INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

Tento projekt je spolufinancován Evropským sociálním fondem a Státním rozpočtem ČR InoBio – CZ.1.07/2.2.00/28.0018

Influences of Forest Management upon Water Quality

Universität für Bodenkultur Wien
Department für Wald- und Boden-wissenschaften

Univ.Prof.i.R. DI Dr. Herbert Hager
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Forest Managment & Water quality

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Department für Wald- und Boden-wissenschaften

Water quality: What is water quality?

Several aspects: physical WQ (temperature, conductivity, turbitity…)

chemical WQ (disolved ions, DOC, DON…)

microbial WQ (content of microorganisms.. For example Escherichia coli etc.)

Concentrate on „chemical WQ“ , highlight with case studies

But first: Consider forest soil as puffer storage and transformer

Forest Managment & Water quality introduction cont.

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Influence of forest vegetation on WQ:

direct influences: turnover, root zone, N-fixing, vegetation of forest floor

indirect influences: deposition from atmosphere, forest pests

Forest managment as factor of influence

fertilization, clearcutting, site preparation, herbicides and pesticides etc.

Summarizing

General considerations: Soils and Ecosystem Processes and Biogeochemistry

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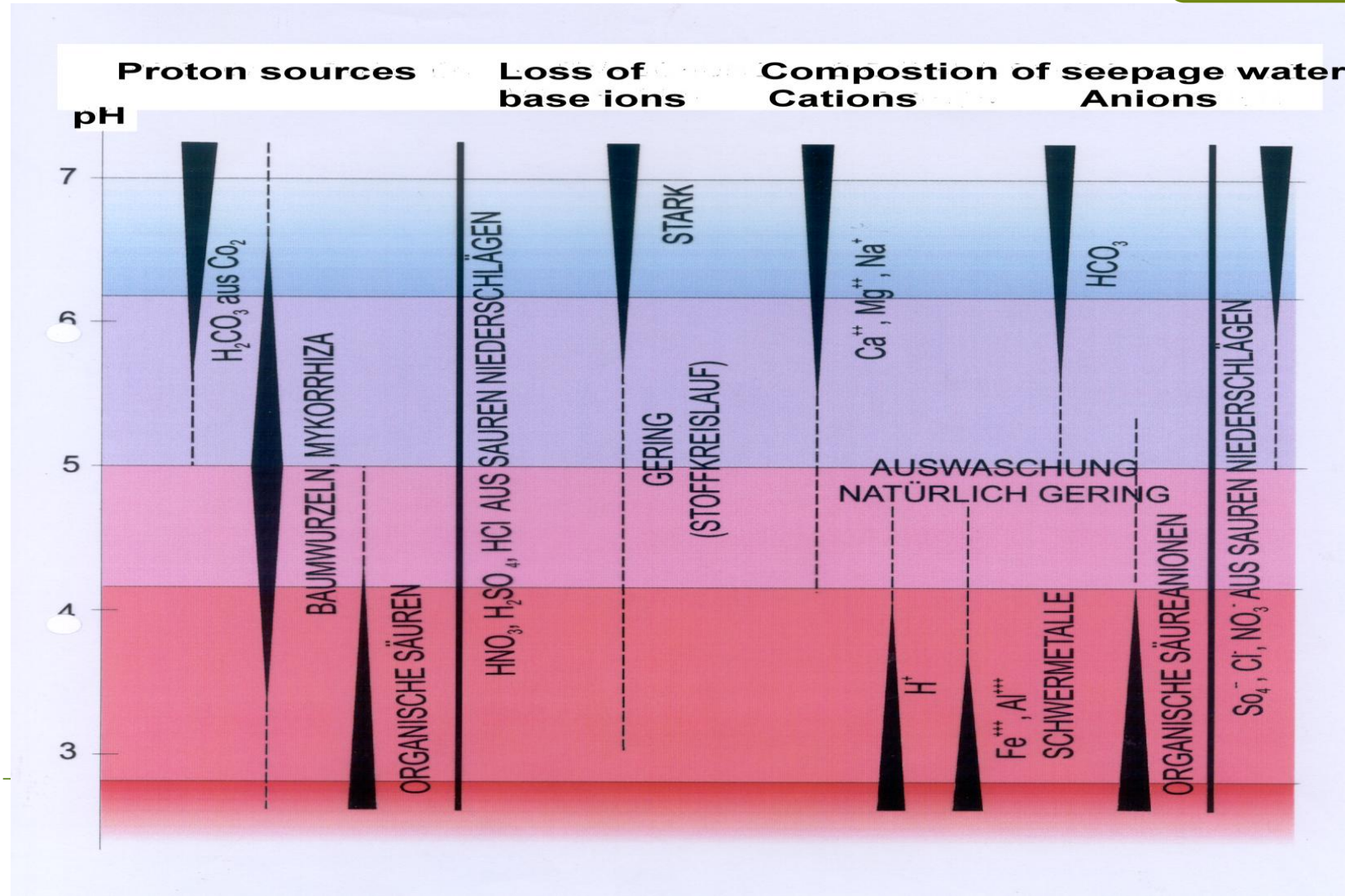
Soils: act as buffer and transformator for ionic compounds which travel with the water through forest ecosystems

Soils: the reaction and these functions may depend on depth, texture, buffer range, mineralogy and other chemical properties

Ecosystem processes and biogeochemistry in forest sites are further determining factors

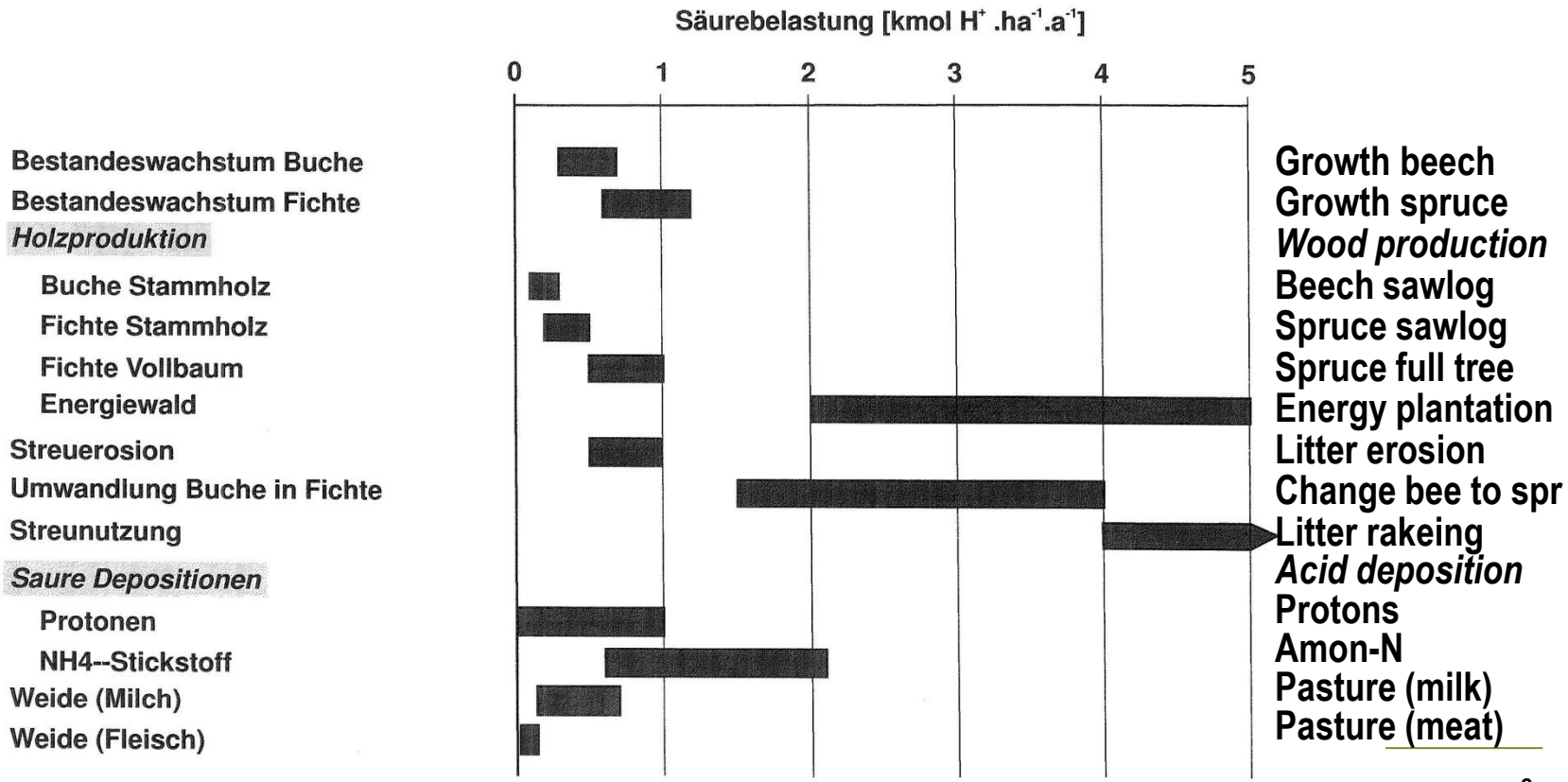
Speeding up of nutrient cycles, depostion of trace constituents from the atmosphere and N-transformation may play an important role

