Critical loads in Europe: overview and latest developments

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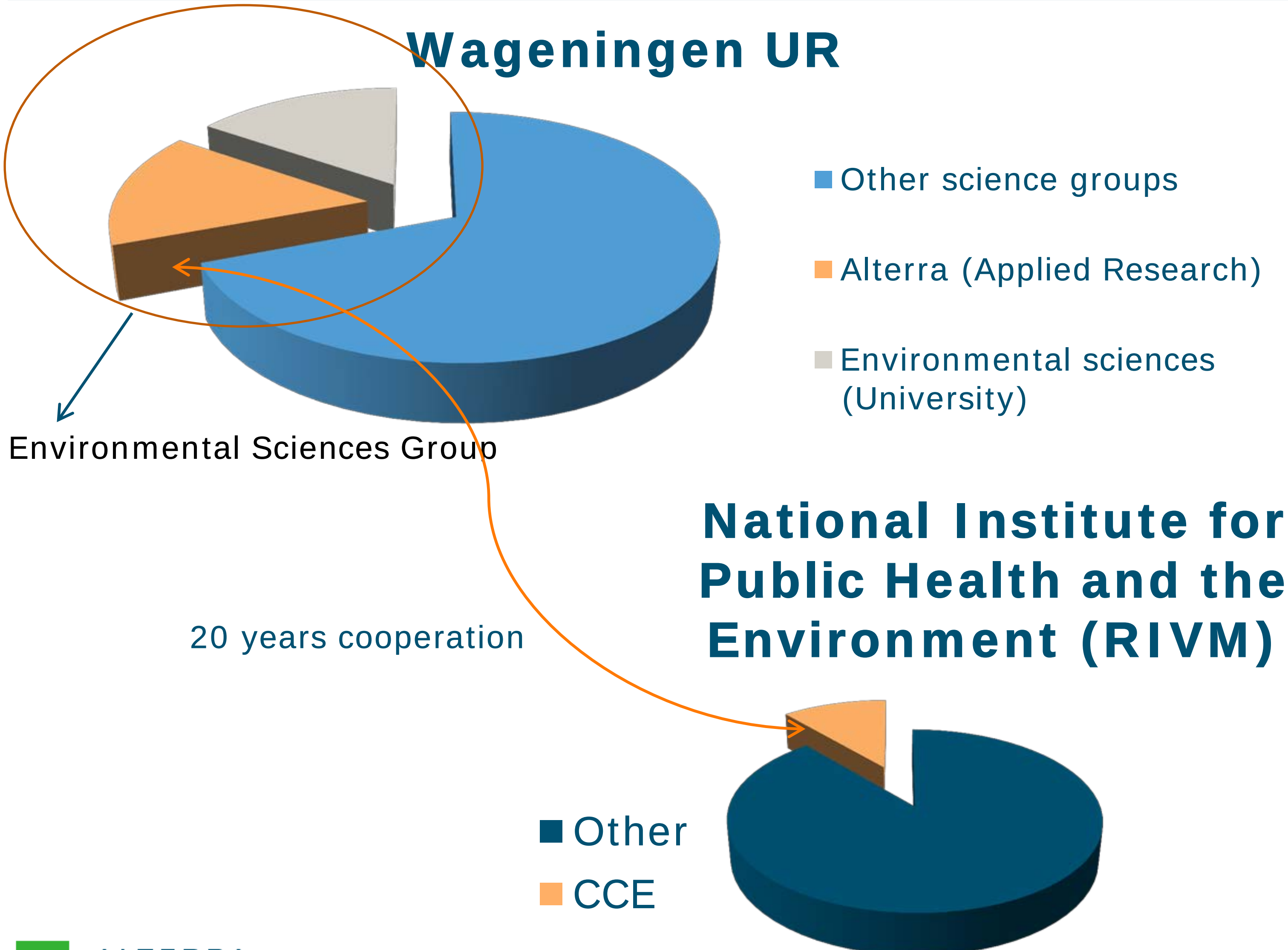
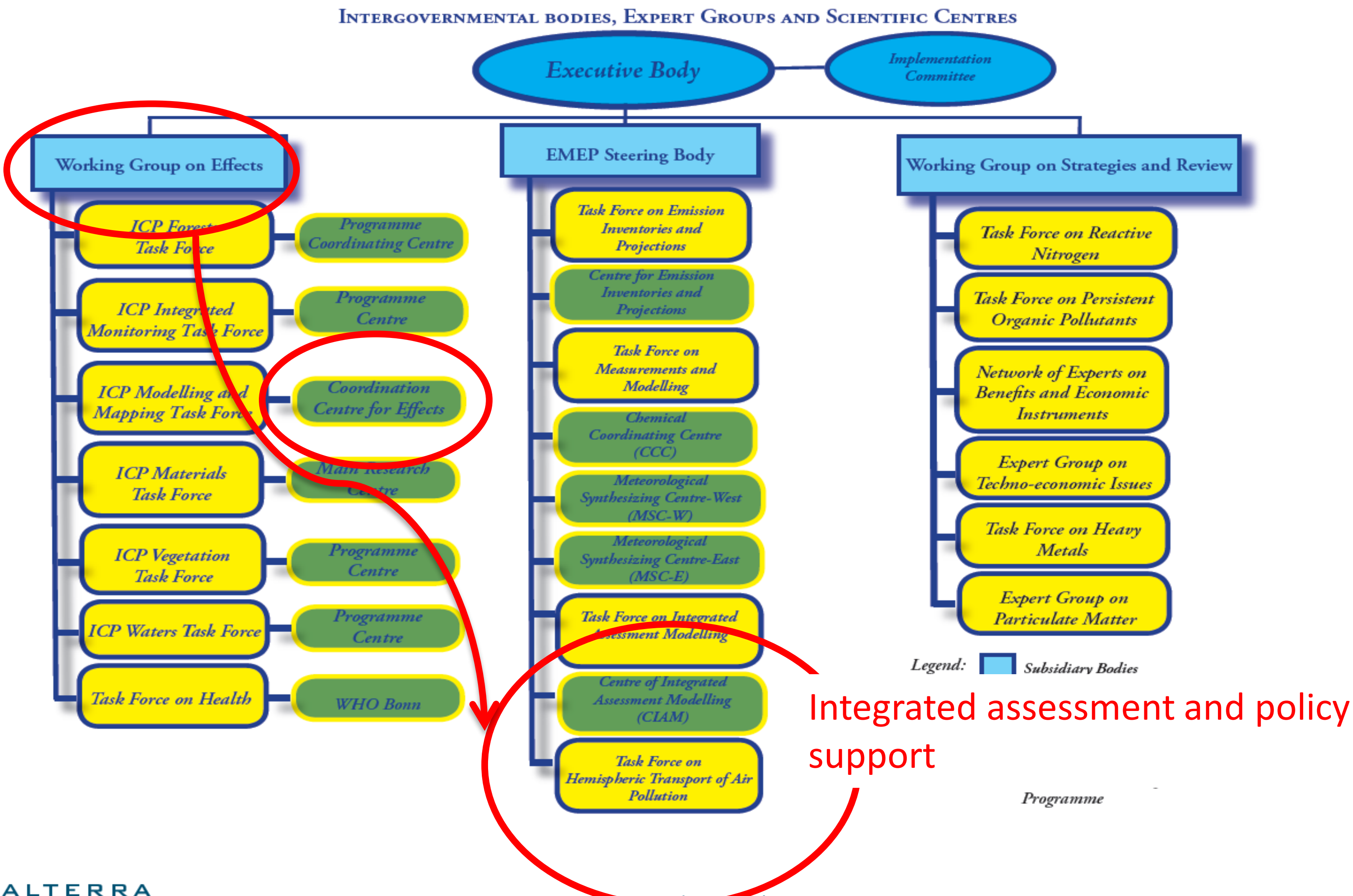
Contents

- Alterra and the CCE
- The critical load process in Europe
  - Organisation
  - Achievements
  - Critical loads for N as a nutrient: using biodiversity criteria for critical loads
- Critical loads for heavy metals
  - Methods
  - Results
- Conclusions

Alterra, Wageningen UR and RIVM-CCE



The critical load process in Europe: The 1979 Geneva Convention on Long-range Transboundary Air Pollution



