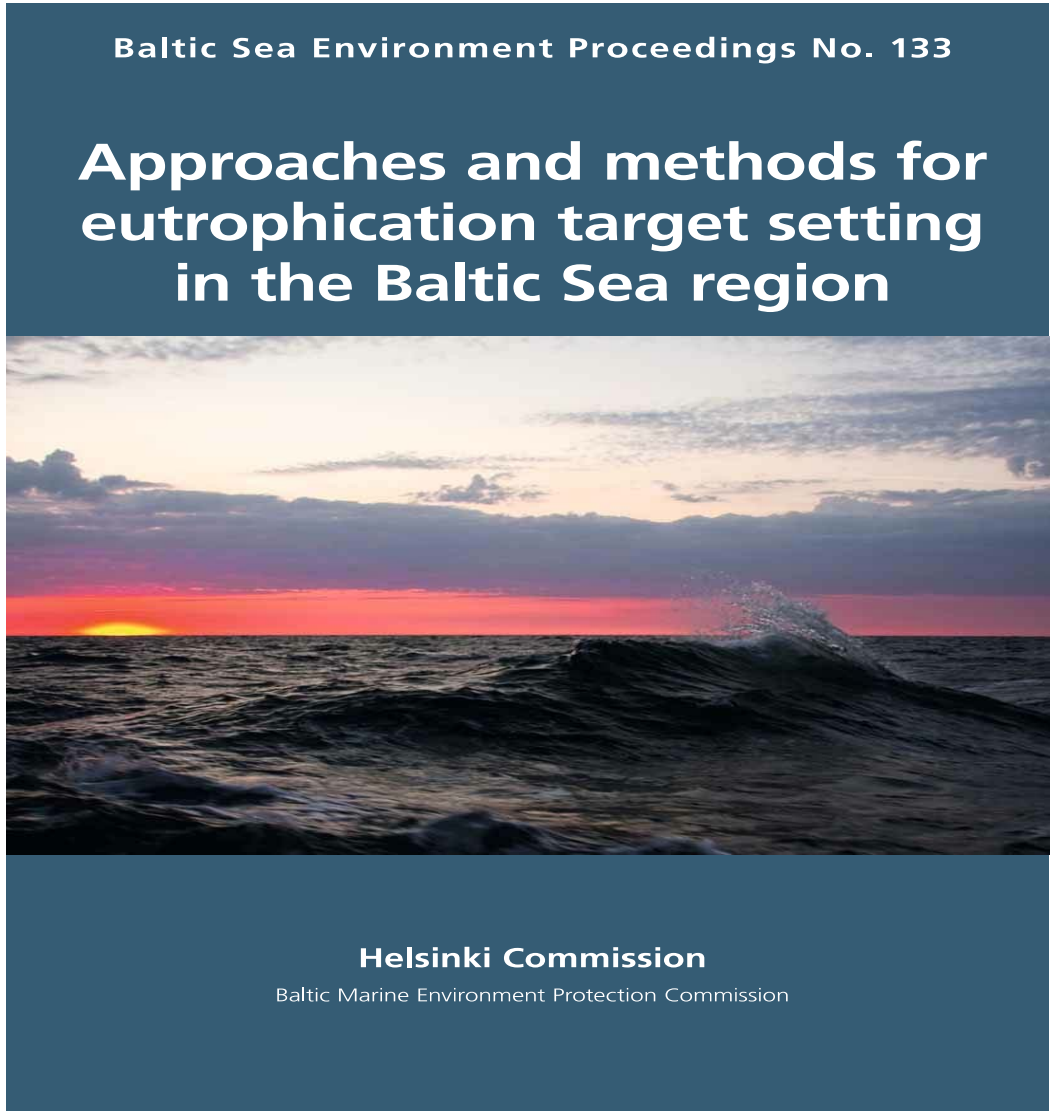


# Environmental targets

An ambitious scientific foundation from the HELCOM TARGREV project
New targets on winter nutrient concentrations, summer Secchi depth and Chl-a concentration; plus targets on oxygen levels

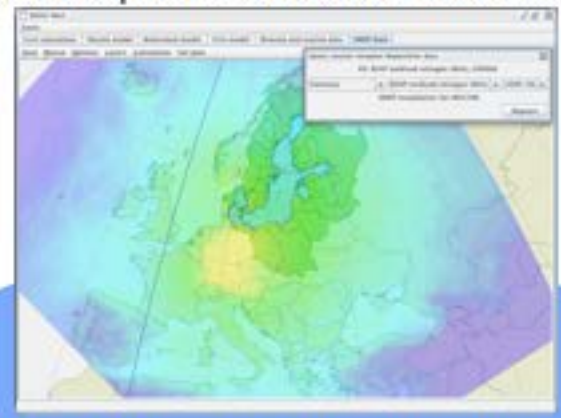
| Basin | Winter | | Summer | |
|---|---|---|---|---|
| | DIN | DIP | Chl *a* | Secchi |
| KT | 5.0 | 0.49 | 1.5 | 7.6 |
| DS | 5.0 | 0.56 | 1.8 | 7.8 |
| BP | 2.6 | 0.30 | 1.7 | 7.4 |
| BS | 2.6 | 0.18 | 1.4 | 6.4 |
| BB | 4.7 | 0.07 | 1.9 | 5.4 |
| GR | 5.2 | 0.41 | 2.7 | 5.0 |
| GF | 3.8 | 0.59 | 2.0 | 5.5 |

+ targets on oxygen



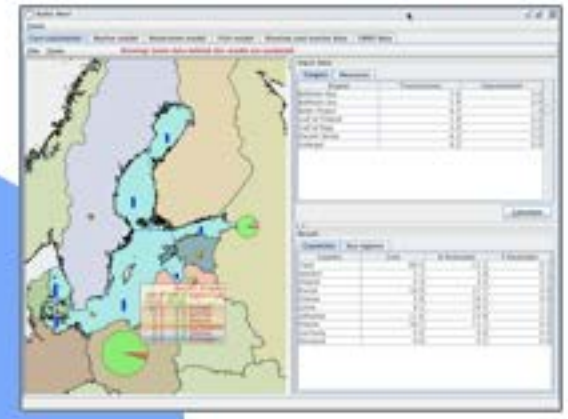
# Baltic Nest Institute – Linking Science and Management

Atmospheric emissions and load



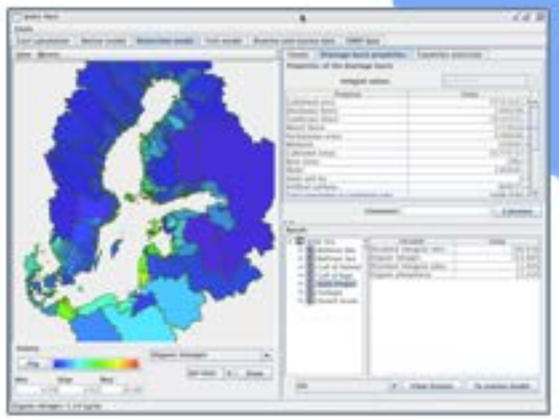
Marine modeling

Cost minimization model



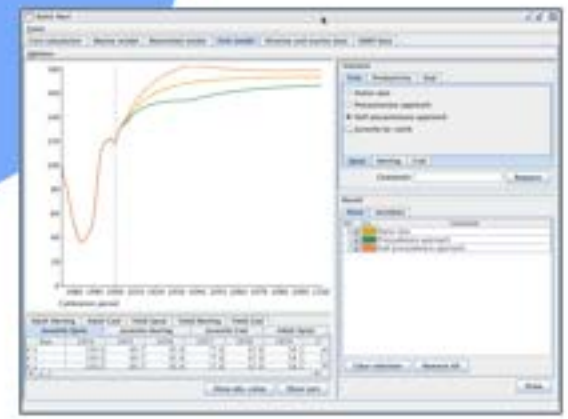
The Nest-system is available on line, free of charge and can be run in both an expert and a manager mode.

Download at www.balticnest.org



Drainage basin modeling

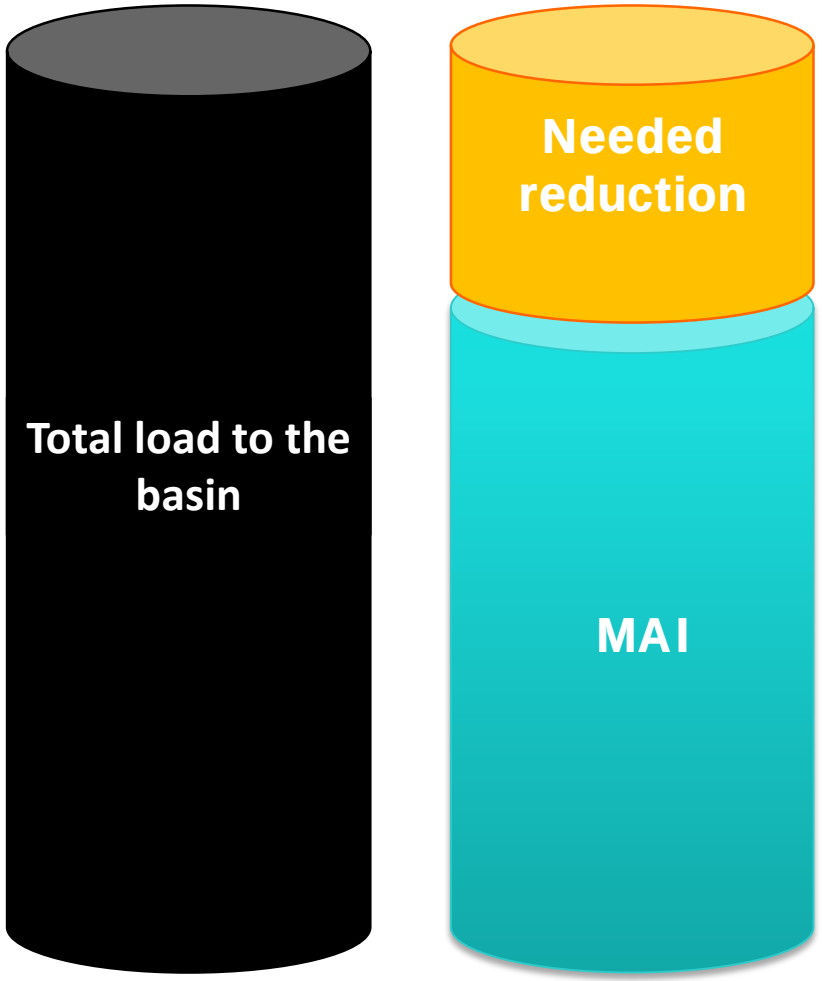
Marine and runoff data



Food web model

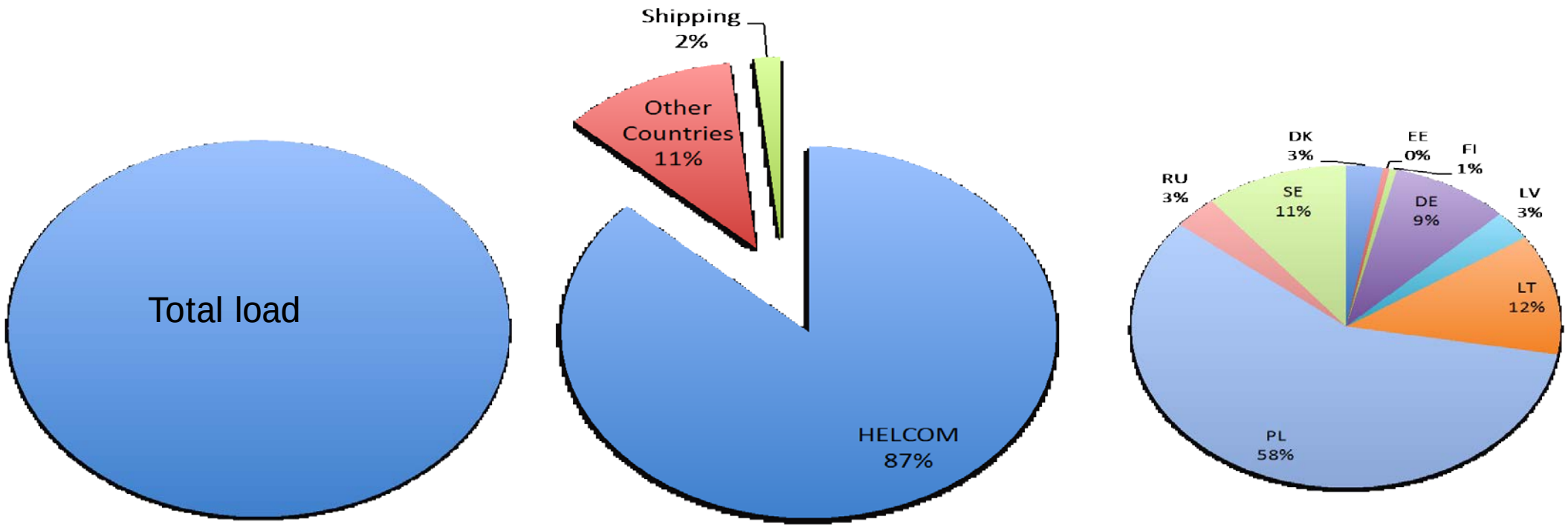
# Defining total reduction target

**Needed reduction** given by the difference between the **total loads** to the basin and the **Maximum Allowable Inputs**

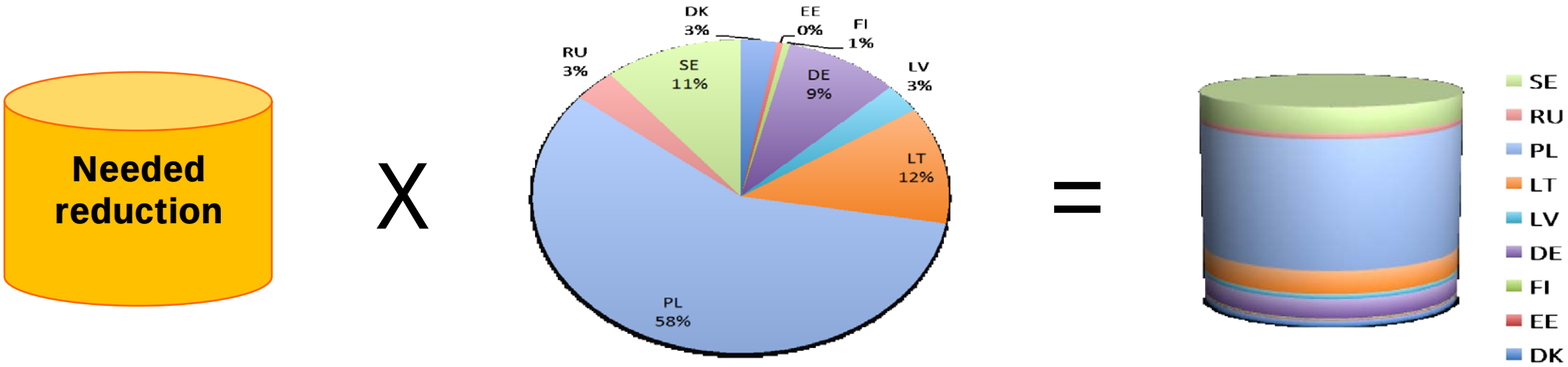


# Calculating the country wise share

**The share is computed from the part of the load emitted from HELCOM countries**



# Calculation of the Country-allocated load reduction target



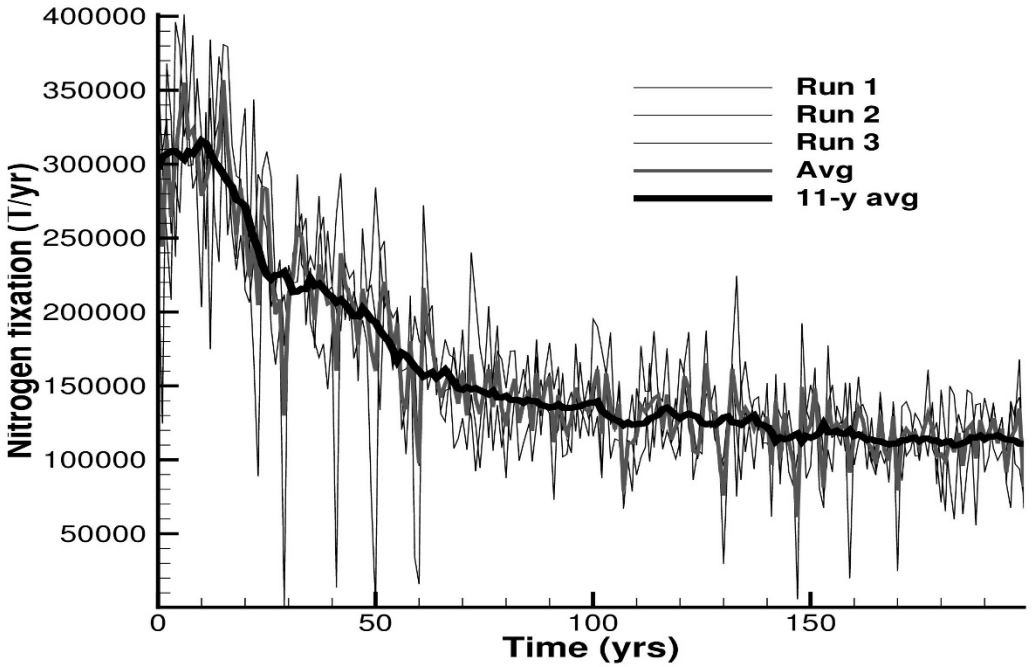

**The needed reduction is multiplied with the share of loads**

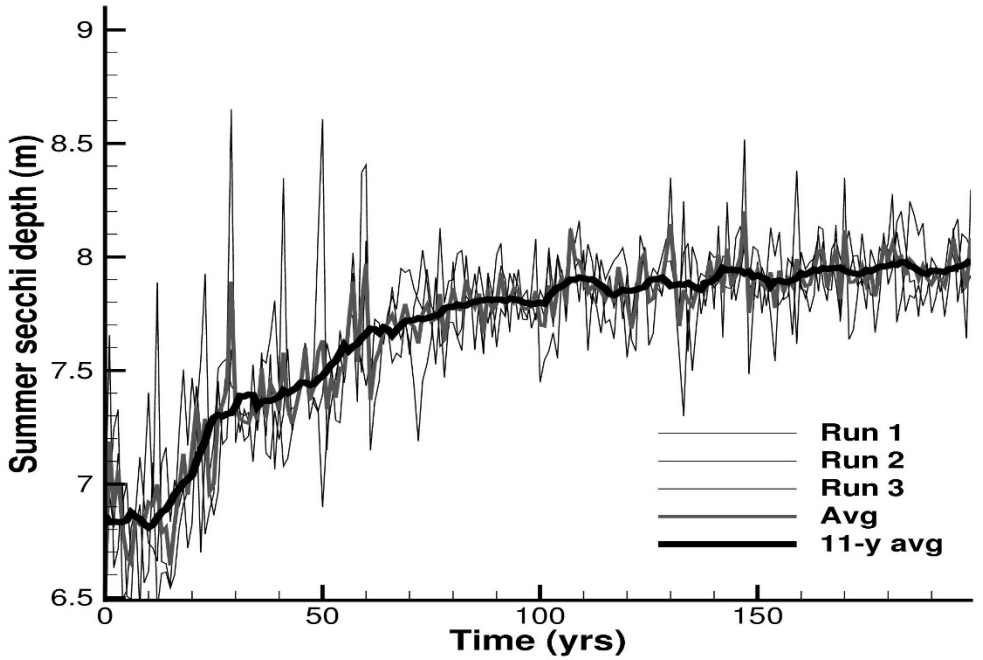
# It takes 10-60 years to reach BSAP environmental targets