General considerations: Soils and chemical loads



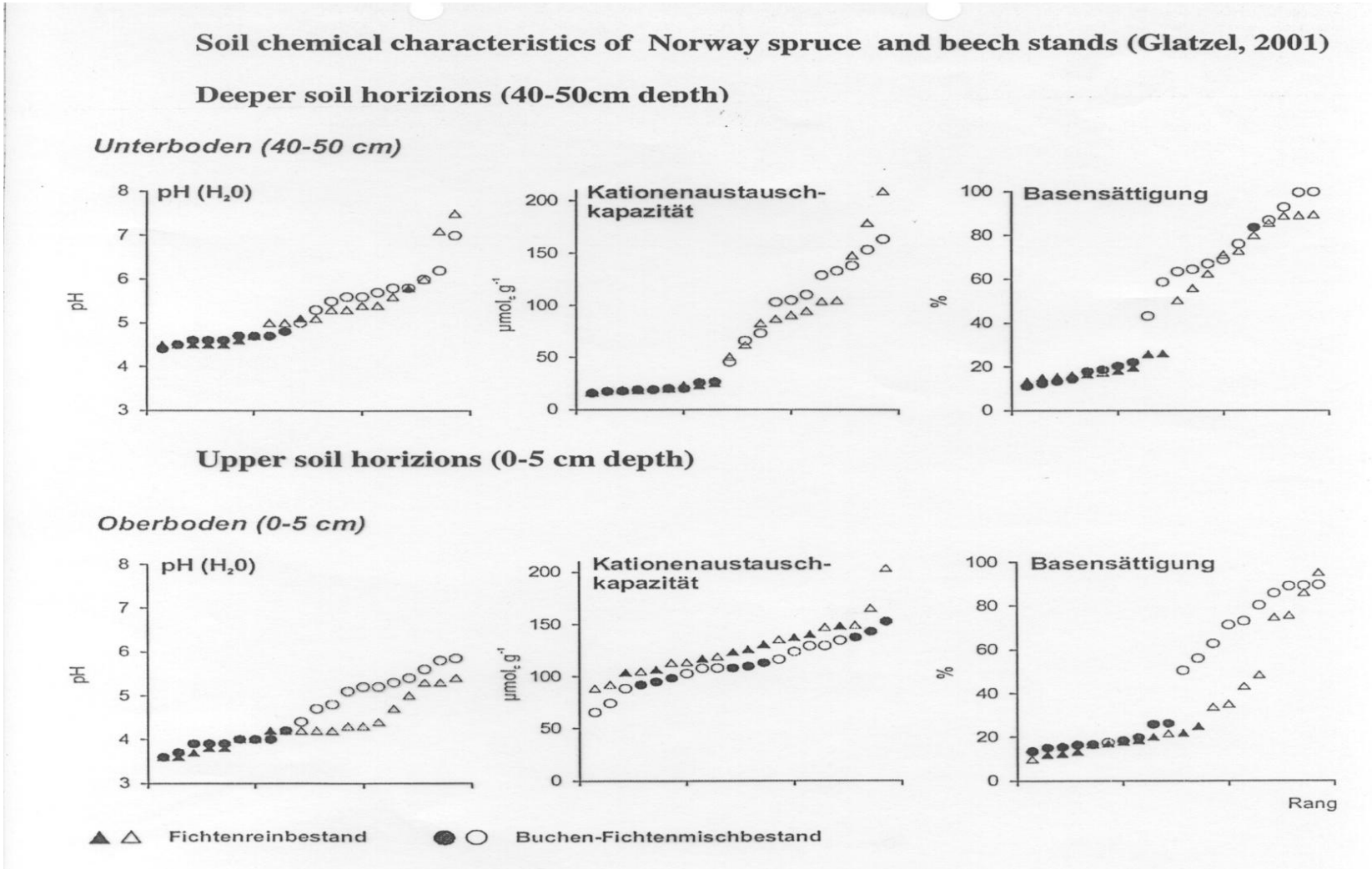
Acidification of forest ecosystem processes

Säurebelastung des Mineralbodens von Wäldern



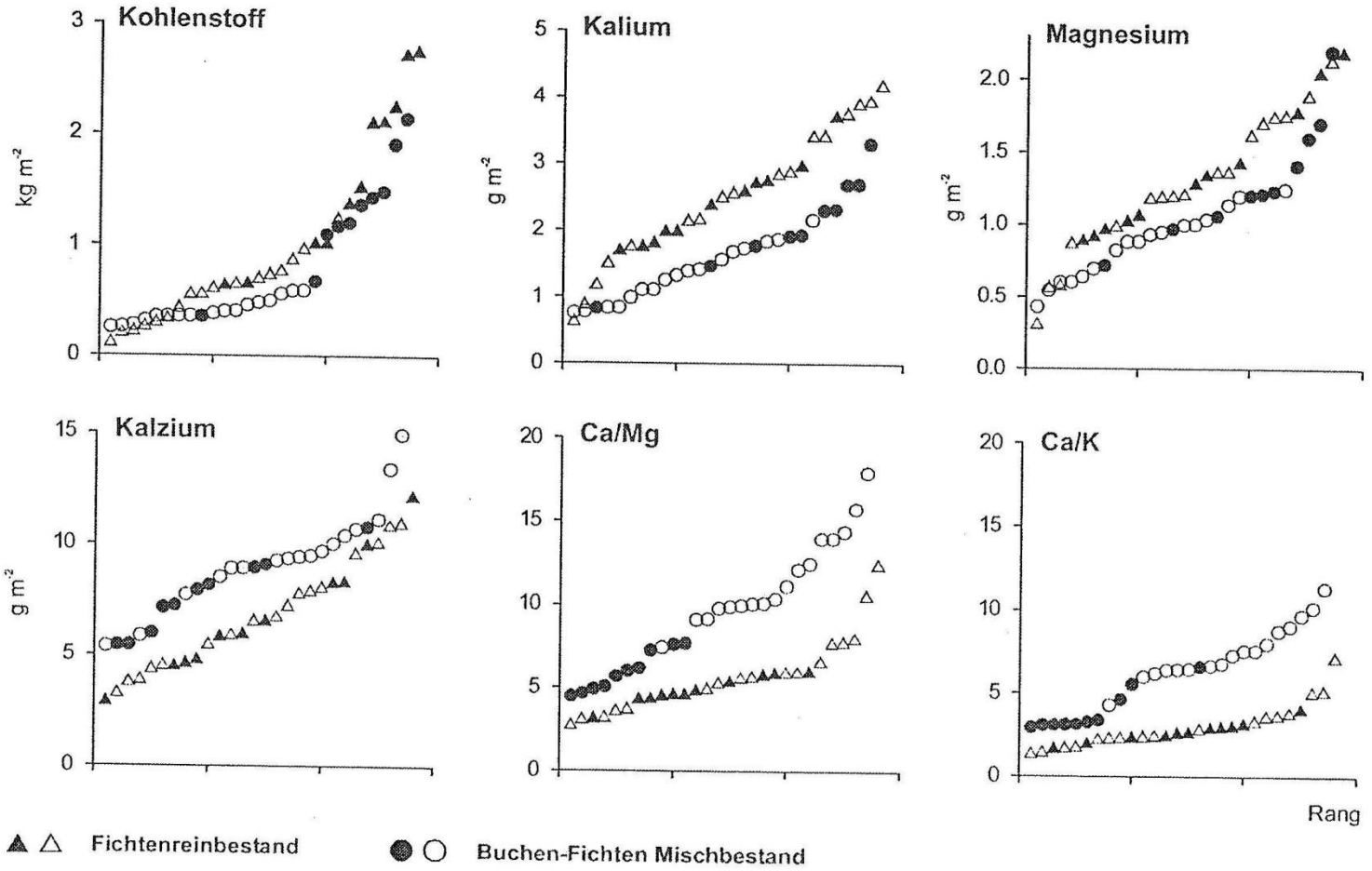
verändert nach Glatzel , 1989

Species selection: conversion to conifers→acidif.



Species selection: conversion to conifers→acidif.

C, K, Mg and Ca stores and Ca/Mg and Ca/K ratios in the forest litter layer in 26 Norway spruce and beech stands on sites in the Austrian tertiary (Glatzel, 2001)



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Species selection: conversion to conifers→loss of rooting and NO3 leaching

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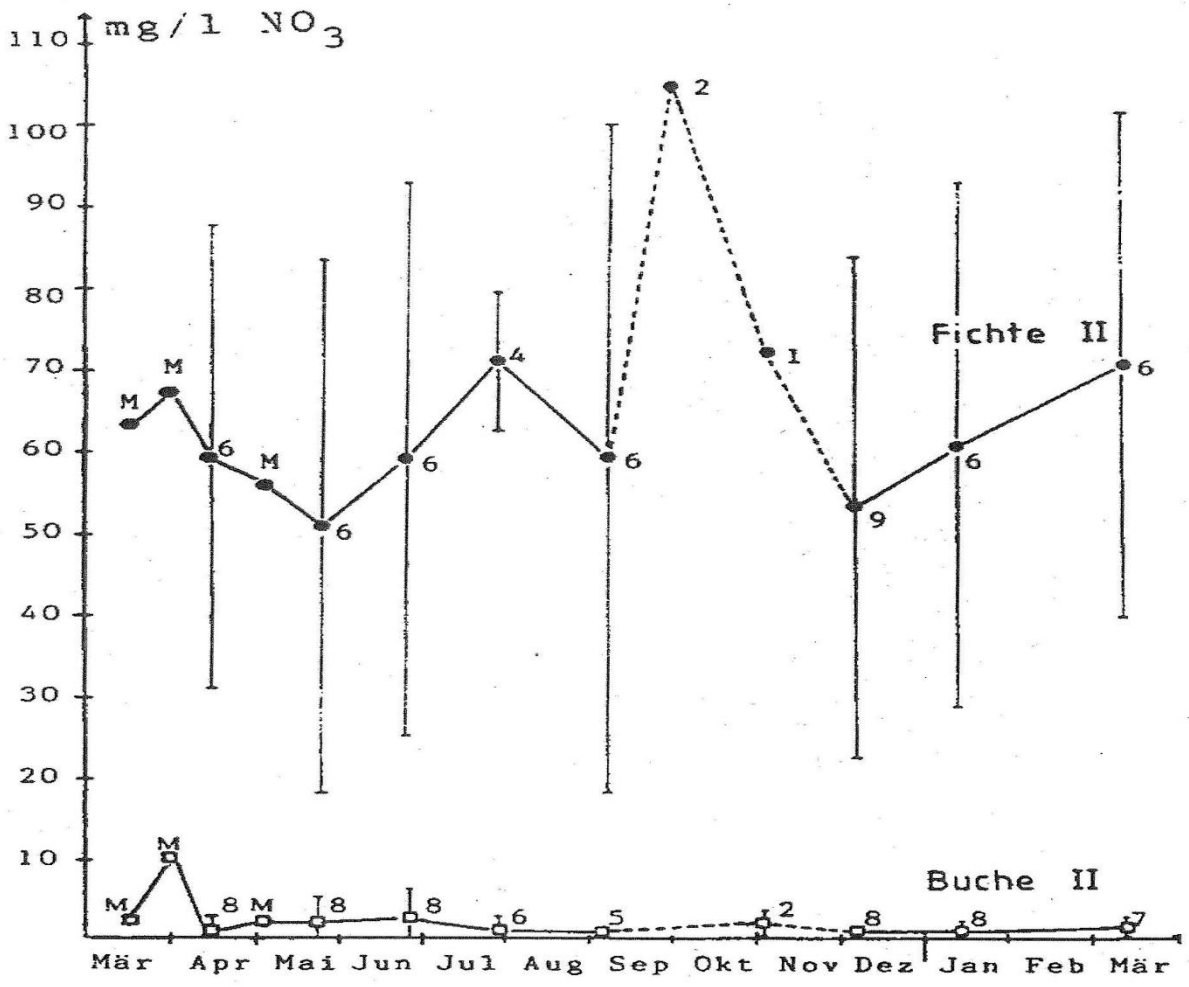

N-im Kronendurchlaß: Fichte 40 kg.ha^{-1}.a^{-1}
Bucher 22 kg.ha^{-1}.a^{-1}

NO3 in seepage water

77-year old spruce stand after mixed hardwood compared with beech old growth (Kreutzer et al. 1986)

