Univerza v Ljubljani
Fakulteta za gradbeništvo in geodezijo

MARS PROJECT
Managing Aquatic ecosystems and water Resources under multiple Stress

European water resources under multiple stressors - implications for water policies and societal development

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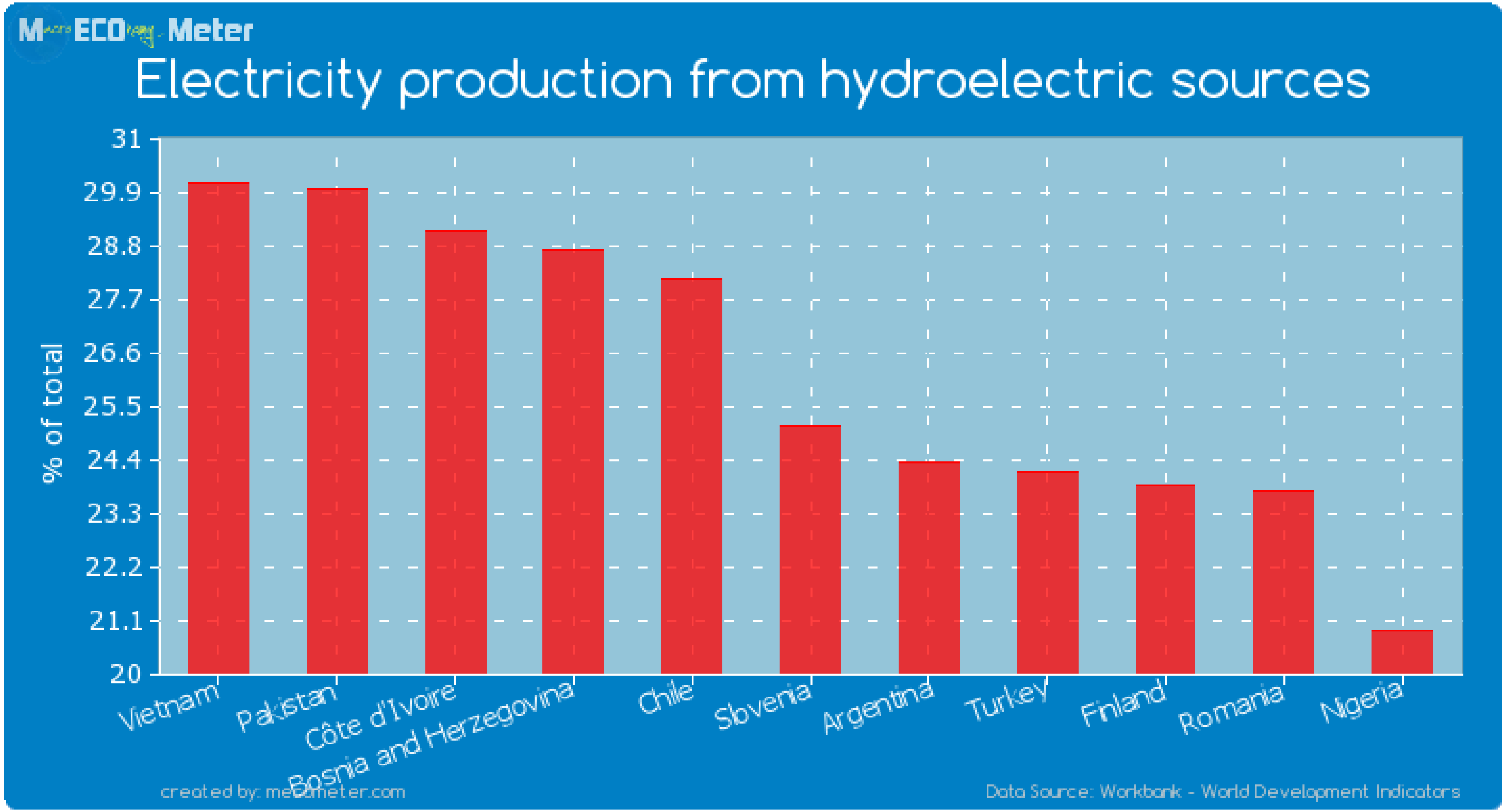
17.6.2016, 2nd South East European Conference on Sustainable Development of Energy, Water and Environment Systems - Piran

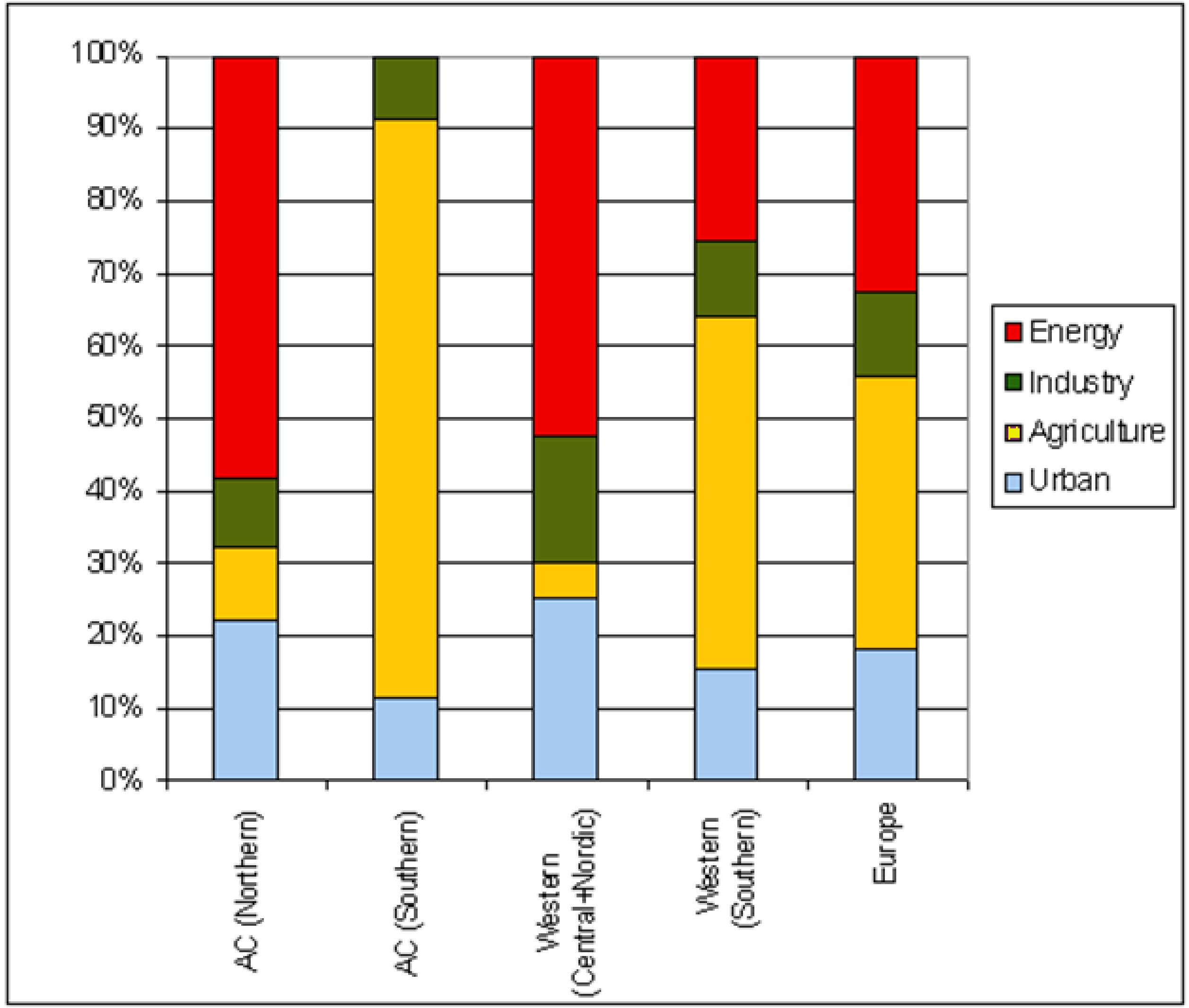
Sustainable development

water – energy - environment

Water as a source of energy

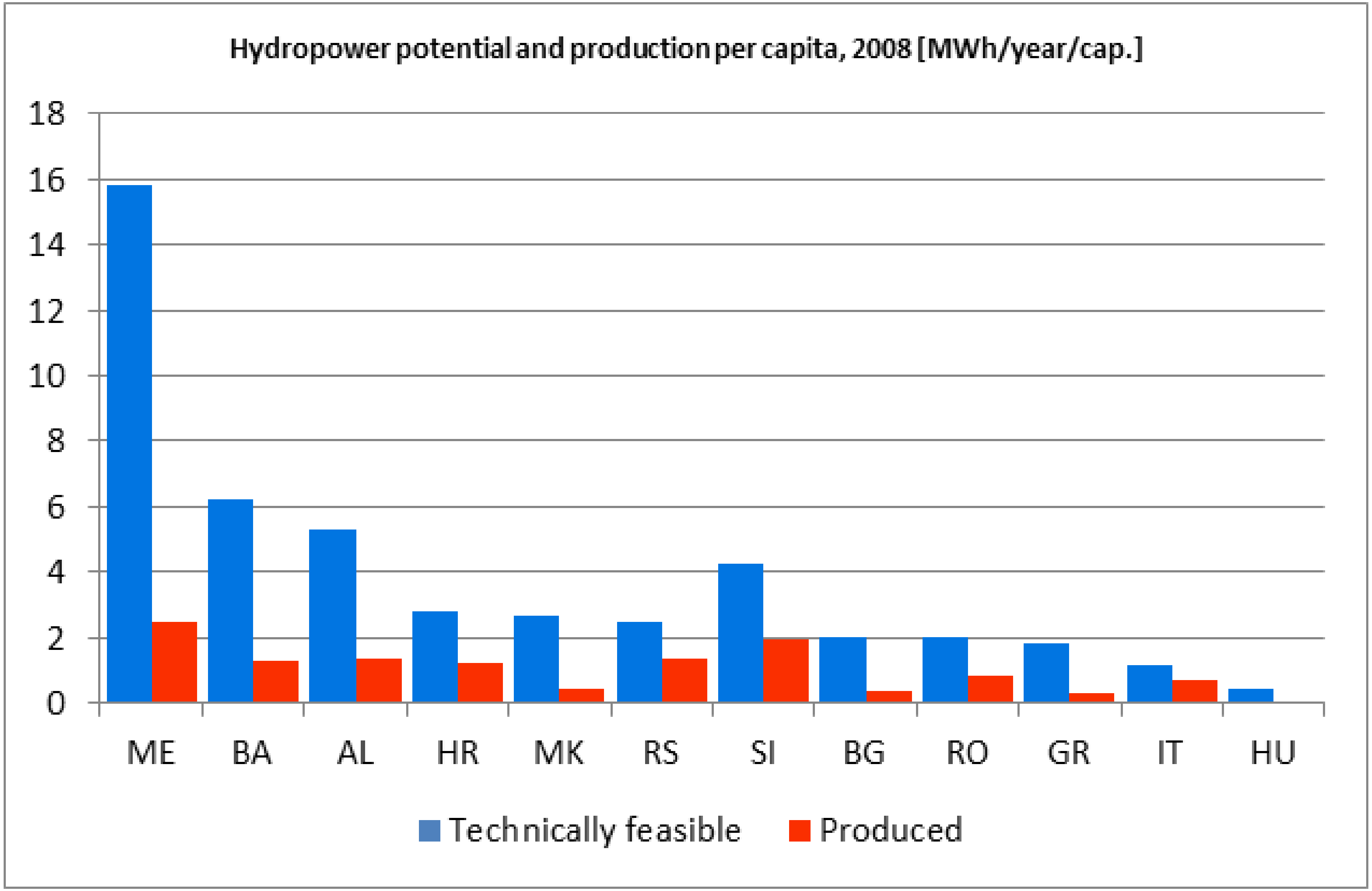


Water use in Europe by sectors



EEA, 2009; AC (Northern): Bulgaria, Czech Rep., Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia ; AC (Southern): Malta, Cyprus, Turkey. Western (Central+Nordic): Austria, Belgium, Denmark, Germany, Ireland, Luxembourg, Switzerland, Netherlands, UK, Iceland, Finland, Norway, Sweden. Western (Southern): France, Greece, Italy, Portugal, Spain.

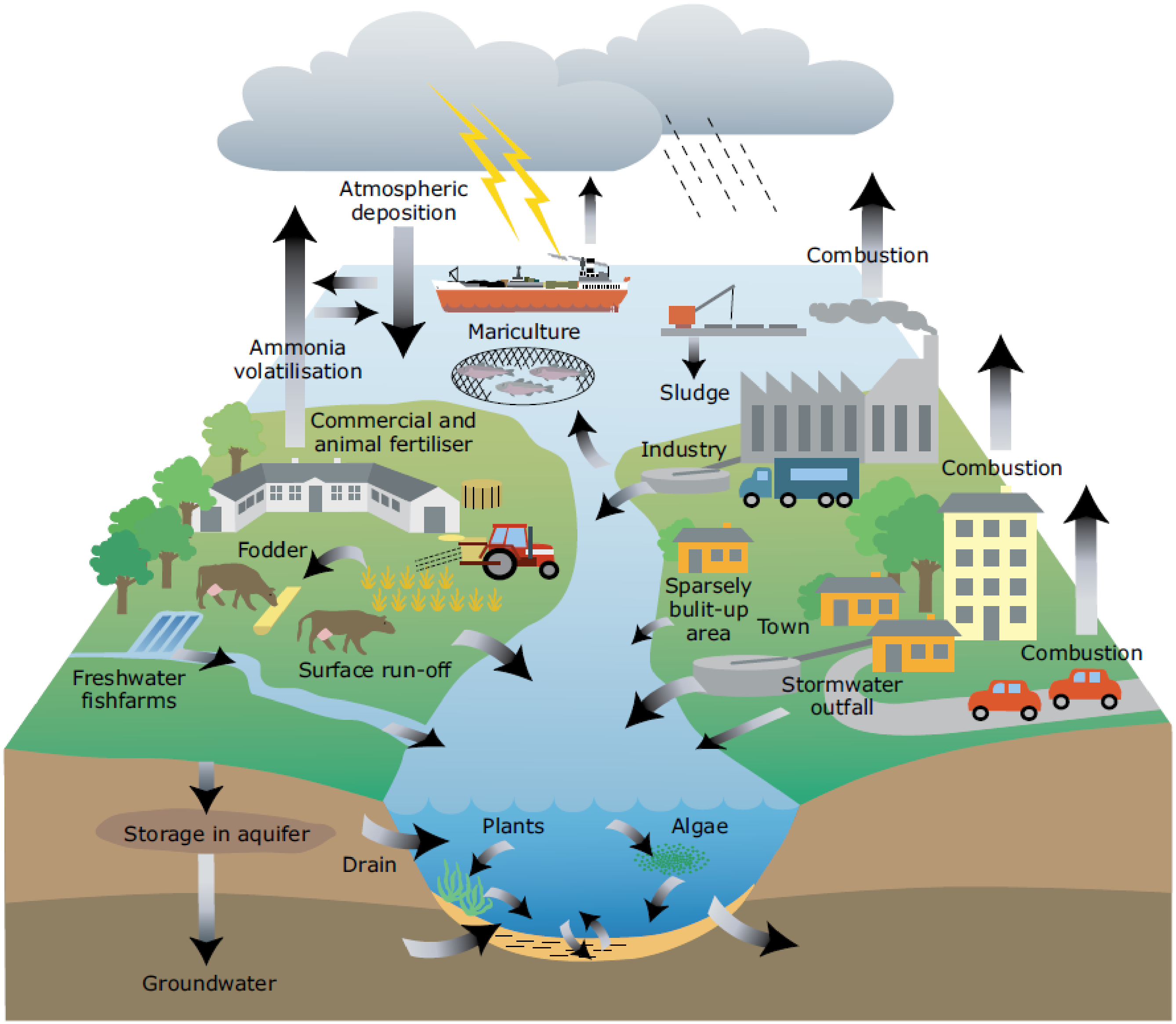
West Balkan region and neighbouring countries