Reductions as prescribed by BSAP 2007 implemented year 0

Two indicators: nitrogen fixation and Secchi depth

3 runs with different weather indicates natural variability



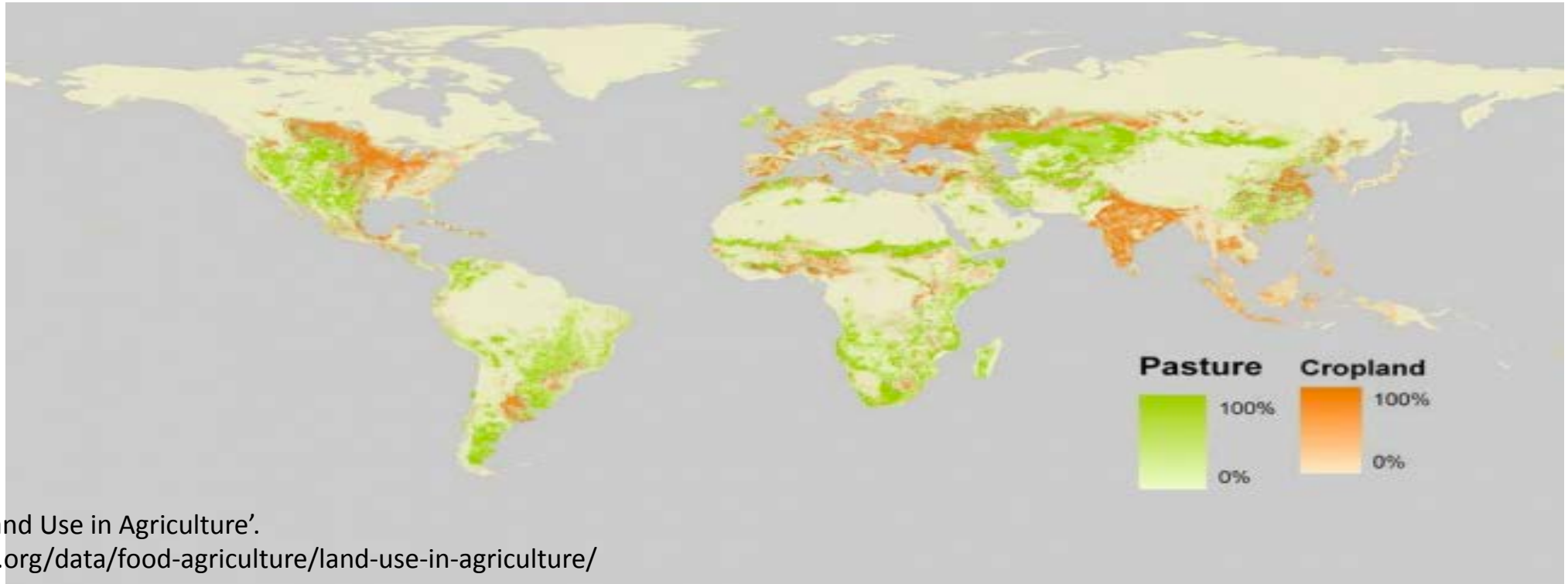



# Agriculture in the Baltic Sea region, major driver and challenges

# Agriculture – a global player

- 40% of global area
- 30% of greenhouse gas emissions
- 70% water withdrawal
- 2 x N and P fluxes

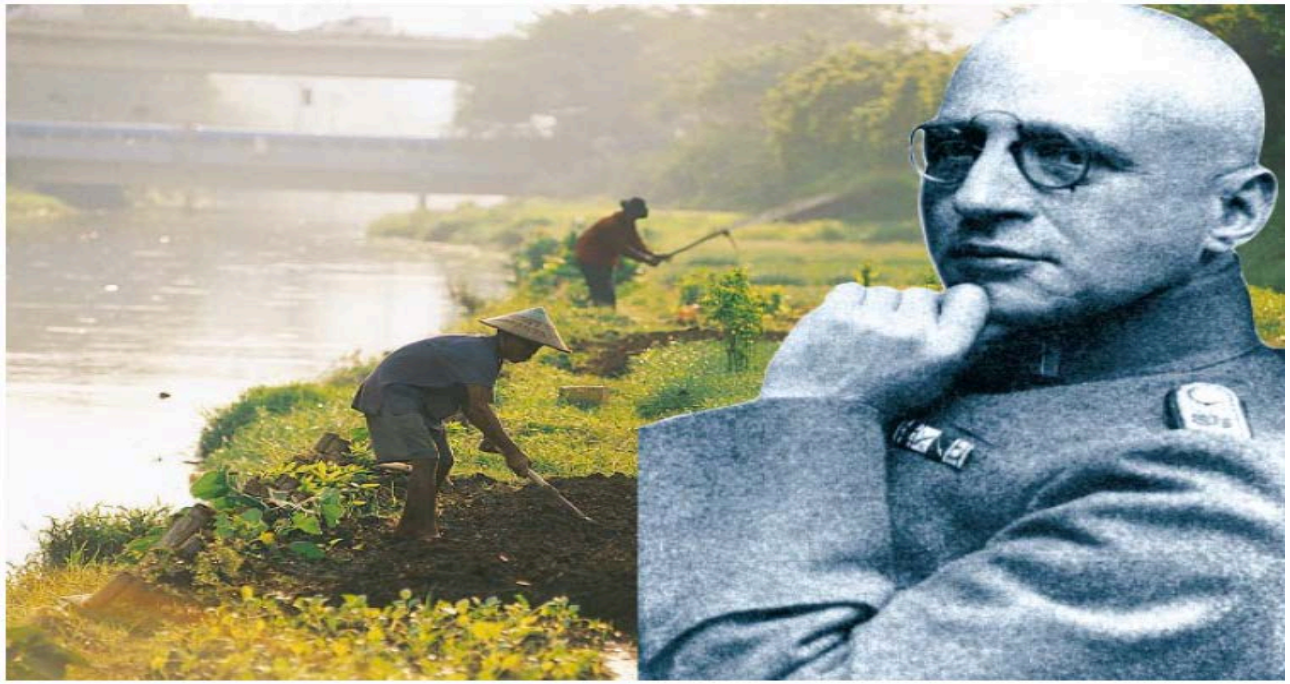
*(Foley et al. Nature 2011)*



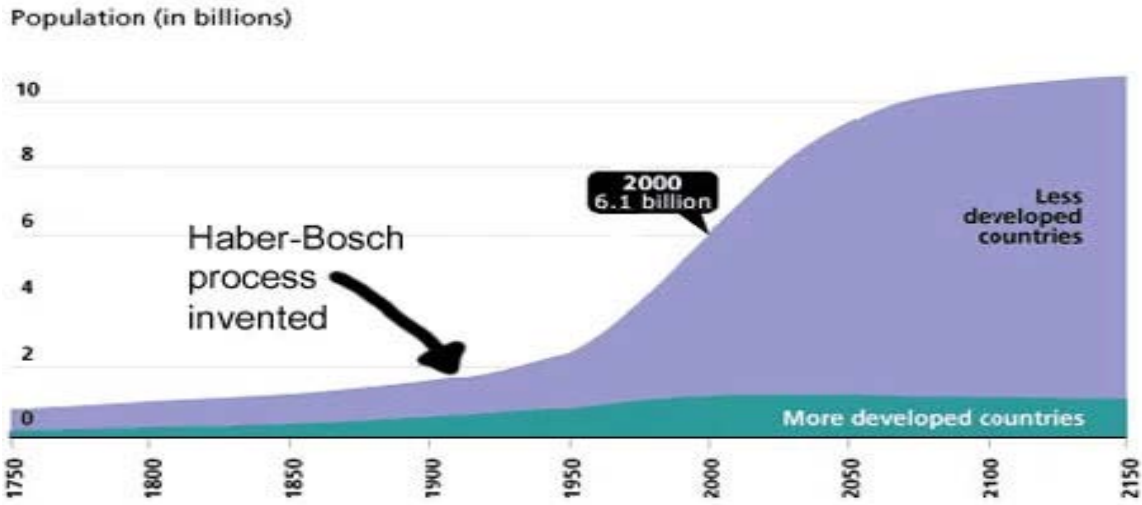

Max Roser (2015) – 'Land Use in Agriculture'.
http://ourworldindata.org/data/food-agriculture/land-use-in-agriculture/

# Detonator of the population explosion

**WIthout ammonia, there would be no inorganic fertilizers, and nearly half the world would go hungry. Of all the century's technological marvels, the Haber–Bosch process has made the most difference to our survival.**



Haber (right) invented the process while Bosch brought the necessary engineering skills.

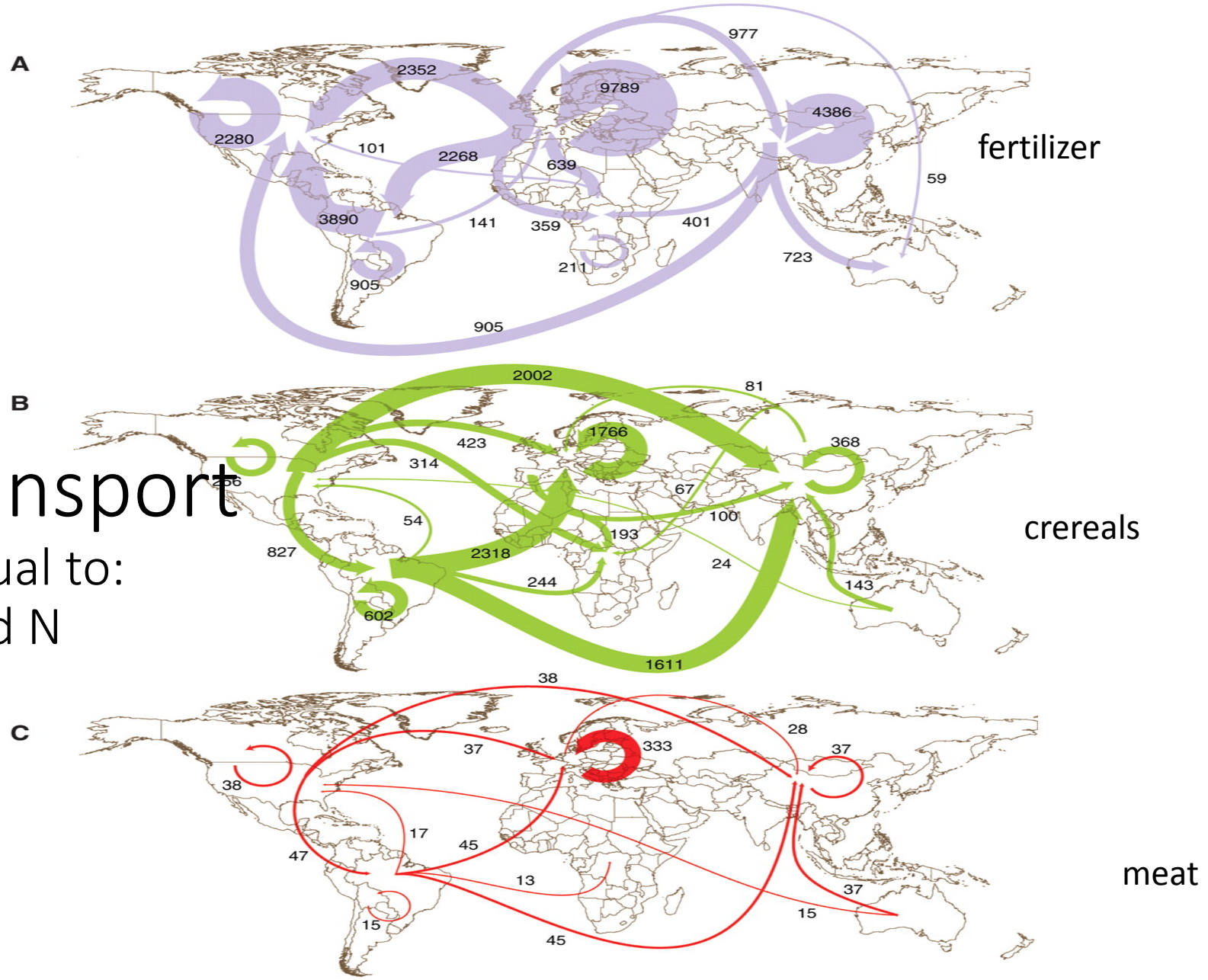



$$N_2\,(g) + 3\,H_2\,(g) \rightleftharpoons 2\,NH_3\,(g)$$

Nitrogen + Hydrogen $\rightleftharpoons$ Ammonia

# Global nitrogenTransport

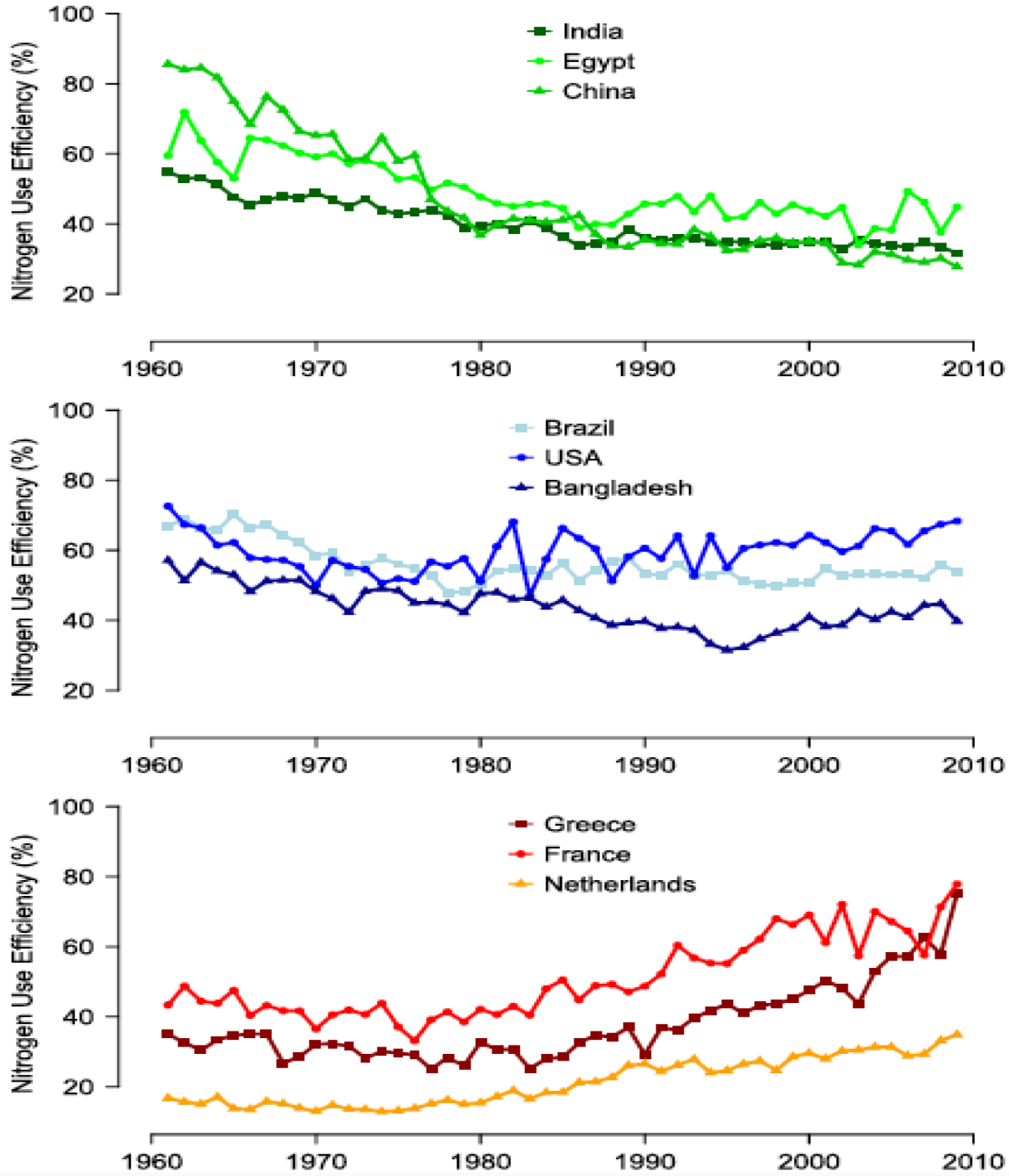
50 million tonnes per year equal to:
1/3 of all industrially produced N




Galloway et al, Science 2008

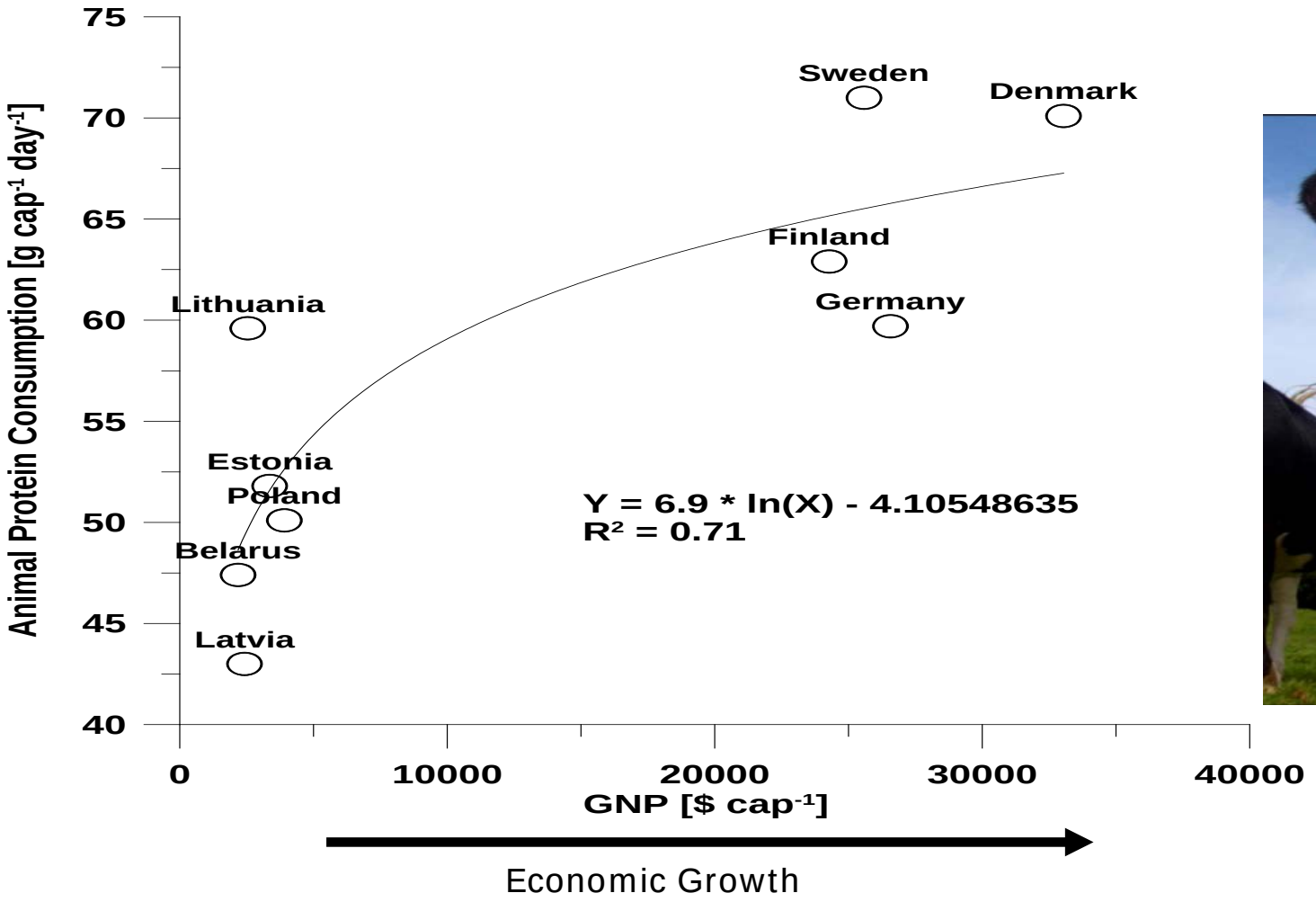
Only 47% of the N*r* added globally onto cropland is converted into harvested products,