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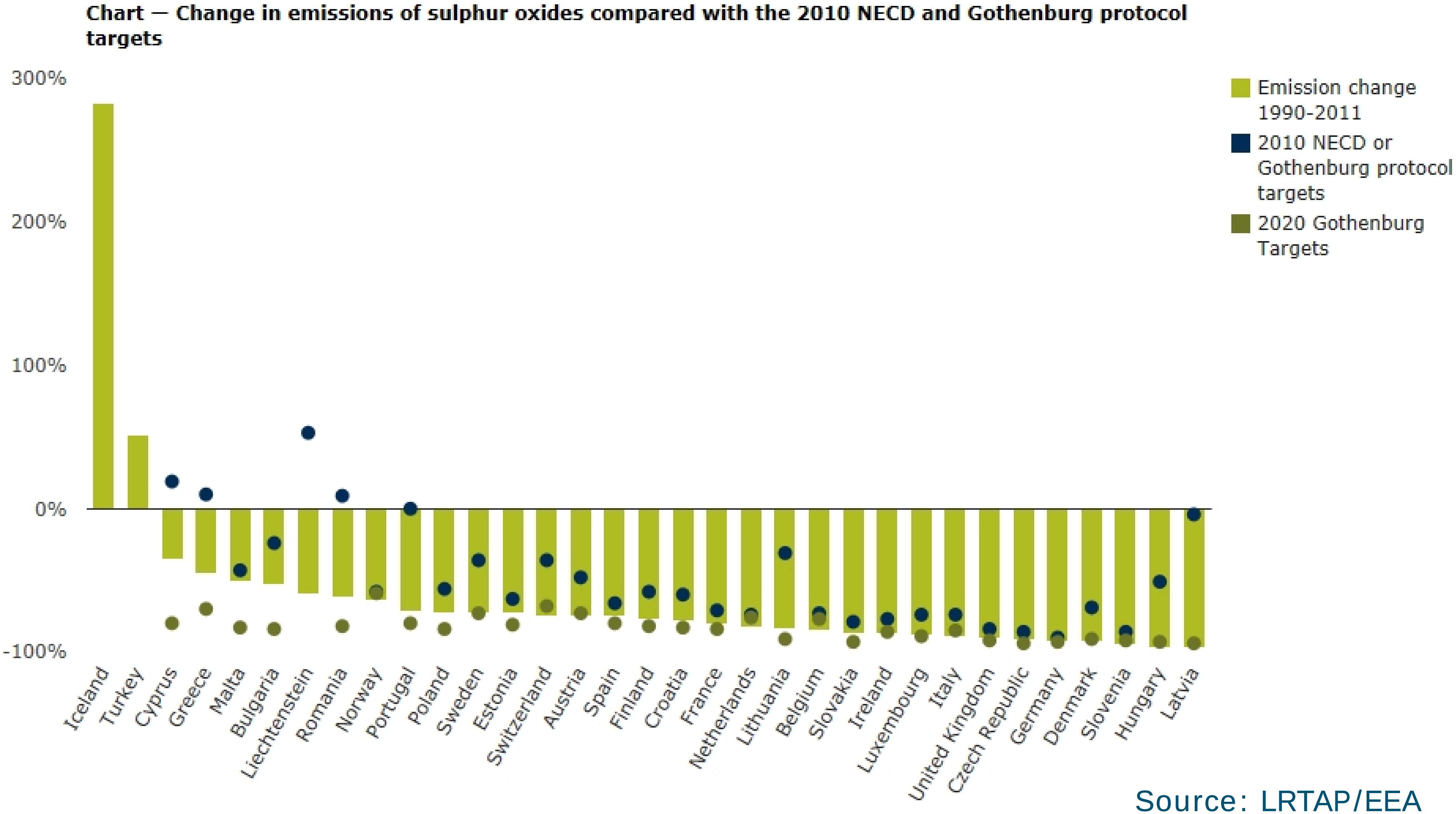
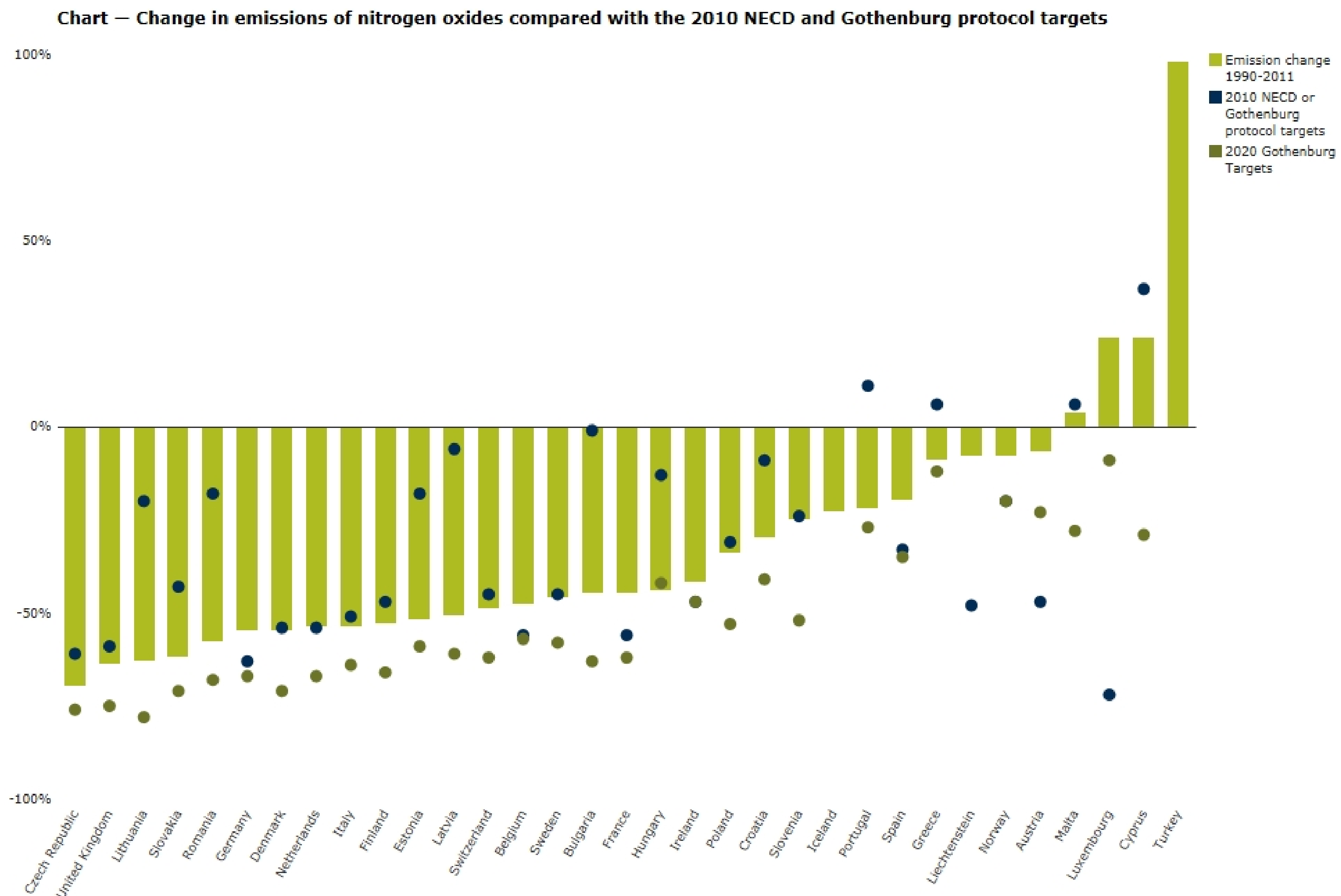
Achievements: emission reductions SO_x



