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Acid deposition: Data from the Swiss Alps

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Abstract

Deposition of nitrogen and sulfur was measured in spruce stands at different altitudes in Switzerland. Both NH_4^+-N and NO_3^--N in throughfall showed a clear altitude dependence whereas SO_4^{2-} was not correlated with altitude. Critical loads for nitrogen and acidity were calculated for six sites in Central Switzerland.

1. INTRODUCTION

The topography and the geology of Switzerland are very heterogeneous. Therefore, the application of the critical loads concept asks for knowledge about the influence of altitude and geology. Critical loads for acidity and nitrogen were calculated in a case study on sites in an area with sensitive geology and compared with actual loads measured by means of throughfall deposition. Some factors of these sites are listed in Table 1.

Table 1: Sites used for the critical load study (canton of Uri, main valley)

Site	Abbreviation	Altitude (m)	Geology	Age (years)	Stock (m^3 ha^{-1})	Stems ha^{-1}
Silenen	SIL	630	Riss-Würm Moraine	150	578	628
Frentschenberg	FRB	910	Riss-Würm Moraine	230	460	558
Waldiberg	WAB	1220	Riss-Würm Moraine	200	274	467
Riggstäfeli	RIG	1740	Riss-Würm Moraine	210	794	633
Rötiboden	ROE	1580	Granite	300	327	233
Eggberge	EGG	1540	Flysch	180	837	633

2. RESULTS

Deposition

Deposition was measured by collecting throughfall in spruce stands and rainwater in adjacent clearings or in open field. No attempt was made to correct the N loads for direct uptake by the trees although this was noticeable especially for NH_4^+-N in the more elevated sites where NH_4^+-concentrations in throughfall were often lower than those in rainwater. Also, there is no information about stomatal uptake of NH_3 or NO_2. Thus, the values reported here are minimum estimates.

Throughfall loads of N were mainly correlated with altitude (Fig. 1). This holds true for NH_4^+-N as well as for NO_3^--N. The altitude dependence was much more important than regional differences. In contrast, the loads in rainwater showed increased values at an altitude of 1000-1200 m, but no other altitude dependence. This is the altitude with the highest cloud frequency. The deposition of SO_4^{2-} in throughfall was not correlated with altitude. In the open field a similar increase of SO_4^{2-} at 1000-1200 m was observed as in the case of NH_4^+ and NO_3^-.

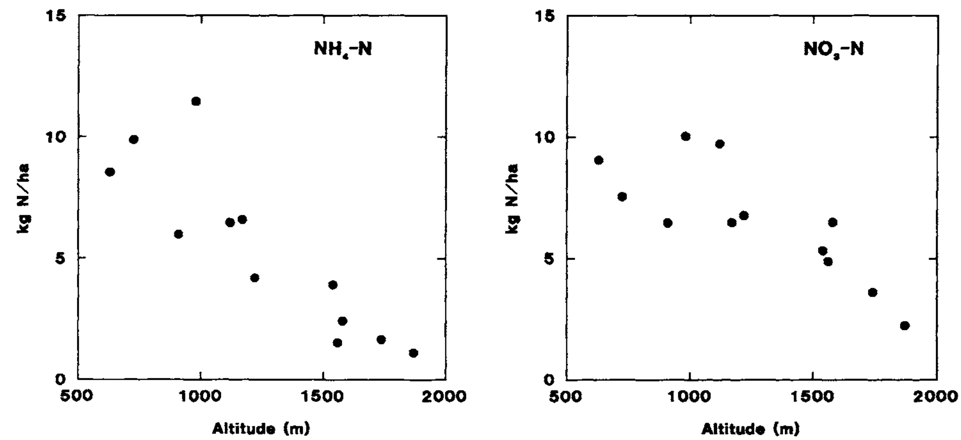

Fig. 1: Throughfall loads of NH_4^+-N (left) and NO_3^--N (right) during the summer (6 months)

Actual loads for acidity

The potential acidity was calculated as the sum of NH_4^+, NO_3^-, SO_4^{2-} and Cl^- minus the base cations Ca^{++}, Mg^{++}, K^+ and Na^+. The dry deposition of Ca^{++}, Mg^{++}, K^+ which enters this calculation was derived from dry deposition on inert surfaces and throughfall loads according to Lindberg et al. (1988) for the sites in the case study or taken from model calculations by Rihm (1994) for the other sites. All other ions were extrapolated from throughfall summer loads to annual loads basing on whole year measurements of open field bulk deposition.

