Baltic Sea Catchment Modelling

- BNI
- Catchment characteristics and threads
- CSIM model
- Modelling eutrophication issues and N and P fluxes
- Isotope studies in AMBER

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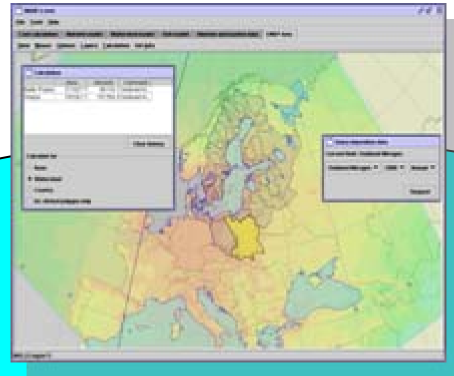
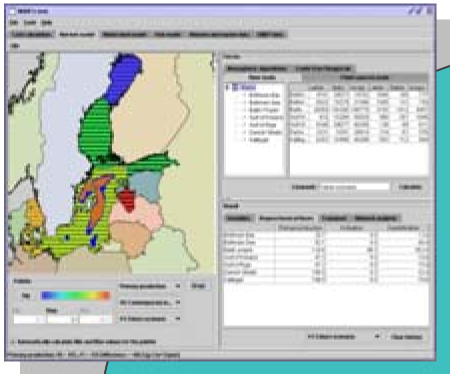
BNI History

- MArine Research on Eutrophication (MARE)
- Funded 1999-2006
- Aim: Define “critical loads” for Baltic eutrophication and illustrate “cost-efficient” ways to reach these loads
- Product: Decision Support System NEST
- “Institutionalized” in 2007 as Baltic NEST Institute (Swedish and Danish branch)

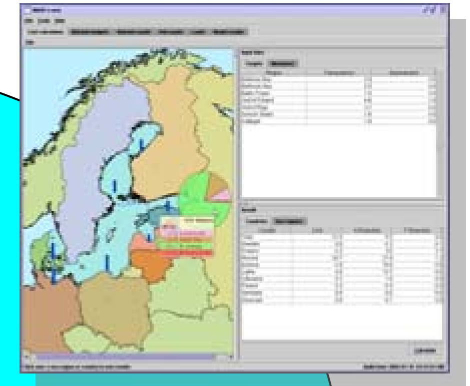
Atmospheric emissions and load



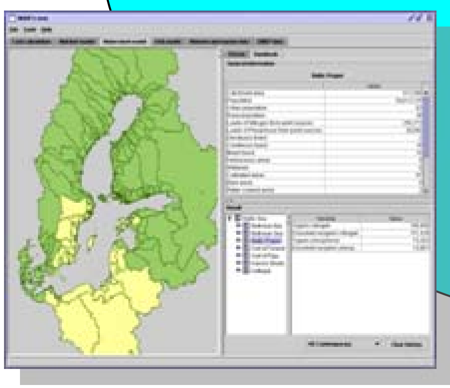
Marine modeling



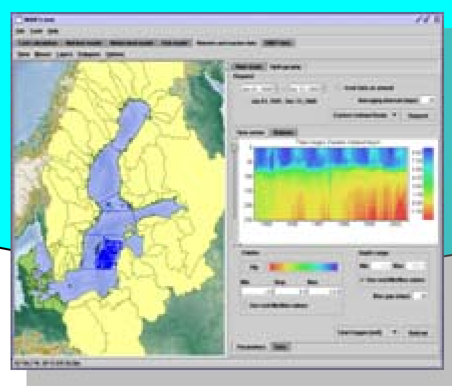
Cost minimization model



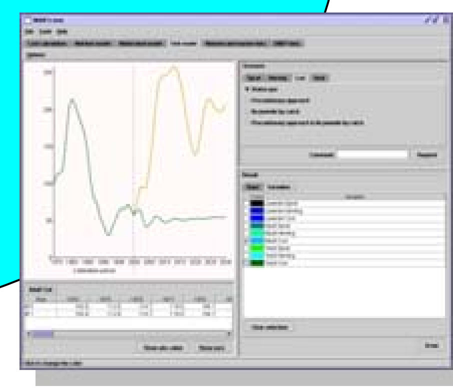
NEST can be used freely
with any computer with Internet
access from
http://www.Balticnest.org



Drainage basin modeling



Marine and runoff data



Food web model

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In order to reach the goal towards a Baltic Sea unaffected by eutrophication

WE AGREE on the principle of identifying maximum allowable inputs of nutrients in order to reach good environmental status of the Baltic Sea,

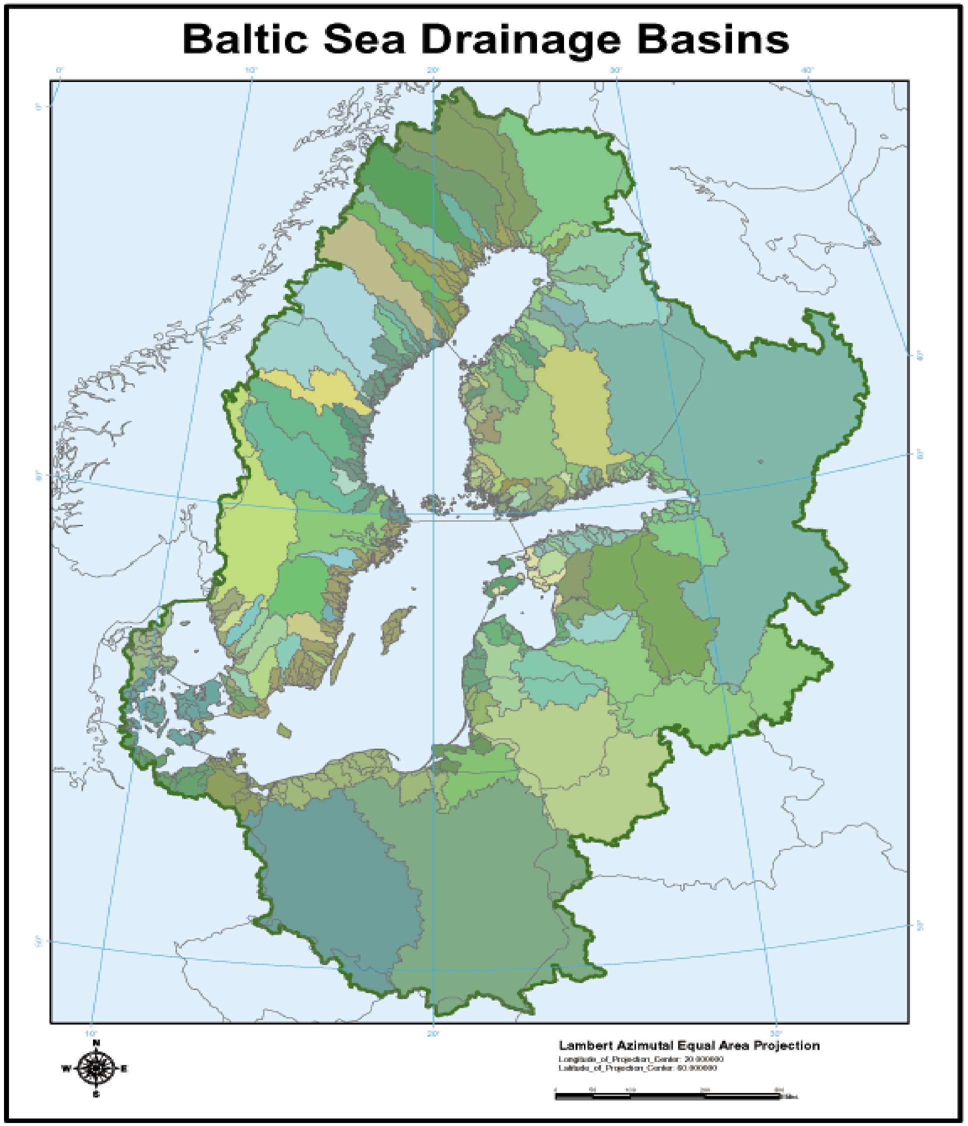
WE ALSO AGREE that there is a need to reduce the nutrient inputs and that the needed reductions shall be fairly shared by all Baltic Sea countries,

BEARING IN MIND that the figures are based on the MARE 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 regard to eutrophication is about 21,000 tonnes of phosphorus and 600,000 tonnes of nitrogen,

WE FURTHERMORE RECOGNISE that, based on national data or information from 1997-2003 in each sub-region of the Baltic Sea, the maximum allowable nutrient inputs to reach good environmental status and the corresponding nutrient reductions that are needed in each sub-region are as follows:

Sub-region	Maximum allowable nutrient input (tonnes)		Inputs in 1997-2003 (normalised by hydrological factors)		Needed reductions	
	Phosphorus	Nitrogen	Phosphorus	Nitrogen	Phosphorus	Nitrogen
Bothnian Bay	2,580	51,440	2,580	51,440	0	0
Bothnian Sea	2,460	56,790	2,460	56,790	0	0
Gulf of Finland	4,860	106,680	6,860	112,680	2,000	6,000
Baltic Proper	6,750	233,250	19,250	327,260	12,500	94,000
Gulf of Riga	1,430	78,400	2,180	78,400	750	0
Danish straits	1,410	30,890	1,410	45,890	0	15,000
Kattegat	1,570	44,260	1,570	64,260	0	20,000
Total	21,060	601,720	36,310	736,720	15,250	135,000

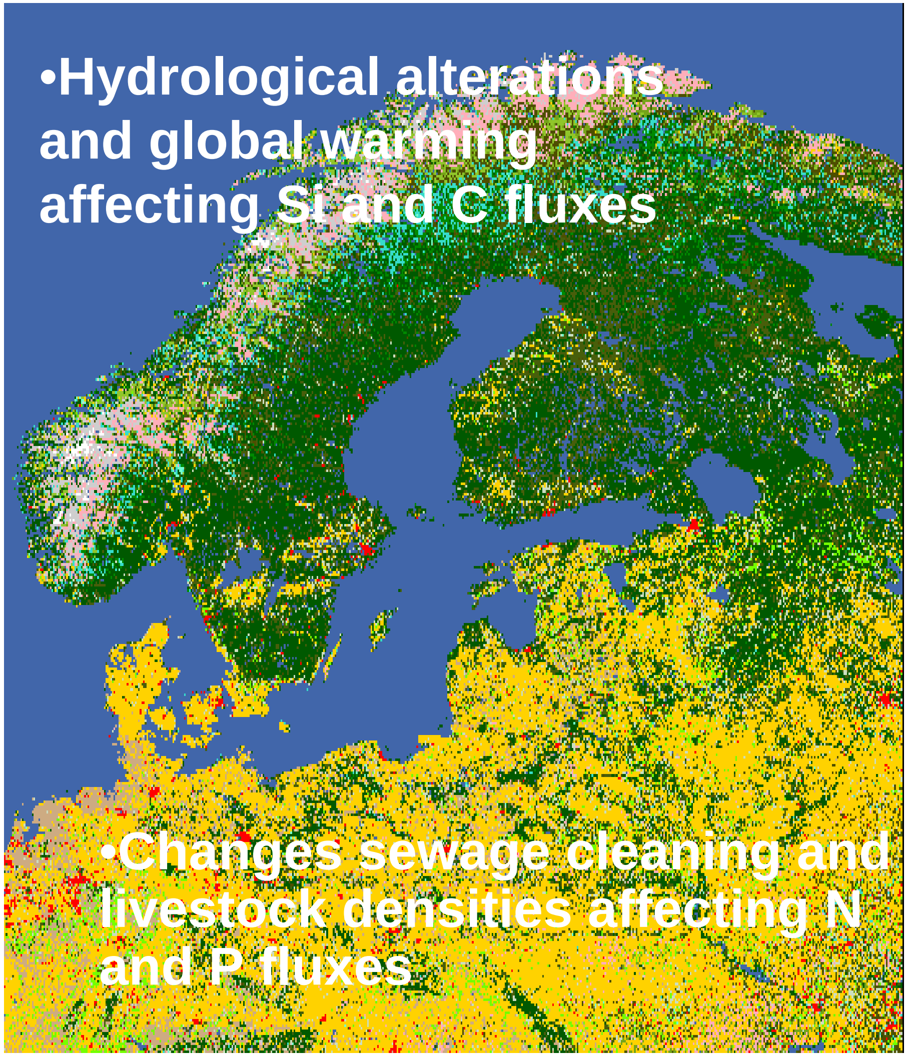
In order to diminish nutrient inputs to the Baltic Sea to the maximum allowable level **WE AGREE** to take actions not later than 2016 to reduce the nutrient load from waterborne and airborne inputs aiming at reaching good ecological and environmental status by 2021,



- 87 major catchments and 21 costal strips
- Hydrological data and nutrient fluxes for 1970-2006
- Landscape types, Population Agricultural data

  Atmospheric deposition
- PLC 5 based on national inconsistent approaches

- Hydrological alterations and global warming affecting Si and C fluxes
- Changes sewage cleaning and livestock densities affecting N and P fluxes



