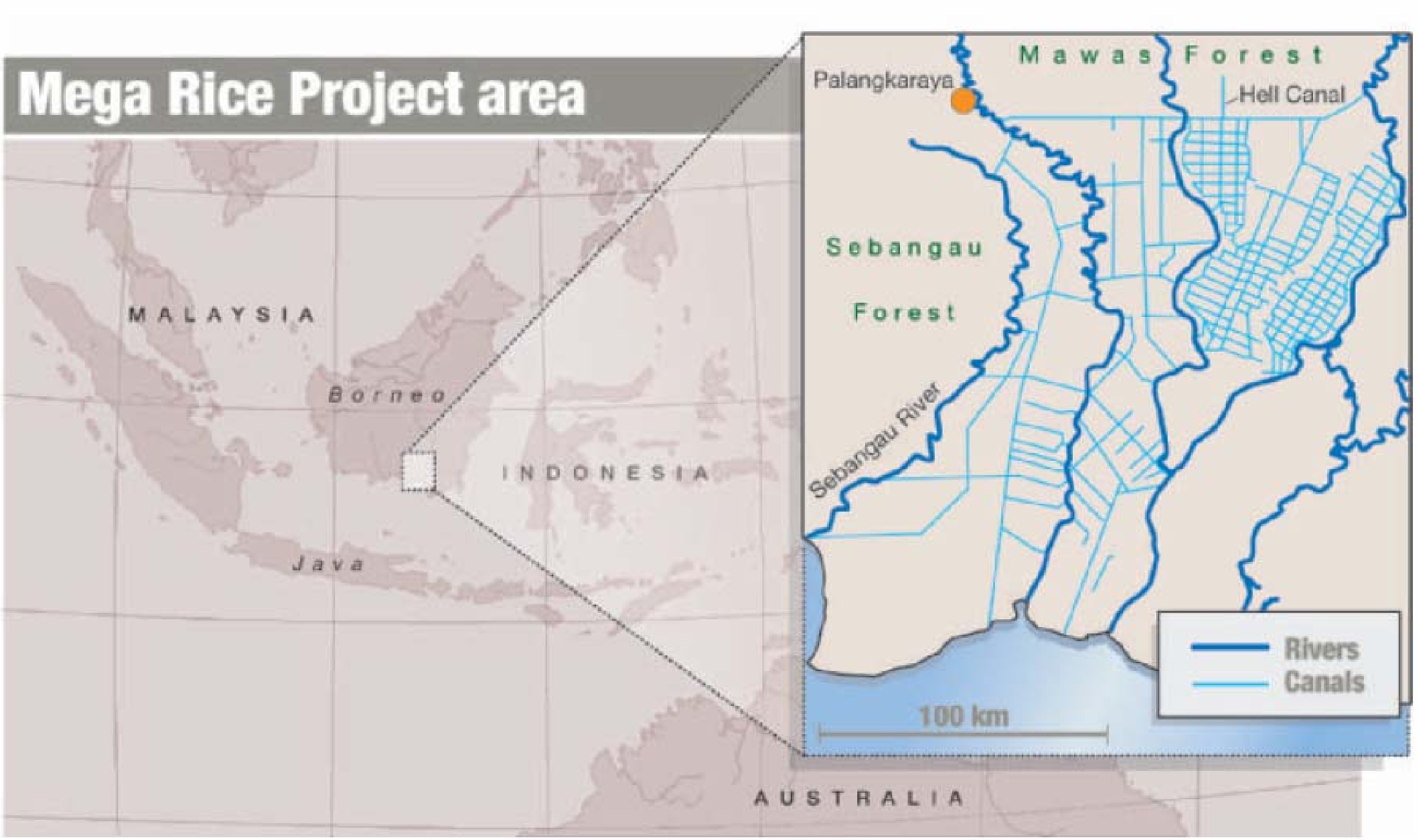
Fragen

- Beispiele für
  - Stress avoidance – Dürre
  - Strain avoidance – Insektenfraß/Frost
  - Stress tolerance – Feuer
  - Resilience – Windwurf
- Störungen und Stoffkreisläufe: Welche „impact types“ sind:
  - Feuer
  - Windwurf
  - Insekten
  - Landnutzung
- Wie könnte man die unterschiedliche Anpassung an Feuer in den borealen Wäldern klassifizieren?

Indonesian peat fires



Aldhous, Nature 432: 2004

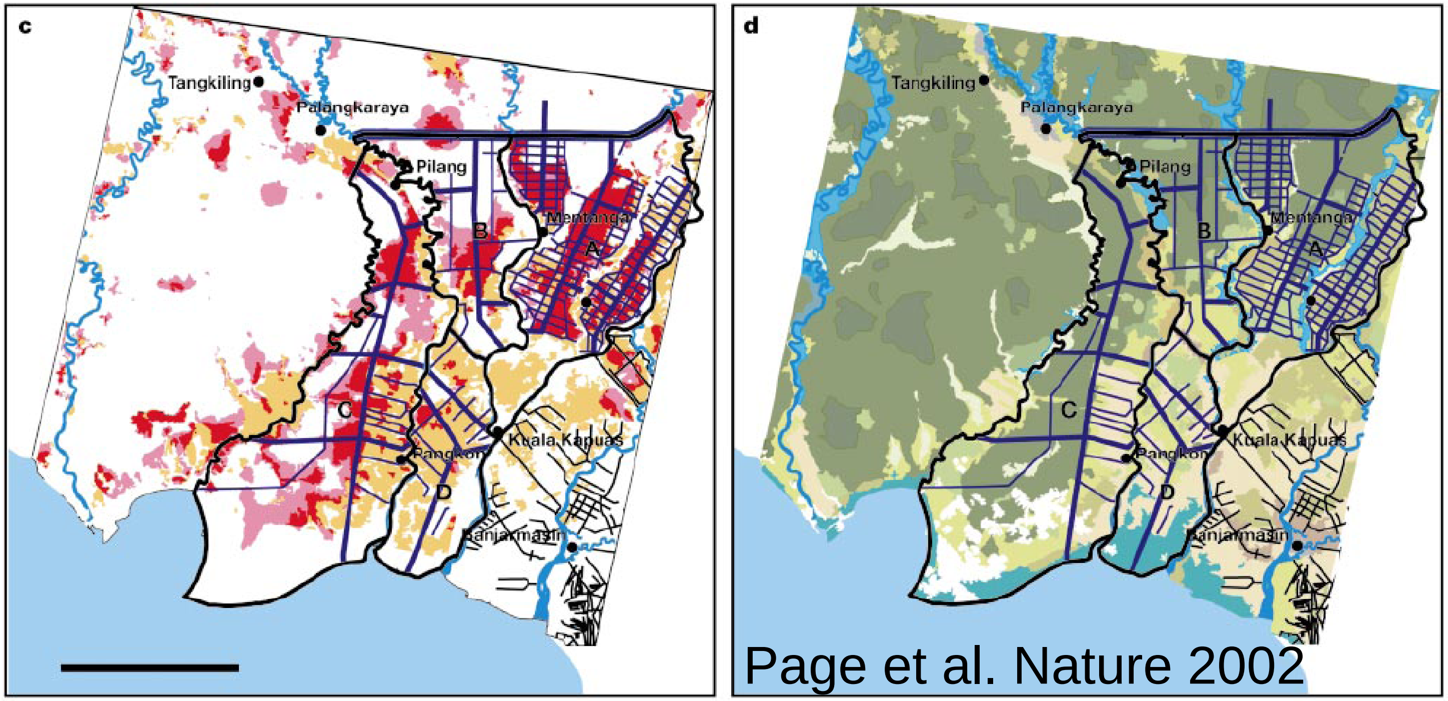
Indonesian peat fires

- Drainage in/since 1995
- Drainage depth:
  often several metres
- Problems
  - Too dry to sustain growth
  - Too acidic to grow rice
  - Fire risk: smouldering
    for months

Aldhous, Nature 432: 2004

Drained: the canals cut through southern Borneo have sapped the peat swamps of life.

Indonesian peat fires in 1997/1998



Page et al. Nature 2002

c, Burned area derived from analysis of post-fire Landsat TM 5 and multitemporal ERS SAR images (bar 50 km); burnt areas detected by both Landsat and ERS are indicated in red; burnt areas detected only by Landsat are shown in purple; burnt areas detected only by ERS SAR and undetectable by Landsat TM 5, owing to plant regrowth are shown in orange. d, Land cover map derived from pre-fire Landsat TM 5 image 118-62, 29 May 1997 (dark green, low pole peat swamp forest (PSF); green, tall PSF; beige, agriculture and fallow land; bright green, fragmented PSF and PSF mosaics; brown green, grass and bushland; blue green, mangrove forests; light blue green, pristine swamp forest (periodically inundated); pale green, dry and swampy grasslands; white, clouds; blue, rivers).

Indonesian peat fires in 1997/1998

- 13-40% of annual global fossil fuel emissions
- 20-85 cm of peat (out of 20m of deposits)
- Emissions
  - burnt vegetation 20% of emissions
  - Peat 80% of emissions
  - Total 0.81 - 2.57 Gt C

Page et al. Nature 2002

Fragen

- Adaptation possibilities for plant species
- How to manage forests prone to fire?

Windthrow

Example: Estonia

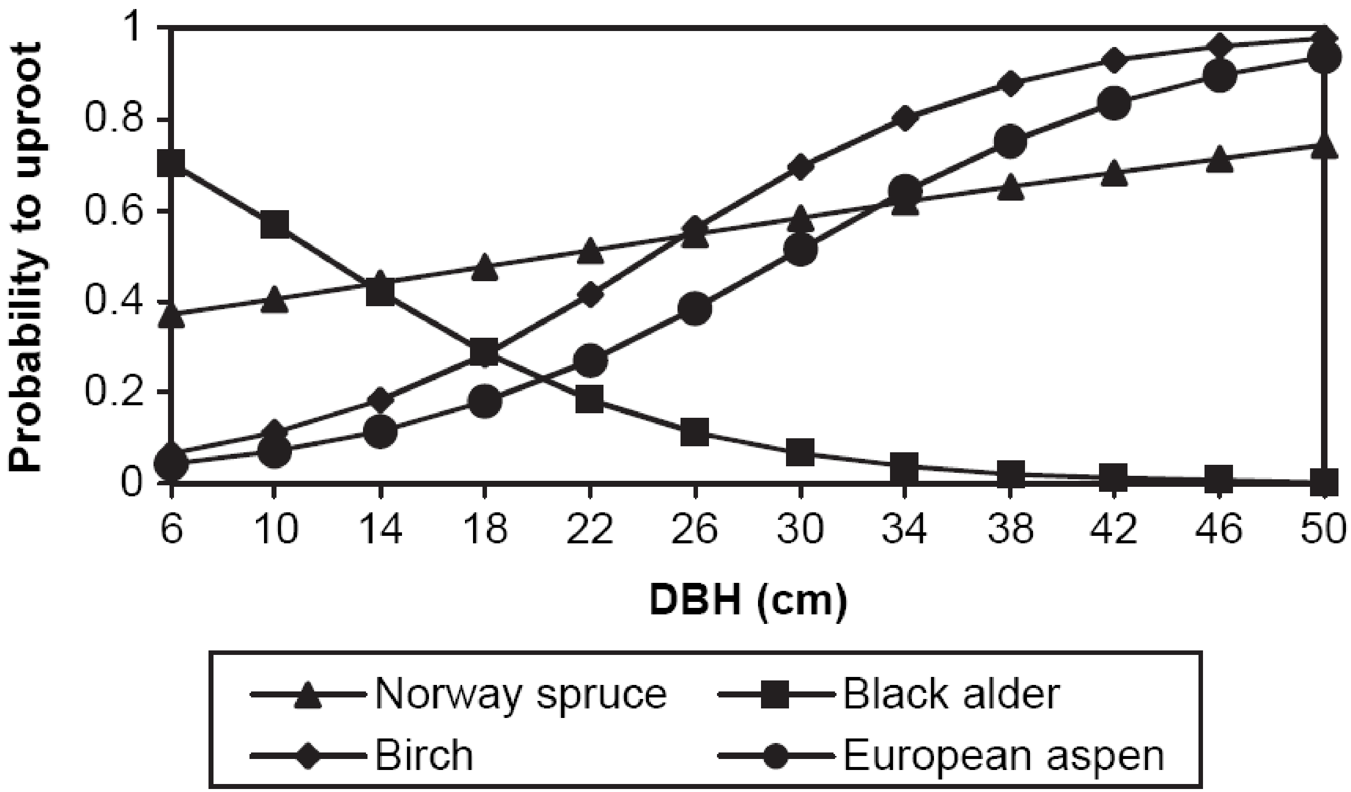


Figure 3. Probability of uprooting as a function of diameter at breast height (dbh) by tree species.