Source: EEA ETC/ICM 2013

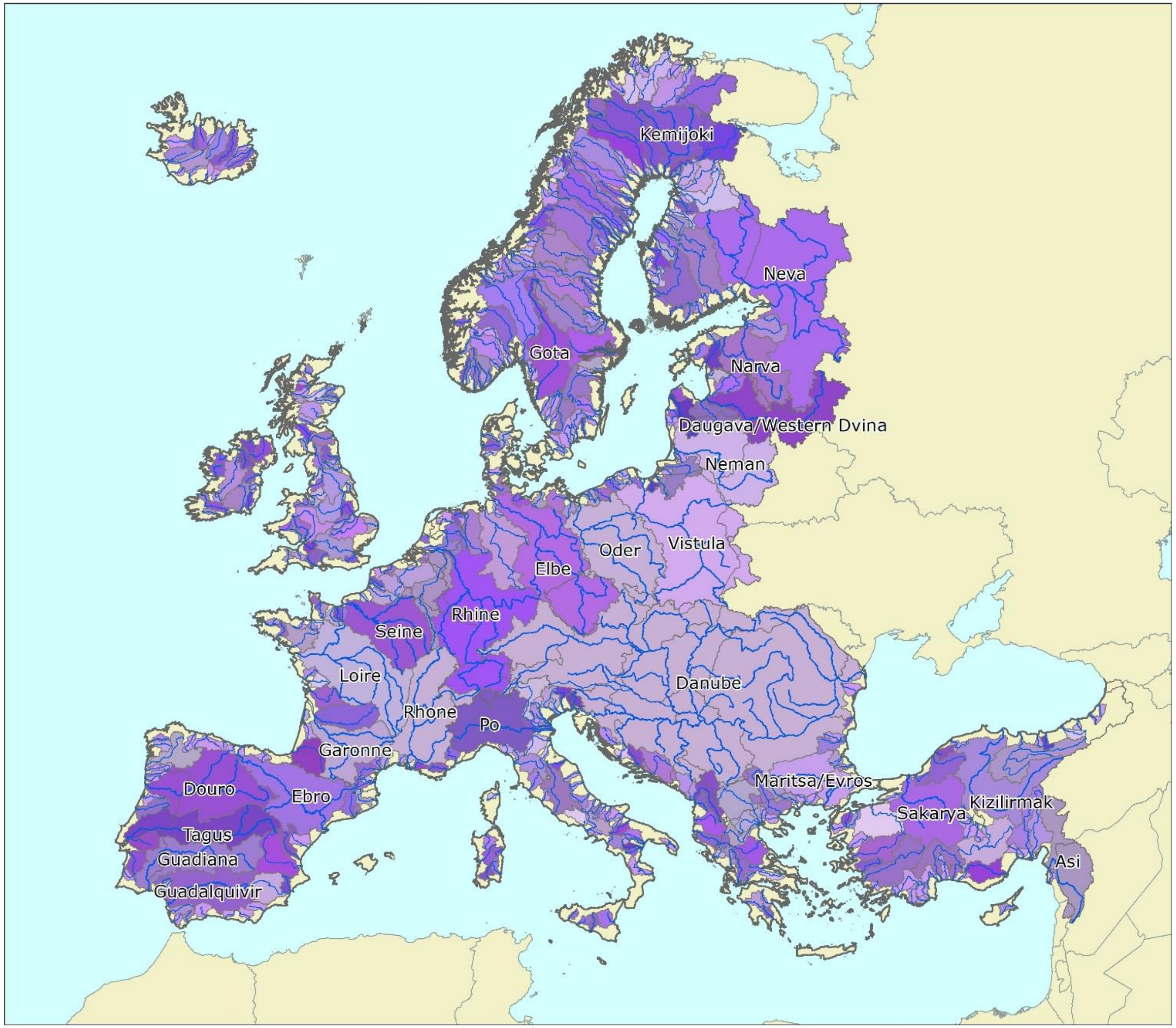
Sustainable development

water – energy - **environment**



Source: Ærtebjerg et al., 2003.

European water resources: rivers, lakes, groundwater, transitional and coastal water, wetlands



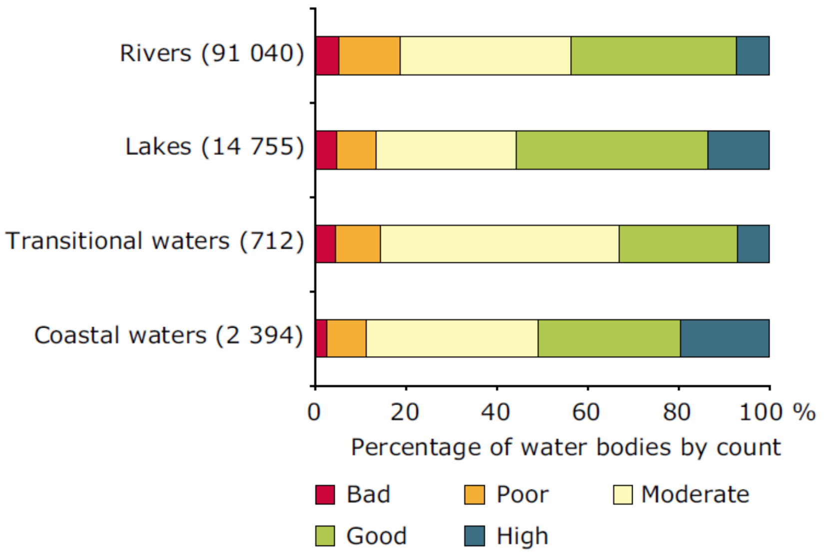
F > 1.000 km2: 454 rivers (1st Hach order)

F > 10.000 km2: 171 rivers

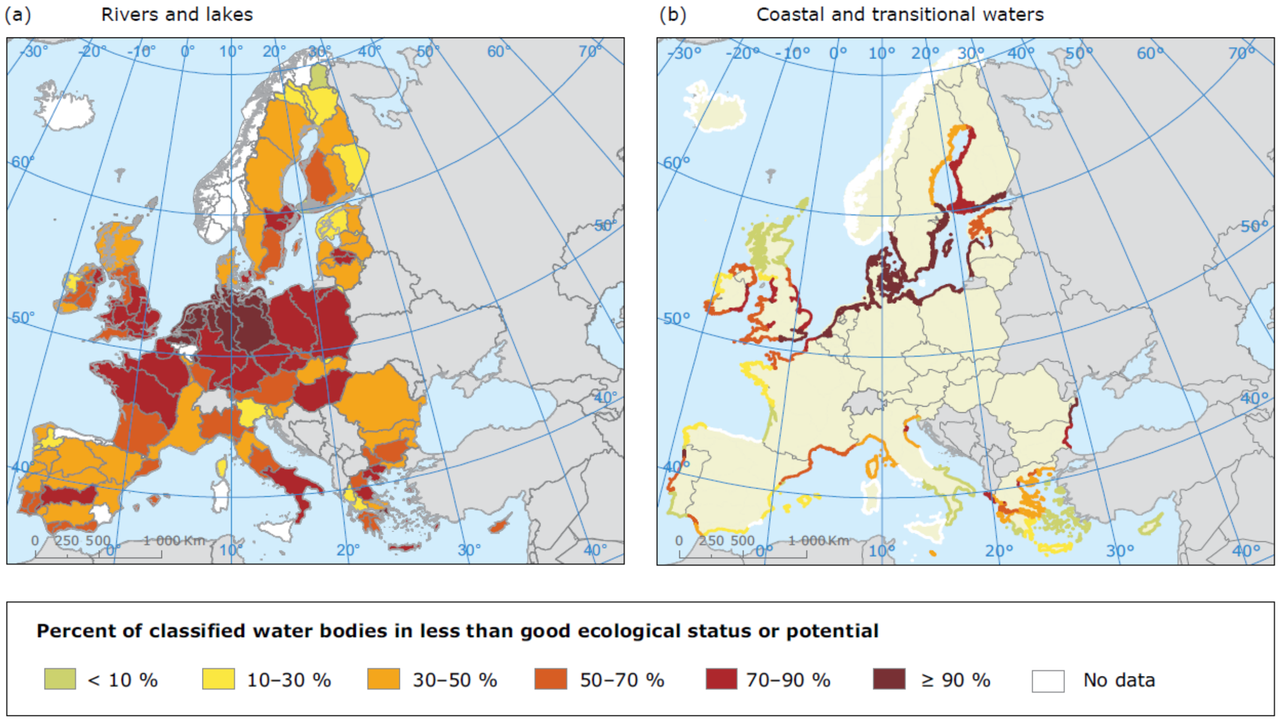
F > 50.000 km2: 31 rivers

State of European water bodies as reported under WFD

Figure 4.1 Distribution of ecological status or potential of classified rivers, lakes, coastal and transitional waters

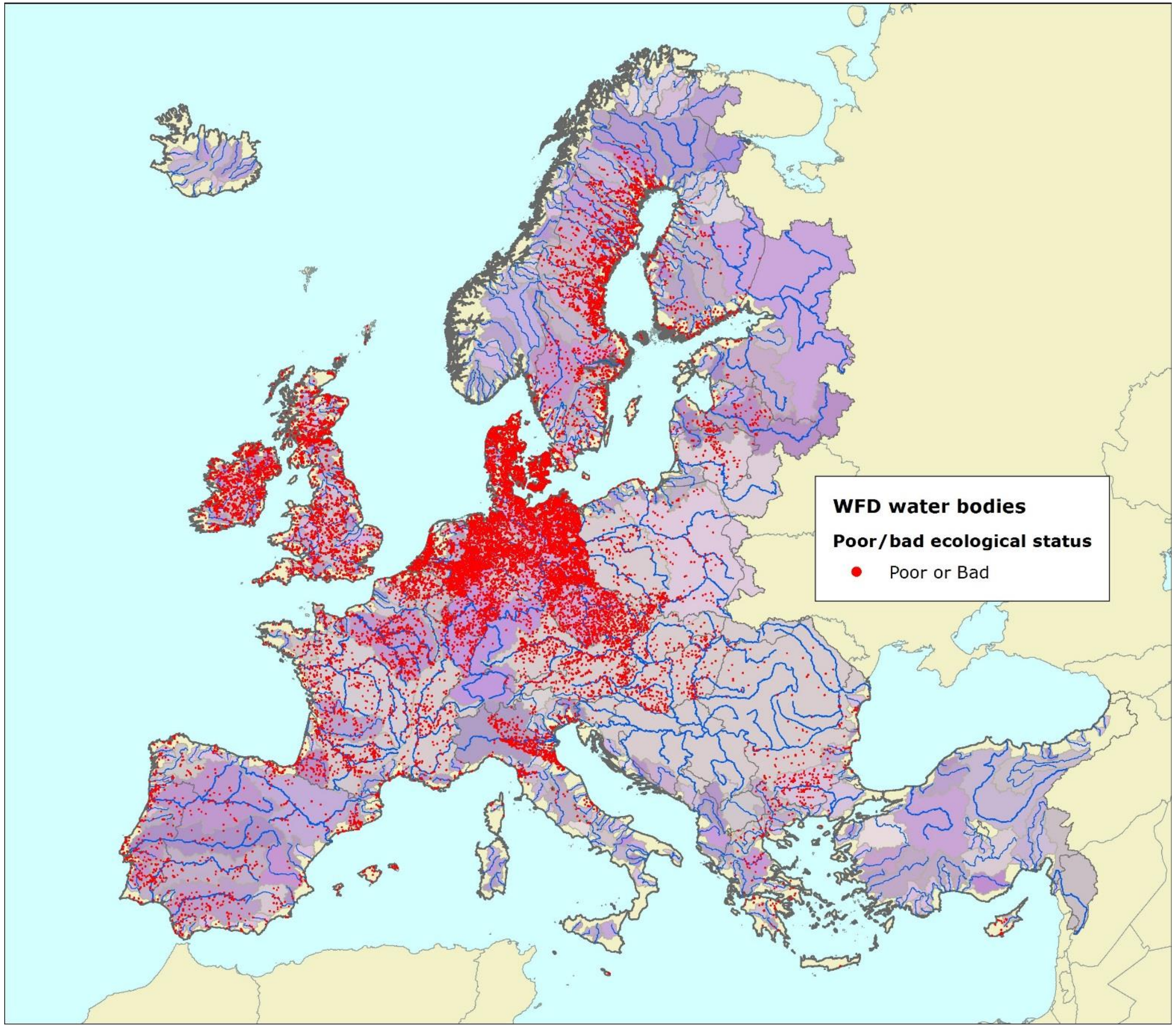


Map 4.1 Proportion of classified surface water bodies in different RBDs holding less than good ecological status or potential, for rivers and lakes (a) and for coastal and transitional waters (b)

