

Fragen

1. Wie wirkt Temperatur auf
 - a. Photosynthese
 - b. Heterotrophe Atmung?

2. Beeinträchtigt Trockenheit stärker die Photosynthese oder die heterotrophe Atmung?

3. Wie könnte sich die Kohlenstoffbilanz von Ökosystemen bei Klimawandel verändern?

Water logging and anaerobiosis



Nachlieferung von O₂

► Diffusion

Antrieb = **Konzentrationsgradient**

1. **Ficksches Gesetz: $I = -D \cdot dc/dx$**

(I = Gasfluß pro Zeit und Fläche,

D = Diffusionskoeffizient, c = Konz.

x = Diffusionsstrecke)

Der Diffusionskoeffizient in Luft ist

ca. 10⁴ mal größer als in Wasser

► Konvektion

Antrieb = **Druckgradient**

z.B. durch Wasserpegelschwankungen

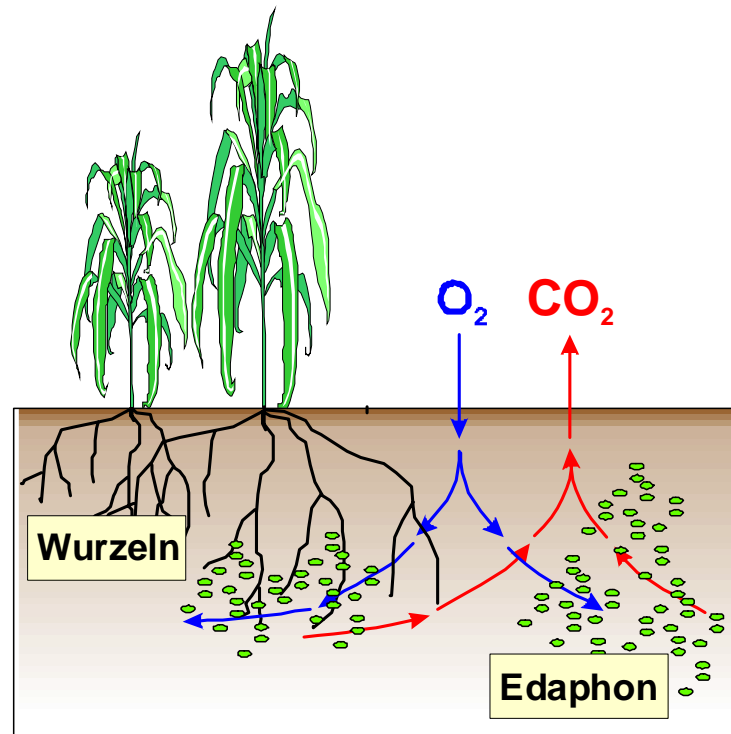
O₂ consumption

► soil respiration

Respiration

Autotrophic =
roots

Heterotrophic =
Soil organisms



Die O₂-Verfügbarkeit ist eine Funktion der **O₂-Transportrate** in den Boden und der **O₂-Verbrauchsrate** im Boden.

Energy metabolism

Aerob

primär durch Dissimilationsstoffwechsels der mikrobiellen Biomasse
d.h. durch Dehydrogenierung, d.h. H₂-Übertragung auf O₂

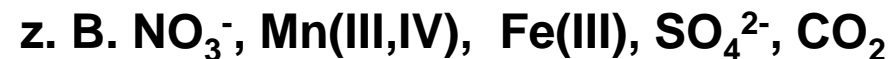
organische Substanz = Substrat zur Energie-Gewinnung



Anaerob (bei O₂-Mangel):

z.B. durch geringe Nachlieferung (hohes WFPS)
bei hoher biologischer Aktivität

alternative Oxidationsmittel (Elektronenakzeptoren)



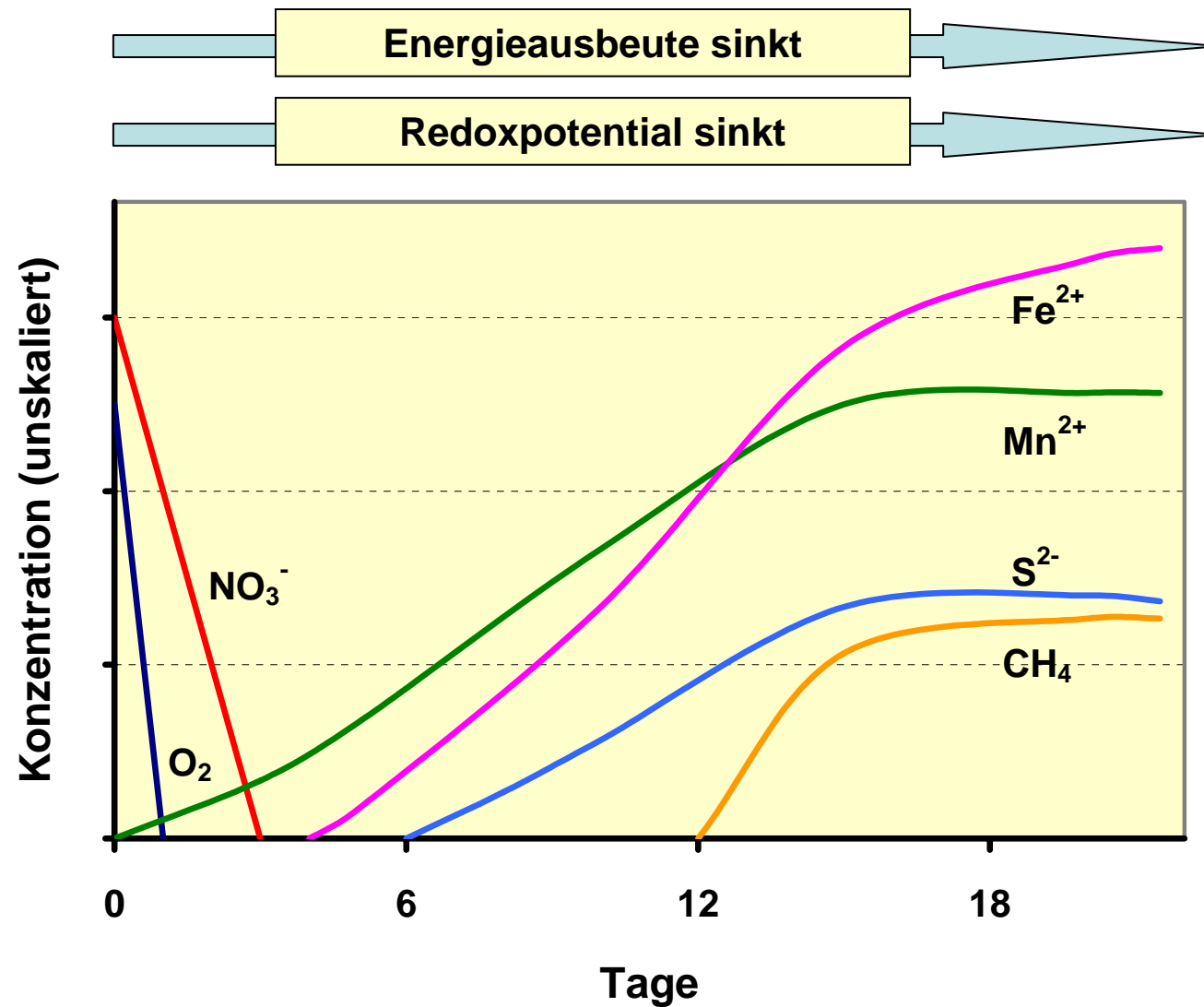
Anaerobic decomposition

weniger biologische Aktivität, langsamerer Abbau als aerob,
selektive Anreicherung bestimmter Substanzen wie Lignin,
Bildung von organischen Säuren, Alkoholen sowie der
Gase CH_4 , H_2S und N_2O

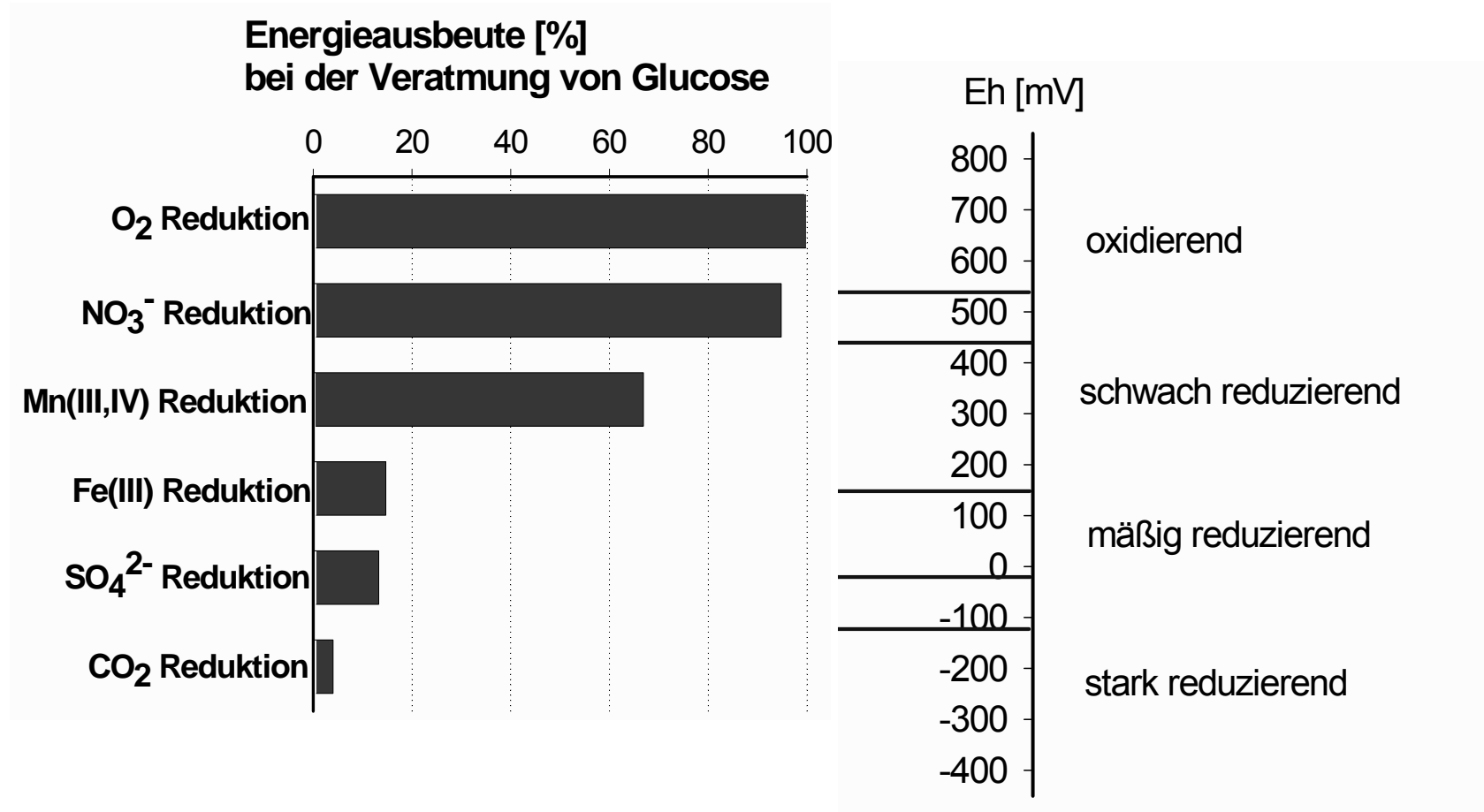
Anaerobe Atmung

- Effektivere Nutzung der im Substrat enthaltenen Energie als bei der Gärung
- Als Wasserstoffakzeptoren dienen statt O_2 beispielsweise
 NO_3^- (Nitratatmung) $\rightarrow \text{N}_2 / \text{N}_2\text{O}$
 SO_4^{2-} (Sulftatmung) $\rightarrow \text{H}_2\text{S}$
 CO_2 (Carbonatatmung) $\rightarrow \text{CH}_4$ (Methanogenese)

