BACC 2 Ch. 5.2.3
Freshwater biogeochemistry

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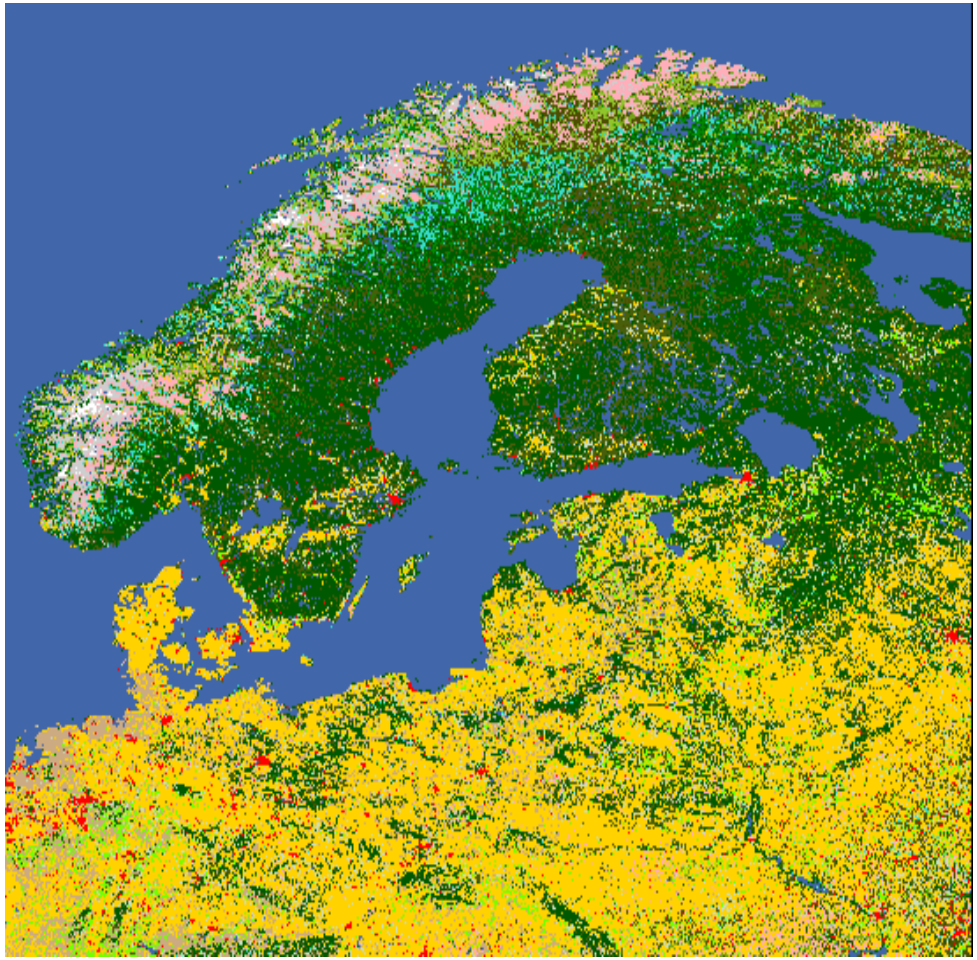
Introduction

- **1.1 Changes in freshwater biogeochemistry shaping the Baltic Sea**
- **1.2 The Baltic Sea catchment**