Deposition of N in spruce in beech

Ecosystem processes: Break down of groundvegetation

Allium ursinum dynamic in European beech forest; Jandl,1992

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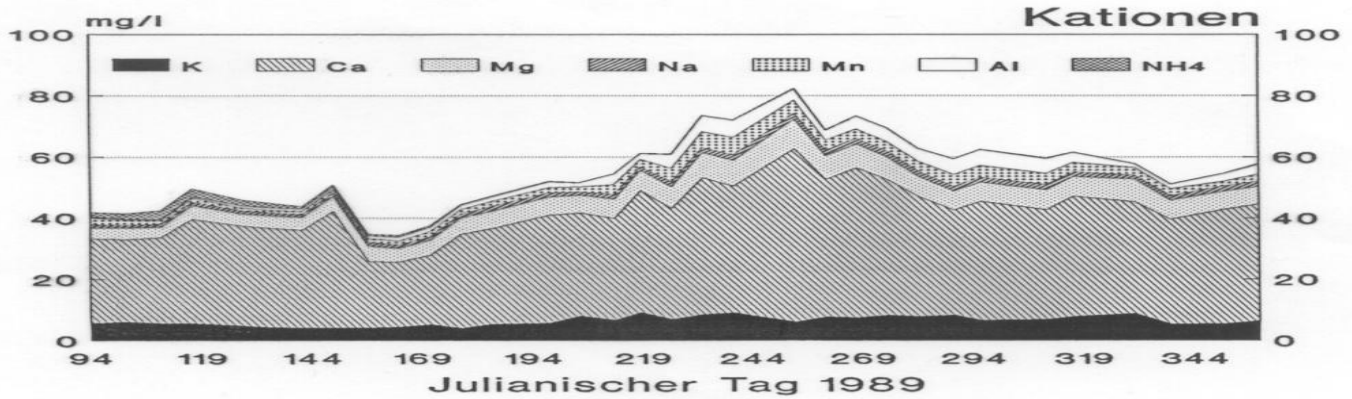
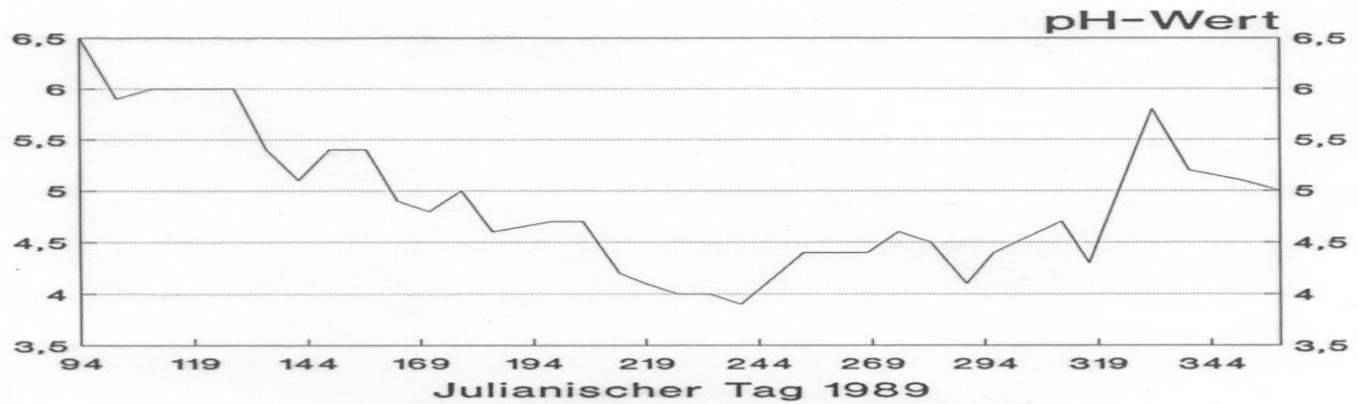
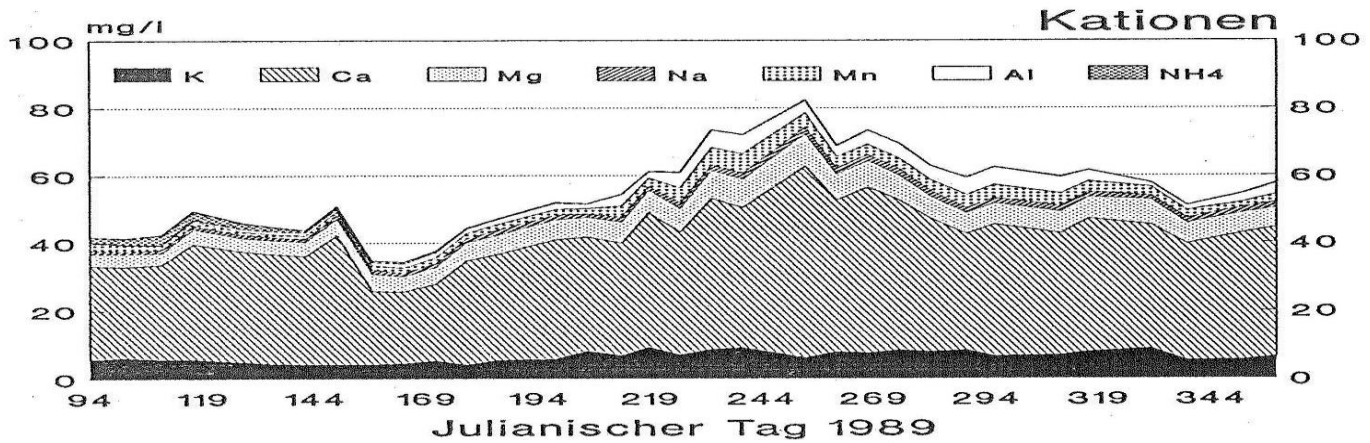
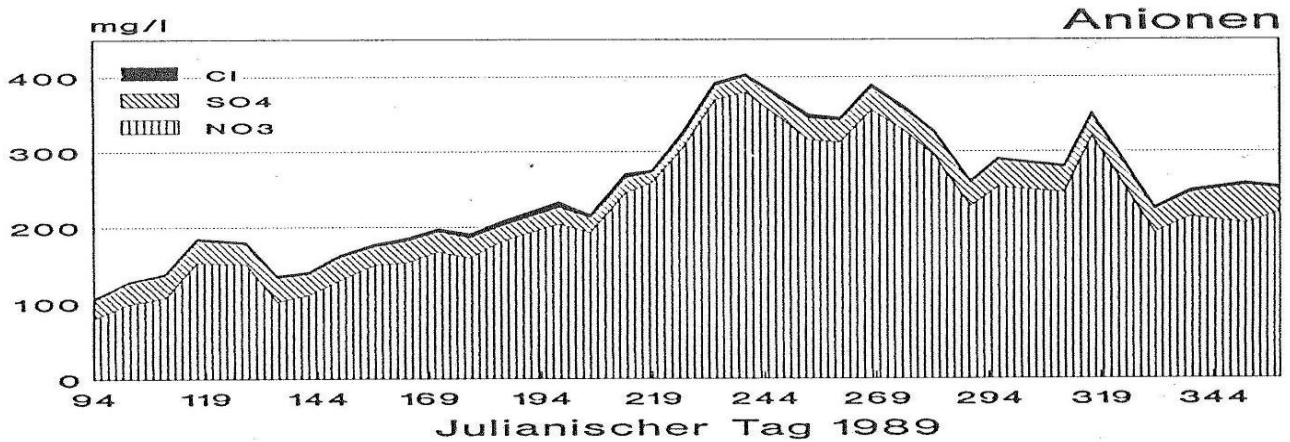




Ecosystem processes: Break down of groundvegetation

Allium ursinum dynamic in European beech forest; Jandl,1992





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N-fixing tree species

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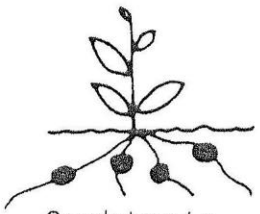
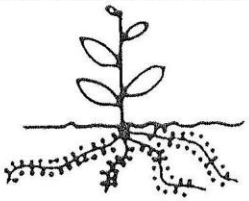
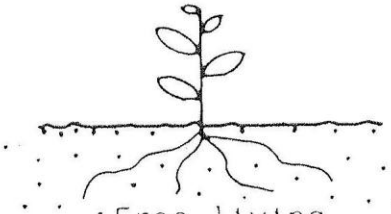
System of N_2 fixation ($N_2 \longrightarrow NH_3$) and microorganisms involved	 Symbiosis (e.g. Rhizobium, actynomycetes)	 Associations (e.g. Azospirillum, Azotobacter paspali)	 Free living (e.g. Azotobacter, Klebsiella, Rhodospirillum)	
Energy source (organic carbon)	Sucrose (and other carbohydrates from the host plant)	Root exudates from the host plant	Heterotroph: Plant residues	Autotroph: Photosynthesis
Fixation capabilities (kg N/ha•year)	Legumes: 57 - 600 Nodulated non-legumes: 2 - 300	12 - 313	0.1 - 0.5	25

Type, energy source, and fixation capabilities of biological N_2 fixation systems in soils. Data for fixation capabilities are from Evans and Barber (1977). By courtesy of K. Isermann.

Ecosystem processes: nitrogen fixing tree species

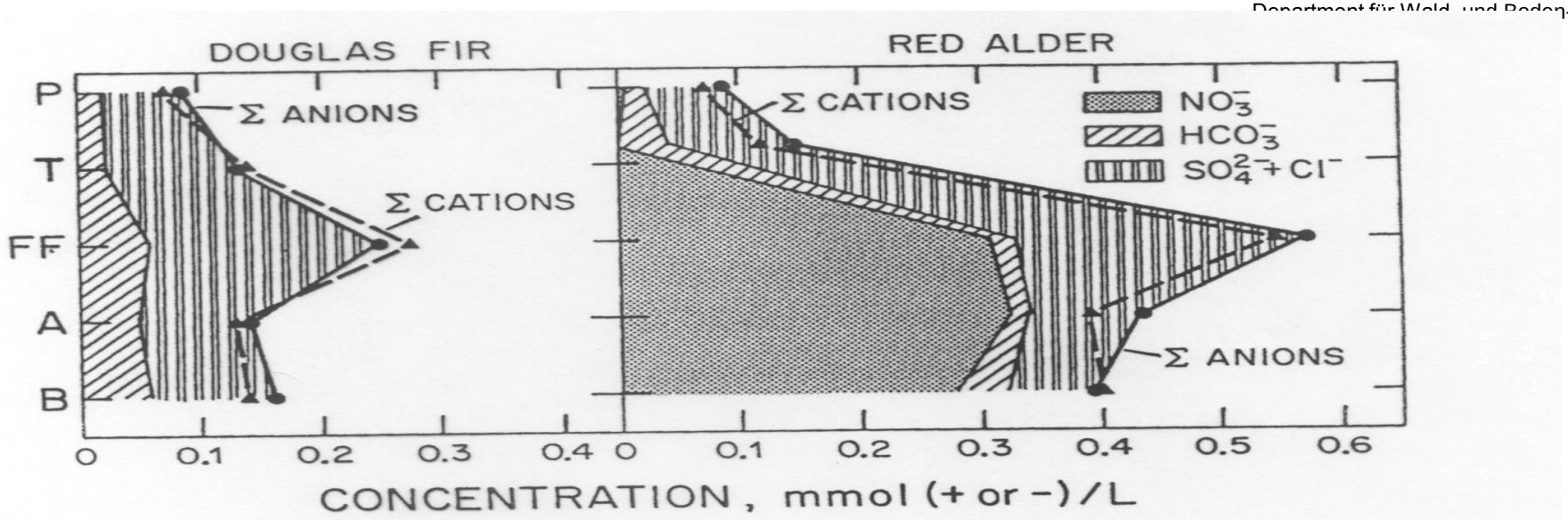


Fig. 1. Weighted average anion and total cation concentration in precipitation (P), throughfall (T), forest floor (FF), A horizon (A), and B horizon (B) solutions collected in the Douglas-fir and red alder ecosystems at the Thompson Research Center [mmol(+ or -) L^{-1}] (from Van Miegroet and Cole, 1985).

