Nutrient loading, lectures and exercises ECGS-021

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SYKE

Course information

- **Topic: Quantification, abatement and effects of diffuse nutrient load, especially from agriculture and forestry**
- **Lectures (13 · 1.5 h)**
  - **Biocenter 2, Class 2012**
  - **Slides: http://www.syke.fi/fi-FI/Asiantuntijat/Petri_Ekholm(28733)**
- **Exam requirements: Lecture material**

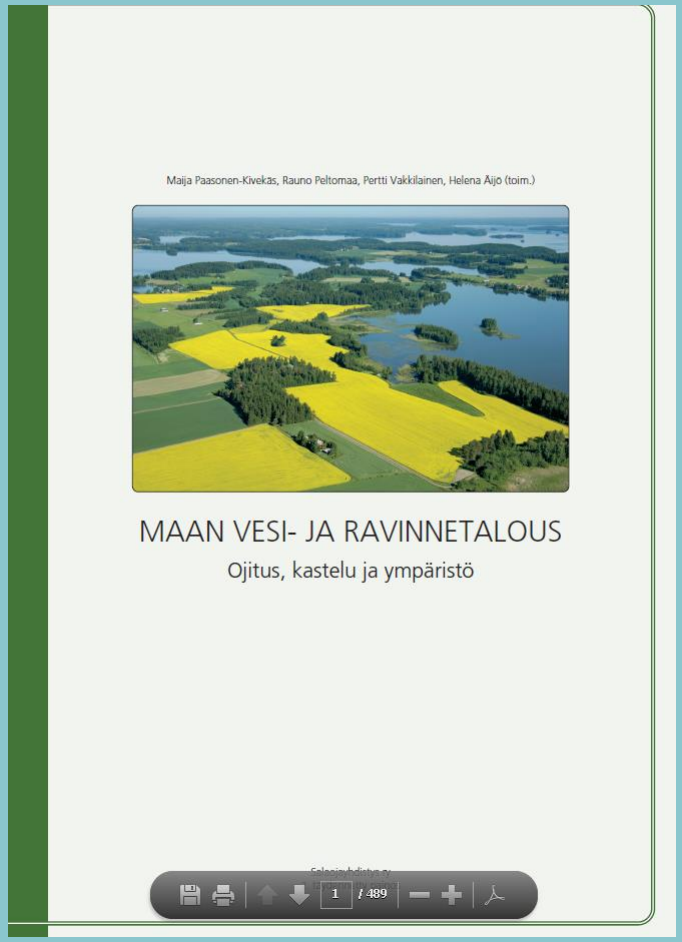
Week	Monday 12:15–13:45	Tuesday 12:15–13:45	Wednesday 14:15–15:45
8	19.2.2018	–	21.2.2018
9	26.2.2018	–	28.2.2018
10	–	–	–
11	12.3.2018	–	14.3.2018
12	19.3.2018	**20.3.2018**	–
13	–	–	–
14	–	–	–
15	9.4.2018	–	11.4.2018
16	16.4.2018	–	18.4.2018
17	**23.4.2018**	–	25.4.2018
18	**30.4.2018**	–	–

HERTTA exercise
”B-building” Class 443
Latokartanonkaari 7

Prof. Jukka Horppila: Resuspension

Exam

Useful textbook



Available on: http://salaojayhdistys.fi/wp-content/uploads/2016/05/web_maanvesijaravinnetalous_B5_2016.pdf