Wechsel von aeroben zu anaeroben Bedingungen



Redox-Prozesse

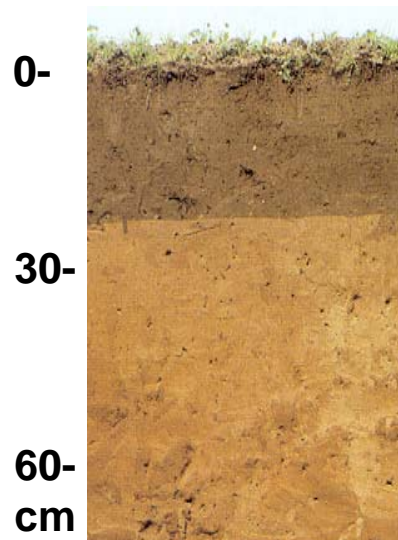
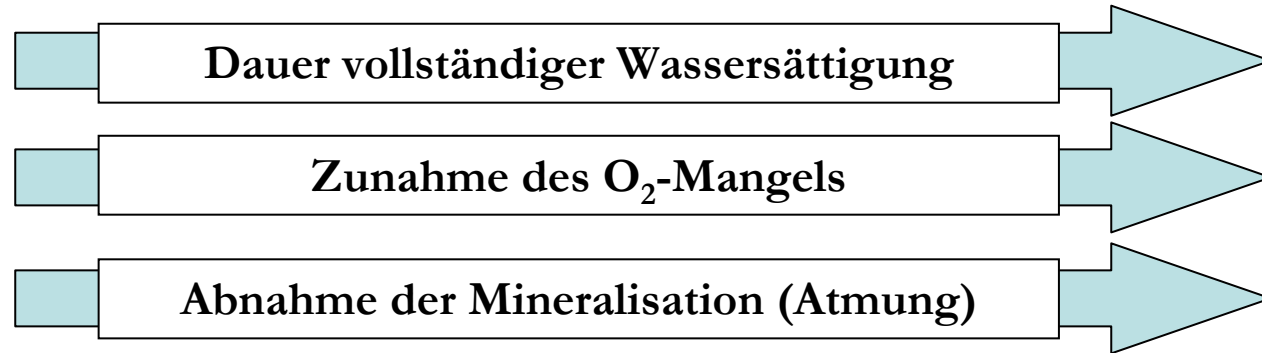


Methanogenesis

- by *Archaea*
- Metabolic pathways:
- **Methane Production via Organic Matter Fermentation**
Acetate fermentation: $\text{CH}_3\text{COOH} \rightarrow \text{CO}_2 + \text{CH}_4$ (*organoheterotrophy*)
(acetate or other C-2 / C-3 from root exsudates, litter)
- **Coupled Organic-Matter Oxidation + Methanogenesis**
Glycolysis: $\text{C}_6\text{H}_{12}\text{O}_6 + \text{SO}_4^{2-} + 2\text{H}_2\text{O} + 2\text{H}^+ \rightarrow \text{CO}_2 + \text{H}_2\text{S} + \text{H}_2$
(*organoheterotrophy*)

CO₂ reduction: $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ (*autolithotrophy*)

**Kleine
Zusammen-
fassung**




Parabraunerde
Humus: 2-3%



Anmoor-Gley
Humus: 15-30%

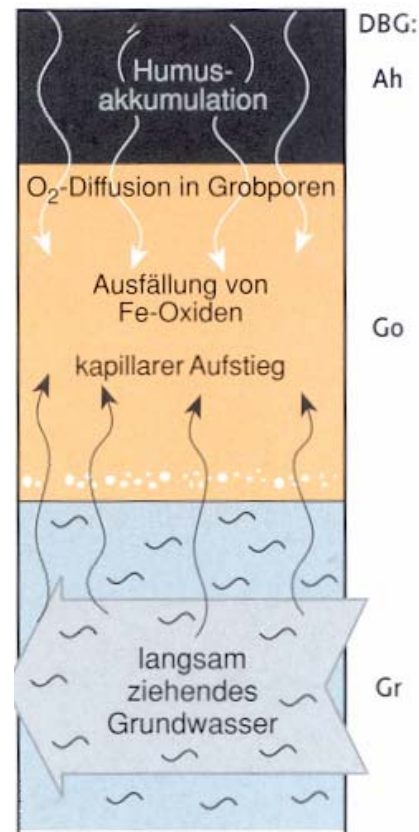


Niedermoor
Humus: > 30%



Indikatoren für O₂-Mangel in Böden ?

Bleichung und Marmorierung bzw. Fe-Oxid-Ausfällungen sind Indikatoren für O₂-Mangel im Bodenprofil und typisch für Grund- und Stauwasserböden (hydromorphe Böden)




➤ **Gley (Grundwassereinfluß)**

➤ **Pseudogley (Stauwassereinfluß)**

Anpassung von Pflanzen an wasser- gesättigte, anaerobe Standorte

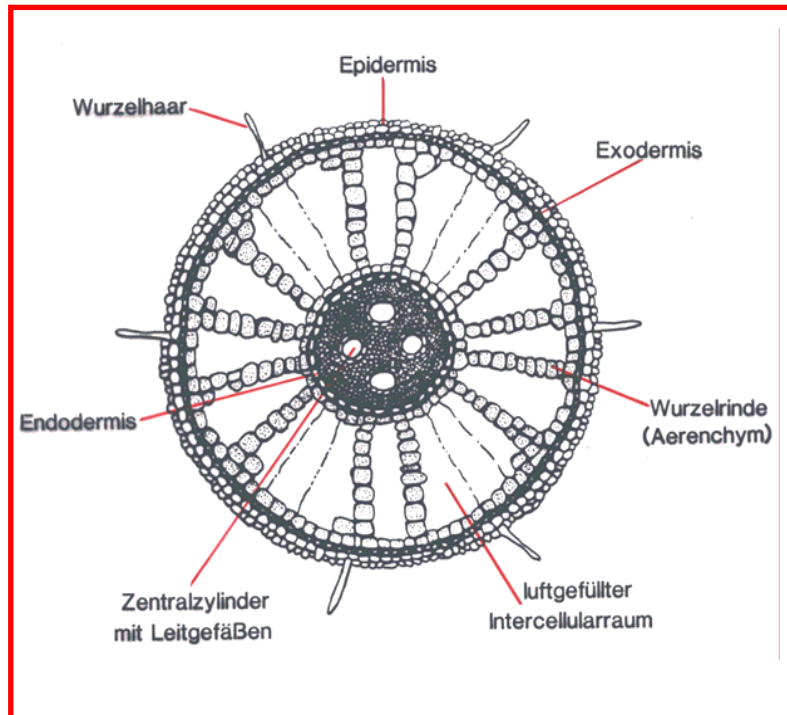
- O₂-Transport durch die Pflanze
(Aerenchym) bis in die Wurzelspitzen
- O₂-Abgabe in die Rhizosphäre





Indikatoren für O₂-Eintrag in anoxische Böden ?

Bildung von Mn- und Fe-Oxiden/Hydroxiden entlang der Wurzeln von Sumpf- und Wasserpflanzen in einem anaeroben Sediment



- Querschnitt durch die Wurzel einer Sumpfpflanze
- Luftleitgewebe (Aerenchym)

- Mn^{2+} -Oxidation \Rightarrow Bildung schwarzer Mn-Oxide
- Fe^{2+} -Oxidation \Rightarrow Bildung rot-brauner Fe-Oxide

Fragen

Anaerober Energiestoffwechsel: in welcher Reihenfolge werden Wasserstoffakzeptoren bei sinkendem Redoxpotenzial reduziert?




Einfluss von Störungen auf Stoffkreisläufe

19.6.2008

Contents

- Definitions
 - Disturbance
 - Ecosystem response
- Disturbance effects
 - Fire
 - Windthrow
 - Disturbance regimes in forests
- Climate change
- Human impacts / degradation



Disturbance is the rule rather than the exception where the world's ecosystems are considered

Osborne 2003

Definitions

Disturbance

„A disturbance is any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment.“

(WHITE/PICKETT 1985:7)

Disturbance regime

„Region-specific typical combination of disturbances and their likelihood to occur“

Descriptors

- Area/size
- spatial distribution
- **magnitude**
 - severity
 - intensity
- **frequency**
- return interval (turnover time)
- rotation period
- predictability
- Synergism

(DALE 2002:263, WHITE und PICKETT 1985:7)

Disturbance types

- large infrequent disturbances: magnitude, frequency.
 - Disaster: would increase ecosystem fitness by adaptation
 - Catastrophy: would decrease ecosystem fitness
- Compounded disturbances: synergism
- Reason
 - Natural
 - Anthropogenic
- Form of disturbance
 - Physical
 - Biological
 - Chemical

Disturbance impact types

Schulze et al. 1999

Ökosystem Störung

Dauerhafte Forcierung des C und N Kreislaufs durch Änderung von:

- Temperatur
- CO₂
- Strahlung (z.B. Aerosole)
- Niederschlag

Plötzliche Verluste von C und N anders als durch heterotrophe Atmung:

Unterbrechung des C und N Kreislaufs aber Erhaltung des organischen Materials im Ökosystem:

disturbance *Percentage of the Earth's surface regularly affected by some major disturbances (after Walker and Willig, 1999)*

<i>Element</i>	<i>Primary disturbance</i>	<i>Percentage*</i>
Earth (tectonic)	Earthquake	1
	Erosion	> 50
	Volcano	1
Air	Hurricane	15
	Tornado	< 1
	Tree-fall	nd
Water	Drought	30
	Flood	15
	Glacier	10
Fire	Fire	> 50
Biota – non-human	Herbivory	nd
	Invasion	nd
	Other animal activity (includes building, excavating, waste products, movement, death, diseases, parasites)	1
Biota – human	Agriculture	45
	Forestry	10
	Mineral extraction	1
	Military activity	1–40 (USA 1%; Vietnam 40%)
	Transportation (includes motorised and non-motorised transportation)	5
	Urban	3

*nd = no data available

Quelle: OSBORNE 2003:164.