Indirect Influences: Depostion from the atmosphere

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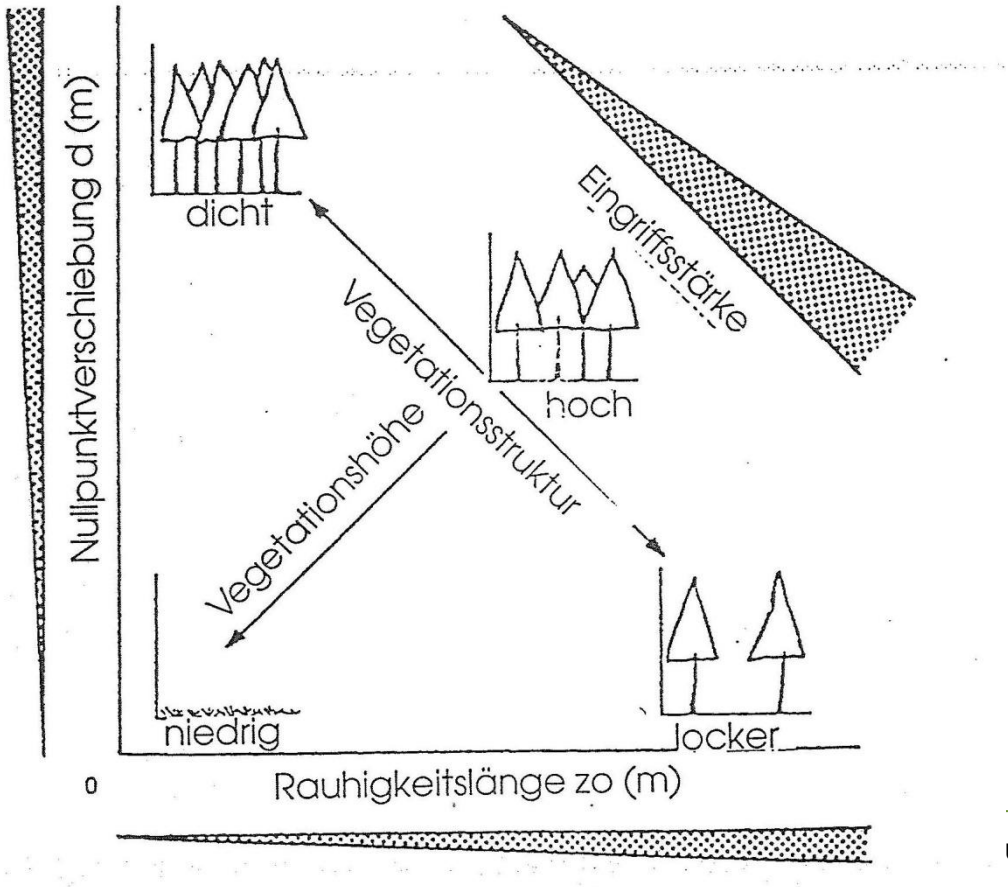
Beeinflussung des Windfeldes durch Bestandesparameter (nach Hager, 1988)

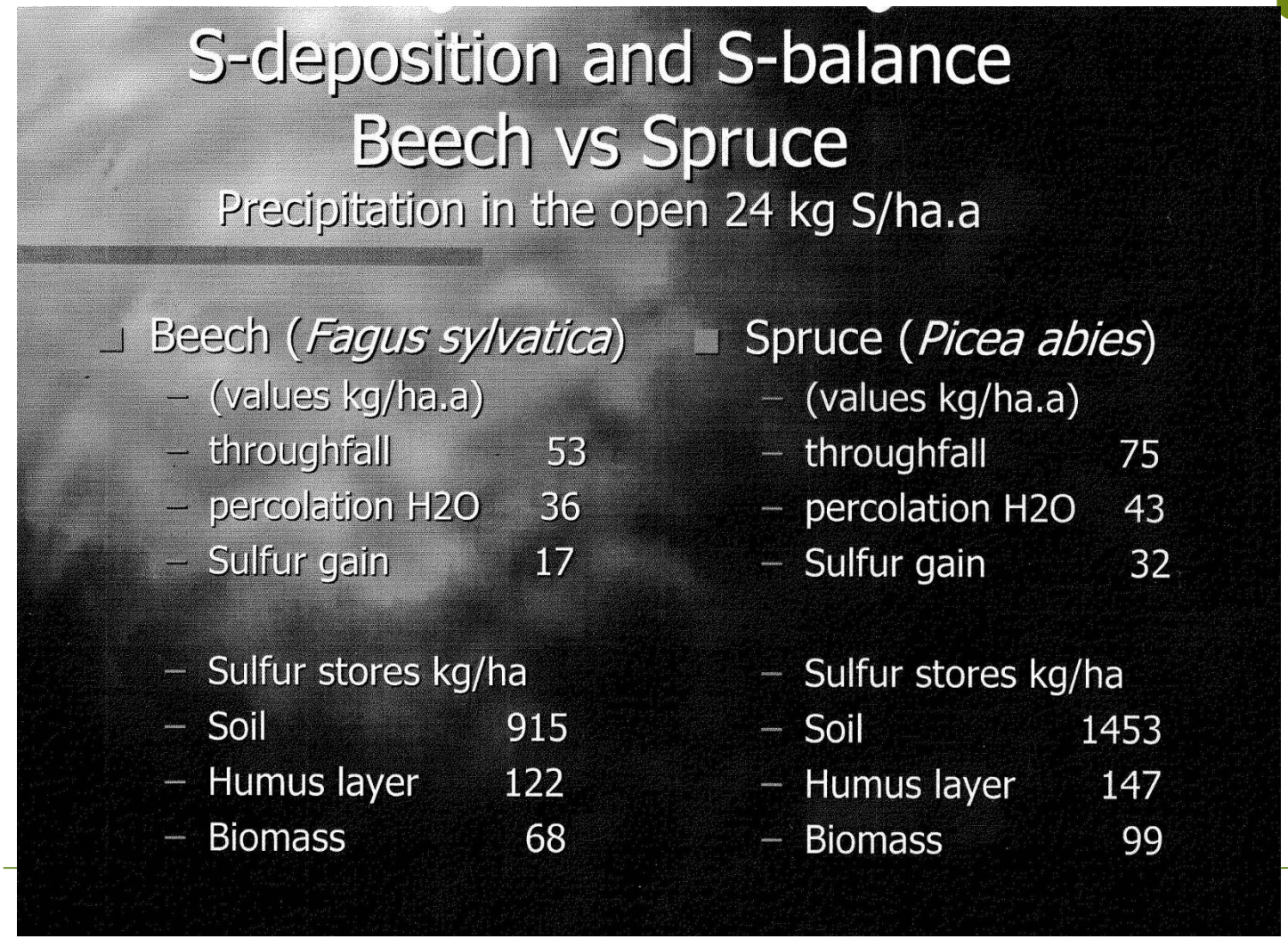


How stand properties:

e.g. height and density may influence depostion of atmospheric trace constituents

deposition velocity is a function of z_o

Indirect Influences: Depostion from the atmosphere



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Indirect Influences: Depostion from the atmosphere

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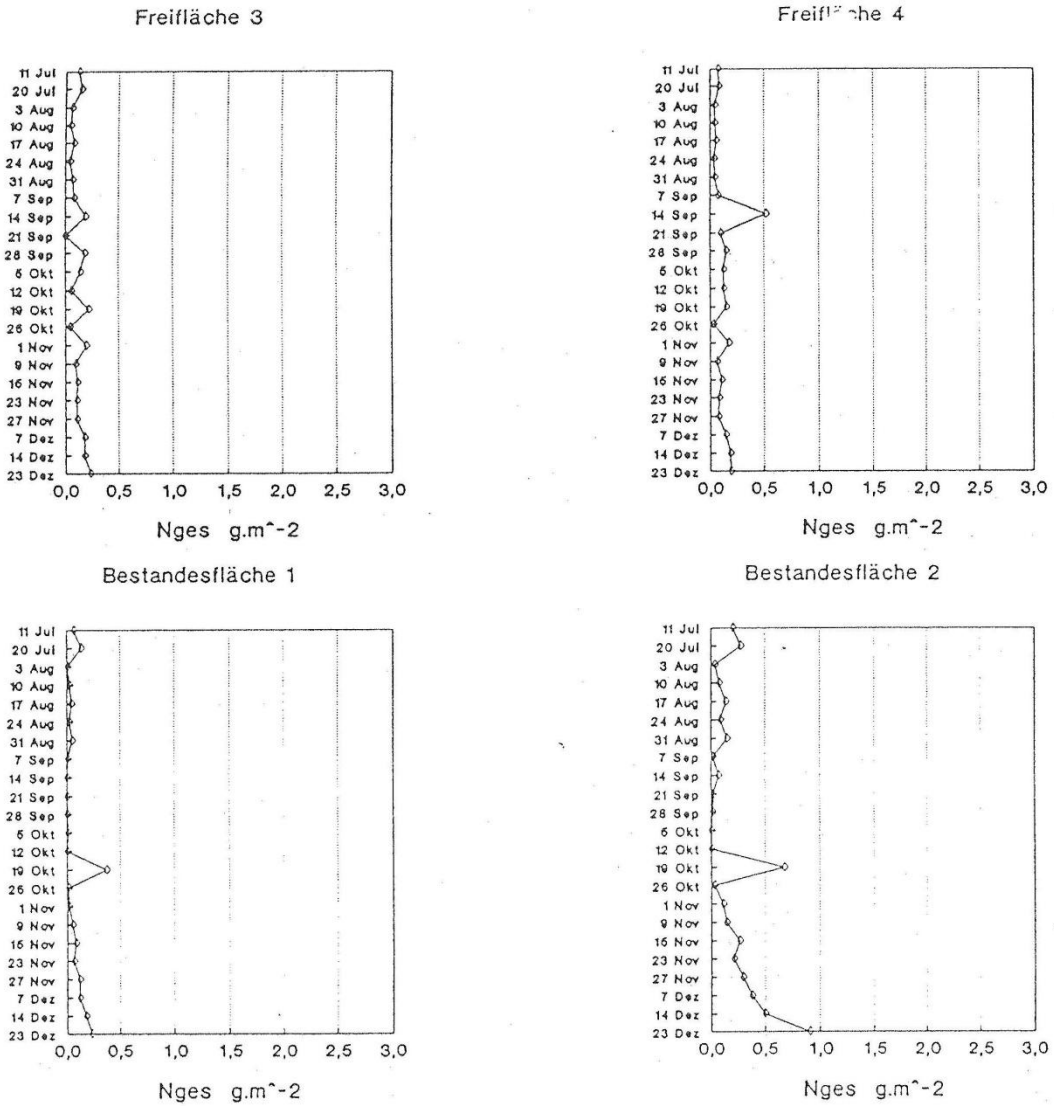