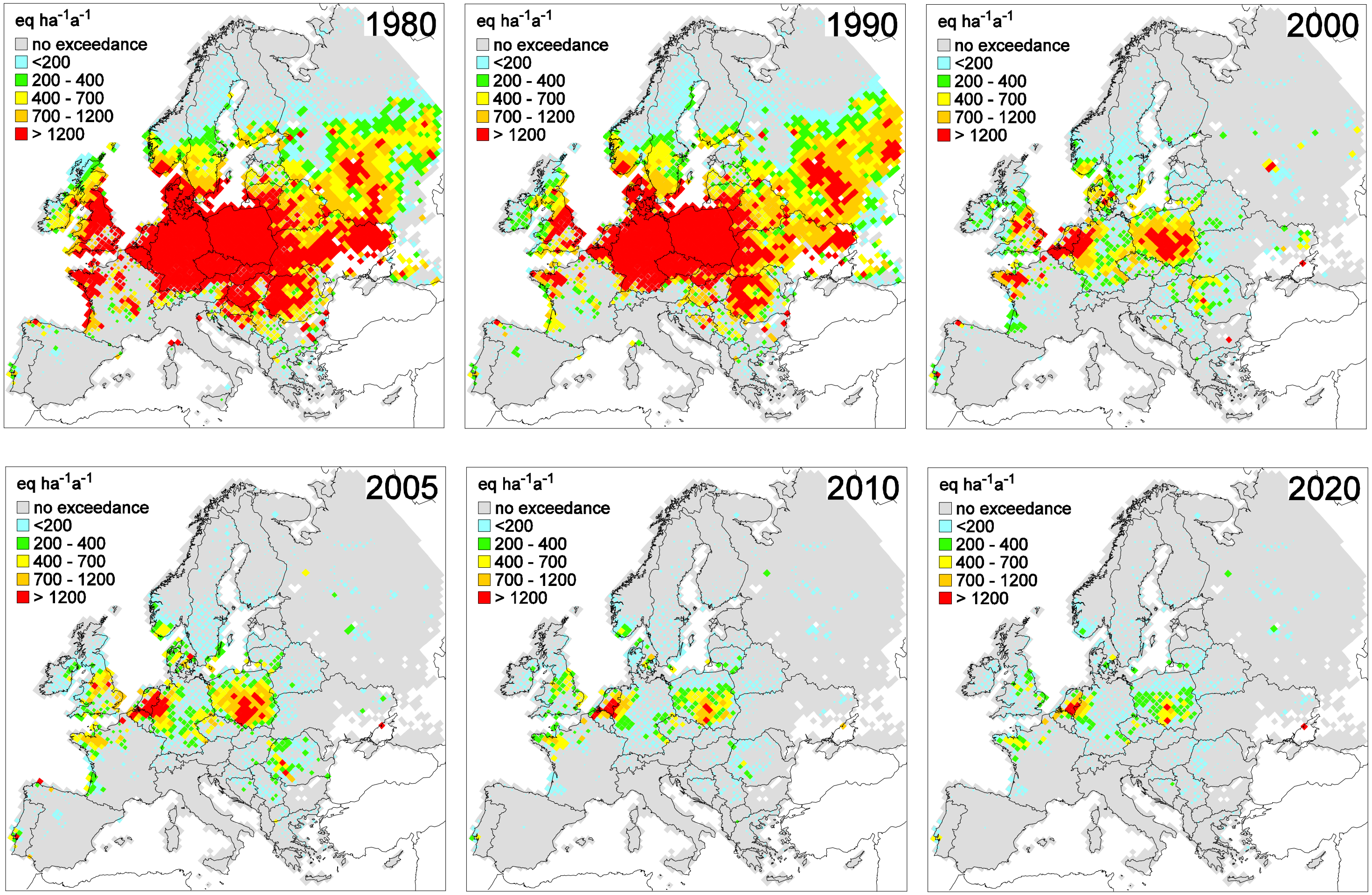
Source: LRTAP/EEA

Achievements: emission reductions NO_x



Source: LRTAP/EEA

Achievements: trends in exceedances: acidity



Areas where critical loads for acidification are exceeded by acid depositions (EMEP50 model; Revised Gothenburg Protocol (RGP)

Source: ICPM&M/CCE

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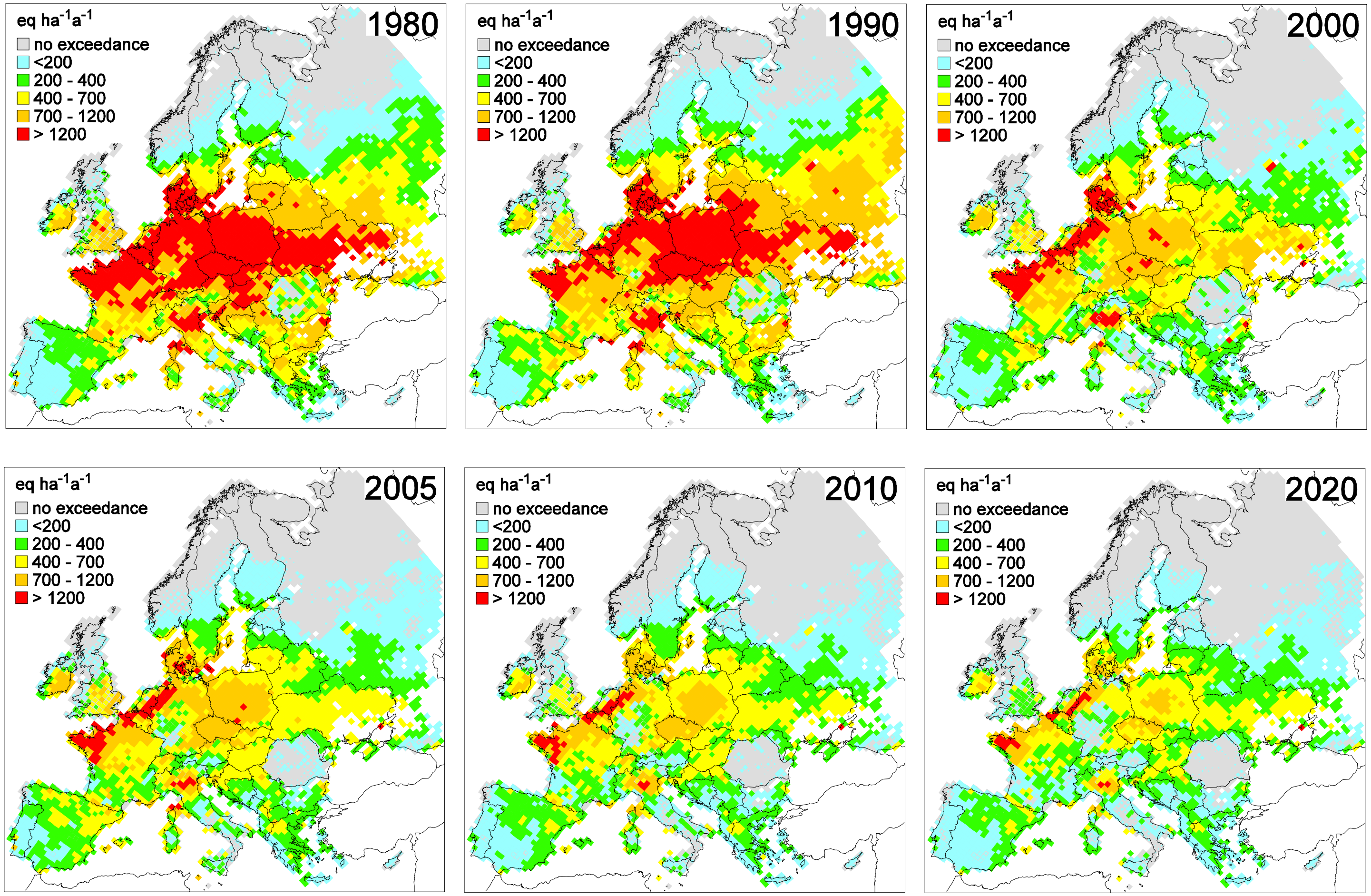
Achievements: trends in exceedances: CLnutN



Areas where critical loads for eutrophication are exceeded by nitrogen depositions (EMEP50 model; Revised Gothenburg Protocol (RGP)

Source: ICPM&M/CCE

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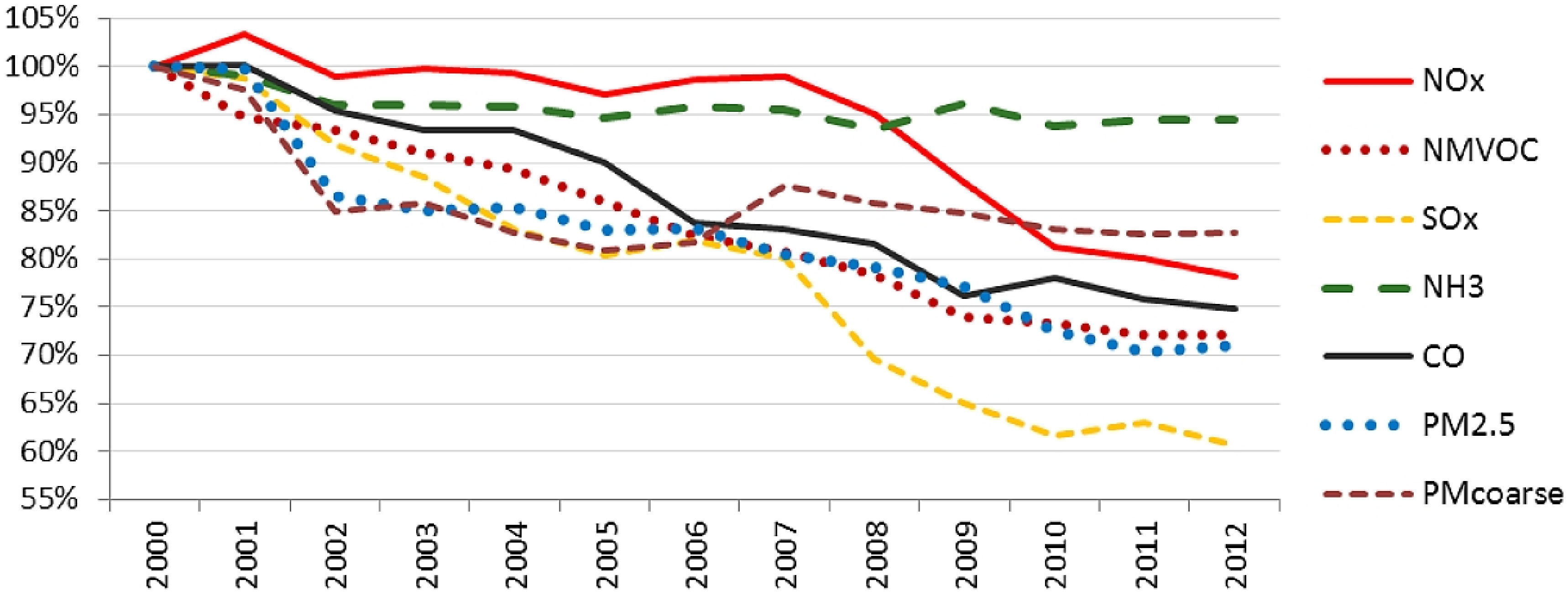
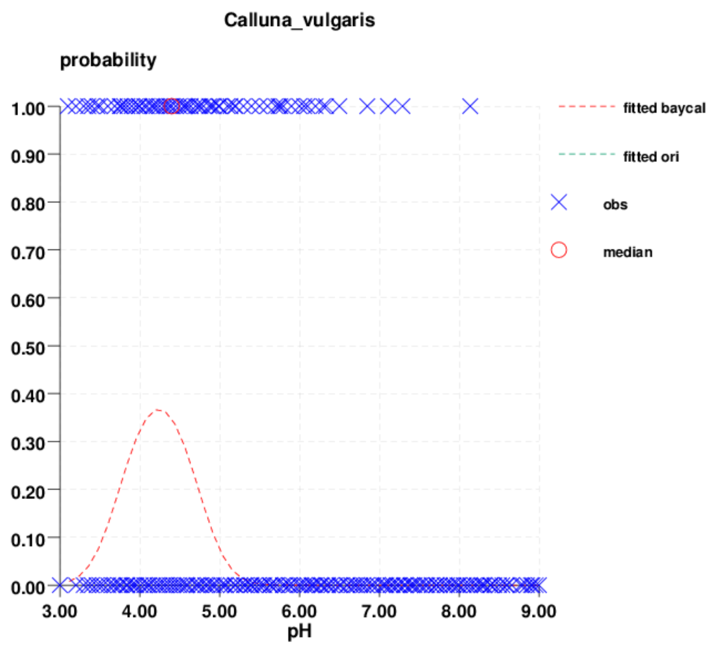
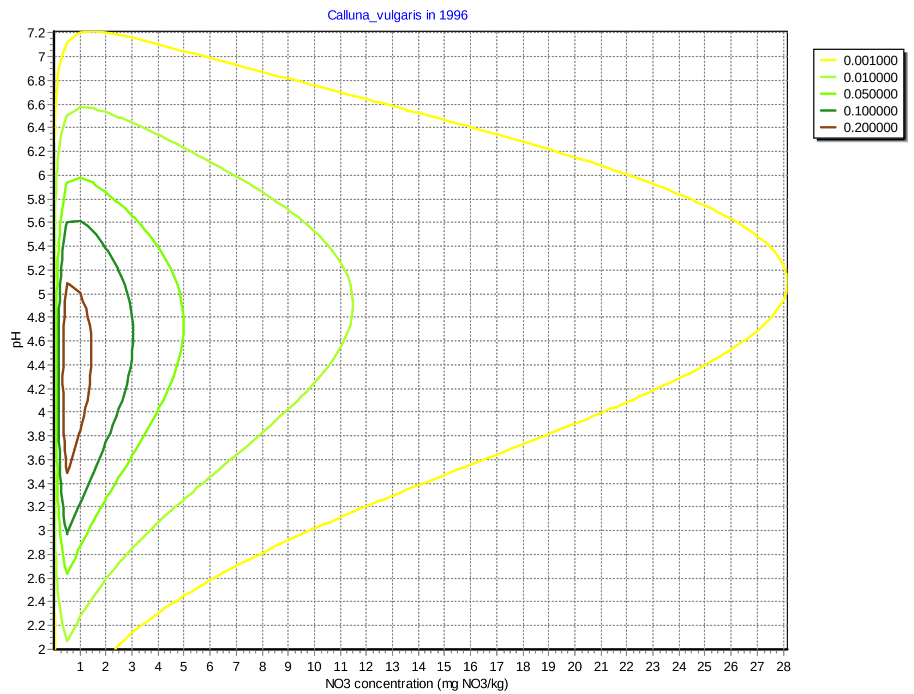
Emission trends