Frage

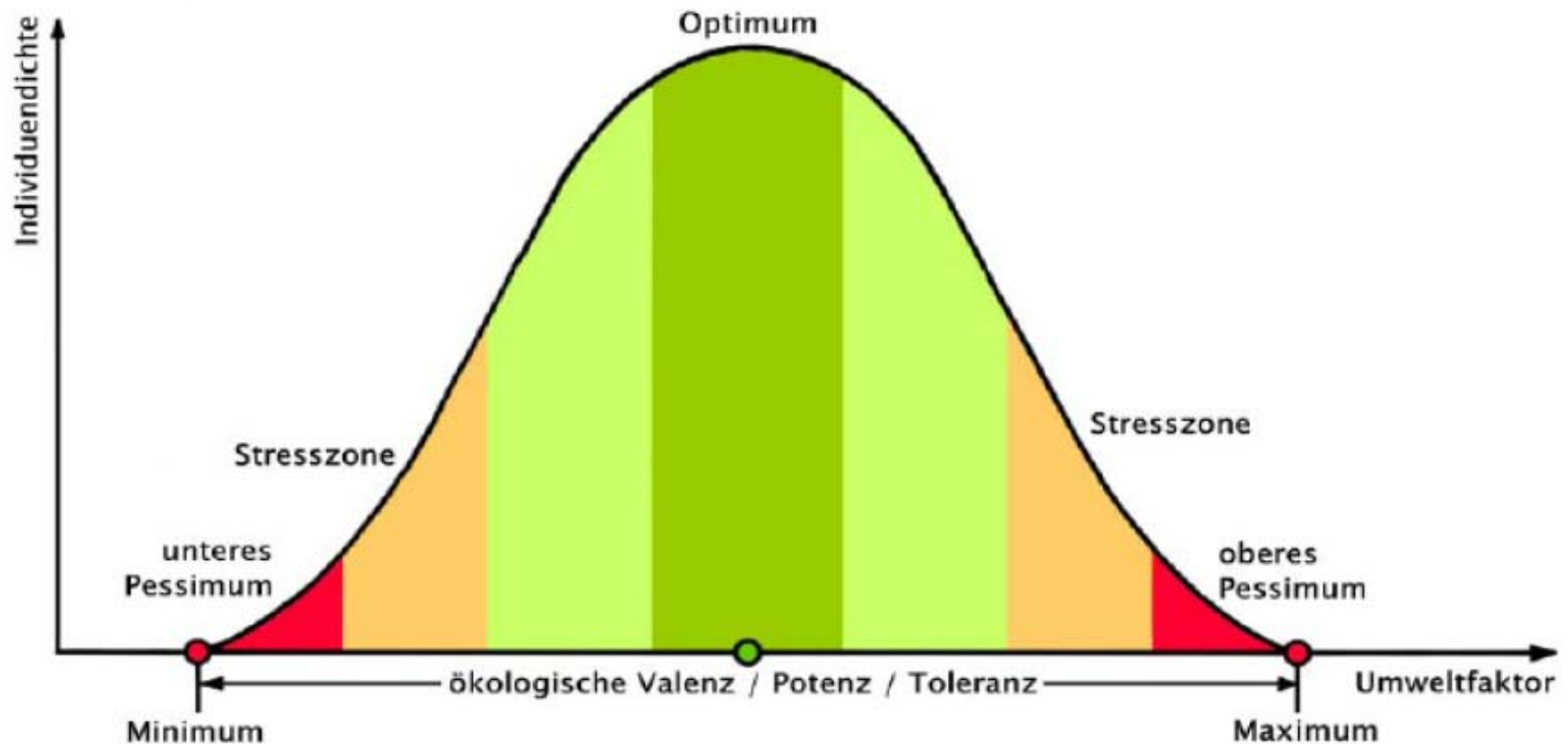
Welche „impact types“ sind:

- Feuer
- Windwurf
- Insekten
- Landnutzung

Ecosystem response

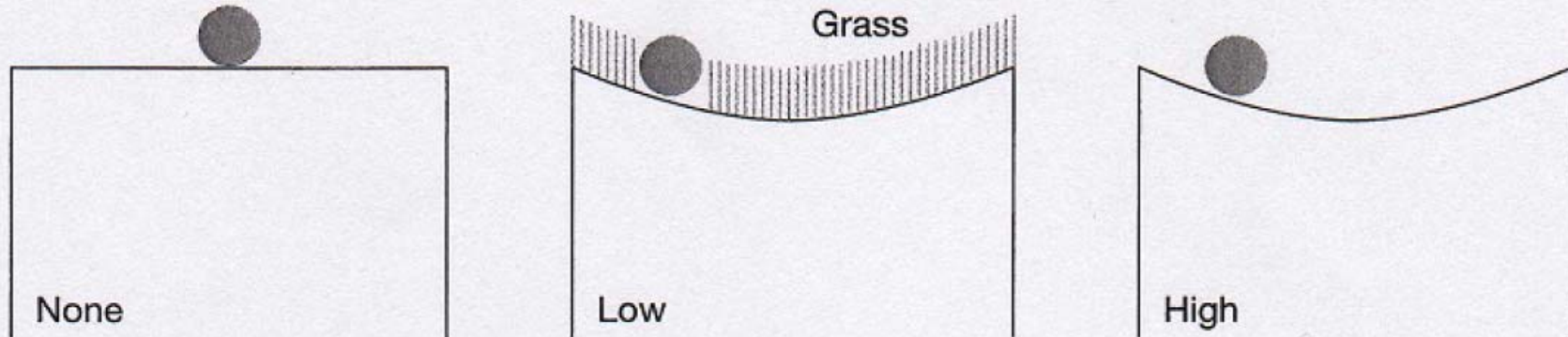
- Ecological potential
- Stability
 - Tolerance
 - Resilience
- Legacy
- Adaptation