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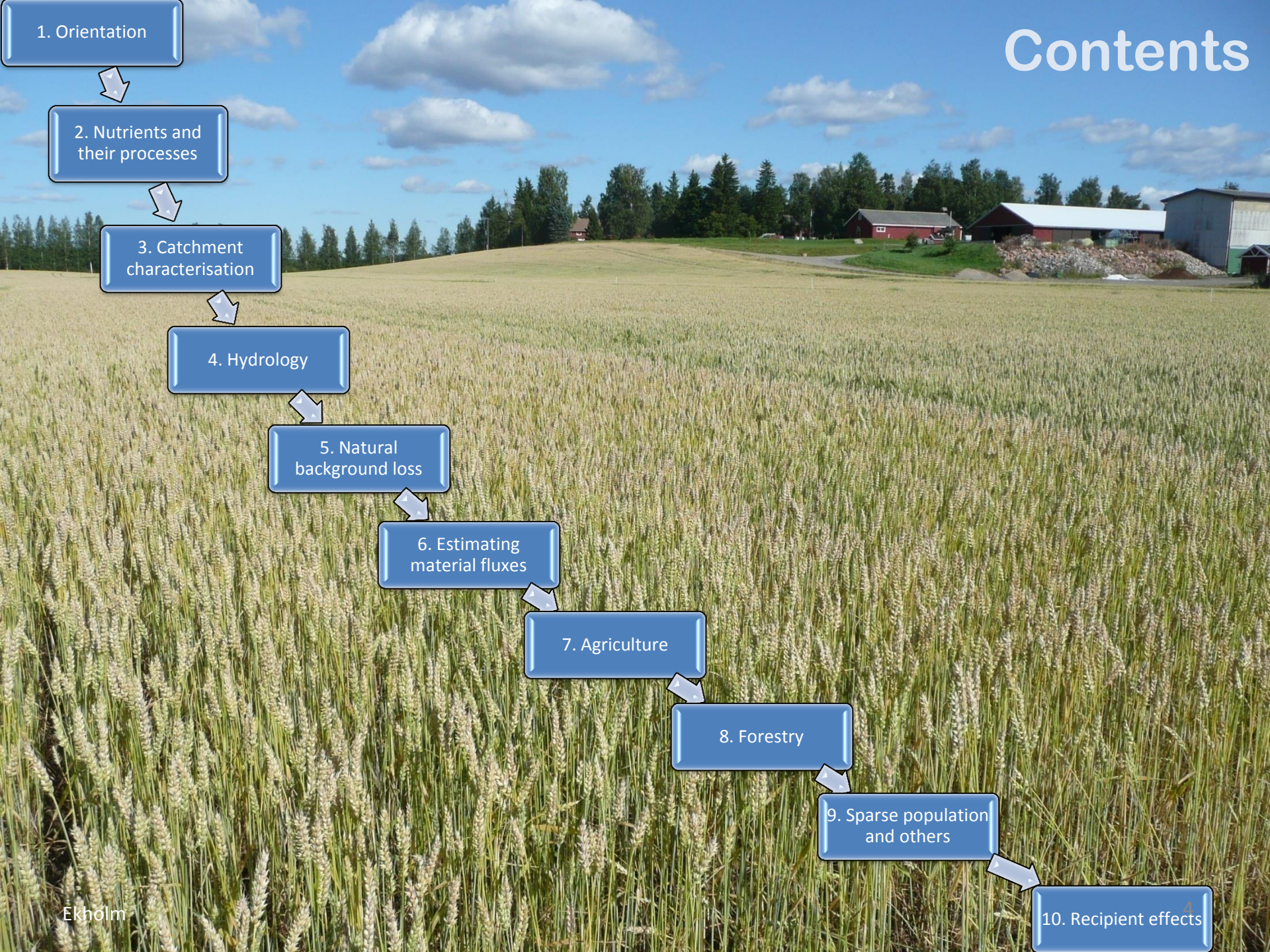
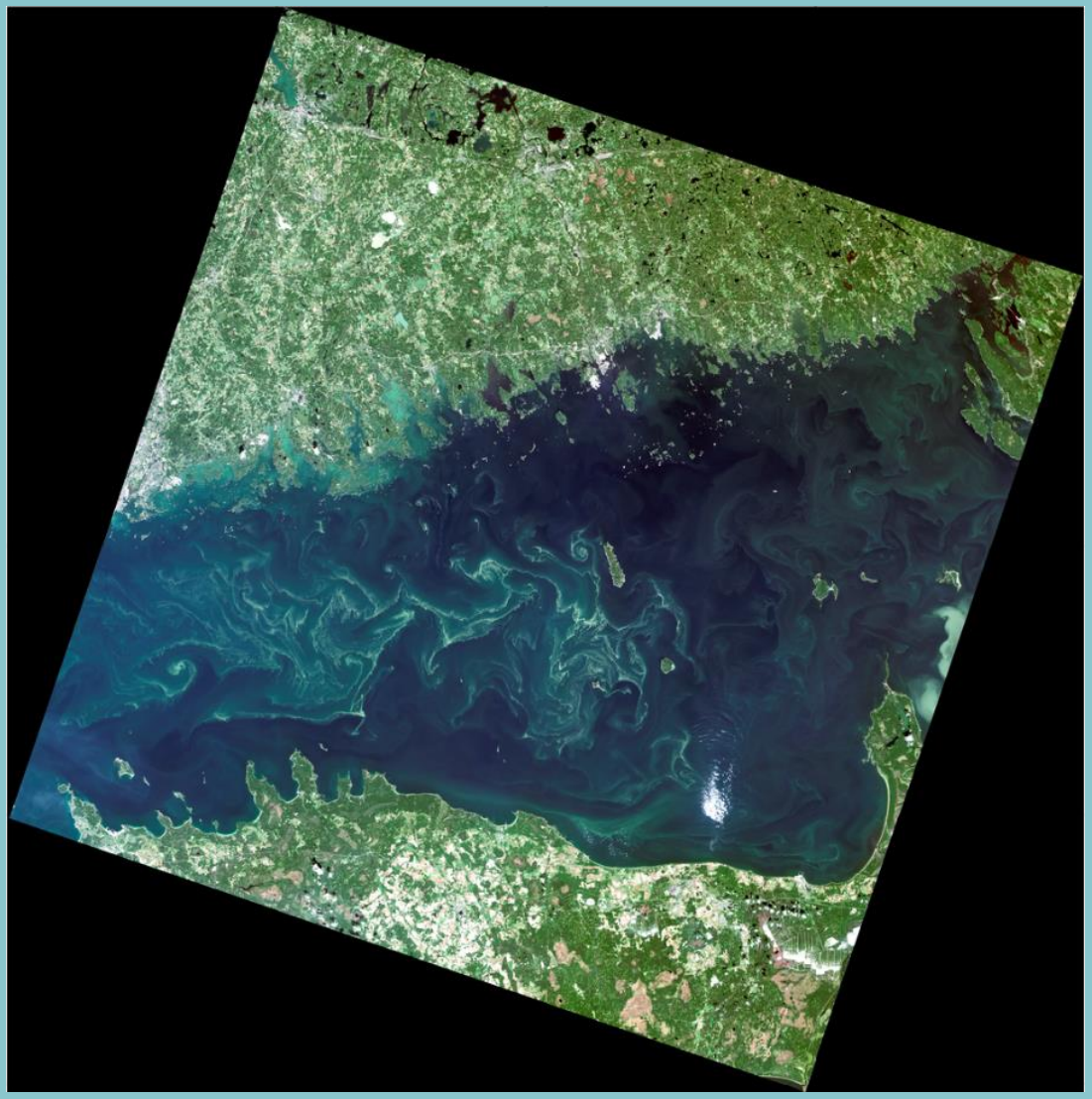
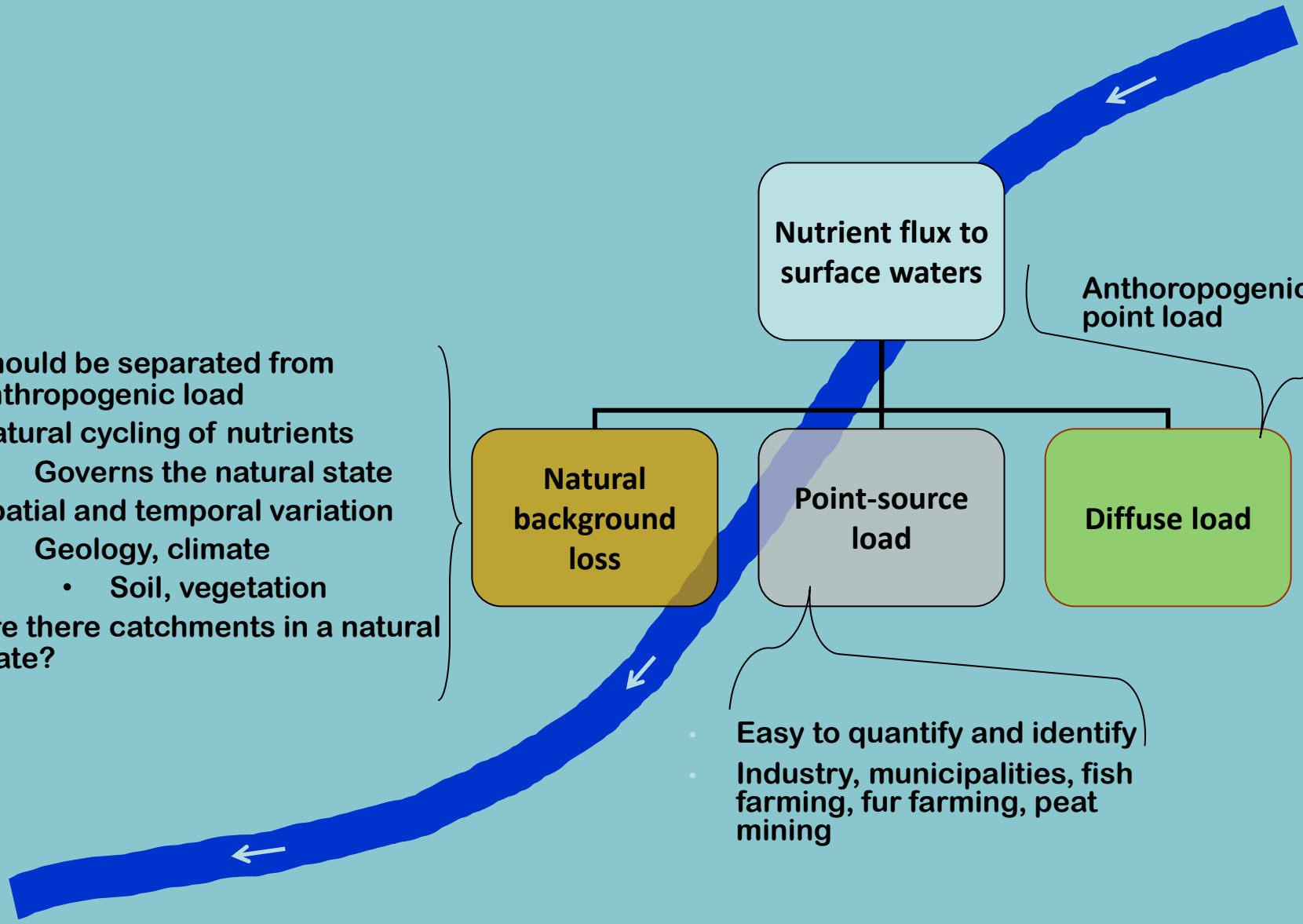