Weekly deposition of N in the vicinity of chicken stalls (Sieghardt&Hager, 1992)

Upper part: open field

Lower part: spruce forest

Indirect Influences: Depostion from the atmosphere

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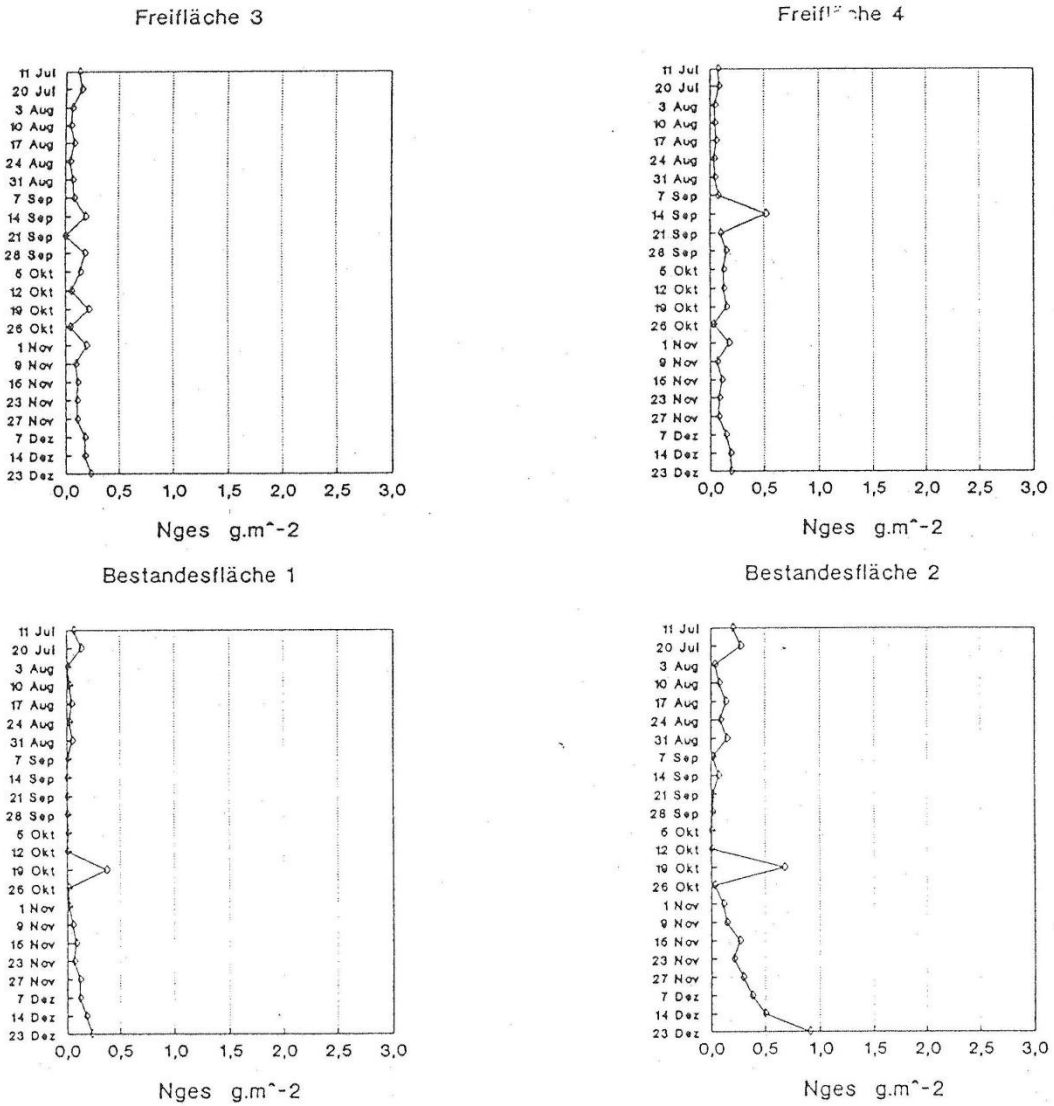

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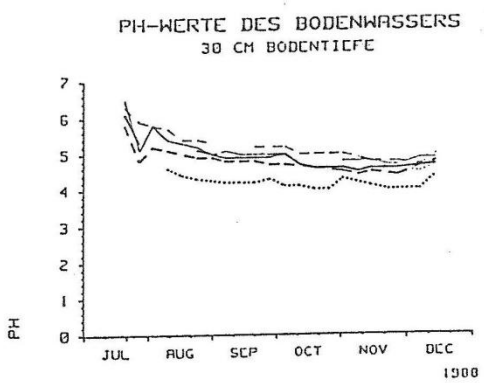

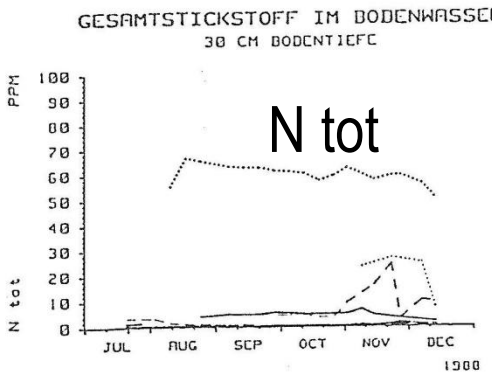

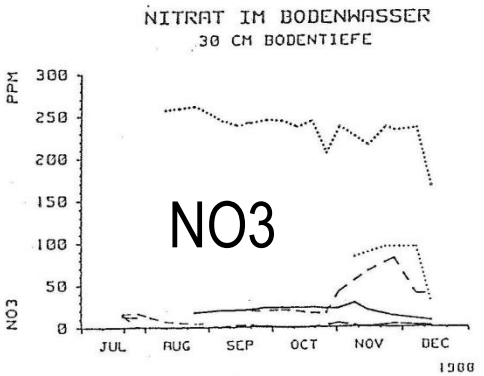

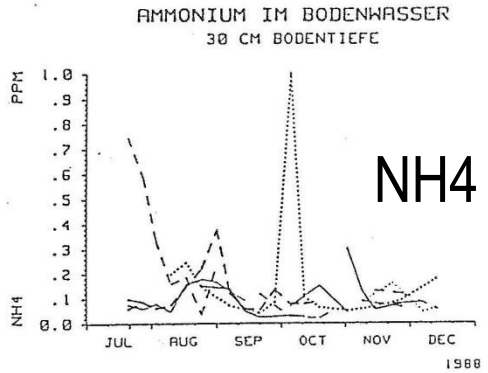

Soil water under high deposition of N in the vicinity of chicken stalls (Sieghardt&Hager, 1992)