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

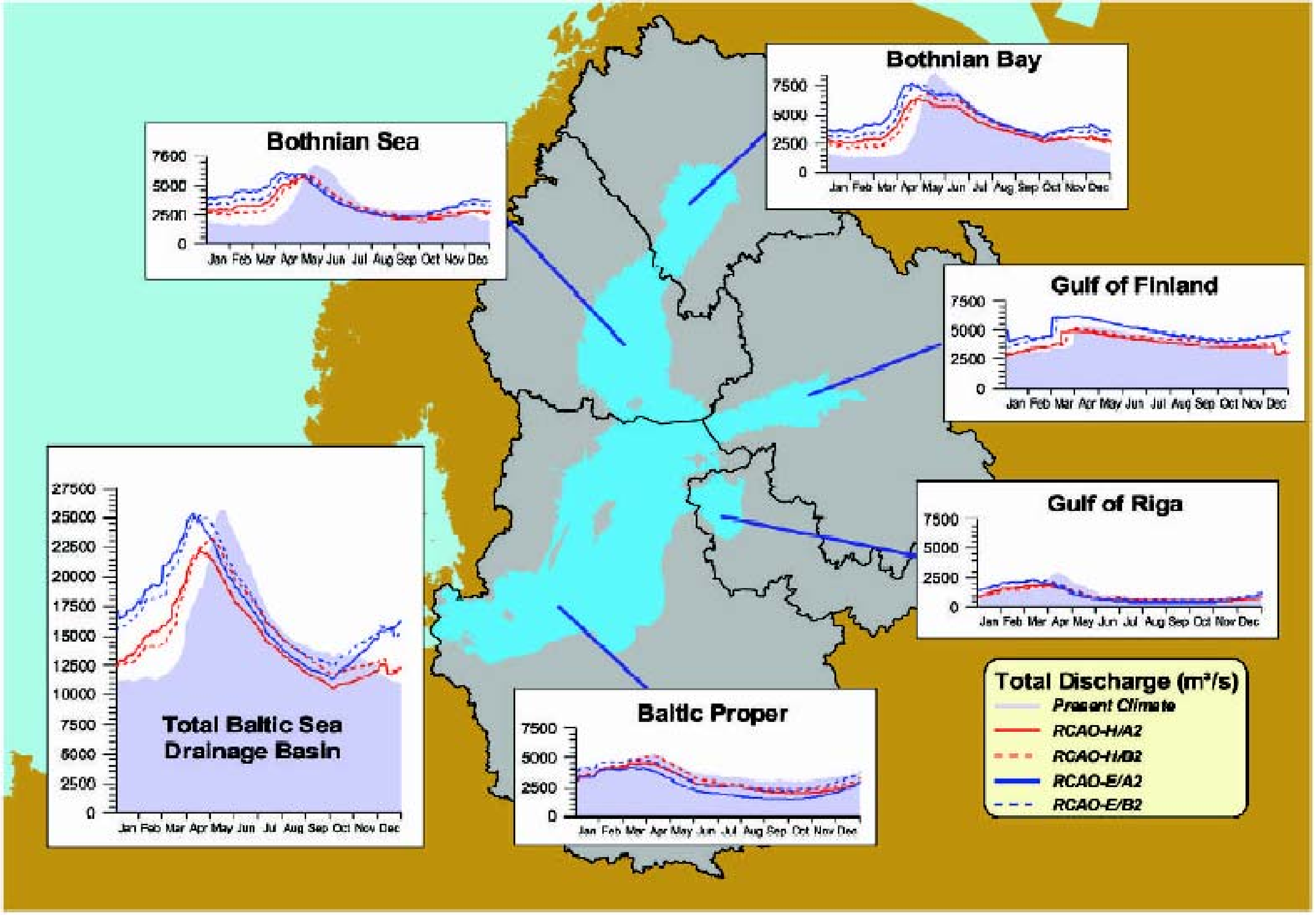
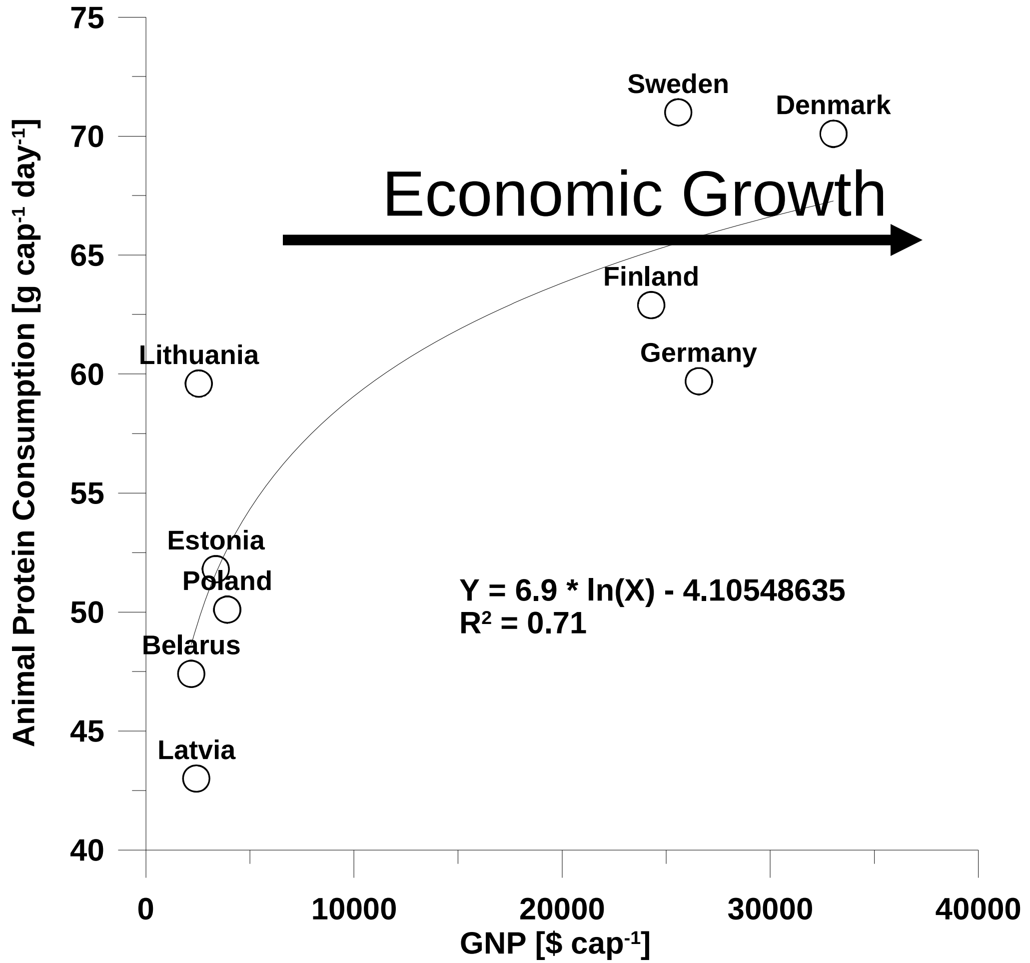


Figure 1. Modeled seasonal river discharge to the Baltic Sea from HBV-Baltic for present-day conditions (shaded) and four climate change scenarios. Shown are daily means over the 23-year modeling period. All plots are drawn to the same X and Y scales.

Graham 2004

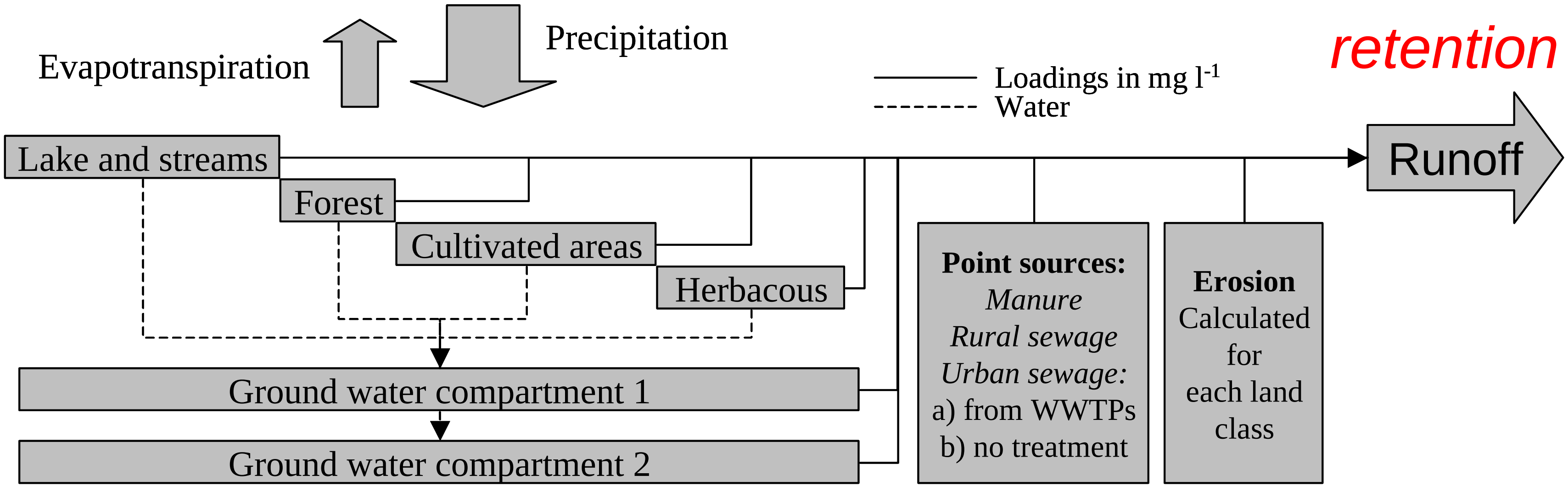
Changes in lifestyles translates into N emissions



CSIM

(Catchment Simulation)

Future: dynamic Riverine retention



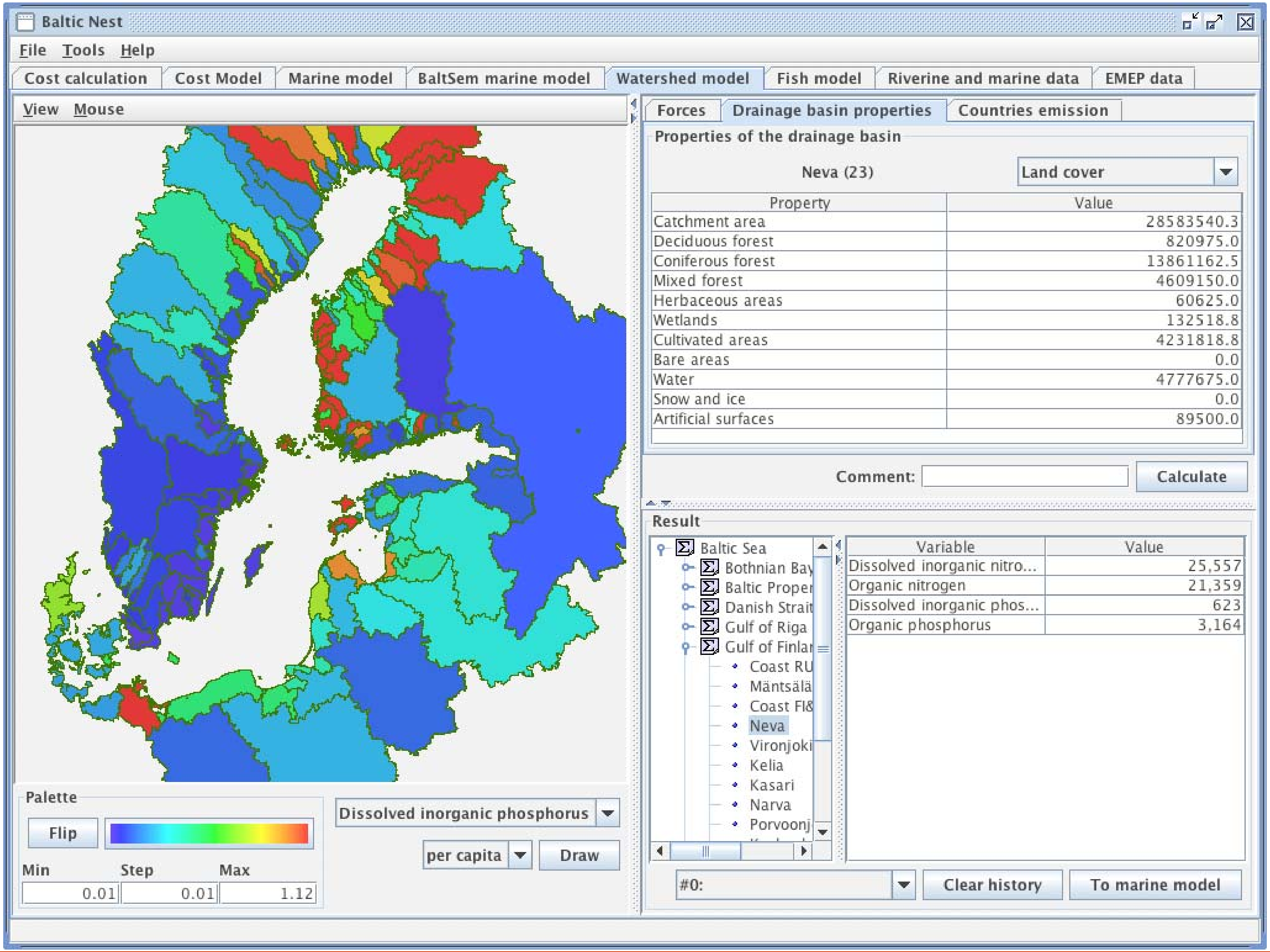
Now: fixed type concentrations

Future: Type concentrations =f(land use)

Mörth et al. 2007

Emission numbers and informations on MWWTPS, rural vs urban poulation, livestock densities, various retention coefficients in soils and river were used for **Scenario Analyses**

Country	Milk cows		Other cattle		Slaughter pigs		Sows		Humans	
	N	P	N	P	N	P	N	P	N	P
Belarus	47.4	9.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Czech republic	63.0	11.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Germany	96.1	16.1	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Denmark	74.2	13.3	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Estonia	94.3	15.9	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Finland	84.8	14.6	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Lithuania	63.5	11.9	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Latvia	62.2	11.7	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Norway	101.6	16.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Poland	63.0	11.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Russia	47.4	9.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1
Sweden	101.6	16.8	34.0	4.5	8.8	3.6	22.0	9.0	3.9	1.1



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Simulated (validation period vs. measured) streamflow,
TN and TP loads