Ökologische Valenz/Potenz/Toleranz

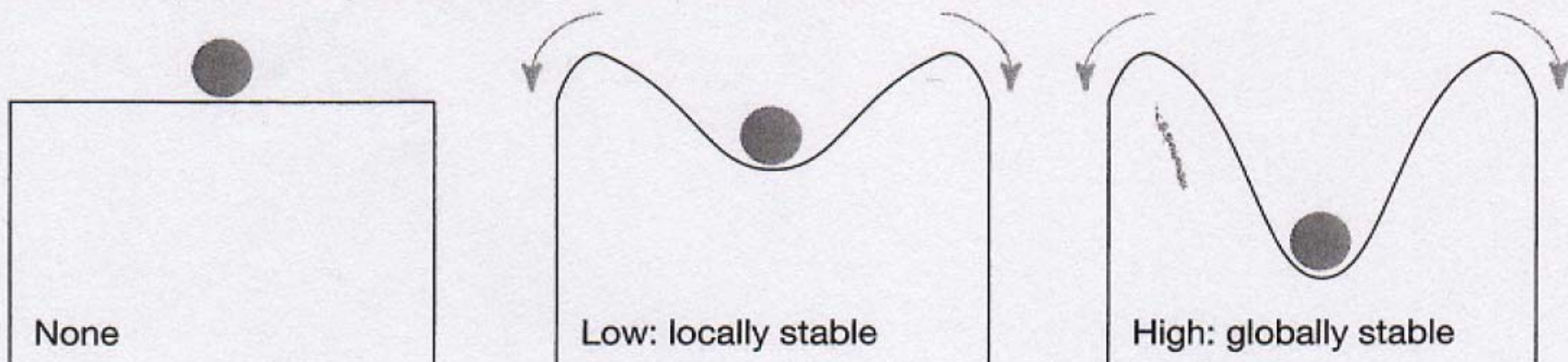


Resilience

Resilience—elasticity: how quickly a community can return to equilibrium



Resilience—amplitude: degree of change from which a community can return



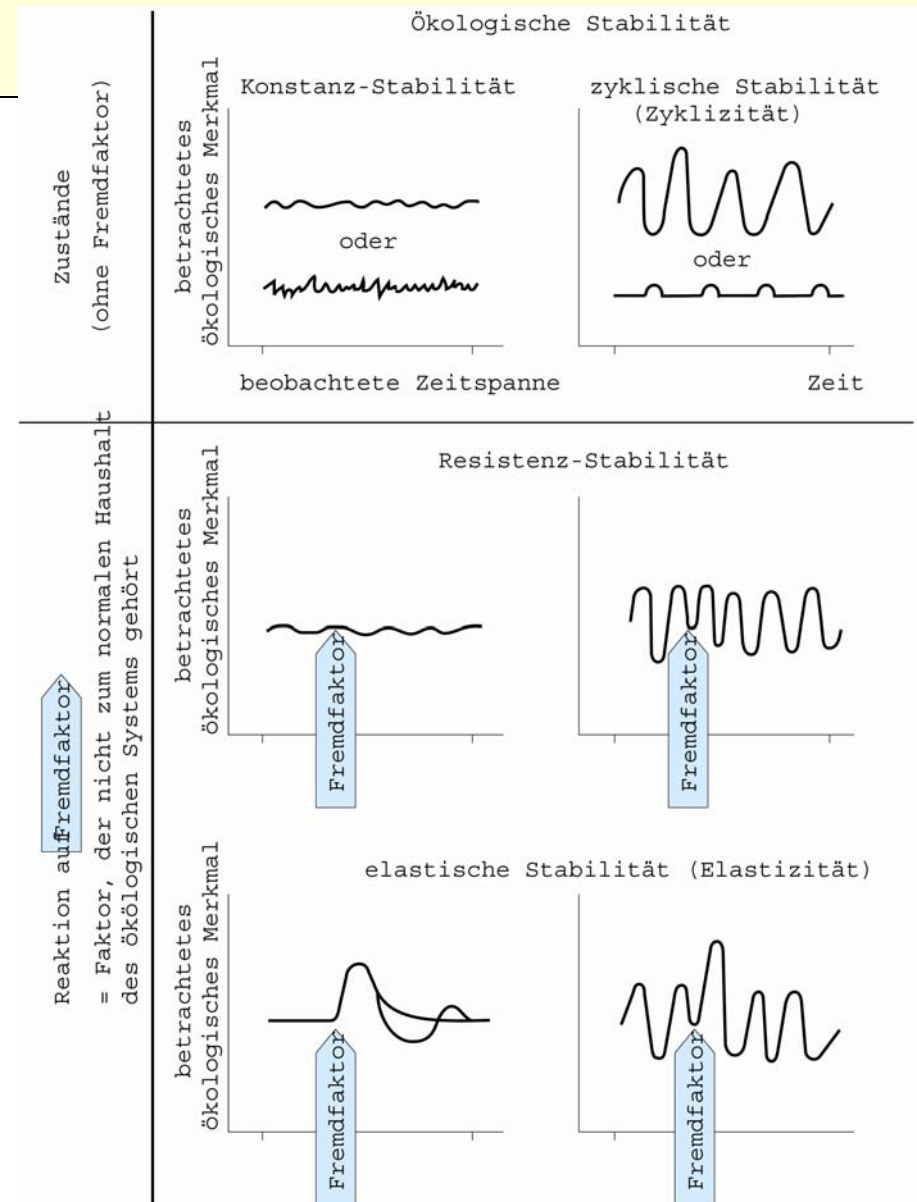
Ecosystem stability

Pimm & Gigon's concepts (1984)

Important descriptors:

- Stability
- Resilience
- Persistence
- Resistance
- Variability

Basic types of **stability**, according to dynamics of chosen characteristics and presence/absence of external factors

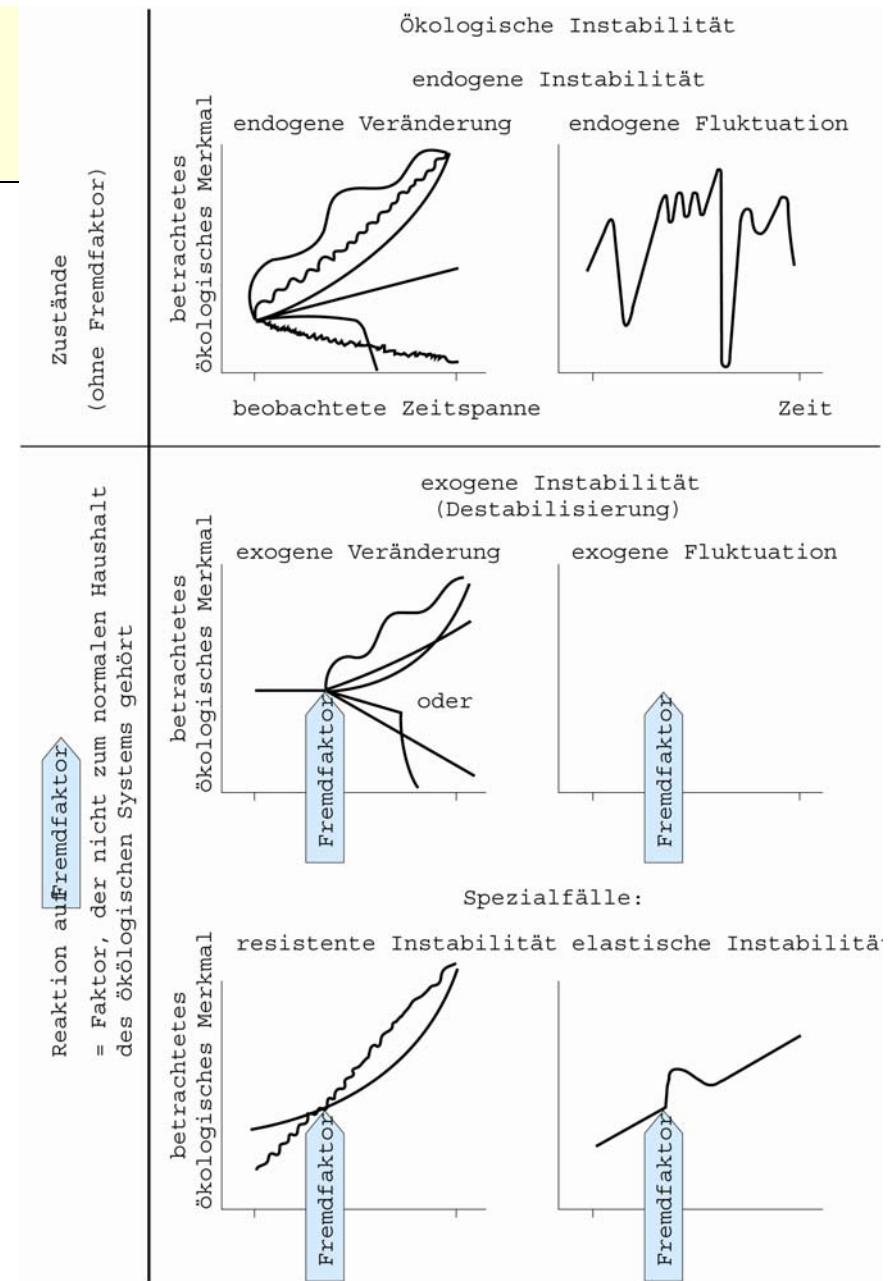


(Gigon 1984, quoted in Schulze/Beck/Müller-Hohenstein 2002)

Ecosystem instability

Pimm & Gigon's concepts (1984)

Basic types of **instability**, according to dynamics of chosen characteristics and presence/absence of external factors



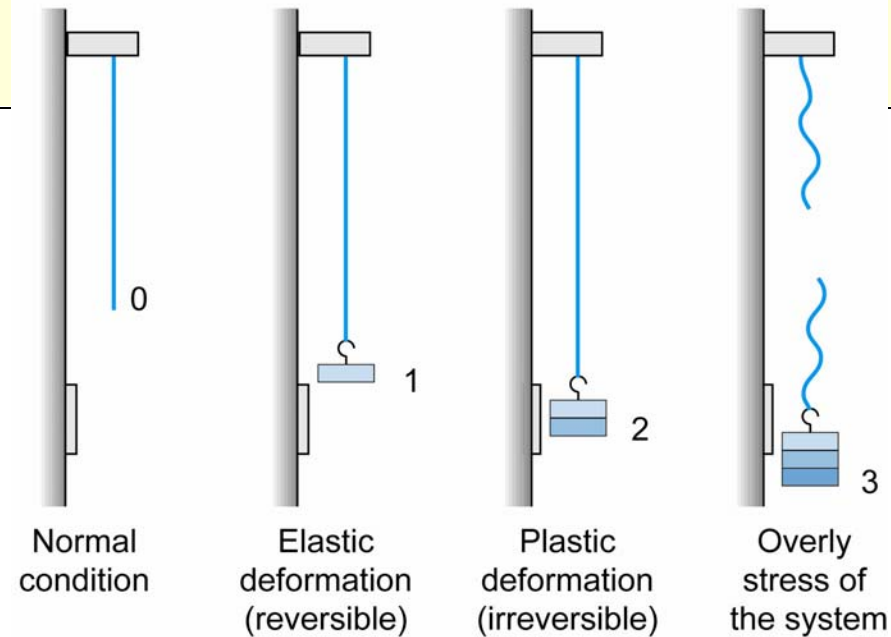
(Gigon 1984, quoted in Schulze/Beck/Müller-Hohenstein 2002)

Physical concept of reactions stress (Levitt 1980)

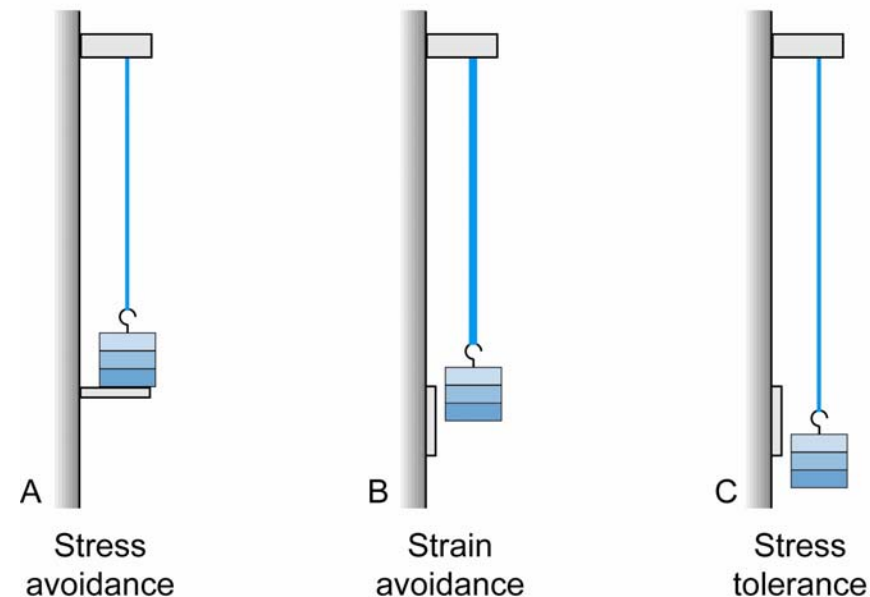
Wichtig in biologischen Systemen:

- Zeitfaktor
- Reparatur
- Anpassung
- Abhärtung/Enthärtung
- Alarm
- Multipler Stress/multiple Antwort

Stress, strain and damage



Three types of strain resistance (stress resistance)



Fragen

- Beispiele für
 - Stress avoidance
 - Strain avoidance
 - Stress tolerance
 - Resilience
- Für Störungen
 - Dürre
 - Insektenfraß
 - Feuer
 - Windwurf