Indirect Influences: Depostion from the atmosphere

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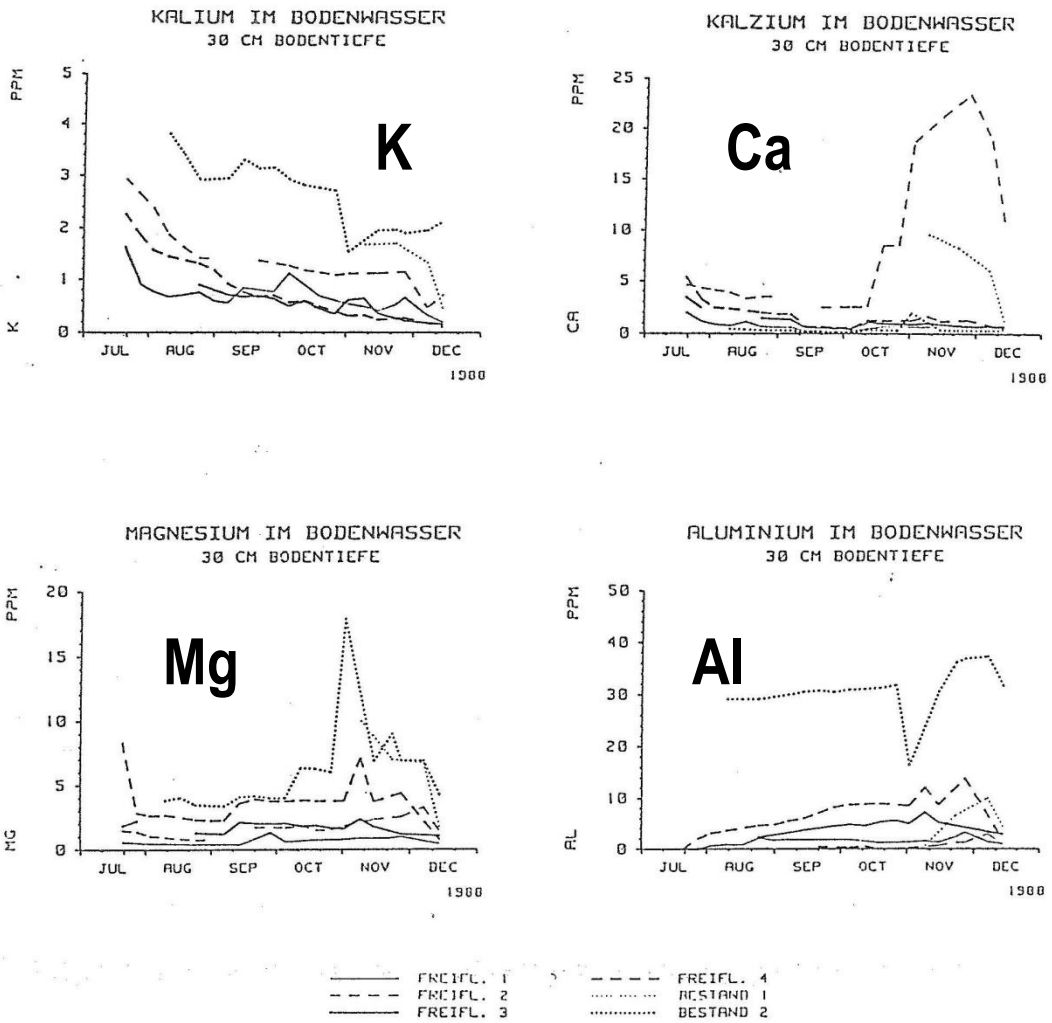
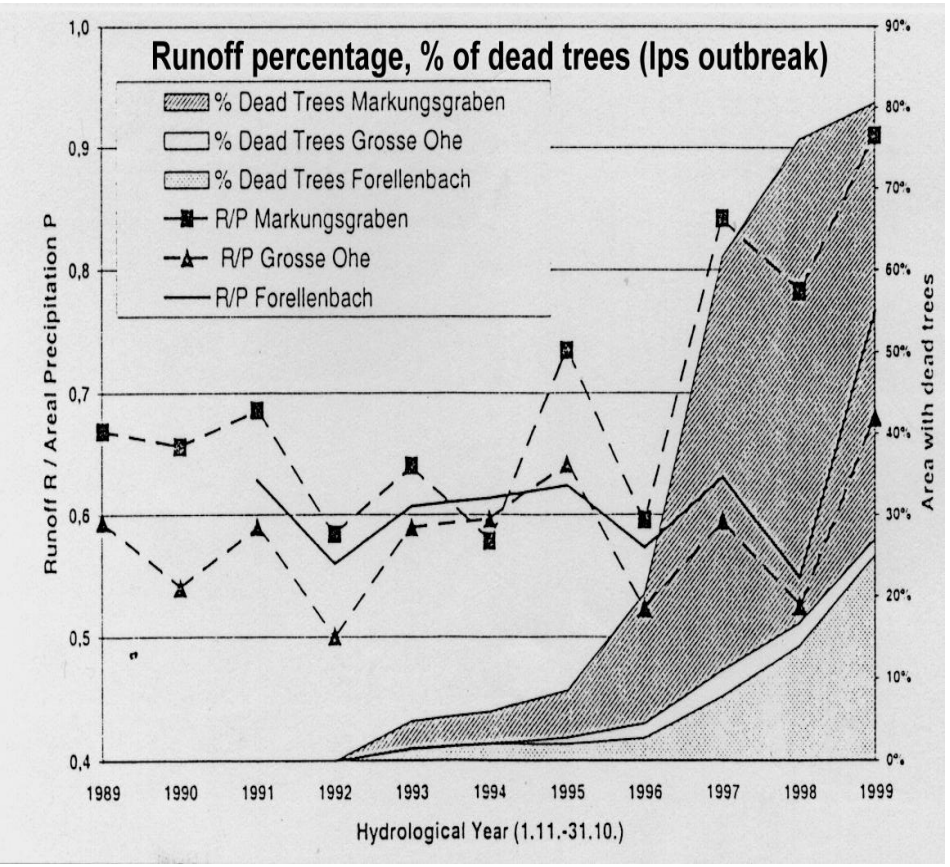
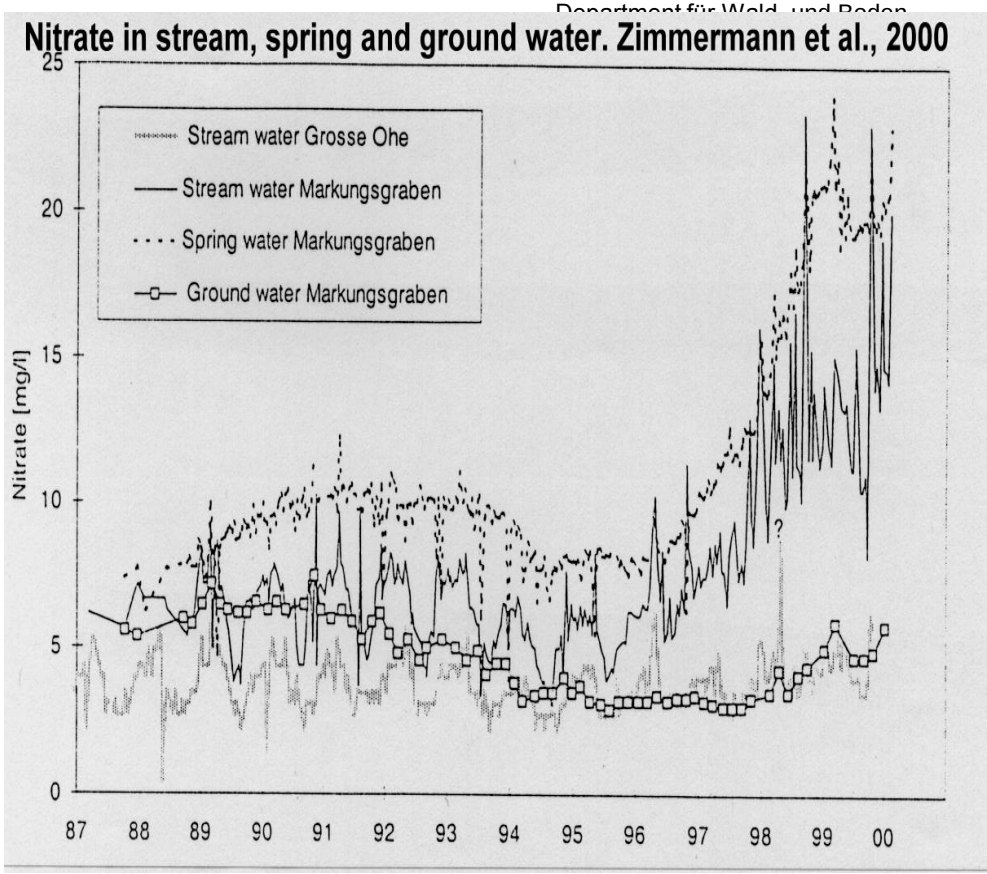


Soil water under high deposition of N in the vicinity of chicken stalls (Sieghardt&Hager, 1992)

Indirect influences: pest outbreak





Influences of management: Lime application

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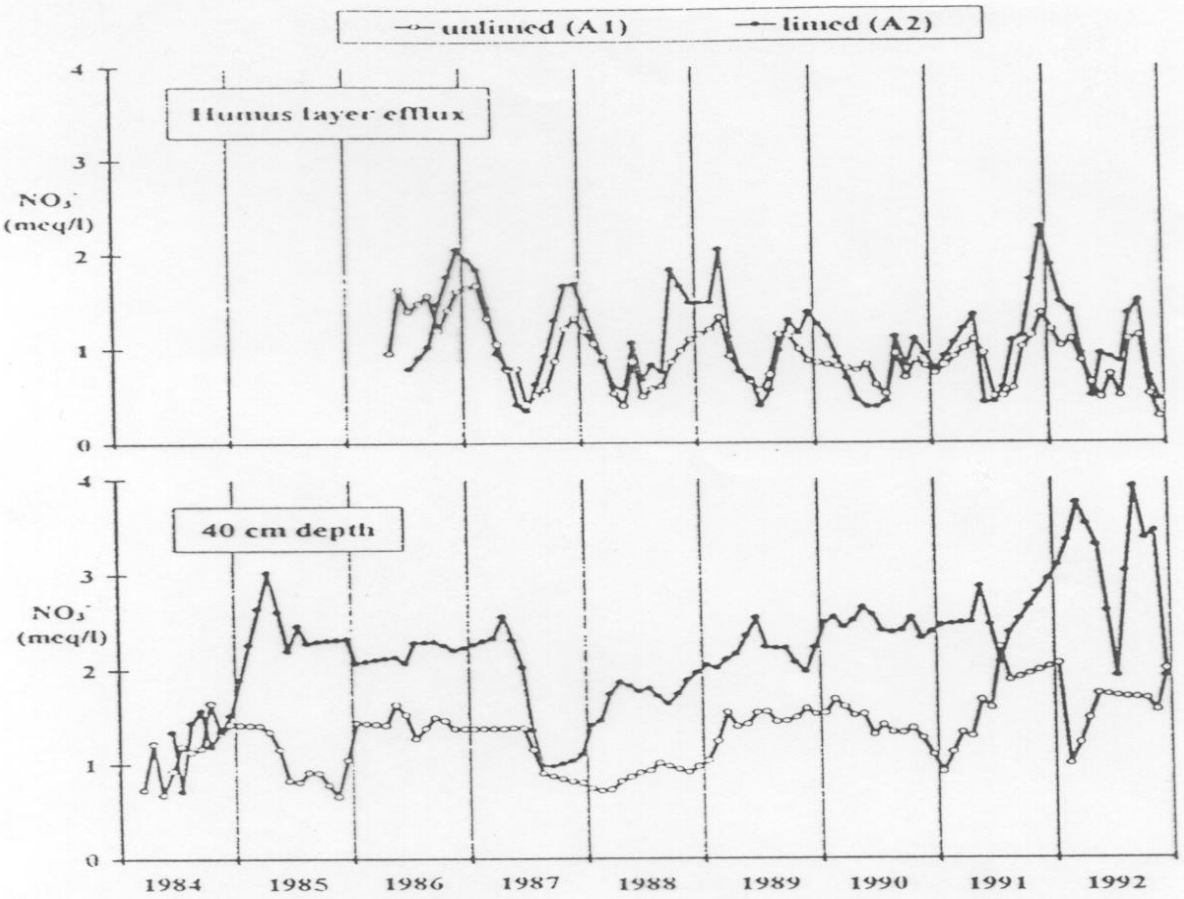

NO_3 in drainage water of the limed plot A2 and control A1 at the depths of 0 cm (humus layer efflux) and 40 cm in the mineral soil, below the main root zone in the space between the trees.