Ilisson et al.Scand. J. Forest Res. 2005

Example: Estonia

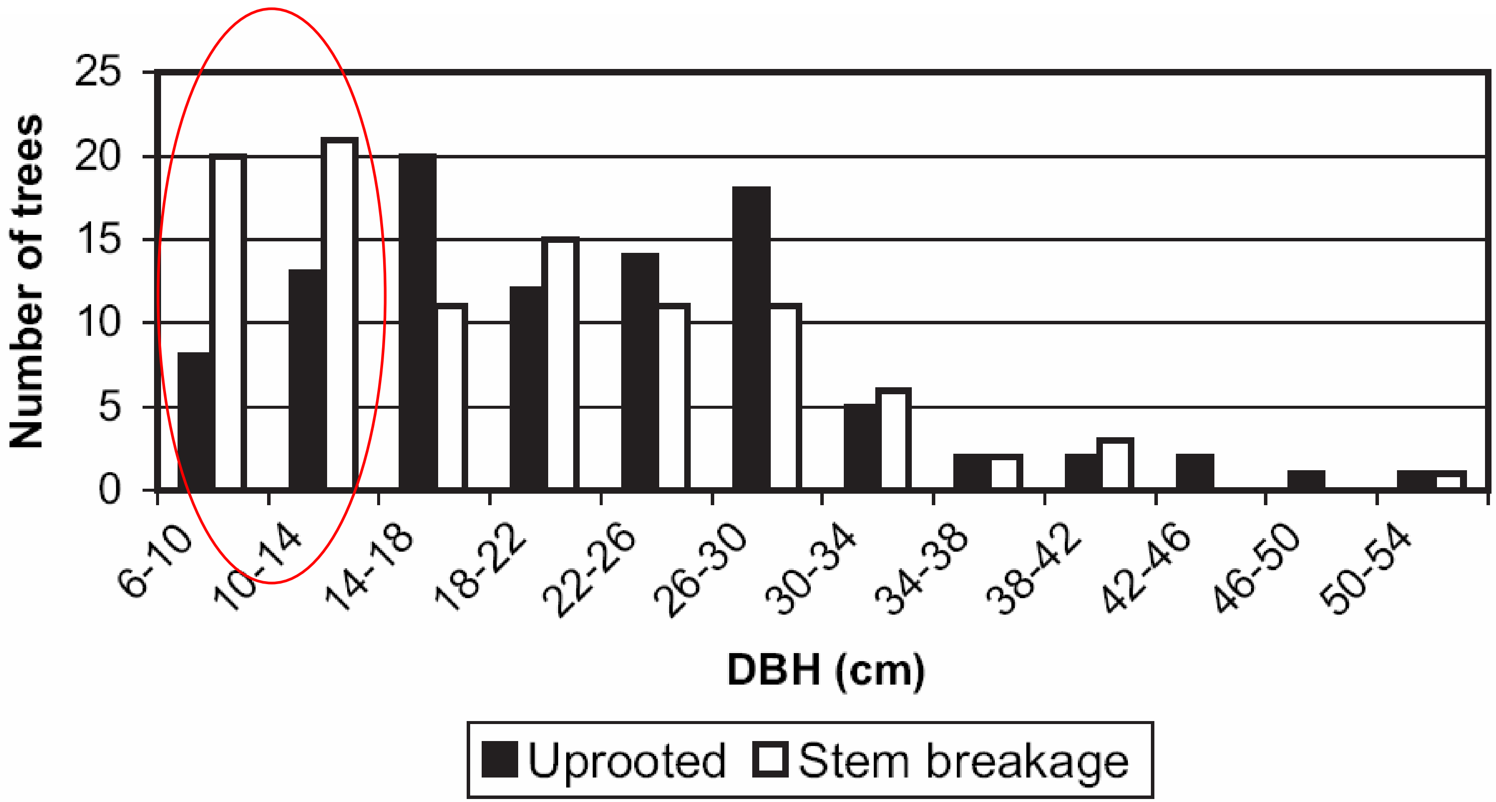
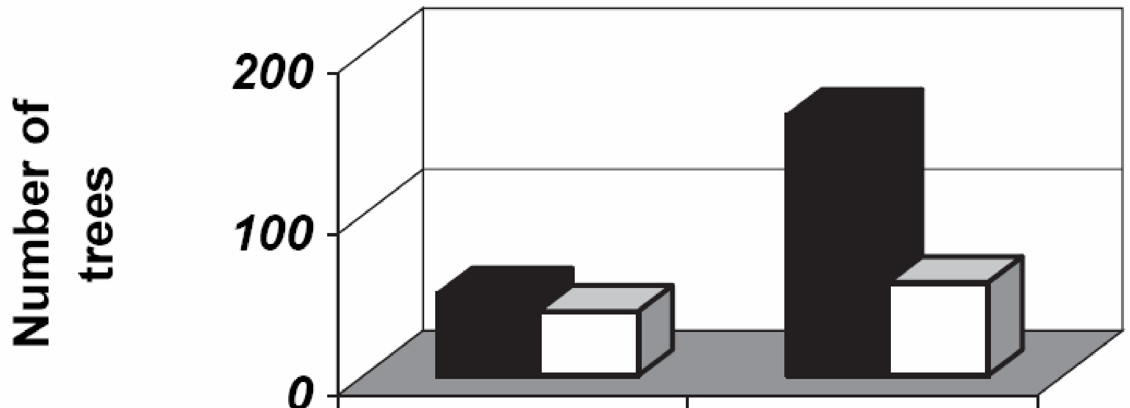


Figure 4. Proportion of uprooted and stem-broken Norway spruce among diameter at breast height (dbh) classes.

Ilisson et al.Scand. J. Forest Res. 2005

Example: Estonia



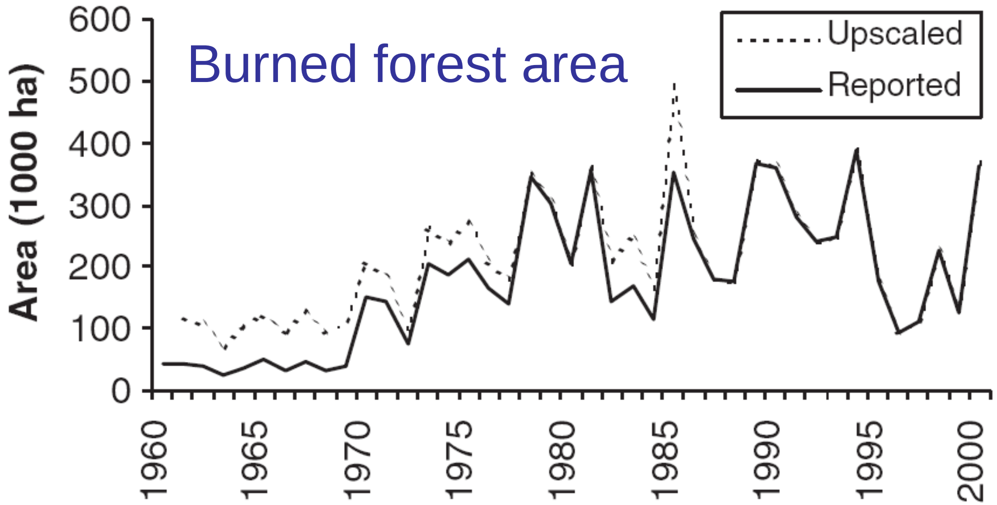
	Gley soils	Podzolic soils
Stem breakages	51	162
Uprootings	40	58

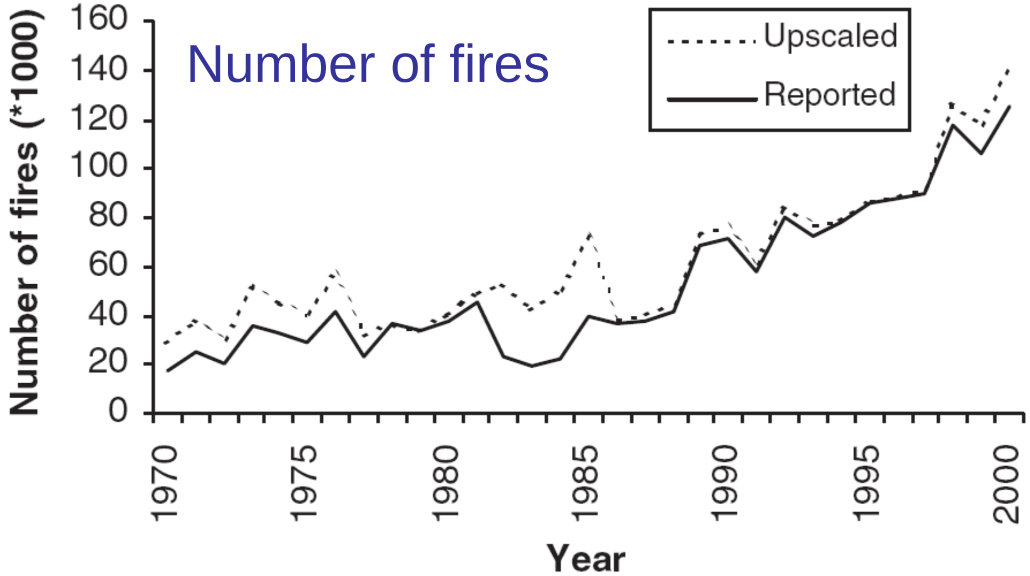
Figure 6. Differences in number of uprootings and stem breakages of Norway spruce between sites on gley and podzolic soils ($\chi^2 = 9.231$, $p = 0.002$). dbh = diameter at breast height.

Ilisson et al.Scand. J. Forest Res. 2005


Disturbance regimes and climate change

Natural disturbances in the European forests in the 19th and 20th centuries





Wood damage

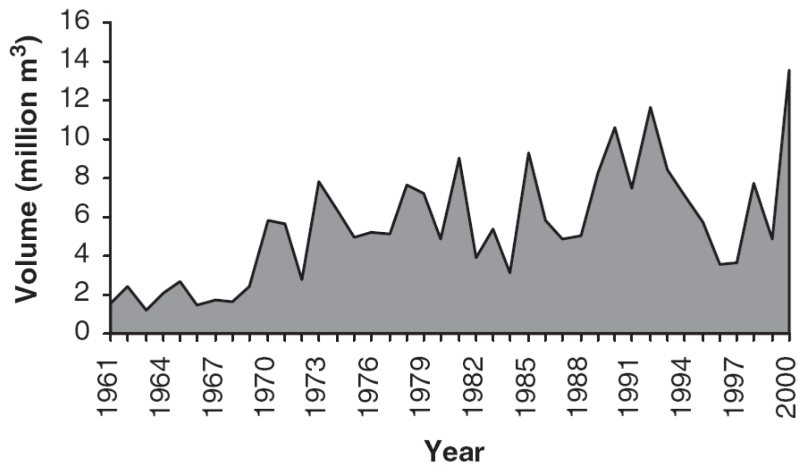
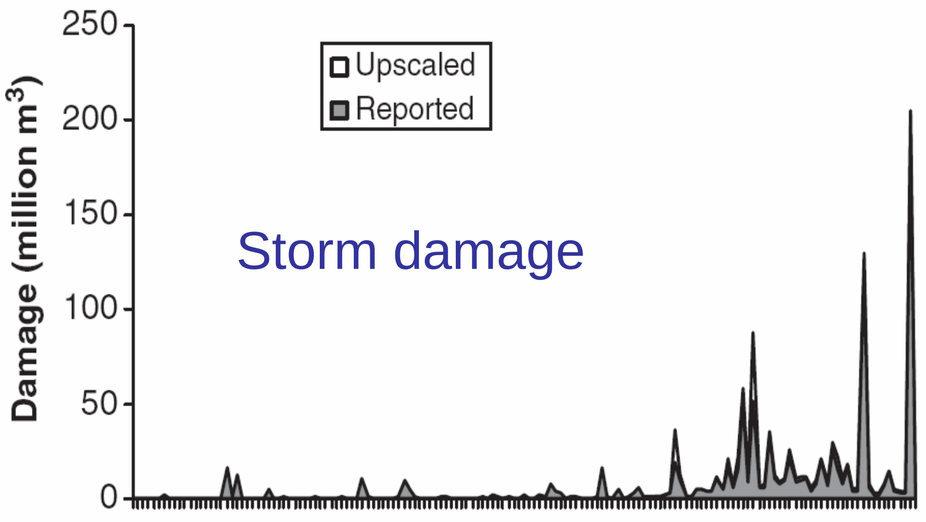


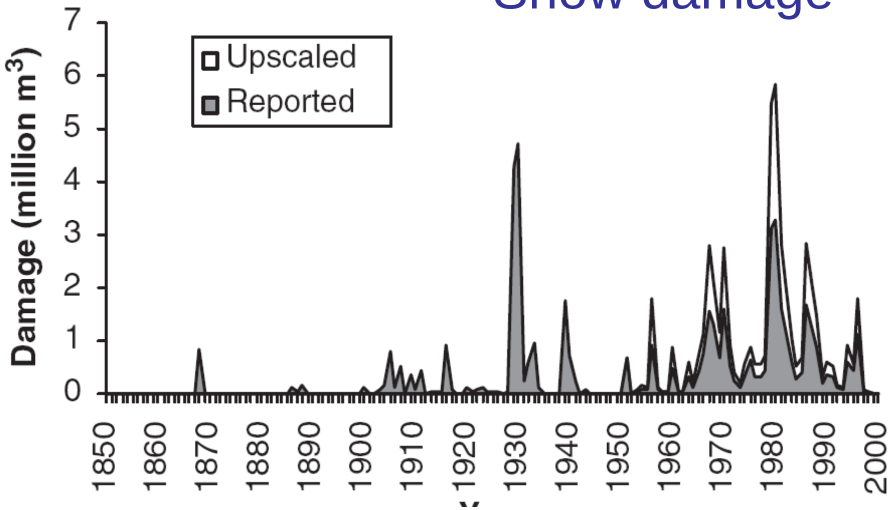
Fig. 4 Volumes of wood damaged by fire for total Europe (1961–2000) as estimated from the total upscaled forest fire area and average wood volume damaged by fire, per country.