Mörth et al. 2007

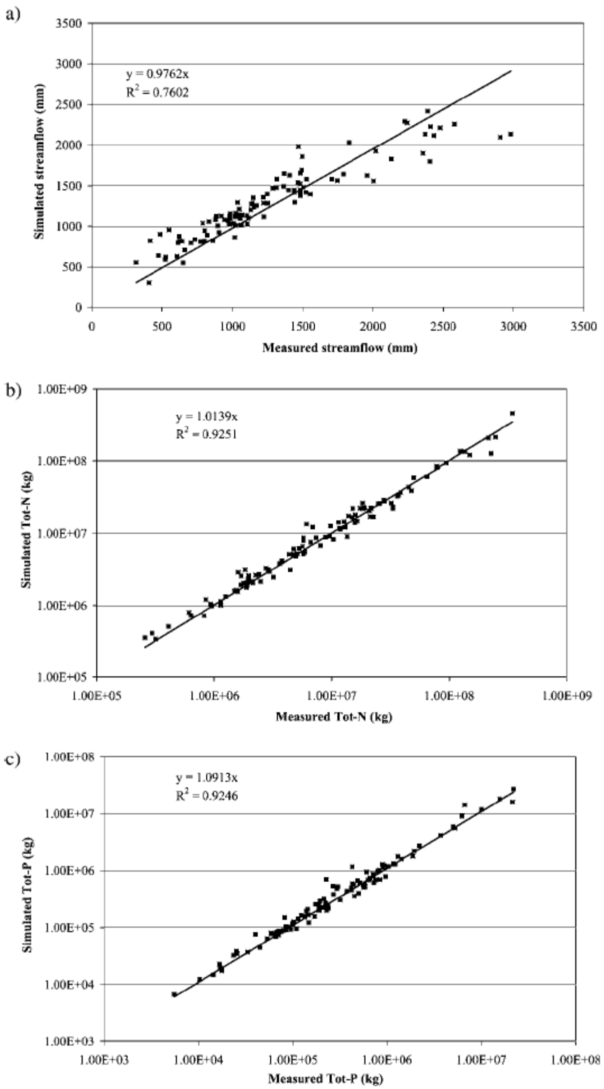
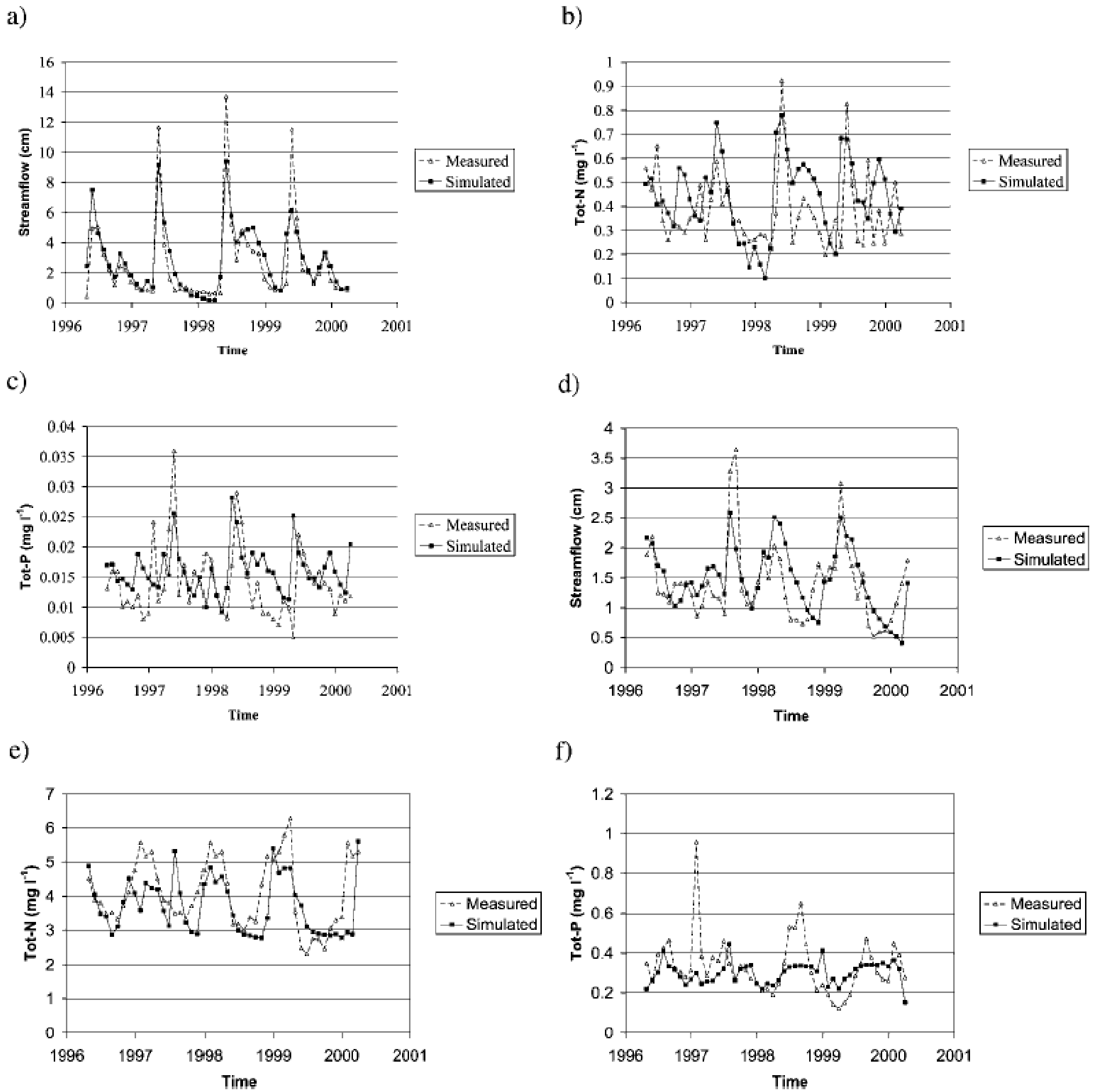


Fig. 5. A multiannual fit of simulated and measured data for the validation period (1990–1994): (a) streamflow, (b) Tot-N, and (c) Tot-P.

Seasonal simulations of an eutrophied (Oder) and unperturbed system (Råne)

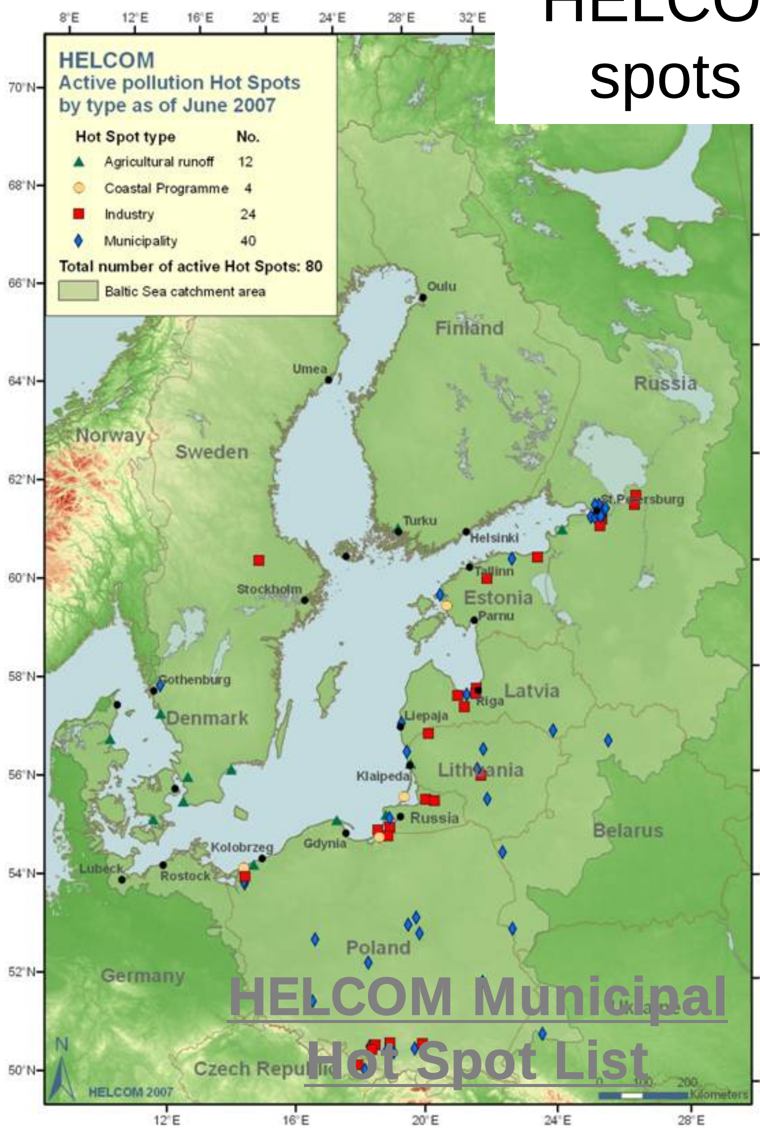
Mörth et al. 2007



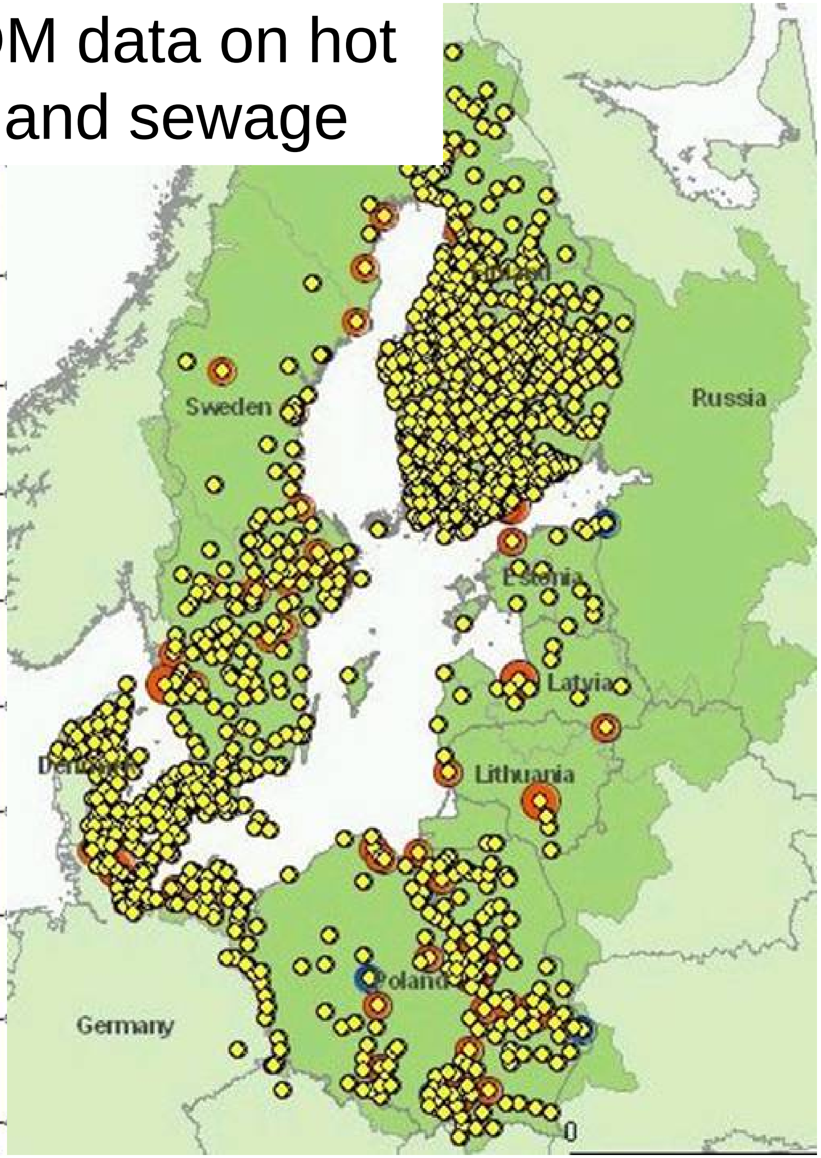
Future plans

- Forcing data update
- Type concentrations = f(soil types, specific runoff, crop type, livetsock density, manure handling etc.)
- Riverine Retention =f (TI, HL)