Fire



Fire pre-conditions

- Drought
- Fuel
- Ignition source

Case study: Kruger National Park

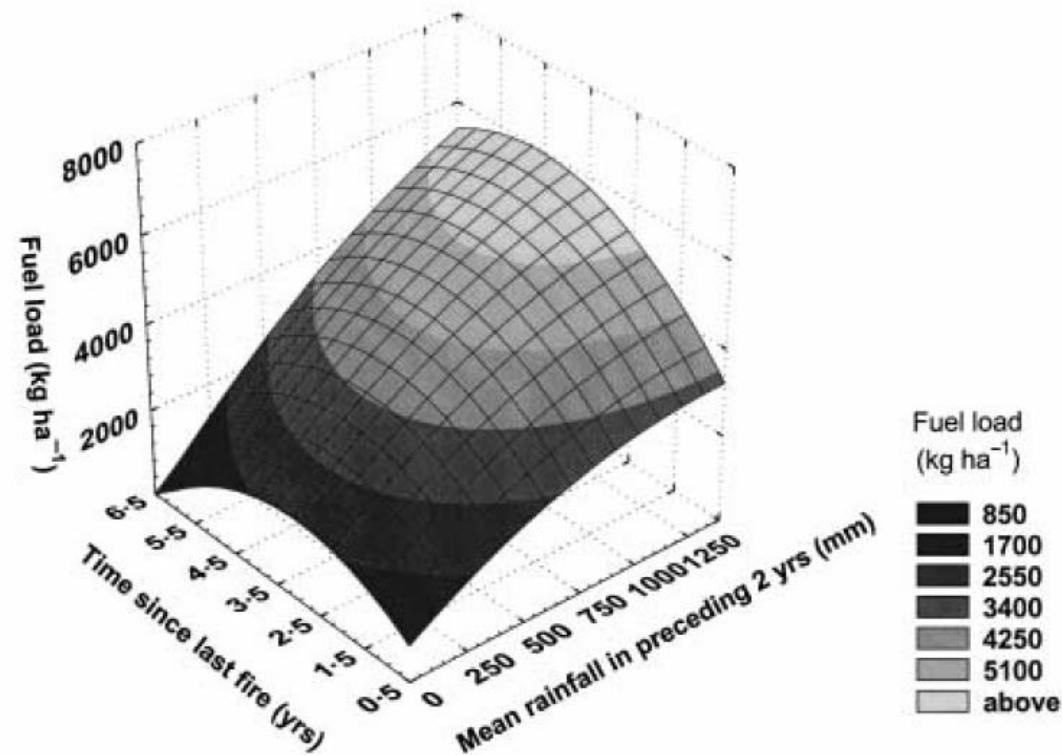


Fig. 1. The effect of time since the last fire, and mean annual rainfall in the preceding 2 years, on grass fuel loads, based on data from experimental burning plots in the Kruger National Park. The relationship is $z = 382.9 + 3.3x + 979.4y - 0.001x^2 + 0.37xy - 161.8y^2$ ($r^2 = 0.169$) where z = fuel load (kg ha⁻¹), y = time since the last fire (year) and x = mean rainfall over the previous 2 years (mm).

Case study: Kruger National Park

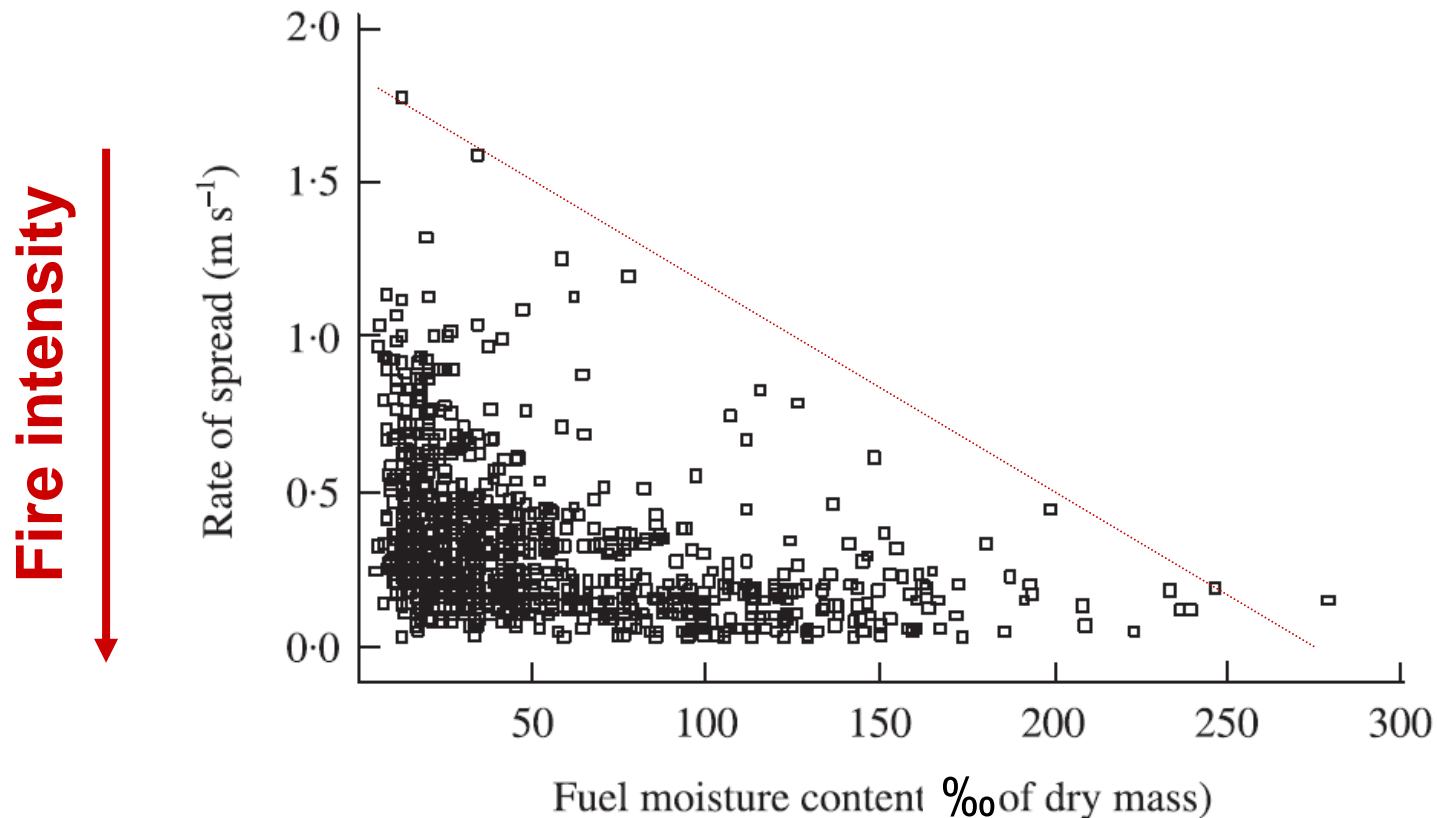


Fig. 5. The relationship between fuel moisture content and the rate of spread from 956 fires on experimental burning plots in the Kruger National Park.

Ignition: Siberia



Light green: „most intact“, Dark green: „intact forest“, Yellow: „non-intact“
Mollicone et al. Nature 2006

Ignition: Siberia

Table 1 | Number and density of fire events in forests of the Russian Federation

	2002	2003	2004	2005
		Density ratio of fire events		
Ratio non-intact/intact	6.5	7.3	12.8	8.1
Ratio non-intact/most-intact	7.9	9.9	14.4	9.0

Even in remote areas like Siberia, most fires are human-induced.

Boreal forest fires

Tree species matter!

Siberia:
ground fires



Pine, Larix

Canada: stand
replacing fires



Black & White spruce

Frage

- Wie könnte man die unterschiedliche Anpassung an Feuer in den borealen Wäldern klassifizieren?

Indonesian peat fires



Aldhous, Nature 432: 2004

Indonesian peat fires

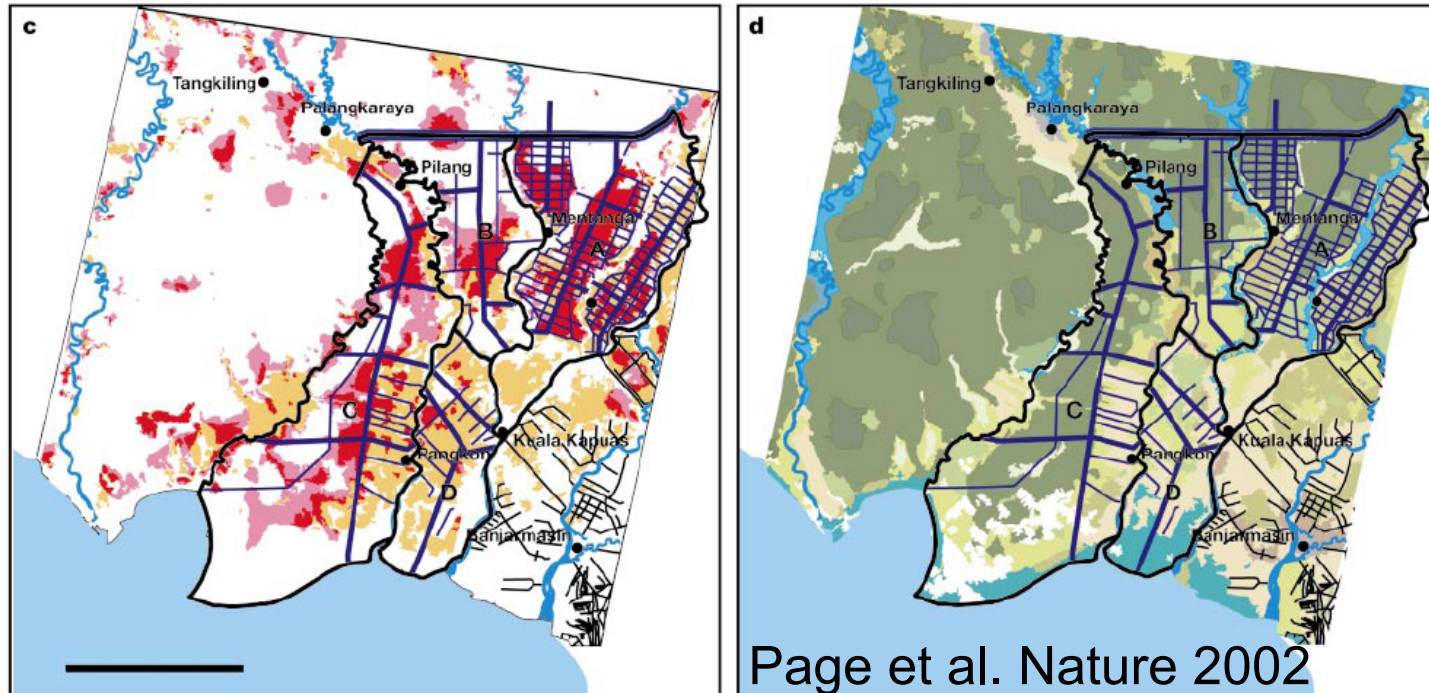
- Drainage in/since 1995
- Drainage depth:
often several metres
- Problems
 - Too dry to sustain growth
 - Too acidic to grow rice
 - Fire risk: smouldering
for months