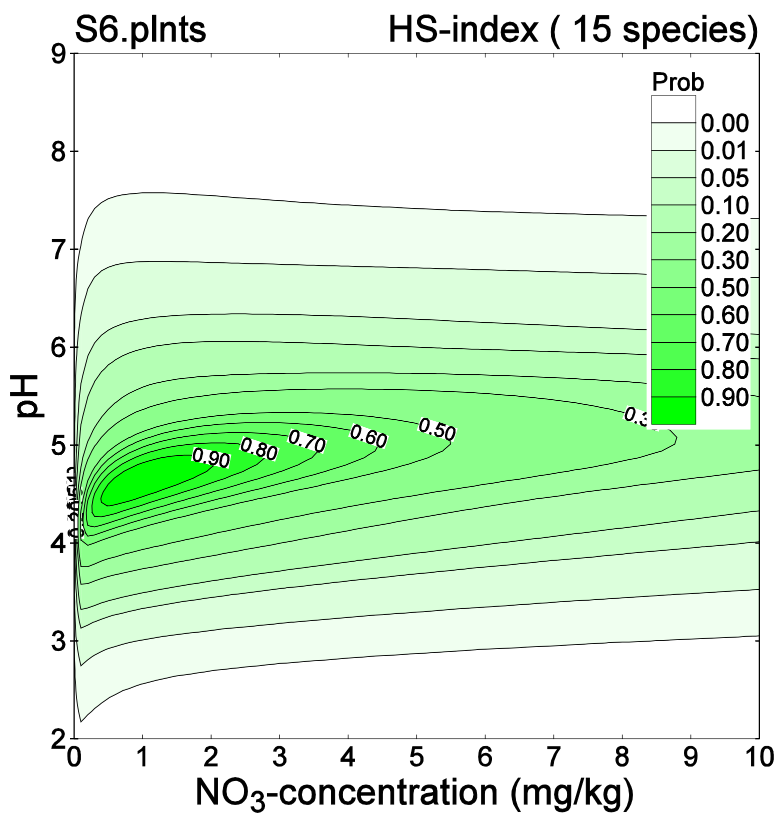
Source: EMEP REPORT 1/2014

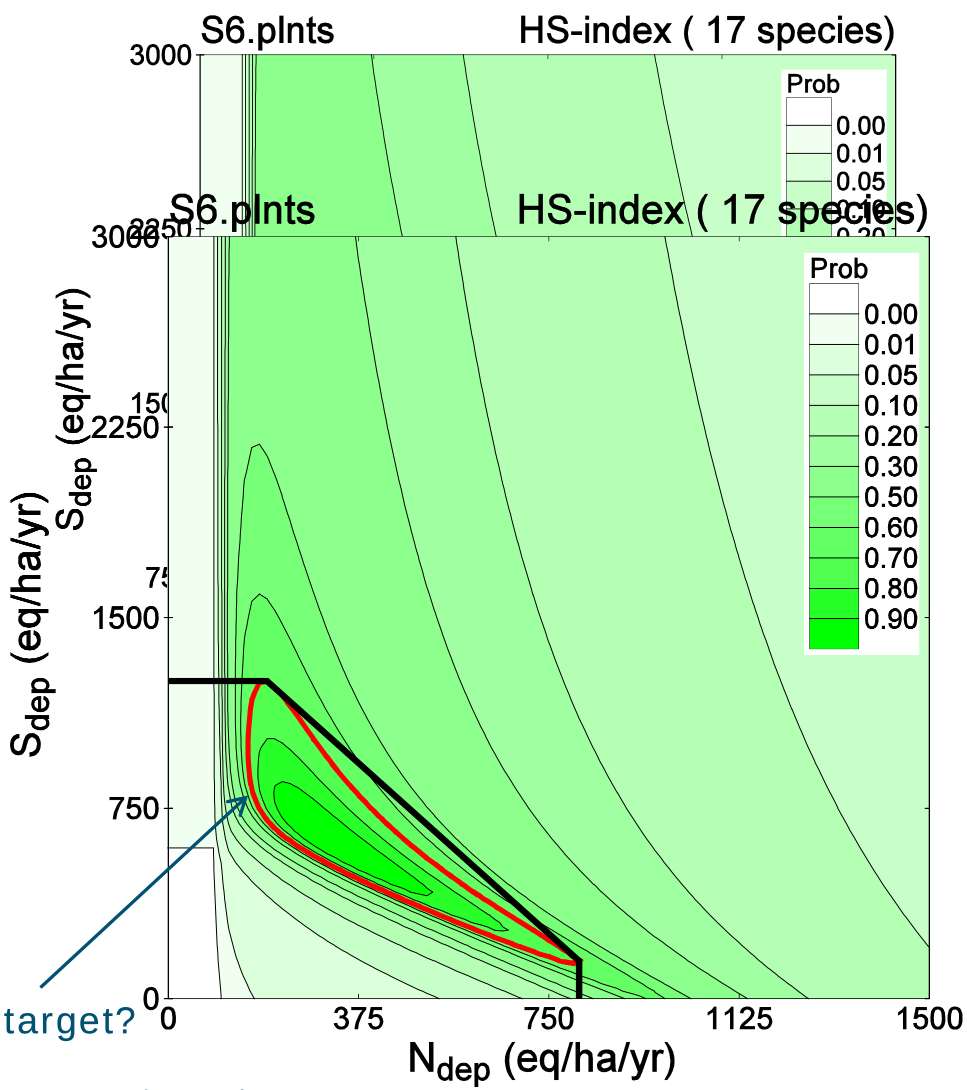
Future directions: Critical loads based on biodiversity endpoints