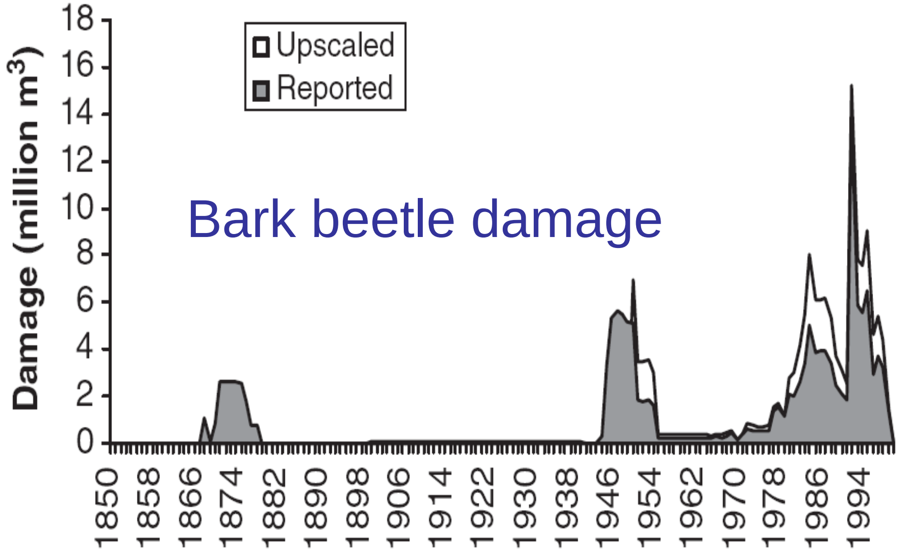
Scheelhaas et al. GCB 2003

Natural disturbances in the European forests in the 19th and 20th centuries



Snow damage





Scheelhaas et al. GCB 2003

Frage

- Wie können die Änderungen im Störungsregime in Europa erklärt werden?

Example: Canada

- More fires, therefore:
- More insects, therefore:
- Lower C stocks

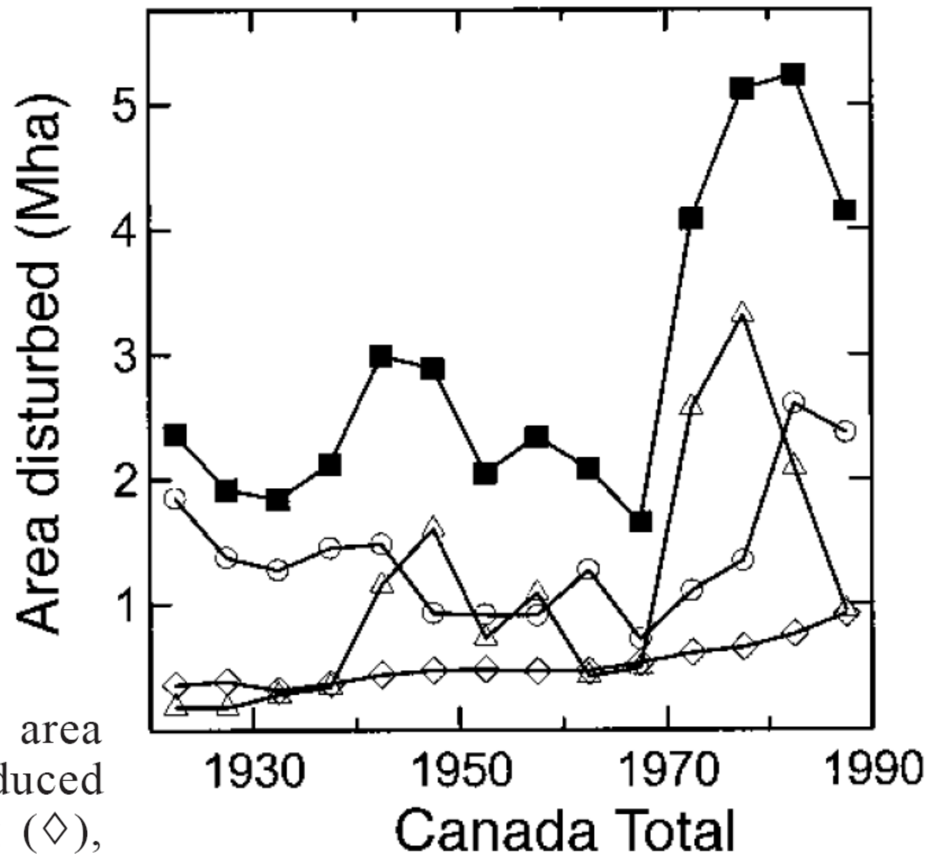
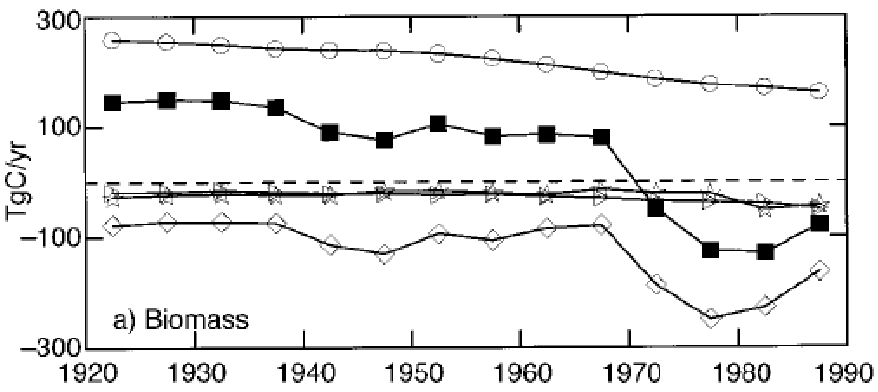


FIG. 3. The five-year averages of the area annually disturbed by fires (○), insect-induced stand mortality (△), clear-cut harvesting (◊), and the total (■) for the period 1920–1989. The

Kurz & Apps Ecol. Appl. 1999

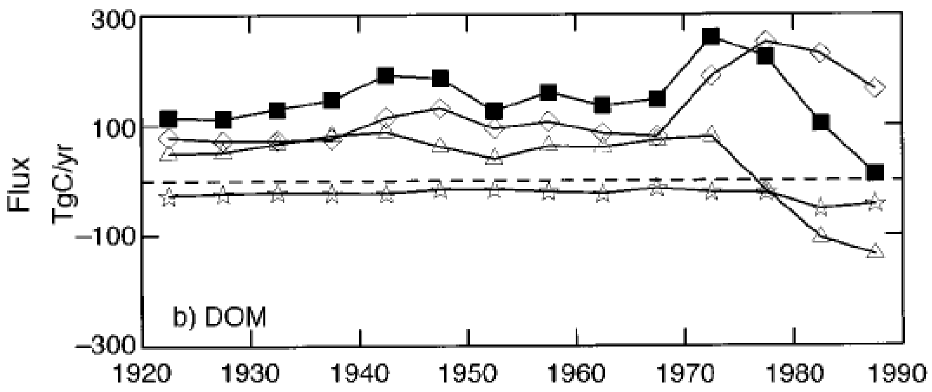
Biomass fluxes

- ○ Biomass growth before disturbance
- ■ Annual change in biomass pools
- ▷ Harvest
- ☆ Release to atmosphere
- ◇ Transfer biomass to litter



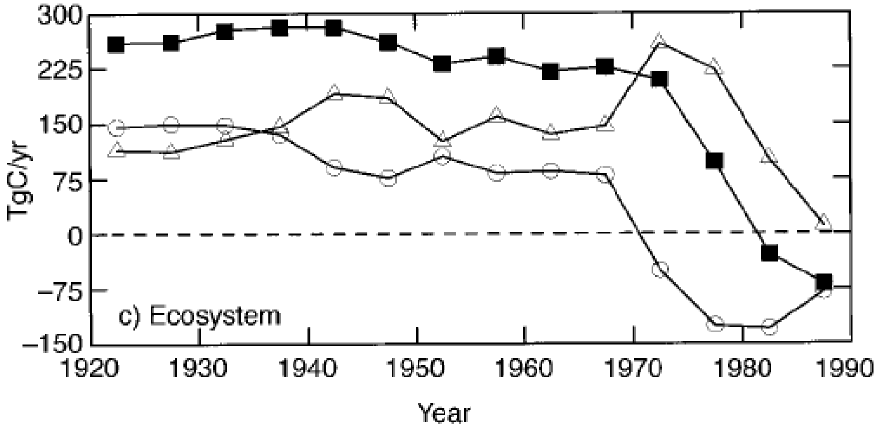
Litter fluxes

- ■ Annual change in litter pool
- ◇ Biomass to litter transfer
- △ Net litterfall
- ☆ Disturbance release



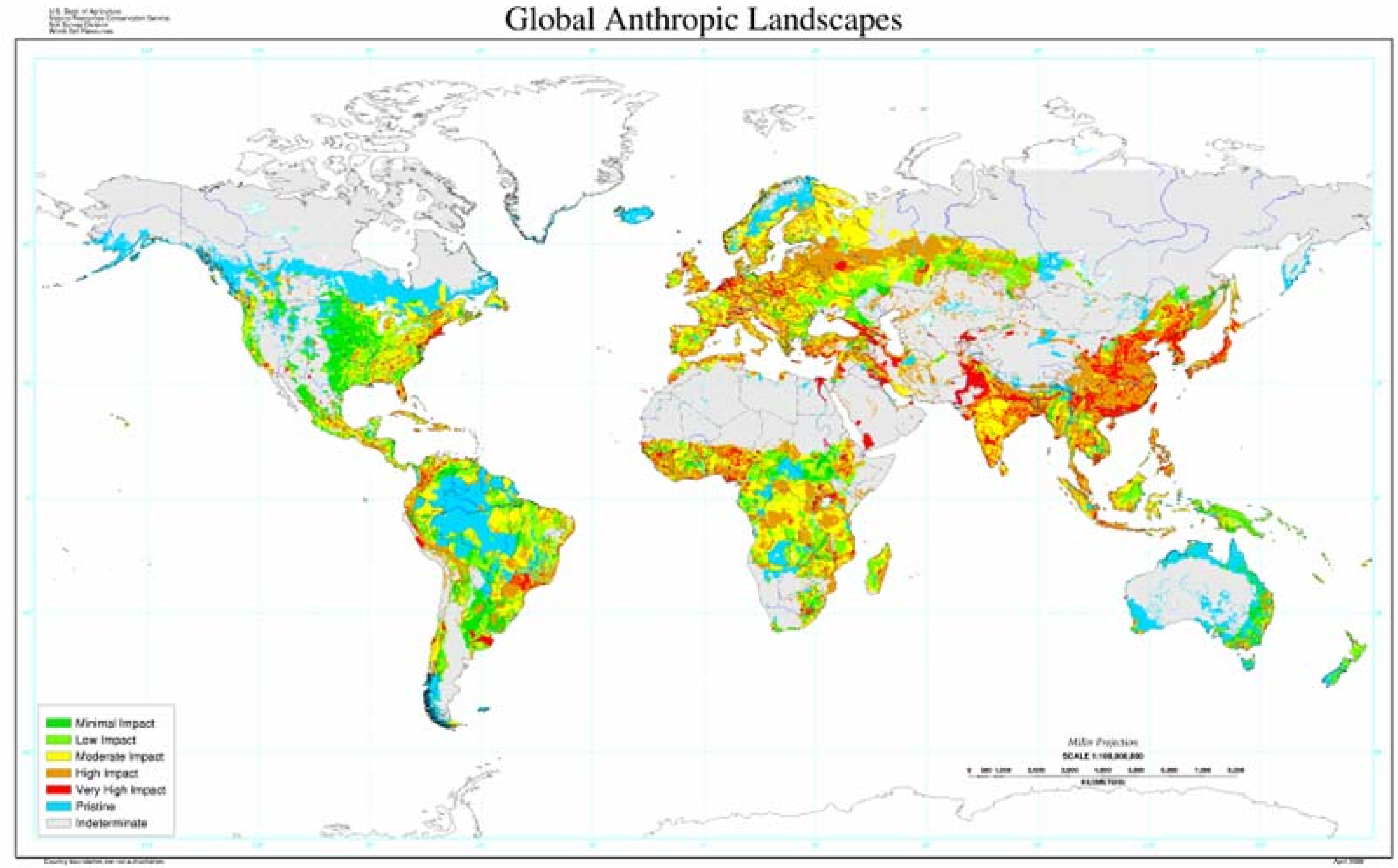
Ecosystem fluxes

- ■ Total ecosystem change
- △ Changes in litter pools
- ○ Changes in the biomass pool



Kurz & Apps Ecol. Appl. 1999

Anthropogenic landscapes



Risiken für C-Verluste in Böden

- Höchste C-Vorräte in Gebieten mit Gefahr durch Klimawandel
  - Permafrost: Auftauen!
  - Boreale Wälder: mehr Feuer?
- Hohe C-Vorräte in Gefahr durch Mensch
  - Entwaldung: Degradation
  - Drainage von Mooren (z.B. Brände in Indonesien)
- Negative Folgen von C-Verlusten in Böden
  - Fruchtbarkeit
  - Erosionsschutz
  - Klimawandel

Fragen

- Wie wirken Störungen auf C-Flüsse?
- Wie wirken Störungen auf Biodiversität?
- Welches sind die wichtigsten Störungstypen
  - Weltweit
  - In borealen Wäldern
  - In temperaten Wäldern
  - In tropischen Wäldern
- Wie kann man in Europa die wachsenden Sturmschäden in Wäldern erklären?