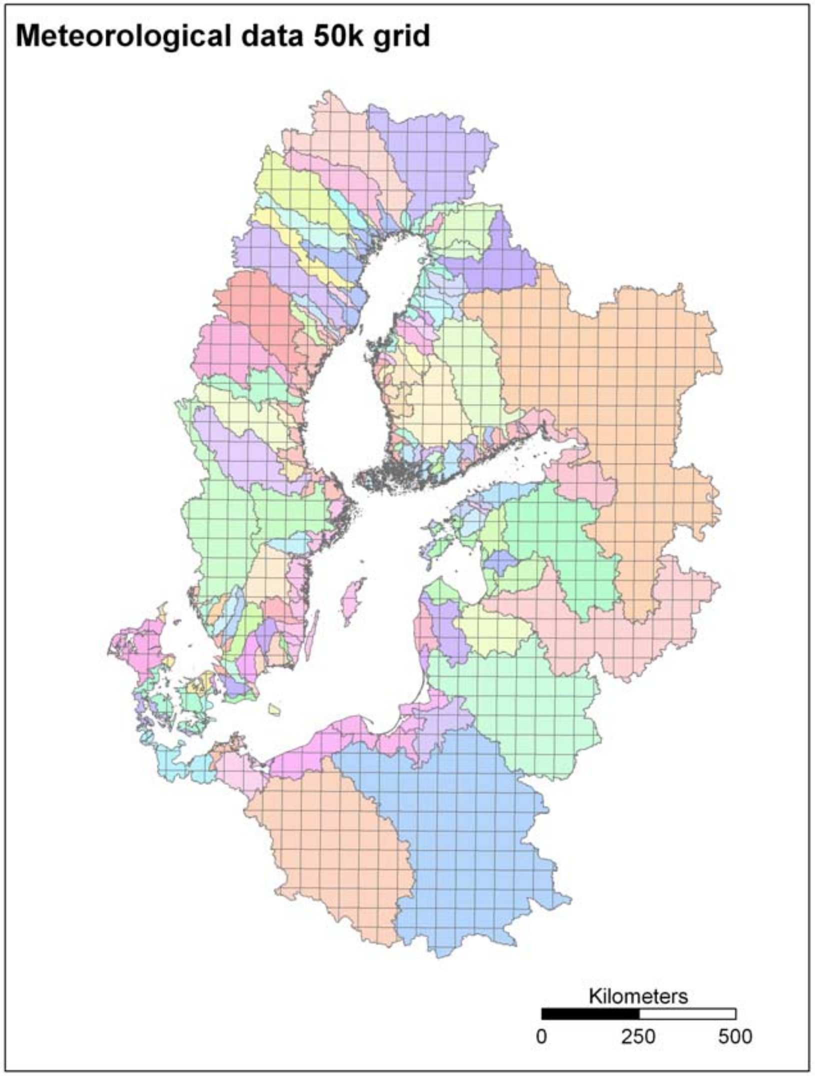
HELCOM data on hot spots and sewage

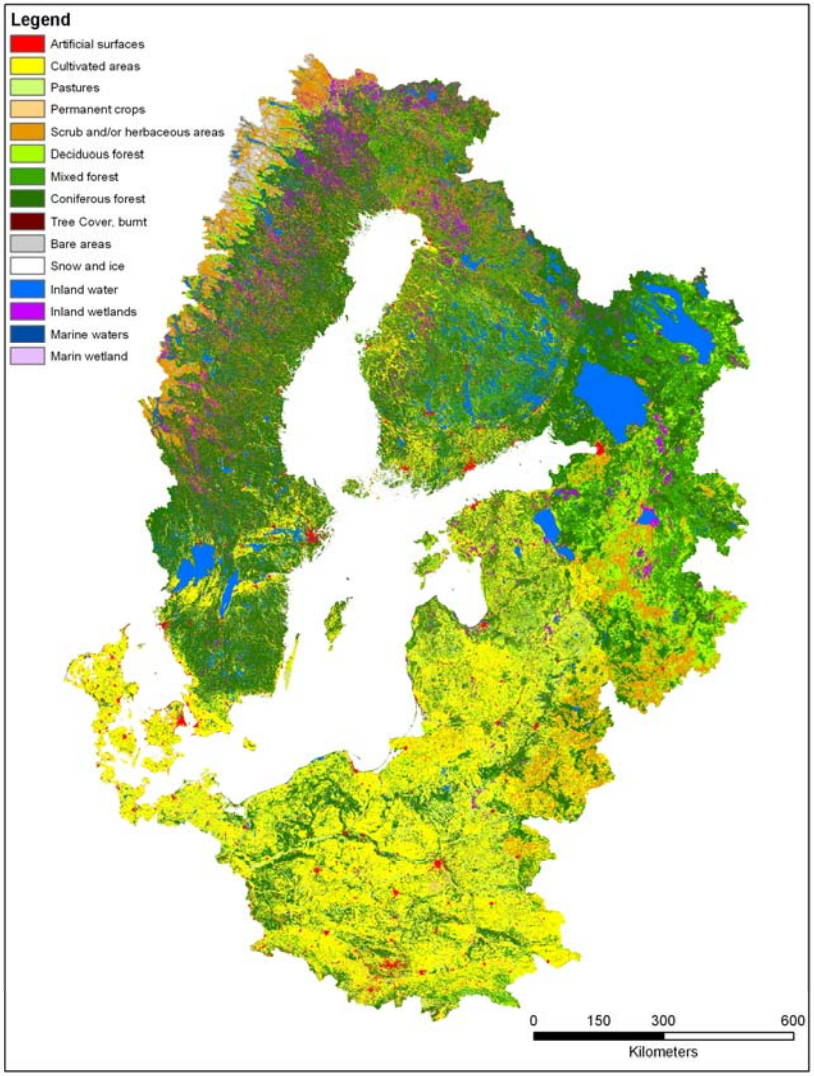


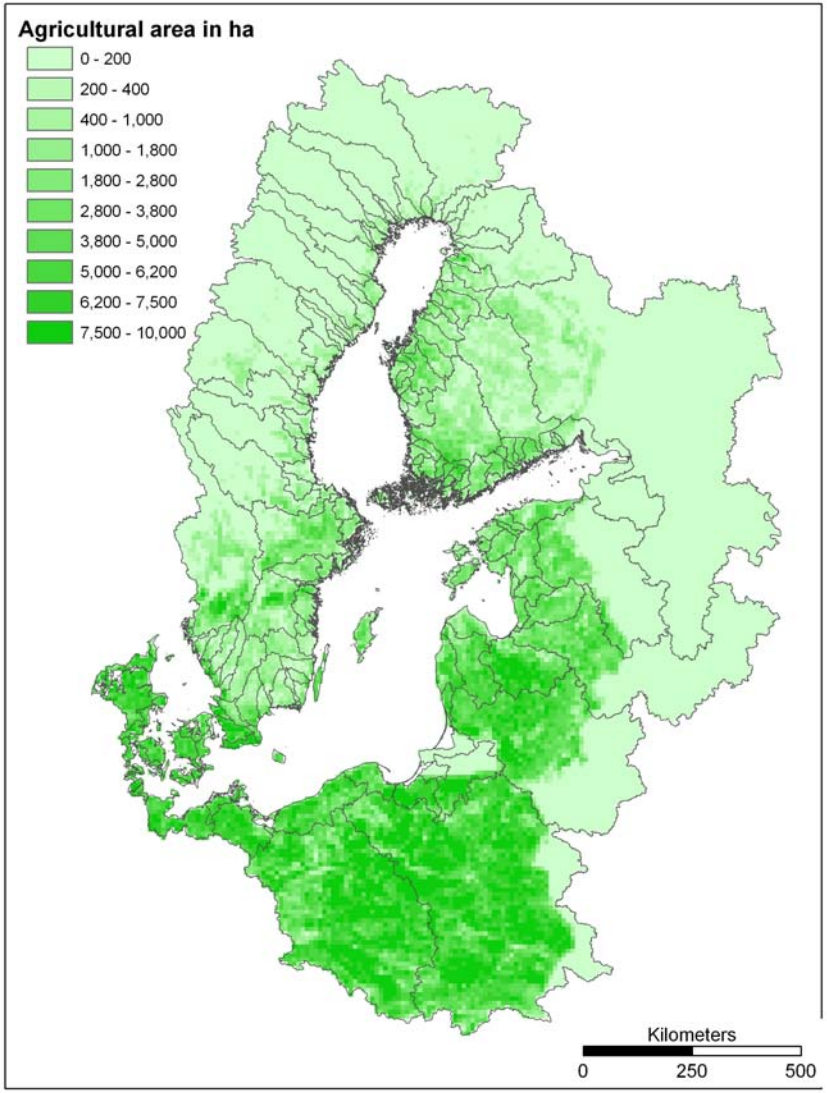
[HELCOM Municipal Hot Spot List]

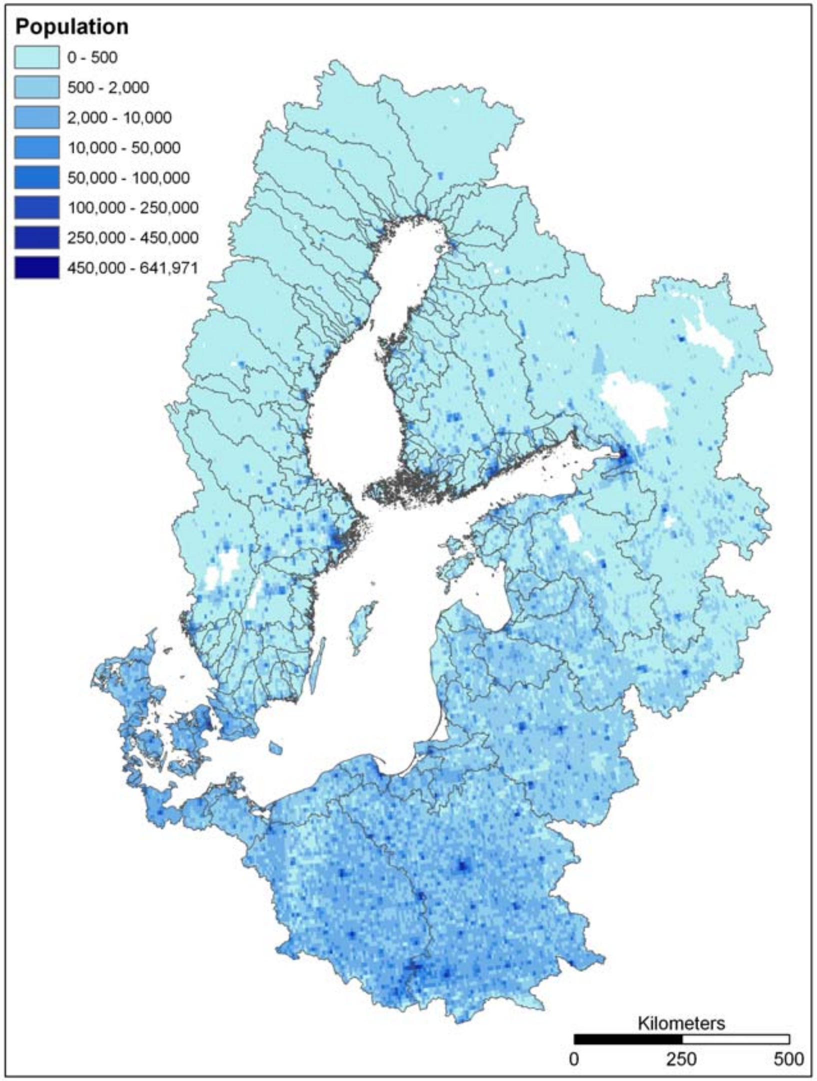


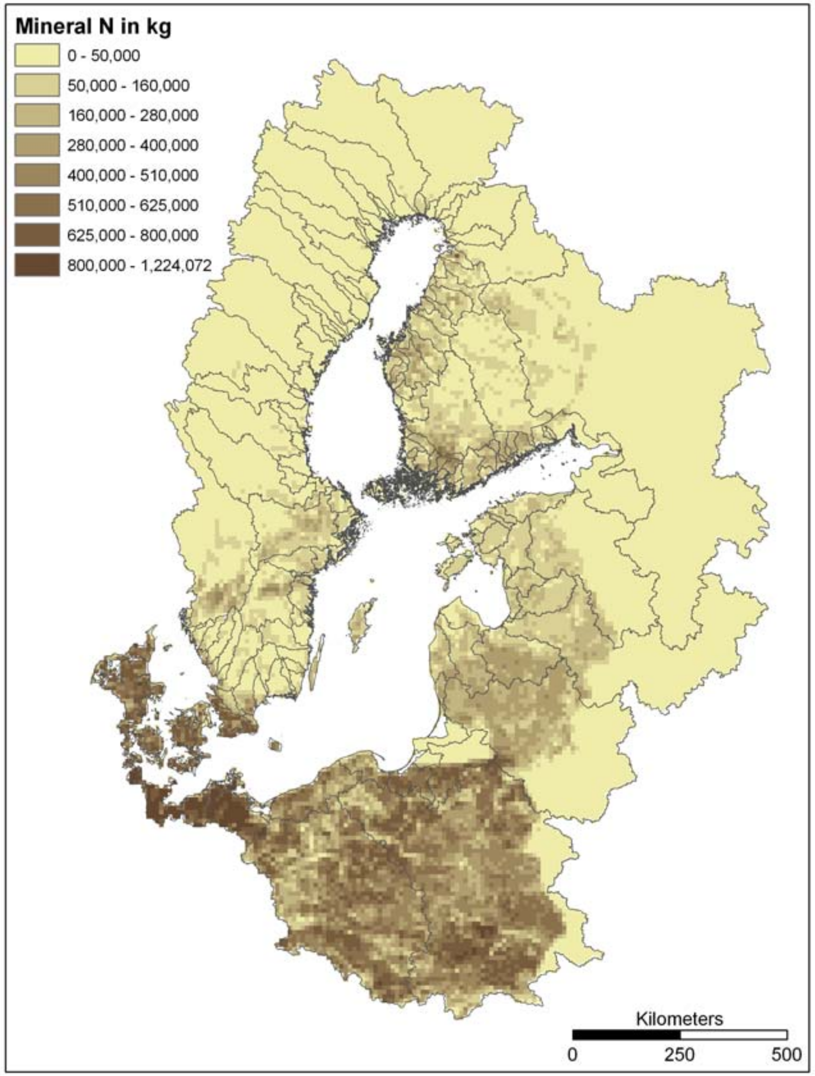
[PLC-4 MWWTP List]