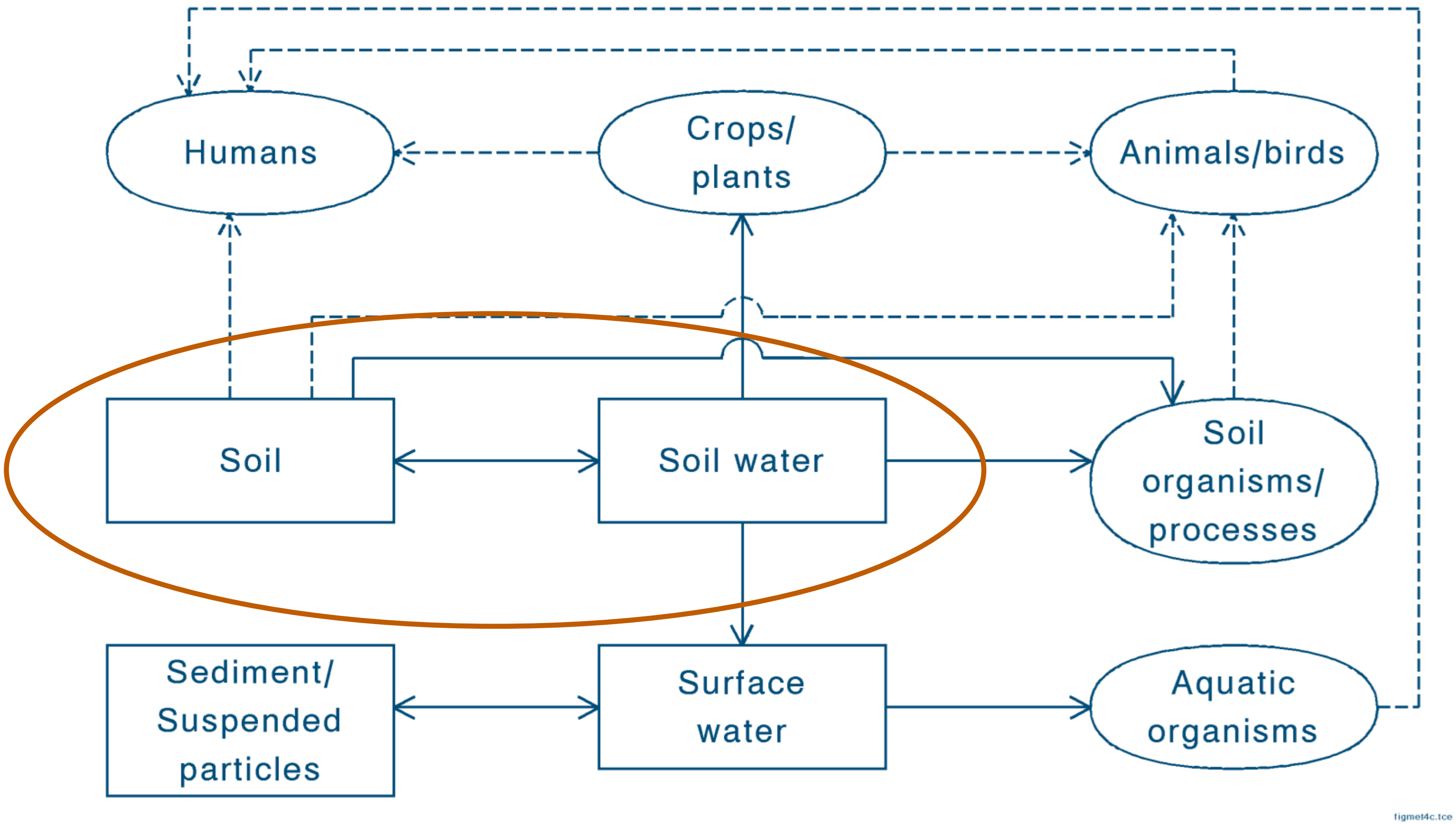


From response to critical load





Part 2: Critical loads for heavy metals



Critical load for terrestrail ecosystems: uptake + leaching:

$$CL(M) = M_u + M_{le(crit)}$$

$$M_u = f_{Mu} \cdot Y_{ha} \cdot [M]_{ha}$$

fMu = fraction of metal uptake within the considered soil layer

Yha = yield of harvestable biomass ($kg.ha^{-1}.a^{-1}$)

[M]ha = metal content in harvestable parts of the plant ($g.kg^{-1}$)

$$M_{le(crit)} = c_{le} \cdot Q_{le} \cdot [M]_{tot,sdw(crit)}$$

Q_{le} = leaching flux ($m.a^{-1}$)

$[M]_{tot,sdw(crit)}$ = critical total concentration of M in soil water ($mg.m^{-3}$)

C_{le} = unit conversion factor

Which critical concentration?

- Critical metal concentrations in ground water (Cd, Pb, Hg) in view of human health effects through intake of drinking water

WHO criteria:
Pb: 10 $mg.m^{-3}$
Cd: 3 $mg.m^{-3}$
Hg: 6 $mg.m^{-3}$

- Critical concentrations of free metal ions in soil solution (Cd, Pb) in view of ecotoxicological effects on soil microorganisms, plants and invertebrates

From toxicity data, as a function of pH and DOC

- Critical metal contents in the soil (Hg) in view of ecotoxicological effects on soil micro organisms and invertebrates in the forest humus layer

Compute Hg in solution from critical Hg in soil

From toxicity data to critical concentrations 1: Toxicity data

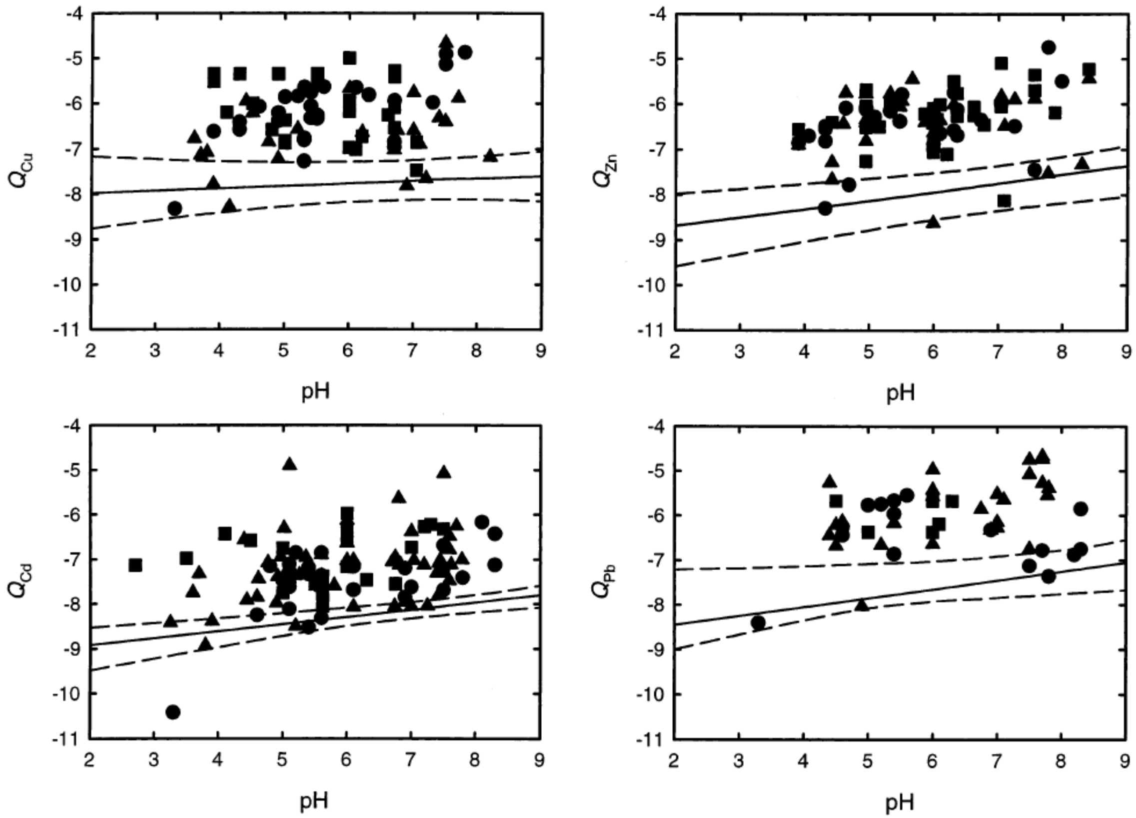
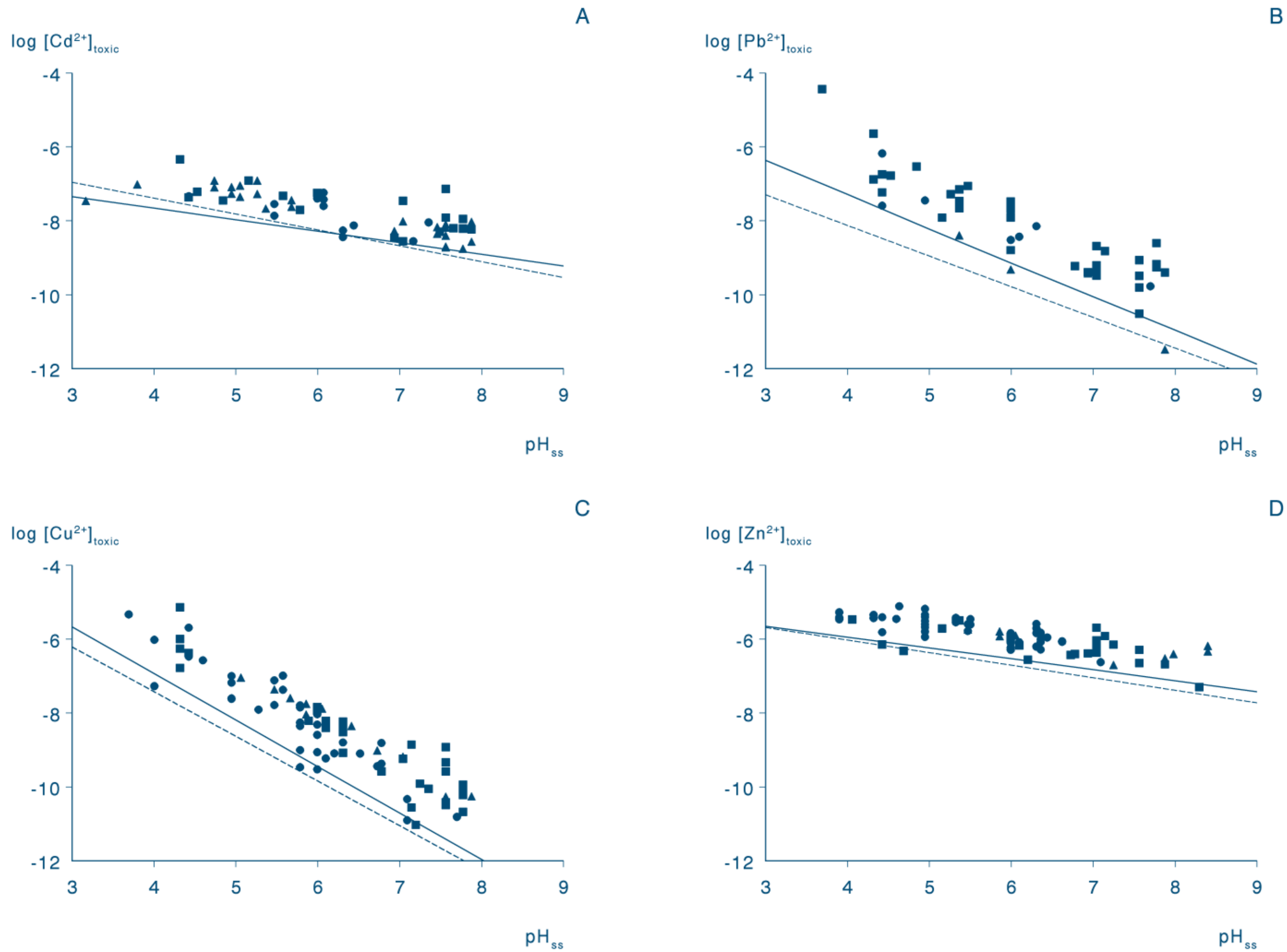