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

Aldhous, Nature 432: 2004

Indonesian peat fires in 1997/1998



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

Fragen

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

Windthrow



Example: Estonia

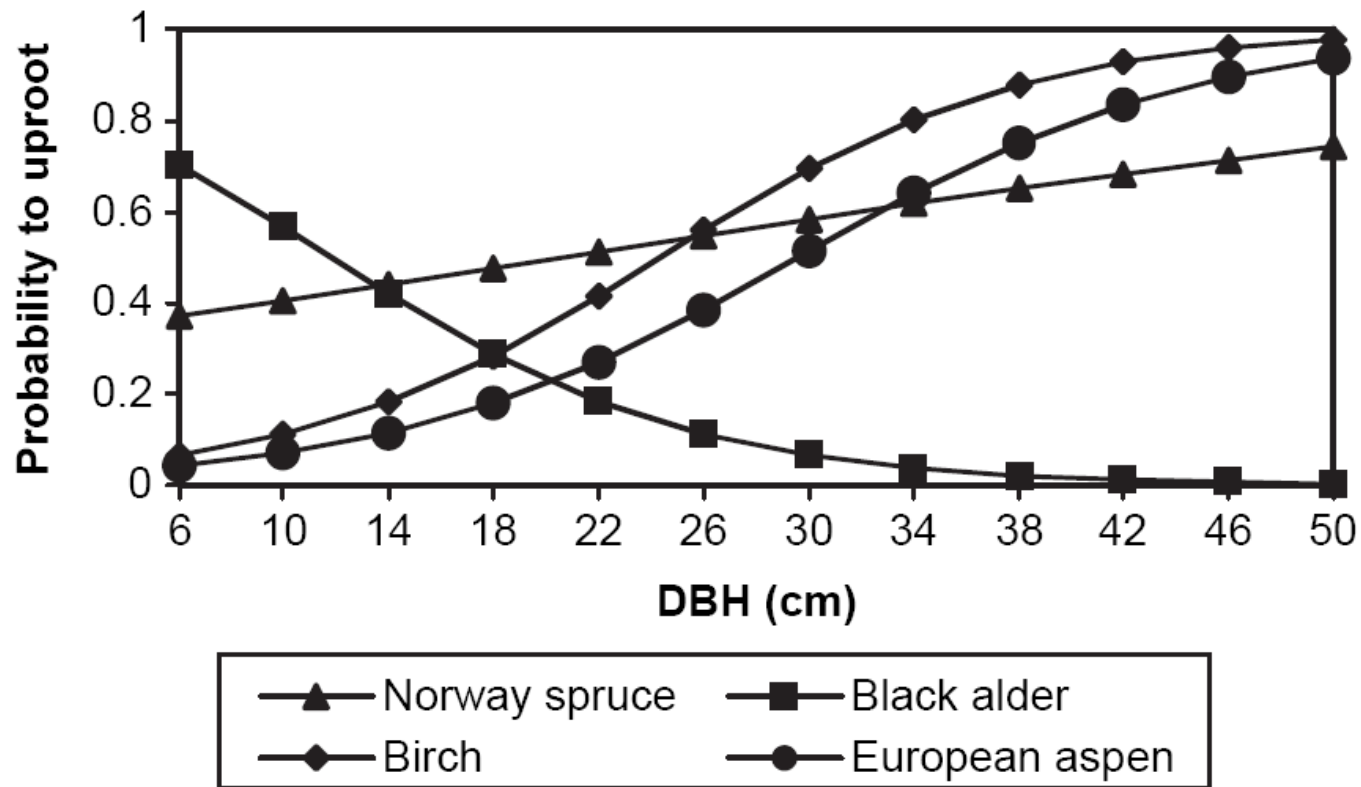


Figure 3. Probability of uprooting as a function of diameter at breast height (dbh) by tree species.

Example: Estonia

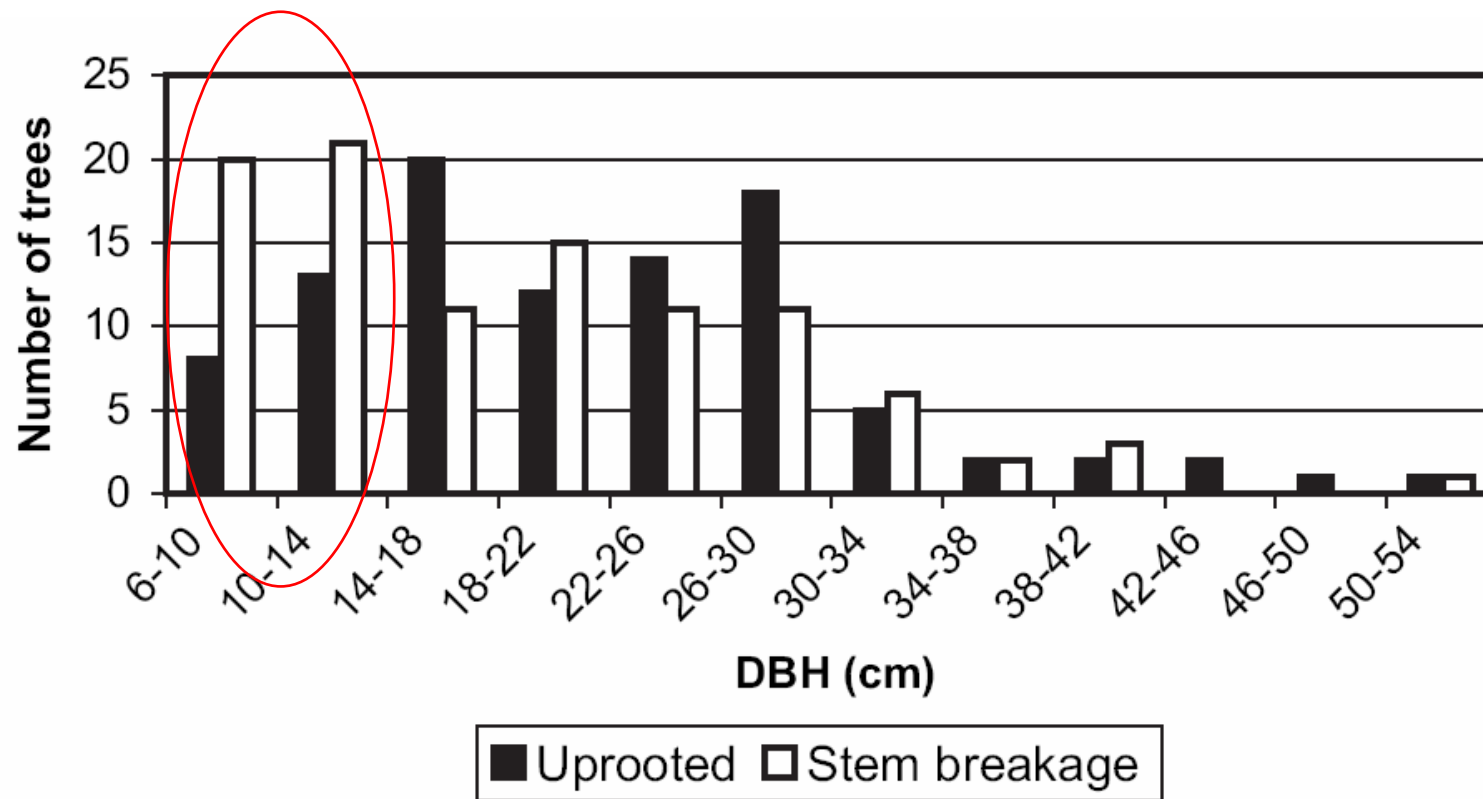


Figure 4. Proportion of uprooted and stem-broken Norway spruce among diameter at breast height (dbh) classes.

Example: Estonia

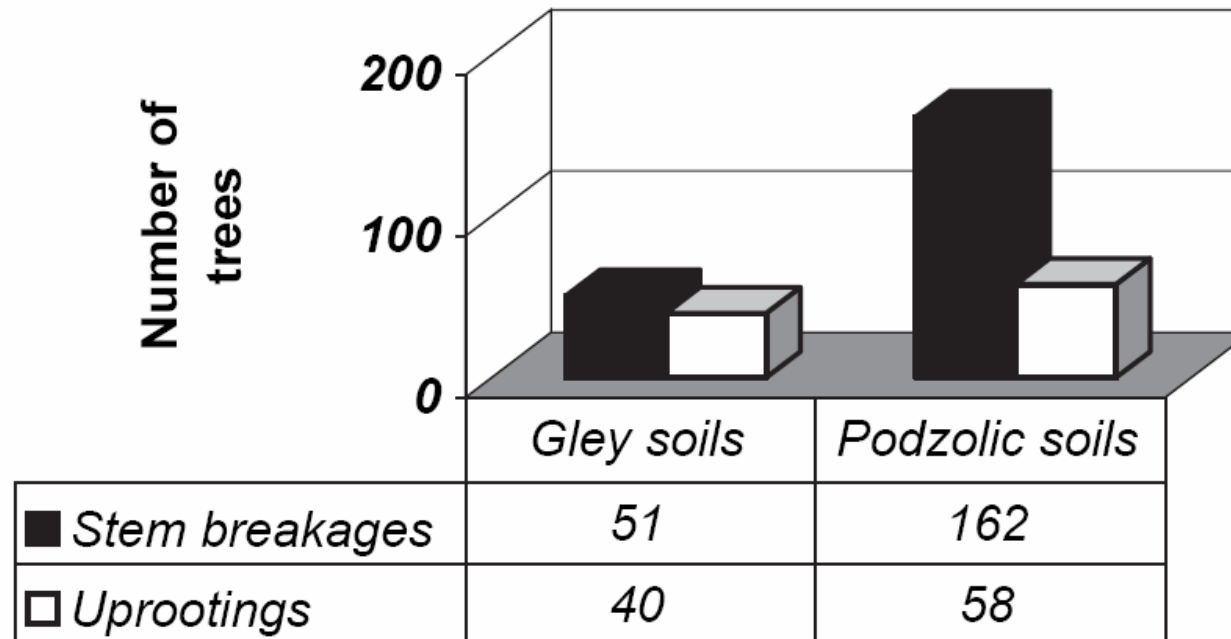


Figure 6. Differences in number of uprootings and stem breakages of Norway spruce between sites on gley and podzolic soils ($\chi^2 = 9.231$, $p = 0.002$). dbh = diameter at breast height.