Legend

glc250m

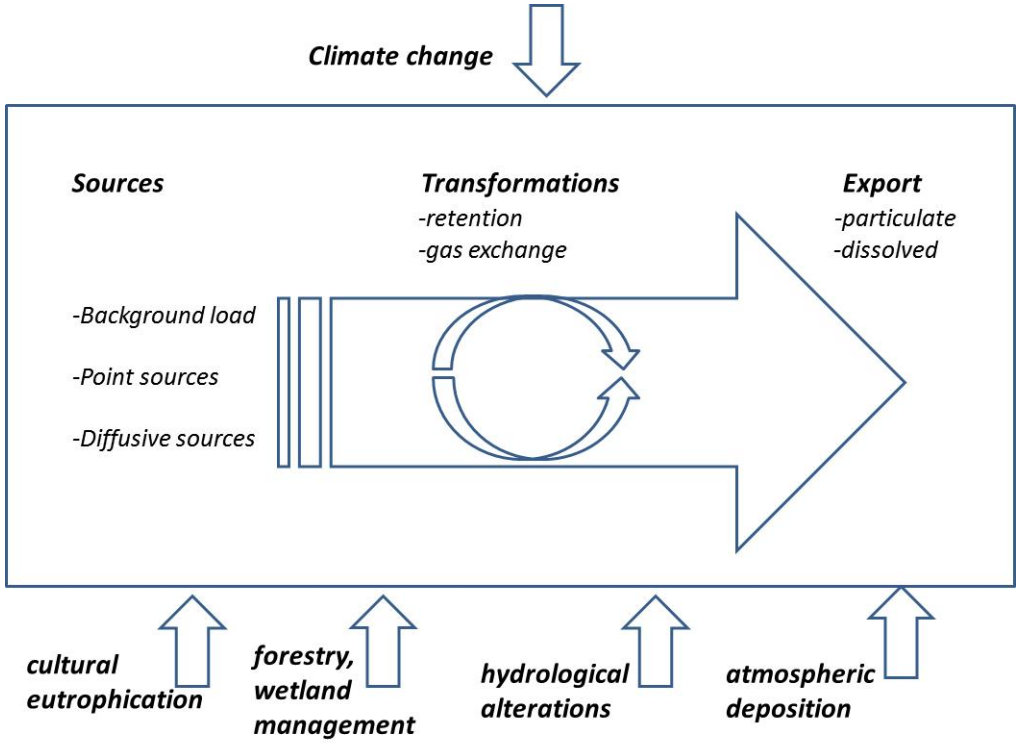
Class_Names

- Artificial surfaces and associated areas
- Bare areas
- Cultivated and managed terrestrial areas
- Herbaceous, closed - pastures, natural grassl
- Herbaceous, open with shrubs
- Lichens and mosses
- Mosaic: crop/ tree cover
- Regularly flooded shrub and/or herbaceous
- Snow and ice
- Sparse herbaceous or sparse shrubs
- Tree cover, broadleaved, deciduous, closed
- Tree cover, broadleaved, deciduous, open
- Tree cover, mixed phrenology, closed
- Tree cover, mixed phrenology, open
- Tree cover, needleleaved, evergreen, closed
- Tree cover, needleleaved, evergreen, open
- Water

- **1.3 Drivers affecting freshwater biogeochemistry**
  - **1.3.1 Cultural eutrophication**
  - **1.3.2 Damming, hydrological alterations**
  - **1.3.3 Forestry, wetland management**
  - **1.3.4 Atmospheric deposition**

Subchapter structure

- **1.4 Sources, transformations and exports of biogenic elements to the Baltic Sea**



2) Climate and freshwater biogeochemistry

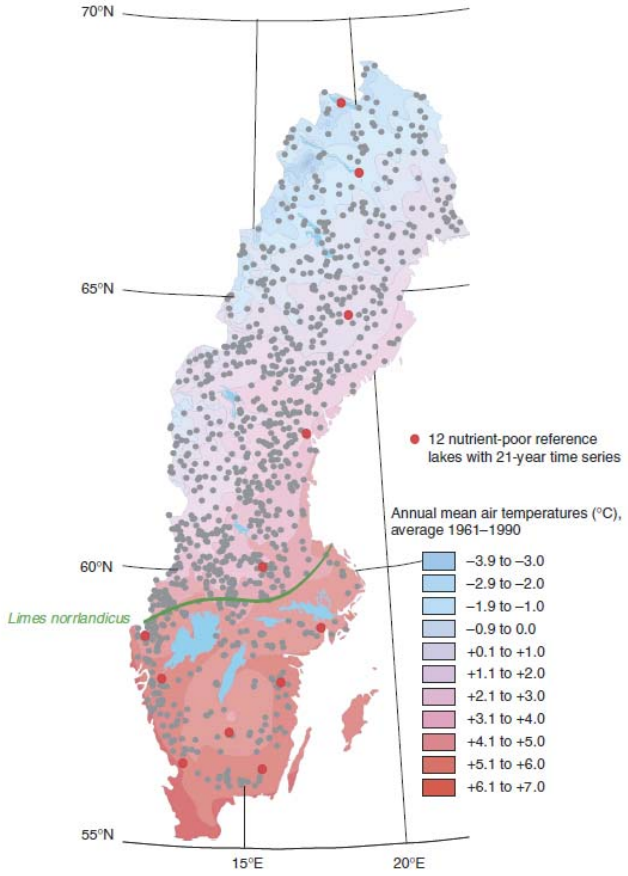


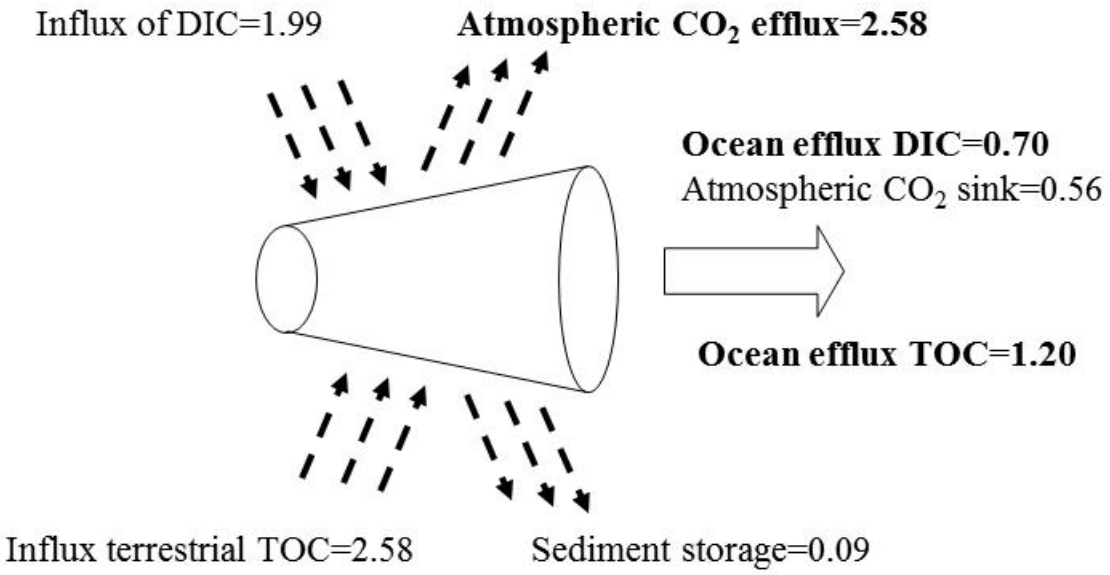
Fig. 1 Map of Sweden showing the locations of the 1041 boreal lakes distributed over 11 air temperature regions, based on average annual mean air temperatures from 1961 to 1990. Of the 1041 boreal lakes, 12 nutrient-poor reference lakes (red dots) have time series on water chemistry from 1988 onwards. Sweden is divided into two parts by the *limes norrlandiucs,* a borderline for biogeographical divergences.