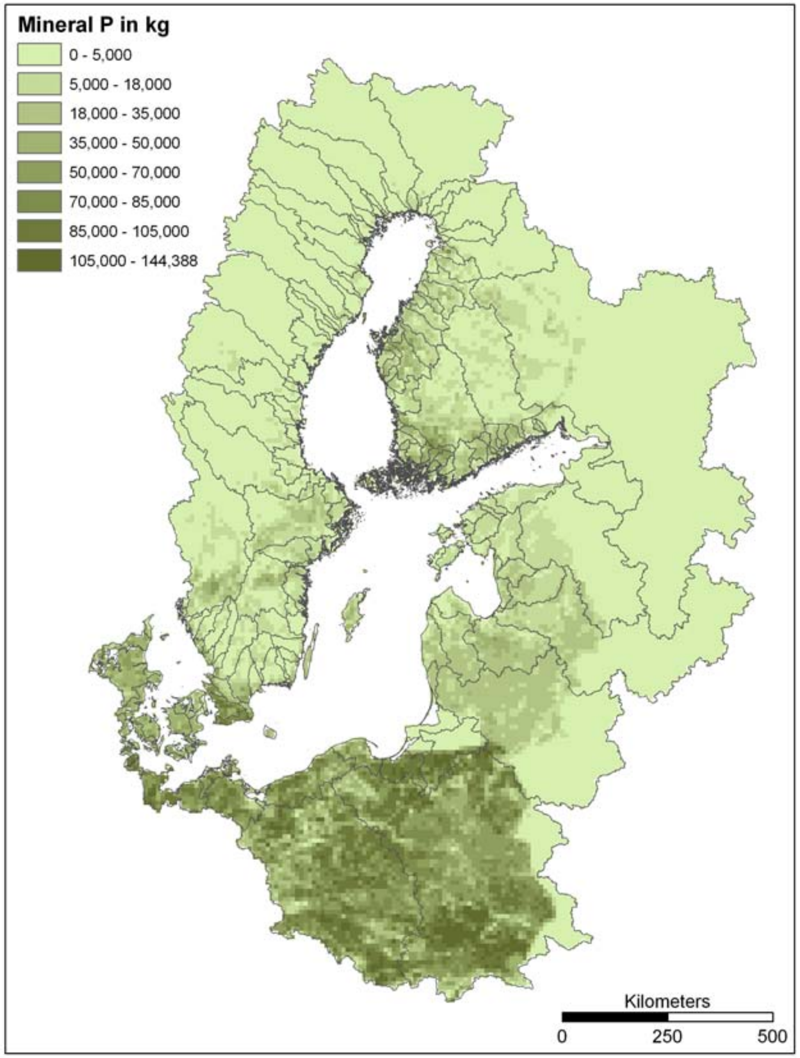

Meteorological data 50k grid
Kilometers
0
250
500

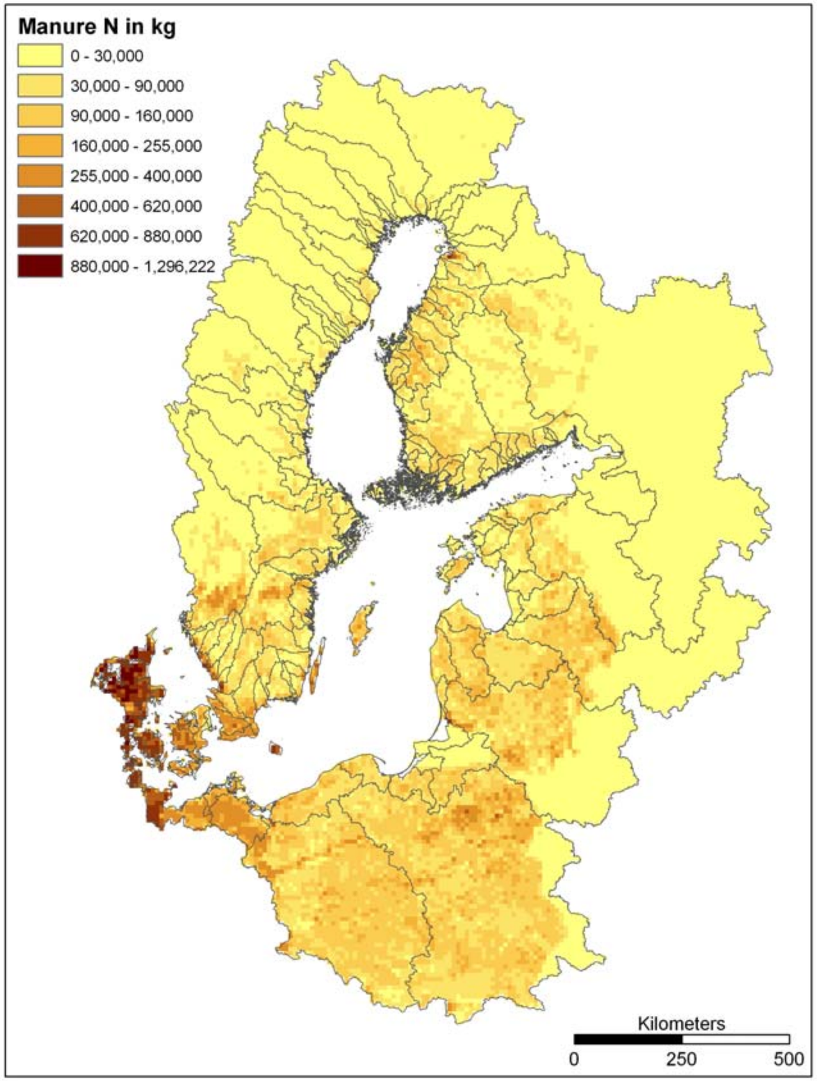

Legend
Artificial surfaces
Cultivated areas
Pastures
Permanent crops
Scrub and/or herbaceous areas
Deciduous forest
Mixed forest
Coniferous forest
Tree Cover, burnt
Bare areas
Snow and ice
Inland water
Inland wetlands
Marine waters
Marin wetland
0
150
300
600
Kilometers

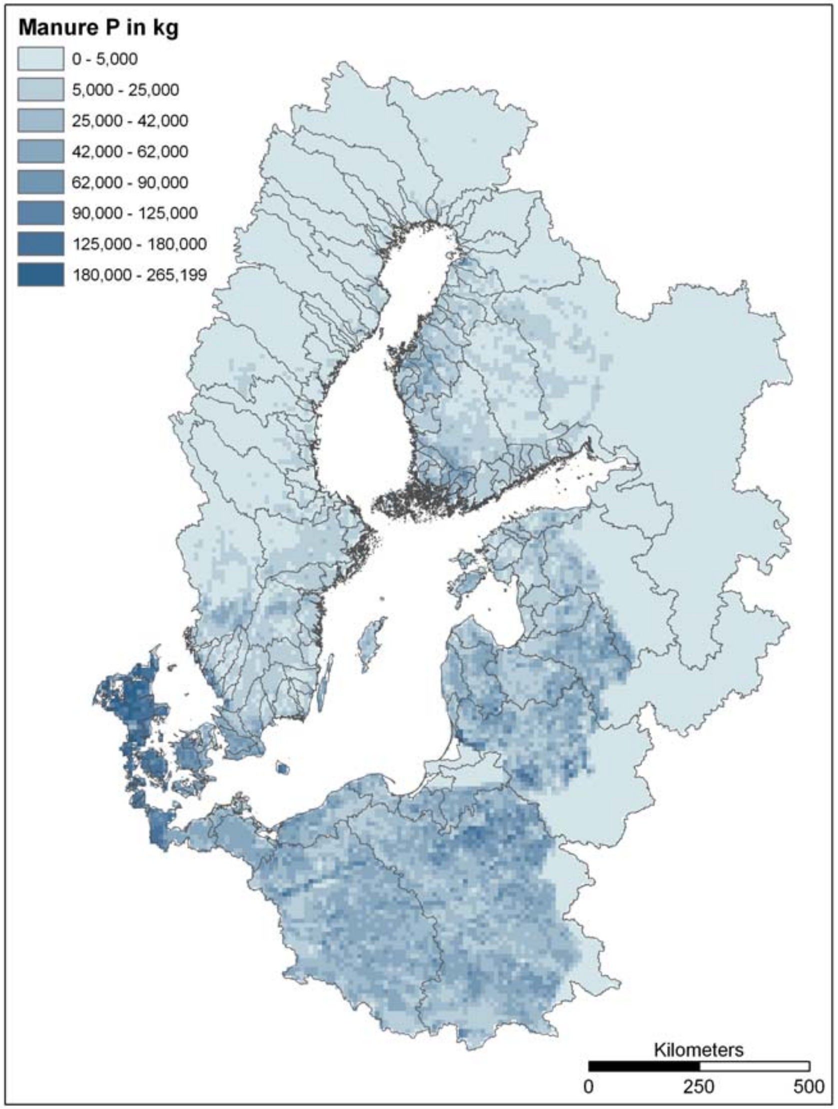

Agricultural area in ha
0 - 200
200 - 400
400 - 1,000
1,000 - 1,800
1,800 - 2,800
2,800 - 3,800
3,800 - 5,000
5,000 - 6,200
6,200 - 7,500
7,500 - 10,000
Kilometers
0
250
500


Population
0 - 500
500 - 2,000
2,000 - 10,000
10,000 - 50,000
50,000 - 100,000
100,000 - 250,000
250,000 - 450,000
450,000 - 641,971
Kilometers
0
250
500


Mineral N in kg
0 - 50,000
50,000 - 160,000
160,000 - 280,000
280,000 - 400,000
400,000 - 510,000
510,000 - 625,000
625,000 - 800,000
800,000 - 1,224,072
Kilometers
0
250
500


Mineral P in kg
0 - 5,000
5,000 - 18,000
18,000 - 35,000
35,000 - 50,000
50,000 - 70,000
70,000 - 85,000
85,000 - 105,000
105,000 - 144,388
Kilometers
0
250
500

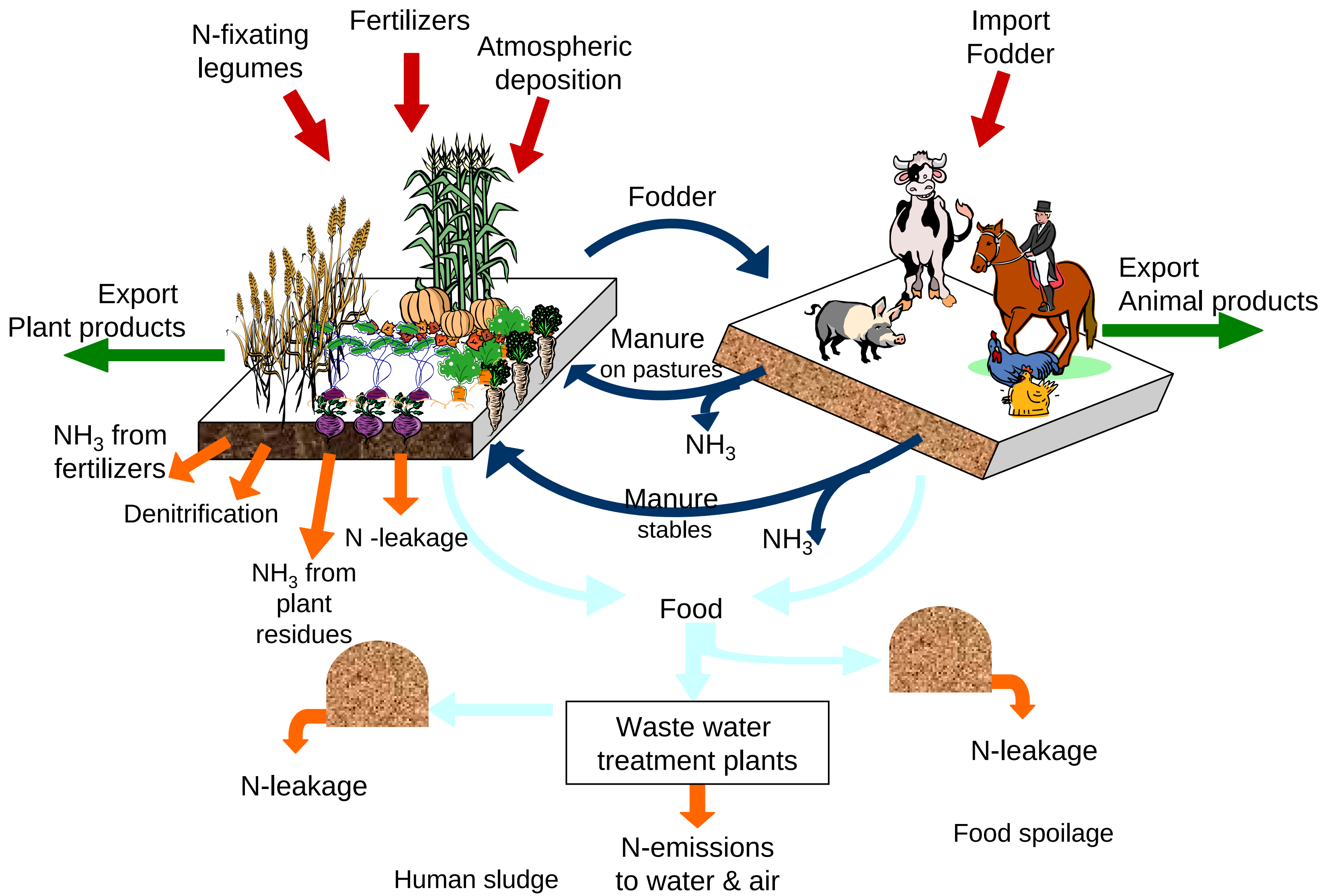

Manure N in kg
0 - 30,000
30,000 - 90,000
90,000 - 160,000
160,000 - 255,000
255,000 - 400,000
400,000 - 620,000
620,000 - 880,000
880,000 - 1,296,222
Kilometers
0
250
500


Manure P in kg
0 - 5,000
5,000 - 25,000
25,000 - 42,000
42,000 - 62,000
62,000 - 90,000
90,000 - 125,000
125,000 - 180,000
180,000 - 265,199
Kilometers
0
250
500

Watershed Nutrient Budgets as a solid base for the scientific and economic analyses