68% in the early 1960s,



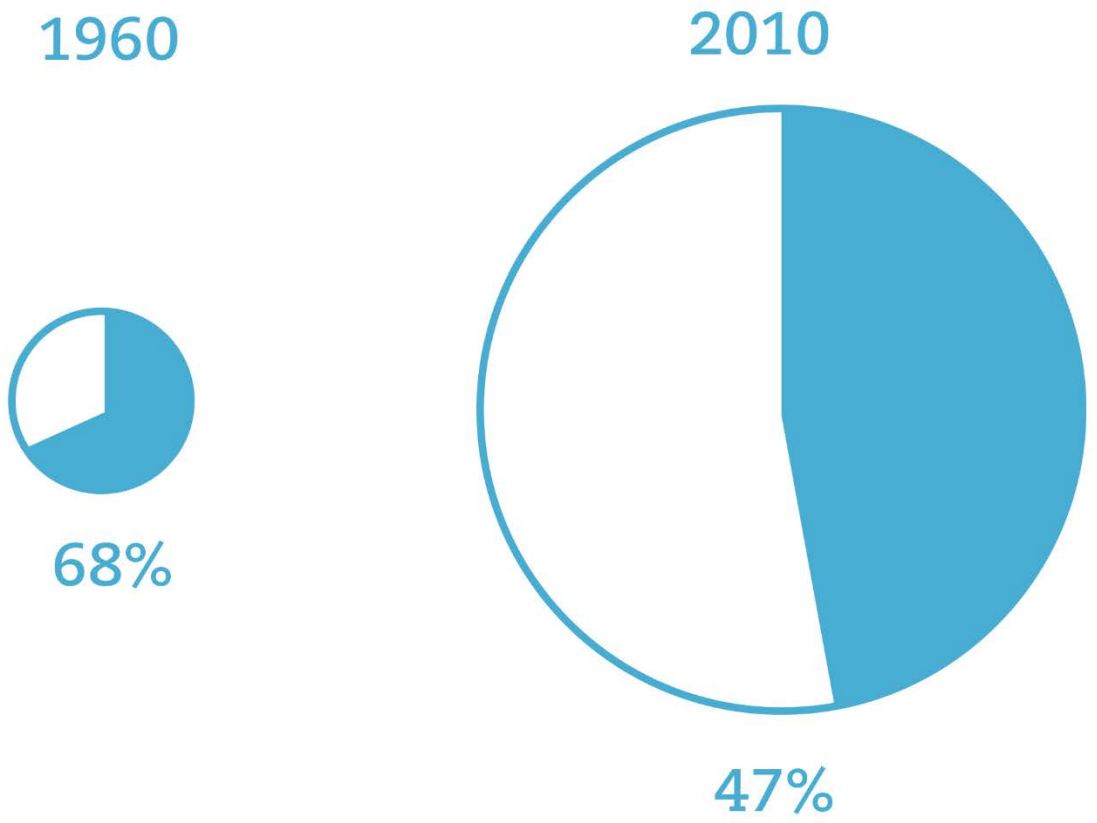

Lassaletta et al., Environ. Res. Lett. 9 (2014)

# Risk: Changes in lifestyle?
# Changes translates to agricultural practices and N emissions




# Global challenges

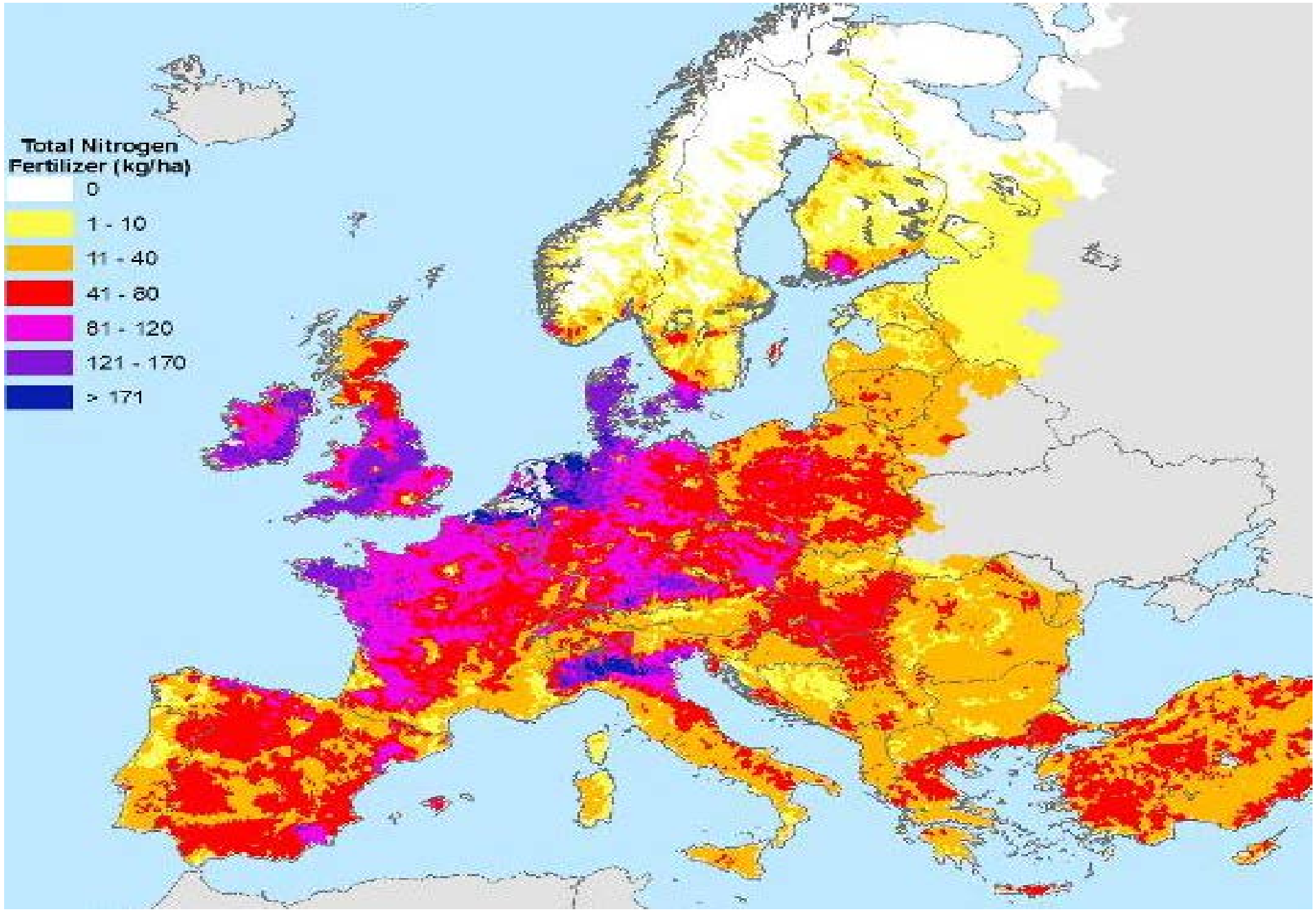
- Feeding 11 billions of people with the same area of agricultural land
- Produce more vegetable protein, we are wasting too much N and P by producing animal protein
- Using more efficient nitrogen and phosphorus in cereal production
- Reducing the leakage of N and P to secure aquatic environments and biodiversity

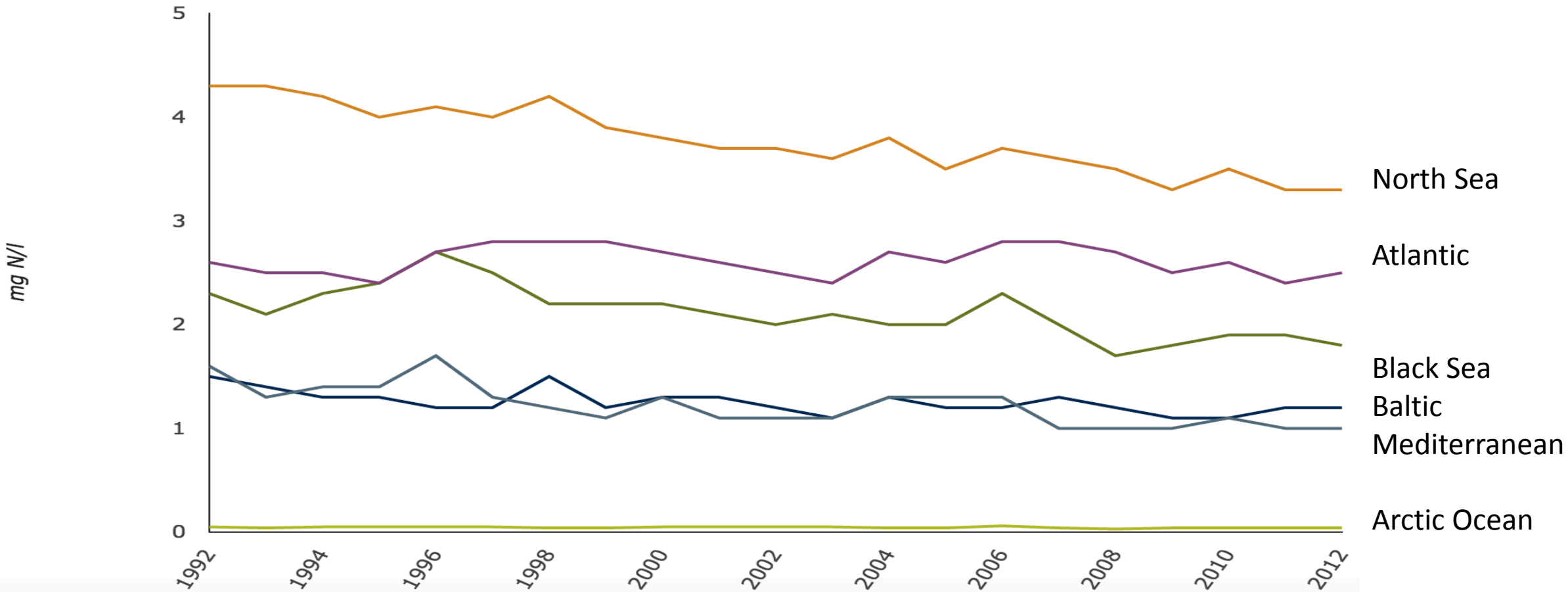



↗ Inorganic fertilizer applications have increased 10 times

↘ Share of harvested products have decreased

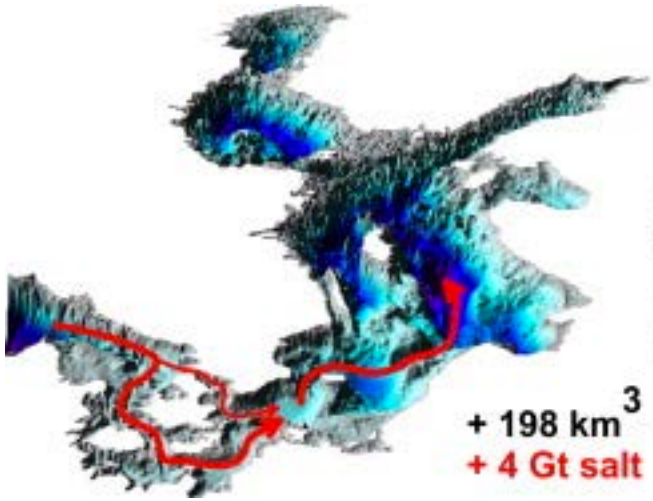
Lassaletta et al., Environ. Res. Lett. 9 (2014)


Total Nitrogen Fertilizer (kg/ha)
0
1 - 10
11 - 40
41 - 80
81 - 120
121 - 170
> 171


mg N/l
5
4
3
2
1
0
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
North Sea
Atlantic
Black Sea
Baltic
Mediterranean
Arctic Ocean

# Questions

- Why is eutrophication such a big issue in the Baltic?
- During a stagnation period is the Baltic more oxic or more anoxic?




# Nutrient accounting tools in the Baltic Sea catchment

- Recent trends in agricultural activities in the Baltic Sea catchment
- Net anthropogenic nutrient inputs (NANI concept)