1. Orientation
2. Nutrients and their processes
3. Catchment characterisation
4. Hydrology
5. Natural background loss
6. Estimating material fluxes
7. Agriculture
8. Forestry
9. Sparse population and others
10. Recipient effects

1. ORIENTATION



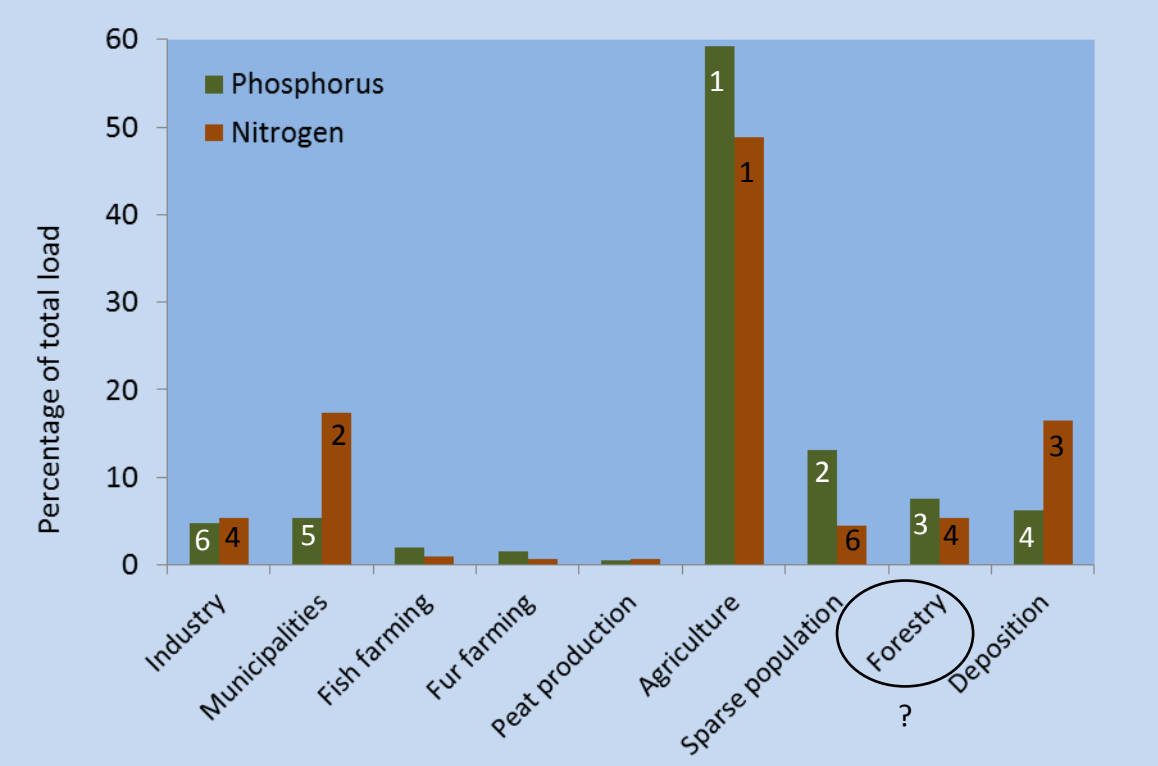
Landsat 8, 22.08.2015, Original picture: USGS/NASA Landsat program, prosessing: SYKE

Nutrient flux to waters



- Should be separated from anthropogenic load
- Natural cycling of nutrients
  - Governs the natural state
- Spatial and temporal variation
  - Geology, climate
    - Soil, vegetation
- Are there catchments in a natural state?