The actual loads for potential acidity are dominated by NH_4^+ and NO_3^- which causes a similar altitude dependence as for the two nitrogen compounds. Of the N and S compounds, NO_3^- contributed 37%, NH_4^+ 28% and SO_4^{2-} 35% to the acid load on an average.

Critical loads for acidity

Weathering rates of single cations were calculated with the soil model PROFILE Vers. 3.2 (Warfvinge and Sverdrup (1992). These weathering rates were entered into the steady-state mass balance (SSMB) equations for critical loads in the form developed for alpine areas (UBA 1993). Critical loads based on both vegetation sensitivity (Tab. 2, CL) and soil stability (Tab. 2, CL*) were calculated. Because of a rather high calculated Al-weathering, CL* is lower in 4 out of 6 sites than CL and causes quite low critical loads.

Table 2: Weathering rate in the rooting zone (ANC_w), critical load for acidity (CL and CL*; see text) and deposition of potential acidity (DepAc) at different sites (abbreviations of site names see Tab. 1). Numbers are in keq ha^{-1} a^{-1}.

Site	ANCw	CL actual harvest	CL max. harvest	CL* rooting zone	CL* whole profile	DepAc	Exceedance
SIL	0.63	2.12	1.44	1.90	14.7	2.25	0.35
FRB	0.35	1.58	1.17	1.05	1.05	1.73	0.68
WAB	0.98	2.85	2.57	2.94	3.47	1.50	0
RIG	1.49	3.85	3.48	4.48	4.91	0.88	0
ROE	0.09	0.78	0.63	0.28	1.14	1.35	1.07
EGG	0.13	0.77	0.77	0.38	0.38	1.08	0.70

Critical loads for nitrogen

Critical loads for nitrogen based on empirical data are given by Bobbink et al. (1992). For acidic coniferous forests, they report values of 15-20 kg $N*ha^{-1}*a^{-1}$ although these values only hold true for managed forests. In the alps, forest management is quite extensive because of slow growth and bad site accessability. The harvest rates in the sites were mainly between 0.6 and 1 $m^3 ha^{-1} a^{-1}$ (Tab. 3). Thus, the amount of N taken up is much less important than the question where the nitrogen is going in the ecosystem and how much can be tolerated. With the present data, this question cannot be answered. At least in one site, a high C/N ratio and the humus form (raw humus) suggests that no nitrification takes place, which will lead to an accumulation of NH_4^+-N.

The critical loads for nitrogen were also considered by nutrient balance calculations according to Gundersen (1992). First, the N loads in deposition can be compared with short and long term uptake. Nitrogen deposition exceeded the current immobilization rate in woody parts by a factor of 2-5. Second, N uptake must be balanced by the supply of other nutrients in weathering or deposition in order to maintain optimal nutrition. Thus, the critical load of N can be seen in view of optimal nutrition (nutrient balance approach). This method suggested that P and /or K was limiting at the sites under examination. It is interesting to note that needle analysis indeed revealed a quite short supply of P, at one site also of K.

Table 3: Comparison of N-deposition, N uptake (immobilization in woody parts) and results of the nutrient balance calculations (maximum amount of N which can be balanced by weathering/deposition input of other elements).

Site	SIL	FRB	WAB	RIG	ROE	EGG
Harvest rate (m^3 ha^{-1} a^{-1})	0.7	0.6	0.6	1.0	0.8	5.1
Stem increment (m^3 ha^{-1} a^{-1})	6.0	5.7	3.9	6.2	3.1	5.3
Deposition of N (kg N ha^{-1} a^{-1})	32	26	21	11	16	17
Immobilization (kg N ha^{-1} a^{-1})	7.3	5.8	4.1	5.7	3.4	4.8
N in harvest (kg N ha^{-1} a^{-1})	0.25	0.18	0.19	0.32	0.23	1.45
Nutrient balance (kg N ha^{-1} a^{-1})	1.6	2.3	4.2	14.4	0.3	5.1
Limiting element	P	P	P	P,K	P	P

3. CONCLUSIONS

The case study suggests that acid loads are of ecological relevance in some parts of Switzerland. It has to be noticed that the examinated sites are forests which protect settlements and main traffic lines. The effect of N deposition on alpine forests deserves further attention.

4. ACKNOWLEDGEMENT

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