FIGURE 1. Plots of Q against pH (eq 6; Table 7) for Cu, Zn, Cd, and Pb. Circles: plant data; squares: invertebrate data; and triangles: microbial process data. Solid line: median critical limit function and dotted lines: 90% confidence limits on the median critical limit.

Q represents [log *M*soil,toxic+[*b*/*c*]log OM]

Source: Lofts et al., 2004

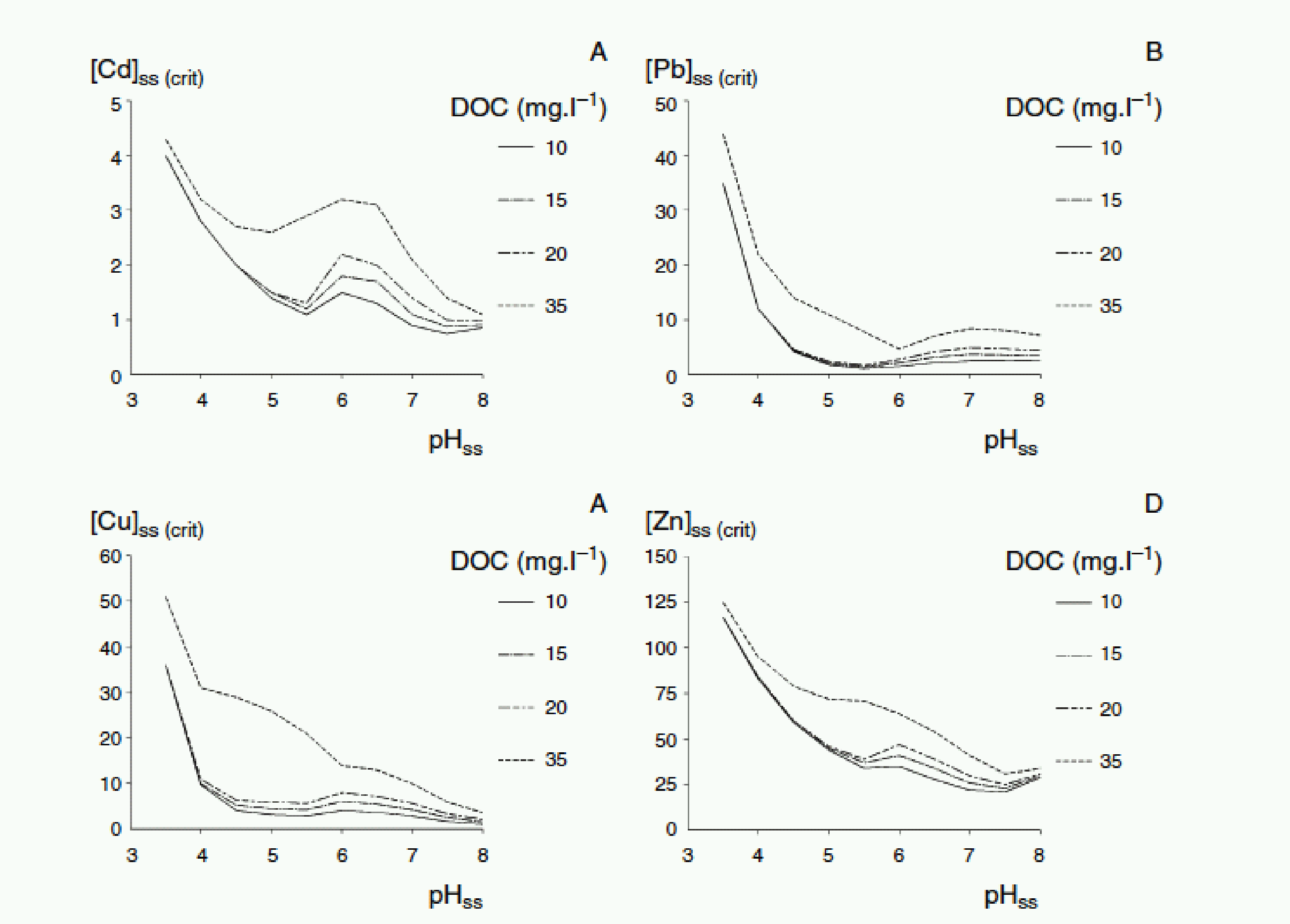
From toxicity data to critical concentrations 2: Critical limit functions



Based on the protective effect of H+ and other cations

Source: Lofts et al., 2004

From toxicity data to critical concentrations 3: Total critical concentrations



Critical total concentrations as a function of pH and DOC using the WHAM model

Source: De Vries, Lofts et al., 2007

Hg: two approaches
1: Using critical limit for the solid phase

$$[Hg]_{dis,sdw(crit)} = [Hg]_{OM(crit)} \cdot f_f \cdot [DOM]_{sdw} \cdot csdw$$

[Hg]dis,sdw(crit) **= critical total** *Hg* **concentration in soil drainage water** *(mg m^{-3})*
[Hg]OM(crit) **= critical limit for** *Hg* **concentration in solid organic matter** *(OM) (0.5 mg (kg OM)$^{-1}$)***.**
ff **= fractionation ratio, describing the** *Hg* **on organic matter in solution** *(DOM)* **relative to that in solids** *(OM) (–)***,**
[DOM]sdw **= concentration of dissolved organic matter in soil drainage water** *(g m^{-3})***,**
csdw **=** *10^{-3} kg g^{-1}***, factor for appropriate conversion of mass units.**

This is the approach given in the mapping manual (but is pH independent)

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Hg: two approaches
2: Using critical free concentrations

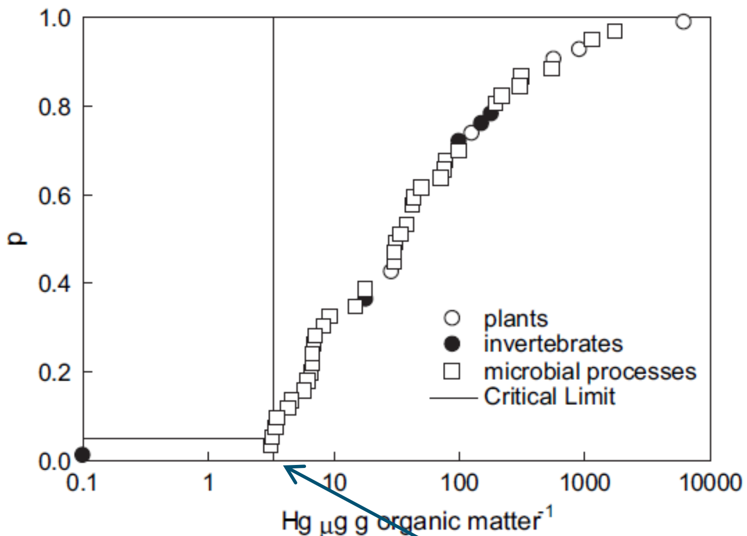


Fig. 1. Species sensitivity distributions for Hg(II) chronic toxicity end-points in soil, expressed in terms of soil solids (upper panel) and soil organic matter (lower panel). The derivation of Critical Limits at the 5th percentile is demonstrated with the horizontal and vertical lines.