- Most evident changes in ice break up and changes in dissolved constitutents are found south of the Limes norrlandicus in boreal watersheds

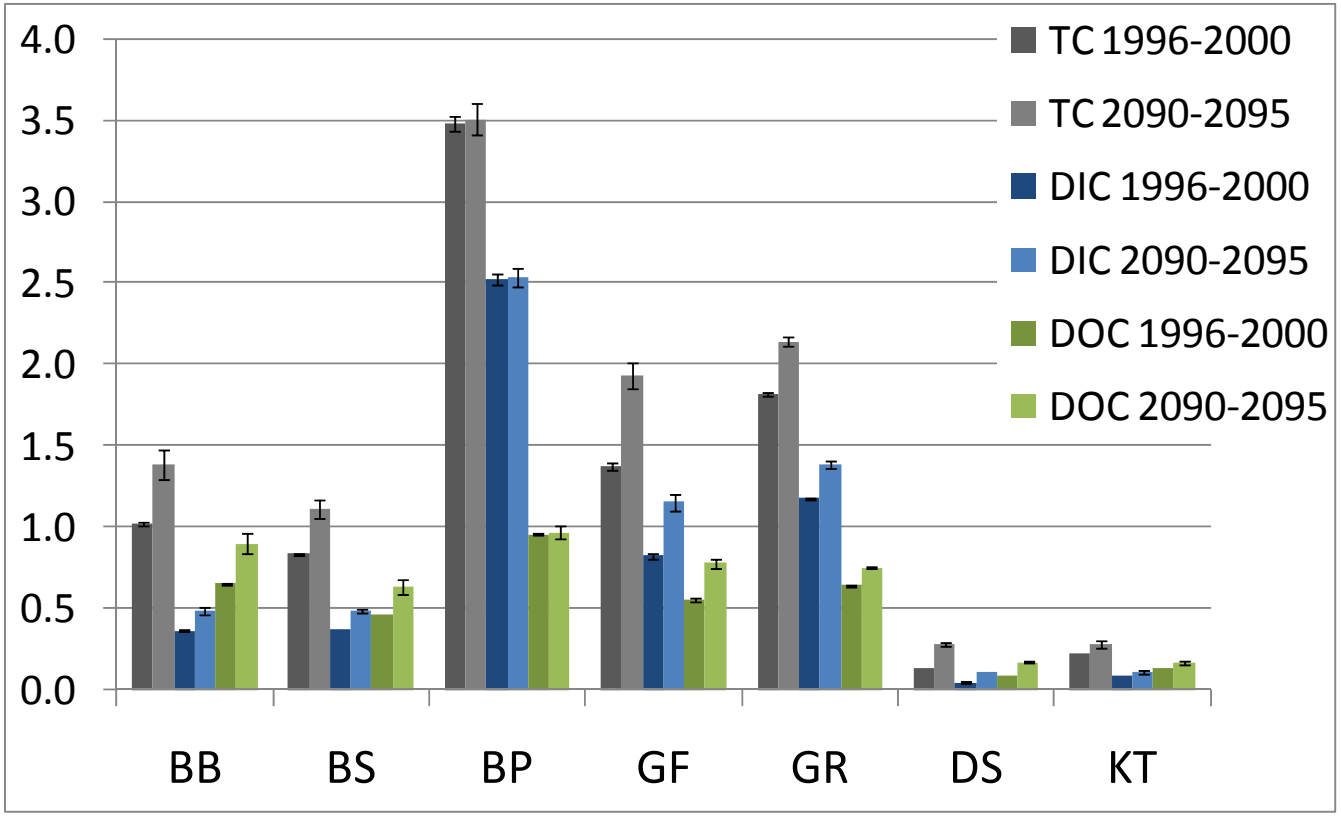
- Observations on the discharge regime of major boreal rivers revealed no changes in mean annual flow, but the seasonal distribution of streamflow changed with potentially large impacts on the redistribution of organic bound carbon and nutrient from land to the Baltic Sea.
- Especially areas with mean annual temperature around 0 °C, i.e. around 61 °North) are most sensitive to further warming

3) Forestry, wetland management and freshwater biogeochemistry

- **3.1. The role of forest and wetlands for waterborne biogeochemical fluxes**
- **3.2. Influence of management practices**
- **3.3. Transformations of carbon along the aquatic continuum**