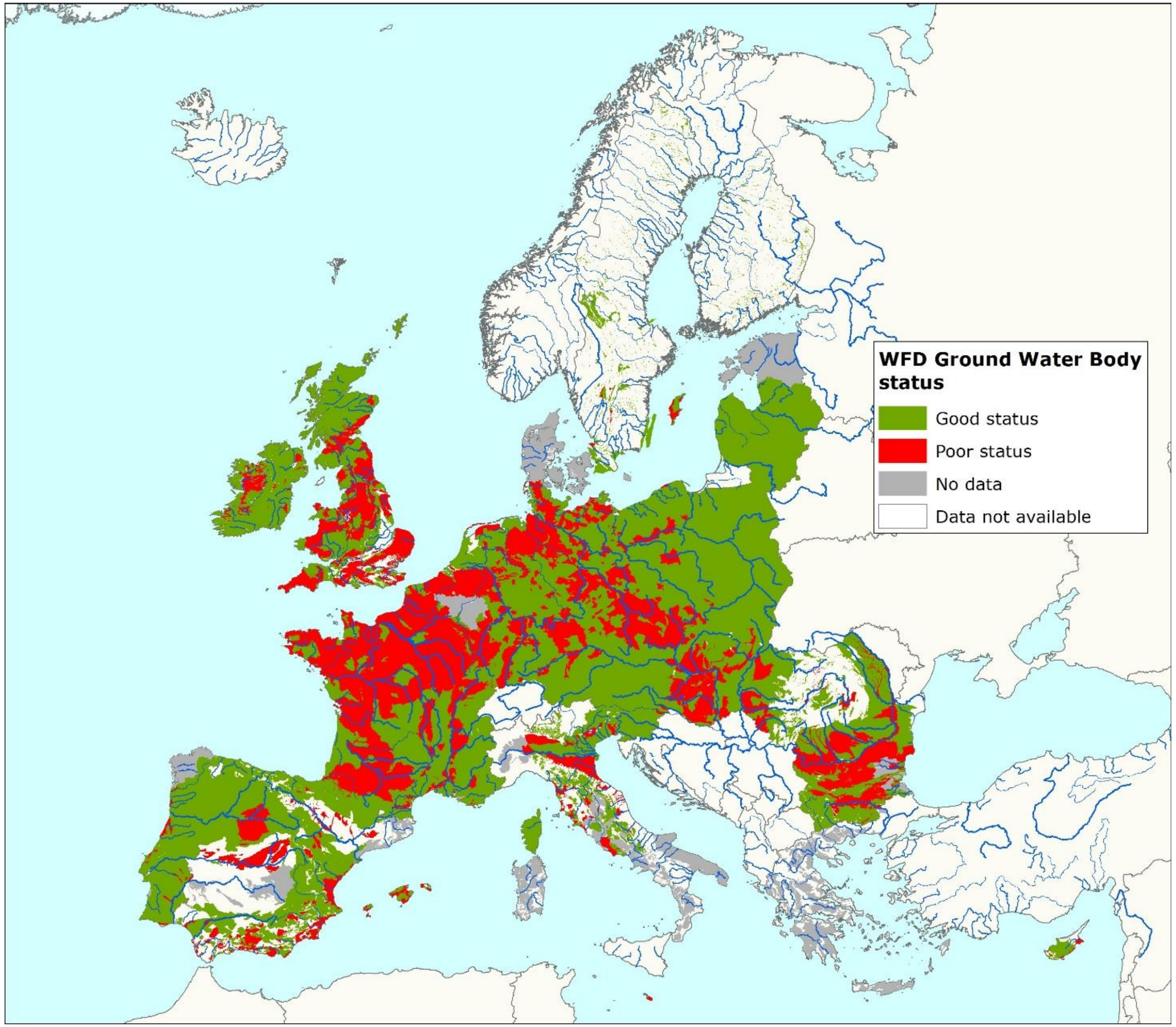


Source: European waters — assessment of status and pressures, EEA Report No 8/2012

State of European rivers:



State of European groundwater:



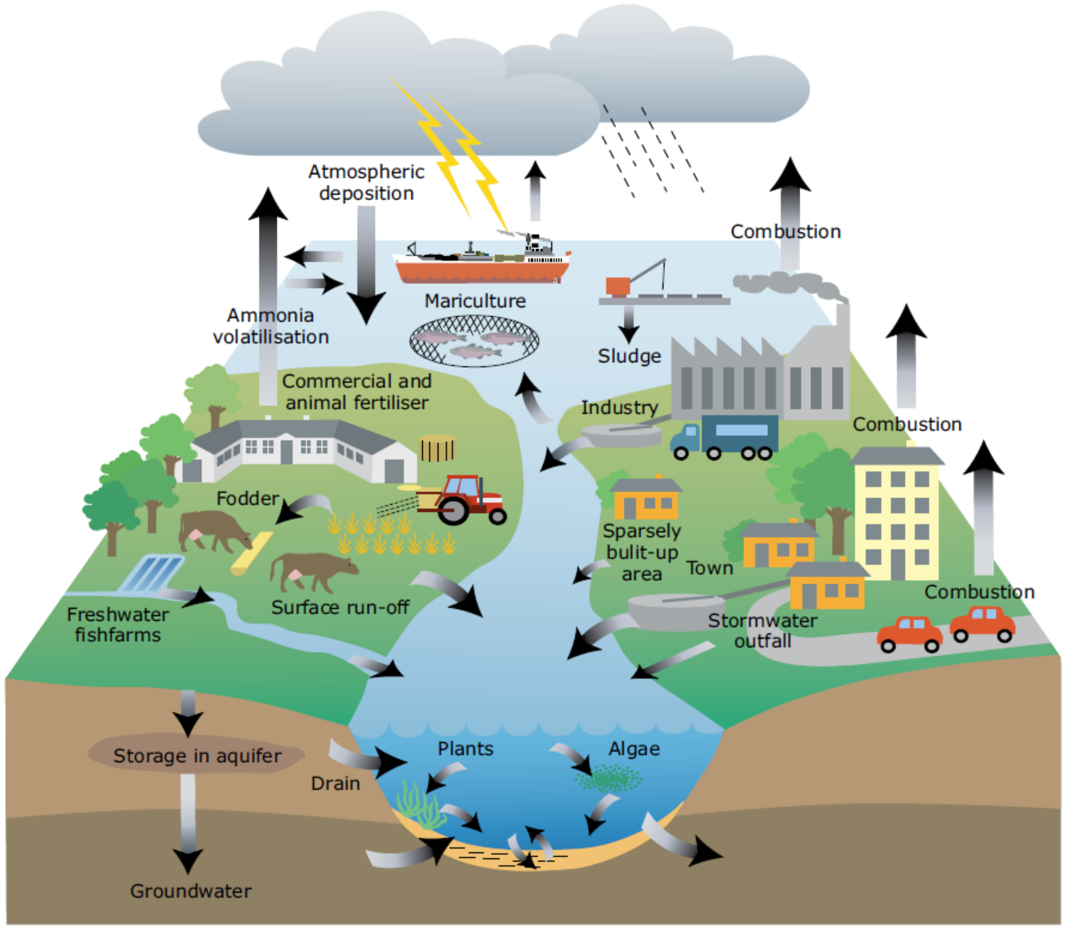
European water resources are highly impacted by humans:

Pollution and changes of natural character of water environment due:

- Industry
- Electricity production
- Agricultural activities
- Cities/urban areas emissions
- Traffic, water transporation and energy supply networks

Pressures:

- Point pollution (nutrients, organic and dangerous substances)
- Diffuse pollution
- Hydromorphological alterations (abstractions, channelisation, barriers, diversions, embankments)
- Other: fishing, allien species, waste disposal



Source: Ærtebjerg et al., 2003.

DPSIR framework

Drivers

An anthropogenic activity (e.g. agriculture, industry) or climate change phenomenon (climate warming, changes in precipitation) that may have an environmental effect

Pressures

The direct effect of the driver (for example, an effect that causes a change in flow or a change in the water chemistry)

State

The condition of the system under study (e.g. water body) resulting from both natural and anthropogenic factors (i.e. physical, chemical and biological characteristics)

Impact

Effects on human beings, ecosystems and man-made capital resulting from changes in environmental State with relevance for valued ecosystem phenomena (e.g.processes and/or components) actively or passively required, demanded, or used by man (e.g. ecosystem services), triggering social Response

Response

The management or policy measures taken to improve the state of the water body (e.g. restricting abstraction, limiting point source discharges, developing best practice Guidance for agriculture).

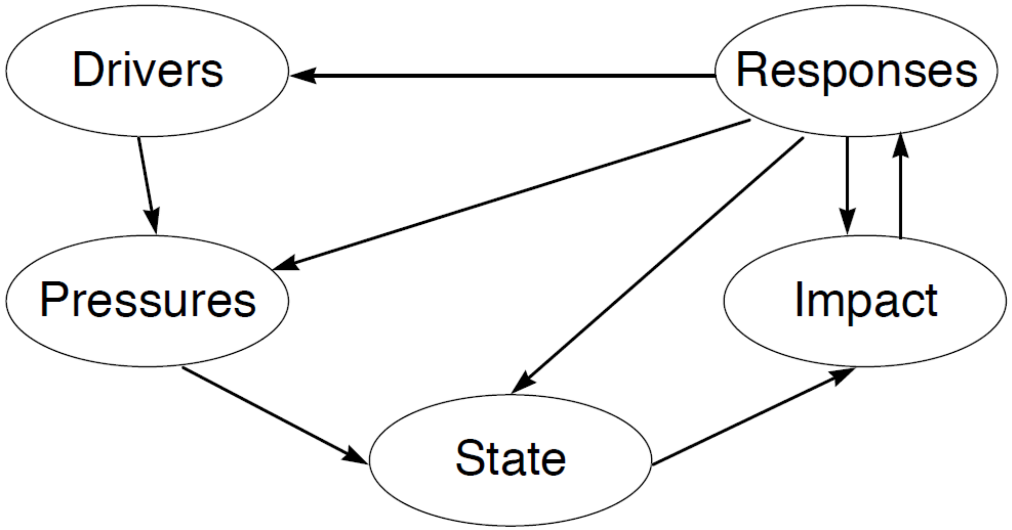
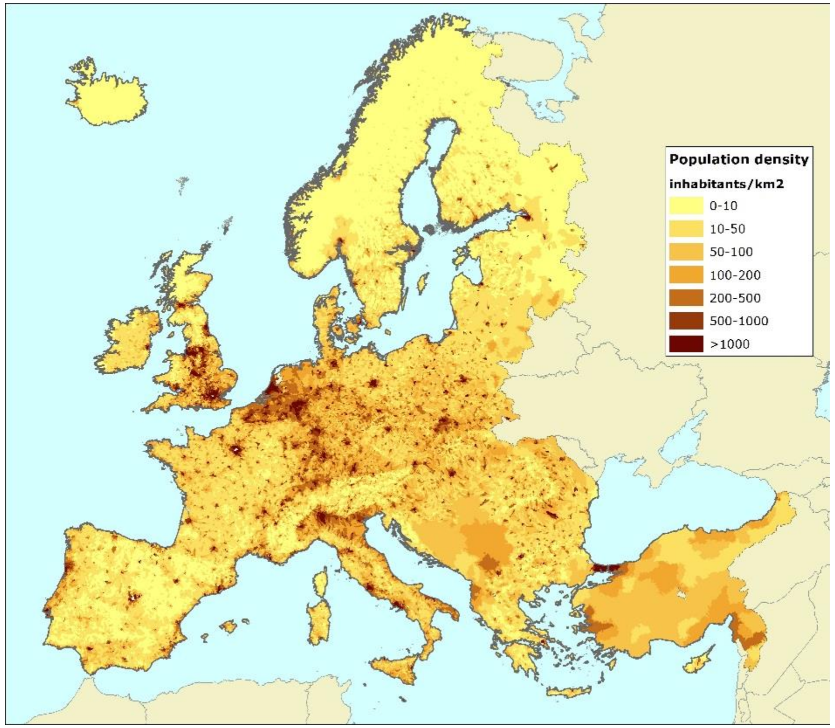
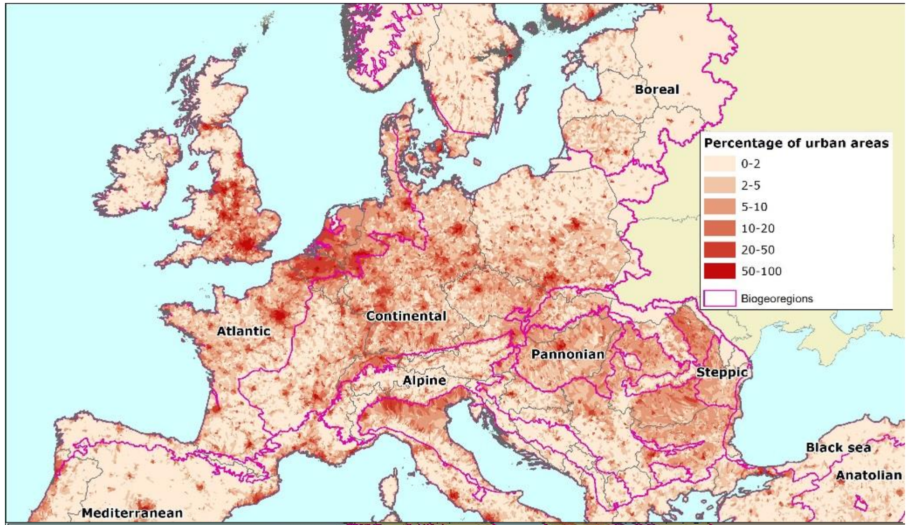


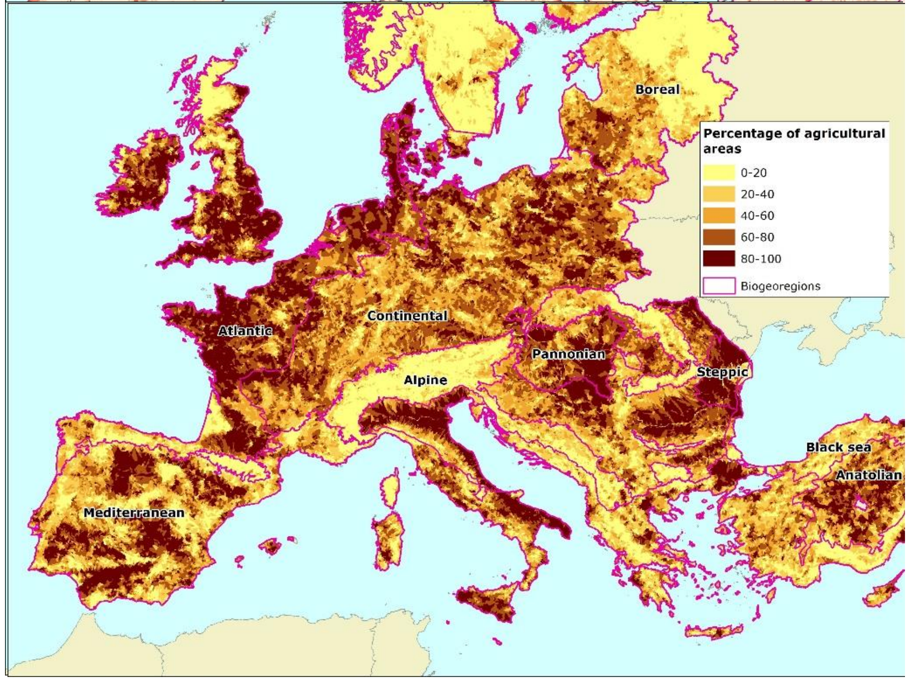
Figure 1: The DPSIR framework for reporting on environmental issues (EEA 1999)