Nutrient imbalances: Eutrophication

Contents

- Eutrophication
  - processes
  - consequences for ecosystems

- pH buffer systems in soils

Eutrophication

- Accumulation of nutrients (N, P,…)

- Natural processes
  - Bioaccumulation (Humus, peat, guano)
  - Mass flow (erosive, fluviatile, aeolian)
  - Weathering
  - BUT: Strong weathering reduces nutrient availability through leaching

- Anthropogenic processes
  - Fertilization
  - Atmospheric deposition
  - Waste waters, sewage
  - Soil movement

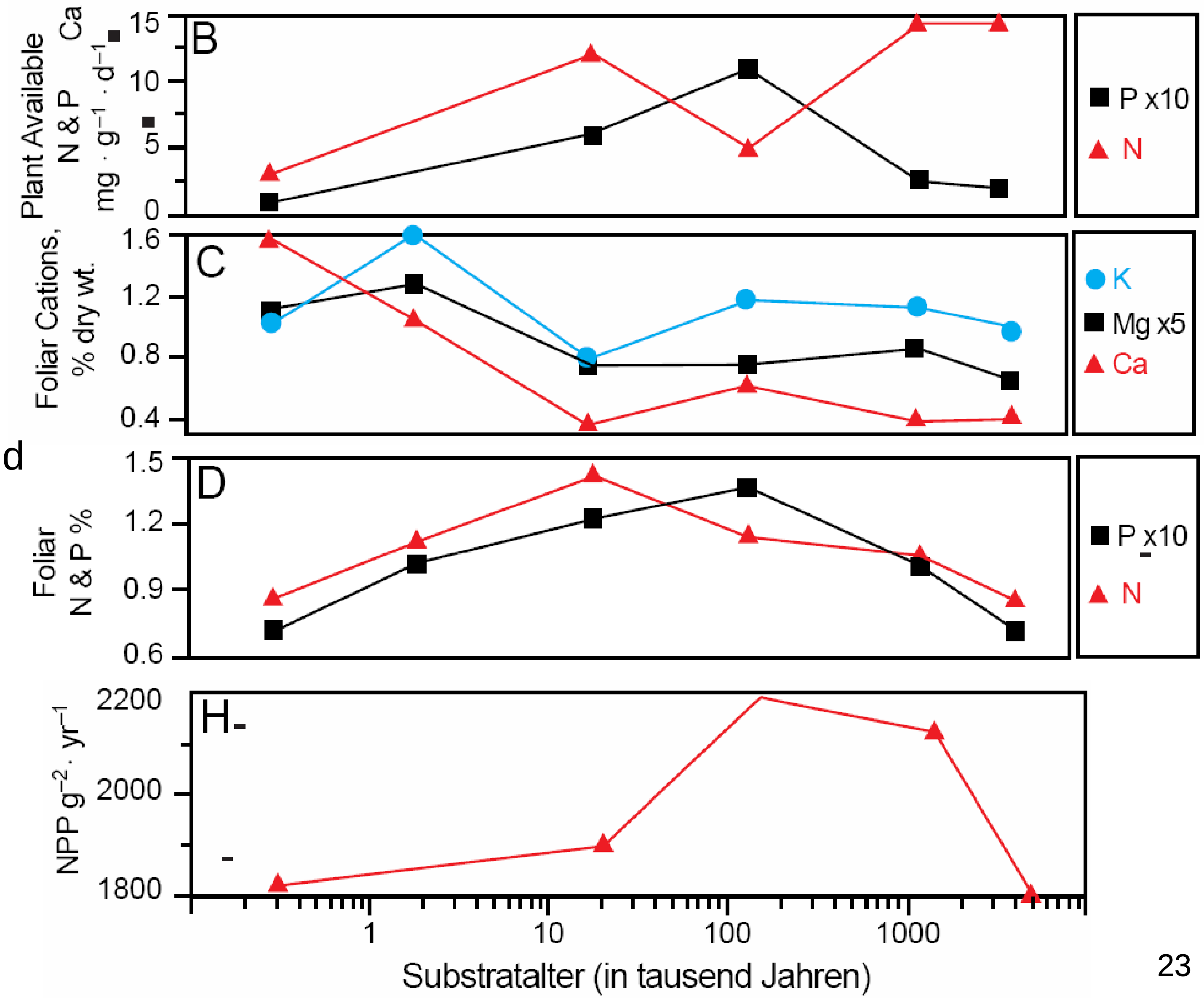
Natural: Nutrient availability in succession

Soil nitrogen and phosphorus

Foliar cations

Foliar nitrogen and phosphorus

Change in concentrations of cations, N and P in soil and leaves over 4000 years of lava weathering in Hawaii.



Schulze et al. 2002, Fig. 3.5.1

Eutrophication

- Accumulation of nutrients (N, P,…)

- Natural processes
  - Bioaccumulation (Humus, peat, guano)
  - Mass flow (erosive, fluviatile, aeolian)
  - Weathering
  - BUT: Strong weathering reduces nutrient availability through leaching

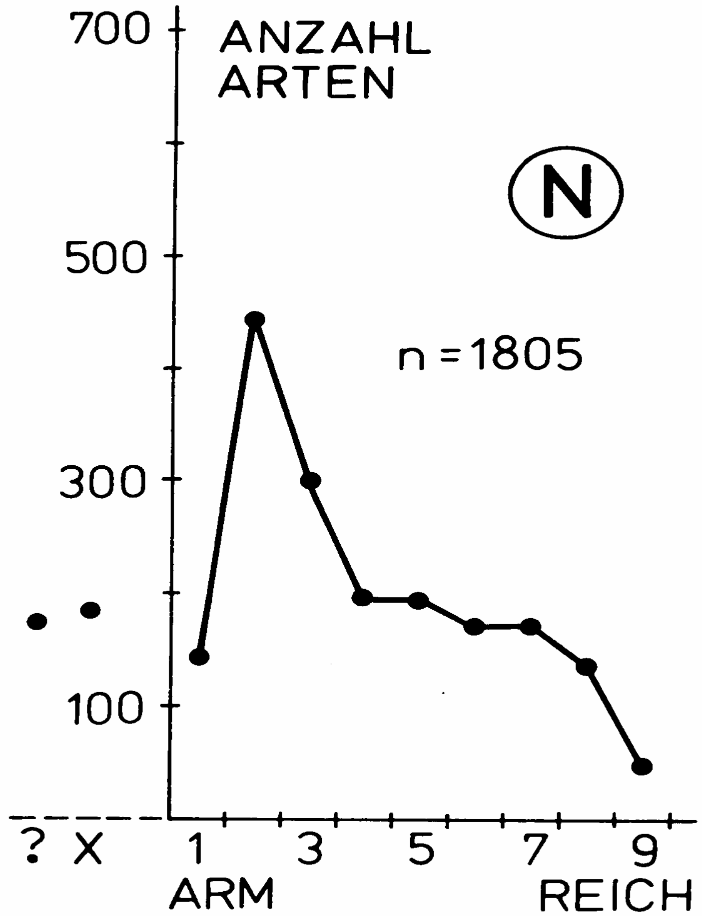
- Anthropogenic processes
  - Fertilization
  - Atmospheric deposition
  - Waste waters, sewage
  - Soil movement

Consequences of eutrophication

- Increased supply of macronutrients
- Often increased productivity (sometimes transient)
- Species change in ecosystems, often reduced community diversity, or trend to more common species
- Nutrient accumulation
- Nutrient saturation / leaching
- Higher plant stress susceptibility

Consequences of eutrophication

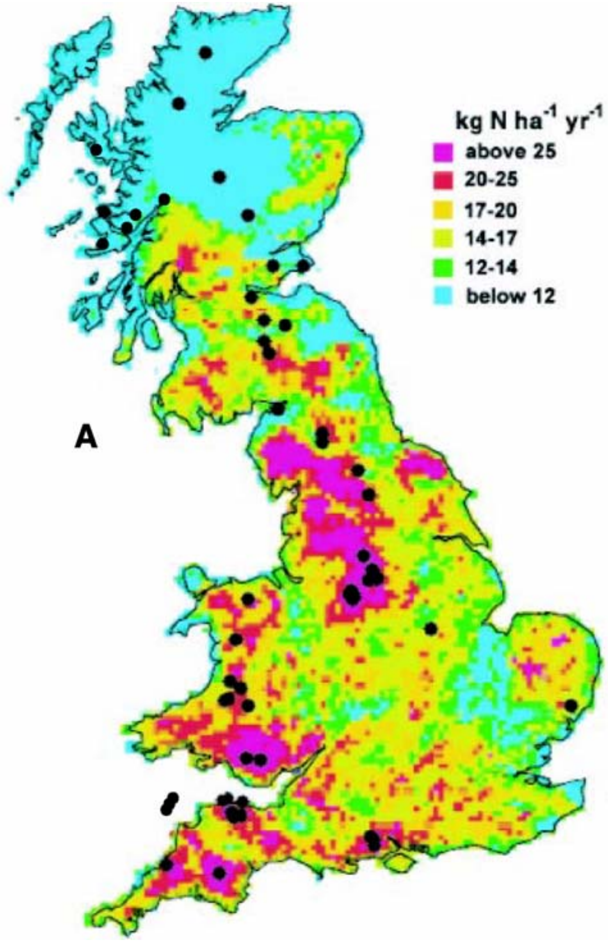
Anpassung der Arten an das Nährstoff-Angebot

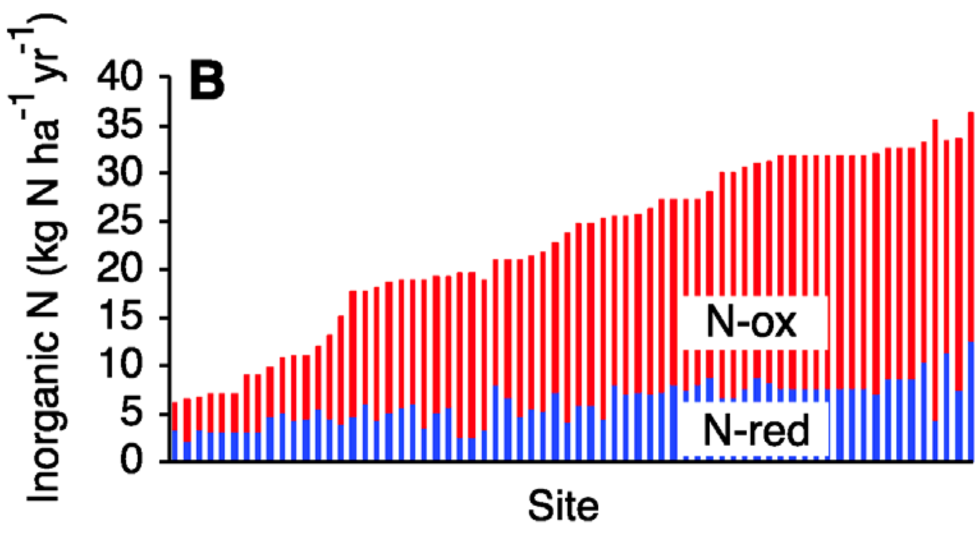


Ellenberg, (1989)

Die Verteilung mitteleuropäischer Gefäßpflanzenarten im Gradienten der Stickstoffzeigerwerte

N deposition in the UK





Stevens et al. (2004)

(A) Total inorganic N deposition (kg N ha^{-1} year^{-1}) to the United Kingdom with field site locations shown.

(B) The deposition of reduced (NH_3, NH_4^*) and oxidized (NO, NO_2,NO_3^-) N across the sites.