Nutrient load to surface waters in Finland in 2015

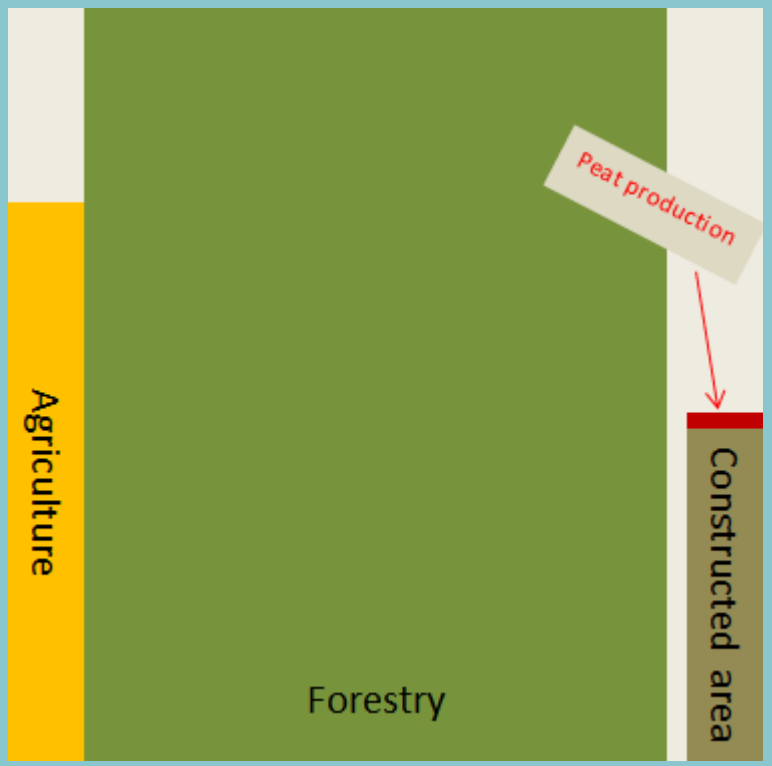


Data sources:

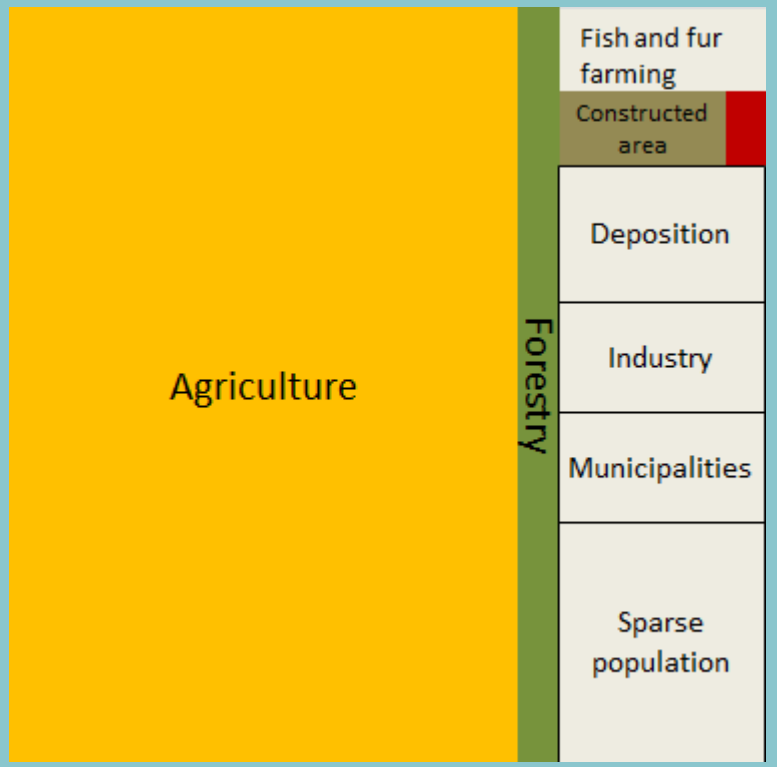
- **Industry, municipalities, fish farming: VAHTI data base (21.8.2017)**
- **Other sources: SYKE's estimate**
- **Missing: urban runoff, local sources**

Land use and phosphorus load in Finland

Land use



Phosphorus load



Share of diffuse sources in total anthropogenic P and N load to the sub-basins of the Baltic Sea from Finland