Population/land use



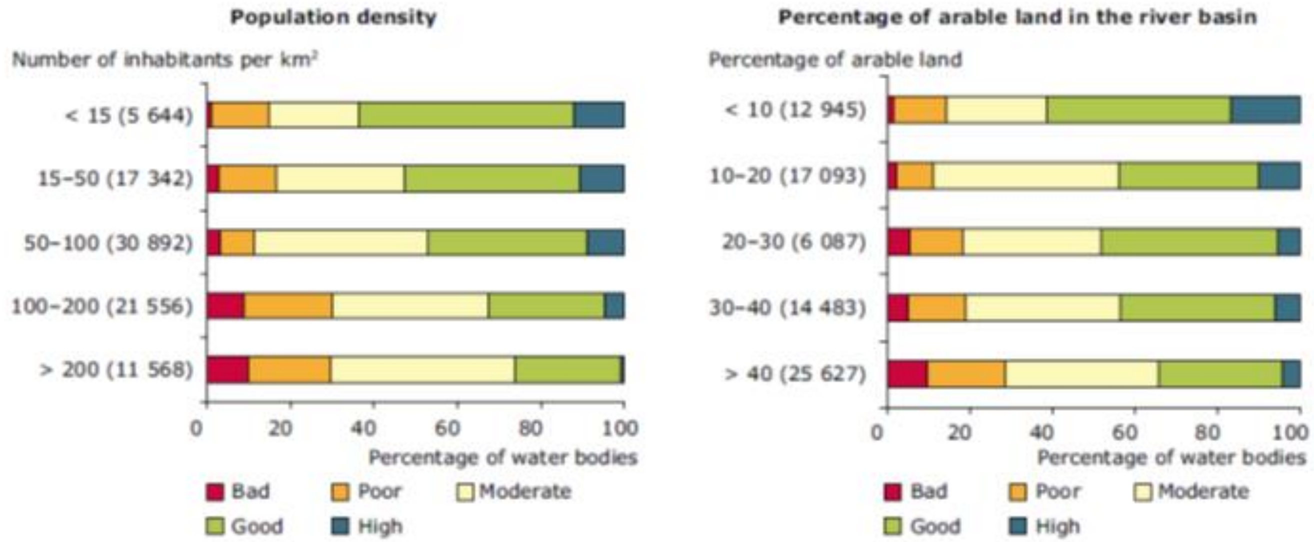


% of urban areas/FEC



% of agricultural areas/FEC

Pressures at European water bodies (as reported under WFD)

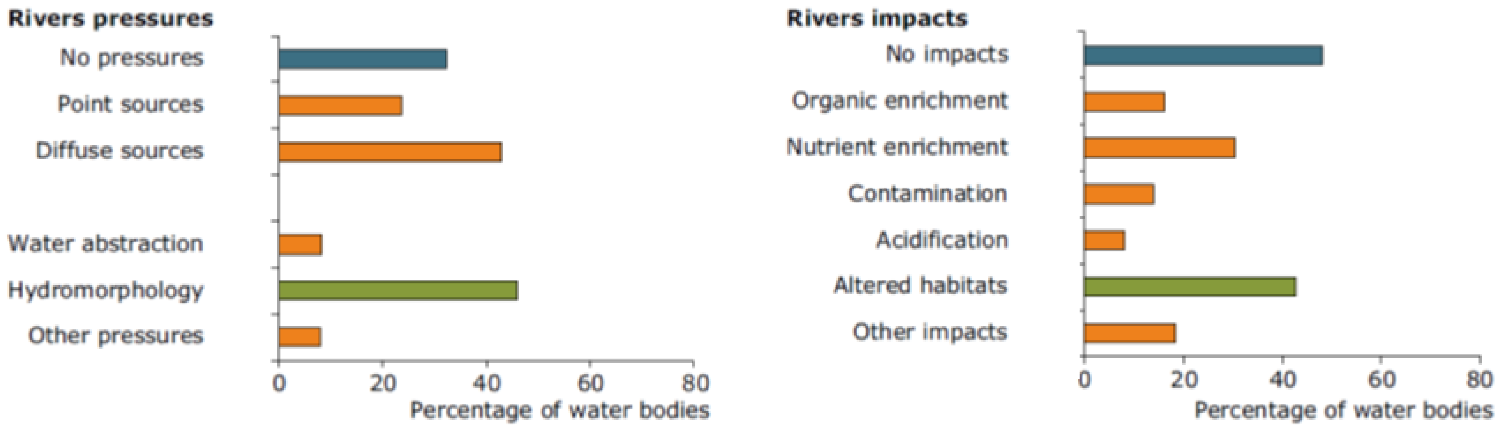


Ecological status according to
population density (left) and percentage of arable land in the river basin (right)

Source: European waters — assessment of status and pressures, EEA Report No 8/2012

Source: European waters — assessment of status and pressures, EEA Report No 8/2012

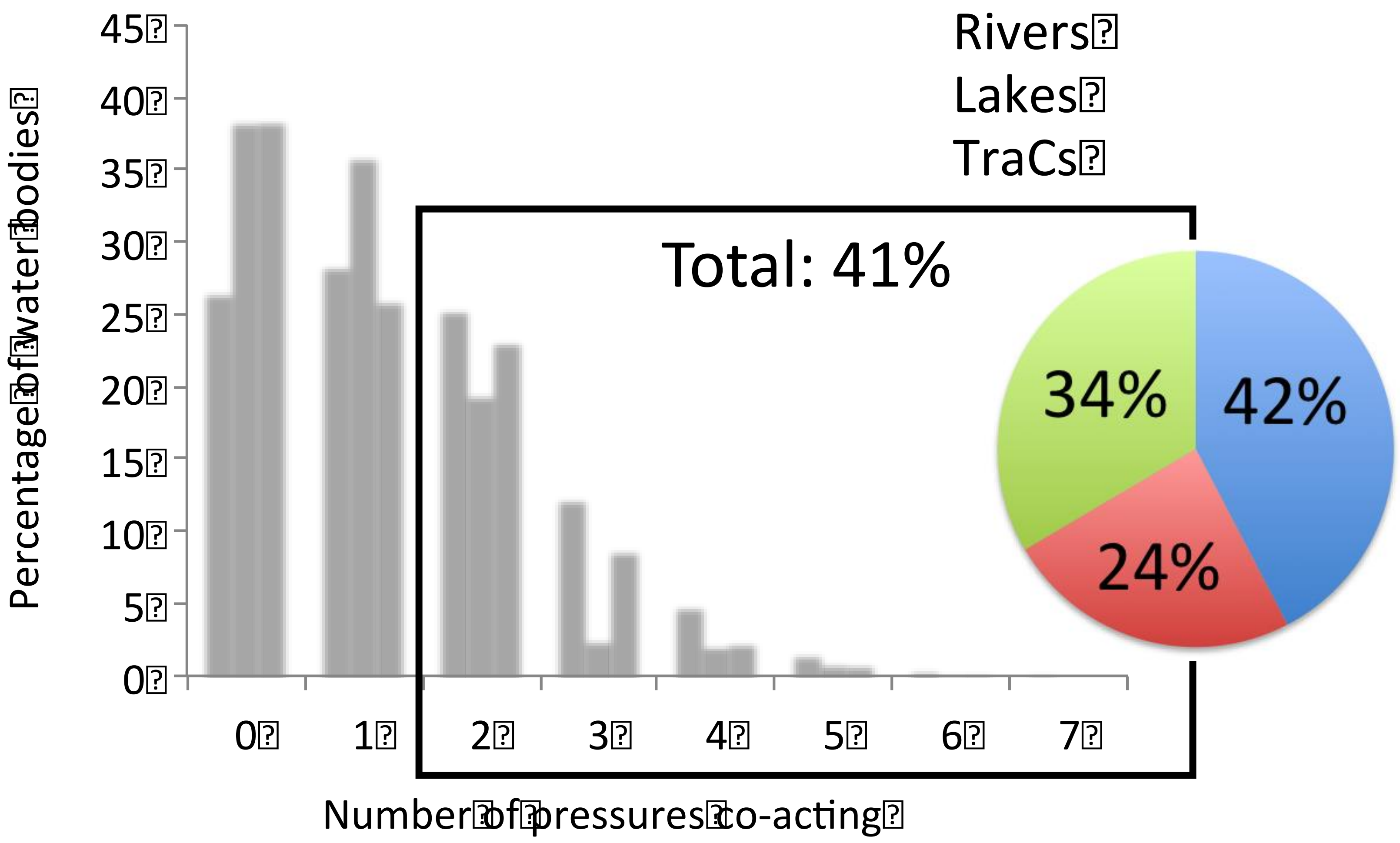
Pressures and impact on European rivers:



Proportion of total number of classified river water bodies with sgnificant pressures (left) and impacts (right)

Source: European waters — assessment of status and pressures, EEA Report No 8/2012

Multiple pressures (none, single, multiple)



Data source: WISE WFD database (EEA 2015; n = 108,130 water bodies of 26 EU Member States)

„stressors“ – „response“ concept

A ***stressor*** is any environmental change in a factor that exceeds the normal variation and causes some **response** by the system of interest (Odum 1985, Underwood 1989, Kolasa & Pickett 1992, Piggott et al. 2015).

The system of interest can be at any organizational level, e.g. **organism, population, ecosystem.** *A direct stressor* represents the immediate cause of an effect (e.g. oxygen depletion causing suffocation of fish).

Multiple stressors (from DPSIR: P and/or S) – how do they interact?

- **Simple:** effect of all stressors combined equal to sum of individual effects

- Complex: combined effect smaller or larger than predicted from single effects

Antagonistic, synergistic, multiplicative (additive) effect (response)

STATE OF THE ART

1 + 1 = 2 ***Additive effects of two stressors co-acting***

KNOWLEDGE GAP:

1 + 1 = 3 ***Synergistic effects of two stressors co-acting***

1 + 1 = (<) 1 ***Antagonistic effects of two stressors co-acting***

Implication for water managment:

- Managers need to know causes of harm and to define thresholds of harm (limits)

- Almost always multiple stressors at work, so managers may get it wrong if stressors interact in unexpected ways

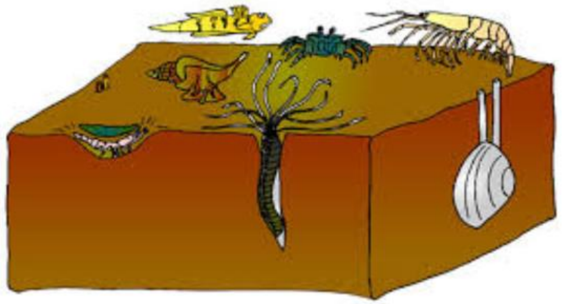
1 + 1 = 2 (*Additive effects):* Management addressing largest stressor has greatest benefit

1 + 1 = 3 (*Synergistic effects):* Management of individual stressor **effect**

1 + 1 = 1 (*Antagonistic effects):* Mitigation of single stressor may adverse effects

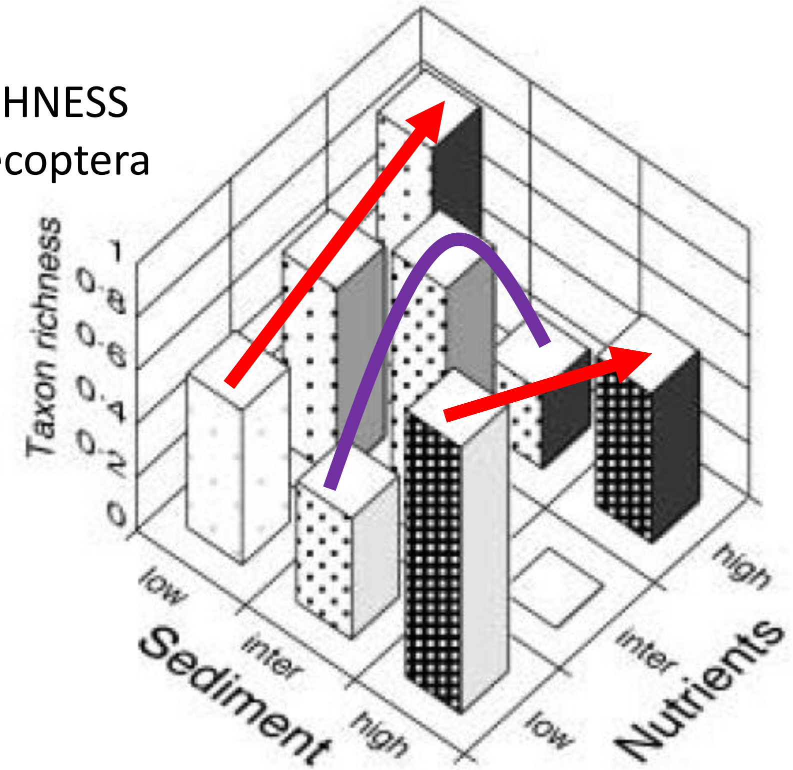
Combined responses to multiple stresssor – experiments and surveys

Two principal stressors, **nutrient concentration and streambed fine sediment cover** in grassland streams converted to pasture in New Zealand (Townsend et al. 2008) – respnoses of benthic invertebrates, field survey and experiments;



INVERTEBRATE TAXON RICHNESS (EPT - Ephemeroptera, Plecoptera and Trichoptera)

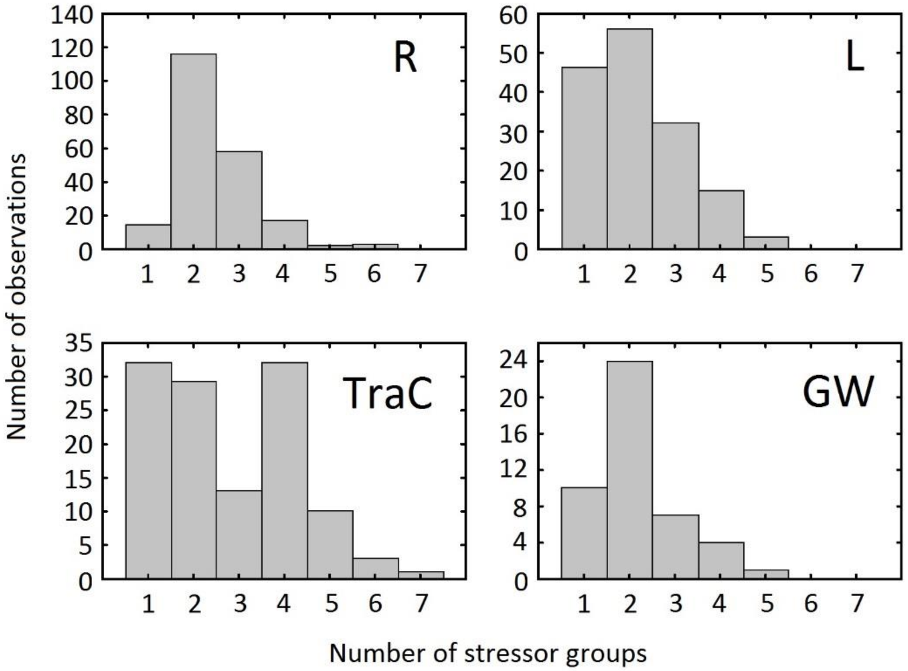
Experiment:
Richness increased with sediment cover at low nutrient concentrations, and increased with nutrient concentration at low sediment cover, but a significant ‘interaction’ term occurred because EPT richness was lowest where both sediment cover and nutrient concentration were intermediate or high (antagonistic multiple stressor response).
Field surveys:
EPT taxon richness was negatively related to sediment cover and unrelated to nutrient concentration.



What do we know?