Species number related to N availability in grasslands

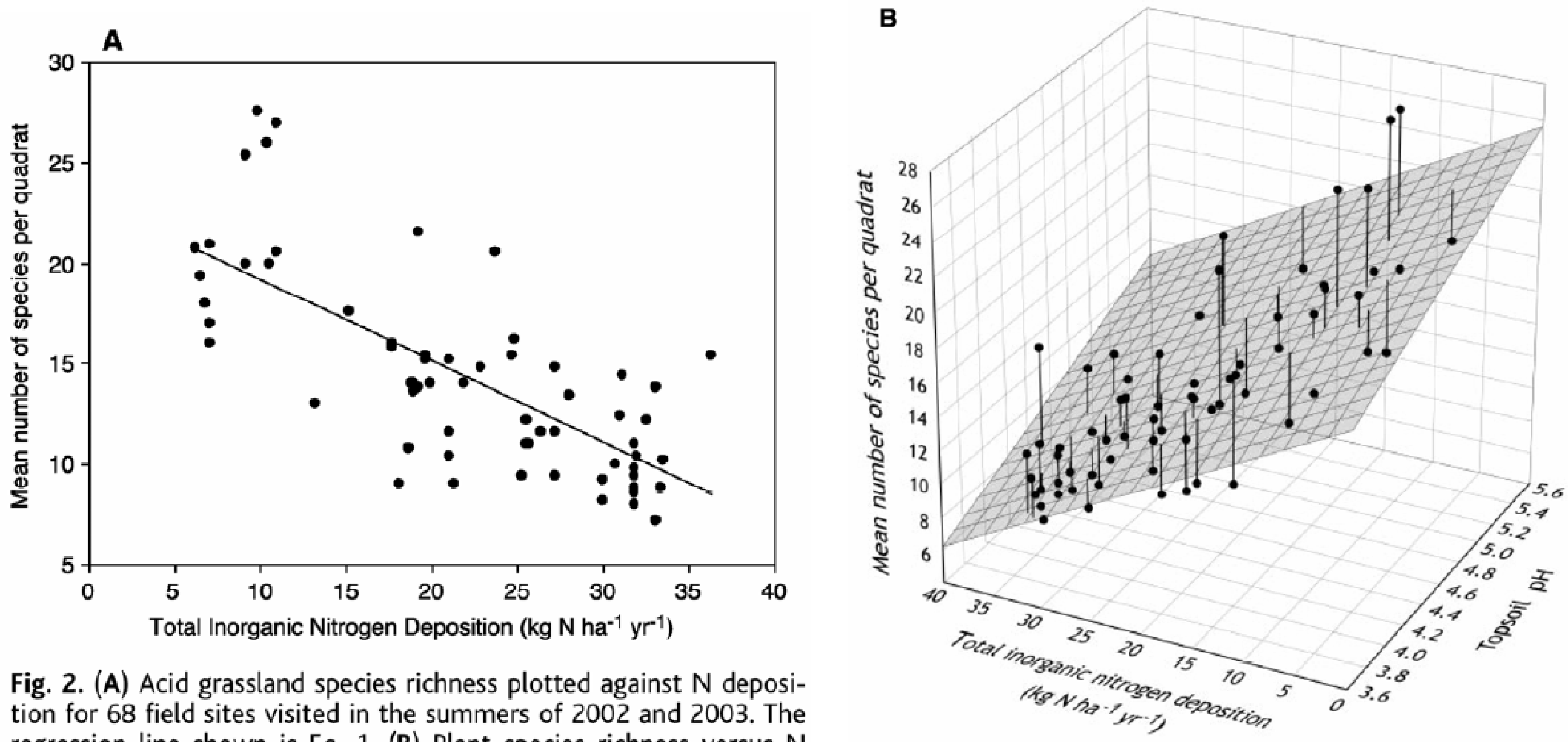


Fig. 2. (**A**) Acid grassland species richness plotted against N deposition for 68 field sites visited in the summers of 2002 and 2003. The regression line shown is Eq. 1. (**B**) Plant species richness versus N deposition and topsoil pH. The regression equation shown is: *Plant Species Richness* = 6.63 + 3.40(*Top pH*) − 0.316(*Nin*); $r^2 = 0.61$, $N = 68$, $P < 0.004$.

Stevens et al. (2004)

Emissionstrends in Deutschland

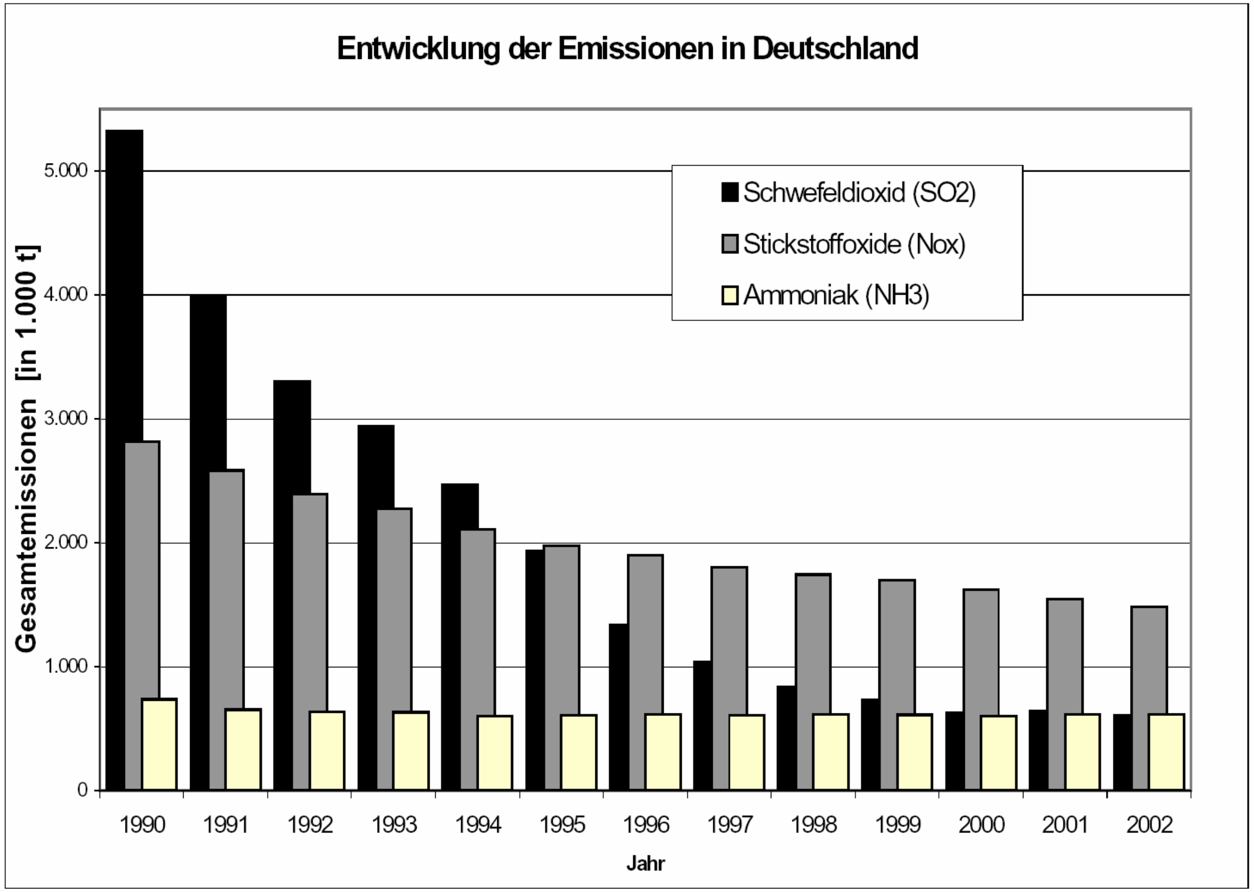
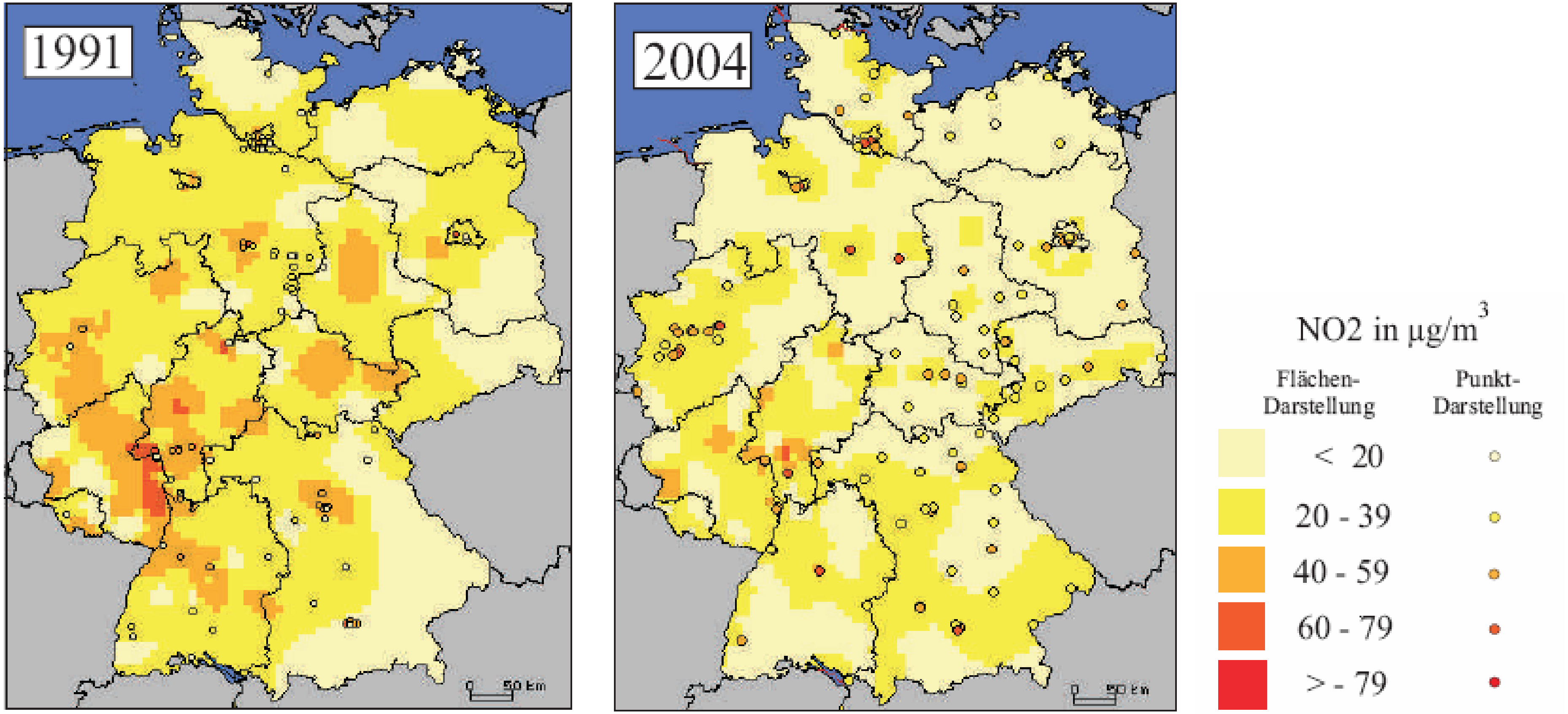


Abbildung 18: Die Emissionen von Schwefeldioxid (SO_2) und Stickstoffoxiden (NO_x) gingen in Deutschland seit 1990 deutlich zurück. Gleichwohl ist der Ausstoß von Stickstoffverbindungen (Stickstoffoxide und Ammoniak) immer noch zu hoch (Quelle: Umweltbundesamt)

Bericht Zustand des Waldes (2004)

NO_2 annual average air concentrations in Germany



NO_2 concentrations measured by UBA

Fragen

- Was sind die Hauptquellen für atmosphärische Stickstoffdeposition in Deutschland?
- Wie könnten die Emissionen reduziert werden?

Critical loads

- **Definition:**

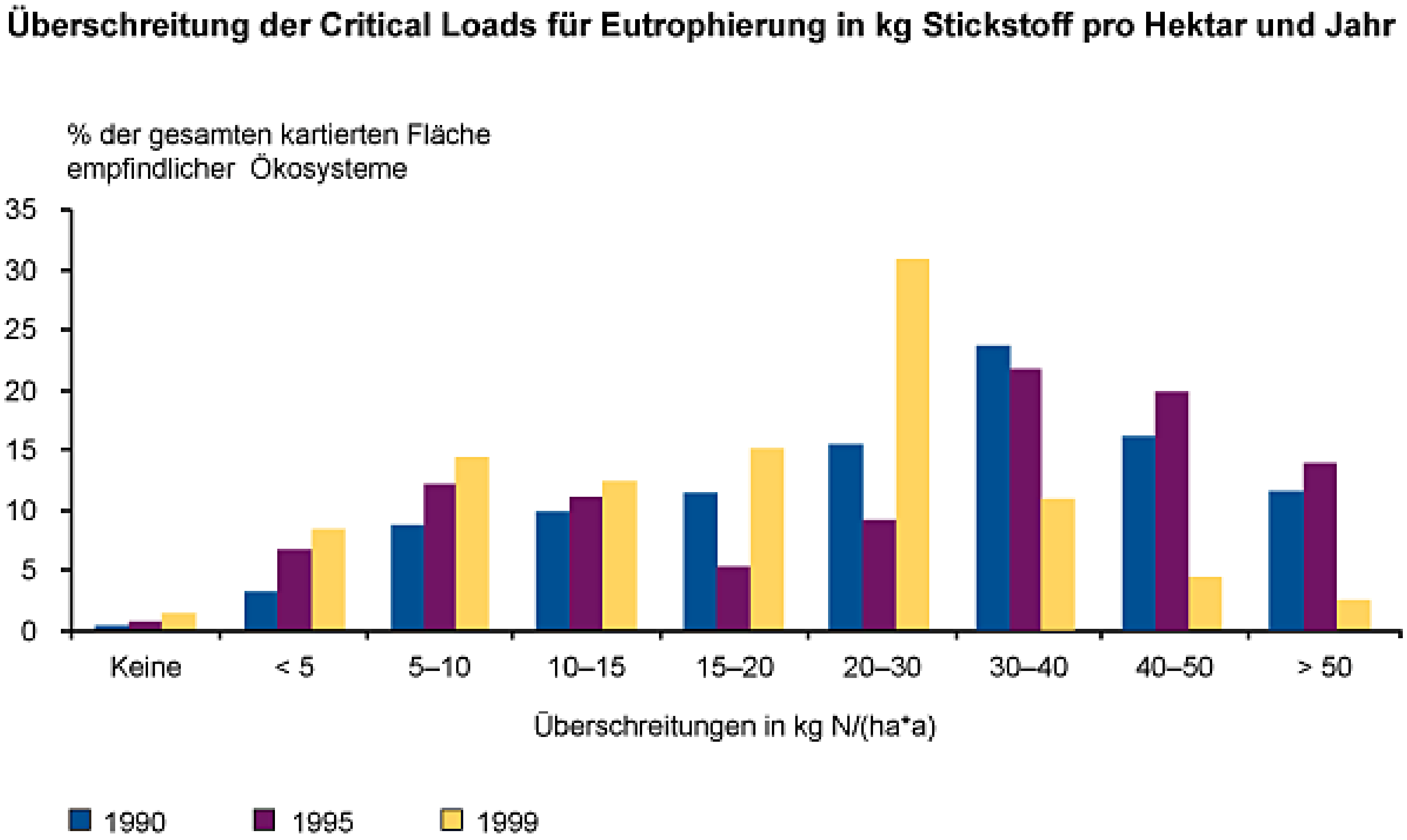
  Critical Load is the quantitative estimate of the level of exposure of natural systems to pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur.