Kreutzer 1995

4t/ha of dolomite applied

In 7 years: 7.2t/ha of humus and 170kg/ha N lost

From Kreutzer 1995

Fertilizer treatments

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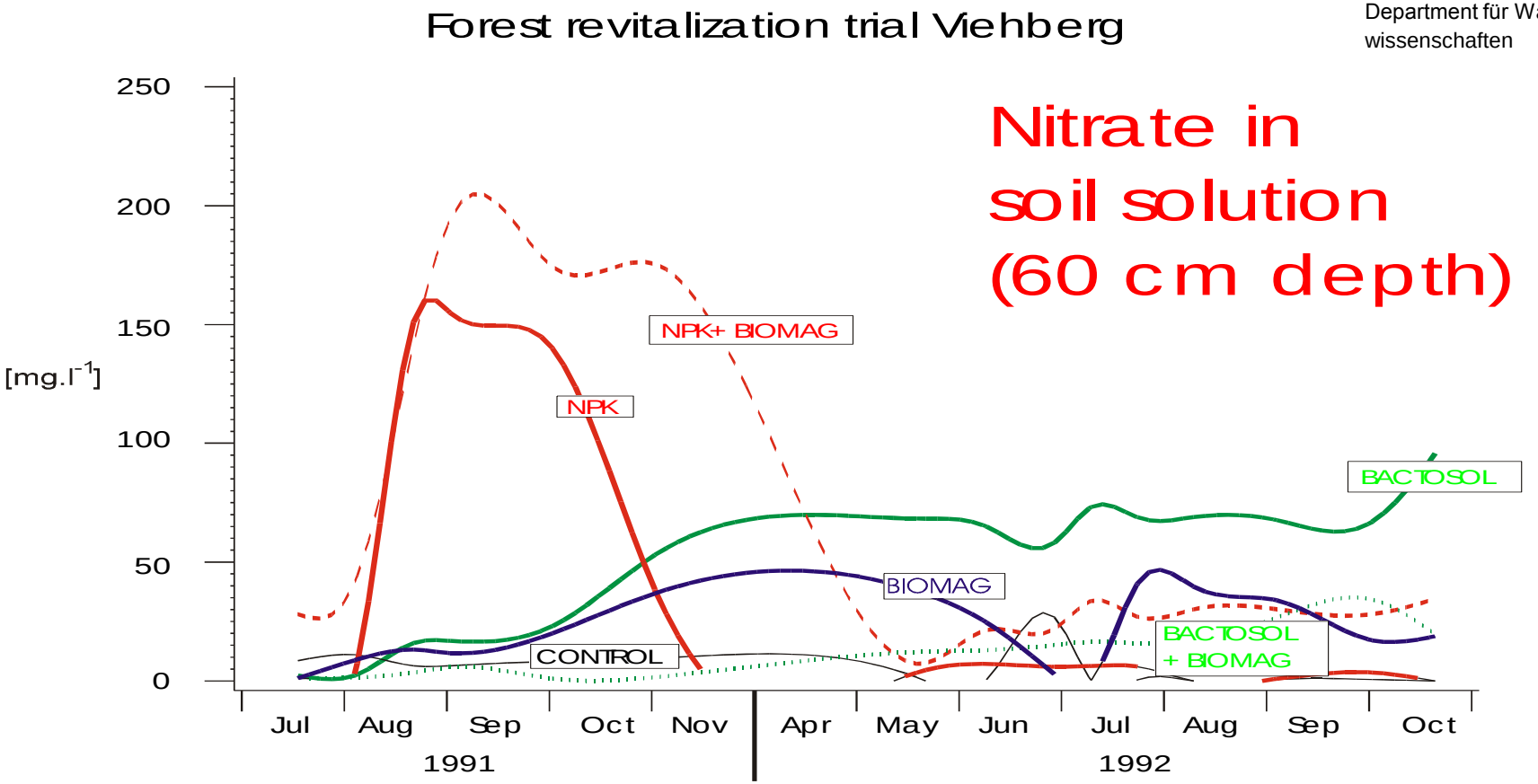

Harvesting and Clearcutting:Bormann&Likens (1979); Hubbard Brook Experimental Forest (HBEF)

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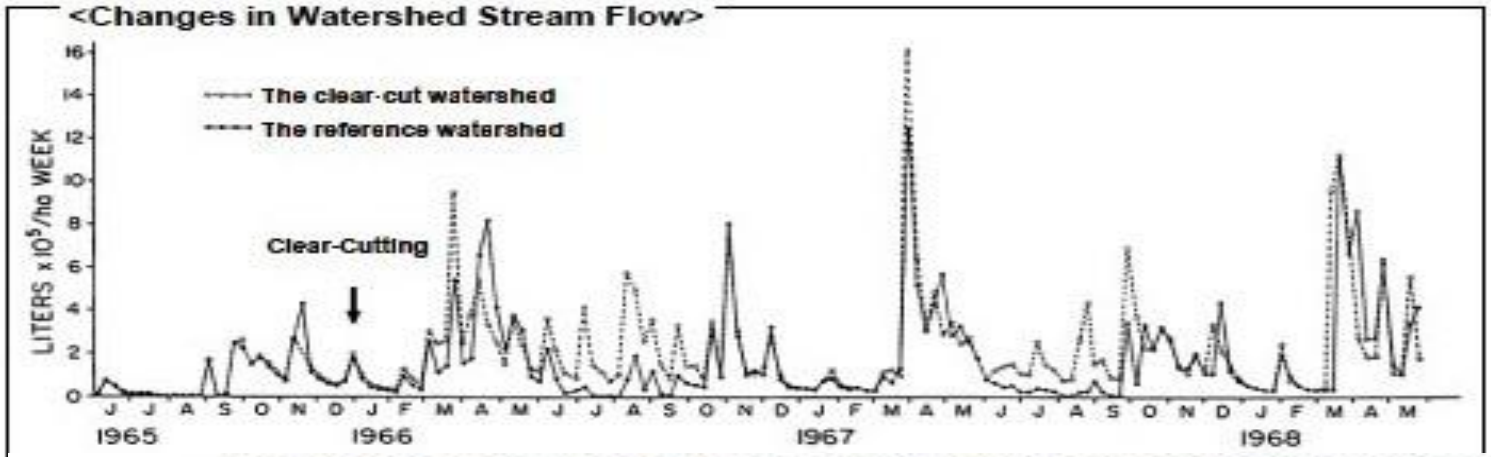

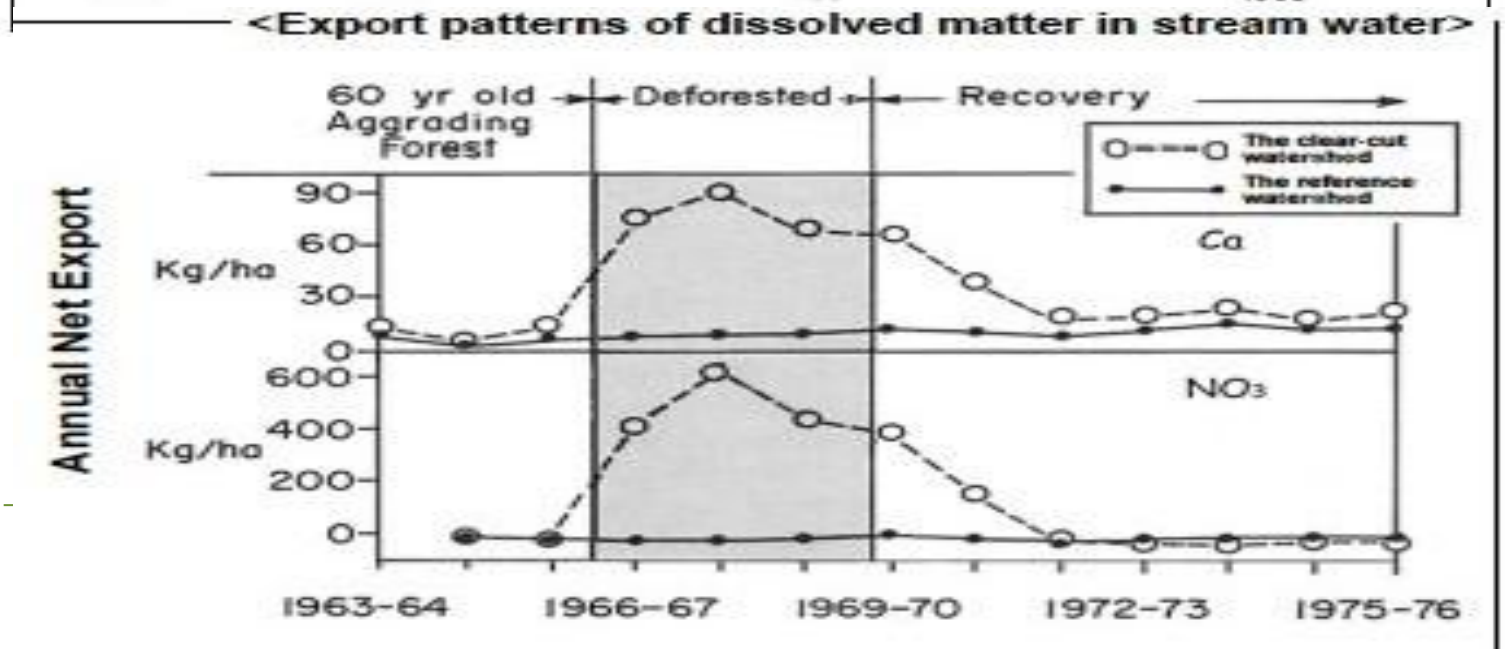

Harvesting and Clearcutting:Bormann&Likens (1979); Hubbard Brook Experimental Forest (HBEF)

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	Nettoverlust oder -gewinn (kg/ha)	
Element	W6	W2
Ca	− 9,0	−77,7
Mg	− 2,6	−15,6
K	− 1,5	−30,3
Na	− 6,1	−15,4
Al	− 3,0	−21,1
NH_4-N	+ 2,2	+ 1,6
NO_3-N	+ 2,3	−114,1
SO_4-S	− 4,1	− 2,8
Cl	+ 1,2	− 1,7
HCO_3-C	− 0,4	− 0,1
SiO_2-Si	−15,9	−30,6
insgesamt	−36,9	−307,8

Average annual loss or gain of nutrient elements in treated (W2) and untreated (W6) forested watershed HBEF

W2 clearcut and herbicide

Different methods of site preparation after Rehfuess (1981)

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Vorräte an organischem Kohlenstoff und Gesamtstickstoff in den Ökosystemen. Einflüsse der Steingehaltsunterschiede covarianzanalytisch ausgeschaltet, Lockerung berücksichtigt

Kompartiment	org. Kohlenstoff (t/ha) C				Stickstoff (kg/ha) N			
	Versuchsglied				Versuchsglied			
	A	u	F	V	A	u	F	V
Kiefernsprosse					–	48	69	72
Kiefernwurzeln > 4 mm					–	2	3	3
Bodenflora-Sprosse		n.b.			41	49	47	23
Feinwurzeln < 4 mm					48	56	34	29
Phytomasse insges.					89	155	153	127
Organische Auflage	31,7	9,7	3,1	3,0	897	268	78	67
Mineralboden 0–50 cm	37,0	39,4	44,3	35,2	2138	2328	2029	2307
Solum insges.	68,7	49,1	47,4	38,2	3035	2596	2107	2374
Abweichung vom Altholzvergleichswert	–	–19,8	–21,3	–30,5	–	–439	–928	–661
Ökosystemvorrat insges.					3124	2751	2260	2501
Abweichung vom Altholzvergleichswert		n.b.			–	–373	–864	–623
Düngungsinput					–	115	115	115