(Systematic literature review including 219 scientific publications (Nõges et al., 2015 STOTEN)

Number of stressor combinations documented in scientific literature:

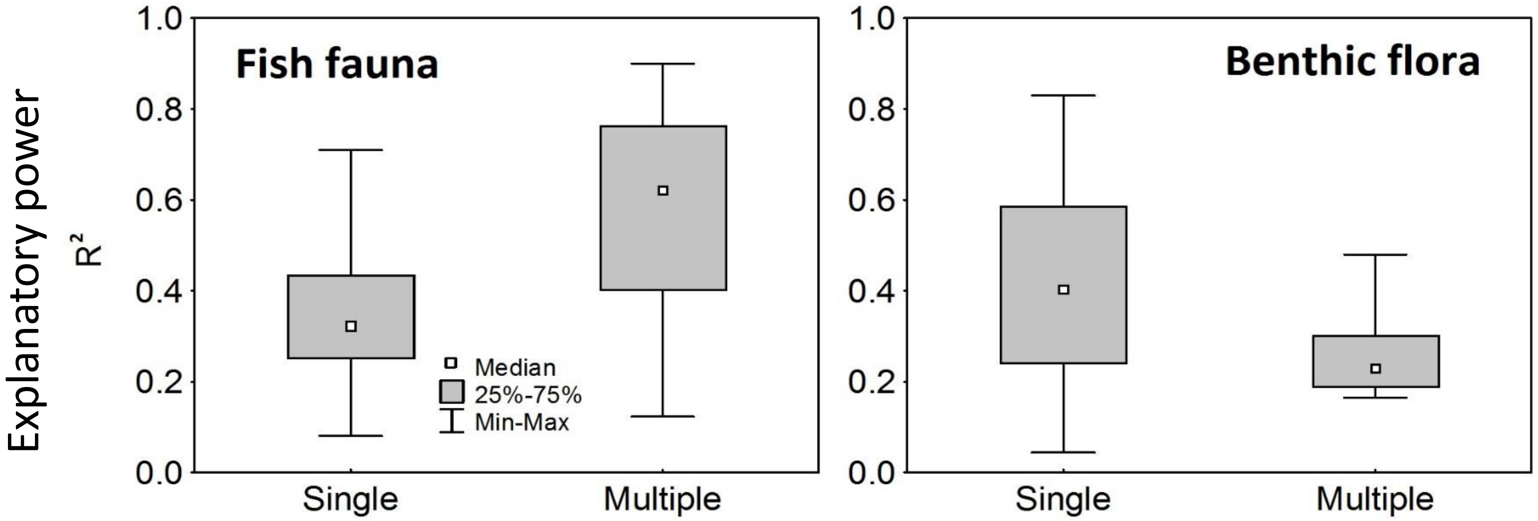


Number of simultaneously acting stressor groups analysed in the reviewed literature

Two-stressor effects studied most frequently (42%)

Source: Birk, S., Nõges, P., Hering, D.: Managing multiple stress for multiple benefits-Towards new scientific concepts, methods and tools in river basin management (SEFS Conference, Geneva, 10 July 2015.

What do we know?
(Systematic literature review including 219 scientific publications (Nõges et al., 2015 STOTEN)



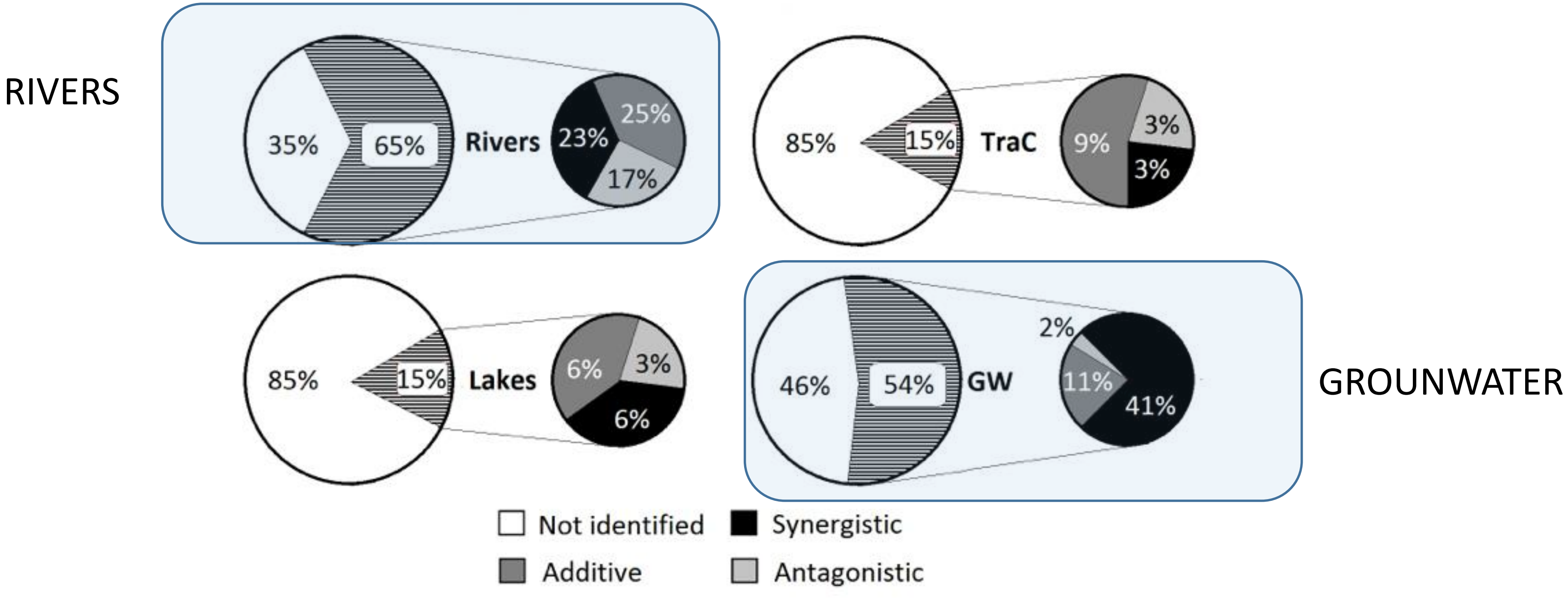
Significant differences in explanatory power between single and multiple stress-effect models by biological group

Source: Birk, S., Nõges, P., Hering, D.: Managing multiple stress for multiple benefits-Towards new scientific concepts, methods and tools in river basin management (SEFS Conference, Geneva, 10 July 2015.

What do we know?

(Systematic literature review including 219 scientific publications (Nõges et al., 2015 STOTEN)

Relevance of synergistic and antagonistic effects:



Interactions between stressors in multiple stress relationships by water categories

Source: Birk, S., Nõges, P., Hering, D.: Managing multiple stress for multiple benefits-Towards new scientific concepts, methods and tools in river basin management (SEFS Conference, Geneva, 10 July 2015.

MARS – new concepts, methods and tools for river basin management; knowledge based decisions

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Managing aquatic ecosystems and water resources under multiple stress — An introduction to the MARS project

Daniel Hering [a,*], Laurence Carvalho [b], Christine Argillier [c], Meryem Beklioglu [d], Angel Borja [e], Ana Cristina Cardoso [f], Harm Duel [g], Teresa Ferreira [h], Lidija Globevnik [i], Jenica Hanganu [j], Seppo Hellsten [k], Erik Jeppesen [l], Vit Kodeš [m], Anne Lyche Solheim [n], Tiina Nõges [o], Steve Ormerod [p], Yiannis Panagopoulos [q], Stefan Schmutz [r], Markus Venohr [s], Sebastian Birk [a]

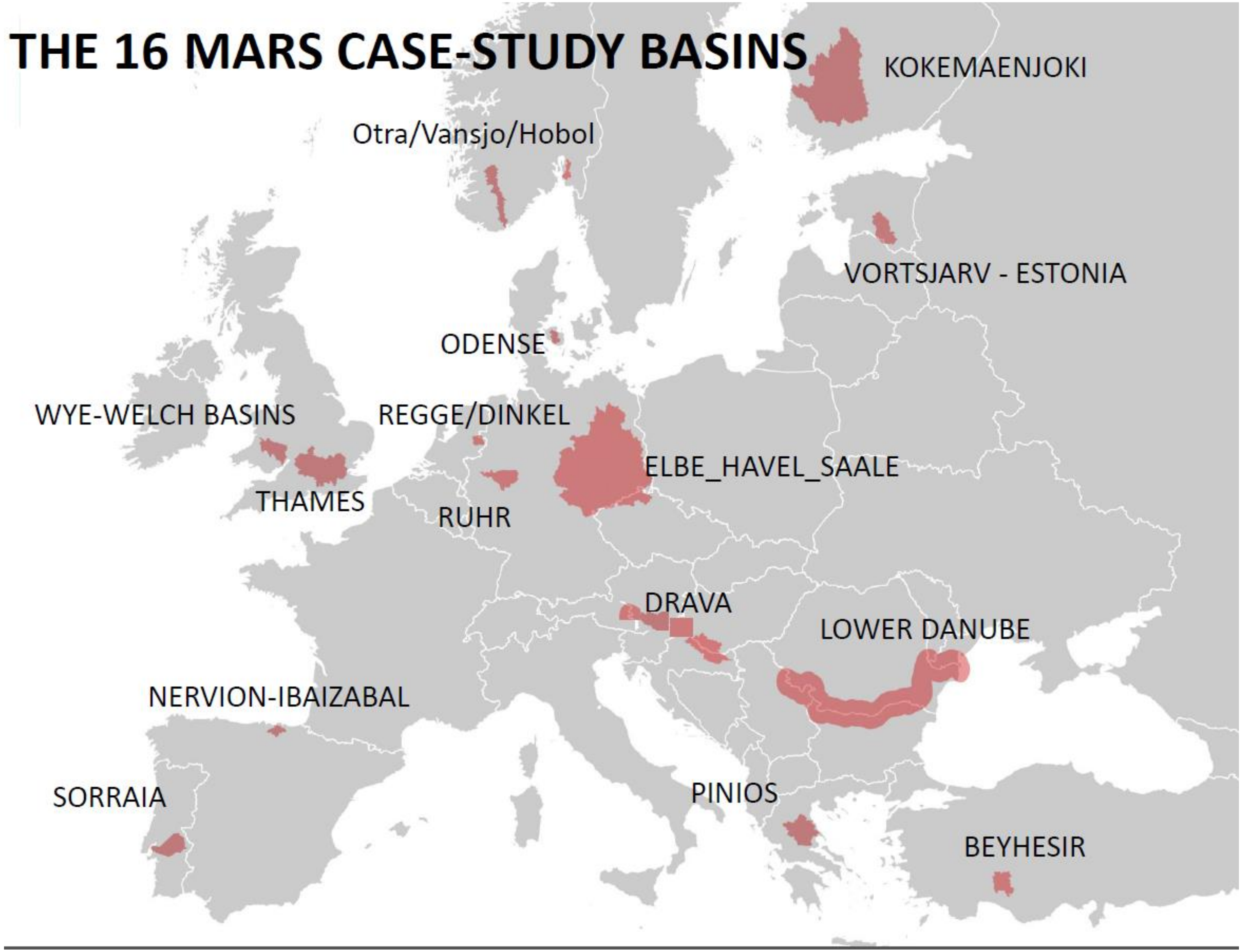
(new concepts, methods and tools in river basin management)

MARS experimental facilities (WP 3)

LakeLab IGB/Berlin (http://www.lake-lab.de/)

HyTEC site (http://hydropeaking.boku.ac.at/hytec_en.htm)

MARS catchment pilot studies (WP 4)

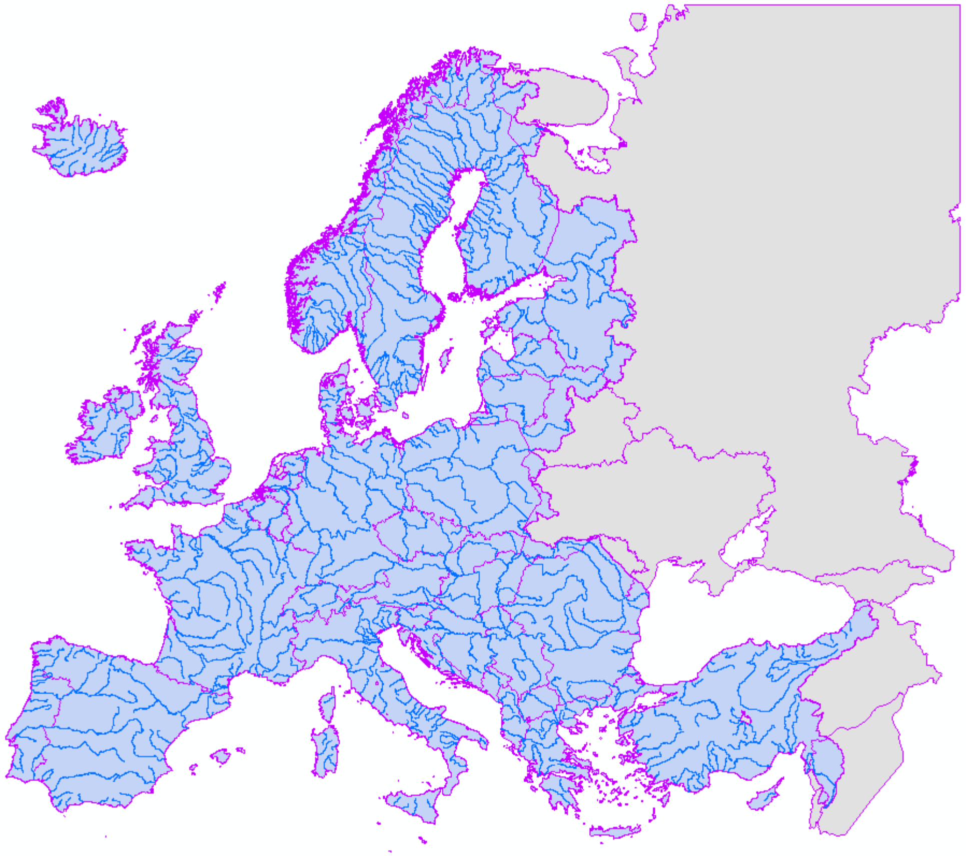


1) Southern Europe: rivers are affected by water scarcity from abstraction, groundwater over-exploitation and flow regulation. Flows are often inadequate to support biota, nutrients, wastewater and pesticides are poorly diluted.

2) In Central Europe: affected by water abstraction for water power generation, channelisation and pollution.

3) In Northern Europe: affected by water abstraction and increasing temperature. Additional stress includes channelisation, diffuse agricultural pollution, acidification, brownification and pollution by toxic and organic pollutants.