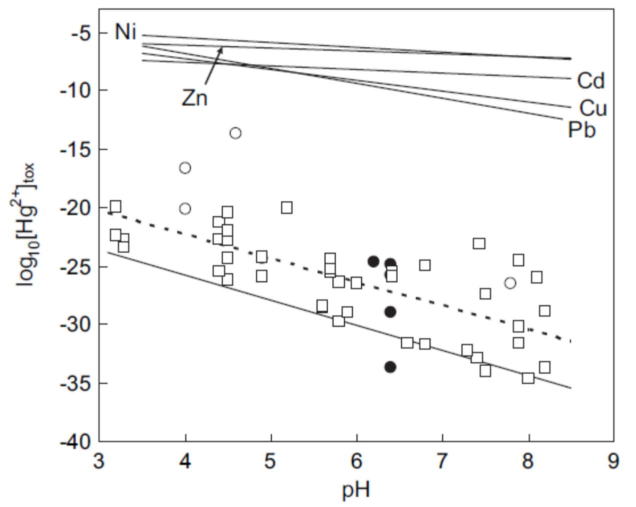
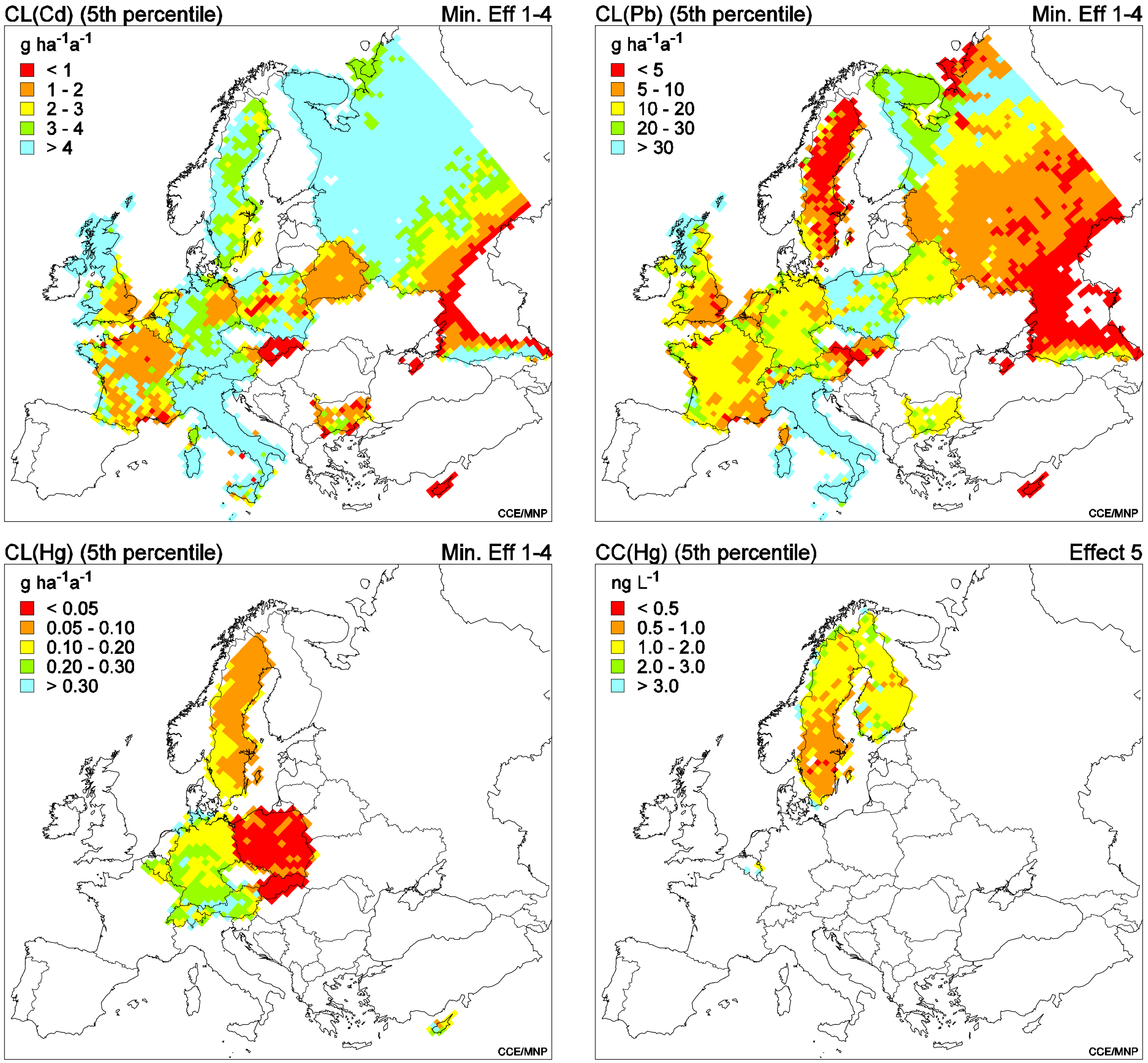


Fig. 2. Toxic end-points expressed as $[Hg^{2+}]$, symbols as for Fig. 1. The dashed line is the median regression, and the solid line the derived Critical Limit Function (CLF). CLFs for Ni, Cu, Zn, Cd and Pb are also shown.

Critical limit about 3.3 $mg.kg^{-1}$
(manual: 0.5 $mg.kg^{-1}$)

Source: Tipping, Lofts et al., 2010

Some results: call for data (2004/2005)

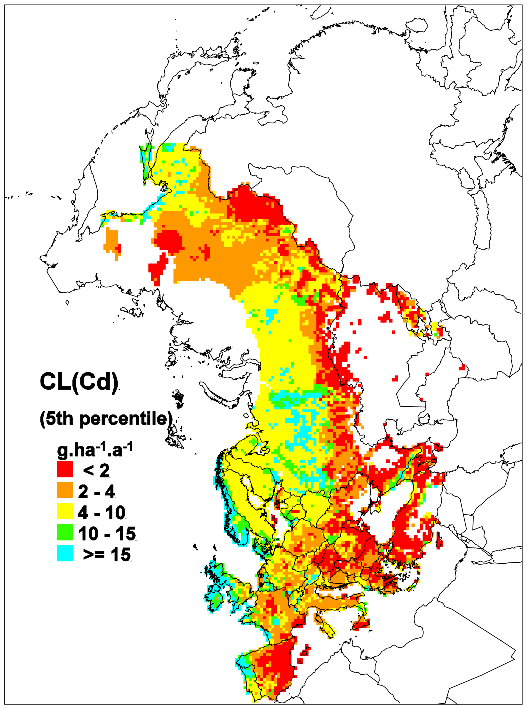


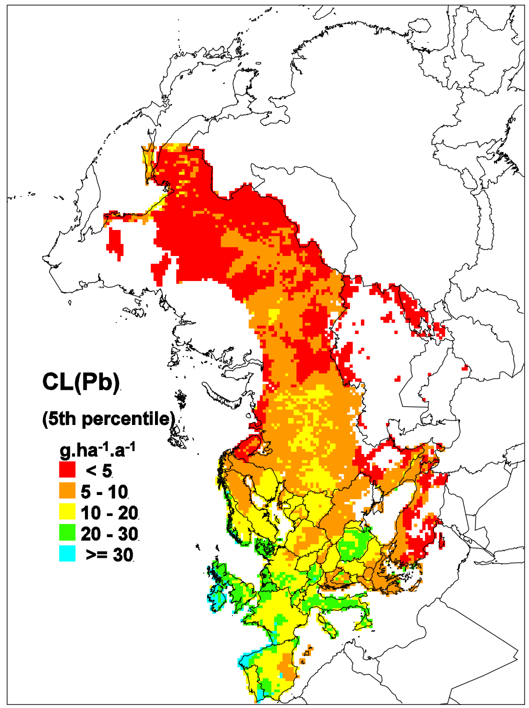
17 countries participated

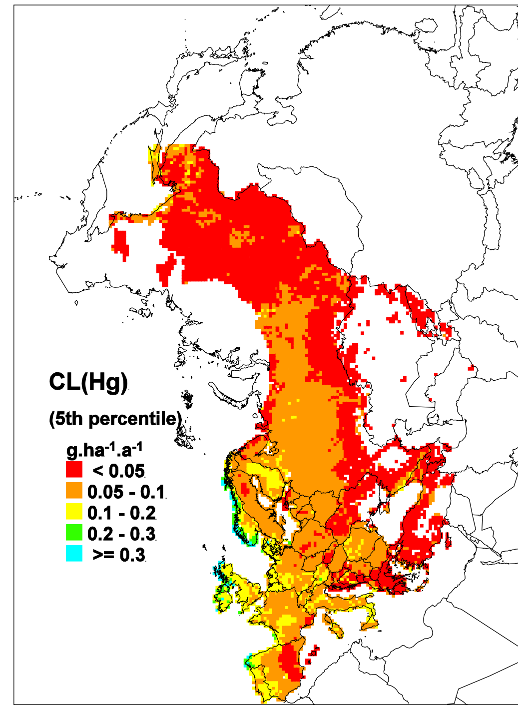
Effect 1-4: terrestrial
Effect 5: freshwater