NANI=Net Anthropogenic Nutrient Input

Howarth et al. 1996; Boyer et al. 2002



N-fixating legumes
Fertilizers
Atmospheric deposition
Import Fodder
Fodder
Export Plant products
Export Animal products
Manure on pastures
NH_3
NH_3 from fertilizers
Denitrification
N -leakage
NH_3 from plant residues
Manure stables
NH_3
Food
Waste water treatment plants
N-leakage
N-leakage
N-emissions to water & air
Human sludge
Food spoilage

NANI = Food and Feed budgets + N-fixation + Fertilizer Use+ Atmospheric Deposition

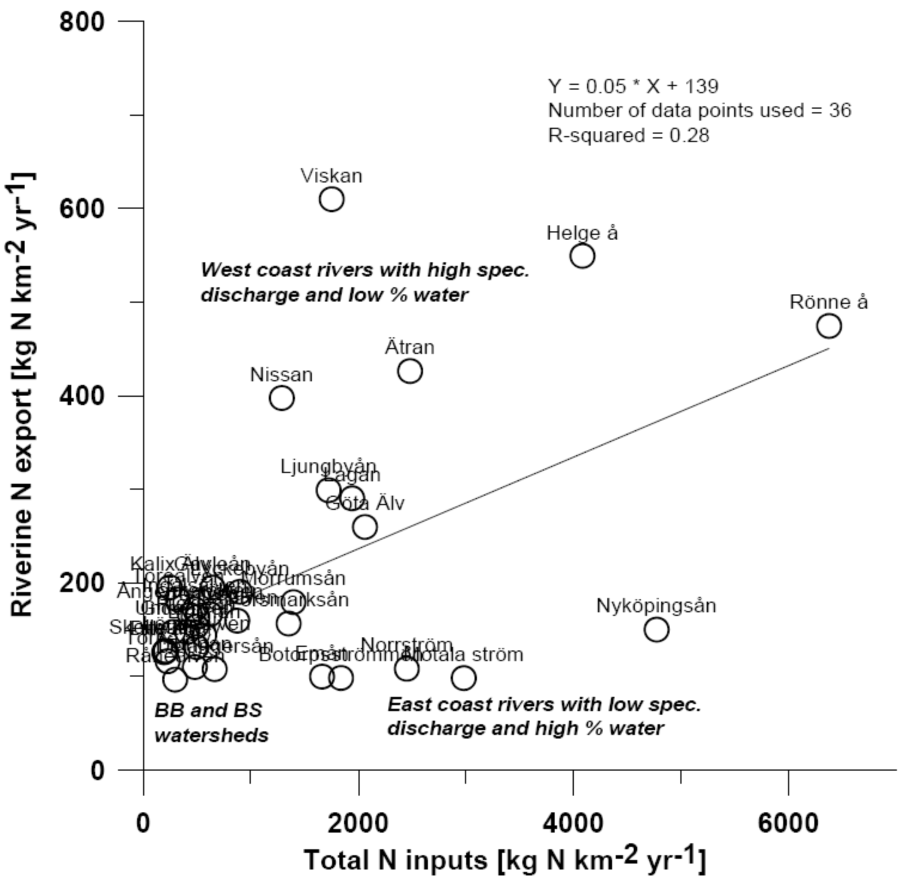
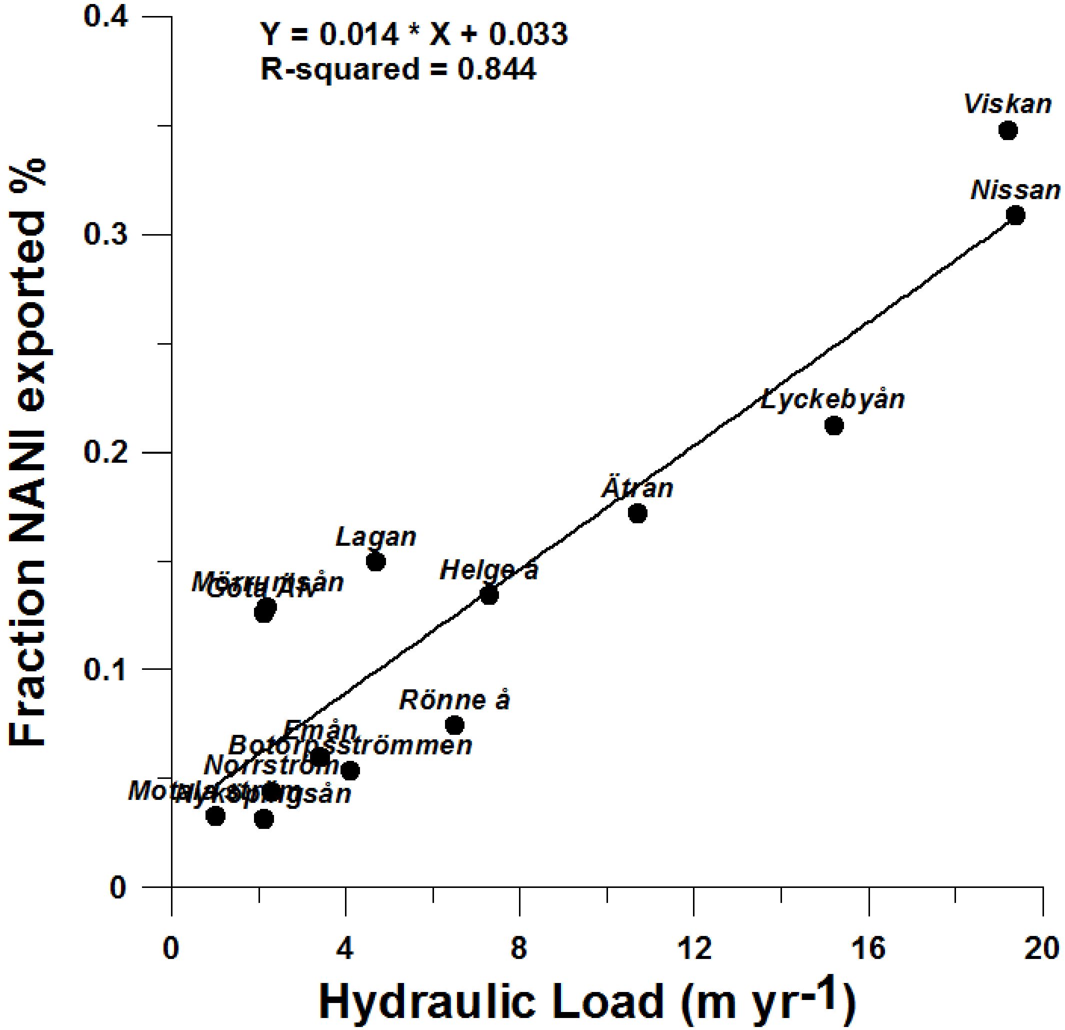
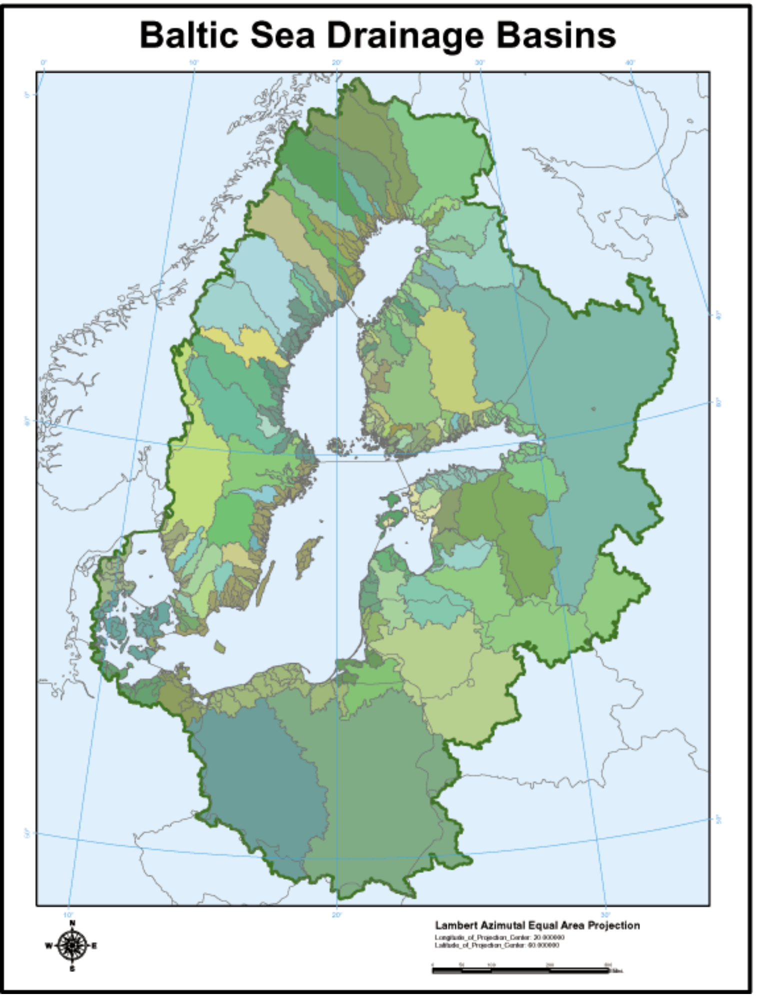


Figure 6. *Net anthropogenic N inputs (kg N km^{-2} yr^{-1}) vs riverine N exports to the Baltic Sea (kg N km^{-2} yr^{-1}) of 36 major Swedish watersheds*

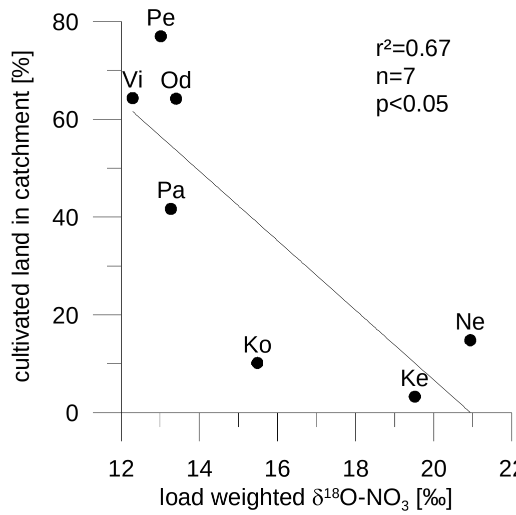
Dynamic description of retention

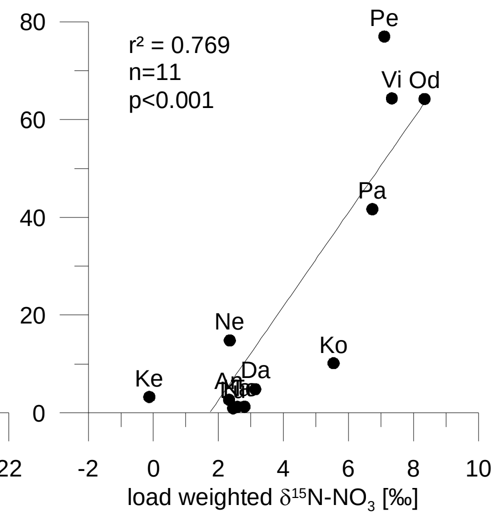


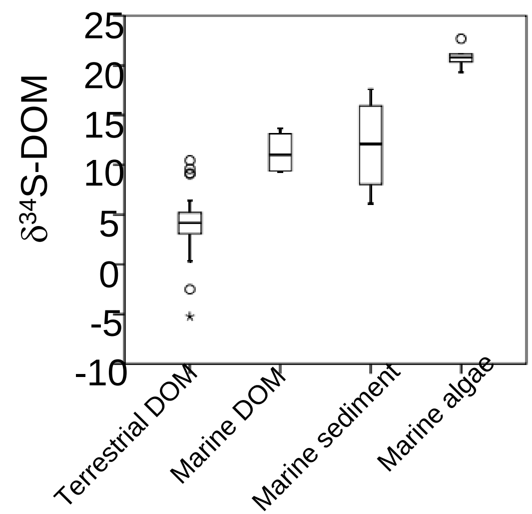
Modelling of the Baltic Sea catchment



Validation by multiple stable isotopes







Tundra and Taiga (Podzol Zone) C-Budgets as linked to Hydrology

- Polar amplification of global warming
- 450 Pg C stored
- ~ 70 annual anthropogenic emissions
- Boreal/subarctic Baltic unperturbed rivers as model systems