MARS European level study (WP 5)



Geo-database

- Multiple stressors
- Ecosystem status

Analysis stressors-response relations

- multi-stressors classification of European regions (typology of classes)
- response of status

E-FLOW
response of ecological status to low flow

Ecosystem Services (regulating, provisioning, cultural)

Analysis stressors-response:

LAKES
response of phytoplankton, macrophytes

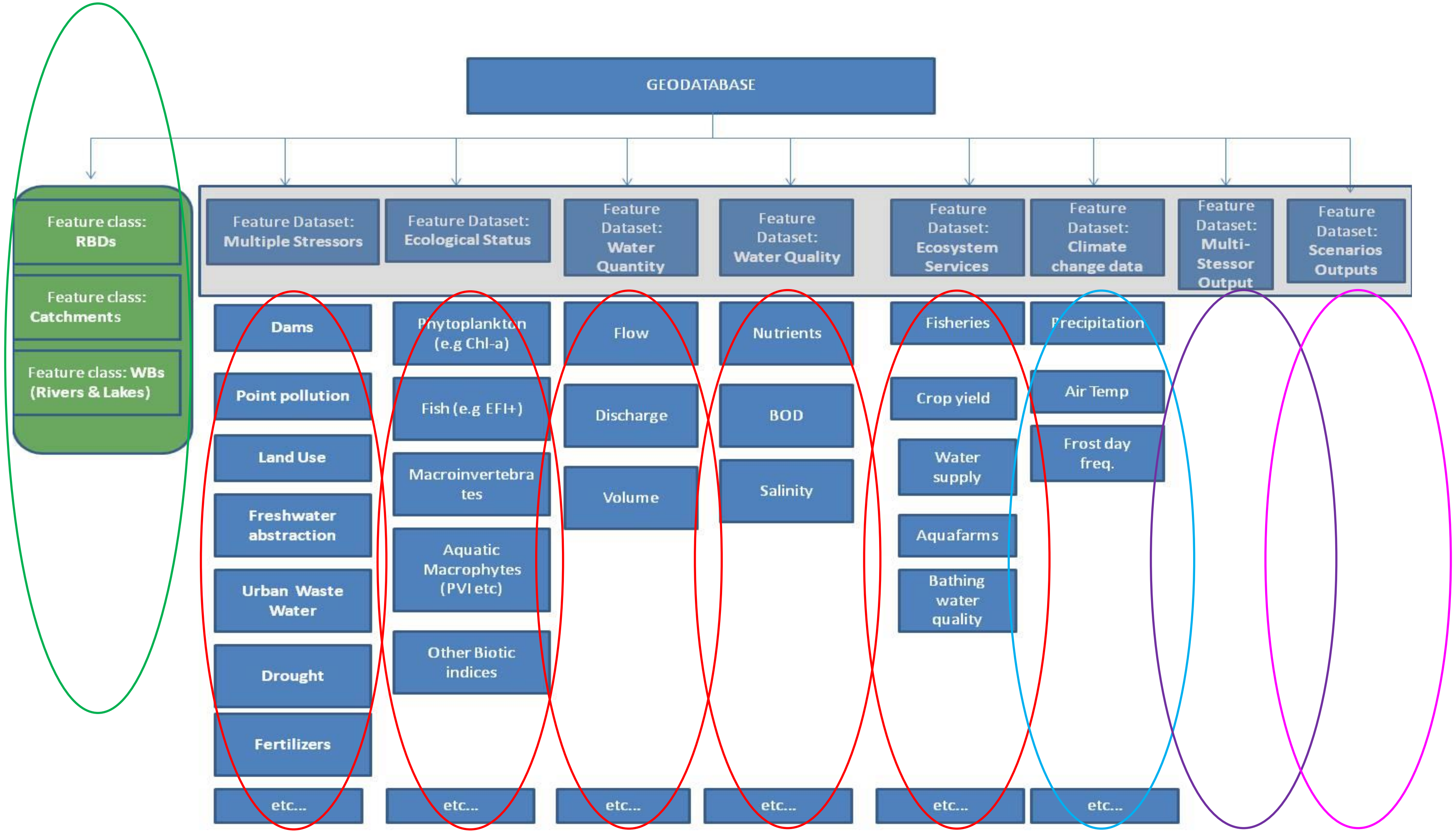
RIVERS
Legacy and tipping points
Assessment system for large European rivers

FISH
response of functional diversity indices
sensitivity of fish metrics
position of exotic species

Geo-database (MARSgeoDB)

Building Geodatabase

- Feature datasets: each dataset has feature classes
- Data in each feature class are arranged by spatial objects in the attribute table(s)
- European climate data series of projected climate variables under various climate scenarios
- analyses will produce new **Feature Datasets** - synthesized layer of *Multi-Stressors*



Multiple stresssor – impact (response)

European data sets:

- WFD data (impact data)
- EUROSTAT data (drivers / pressures data)
- UWWTD data (drivers / pressures data)
- SoE water quality data, SoE and EWA water quantity data
- E-PRTR data (European Pollution Release and Transfer Register)

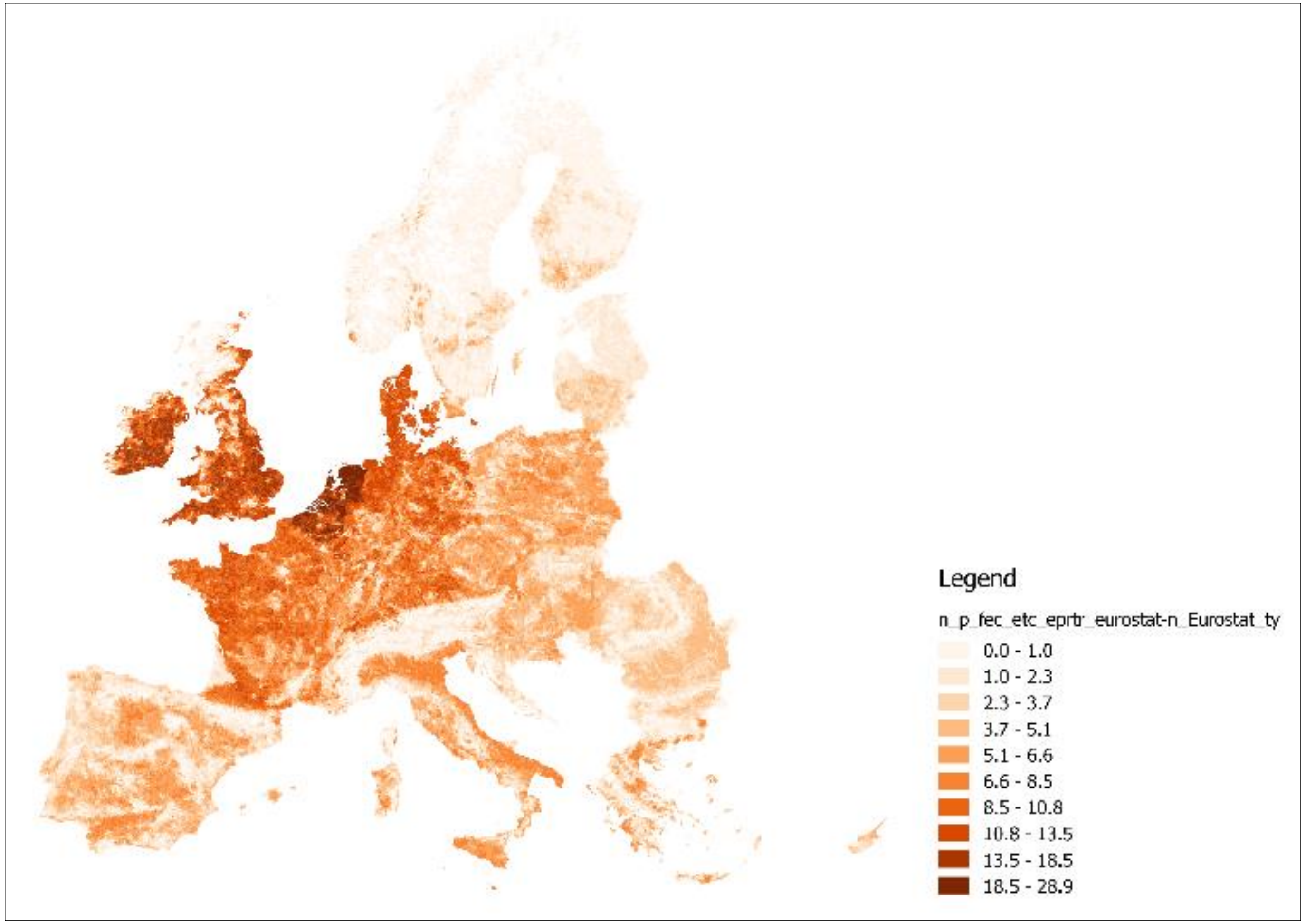
Modelled data (JRC- Green, IGB - Moneris)

Nutrient pollution (nitrogen, phoshorus) – monitoring data

Nitrogen input by agriculture (EUROSTAT) in 2010 *(data available 1992-2012)*

- Total N
- t/y/NUTS …..
- Loads in one NUT distributed in relation to share of agricultural land in FECs inside NUTS **[t/y/(km2 of FEC)]**

5 - 15 t/y/km2



Nutrient pollution (nitrogen, phoshorus) – monitoring data

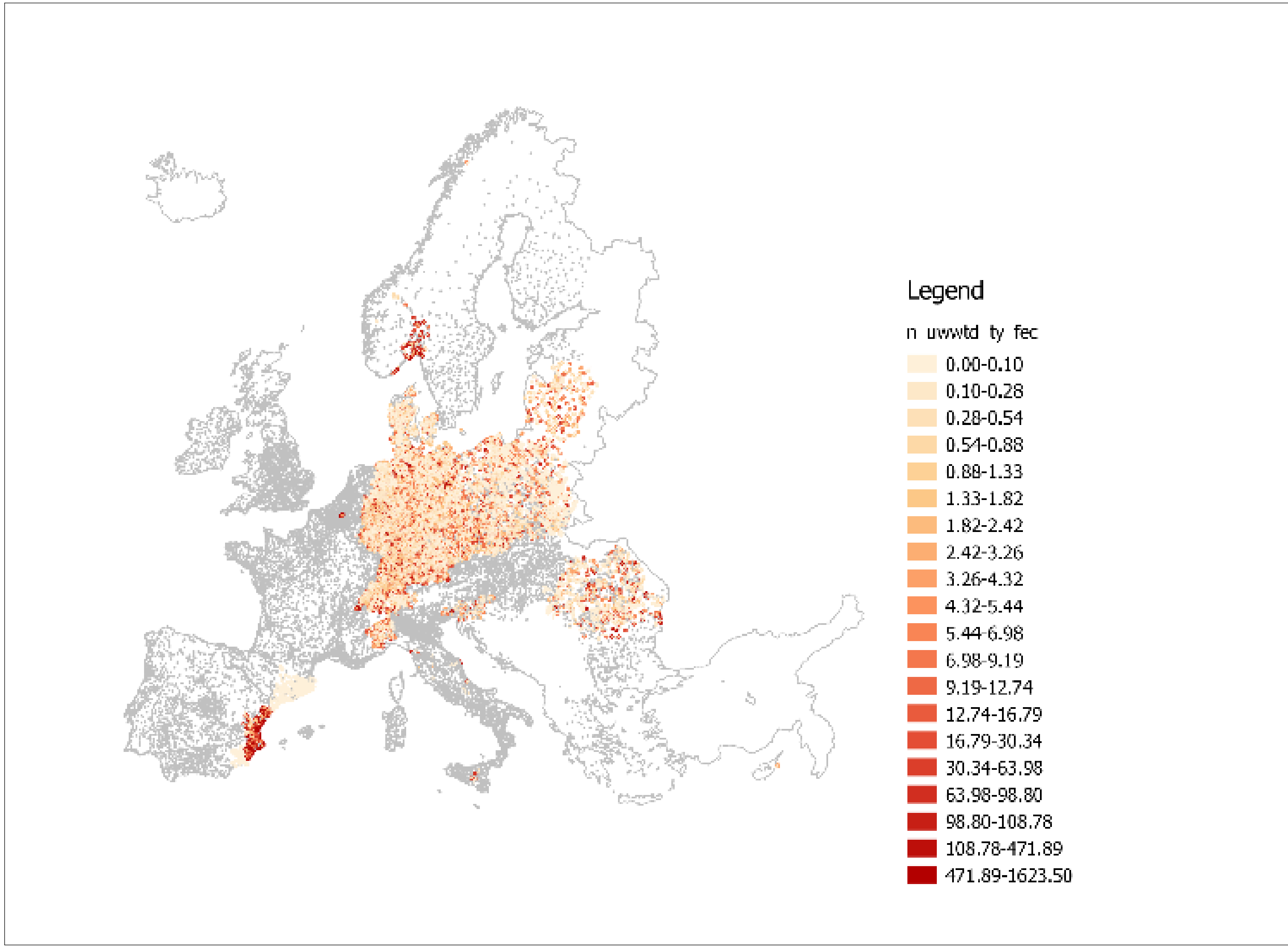
Nitrogen input by treated waste water (point sources, UWWTD) in 2010

- 8700 point objects
- t/y/(UWWT discharge point to water)
- For use in MARS: data linked to river segments and aggregated to FEC and hinterlands.
- Loads in FEC [t/y/(km2 of FEC)]