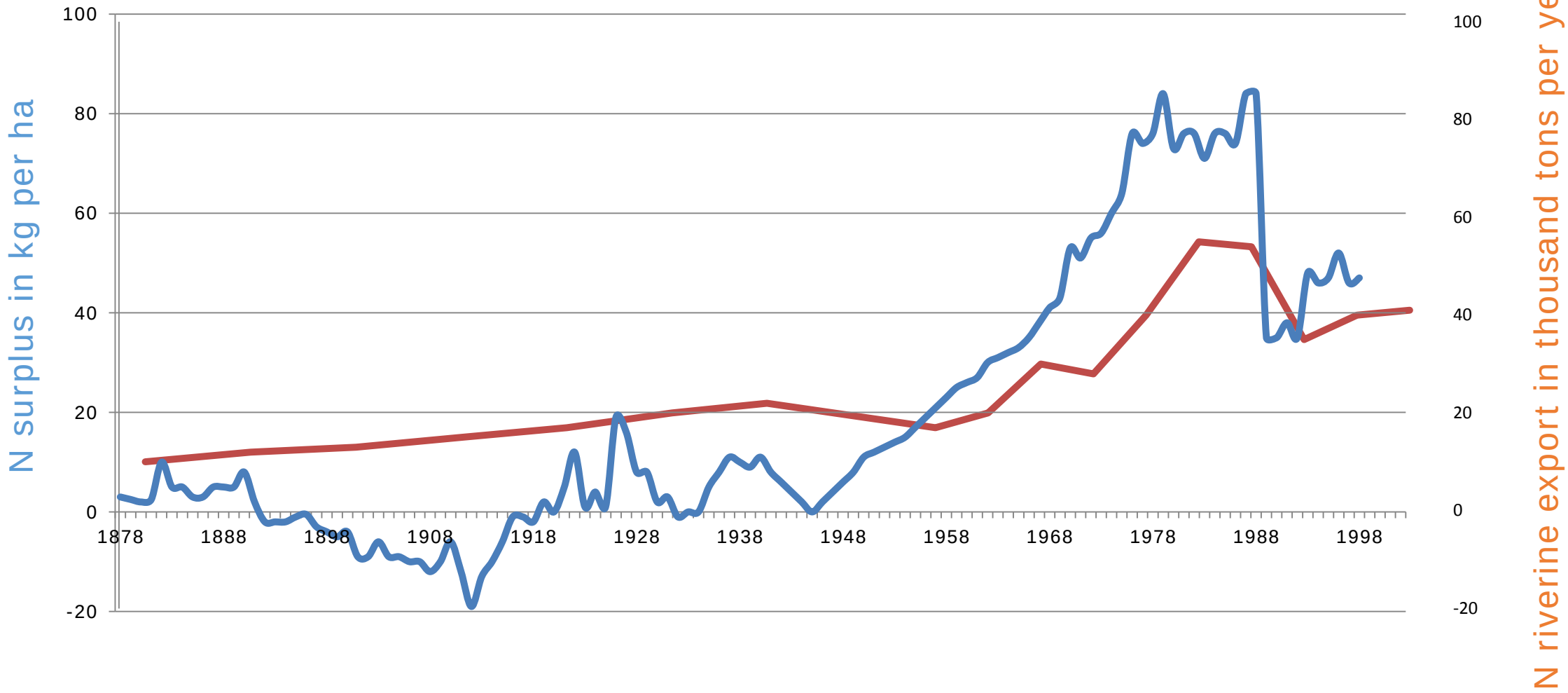
# Land cover of the Baltic Sea Basin

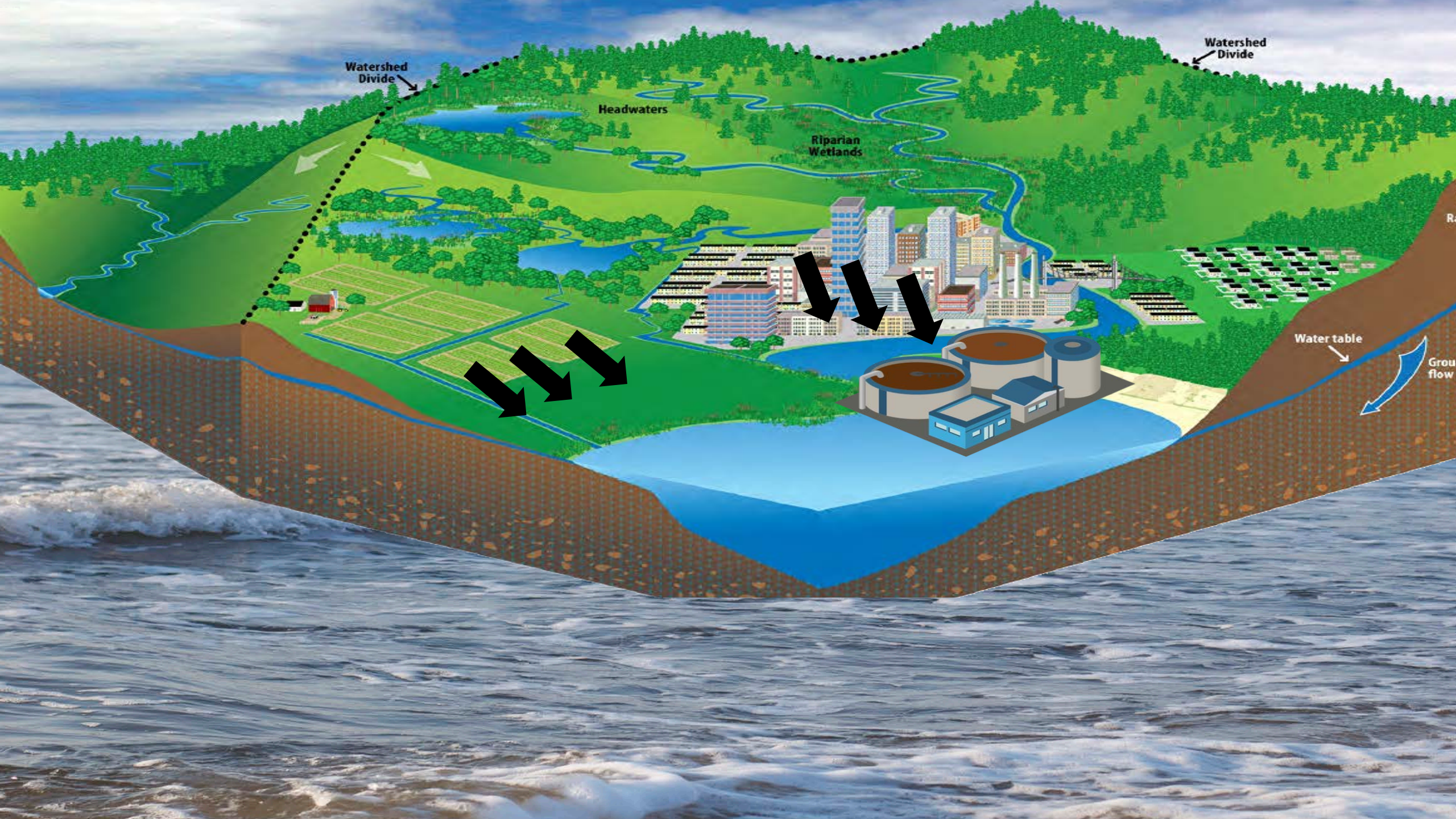
Needleleaved closed forest

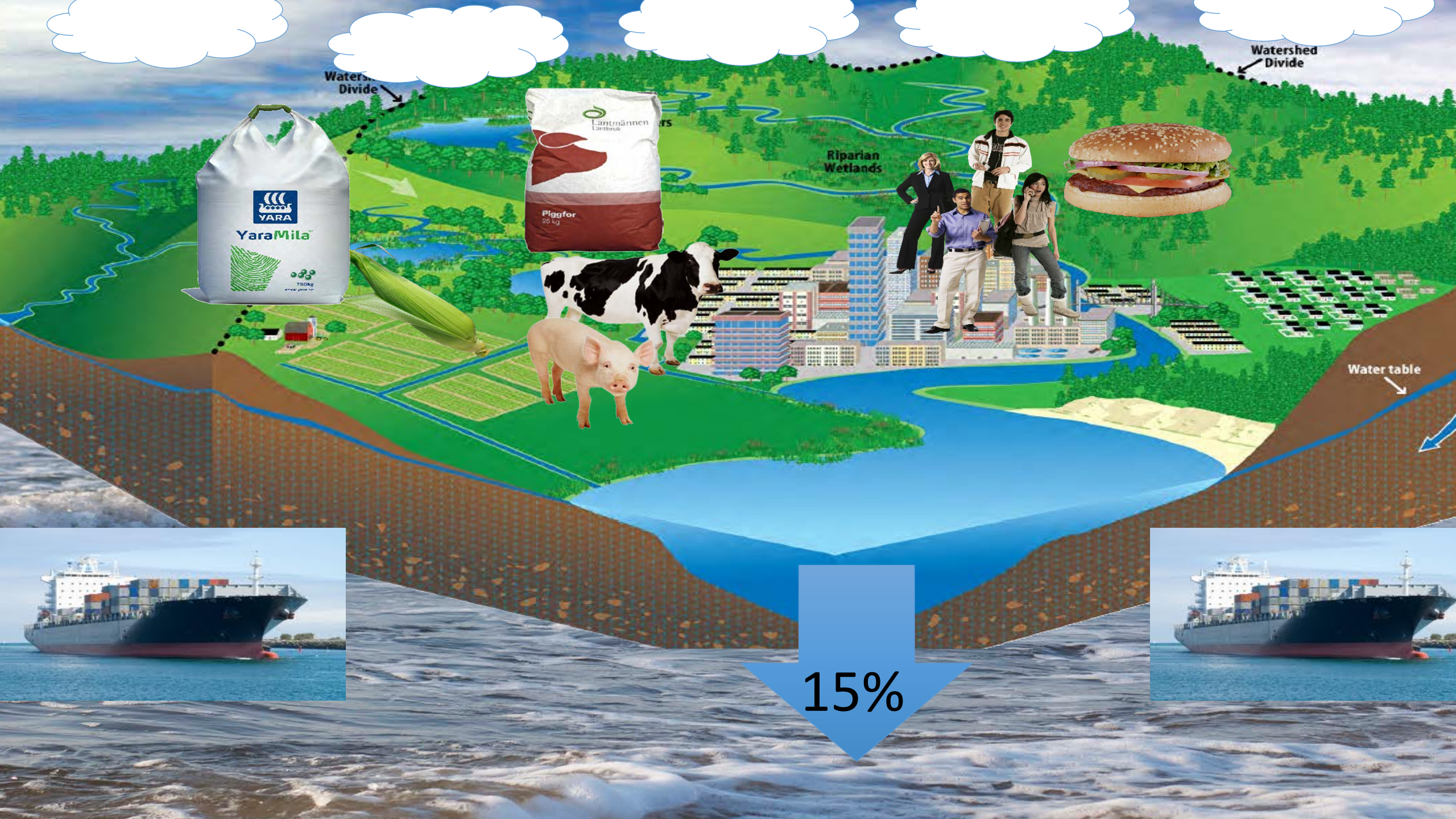
Needleleaved open forest

Water

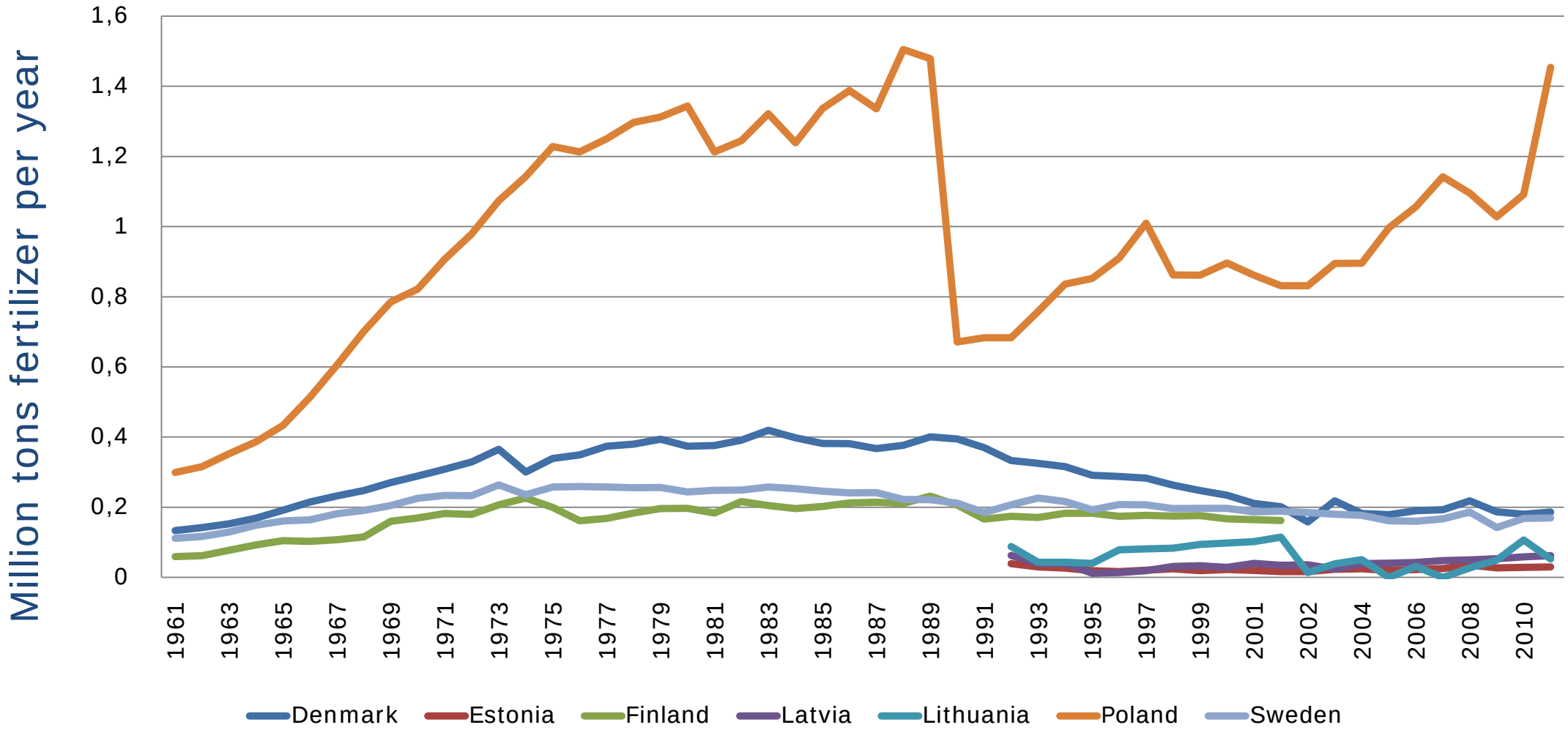
# N surplus in Oder catchment



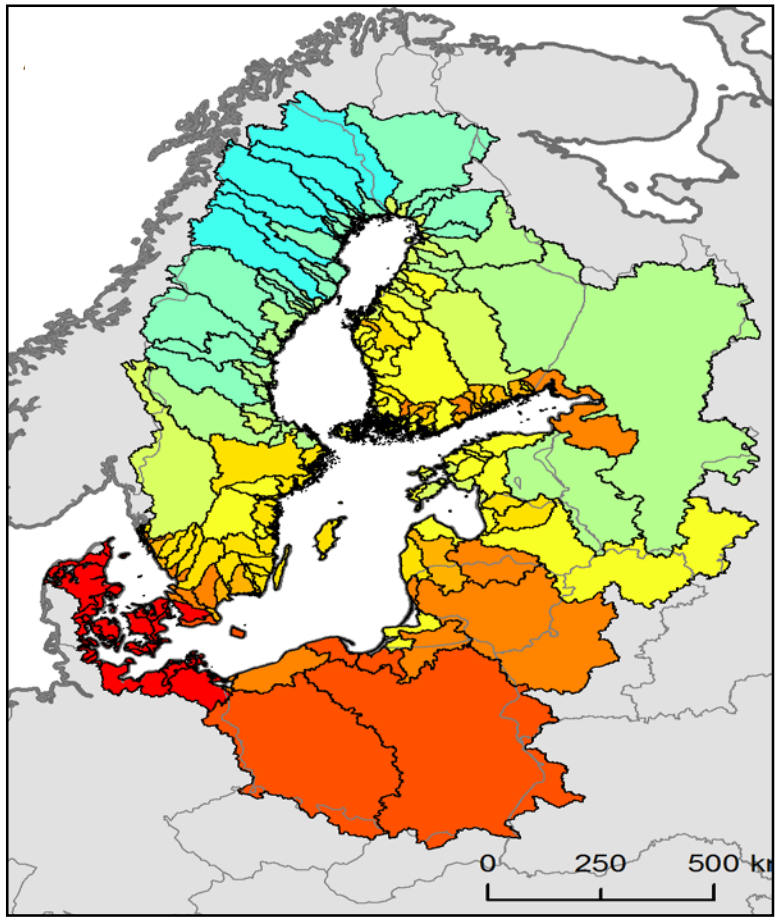

Watershed Divide
Headwaters
Riparian Wetlands
Watershed Divide
Water table


Watershed Divide
Riparian Wetlands
YARA
YaraMila
Piggfor
Water table
15%

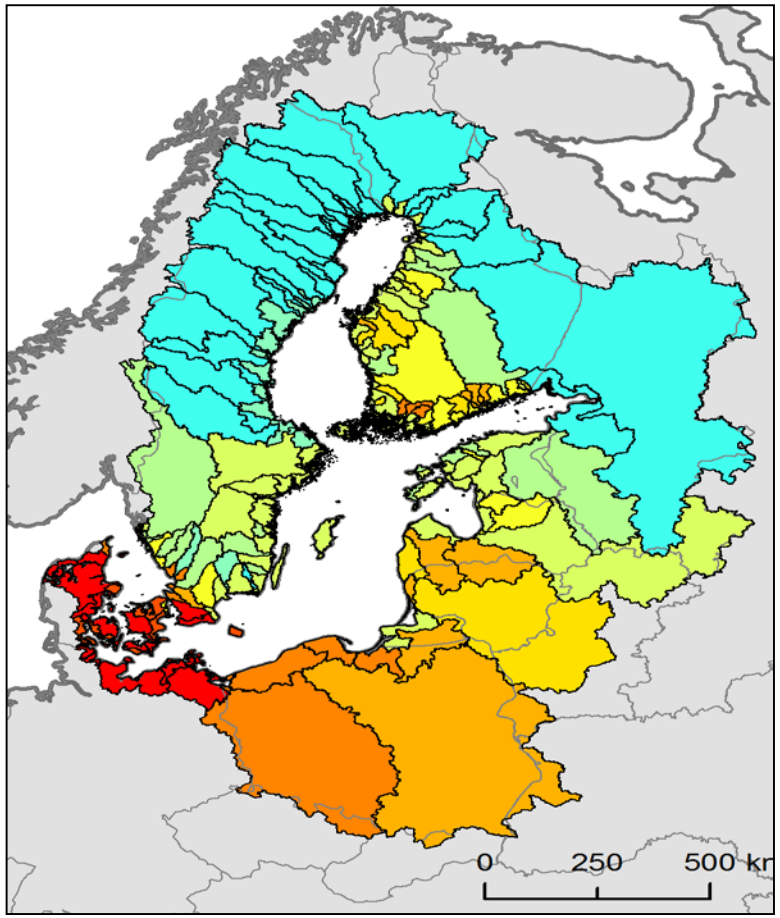
# Total N fertilization



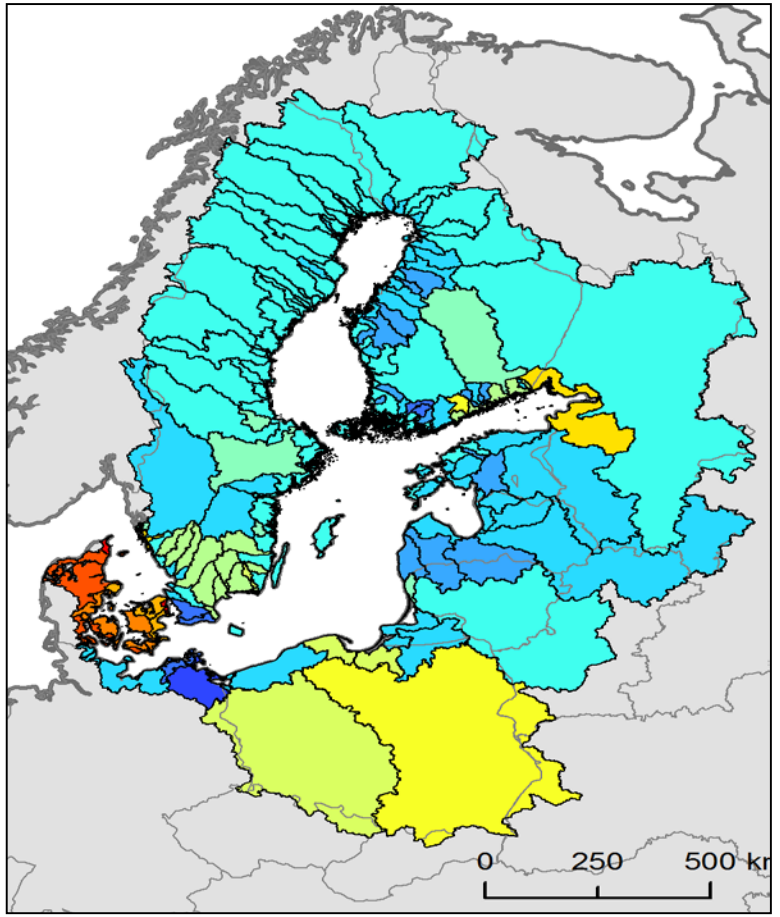
# Large N inputs through fertilizer and feed import in Polen och Danmark