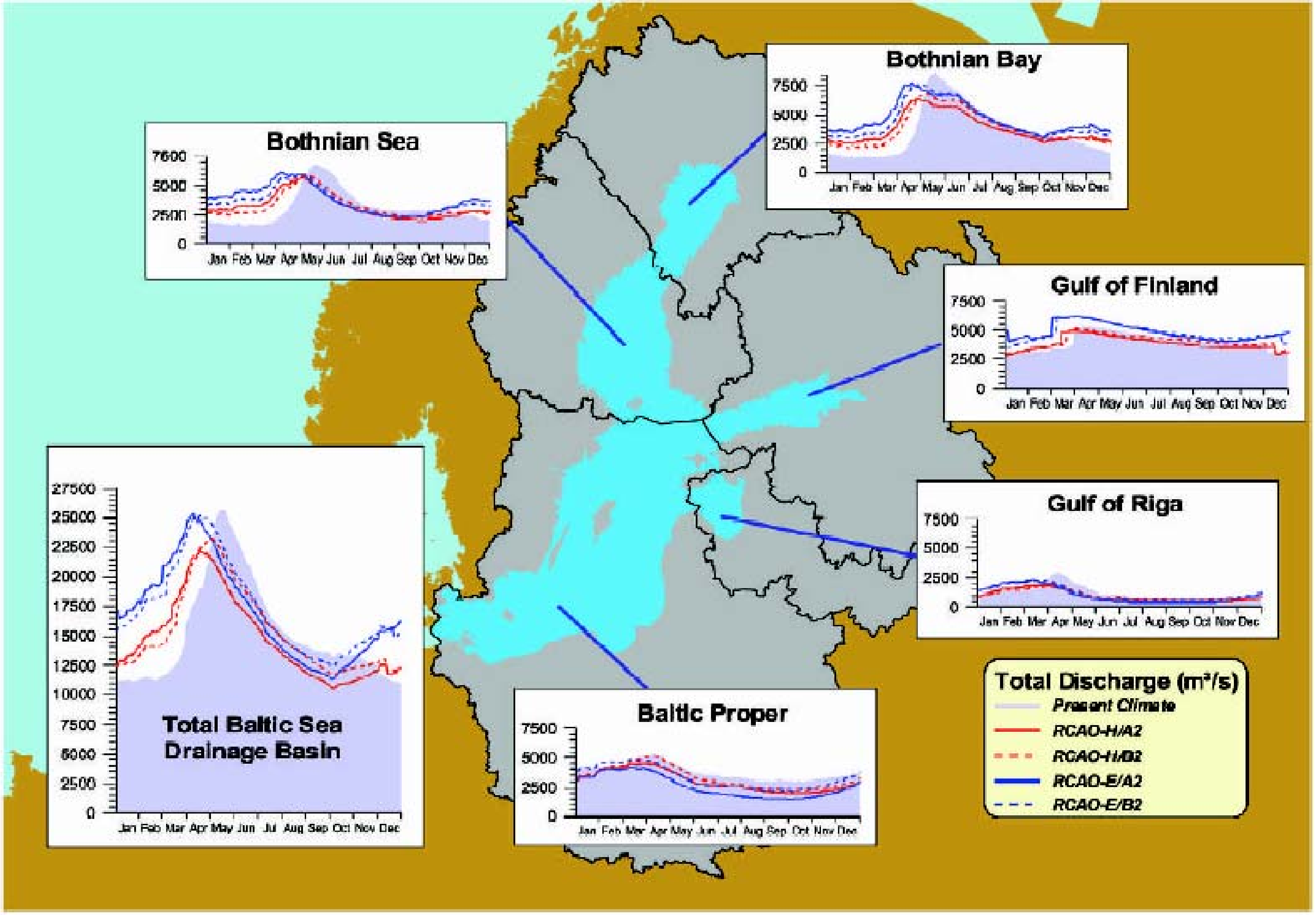


Figure 1. Modeled seasonal river discharge to the Baltic Sea from HBV-Baltic for present-day conditions (shaded) and four climate change scenarios. Shown are daily means over the 23-year modeling period. All plots are drawn to the same X and Y scales.

Graham 2004

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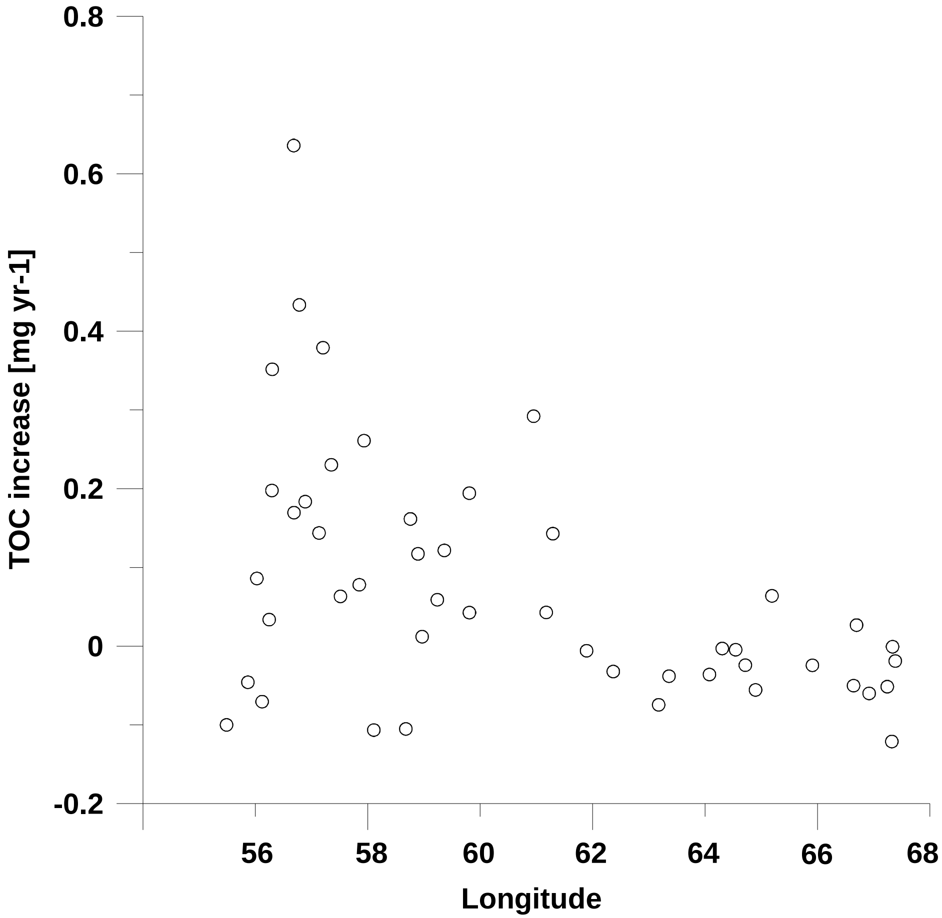
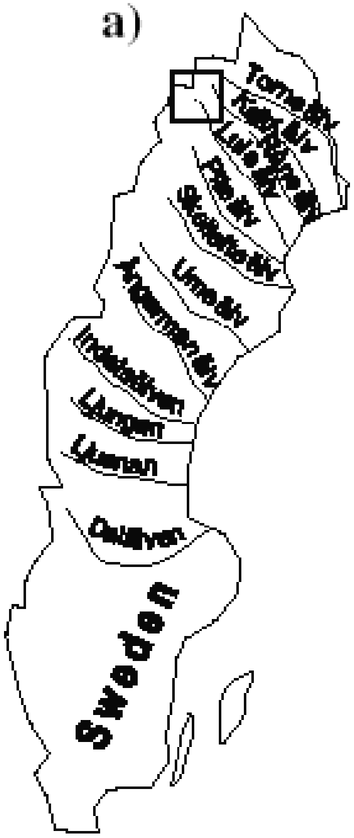
DOC increases up to mid lattitudes in Sweden





Trend analysis
30 years
Monitoring data
With monthly
Resolution

Humborg et al., 2007
HESS

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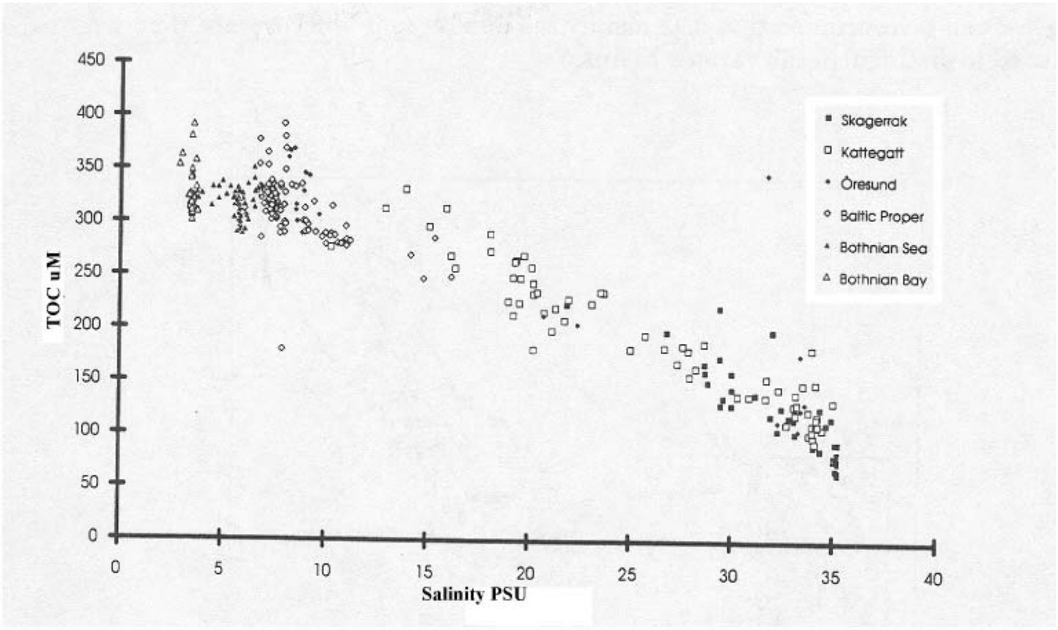
Baltic Nest Institute

RV Maria S. Merian
28 feb 2006 – 17 mars 2006

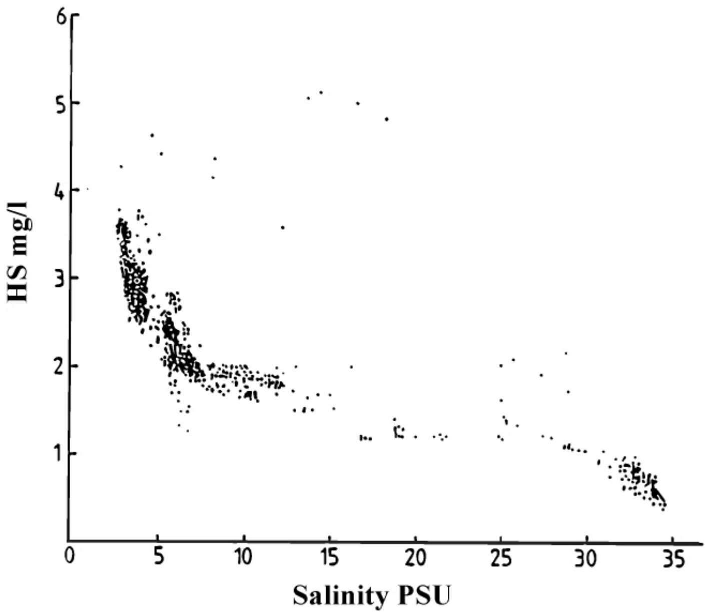
Conservative mixing of TOC in the Baltic?

TOC



Wedborg et al, 1997

Humic Substances

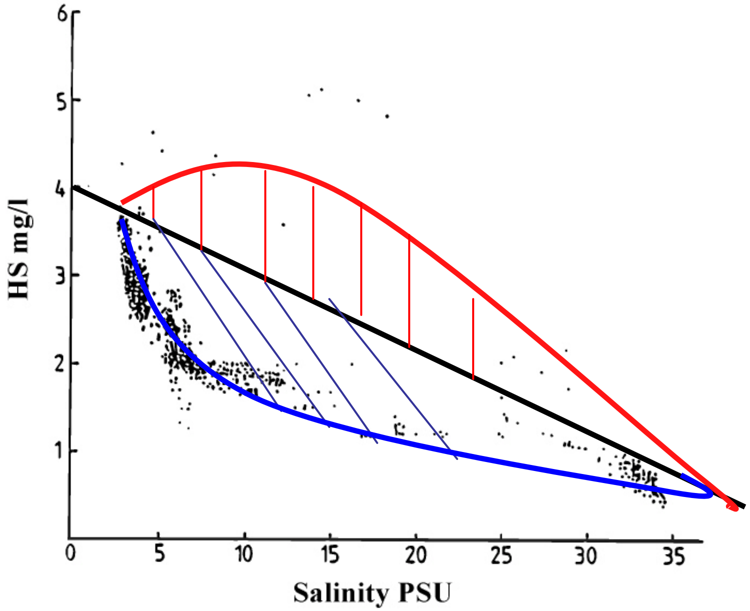


Fonselius 1995

Conservative mixing of TOC in the Baltic?

Degradation patterns can not be seen by just comparing TOC/Salinity

Discrimination between terrestrial and marine TOC has to be made



Fonselius, 1995

How to use isotopic signatures

Terrestrial source
(end member)
δ ^{13}C = -28 ‰

Marine source
(end member)
δ ^{13}C = -21 ‰

δ ^{13}C = -25 ‰ → 57 % terrestrial DOC 43 % marine

δ ^{13}C: -28 (‰) ... -21

Methods

- Ultra filtration (cross flow filtration) used to up-concentrate DOM
- Natural stable isotopes, specific value of each source –each ***end member***