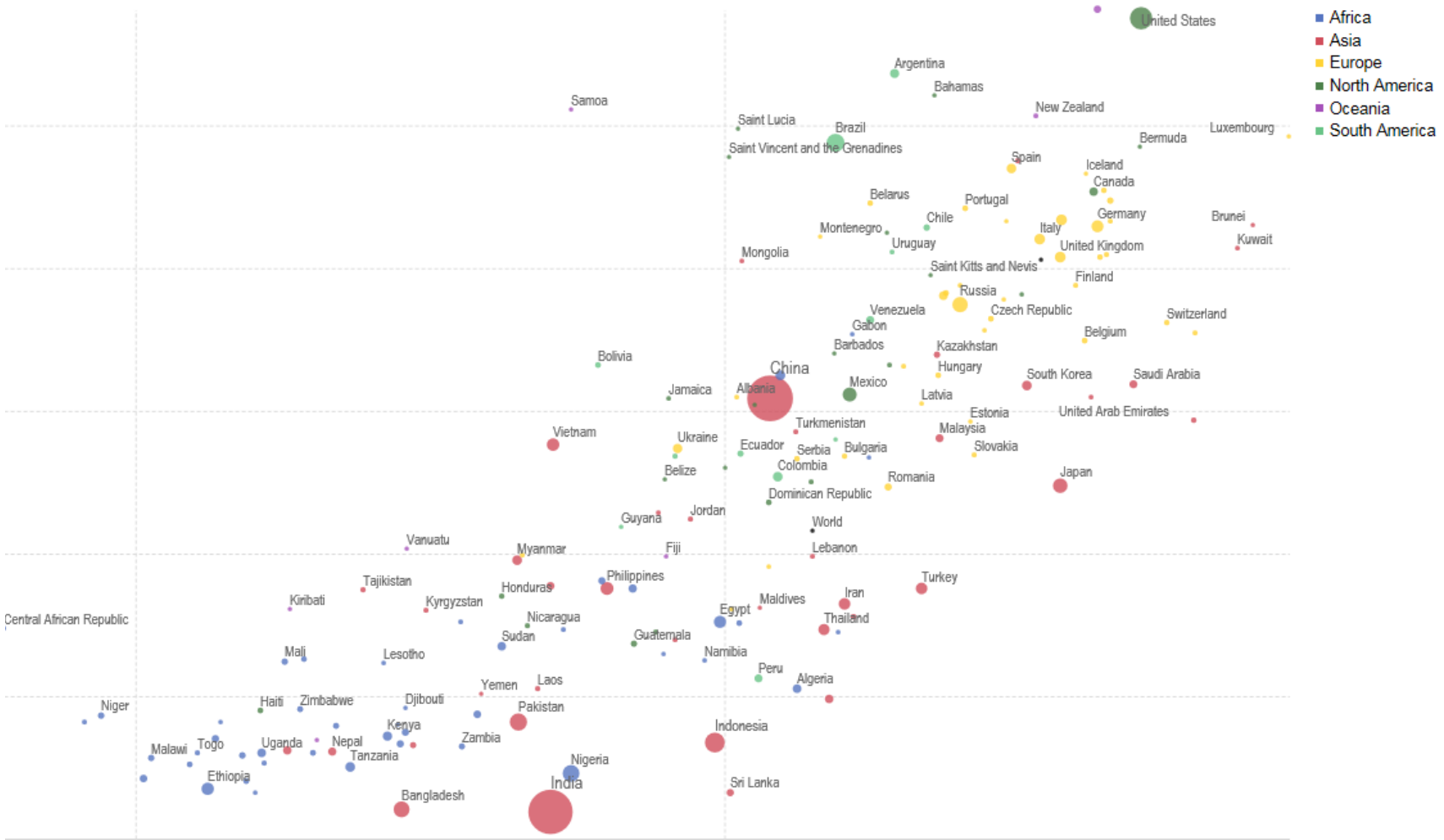
Years 2008–2012

	Agriculture P N	Forestry	Sparse population	Urban runoff	Deposition
Gulf of Finland	60%—47%	4%—3%	15%—7%	1%—0%	6%—16%
Archipelago Sea	82%—77%	2%—2%	9%—5%	3%—2%	1%—3%
Bothnian Sea	66%—59%	5%—4%	14%—5%	1%—1%	3%—8%
Bothnian Bay	53%—52%	16%—8%	12%—4%	1%—0%	9%—14%

Diffuse load

- Agriculture, forestry, sparse population (+ holiday houses), urban runoff, atmospheric deposition (originates from agriculture, settlements, industry, traffic)
- Transported by water or wind
- Temporal and spatial variation
- Major uncertainties related to
  - Magnitude, spatial and temporal distribution, ecological effects, abatement…
- Multidisciplinary phenomenon, many administrative sectors involved, policy mix…
- Was ”discovered” when recovery after cutting down point sources was lower than expected or problems were found in waters without point sources
- The relative (and sometimes absolute) importance increased
- First large diffuse load study (International Joint Commission 1969)

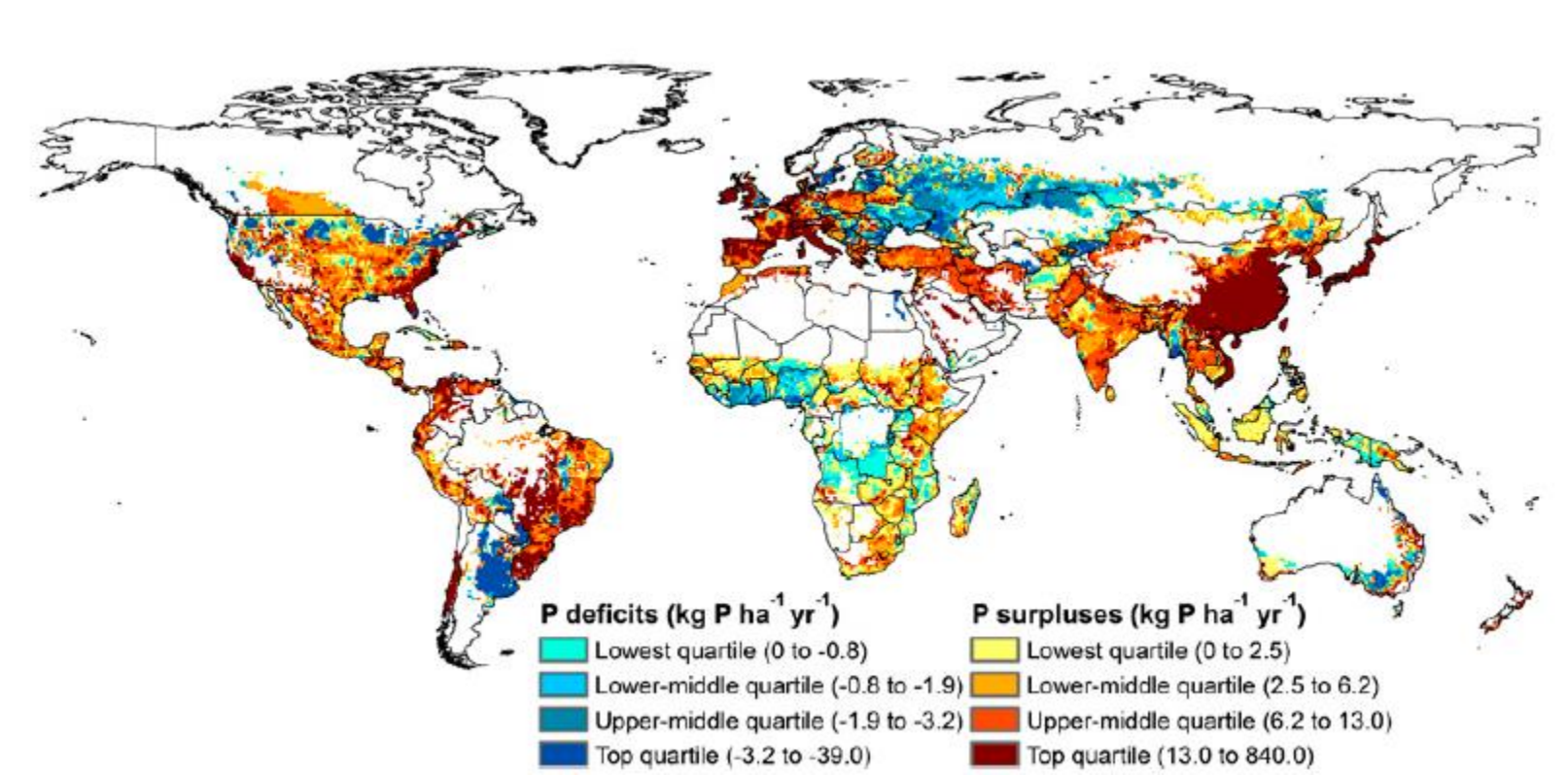
  “*The current conditions in the lakes (Erie, Ontario) could not be related entirely to pollutant loadings from readily identifiable point sources*”