0.5 - 2 t/y/km2

Nitrogen input by un-treated waste water (point sources, UWWTD) in 2010

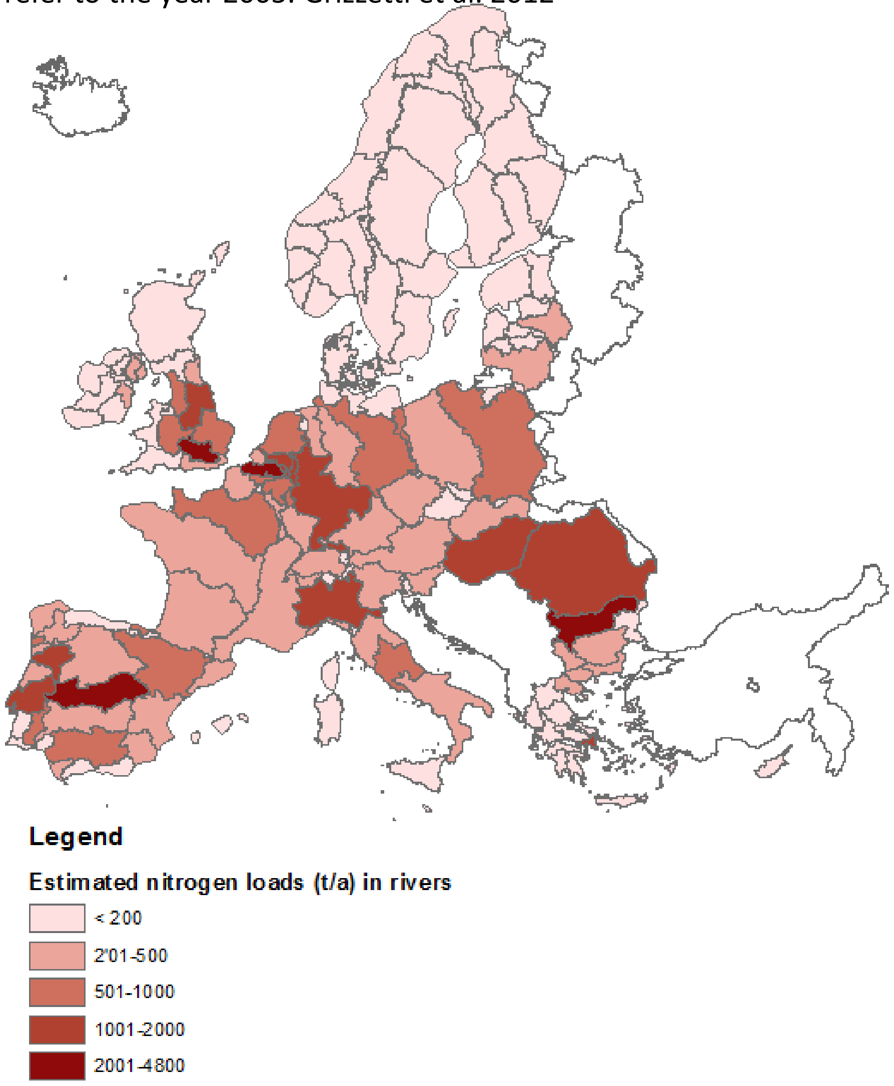
1 – 20 t/y/km2



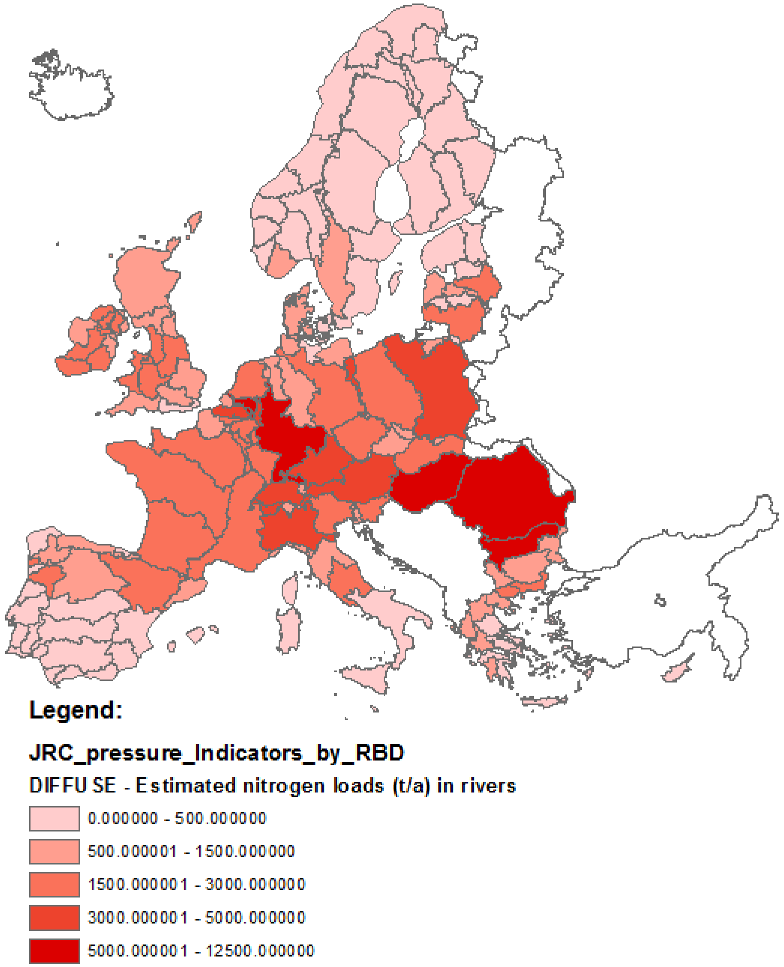
Nutrient pollution (nitrogen, phoshorus) - modeling results:

Nitrogen

POINT SOURCE: Estimated nitrogen loads (t/a) in rivers, based on the model GREEN. Values refer to the year 2005. Grizzetti et al. 2012



DIFFUSE SOURCE: Estimated nitrogen loads (t/a) in rivers, based on the model GREEN. Values refer to the year 2005. Grizzetti et al. 2012

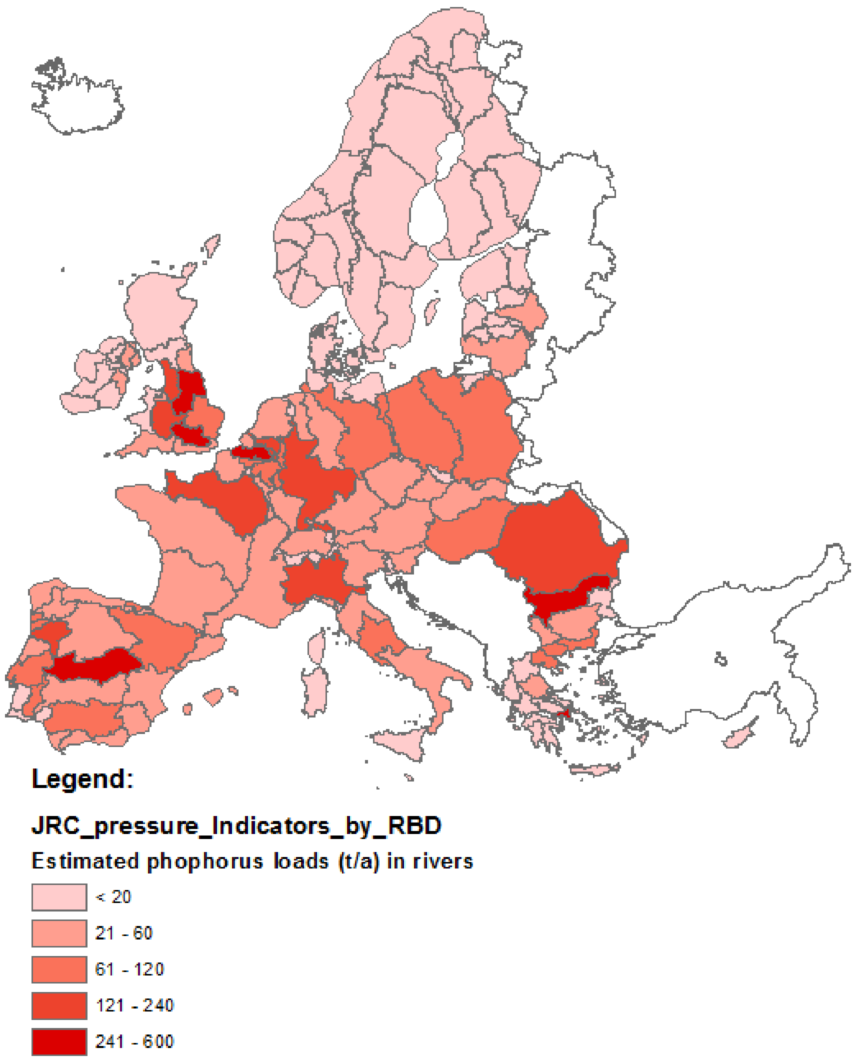


MARS PROJECT

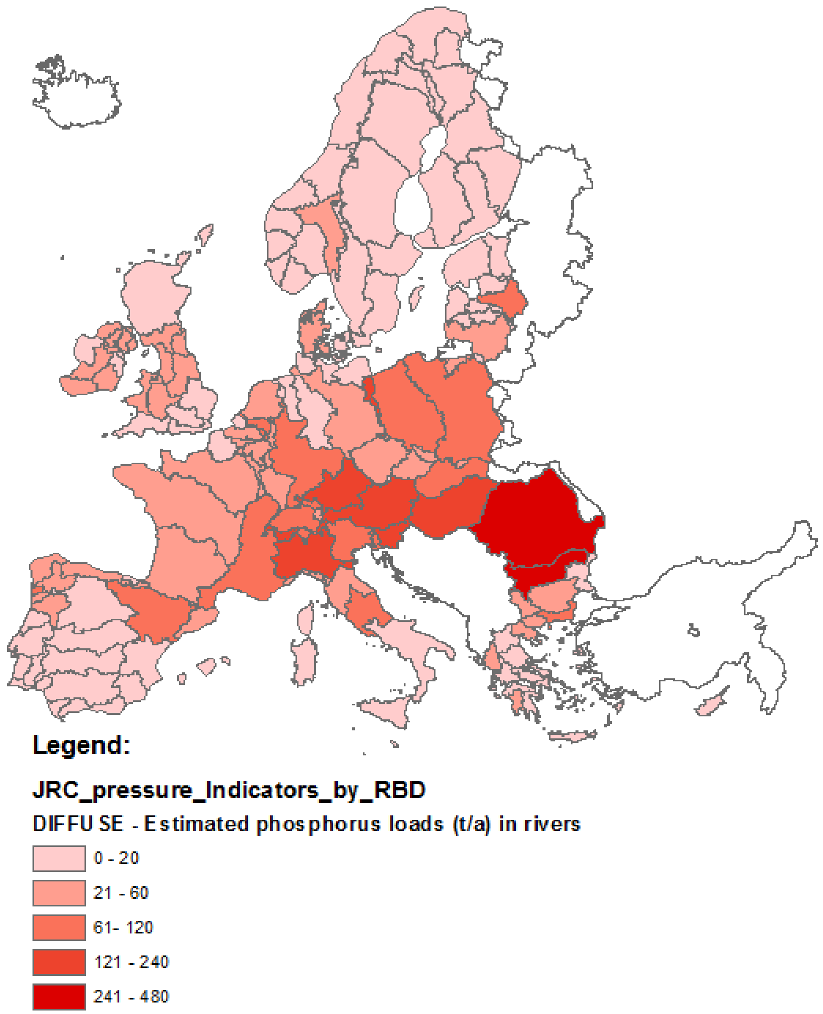
Multiple stresssor – impact (response) analysis with modeling:

Phosphorus

POINT SOURCE: Estimated phosphorus l loads (t/a) in rivers, based on the model GREEN. Values refer to the year 2005. Grizzetti et al. 2012

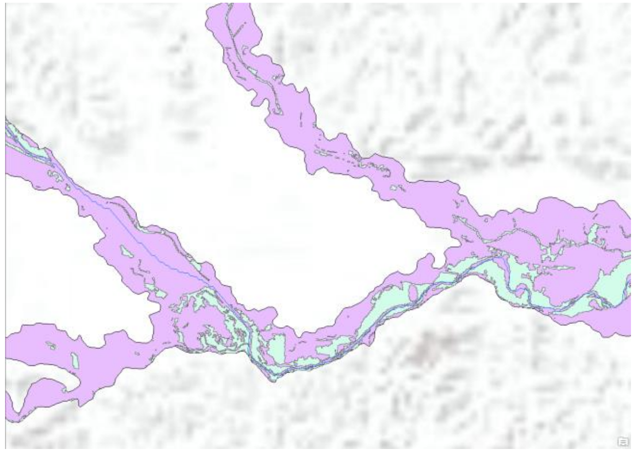


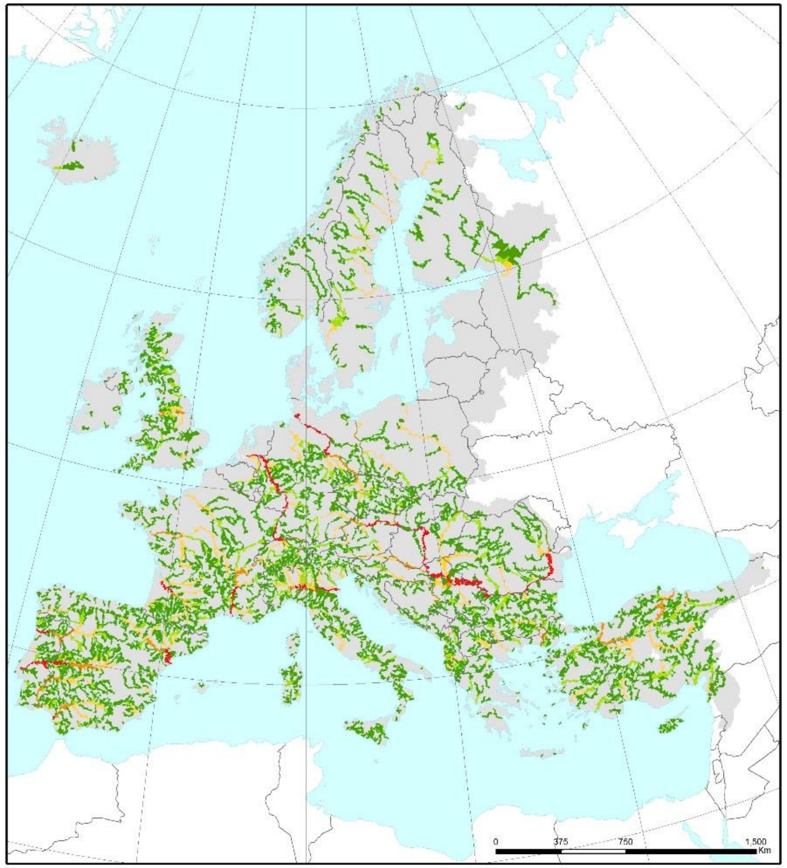
DIFFUSE SOURCE: Estimated phosphorus loads (t/a) in rivers, based on the model GREEN. Values refer to the year 2005. Grizzetti et al. 2012



Hydromorphological pressures – monitoring, field surveys/interpretation

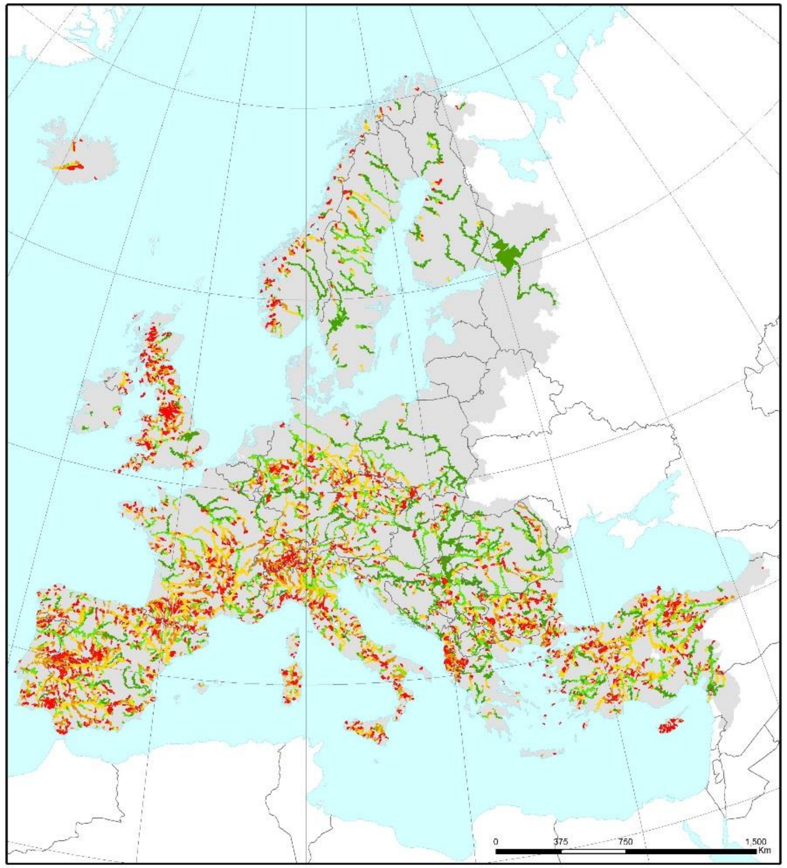
- 1392 barriers on main rivers
- 5043 all dams
- 70% riparian& flood araes were changed to agricultural/urban