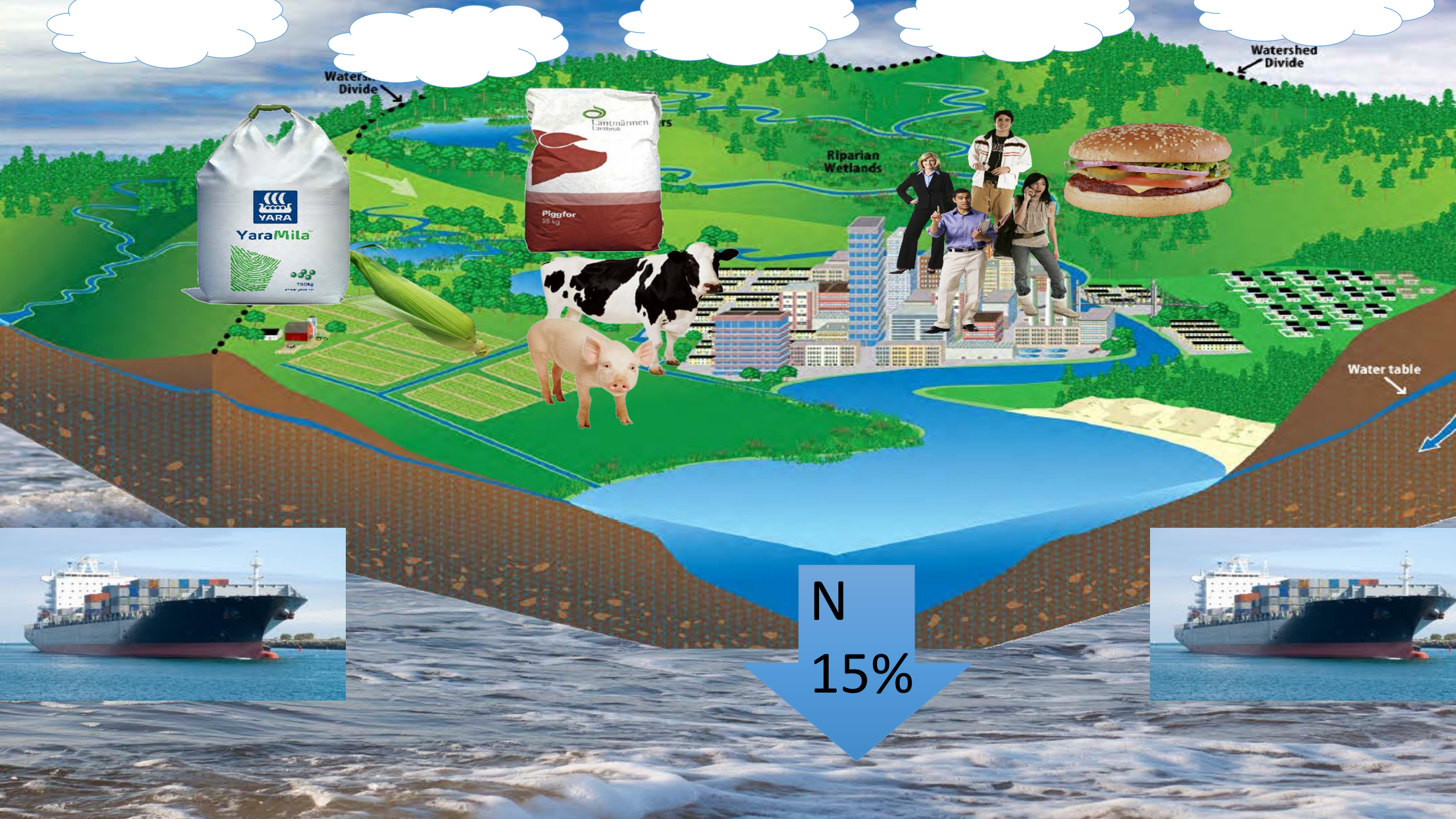

NANI



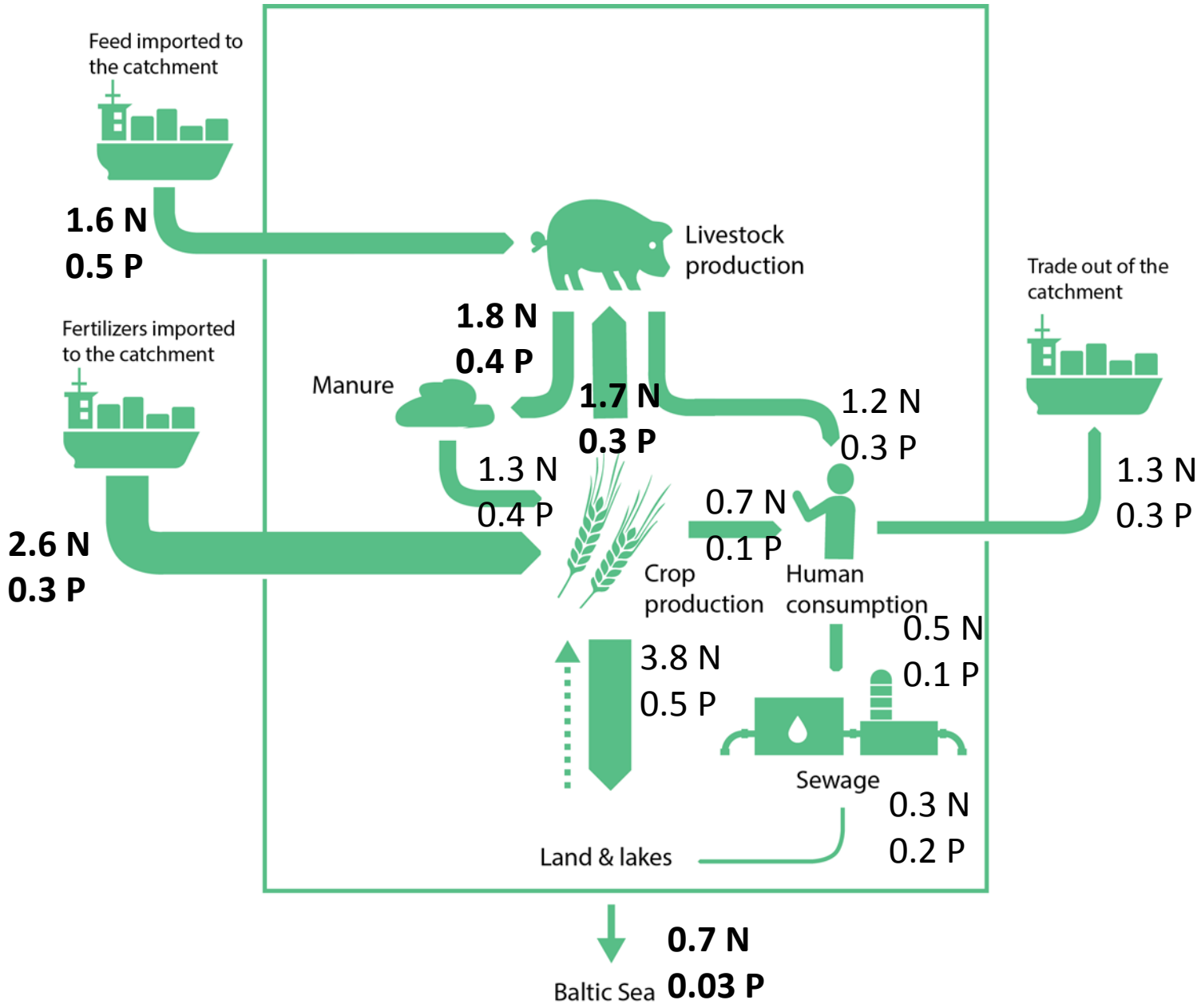

Fertilizer



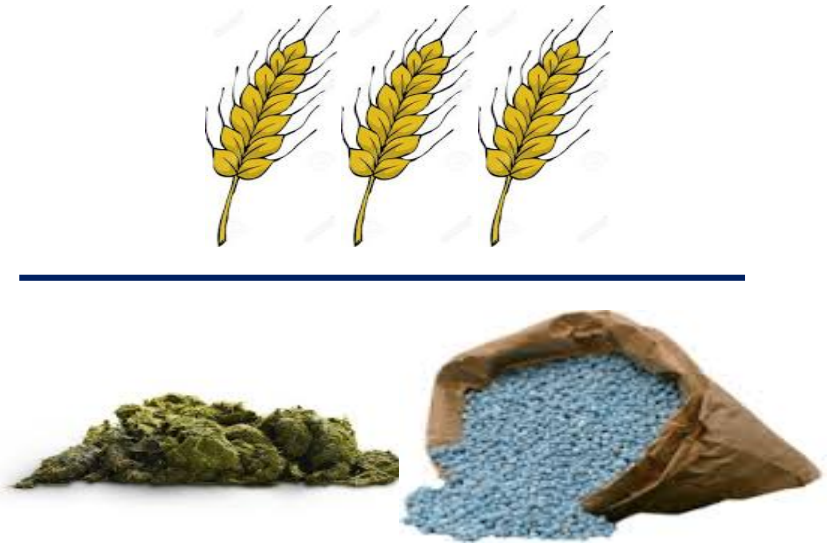

N in feed


Watershed Divide
Riparian Wetlands
YARA
YaraMila
Piggfor
Water table
N
15%

# Nutrient flows in the Baltic Sea catchment



# **N**utrient **U**se **E**fficiency



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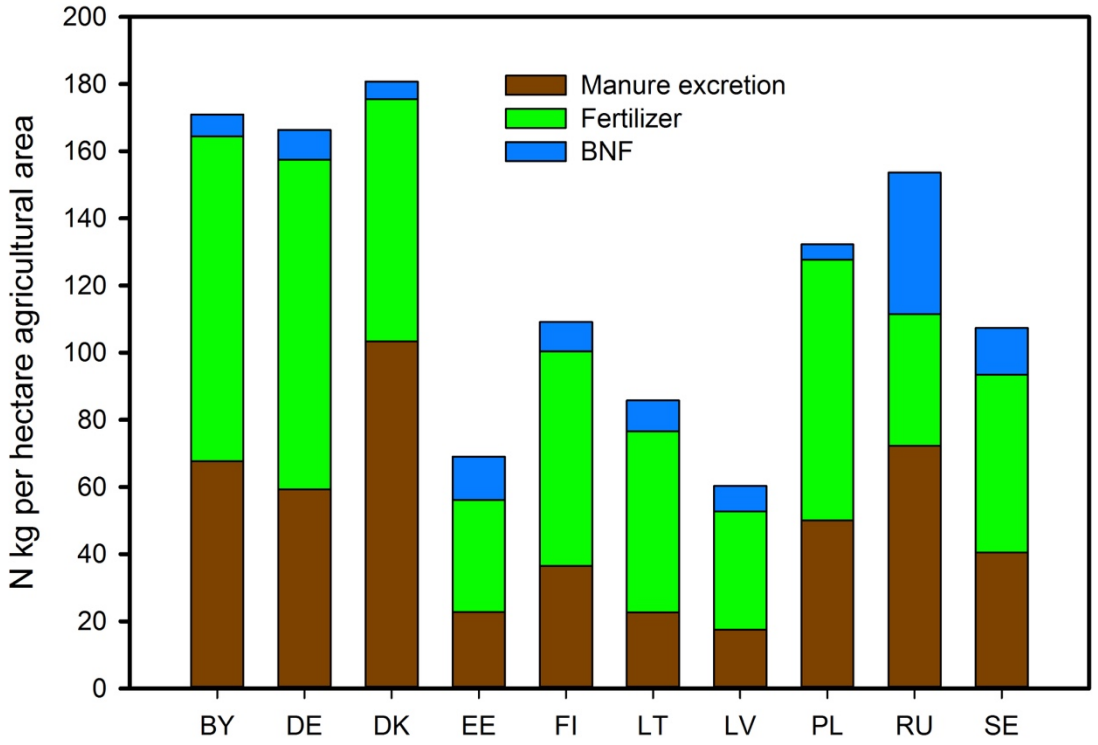
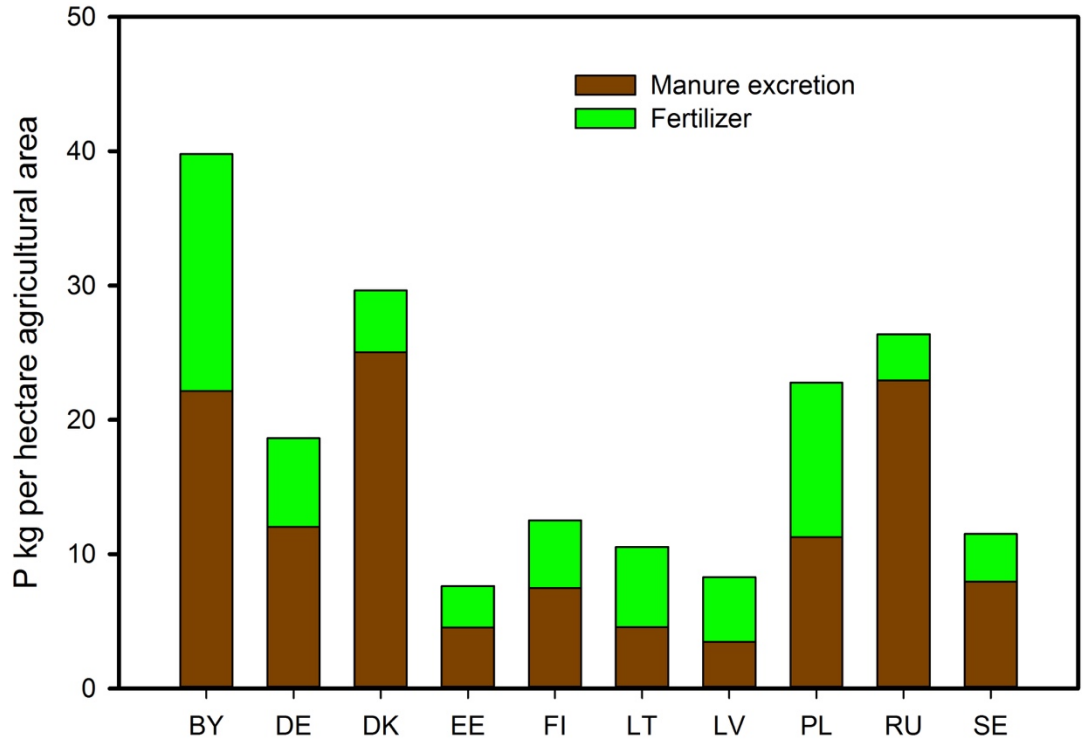
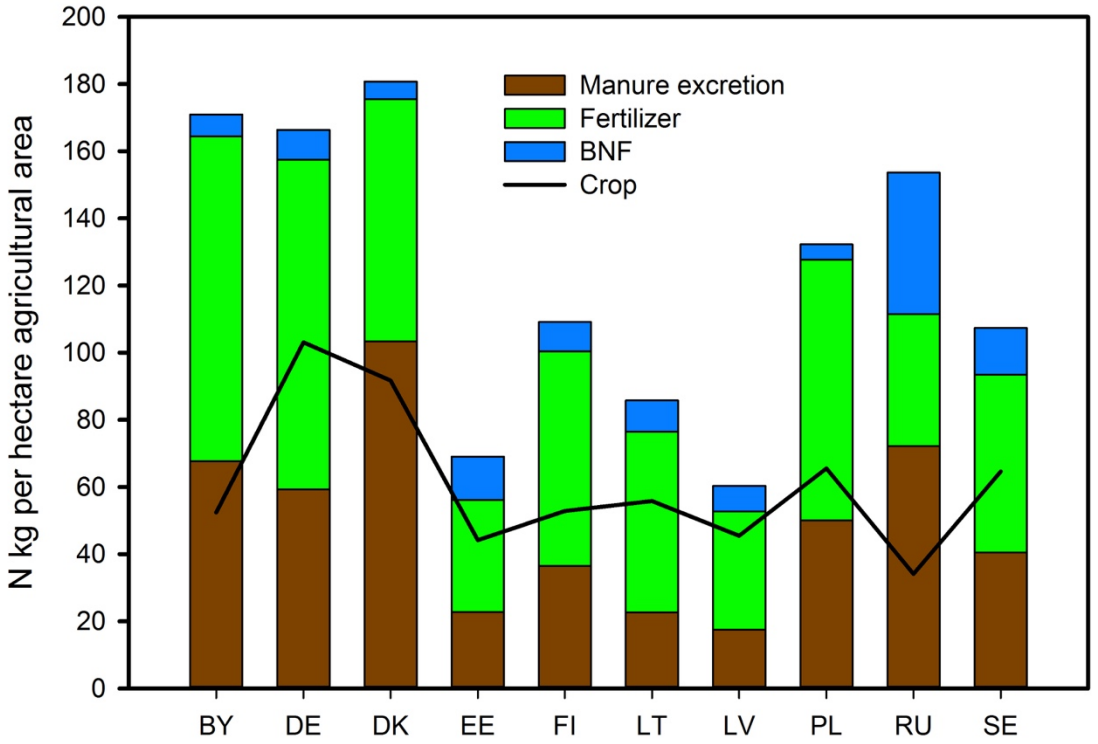
**NUE**

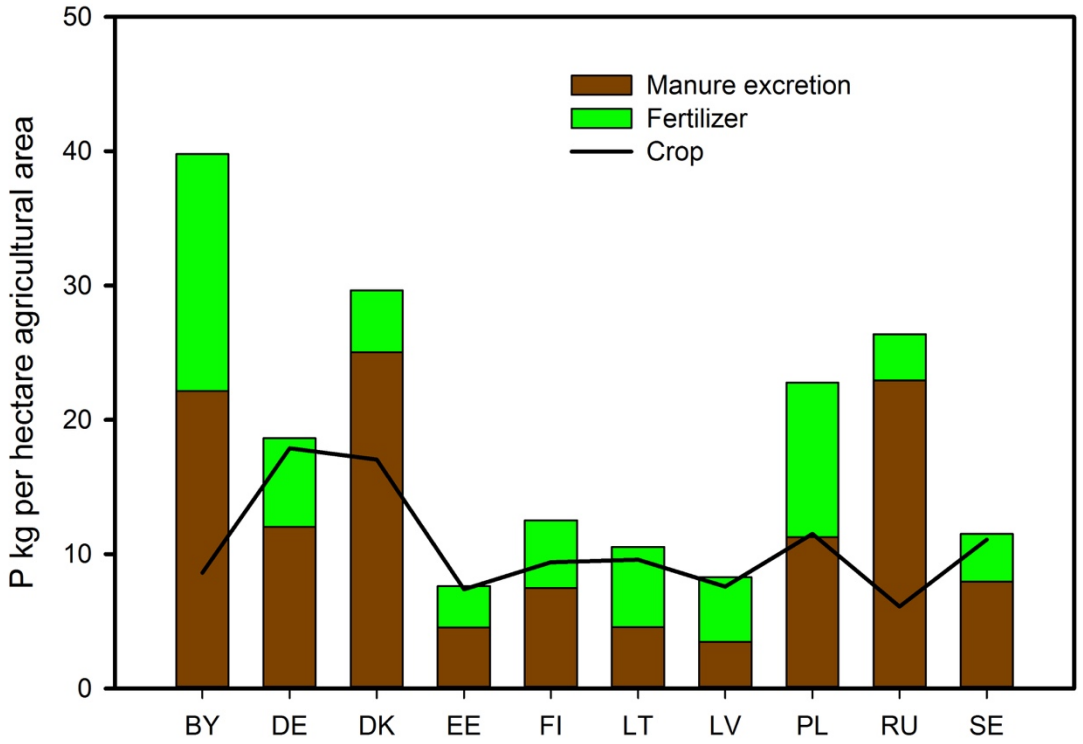
# Nutrient Use Efficiency 2010-2014 average