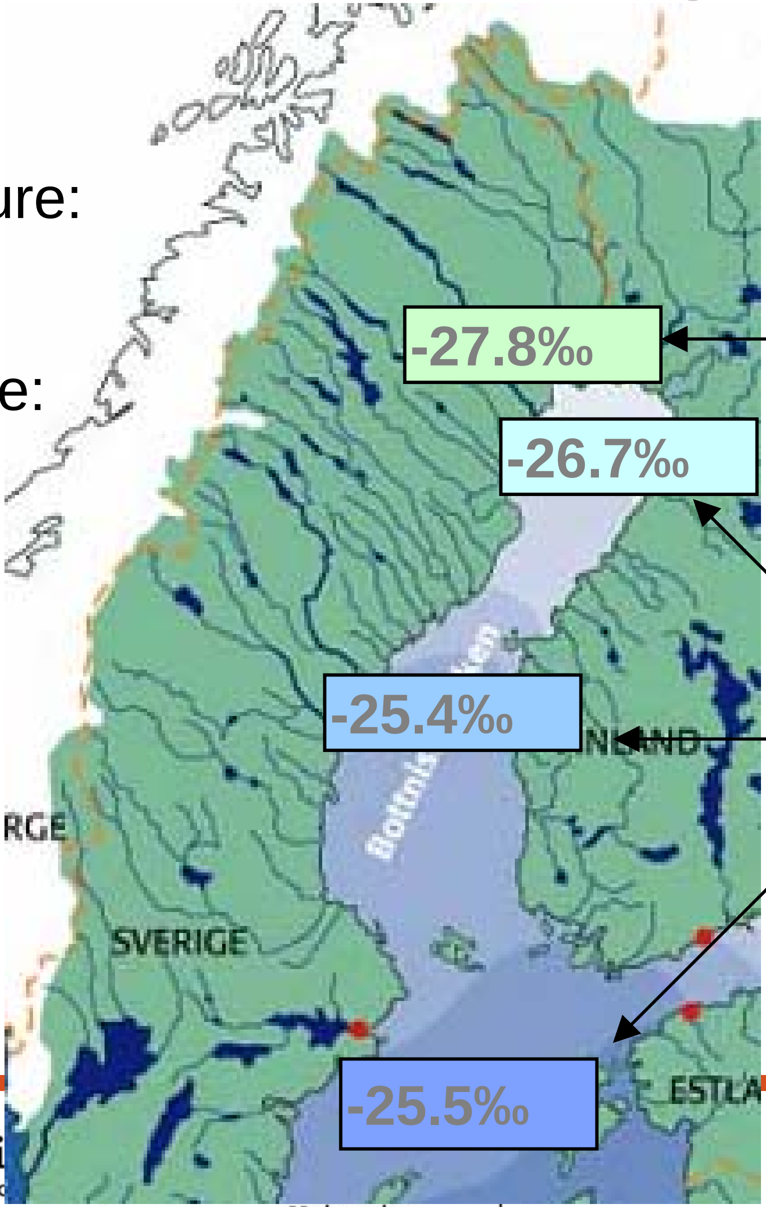
DOM-concentrates from Bothnian Sea and Bothnian Bay

Results of δ ^{13}C analysis of the DOM

Terrestrial signature: -28‰

Marine signature: -21‰

Estuarine production: about -24‰



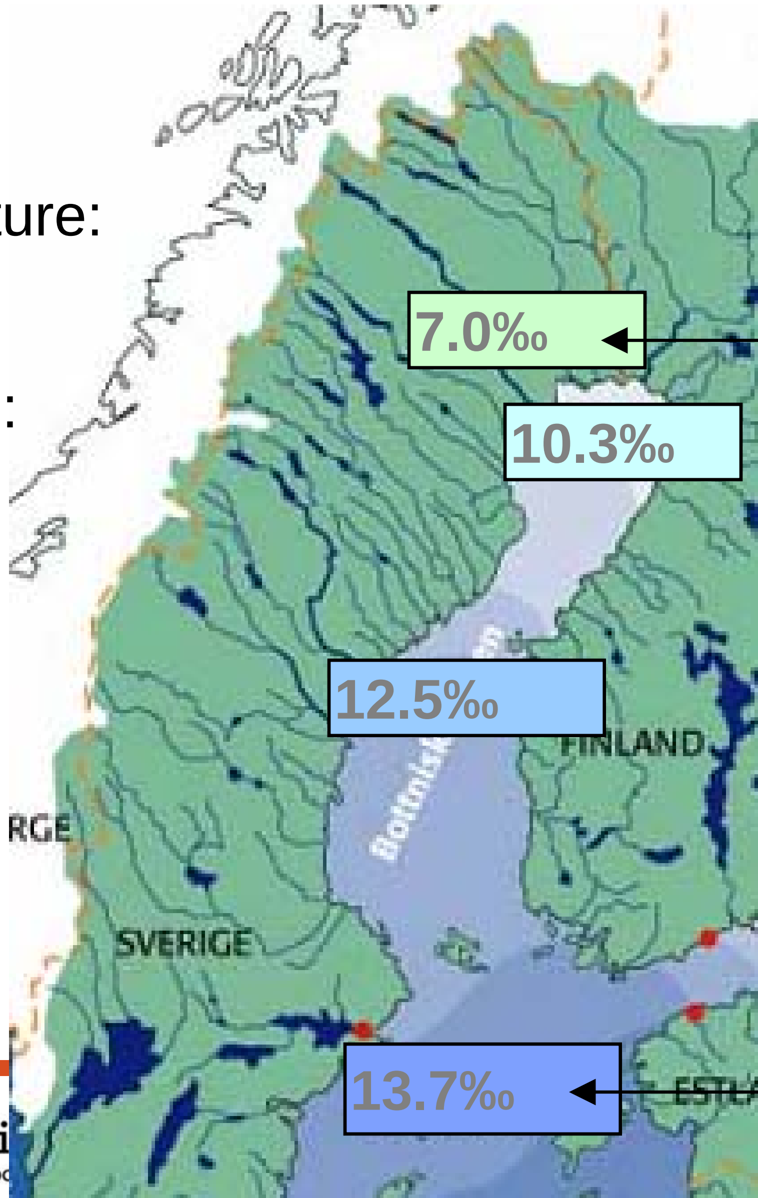
Normal terrestrial signal

Too little difference from the total terrestrial sample to make a quantification of terrestrial input.

Results of $\delta^{34}S$ analysis of the DOM

Terrestrial signature:
6.9‰

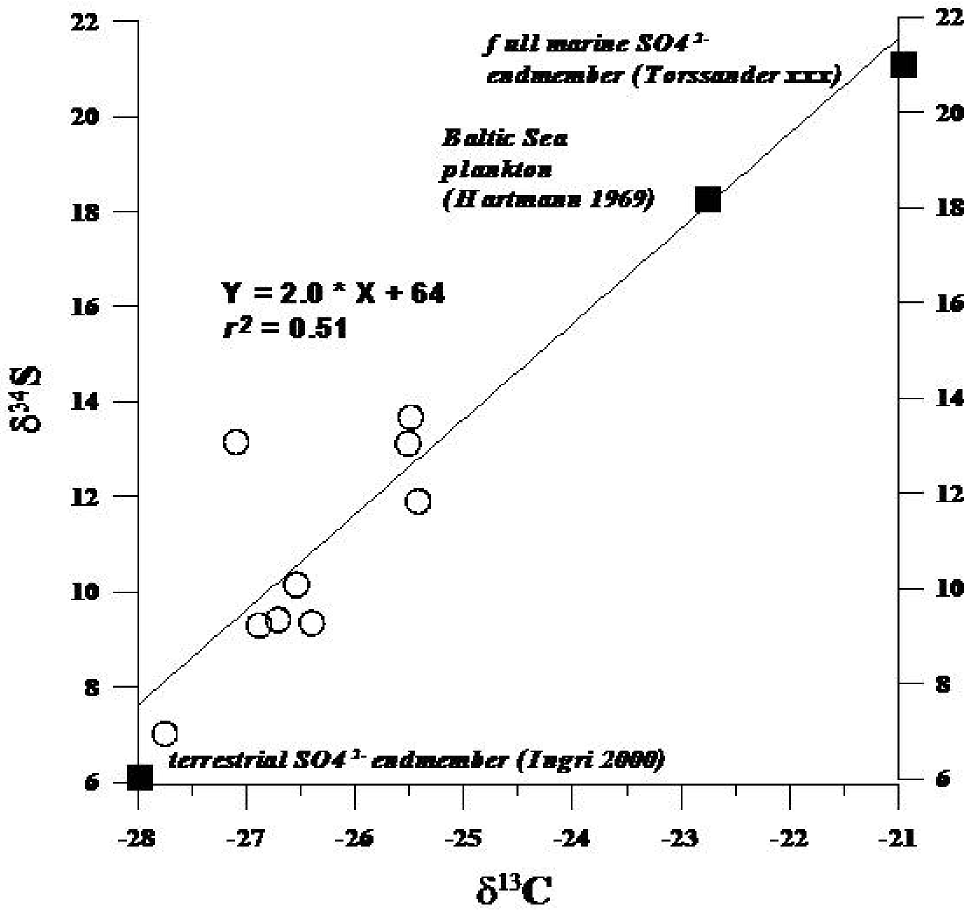
Marine signature:
18.1‰



Terrestrial
end member

Still not a total
marine signature

δ ^{34}S *vs.* δ ^{13}C



End points of the two isotope signatures correspond well

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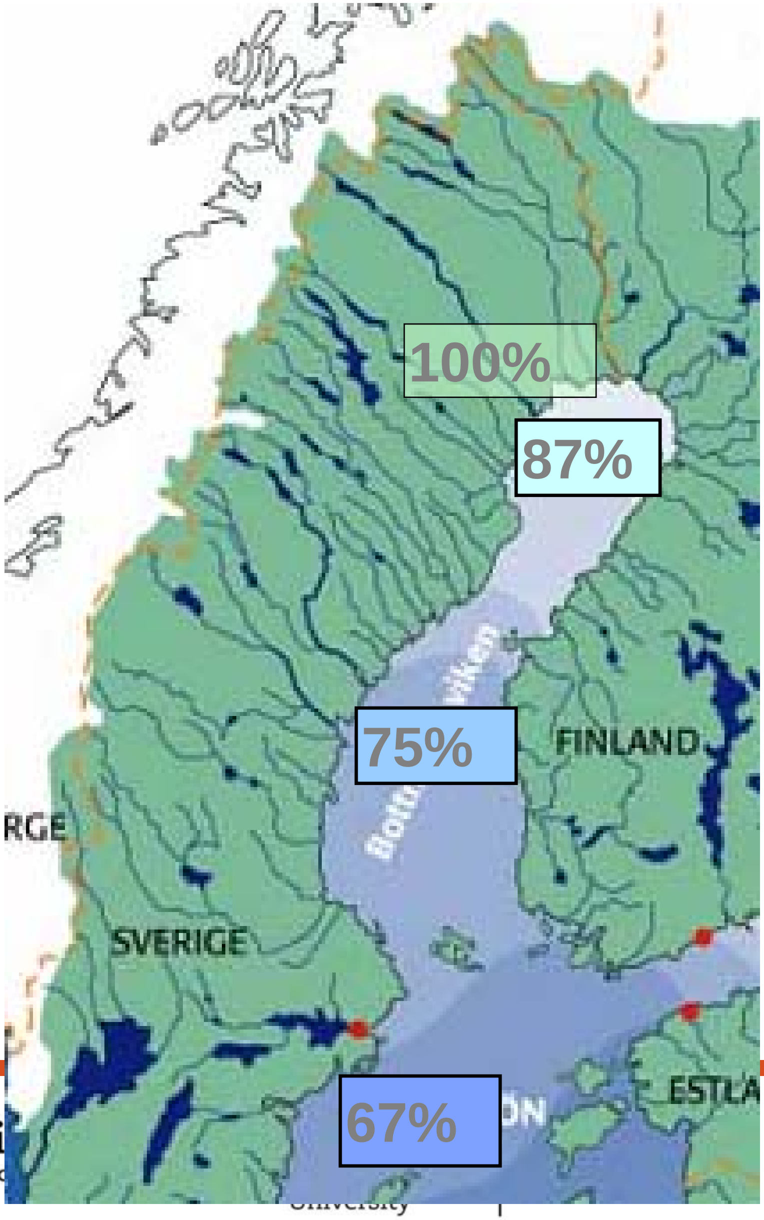
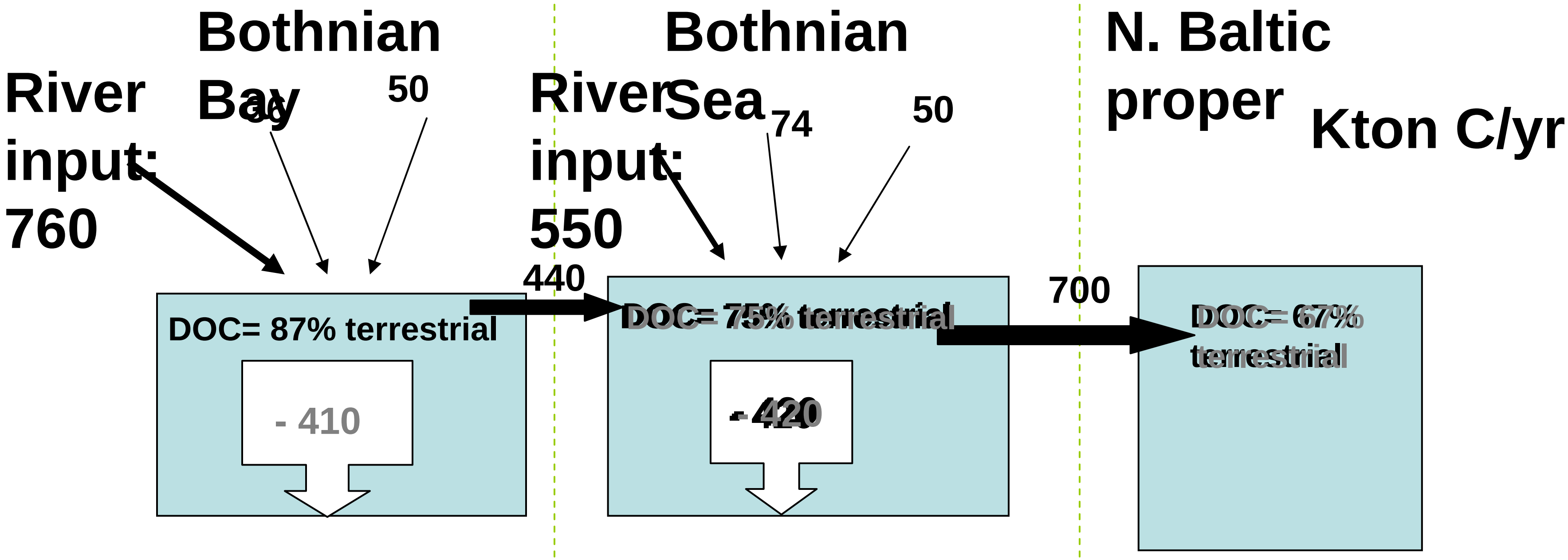
Terrestrial fraction of DOC



Simple box model
-fluxes of terrestrial DOC



~50% to sediments and/or respired