- **3.4. Climate impacts on waterborne losses from forests and wetlands**
- **3.5. Current and future export patterns to the Baltic Sea**



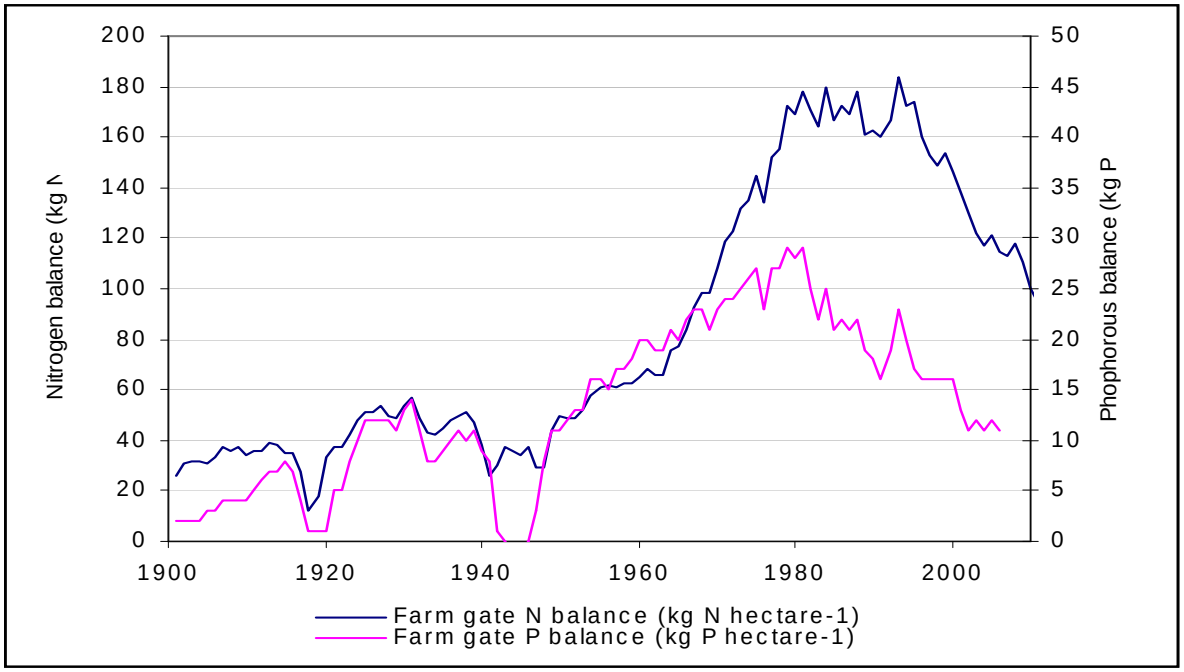
- Annual fluxes (Tg) ocf TC, DIC and DOC.
  1996-2000 compared to 2090-2095 (Wällstsedt **sumitted?!)**

Forestry

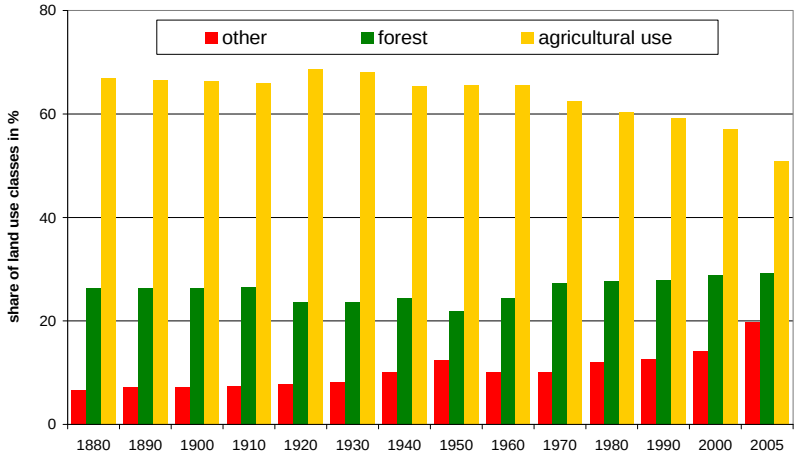
- Overall, it is clear from numerous studies that forests and wetland have a key role for the terrestrial export of organic bound nutrients and carbon.
- Ditching and clear cutting often results in increased concentrations and leaching some years after the treatment but in the long term and after reestablishments of forest, this will likely result in lower water table and decreasing leaching. However, forest management nowadays affects only small parts of the overall area covered by boreal forests and the effect on fluxes of organic bound nutrients and carbon is probably minor.
- On the short-term, climate change is unlikely to affect the spatial distribution of wetlands, except palsa mires that cover too small areas in the boreal watersheds to be significant for element fluxes to the Baltic Sea.
- Knowledge gained from small scale field and modelling studies indicate that increased temperature and precipitation will probably increase the DOM transport to the Baltic Sea significantly.
- However, modelling studies of the effect of changes vegetation cover and structure for river loads to the Baltic Sea are under progress und have not been published yet.