Africa
Asia
Europe
North America
Oceania
South America
United States
Argentina
Bahamas
Samoa
New Zealand
Saint Lucia
Brazil
Luxembourg
Bermuda
Saint Vincent and the Grenadines
Spain
Iceland
Canada
Belarus
Portugal
Germany
Brunei
Chile
Montenegro
Italy
Kuwait
Uruguay
United Kingdom
Mongolia
Saint Kitts and Nevis
Finland
Russia
Venezuela
Czech Republic
Switzerland
Gabon
Belgium
Barbados
Kazakhstan
Bolivia
China
Hungary
South Korea
Saudi Arabia
Jamaica
Albania
Mexico
Latvia
Estonia
United Arab Emirates
Turkmenistan
Malaysia
Vietnam
Ukraine
Ecuador
Serbia
Bulgaria
Slovakia
Colombia
Belize
Romania
Japan
Dominican Republic
Guyana
Jordan
World
Vanuatu
Myanmar
Fiji
Lebanon
Philippines
Turkey
Tajikistan
Honduras
Iran
Kiribati
Kyrgyzstan
Maldives
Egypt
Central African Republic
Nicaragua
Thailand
Sudan
Guatemala
Mali
Lesotho
Namibia
Peru
Yemen
Laos
Algeria
Niger
Haiti
Zimbabwe
Djibouti
Pakistan
Kenya
Indonesia
Malawi
Togo
Uganda
Nepal
Zambia
Tanzania
Nigeria
Ethiopia
India
Sri Lanka
Bangladesh

Diffuse load continues to be a challenge

- Agriculture considered to be the major source of nutrient load to surface waters in many (most?) countries
- The load is linked to world population, its food production and standard of living
  - 2100: > 11 • 10^9 people
  - Productivity (per hectare) has to increase by 70%
  - Eutrophication can increase 2–3-fold (Tilman et al. 2002)
- Climate change may further increase the load
- Coastal areas in the vicinity of agricultural areas show water quality problems (Berman et al. 2005)
  - Baltic Sea, Gulf of Mexico, Bay of California, Southern China Sea, Bay of Bengal…

Phosphorus balance of agricultural fields in 2000



MacDonald (2011)

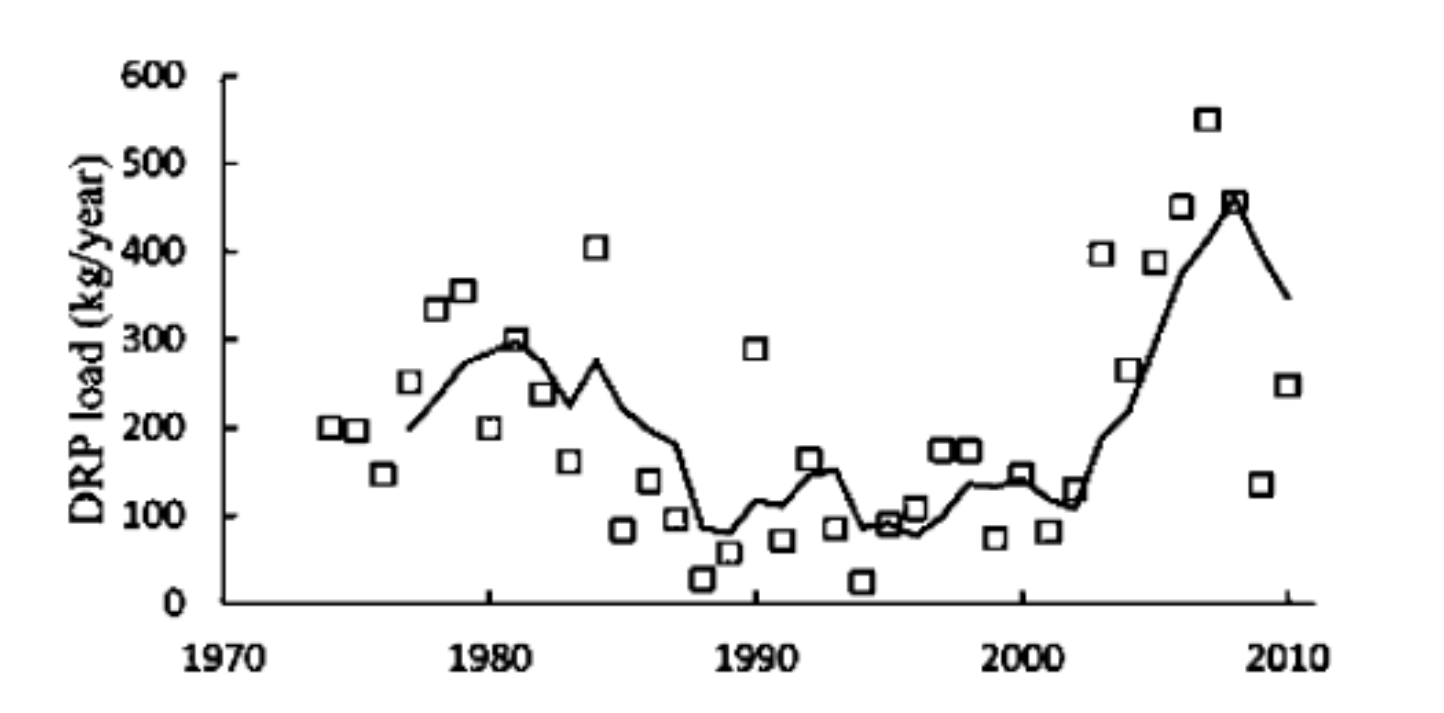
Re-eutrophication of Lake Erie

New York Times 3.10.2017

Phosphorus load remained below the target level (11 000 t y^{-1})