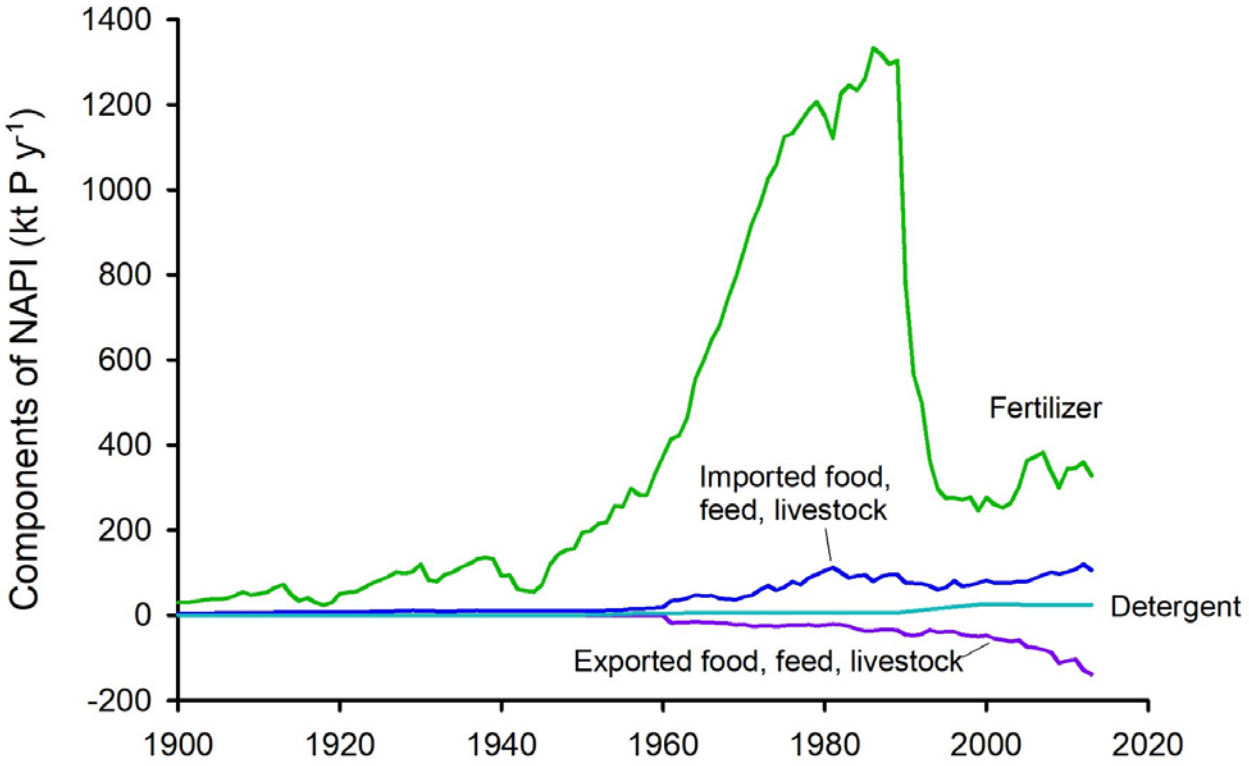



# Nutrient Use Efficiency 2010-2014 average



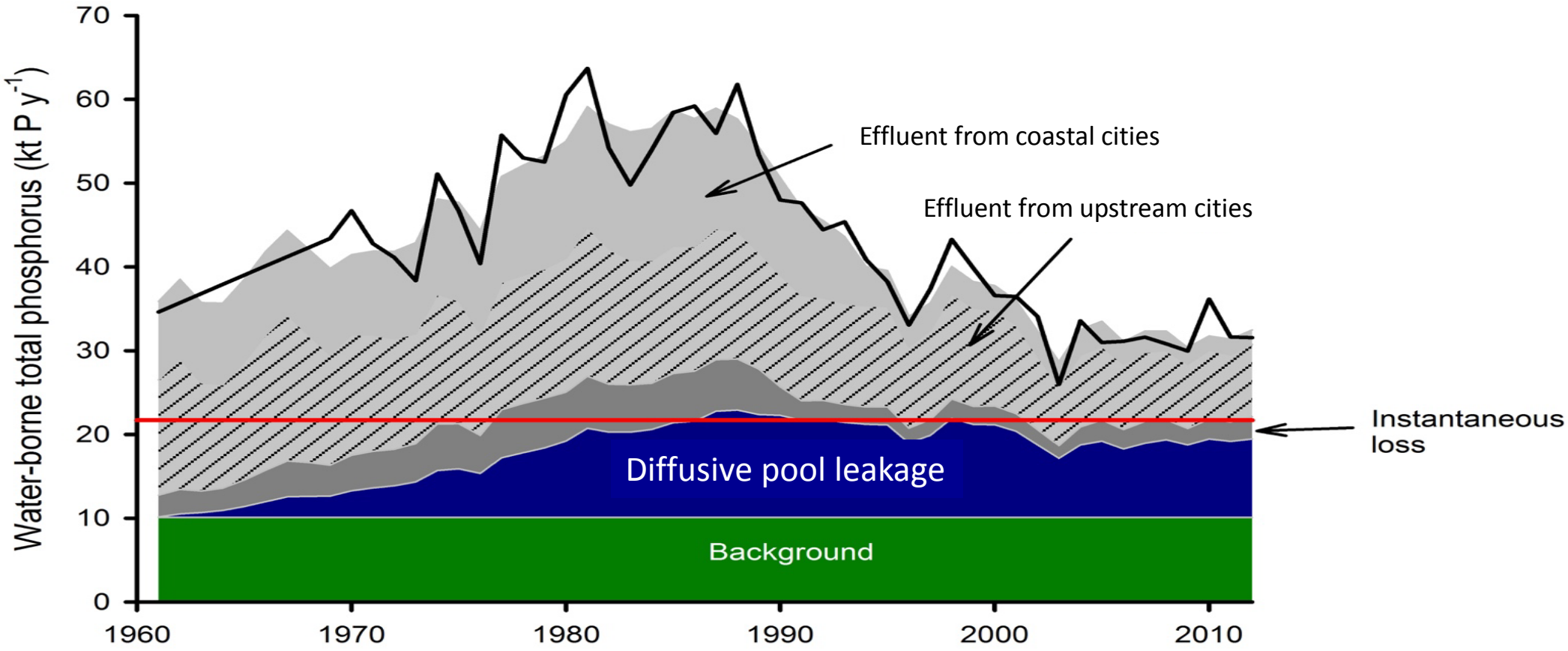



# 46 Mt NAPI since 1900

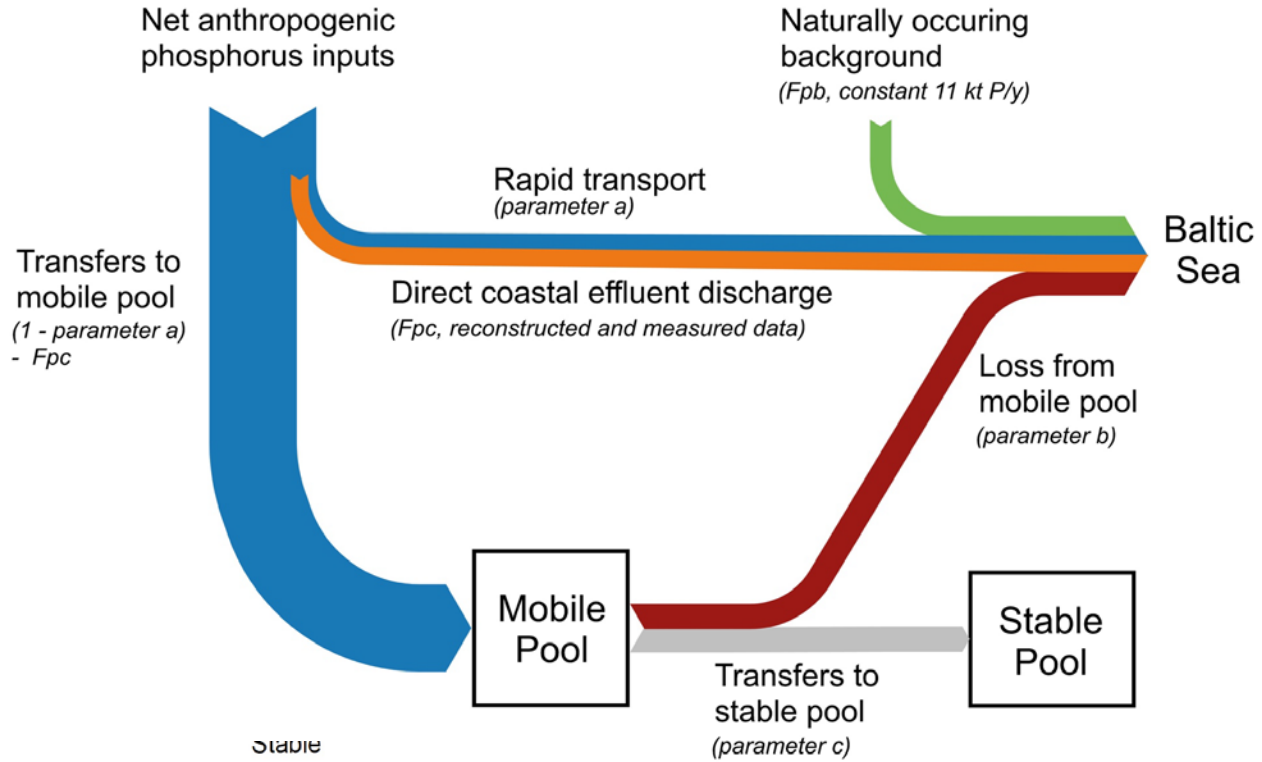


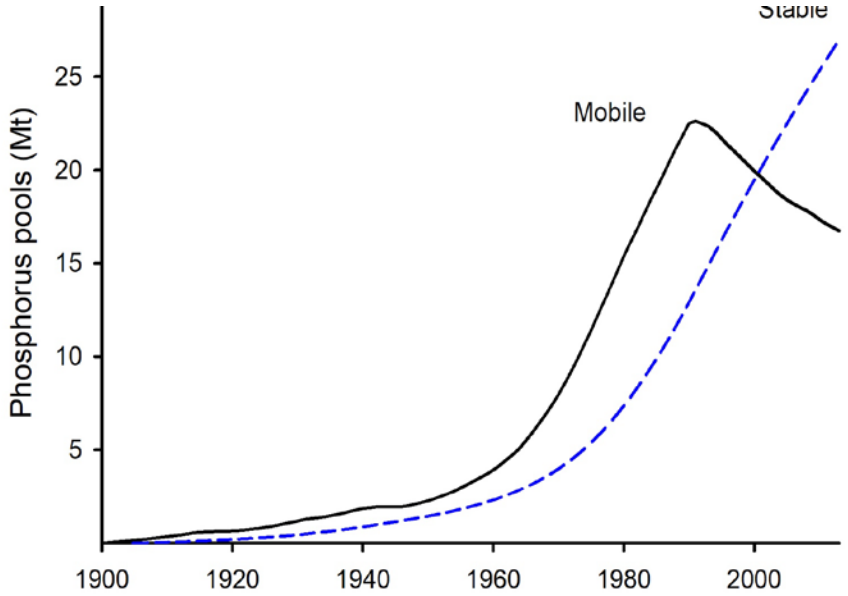

McCrackin et al. (In Press)

# Sources of P in water-borne loads

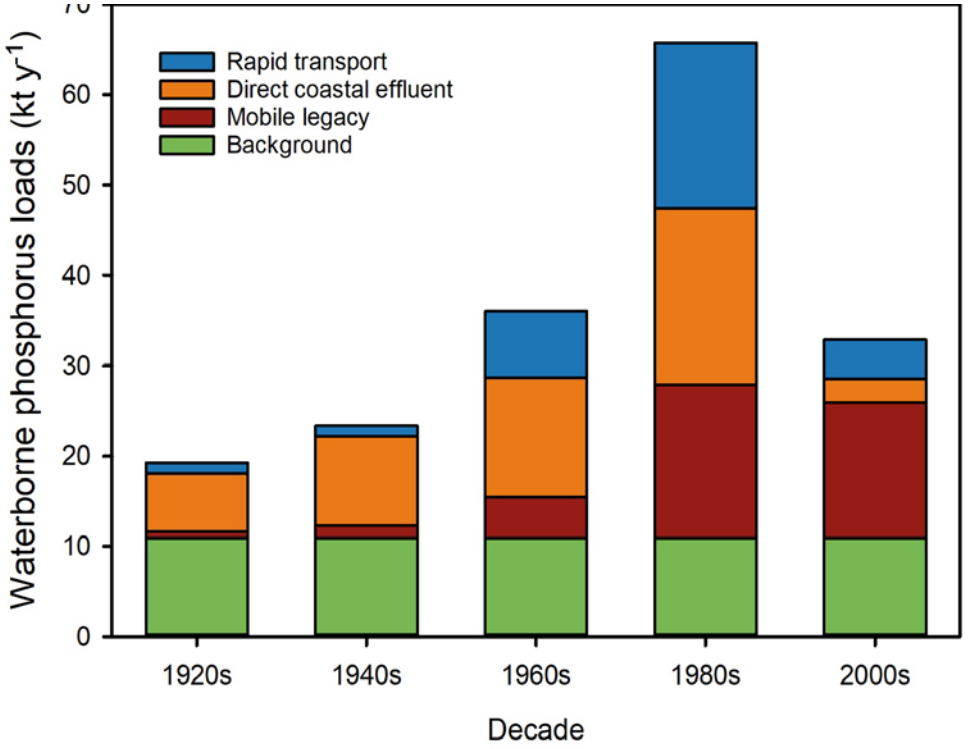


# Fate of P

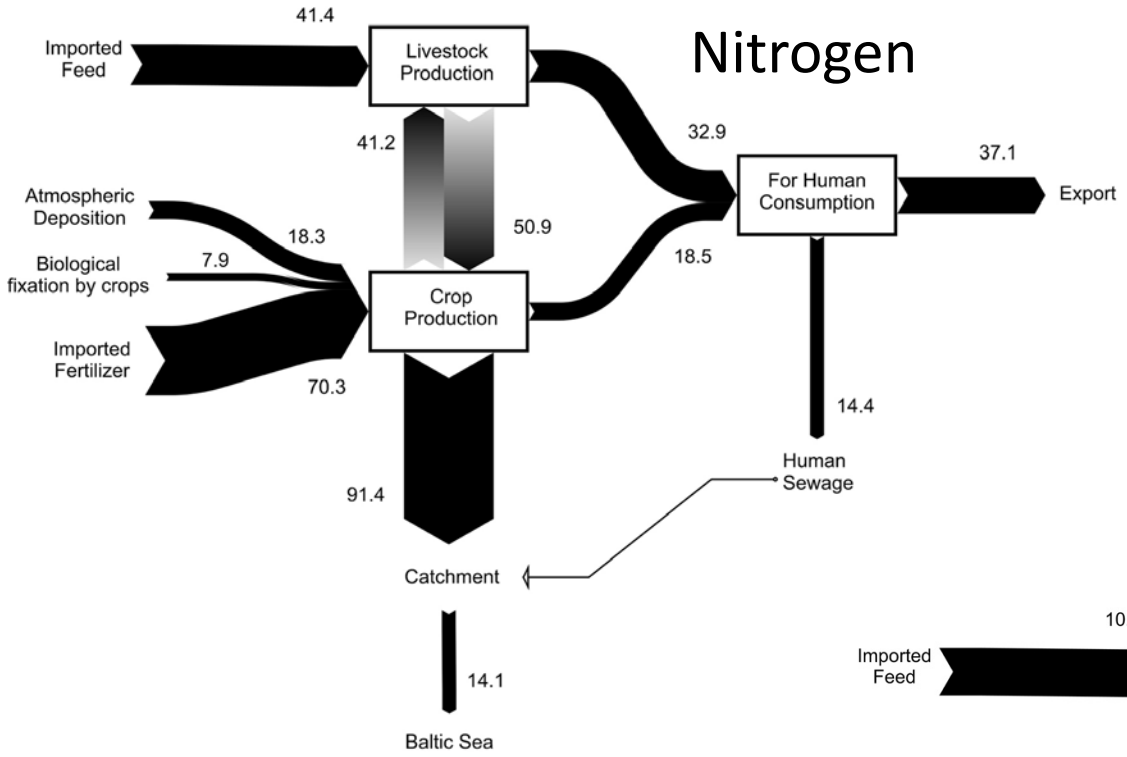

Net anthropogenic phosphorus inputs
Naturally occuring background
(Fpb, constant 11 kt P/y)
Rapid transport
(parameter a)
Baltic Sea
Transfers to mobile pool
(1 - parameter a) - Fpc
Direct coastal effluent discharge
(Fpc, reconstructed and measured data)
Loss from mobile pool
(parameter b)
Mobile Pool
Stable Pool
Transfers to stable pool
(parameter c)

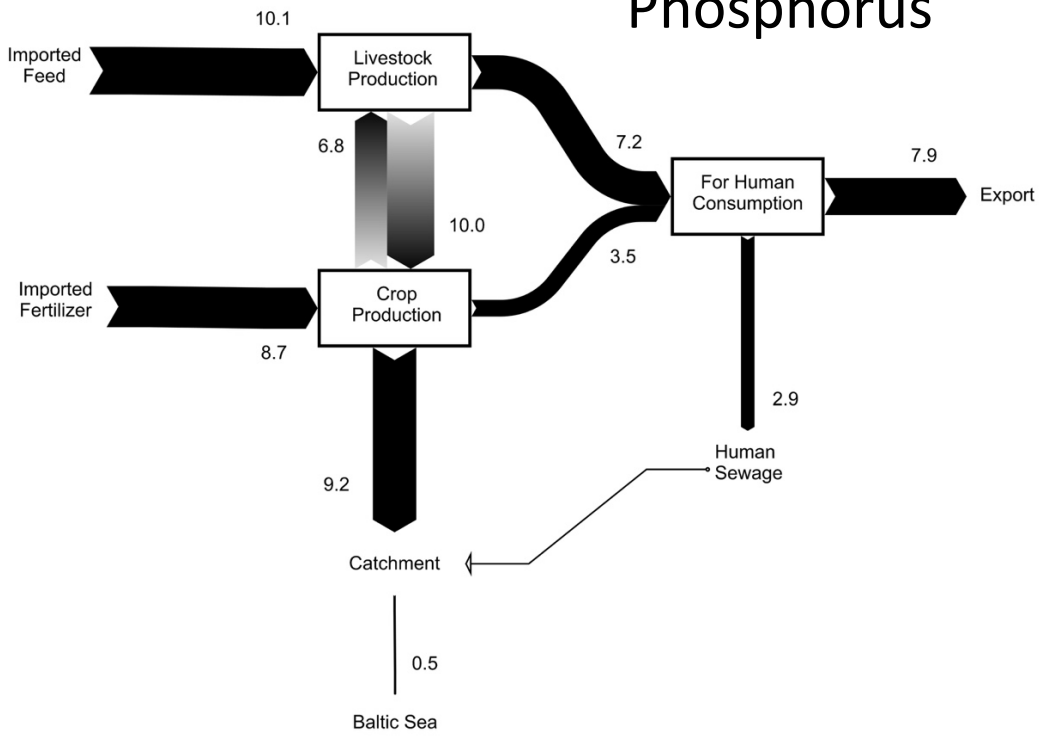

Stable
Mobile
Phosphorus pools (Mt)
25
20
15
10
5
1900
1920
1940
1960
1980
2000

# Legacy P contributes ~50% of current load

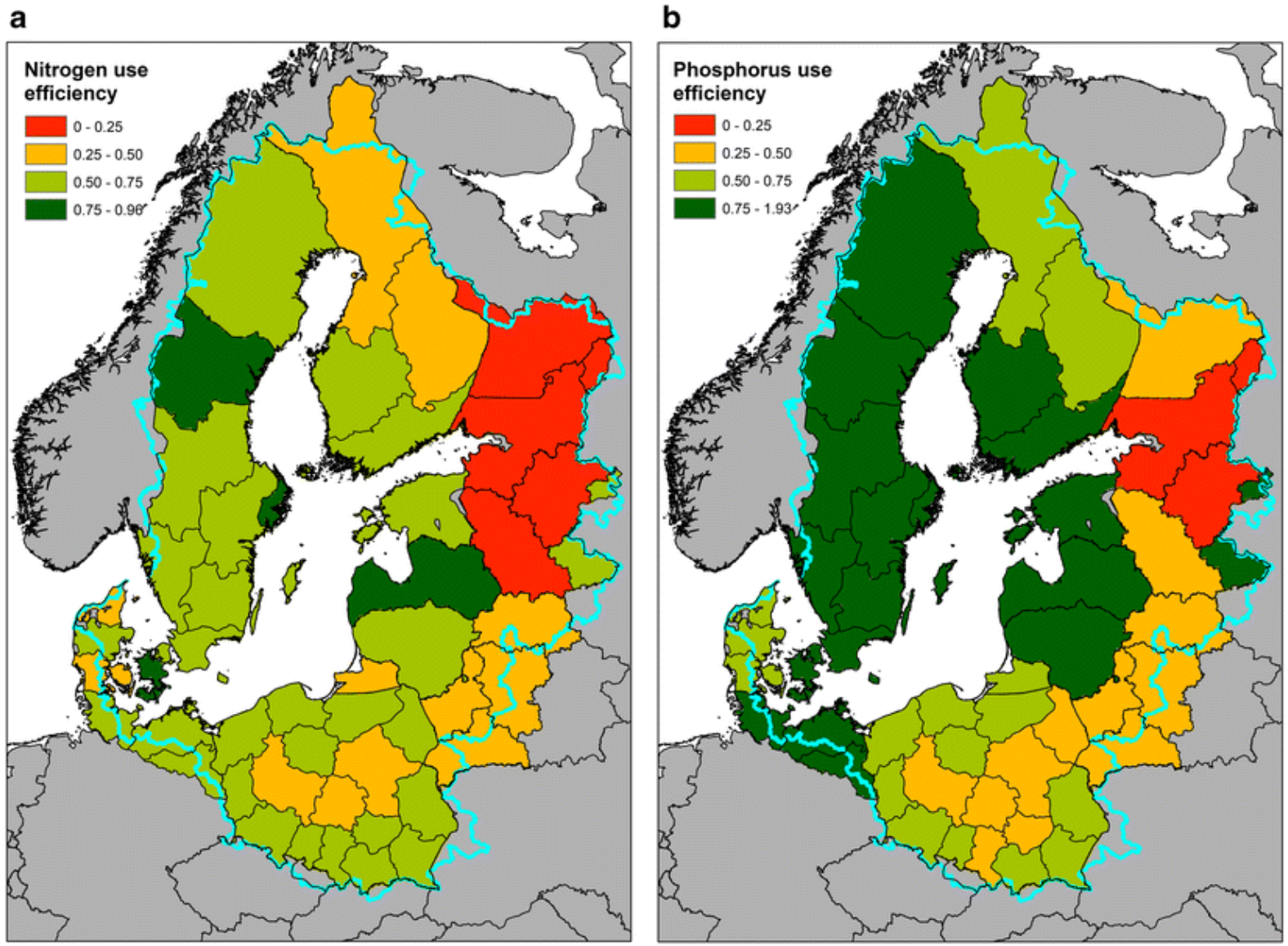


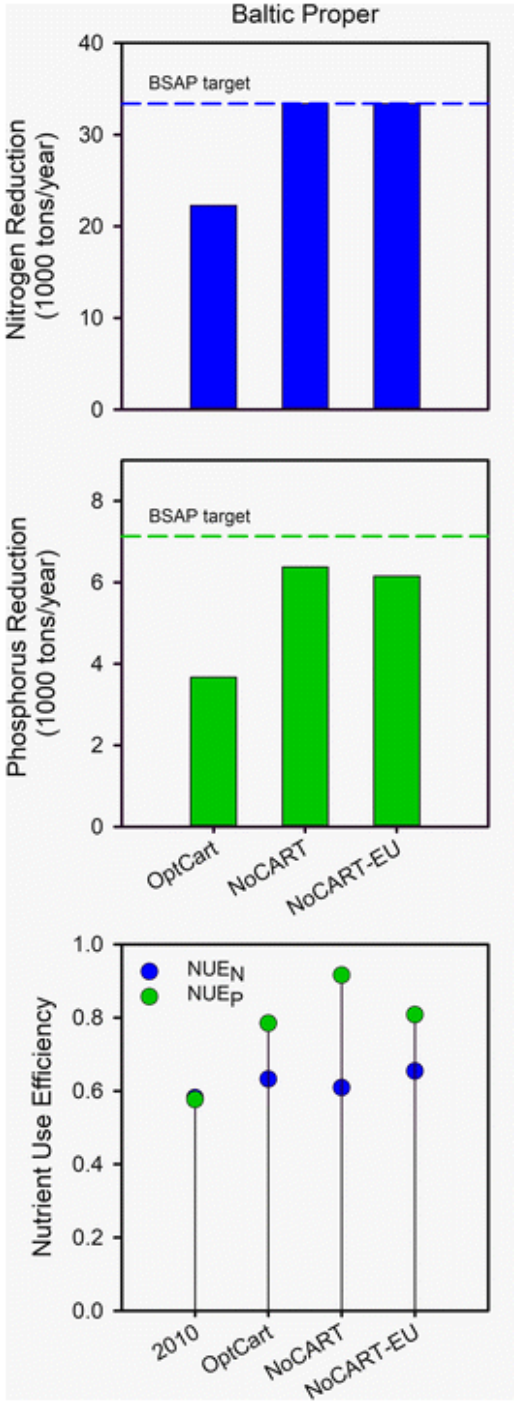
# Nutrient Cycles (kg/ha UAA, 2010)