Critical loads

- minimum critical load of nitrogen, **CLmin(N):** all deposited N is consumed by sinks of N (immobilization in the soil and uptake by plants).

- maximum critical load for nitrogen, **CLmax(N):** not only takes into account these N sinks, but considers also deposition-dependent N processes (such as denitrification).

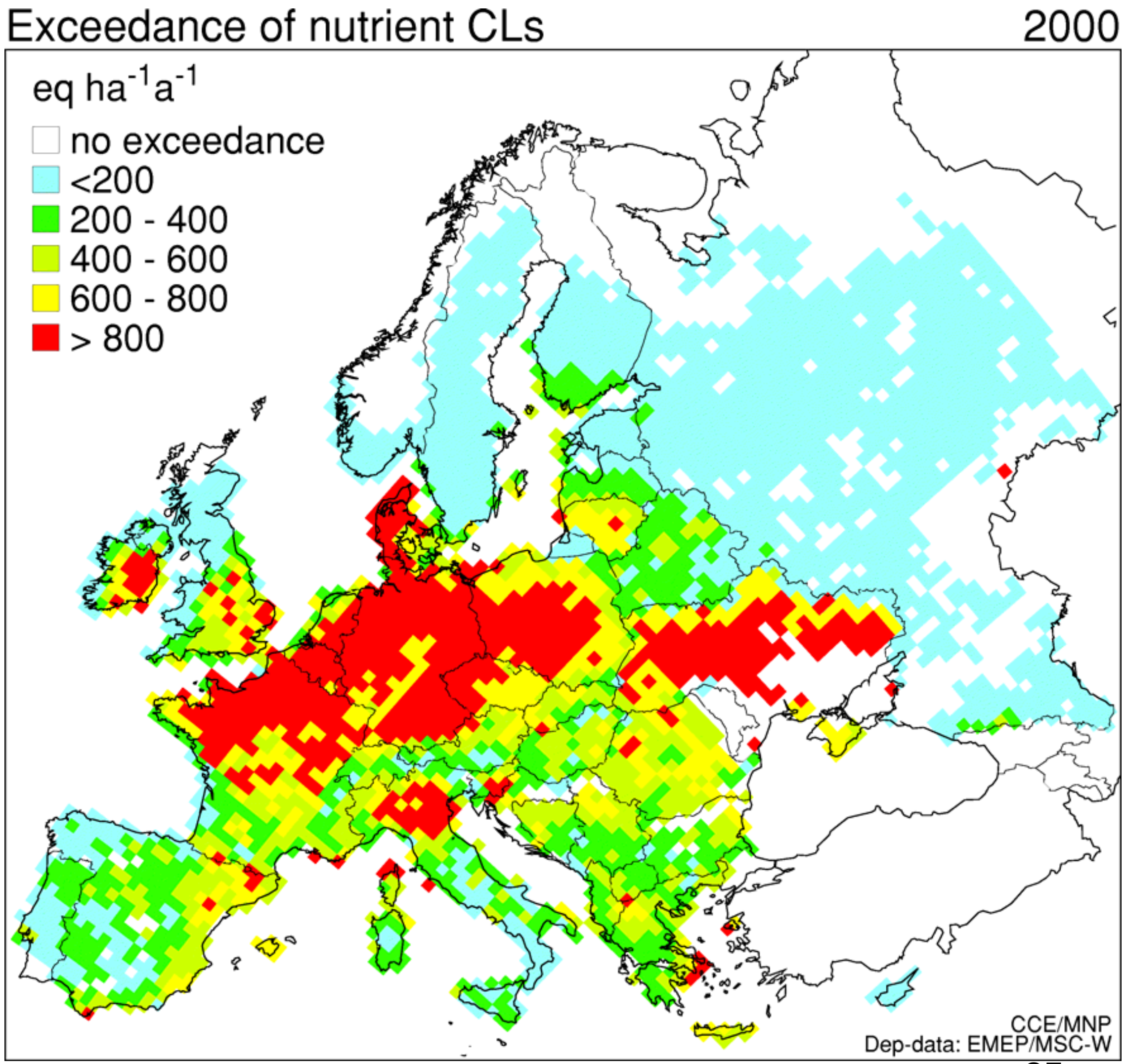
Exceedance of N critical loads in Germany



Quelle: Umweltbundesamt 2005 – UBA; Universität Stuttgart, Institut für Navigation: UBA Vorhaben 299 42 210: „Kartierung ökologischer Langzeittrends atmosphärischer Stoffeinträge und Luftschadstoffkonzentrationen in Deutschland und deren Vergleich mit Critical Loads und Critical Levels", Abschlussbericht 2003; Öko-Data GmbH: UBA-Vorhaben 200 85 212: „Critical Loads für Säure und eutrophierenden Stickstoff", Abschlussbericht 2005

Eutrophication in Europe

- **Eutrophication** has fallen slightly since 1980. However, only limited further improvement is expected by 2010 with current plans.

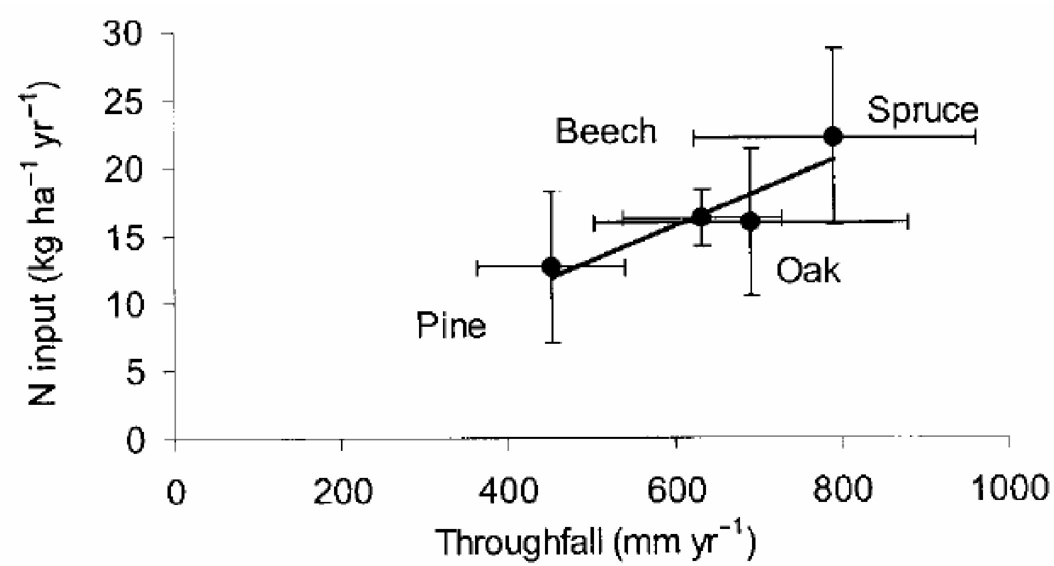


EEA 2005

N leaching in German forests

- N saturation ➡ N leaching

- Risk higher where
  - N deposition is high
  - precipitation is high
  - C/N ratio of organic layer <25



- Average leaching
  - pine 0.5 kg N ha^{-1} yr^{-1} (4%)
  - oak 1.2 kg N ha^{-1} yr^{-1} (8%)
  - beech 1.9 kg N ha^{-1} yr^{-1} (11%)
  - spruce 5.8 kg N ha^{-1} yr^{-1} (24%)

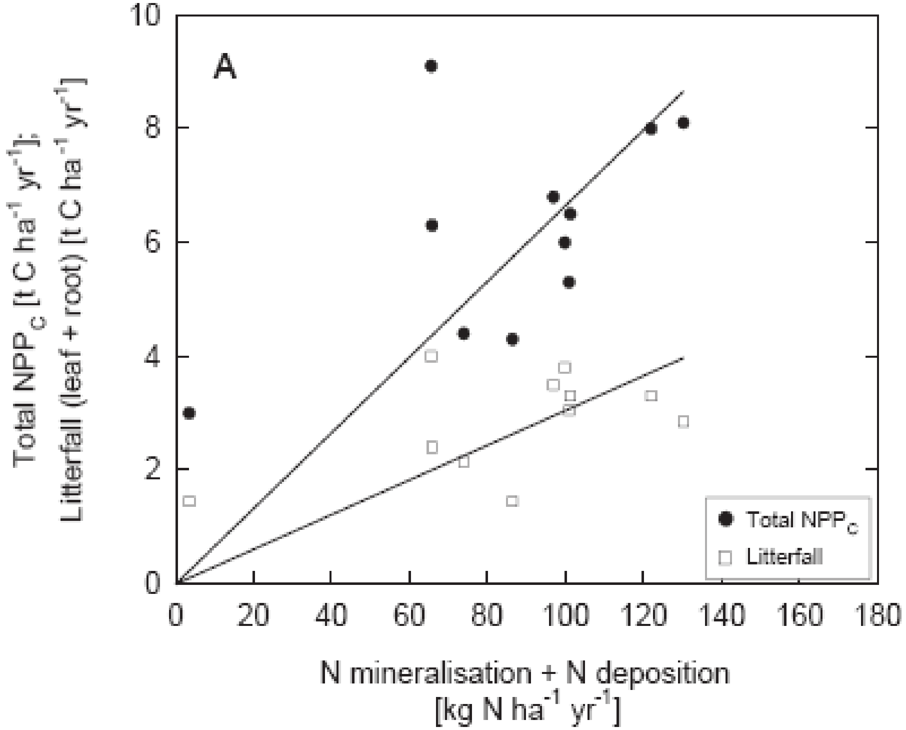
  - Cropland: 20-50 kg N ha^{-1} yr^{-1} (30%)

Borken and Matzner 2004

C-N interactions in forests

Relationship between growth (NPP, litter) and N supply:

No growth saturation with N

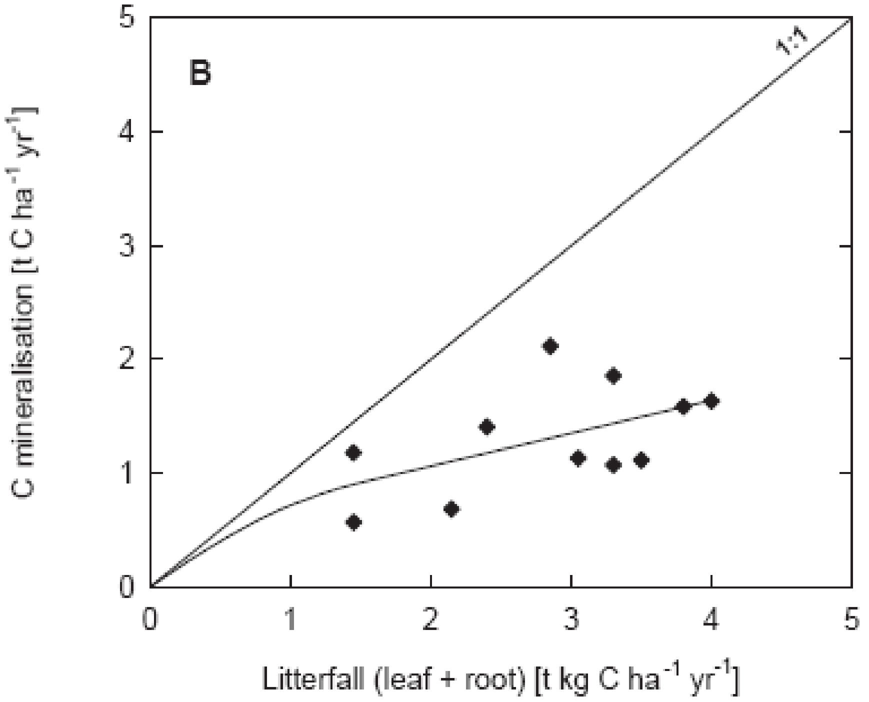


Schulze et al. 2000

C-N interactions in forests

Relationship between
C mineralisation and C supply
by litter:

Litter accumulation! Why?