4) Cultural eutrophication and freshwater biogeochemistry

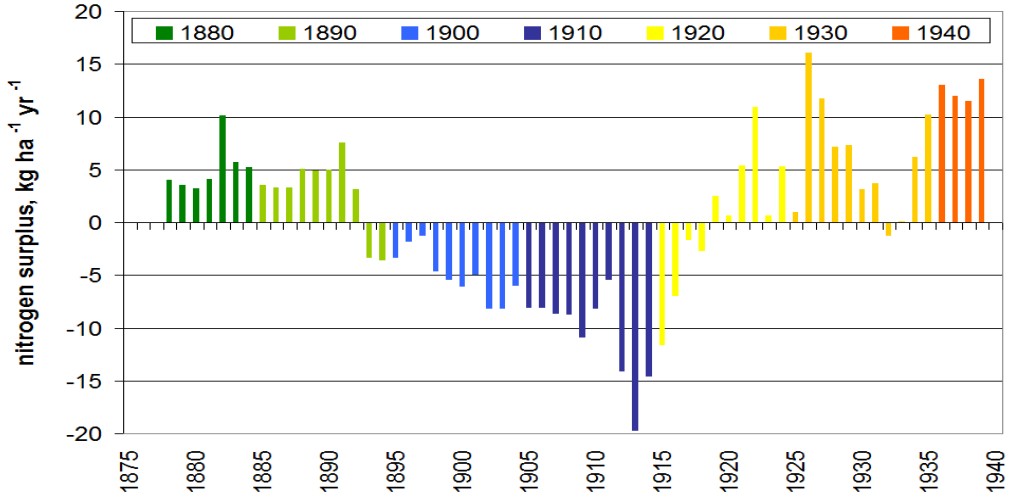
- **4.1 Land use in the Southern Baltic drainage basin**



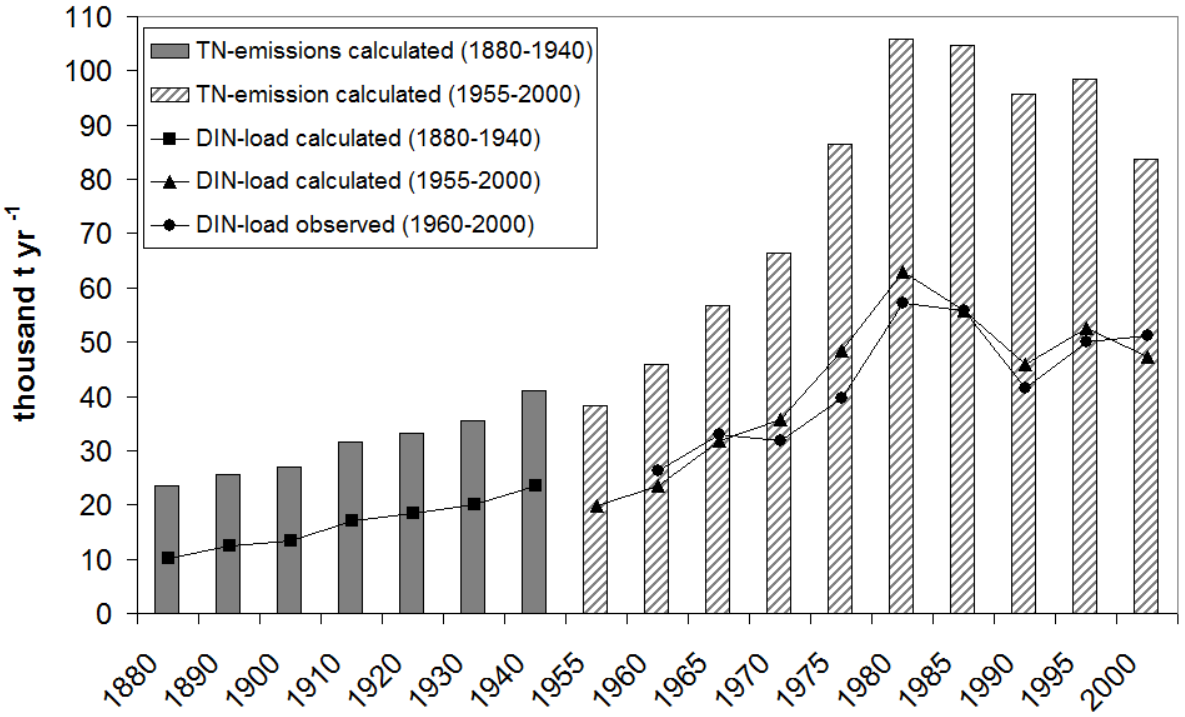
- Figure 4.1. Farm gate N and P balance for Denmark in the period 1900-2010 (Kyllingsbæk 2008; Kyllingsbæk and Hansen, 2007).



- Figure 4.2. Development of land use (1880 - 1940 detailed for OderRiver System (Gadegast et al. 2011), 1950 - 2005 entire Poland (Hirschfeld et al. 2009); reconstructed from official statistics)



- Figure 4.3. Changes in N surplus on agricultural areas in the Oder River System (1878-1939) (Gadegast et al. 2011).