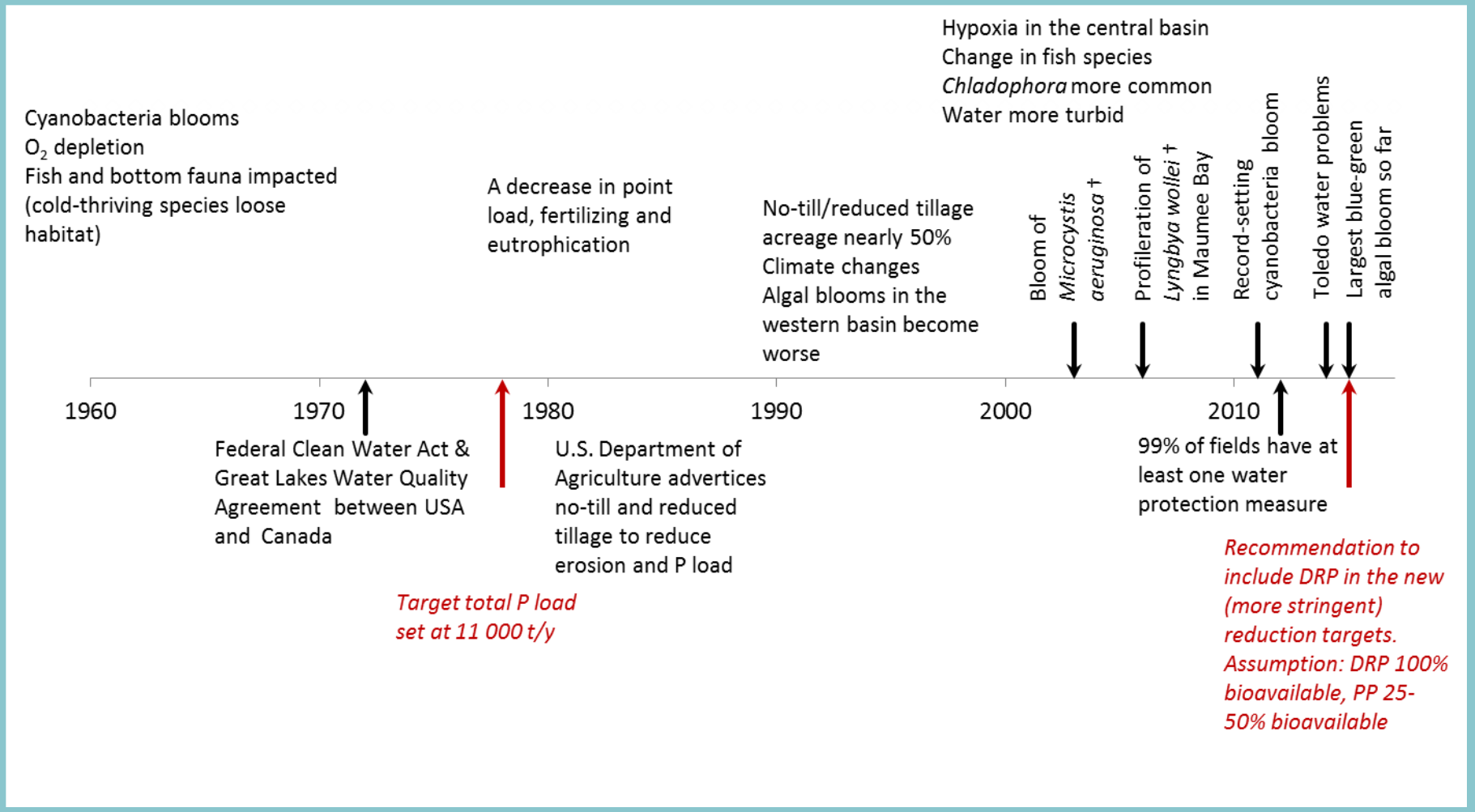
- **Composition of P changed: dissolved reactive P increased (Daloğlu et al. 2012, Michalak et al. 2013, Jarvie et al. 2017)**

Modelled and observed load of dissolved reactive P (DRP) into Lake Erie



Daloğlu et al. (2012)

Development of eutrophication in Lake Erie



Ekholm et al. (2016)
https://yle.fi/uutiset/3-9861482

A suggested remedy

- **Re-establishment of the Great Black Swamp, 10% (= 405 km^2) of the former area**
  - **Fields would be temporally transformed to wetlands**
  - **Might decrease P load by 40%**

https://undark.org/article/great-black-swamp-ohio-toledo/

Erosion

The River Taasianjoki
- **530 km^2**
- **Lakes 0.5%**
- **Fields 30%**

The River Kymijoki
- **37 107 km^2**
- **Lakes 19.7%**
- **Fields 8.6%**

25.5.2015 Landsat 8 OLI (RGB photo), Original photo: USGS/NASA Landsat Program, processing: SYKE (2015)

The Black Sunday dust storm

https://www.weather.gov/oun/events-19350414-maps

On April 27, 1935 US Congress passed a Public Law recognizing that "*the wastage of soil and moisture resources on farm, grazing, and forest lands . . . is a menace to the national welfare*" -> Establishment of Soil Conservation Service (SCS) under the USDA, renamed later as Natural Resources Conservation Service (NRCS)

Hypoxia in northern Gulf of Mexico

Missisippi (N)

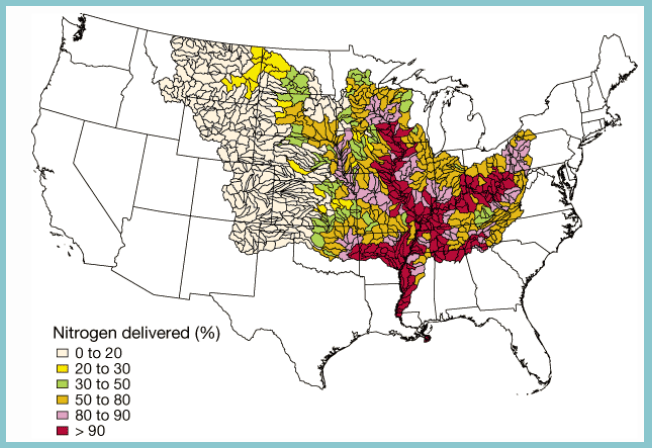
Primary production
$(CH_2O)_{106}(NH_3)_{16}(H_3PO_4)$

- Catchment covers 40% USA
- N originates from fertilizers
- P from fertilizers, manure and municipalities