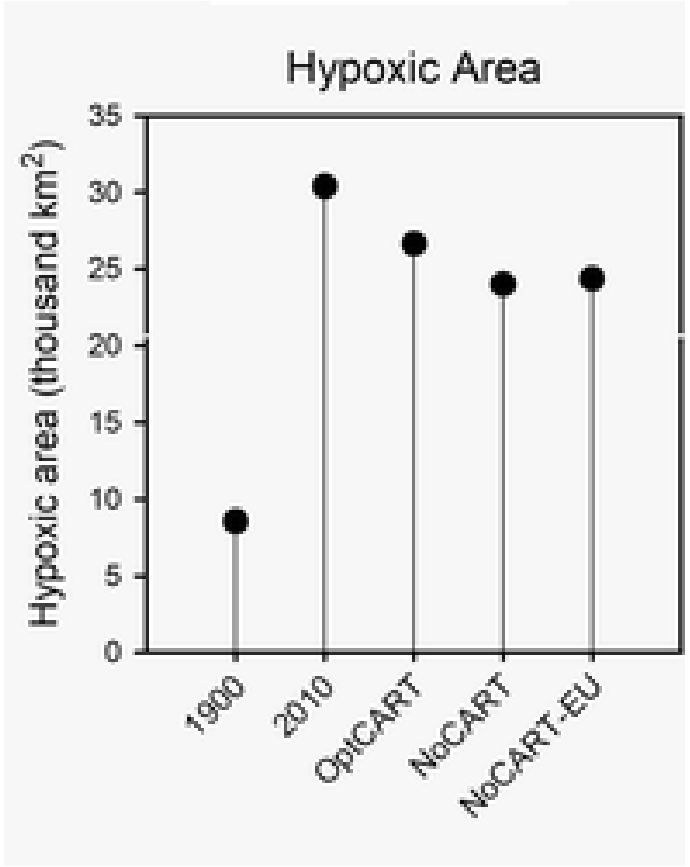



# Nutrients are not used efficiently everywhere

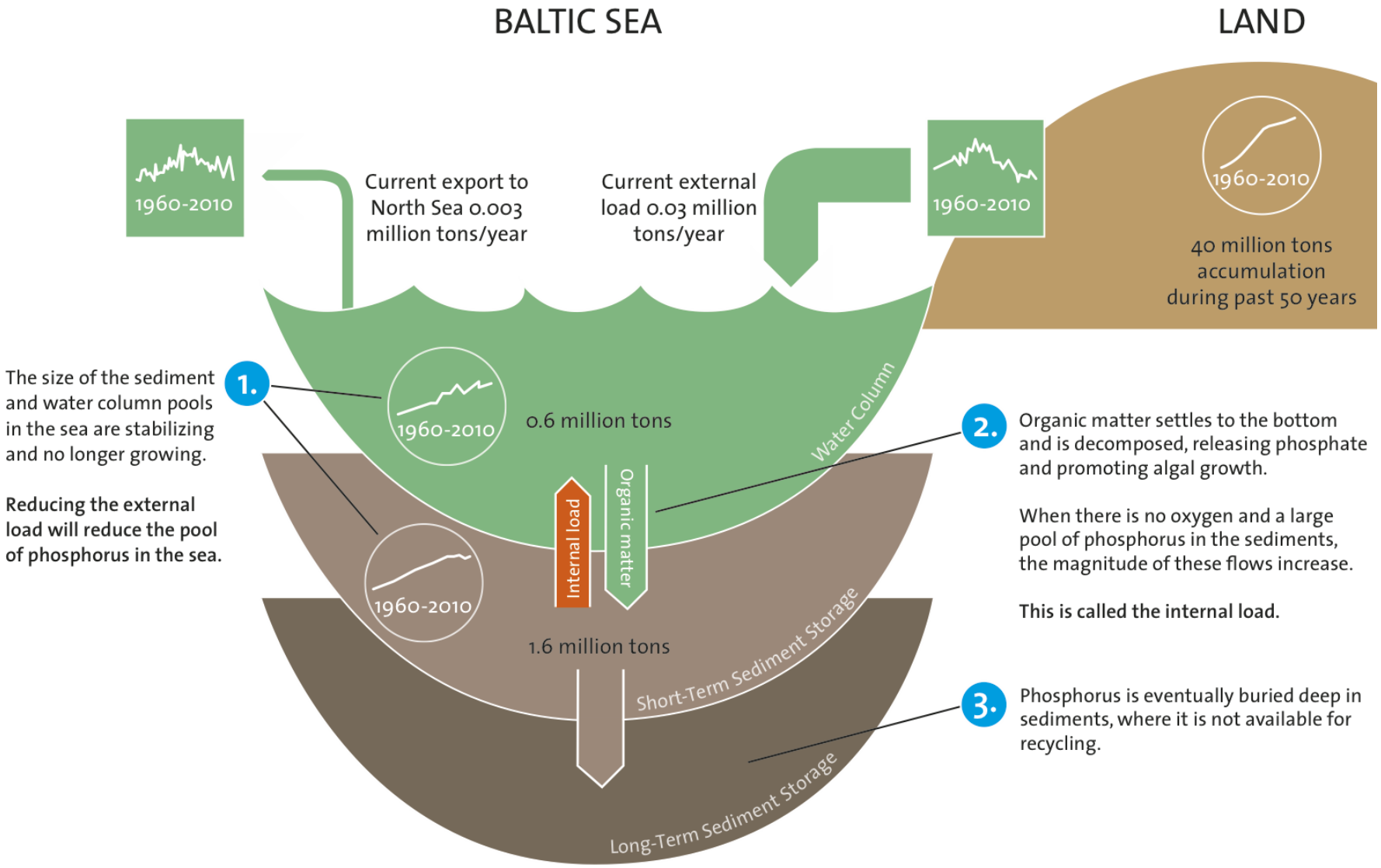




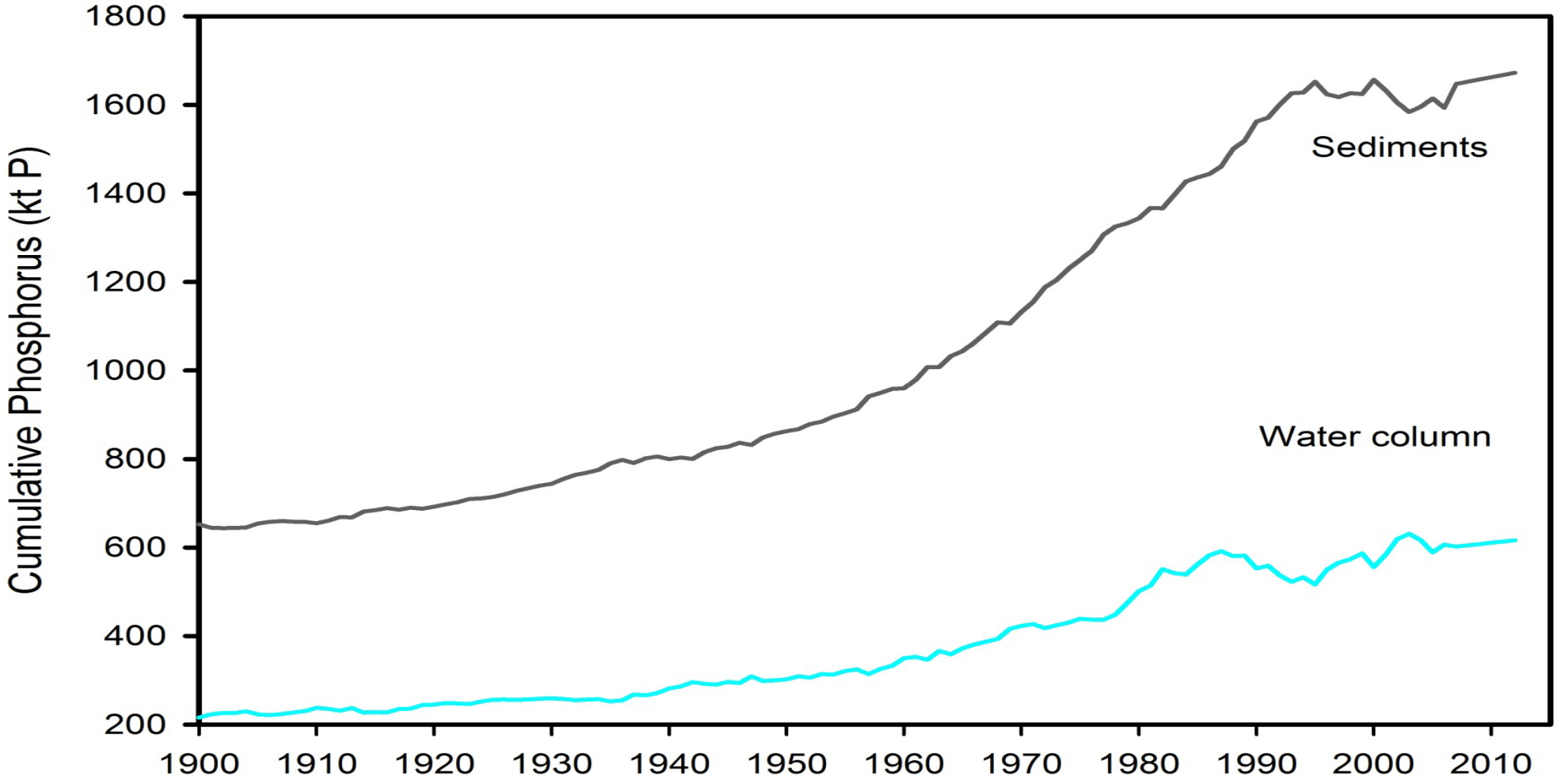

A substantial portion of BSAP load reductions can be reached and Baltic Sea environment improved if nutrient use efficiency is increased




McCrackin et al, 2018

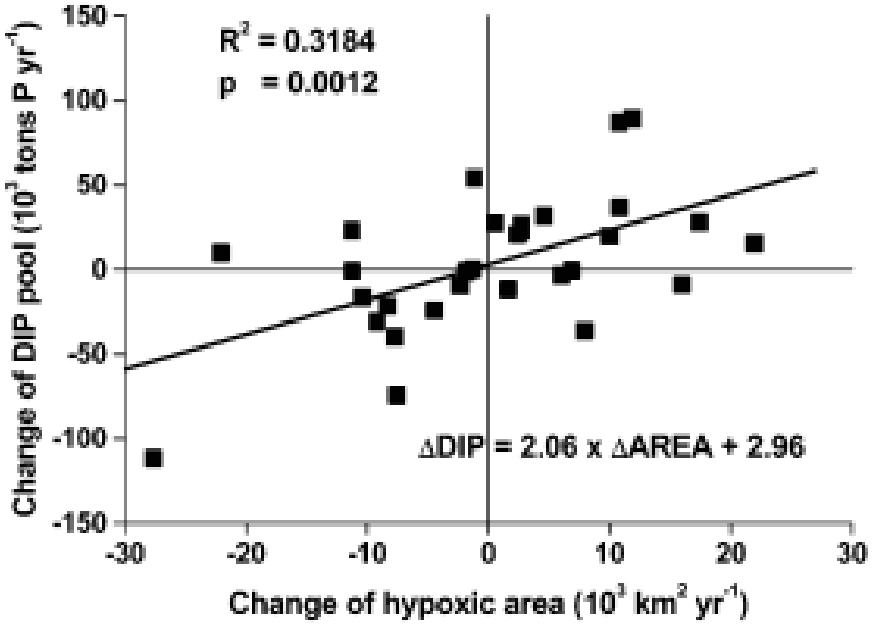

BALTIC SEA
LAND
1960-2010
Current export to North Sea 0.003 million tons/year
Current external load 0.03 million tons/year
1960-2010
1960-2010
40 million tons accumulation during past 50 years
The size of the sediment and water column pools in the sea are stabilizing and no longer growing.
Reducing the external load will reduce the pool of phosphorus in the sea.
1.
1960-2010
0.6 million tons
Water Column
2.
Organic matter settles to the bottom and is decomposed, releasing phosphate and promoting algal growth.
When there is no oxygen and a large pool of phosphorus in the sediments, the magnitude of these flows increase.
This is called the internal load.
Internal load
Organic matter
1960-2010
1.6 million tons
Short-Term Sediment Storage
3.
Phosphorus is eventually buried deep in sediments, where it is not available for recycling.
Long-Term Sediment Storage