TN-emissions calculated (1880-1940)
TN-emission calculated (1955-2000)
DIN-load calculated (1880-1940)
DIN-load calculated (1955-2000)
DIN-load observed (1960-2000)
thousand t yr -1
0
10
20
30
40
50
60
70
80
90
100
110
1880
1890
1900
1910
1920
1930
1940
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000

- **4.2 The role of agriculture and urban areas and their management for waterborne biogeochemical fluxes**
- **4.3 Transformations of nutrients along the aquatic continuum**

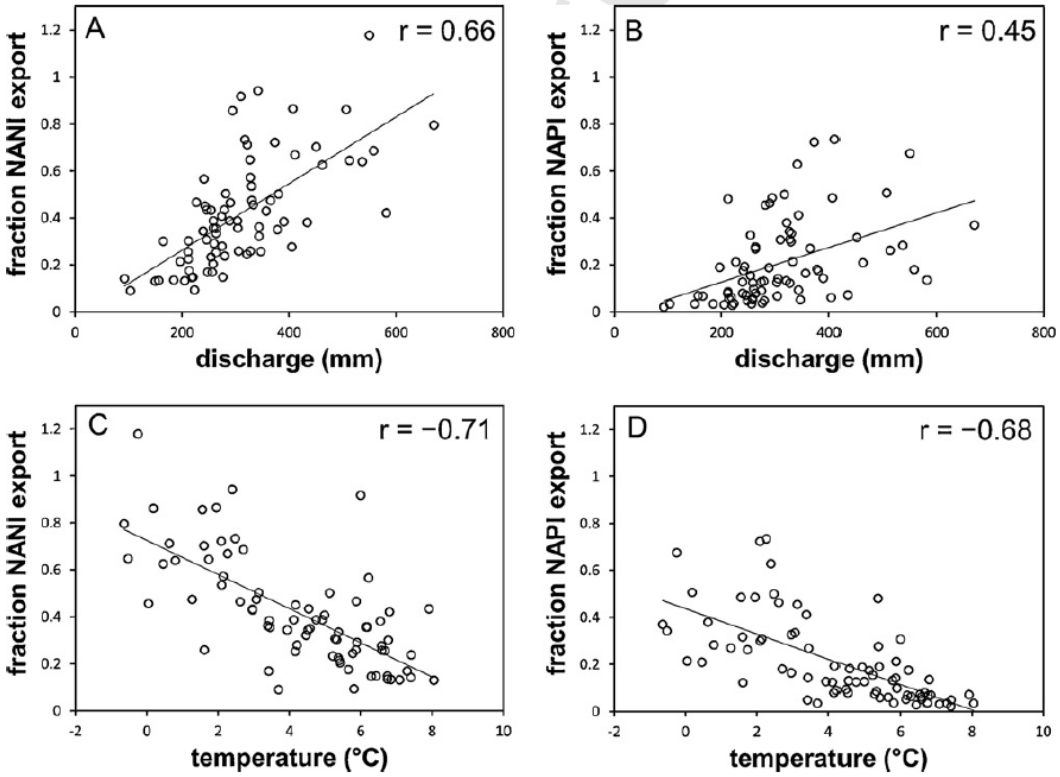
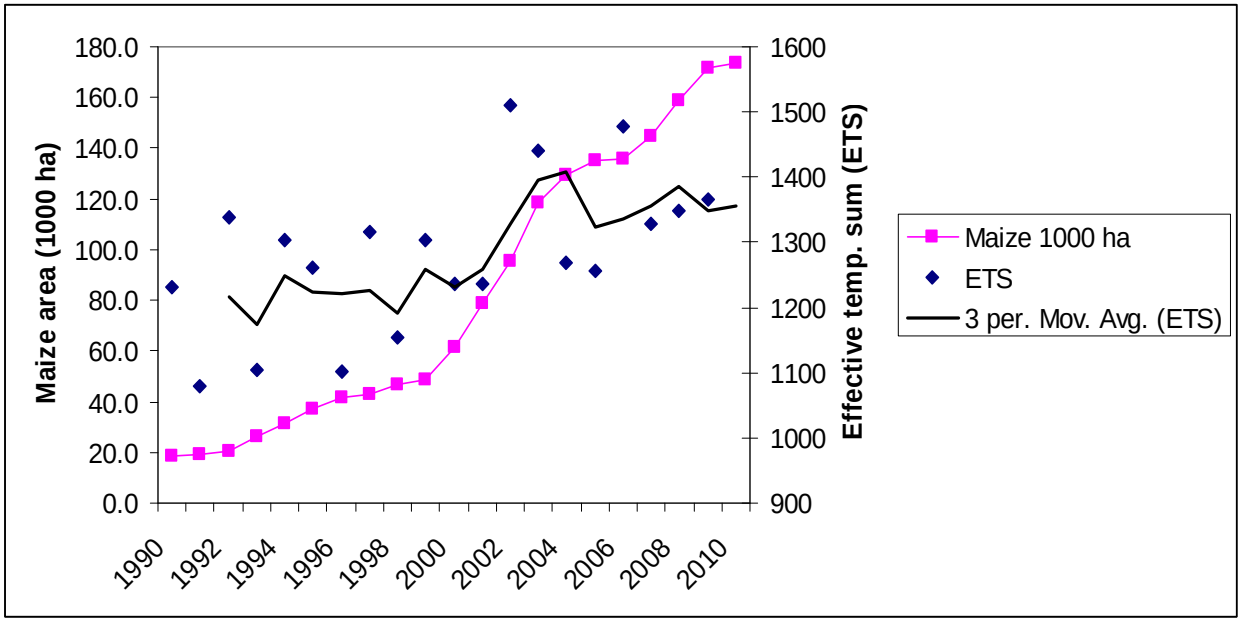


Fig. 8. Fractions of NANI (A and C) and NAPI (B and D) exported as riverine fluxes controlled by discharge (A and B) and temperature (C and D).