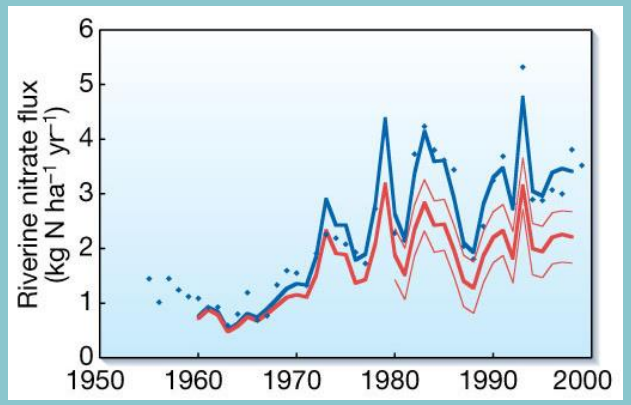
Pycnocline

Hypoxia: O_2 < 2 mg l^{-1}

- Maximum area of hypoxia (2002) 22 000 km^2
- Number of species declined
- Mortality of bottom fauna increased
- Fishery impacts



Alexander et al. (2000)

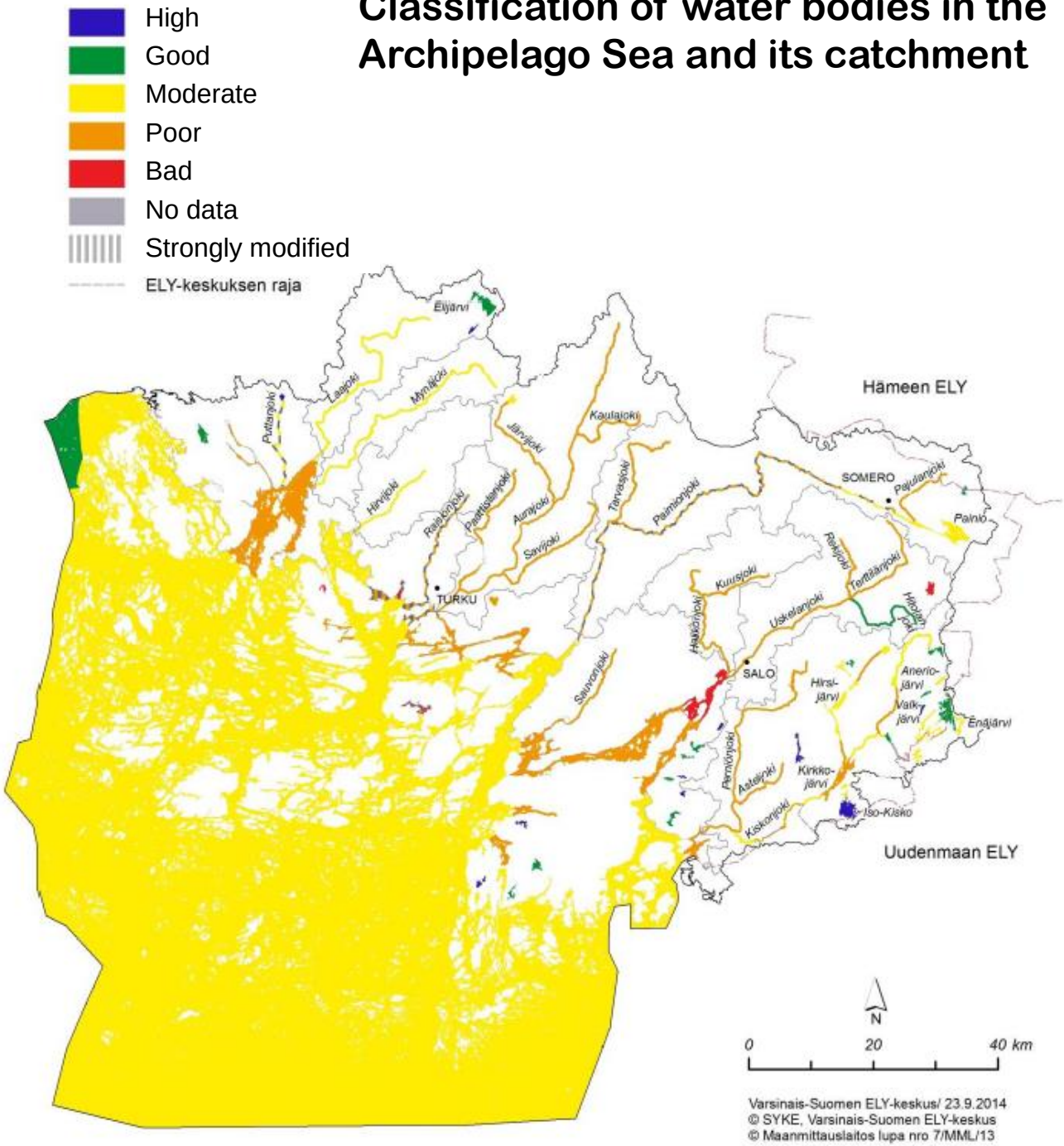


Net Anthropogenic N input (NANI)
McIsaac et al. (2001)

Programmes addressing diffuse load

- EU Water Framework Directive
  - European waters in a good ecological (and chemical) state by 2015, 2021 or 2027
  - Water districts, River basins, River Basin Management Plans, Programme of Measures, typification, classification, 1st planning cycle 2010–2015, 2nd planning cycle 2016–2021
- EU Marine Strategy Directive
  - Good environmental status by 2020
  - 11 descriptors (”Ocean’s eleven”)
- HELCOM Baltic Sea Action Plan
  - Accepted 2007, revised 2013
  - Good ecological state by 2021
  - Maximum Allowable Inputs
  - Country-Allocated Reduction Targets
  - Nutrient load into the Baltic Sea must be reduced by 13% (N, 118 000 t y^{-1}), 41% (P, 15 000 t y^{-1})
  - Finland has to reduce the load of P into the Gulf of Finland by 364 t y^{-1}
  - Even if all the planned measures were fully implemented, the target would fall about 250 t y^{-1} short (Knuuttila et al. 2017)
- Baltic Sea Action Summit 2010

Classification of water bodies in the Archipelago Sea and its catchment



Example: the River Savijoki

- River basin district
  - River Kokemäenjoki-Archipelago Sea-Bothnian Sea
- Sub-district
  - Rivers Paimionjoki-Aurajoki
- Type
  - Medium-sized rivers in regions with clay soils
- Hydromorphological alteration
  - Low
- Chemical state
  - Good (or no data?)
- Class
  - Total P: 177 µg l^{-1} (= Bad)
  - Fish: Good
  - Overall class: Poor
- Good status achieved (= total P ≤60 µg l^{-1}) by 2027
  - Deadline postponed from 2015 due to insurmountable natural conditions
    - The catchment has plenty of sloping, nutrient rich fields
    - Lowering of soil P status takes years to decades

References

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