# Management strategies: Internal vs. external loads

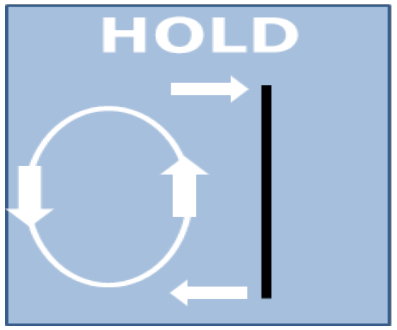



Gustafsson 2012

# Internal load?



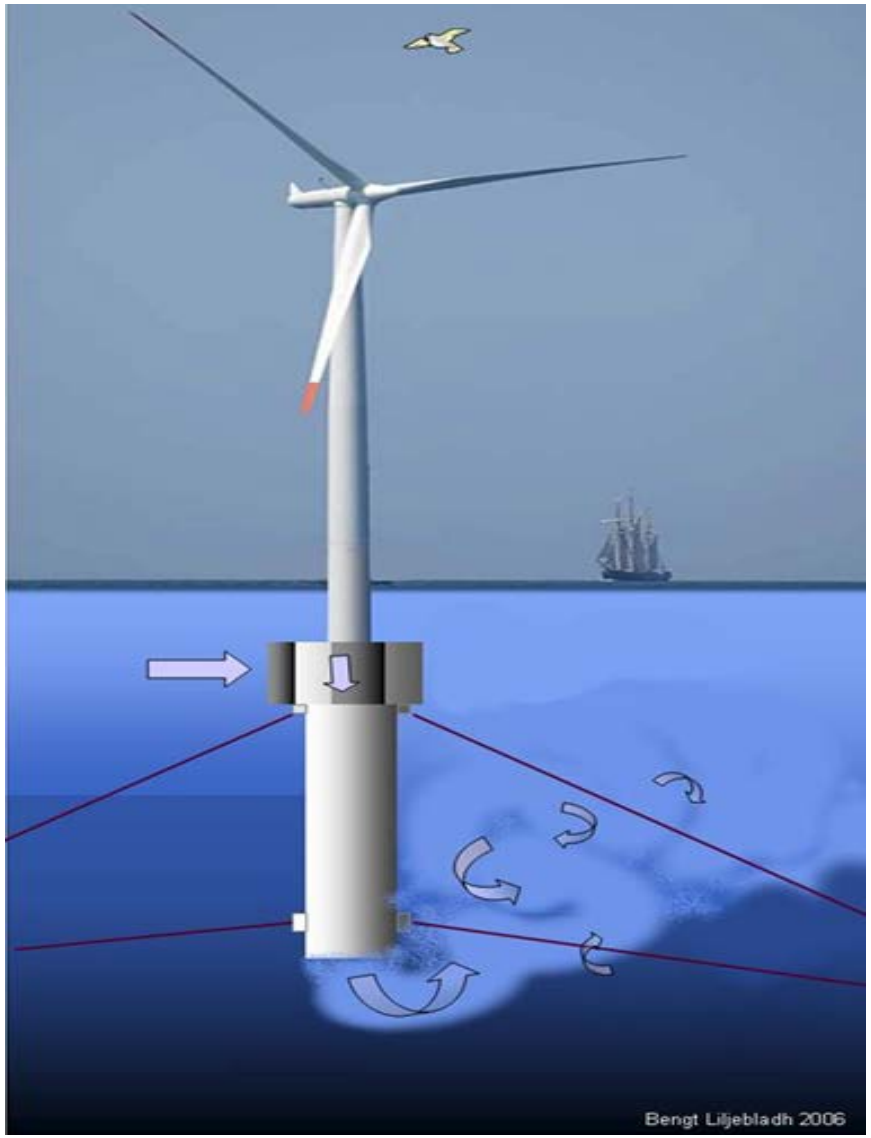

Conley et al. 2002



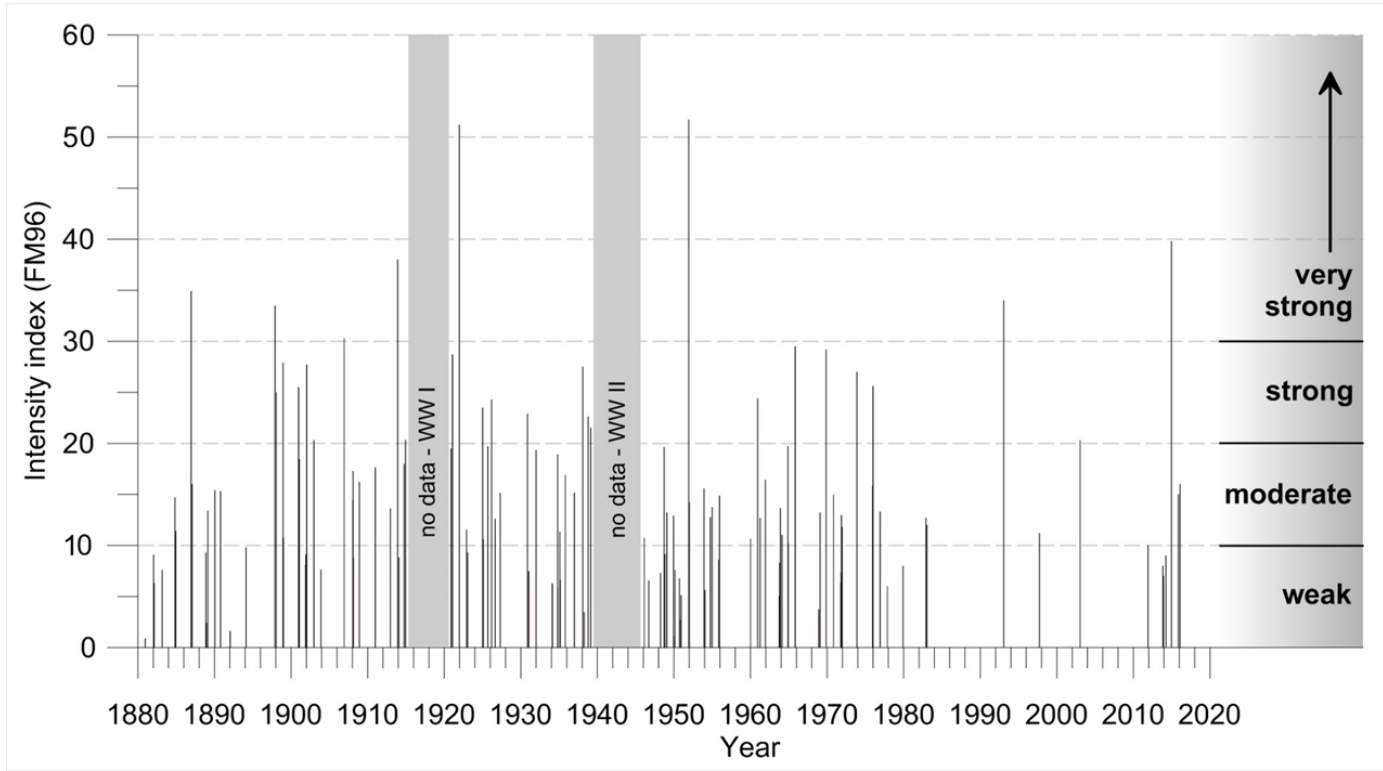

**Pumping water of**
**High Oxygen**
**Low Density**

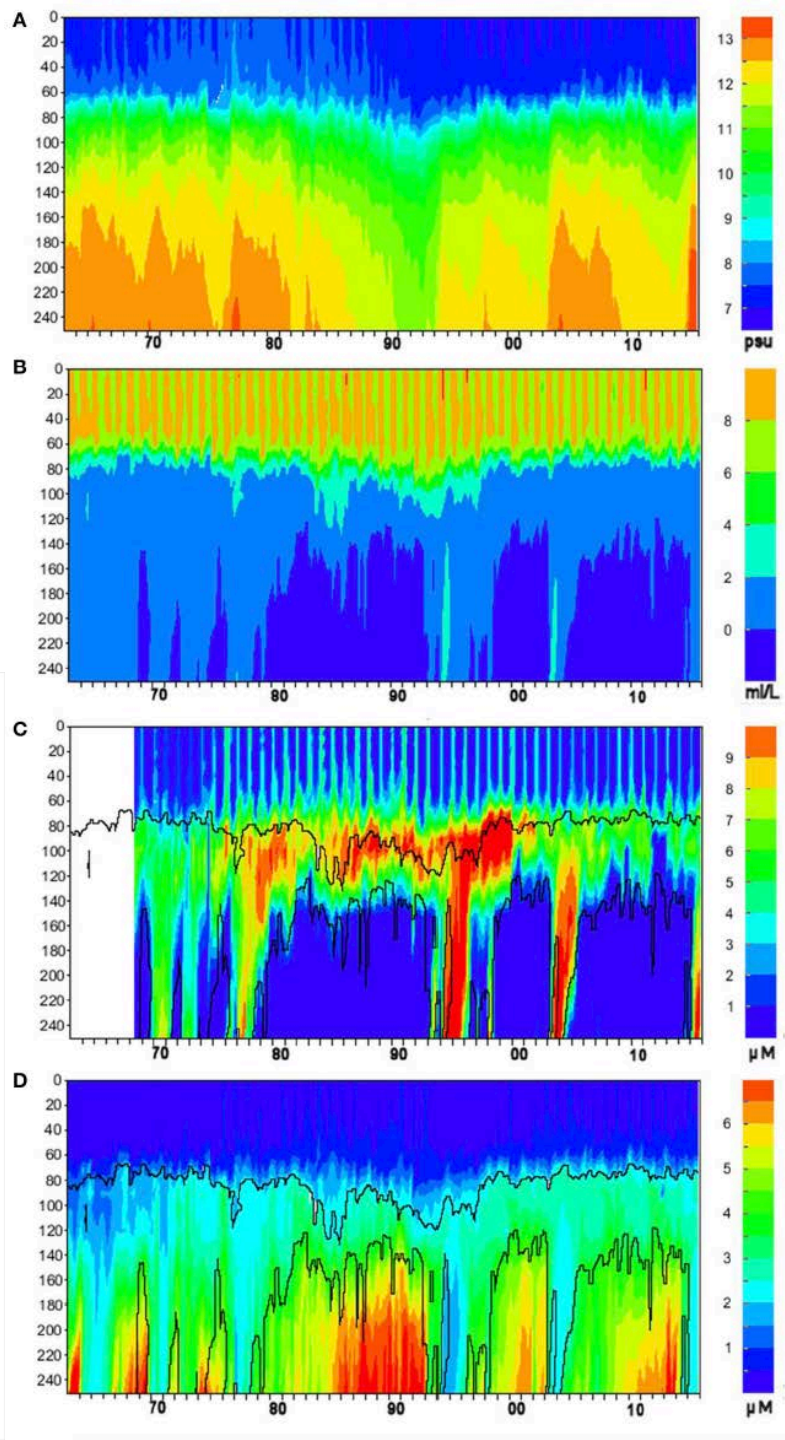
Pump arrangement used in the By Fjord

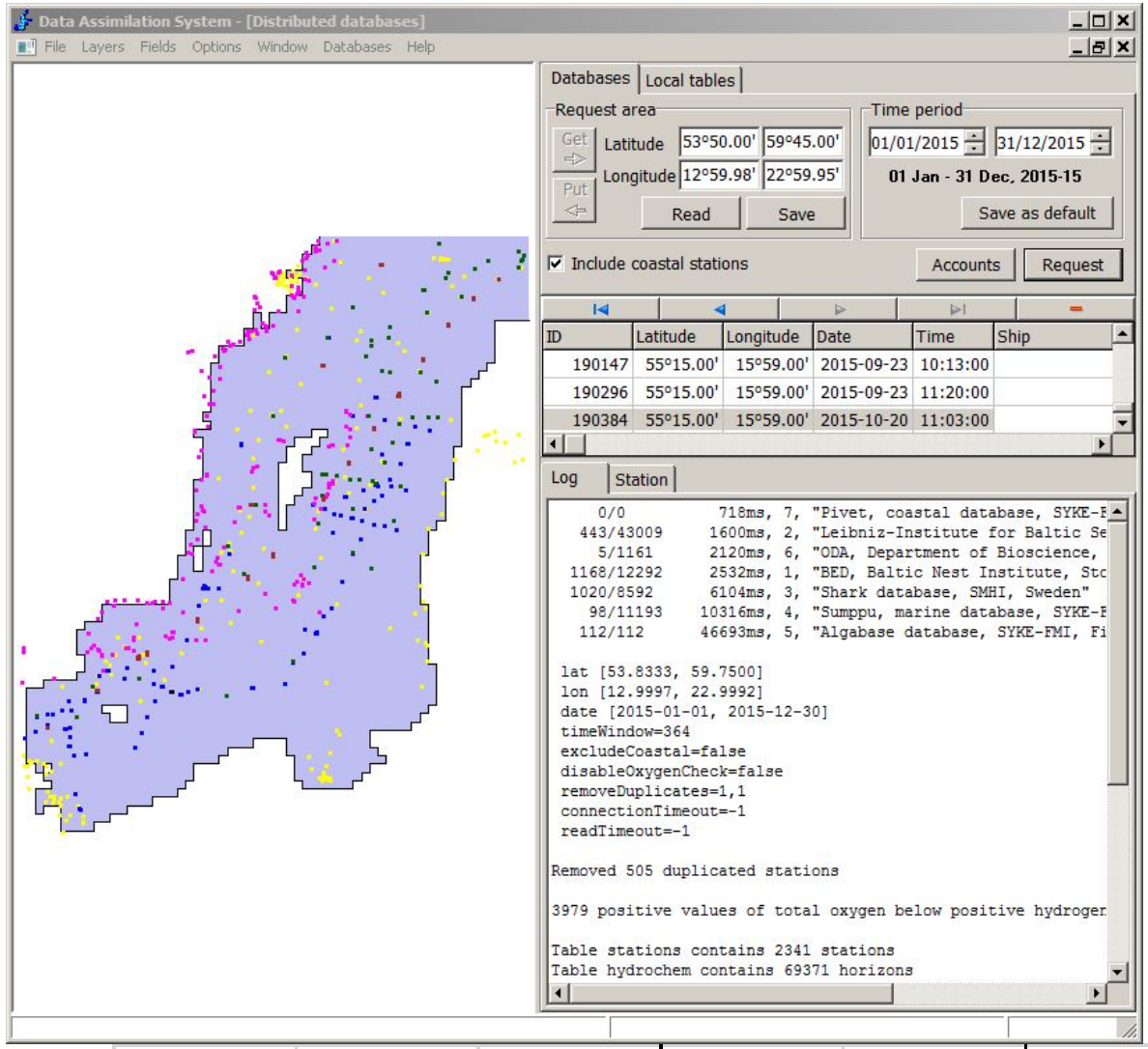
Floating wind power station with pump




Stiegebrandt et al. 2015


Intensity index (FM96)
Year
no data - WW I
no data - WW II
very strong
strong
moderate
weak

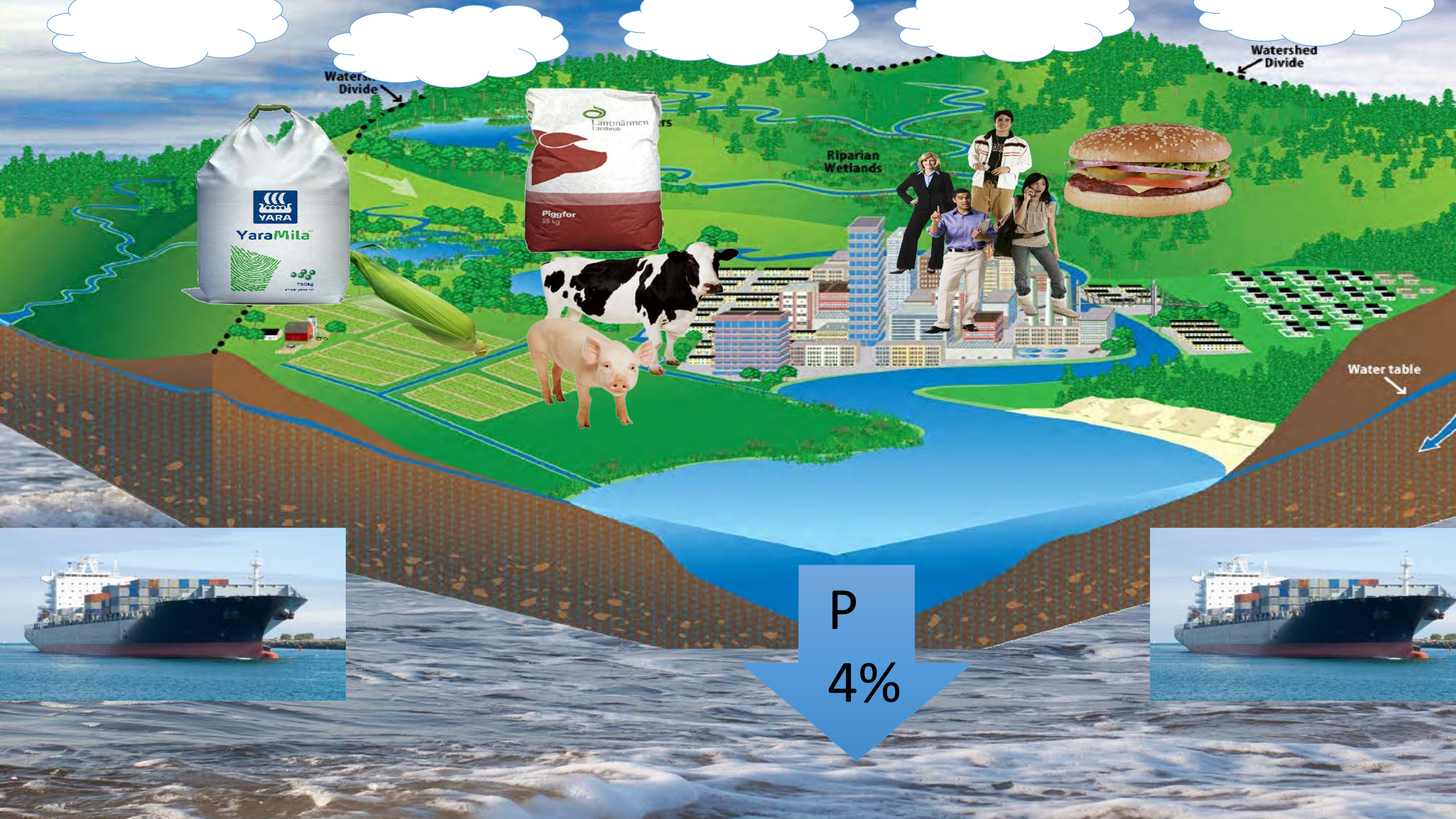

A
B
C
D
psu
ml/L
µM
µM



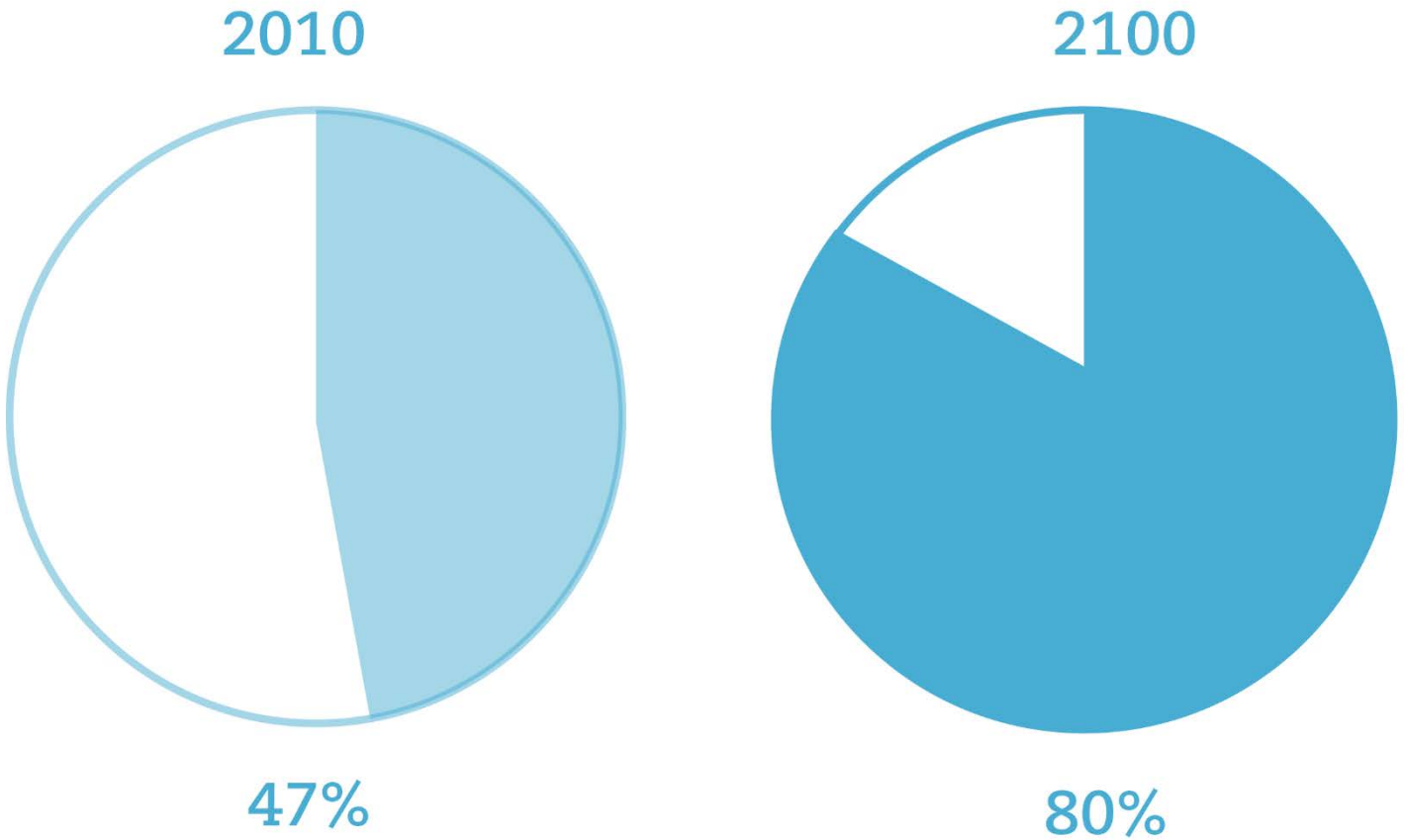

| BP | TP uM | | PO4 uM | | TP 10^3 tonnes | | PO4 10^3 tonnes | |
|---|---|---|---|---|---|---|---|---|
| Year | BP 0-60 | BP 60-bot | BP 0-60 | BP 60-bot | BP 0-60 | BP 60-bot | BP 0-60 | BP 60-bot |
| 2013 | 0.86 | 2.61 | 0.50 | 2.46 | 250 | 270 | 145 | 255 |
| 2014 | 0.96 | 2.82 | 0.54 | 2.40 | 279 | 292 | 157 | 248 |
| 2015 | 1.06 | 2.68 | 0.60 | 2.34 | 308 | 277 | 174 | 242 |
| 2016 | 1.05 | 2.75 | 0.63 | 2.35 | 305 | 285 | 183 | 243 |

# Conclusions

- There is still room reducing the leakage of N and P from land
- Geo-engineering solutions may switch focus from causes to symptoms
- Both N and P should be reduced, but for the Baltic Sea there should be an emphasis on P management
- However: there is clear reason why agriculture can do better
- We have to restructure our agriculture and increase NUE
- Manure is a given capacitor that can make a difference in NUE


Watershed Divide
Riparian Wetlands
YARA
YaraMila
Lantmännen
Piggfor
25 kg
Water table
P
4%

# The Challenge…….for the Globe and the Baltic



# Thank you

# Regional solutions may help to find global challenges

Modern agriculture is based on the extensive use of chemical fertilizers and the decoupling of crop and animal production