C_{org} and N stores

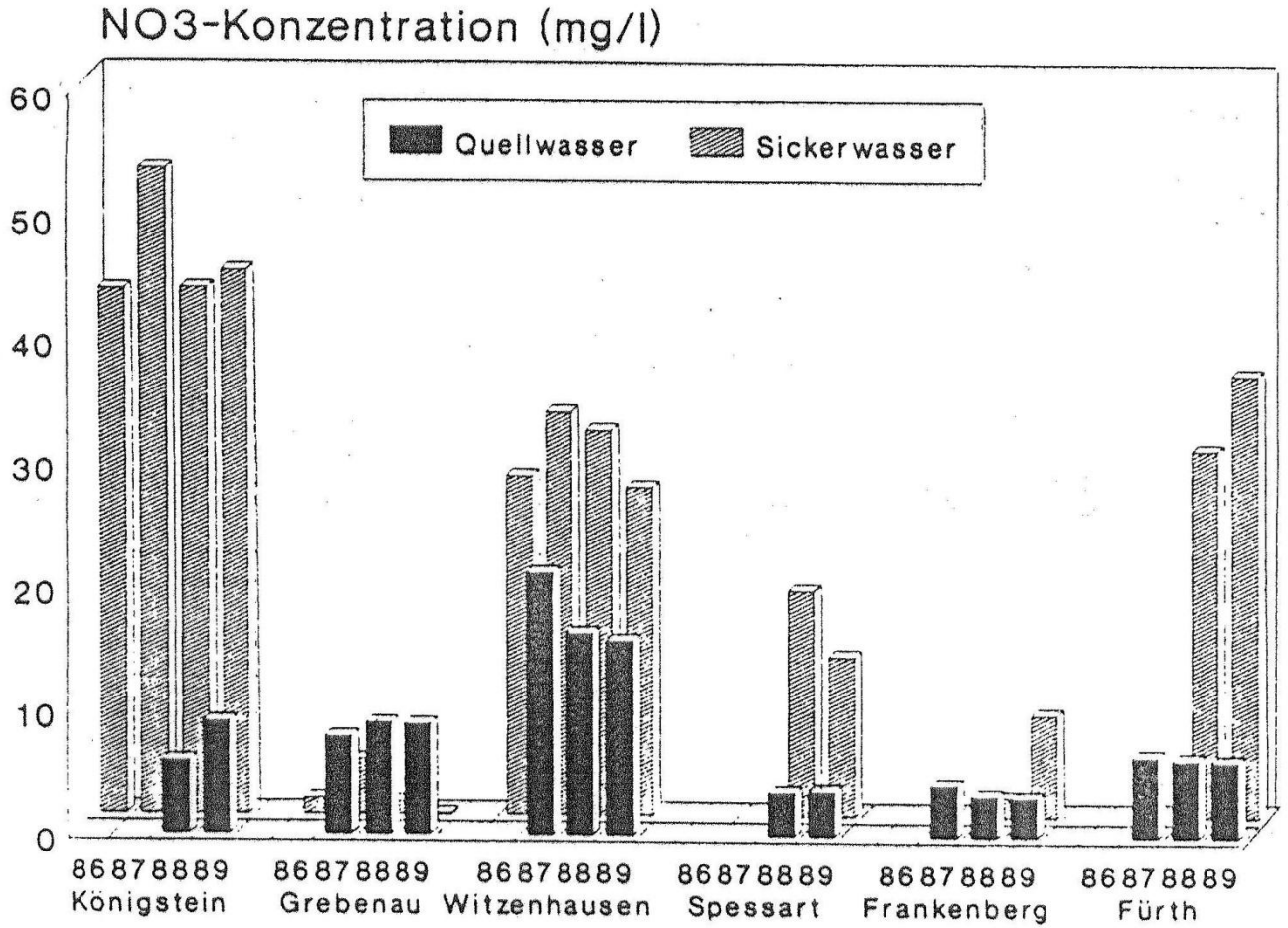
A = Pine old growth

U = 9yr old Pine + herbicide

F = rototilling

V = deep plowing

NO3 in river and spring water vs. Soil leachate (Balazs, 1992)



from 6 watershed studies in Hessia (Germany)

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Forest management and suspended sediment (Fredericsen et al., 1975)

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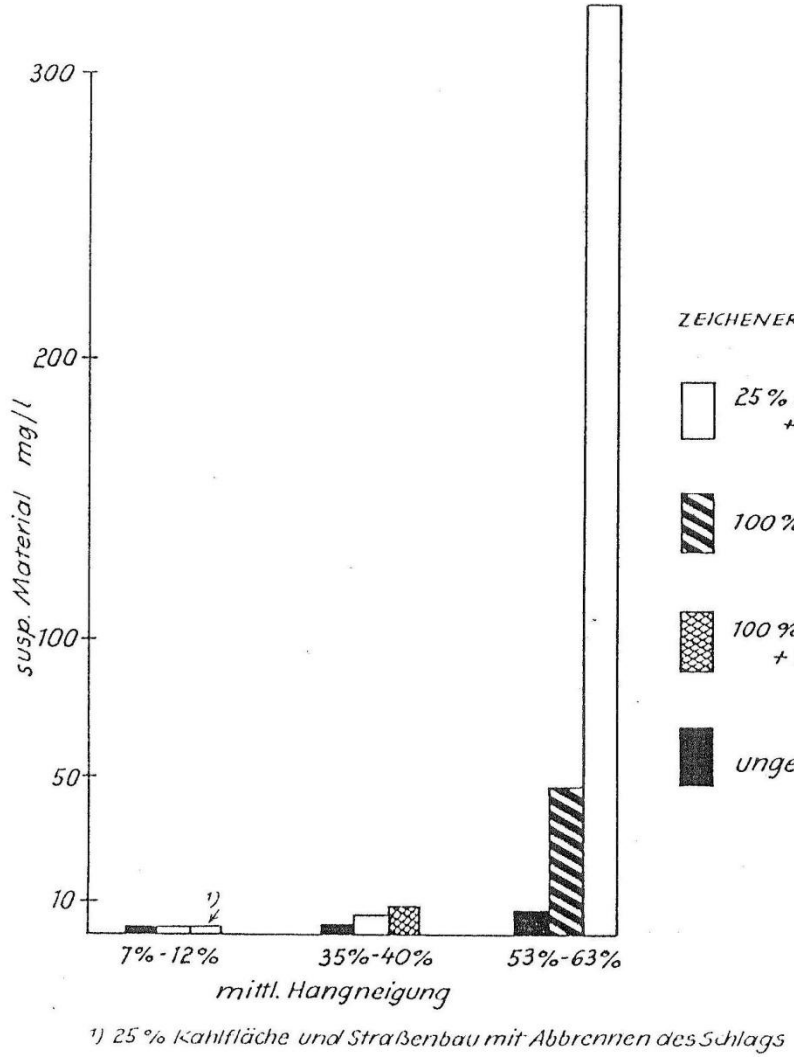

1) 25 % Kahlfläche und Straßenbau mit Abbrennen des Schlags

Clearcut and roads vs slope inclination in watershed

25% clearcut plus roads

100% clearcuts

100% clearcut plus roads

undisturbed

Forest management and suspended sediment (Stott et al., 2001)

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Numerous are the studies on sediment yield and logging operations: for example (see below)

Table 4. Sediment yields associated with timber harvesting in upland Britain

Catchment	Reports	Area km^2	Land use	Years of data	SSY t km^{-2}	% change
Kirkton, Balquhidder, central Scotland	Stott *et al*., 1986 Johnson, 1993	6·85	Mature forest	4	56·6	
			progressive felling to 50% of catchment	4	462·8	+718
Loch Ard, central Scotland (Catchment 10)	Ferguson *et al*., 1991	0·84	Mature forest	1	55·2	
			clear-felling	2	89·6	+62
			post-clear-felling	0·25	98·4	+78
Plynlimon, mid-Wales	Leeks, 1992	3·08	Mature forest	2	24·4	
Hore			felling	1	57·1	+134
Tanllwyth	This study, 1995–7	0·89	mature forest	1	24·2	
			clear-felling of 20%	1	43·8	+81 (39%)

Forest management and suspended sediment (Mcdonald et al., 2003)

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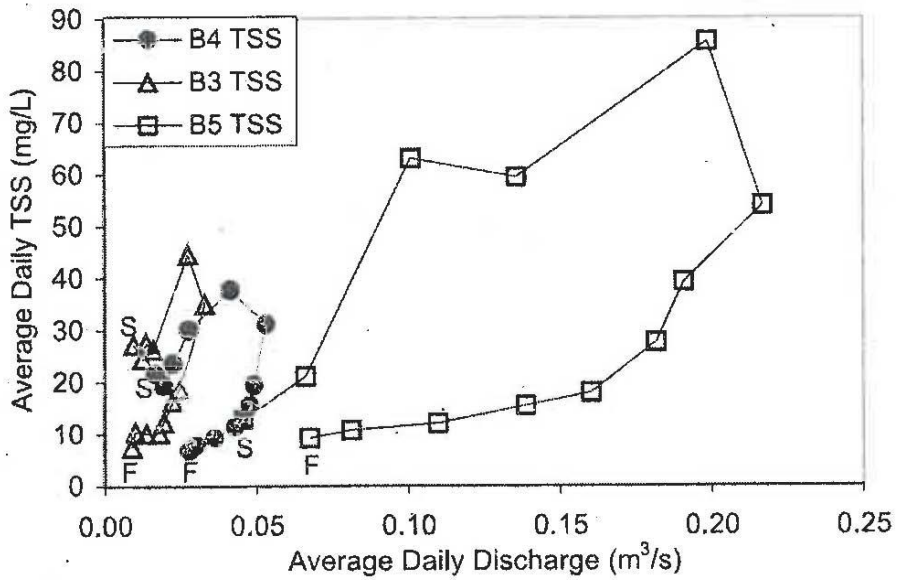
Table 2. Forest types, logging operations, and riparian treatments in the three study watersheds.

Watershed	Dominant tree species[a]	% of watershed clear-cut harvested	Length of channel harvested (m)	Riparian treatment[b]
B3	Bl, Sx	55	900	High retention
B4	Bl, Sx, Pl	Unlogged	Unlogged	Unlogged
B5	Bl, Sx, Pl	53	1060	Low retention

[a]Bl, *Abies lasiocarpa* (Hook.) Nutt. (alpine fir); Sx, *Picea glauca* × *Picea engelmannii* (hybrid white spruce); Pl = *Pinus contorta* Dougl. ex Loud. var. *latifolia* Engelm. (lodgepole pine).
[b]See text for treatment prescriptions.

Logging operations increase TSS but precautions can make a difference → BMP

Fig. 6. Sediment output during the rising and falling limbs of the snowmelt hydrograph in the three experimental streams to provide an example of event hysteresis in 1998. S, the beginning of an event; F, the end of an event; TSS, total suspended sediment.



Agrochemicals in forestry and agriculture with the USA after Norris (1991)

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	Total use (1000t/yr)		use per unit area(kg/km2*yr)	
	AGR	FOR	AGR	FOR
Insecticide	138924	71	90.3	0.092
Herbicide	202030	169	131.4	0.220
Fungicide	22700	9	14.8	0.011

Summarizing water quality

- Soils and site factors very important (puffer range, CEC cation content, minerals for weathering)
- Tree species selection, especially conifers
  →acidification >>load, nutrient cycling, rooting depth
  →“nutrient pump“
- N-fixing tree species similar to N-input from atmosphere
- Acidogenic atmospheric input >> also chemical loads
- Ecosystem predisposition, instability

Summarizing water quality(cont.)

- Mobilizing compartments in the forest ecosystem >>chem. load
  - e.g. fertilizing, limeing, pest outbreak, die back, site preparation
  - lost rooting depth (Kreutzer et al. 1986, conversion)
  - Clearcutting or slash & burn
- Climatic caused nitrification bursts (Matzner, 1993)
- Last not least: denitrification may ameliorate NO3 in springs
- Logging and roading can increase TSS but BMP!
- Little use of agrochemicals → forest yield good water

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THANK YOU FOR YOUR ATTENTION !