Disturbance regimes and climate change



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

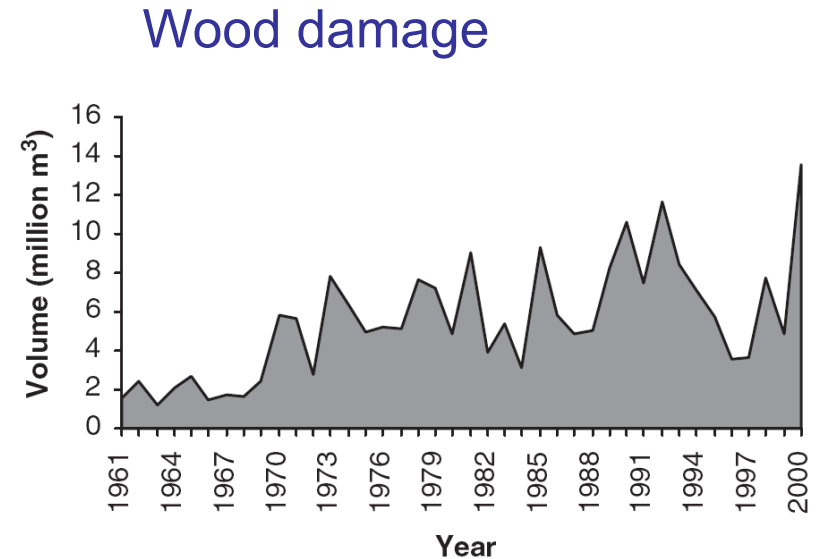
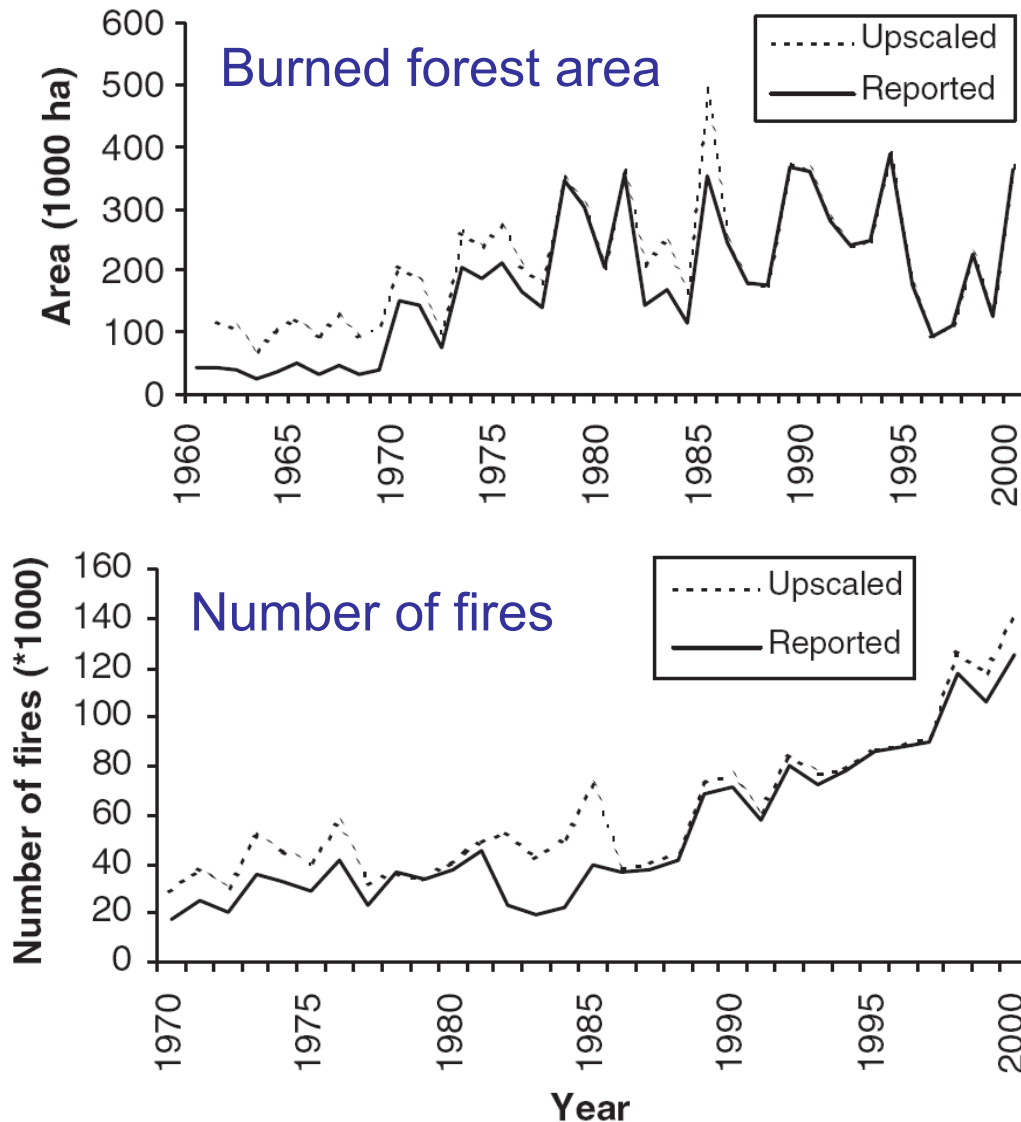
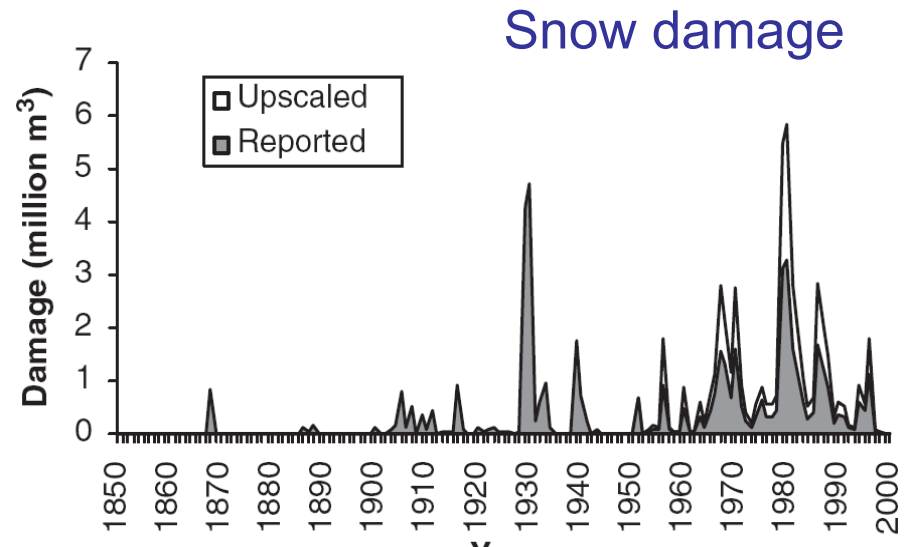
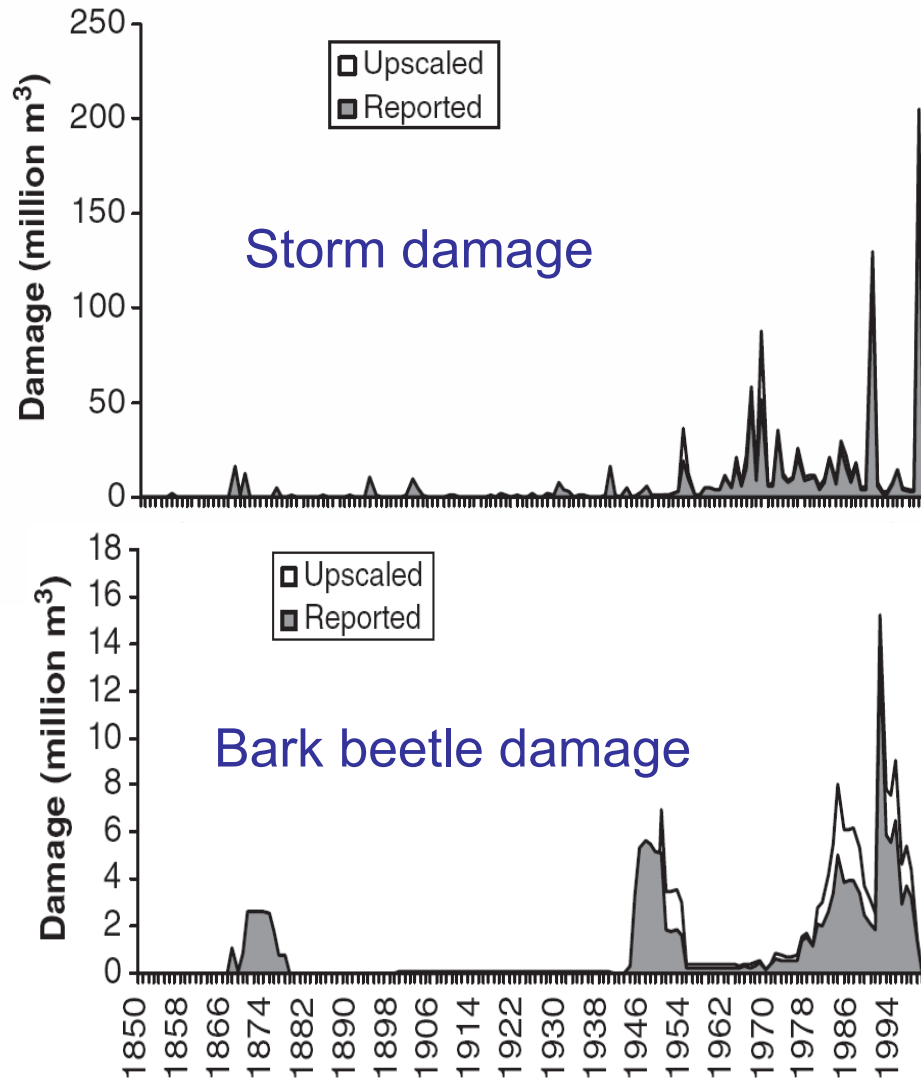


Fig. 4 Volumes of wood damaged by fire for total Europe (1961–2000) as estimated from the total upscaled forest fire area and average wood volume damaged by fire, per country.