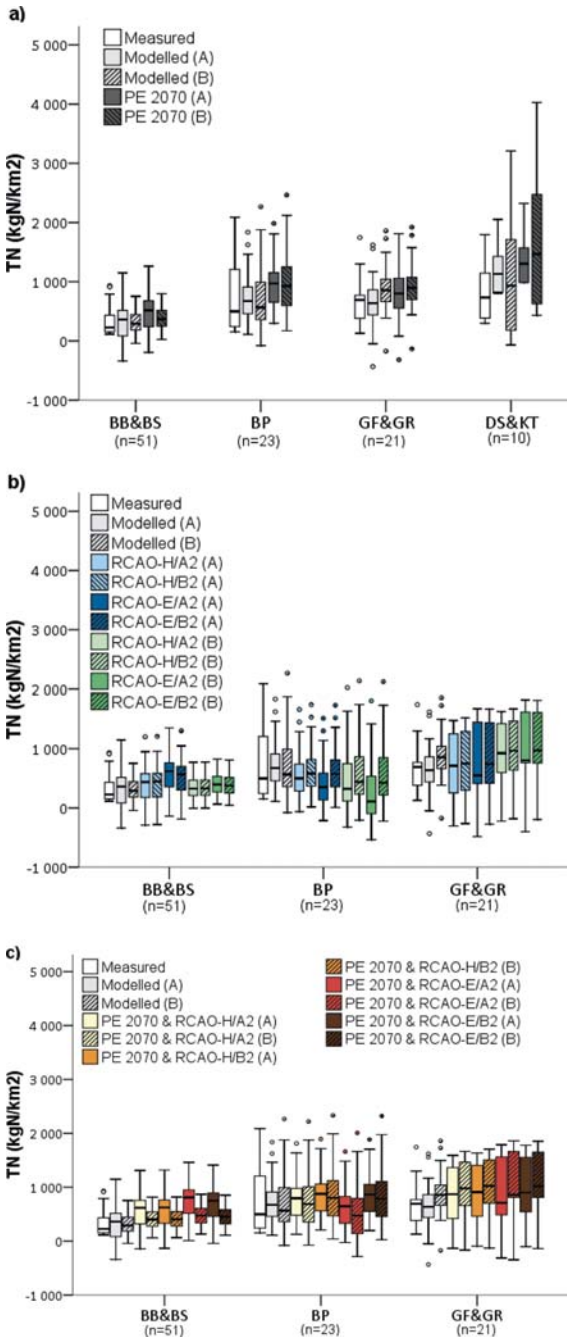
4.4 Climate impacts on waterborne losses from agriculture and urban areas



Figur 4.5. Area with maize in Denmark and effective temperature sum, ETS. ETS is calculated as the sum of daily mean temperatures above 6 ^{o}C from 15. April to 30.September. Maize demands ETS above 1200 ^{o}Cd.

- **4.5 Current and future export patterns to the Baltic Sea**

- *FIGURE 4.6: Boxplots with measured (mean 1992-1996), modeled (modeled for 1992-1996), and simulated TN fluxes (kg N km-2 y-1) for the four sub-basins, Bothnian Bay and Bothnian Sea (BB and BS), Baltic Proper (BP), Gulf of Finland and Gulf of Riga (GF and GR), and Danish Straits and Kattegat (DS and KT) using the all catchment regression (A) or the basin specific regressions (B), nonarea weighted data. a) Primary emissions scenario "PE 2070". b) The four climate scenarios "RCAO-X/XX". c) The net scenarios with both changed primary emissions (PE 2070) and changed climate (RCAO-X/XX).*