Source: RIVM-CCE

Some results: using the CCE background database







Simple critical load approach was also used for Cr, Ni, Cu, Zn, As, Se

Modelled depositions

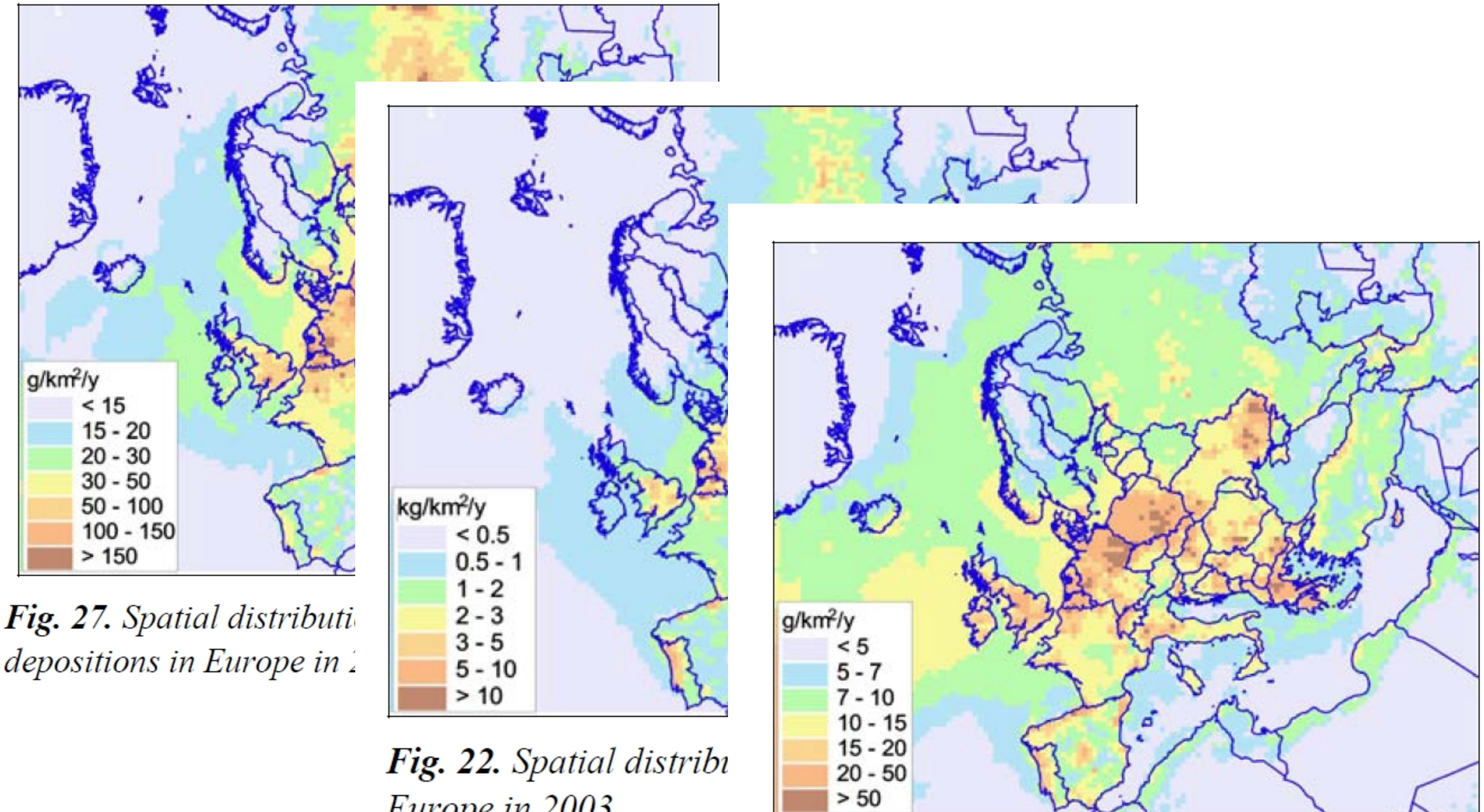


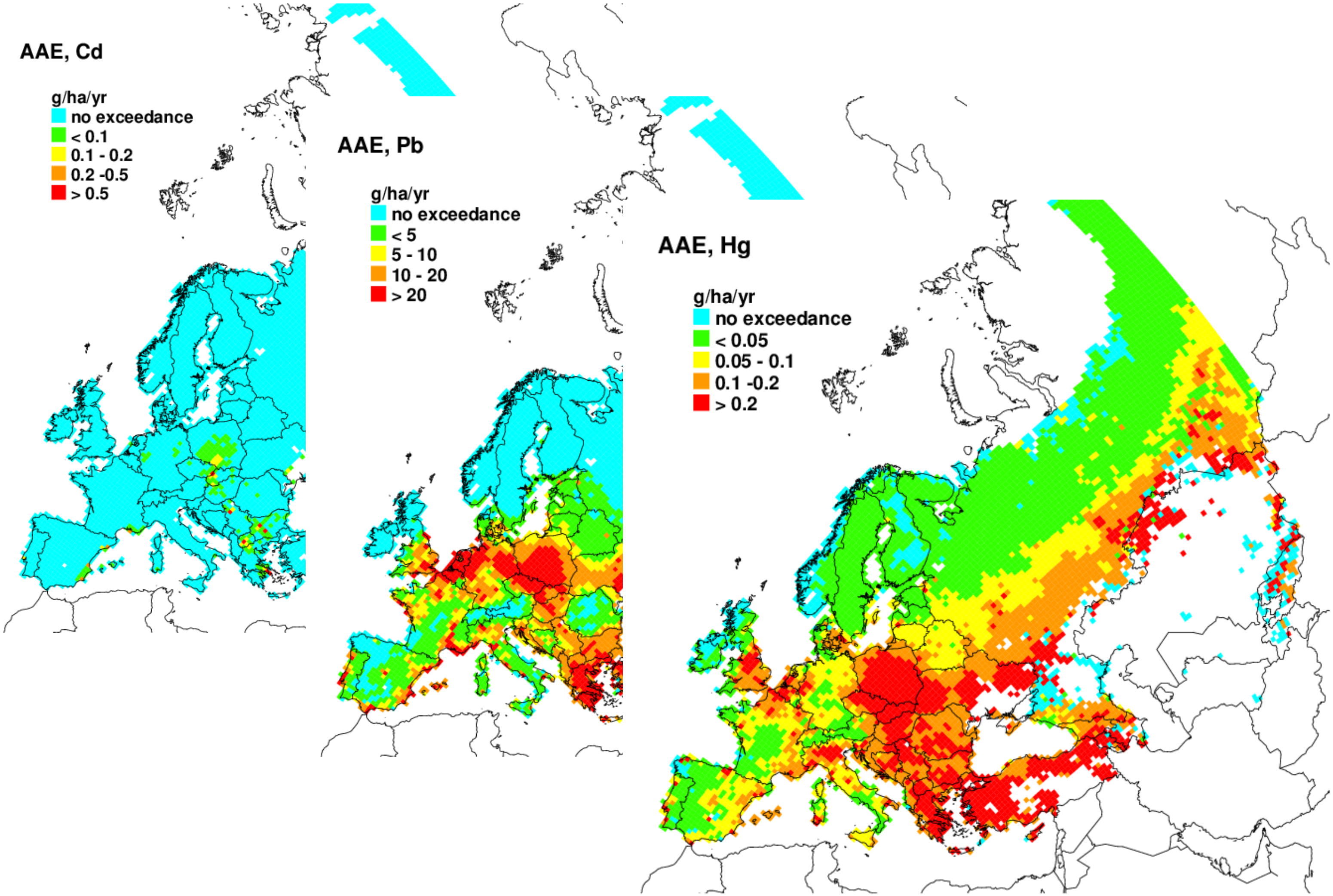
Fig. 27. *Spatial distributi*
depositions in Europe in

Fig. 22. *Spatial distribu*
Europe in 2003

Fig. 32. *Spatial distribution of mercury depositions in Europe in 2003*

Source: EMEP MSC East, 2005

Exceedances (deposition year: 2006)



Conclusions, N + S

- critical loads of N and S have been and are the basis for successful emission reductions
- Substantial reduction of NH_3 emissions remains difficult in Europe; exceedances of CLnutN persist in the future
- Future CL(N) could/will be based on biodiversity endpoints, rather than abiotic limits; this work is under development within EU FPVII Eclaire project

Conclusions, heavy metals

- For heavy metals, critical loads, depositions and exceedances have been computed but have not been used directly in emission abatement
- Other activities (UN Minamata convention) halt the use of CL(HM) for ecosystems, human health is considered more important
- There is a substantial uncertainty in critical limits for HM as well as in emissions and depositions especially for Hg
- Preliminary results show no or very little exceedances for metals other than Cd, Pb and Hg

End