Scheelhaas et al. GCB 2003

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



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

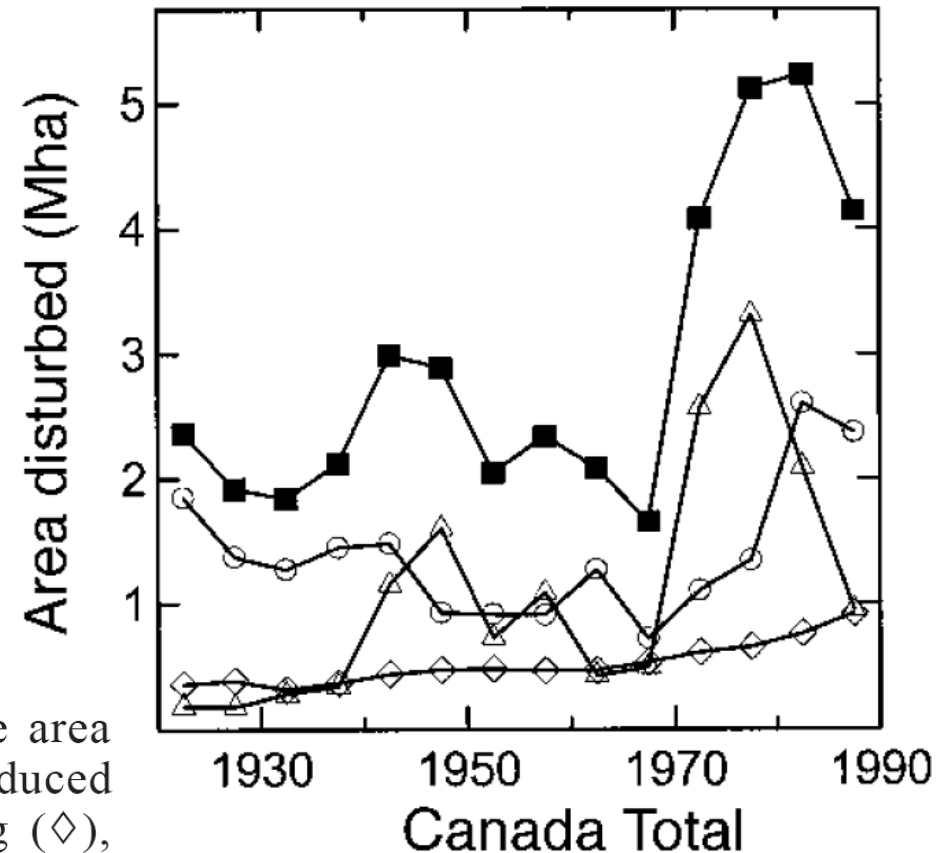
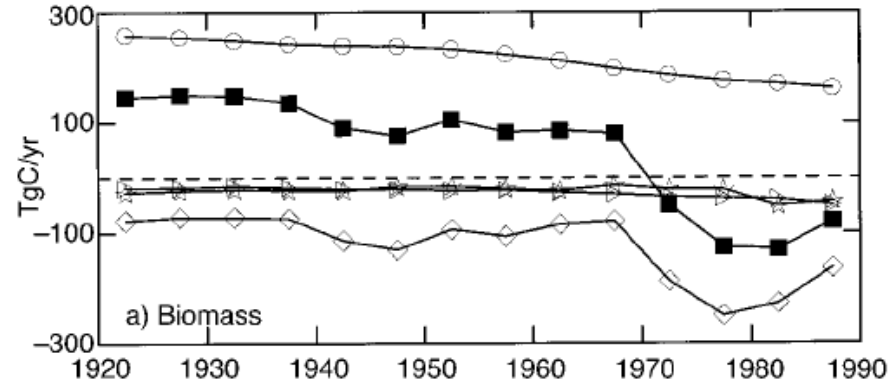


FIG. 3. The five-year averages of the area annually disturbed by fires (○), insect-induced stand mortality (△), clear-cut harvesting (◇), and the total (■) for the period 1920–1989. The

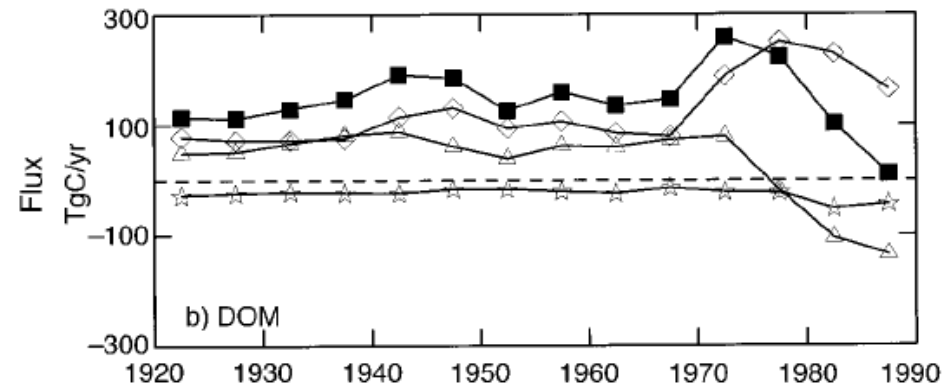
Biomass fluxes

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



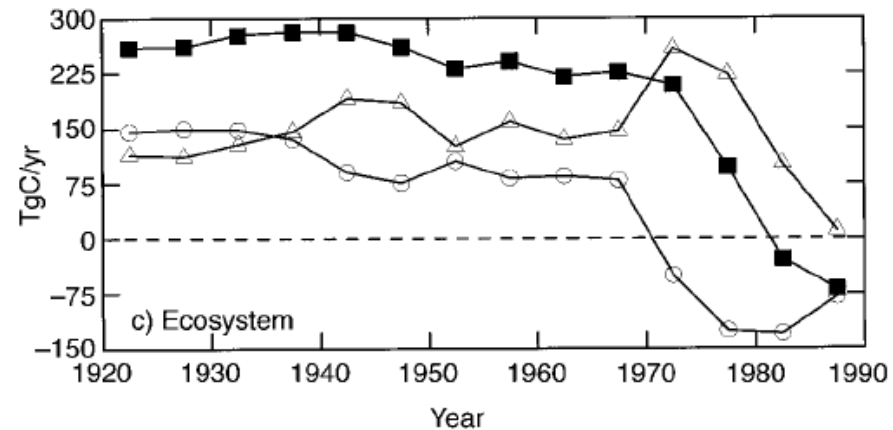
Litter fluxes

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

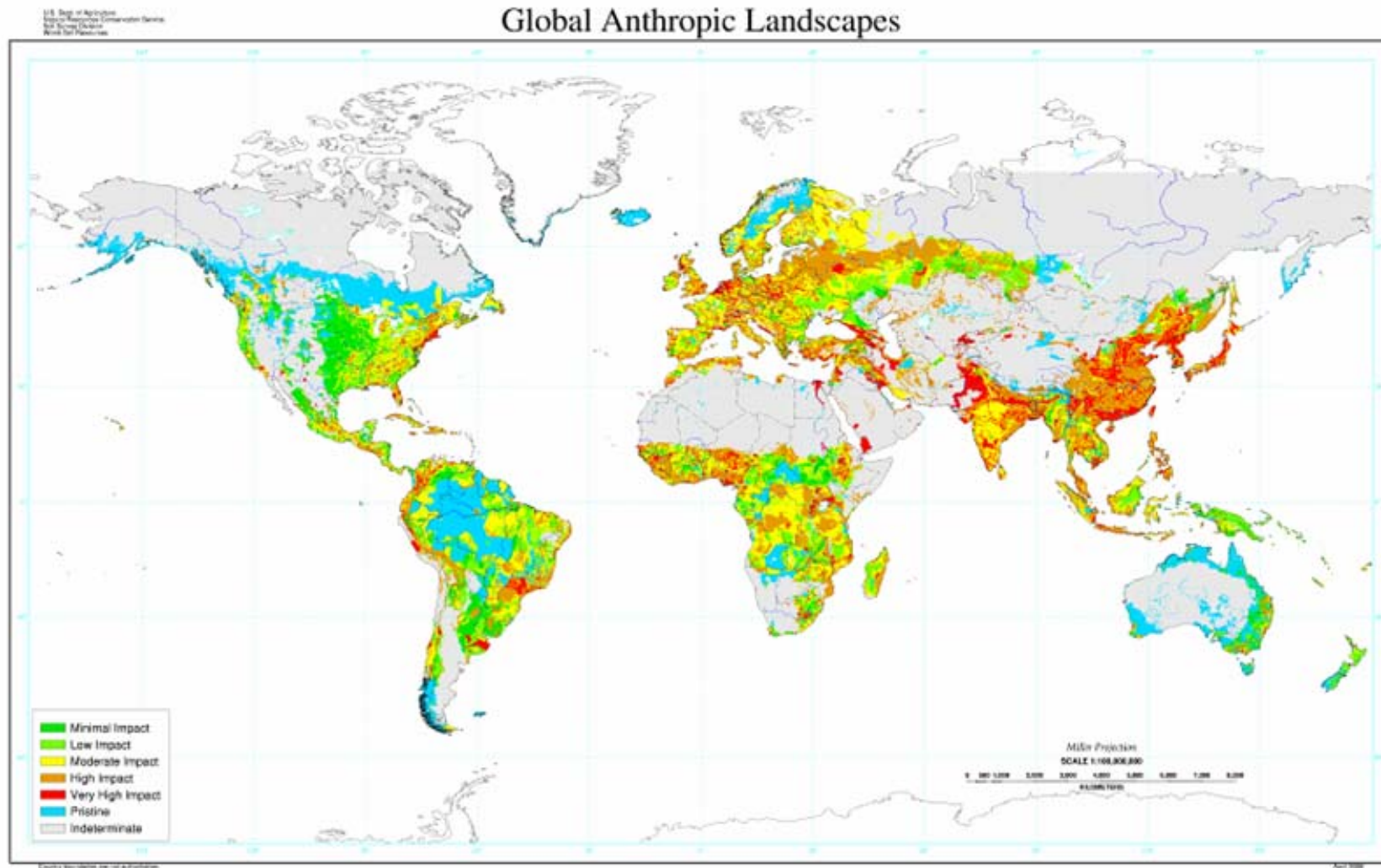


Ecosystem fluxes

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



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?
- Wie passen sich Ökosysteme an Feuer an?