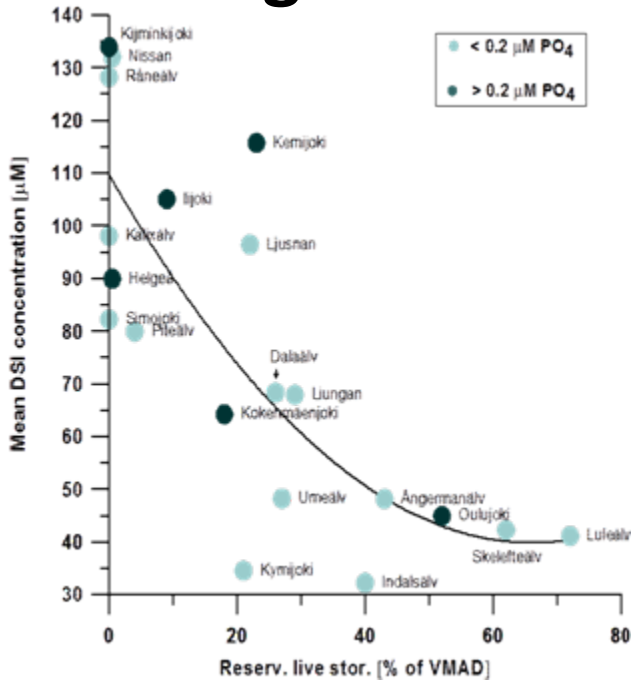


Cultural eutrophication

- Nutrients loads from these cultivated rivers to the Baltic Sea increased by several times over the last 150 years peaking in the 1970s and 80s and a slightly decrease only in P loads is visible in the recent years probably as a result of improved sewage treatment from urban areas, especially in Poland.
- Changes in climate is not homogeneous in the cultivated southern catchment area; in the southwestern part, i.e. Denmark and Germany, precipitation has increased since the 80s and farmers currently adapt to a warmer and wetter climate by selecting heat-demanding and nutrient demanding crops like maize.
- Whether increased fertilizer use that may even occur in the transitional countries like Poland and the Baltic will lead to an increased nutrient flux to the Baltic Sea is still unknown, because water discharge especially in the southeaster part of the catchment is foreseen to decrease and the retention of nutrients will increase
- However, catchment wide modelling studies on water discharge is still too few and observation and modelling of retention patterns are small scale to allow overall estimates on these processes for the Baltic Sea.

5) Damming, Hydrological alterations and freshwater biogeochemistry

- **5.1 The role of hydrological alterations for waterborne biogeochemical fluxes**



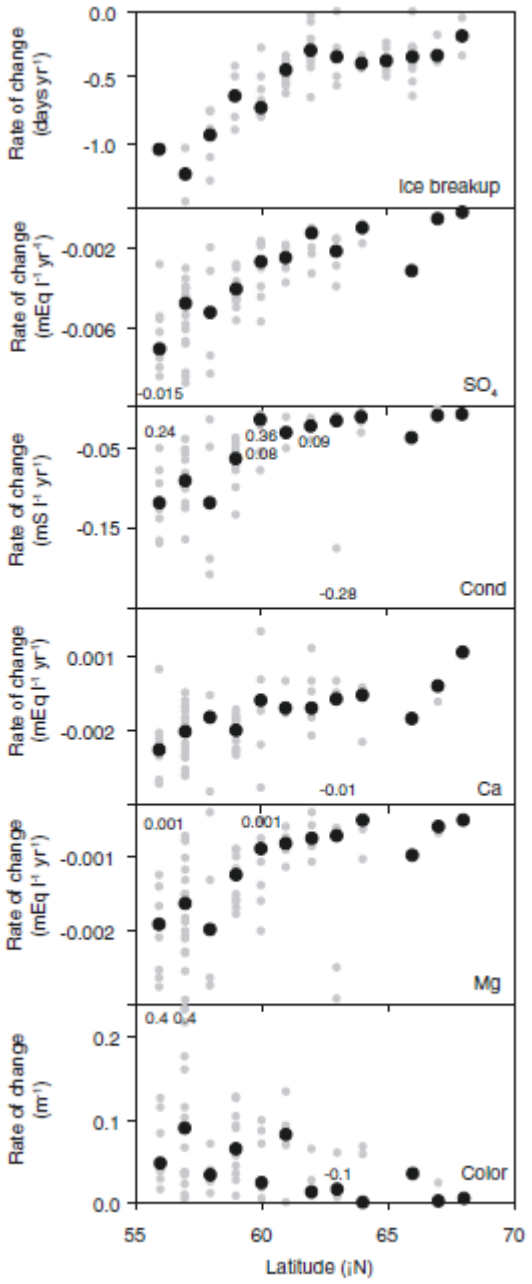
- *Fig. 5.1 DSi concentration vs reservoir life storage from Swedish and Finnish rivers*

- Hydrological alterations have lowered the nutrient flux to the Baltic Sea, especially for silica. Overall, the dissolved silica fluxes to the Baltic have decreased by one third as a result of damming and eutrophication of natural lakes.
- The foreseen increase in precipitation in the boreal part of the Baltic Sea catchment allows for an increase in 15-30% of the hydropower potential.
- It is unlikely that the potential formation of new artificial lakes by damming will change the amount of water entering the Baltic Sea through rivers, however, the seasonal patterns can further change significantly by smoothing out seasonal hydrological patterns.

6) Atmospheric deposition and freshwater biogeochemistry

- **6.1 The role of atmospheric deposition for waterborne biogeochemical fluxes**
- **6.2. Transformations of deposited nutrients along the aquatic continuum**

- **6.3 Climate impacts on atmospheric deposition and their effect on waterborne biogeochemical fluxes**
- **6.3 Current and future export patterns to the Baltic Sea**



- During the past decades and especially in the 1970s and 1980s atmospheric deposition had probably a stronger effect on freshwater biogeochemical conditions in the Baltic Sea drainage area than climate.
- This pattern, however, seems to change along with decreasing atmospheric deposition. It is likely that freshwater biogeochemistry will shift back from atmospheric deposition dominance to climate.
- If this being the case biogeochemical conditions of freshwaters and the Baltic Sea are expected to rapidly change.

- **5.2 Climate impacts on regulated rivers and their effect on waterborne biogeochemical fluxes**
- **5.3 Current and possible future export patterns from regulated rivers to the Baltic Sea**