Schulze et al. 2000

Does N deposition reduce decomposition?

- Concept of „limit values“ =
  accumulated mass of litter that has been lost when the decomposition rate is zero

  m.l. = m (1 – $e^{-kt/m}$)

  m.l. mass loss (%)

  m asymptotic level of ultimate mass loss („limit value, %)

  k decomposition rate at t=0

- „Limit values“ related to litter concentrations of N, Mn, Ca (= elements regulating lignin decomposition)

Case study in boreal forests

Faster decomposition in site with higher nutrient availability

Higher N content does not lead to higher total mass loss

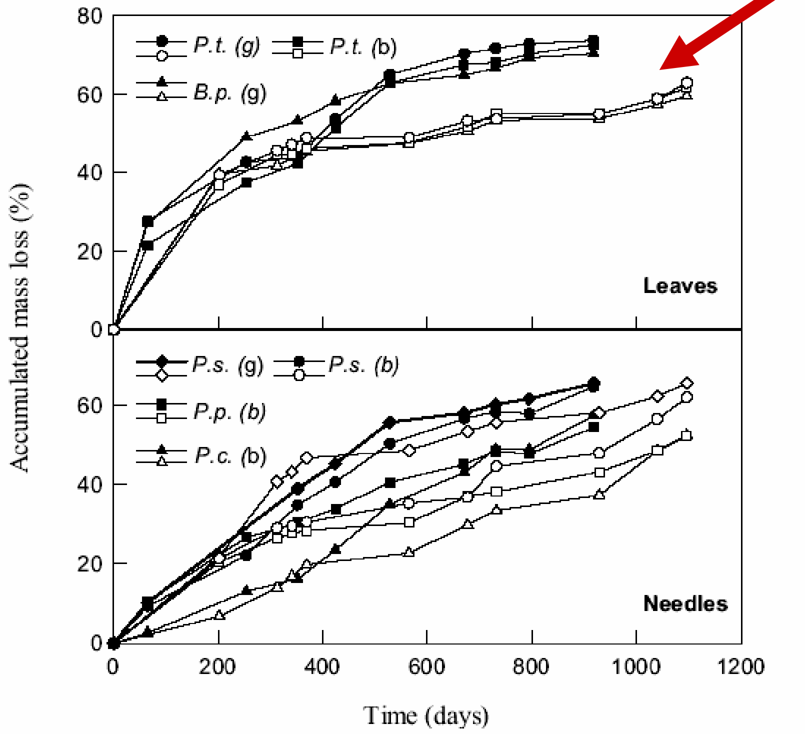


Fig. 1. Decomposition of seven litters types incubated in a silver-fir forest (Monte Taburno—filled symbols) and in a Scots pine forest (Jädraås—open symbols). *Populus tremula* (P.t.), *Betula pubescens* (B.p.), *Pinus sylvestris* (P.s.), *Pinus pinea* (P.p.), and *Pinus contorta* (P.c.). (g) stands for green and (b) for brown.

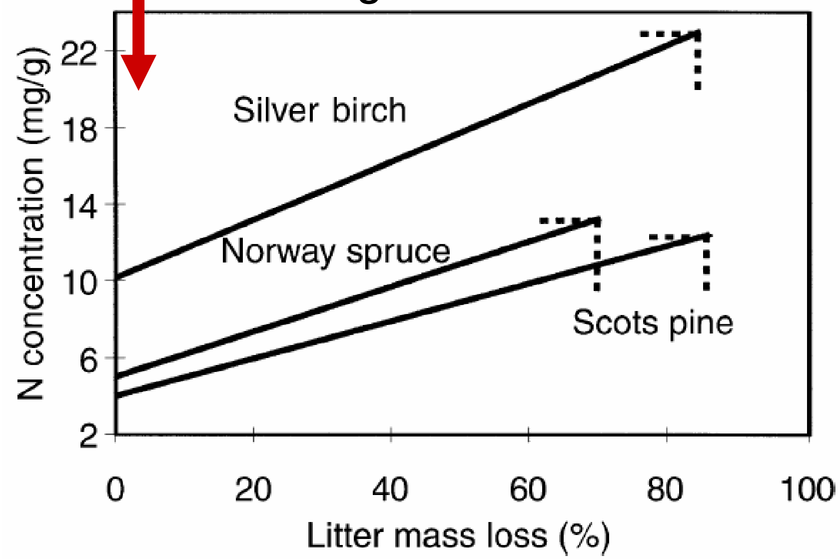
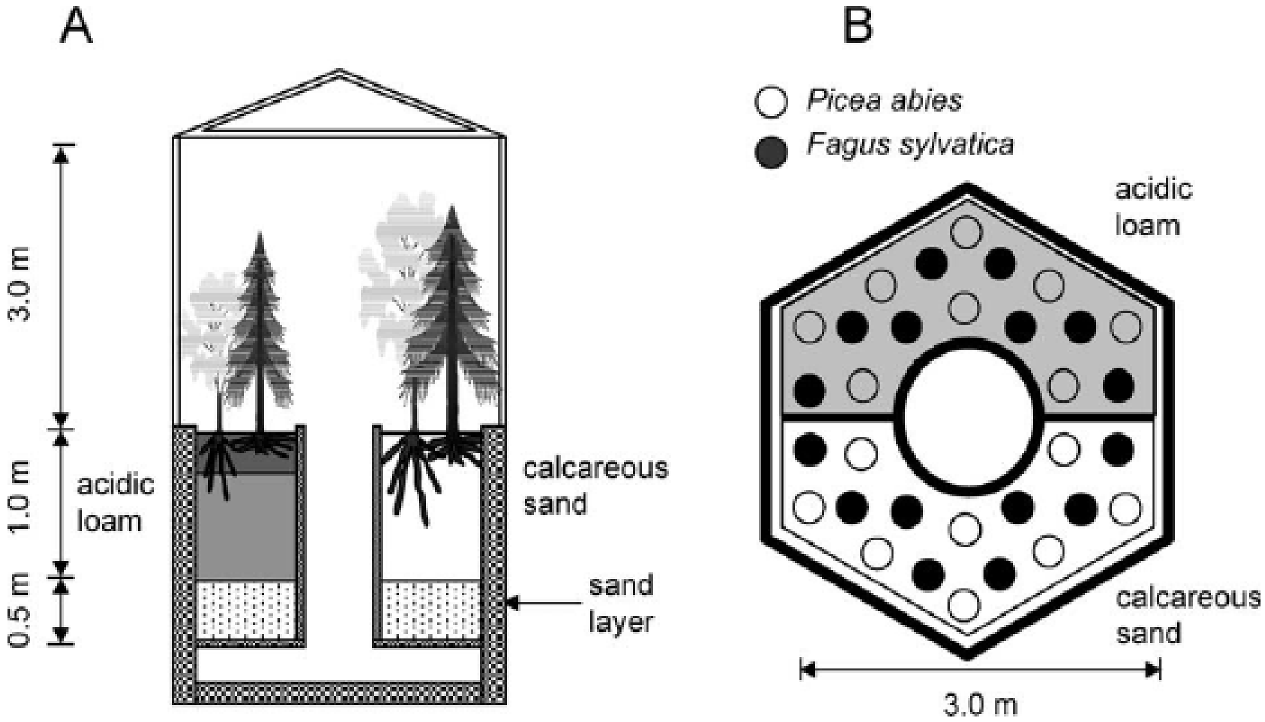


Fig. 1. The relationship between N concentration in decomposing litter and litter mass loss for three different tree species, and their estimated N concentration at the limit value (N_{limit}). At the end of the lines the limit value is indicated (vertical line) and the N concentration at the limit value (horizontal line).