HYMO 3a: Number of dams in FEC catchment

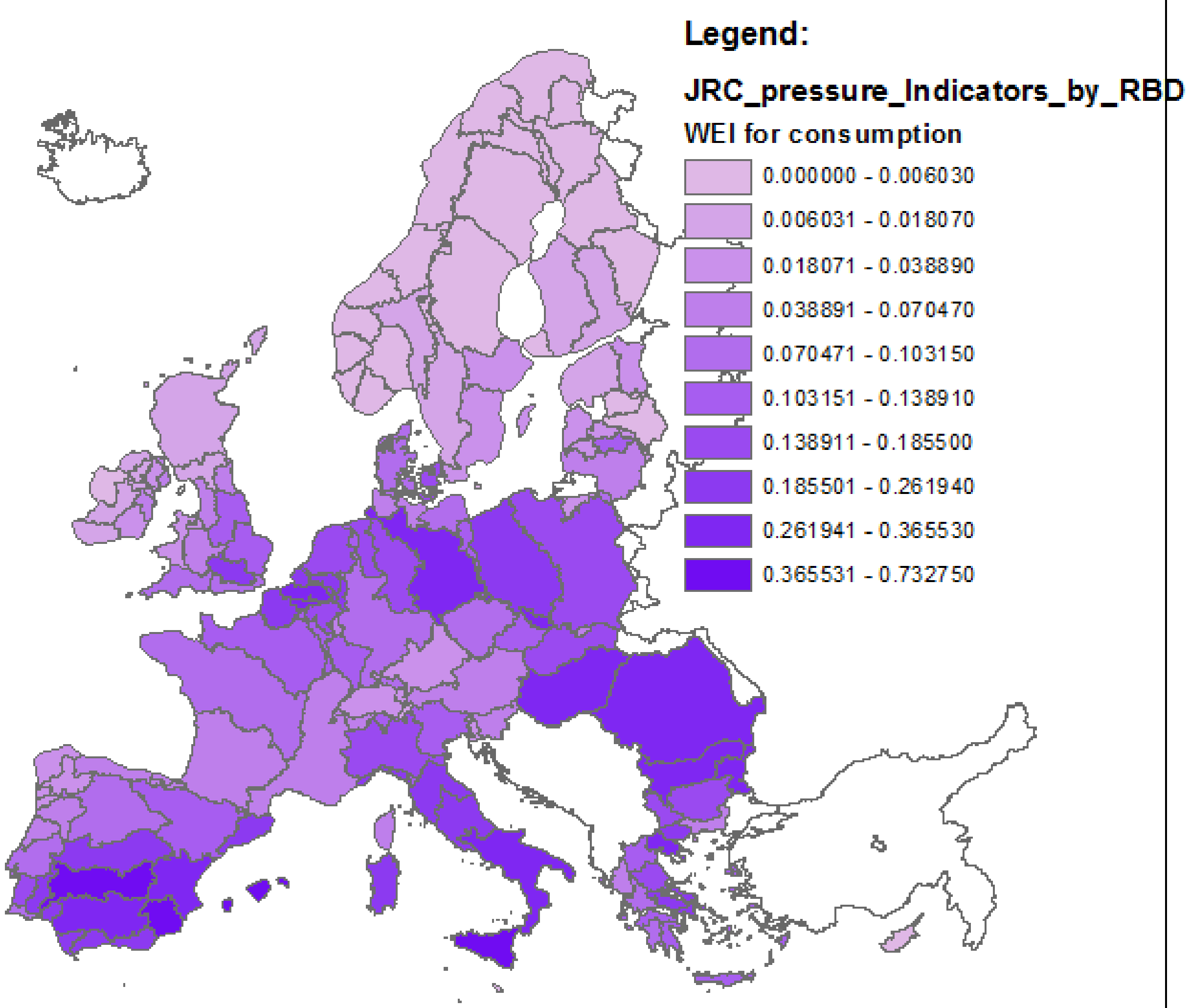
0 or no data aavailable	Coastline
>0 - 5	Country borders
>5 - 10	Outside MARS extent
>10 - 50	
>50 - 100	
>100 - 500	



HYMO 3b: Percentage of catchment area intercepted by dams on FEC

0 or no data available	Coastline
>0- 5	Country borders
>5 - 10	Outside MARS extent
>10 - 20	
>20 - 50	
>50 - 100	

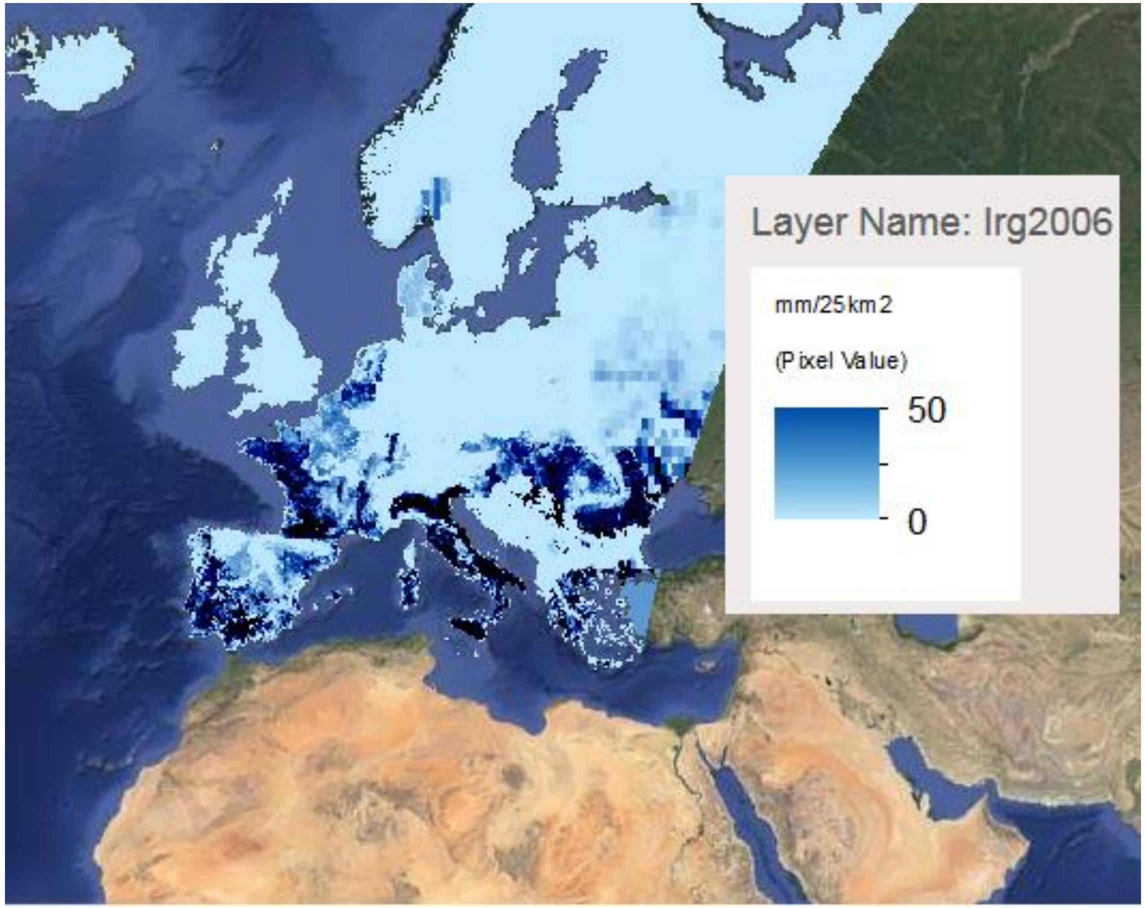
Hydromorphological pressures - modeling results:



Water exploitation index (WEI) for abstractions by RBD (River Basin Districts)

JRC for Water Blueprint Assessment, (referred to surface waters only). The WEI is computed as the ratio of gross consumption to water availability (locally generated + flowing from upstream) (De Roo et al. 2012)

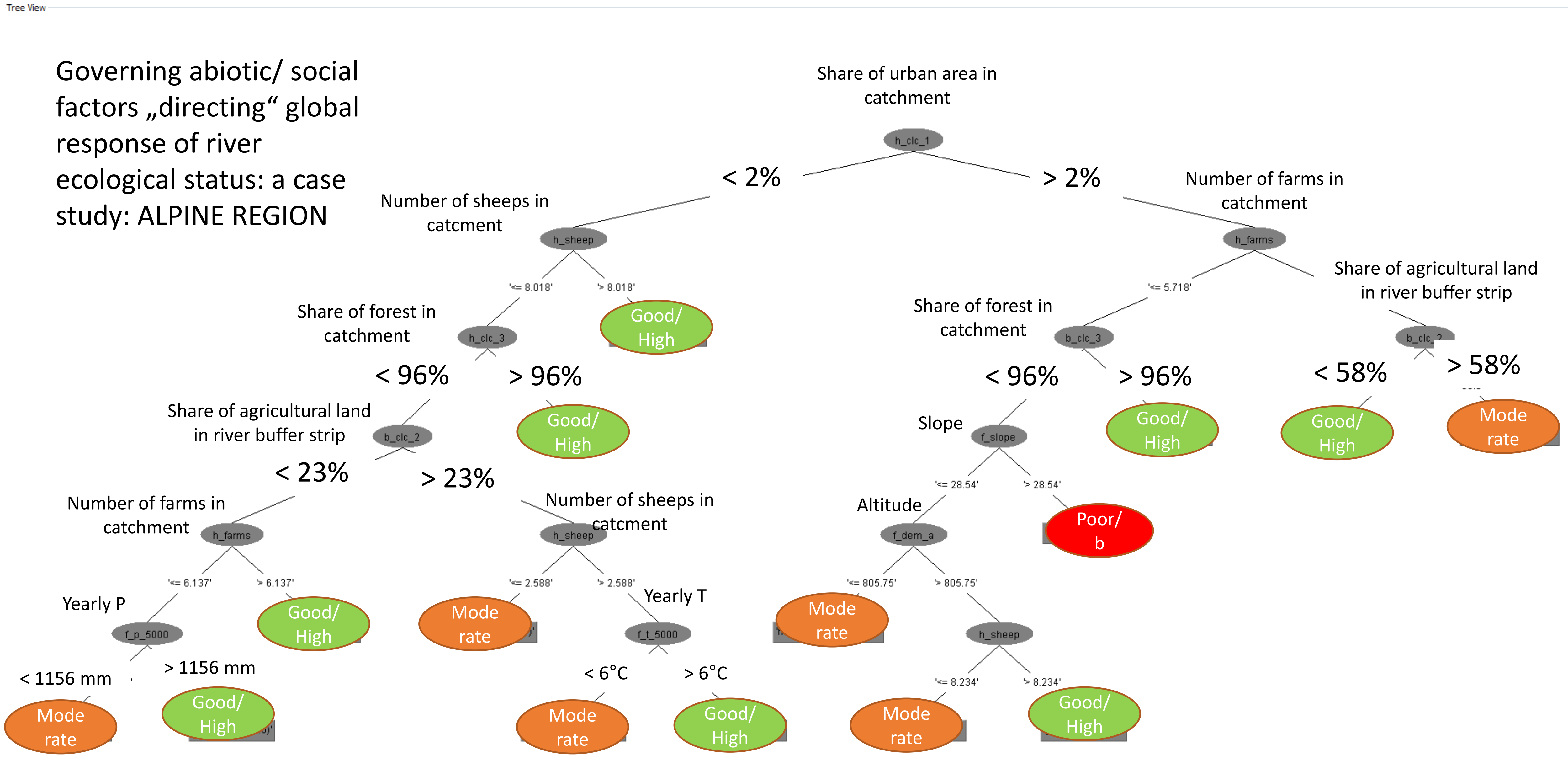
Hydromorphological pressures - modeling results:



http://water.jrc.ec.europa.eu/

Annual water abstraction for irrigation needs for year 2006
(source: JRC)

Governing abiotic/ social factors „directing“ global response of river ecological status: a case study: ALPINE REGION



Conclusions

- Multistressor conditions are present in European rivers;
- Nutrient pollution and hydromorphological alterations are significant pressures; impact differ over regions and river types;
- Pressures interactions and their effects to river ecosystems are to a great extent unexplored topic (all present: synergy, anatagonism, additive). Present scientific knowledge still have low predictive capacity to guide management, but research is under way to predict threholds to be taken into account. But in geenral we know, that
- When stressor condition are reduced, negative effects to water ecosystems are reduced: **vital and healthy water environment: leads to sustainability**
- water bodies have to be managed **in the context of their catchments as ecosystem**

"Healthy river"…sustainable water resources

Ecosystems (2002) 5: 802–814
DOI: 10.1007/s10021-002-0192-7

ECOSYSTEMS

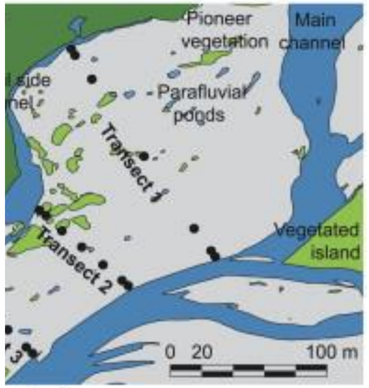
Aquatic Habitat Dynamics along a Braided Alpine River Ecosystem (Tagliamento River, Northeast Italy)

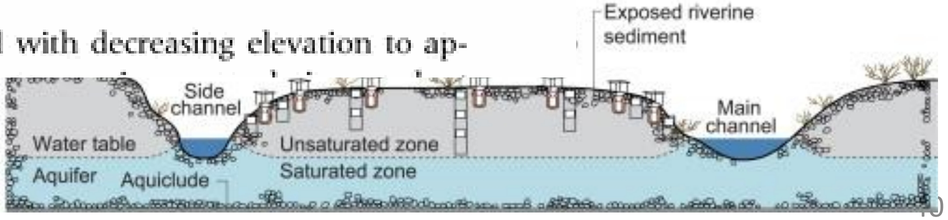
Dave B. Arscott,* Klement Tockner, Dimitry van der Nat, and J. V. Ward

Department of Limnology, Swiss Federal Institute for Environmental Science and Technology (EAWAG/ETH), 133 Überlandstrasse, 8600 Dübendorf, Switzerland

ABSTRACT

Aquatic habitat change caused by flooding was quan- turnover decreased with decreasing elevation to ap-





Ecosystem management

- Approach as an attempt to move away from unsatisfying management schemes:
  - away from something unwanted rather than
  - move toward clearly outlined goals and strategies.
- **not „multiple-use**, in which everyone was offered everything with no one having to sacrifice anything;
- **not a single species approach**, which emphasizes that particular species people think are important, and often involves crisis management, in which species are targeted for conservation only when they become very close to extinction
- **not grounded on purely biotechnologist views** (suggest that nature can be improved by the works of humnas) or bioconservative ideals, which seek to preserve the biological and ecological status quo
- **not maximize yield/yields, but sustain ecosystem - biodiversity and productive capacity;** identificaiton of thresholds, level of degradation below the ecosystem can not drop without losing certain vital attributes or functions
- „**no free lunch“,** so mngs should present the choices and trade-off, estimating and monitoring the costs and benefits; understanding and accepting losses are part of ecosystem management

Water ecosystem management

- **not a „multiple-use“**
- **not a „single species approach“**
- **not to be „grounded on „purely biotechnologist views“**
- **not a „maximization of yield“, but sustain ecosystem**
- **„no free lunch“**
-

➢ presenting choices and trade-offs (biodiverstiy, production capacities, thresholds)

➢ estimating and monitoring costs and benefits

➢ understanding and accepting losses are part of ecosystem management







Images from the Mura river in Slovenia.

Thank you!