Berg et al. 2003

Berg and Dise 2004

Increased N deposition retards mineralization of old soil organic matter



Hagedorn et al. 2003

Increased N deposition retards mineralization of old soil organic matter

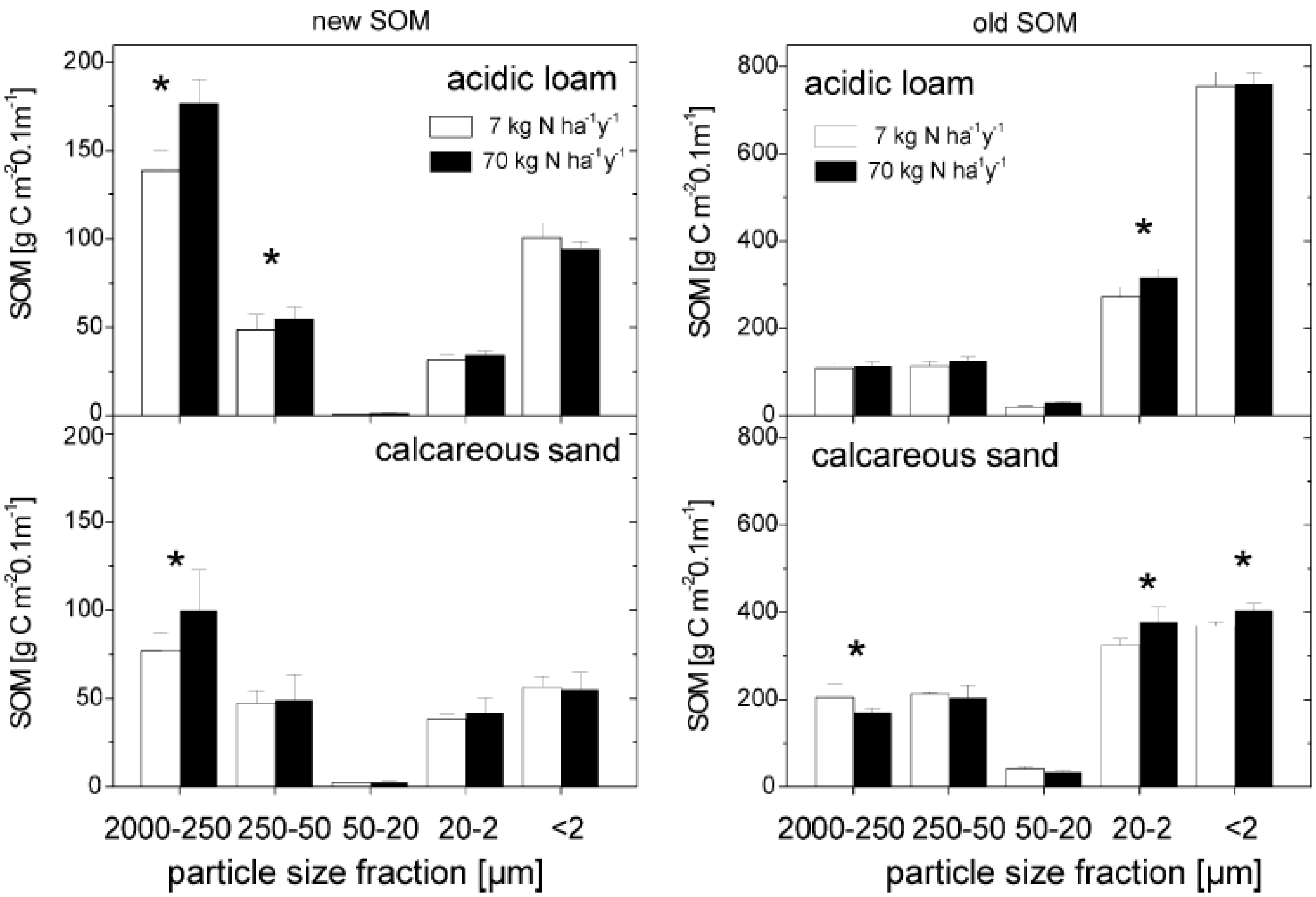


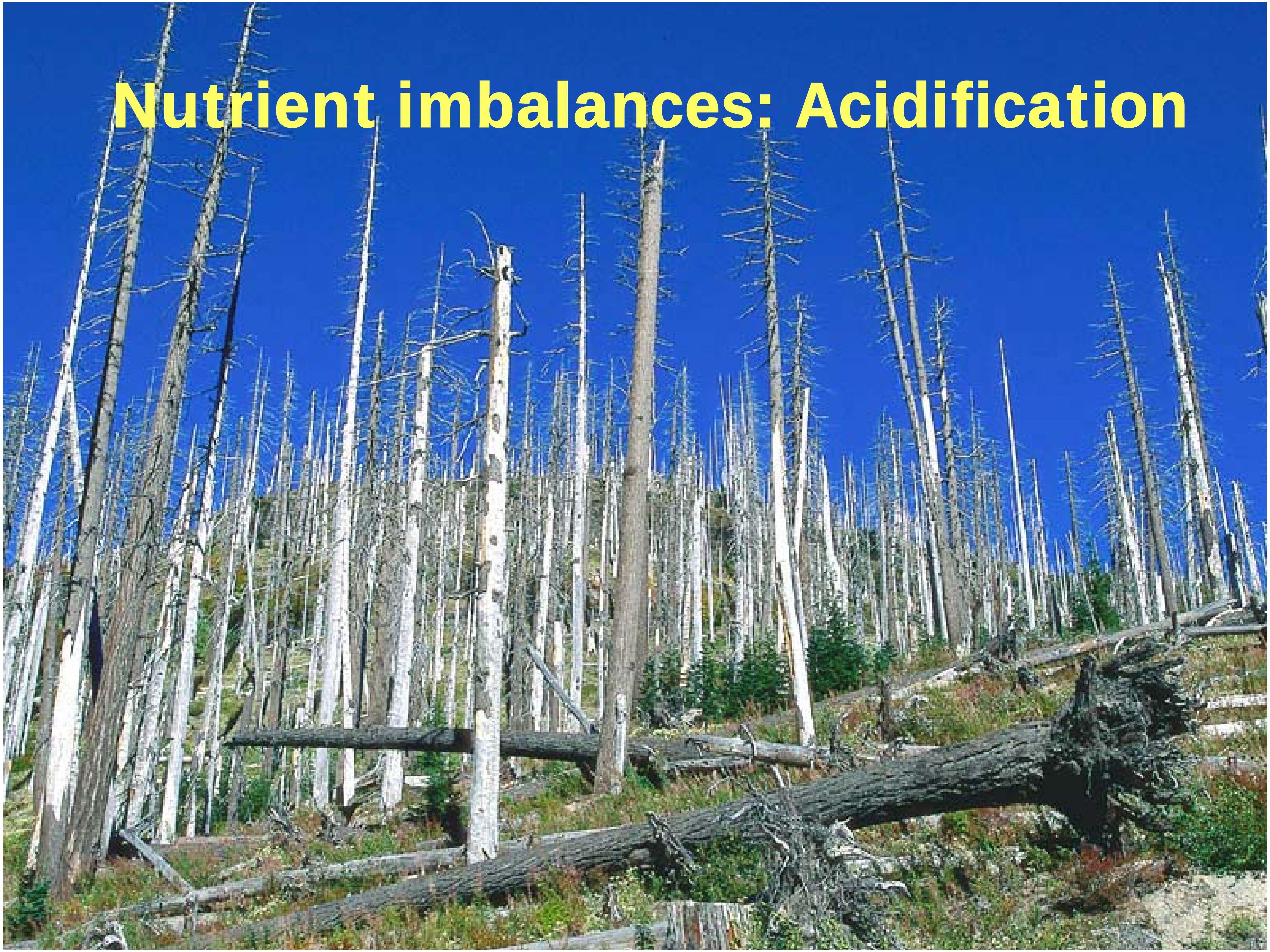
Fig. 5. Amounts of new and old soil organic matter after 4 yr of N deposition. New C was derived from exposure of trees to elevated CO_2 for 4 yr; old SOM represents the carbon older than 4 yr. Means and standard errors of four replicates of the two N deposition levels under elevated CO_2. Significant effects of increased N deposition are indicated by * ($P < 0.05$ with both CO_2 levels included in the ANOVA). Note the different scales of the graphs.

Hagedorn et al. 2003

Frage

- Was sind die wichtigsten Wirkungen und Folgen von N-Eintrag in Ökosysteme?
  - in kleinen Mengen
  - in Überdosis

Nutrient imbalances: Acidification

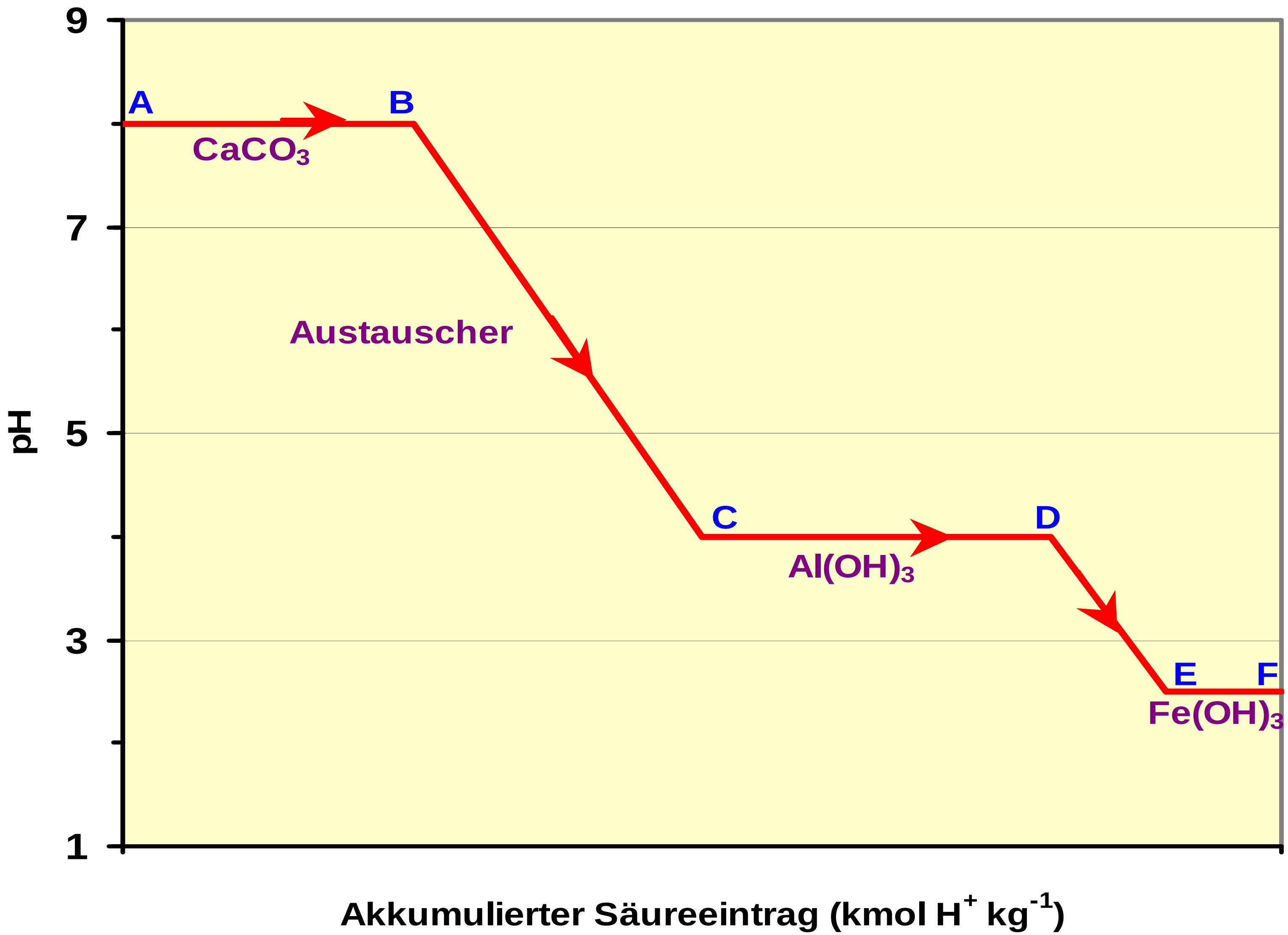


Protonenpufferung

Anionen schwacher Säuren:

$$A^{-} + H^{+} \rightarrow AH$$

Verlauf pH-Werts in gut durchlässigen Böden bei stetigem Säureeintrag



pH – Puffersysteme

Carbonate

Carbonat
$CaCO_3 + \mathbf{H^+} \rightarrow Ca^{2+} + HCO_3^-$ ***pH*** **8…6.5**

Hydrogencarbonat
$HCO_3^- + \mathbf{H^+} \rightarrow CO_2 + H_2O$ ***pH*** **7…4.5**

Verlust von $CaCO_3$ als $Ca(HCO_3)_2$

pH – Puffersysteme

Variable Ladungen

Tonminerale, Oxide

$\text{-Fe-OH} + \mathbf{H^+} \rightarrow \text{Fe-OH}_2^+$ ***pH <7***

Huminstoffe

$\text{R-NH}_2 + \mathbf{H^+} \rightarrow \text{R-NH}_3^+$ ***pH $>7 \ldots 4$***

→ Protonierung variabler Ladung,
Verlust austauschbarer Kationen

pH – Puffersysteme

Silikate

Sekundäre Silikate

$-(SiO)_3Al + 3\mathbf{H^+} \rightarrow -(SiOH)_3 + Al^{3+}$

↓

Al gelangt in die Bodenlösung (toxisch!)

pH – Puffersysteme

Hydr- / Oxide

Al-Hydroxide

$Al(OH)_3 + 3\mathbf{H^+} \rightarrow Al^{3+} + 3H_2O$ ***pH 4.8…3***

Al-OH-Sulfate

$AlOHSO_4 + \mathbf{H^+} \rightarrow Al^{3+} + SO_4^{2-} + H_2O$ ***pH 4.5…3***

Fe-Hydr-/Oxide

$FeOOH + 3\mathbf{H^+} \rightarrow Fe^{3+} + 2H_2O$ ***pH <3***

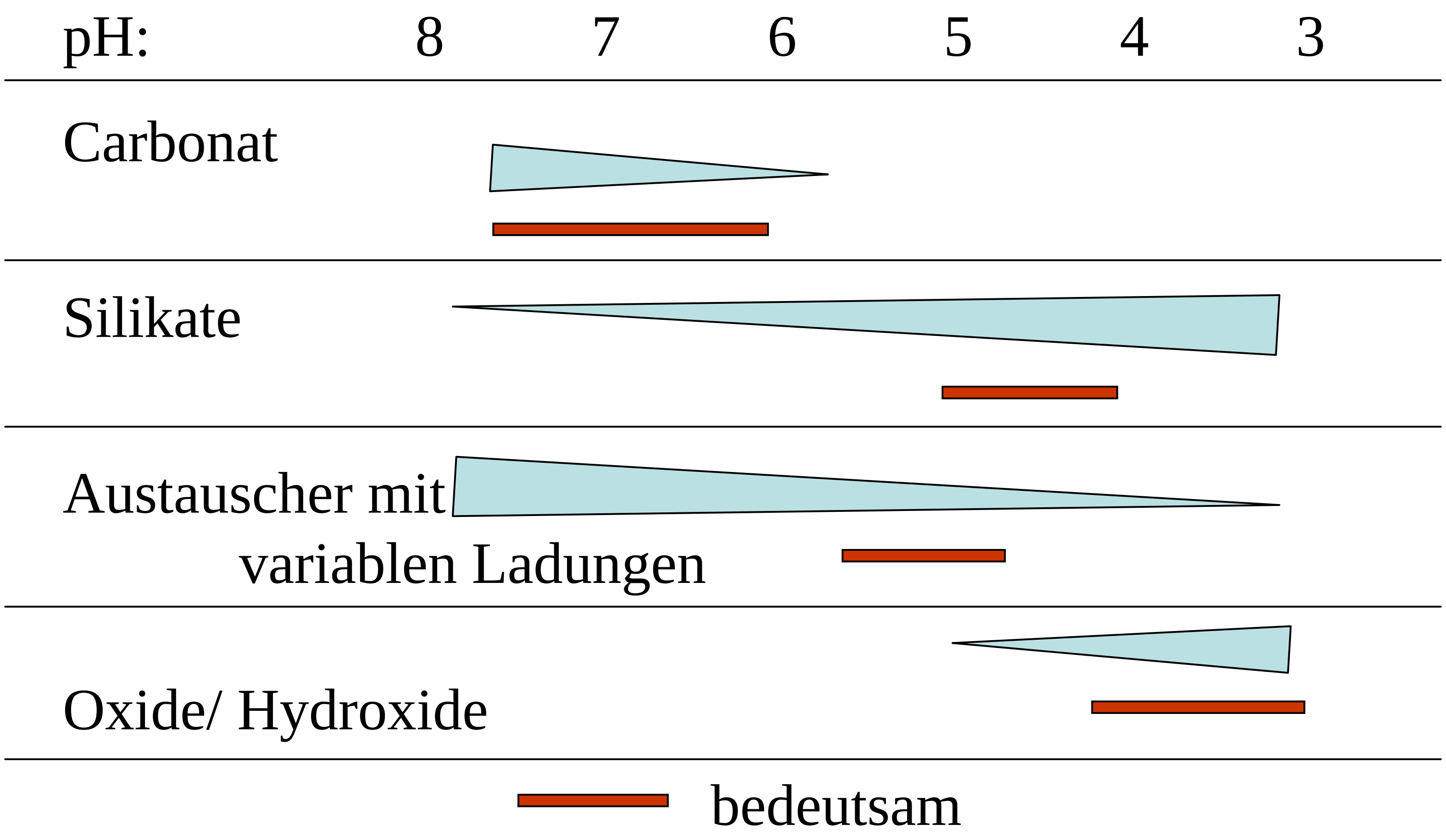
$4FeOOH + CH_2O + 8\mathbf{H^+} \rightarrow 4Fe^{2+} + CO_2 + 7H_2O$ ***pH <7***

Mn-Hydr-/Oxide

$2MnO_2 + CH_2O + 4\mathbf{H^+} \rightarrow 2Mn^{2+} + CO_2 + 3H_2O$ ***pH <8***

⟶ Freisetzung von Fe, Mn, Sulfat, Al

Bdeutung von Puffersystemen



Frage

- Wie wirkt Eutrophierung auf Ökosysteme?
- Wie wirkt N-Eintrag auf Abbau organischer Substanz in Böden?
- Was sind die wichtigsten Puffersysteme in Böden?
- Was sind die häufigsten pH-Wert Bereiche von Böden? Warum?