NITRATE LEACHING NOT ALWAYS A SYMPTOM OF N SATURATION

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NITREX
NITROGEN SATURATION EXPERIMENTS
http://www.wsl.ch/wus/nitrex

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The full value of forests to society

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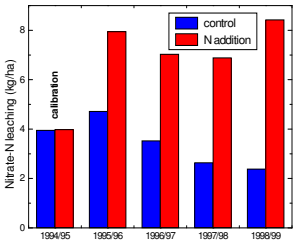
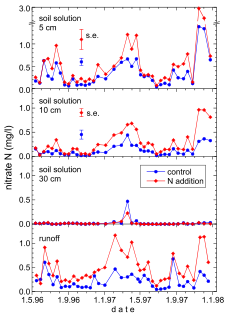
The fact: nitrate leaching

Nitrate leaching from the forested catchments



In spite of relatively moderate deposition rates, nitrate is leached from the control catchment. The addition of NH_4NO_3 more than doubled this nitrate output.

Nitrate N in soil solution and runoff

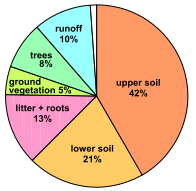


Throughfall and soil solution (from suction plates and cups) were collected in 5 treated and 5 control plots. Nitrate concentrations increased in the solution of the topsoil, but not below 10 cm depth. Nitrate in the runoff water can thus only be explained by preferential and/or near-surface flow.

Argument 5: ^{15}N labelling

The added NH_4NO_3 included a ^{15}N label during the first treatment year. The pulse of $\delta^{15}N$ measured in the runoff nitrate accounted for 10% of the added N.

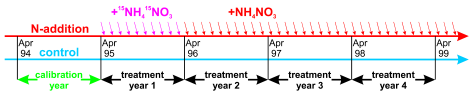
^{15}N partitioning



During the same time, nitrate leaching increased by 3.2 kg N ha^{-1} $year^{-1}$ = 11% of the addition. This indicates that the increased leaching came mainly from the added N, without exchanges with (unlabelled) soil N pools.

The experiment: nitrogen addition

12 kg ha^{-1} $year^{-1}$ bulk inorganic N are deposited in the subalpine forest at Alptal, Switzerland (1200 m altitude, Gleysols, 2300 mm annual precipitation). In a paired-catchment experiment, 27 kg N ha^{-1} $year^{-1}$ (as NH_4NO_3) are added to rain water and sprinkled on a treated plot. The control receives only rain water.



The question: N saturation ?

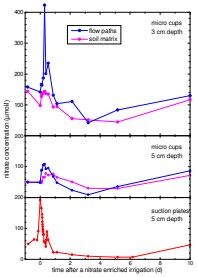
Usually, nitrate leaching from a forest is regarded as a symptom for its eutrophication or N saturation.

Other symptoms of N saturation are, however, not encountered at Alptal:

- spruce needles show a slight N deficiency (1.1% N),
- nitrophilous species are not predominant in the species-rich herb layer,
- no net nitrification can be measured in the soil.

Is this compatible with the N saturation suggested by nitrate leaching ?

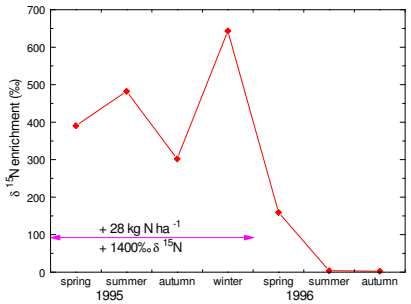
Argument 3: preferential N transformations



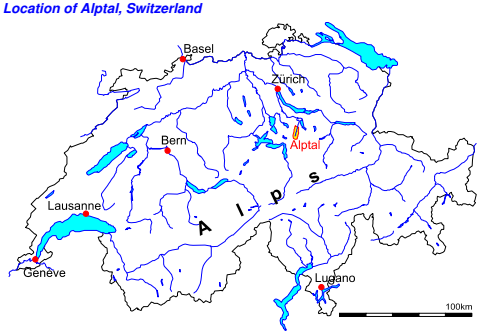
Compared to those in the matrix, micro cups on flow paths have:

- a stronger peak from homogeneously applied nitrate,
- a faster decrease in the next 3 to 4 days (interpreted as denitrification),
- a faster increase afterwards (nitrification upon drying-up),
- similar dynamics as suction plates in immediate vicinity.

^{15}N labelling of nitrate in runoff



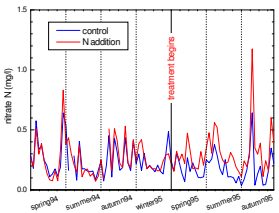
Location of Alptal, Switzerland



Argument 1: response time

Nitrate leaching responded within weeks to the experimentally increased N deposition.

Nitrate leaching at the onset of the treatment



Increased leaching thus already occurred after only 1 kg N ha^{-1} had been added, long before any change in the overall ecosystem N status could be expected.

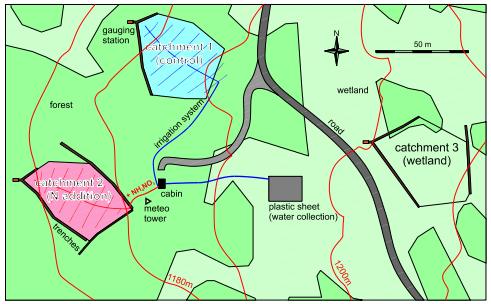
Argument 4: EMMA

To assess the water flow regime, an end member mixing analysis (EMMA) was calculated for a rain event sampled with a higher frequency. Contributions of water sources were estimated based on Ca^{2+}, Cl^-, SO_4^{2-} concentrations and electrical conductivity. It appeared that: (1) pre-event water is similar to the soil-solution of the B horizon; (2) precipitation contributes directly to the flow peaks; (3) the topsoil is the dominating water source towards the end of the event. Most of the soil matrix is thus bypassed during runoff events.

The conclusion

All the obtained data agree in showing the importance of preferential flow for nitrate leaching. Contact of precipitation or snowmelt water with the soil matrix appears to be sufficient for ammonium to be removed by cation exchange (or by chemical reactions with the organic matter), while slower microbial immobilisation of nitrate remains incomplete. Nitrate leaching is therefore hydrologically driven and does not essentially indicate a nitrogen saturation of the ecosystem.

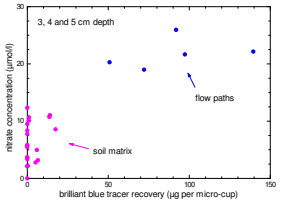
NITREX experimental setup at Alptal (catchments ≈1500 m²)



Argument 2: preferential flow

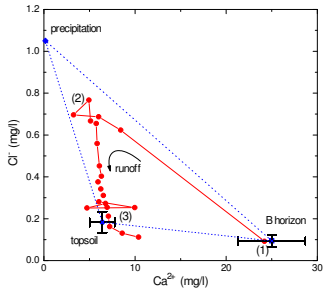
Fifty micro suction cups (12 mm^2 each) were installed in a regular grid in the uppermost 5 cm of the soil.

Nitrate and dye recovery of micro suction cups



Less than half responded to the application of a brilliant blue dye within 24 h. They were considered as being on flow paths, as opposed to those in the soil matrix.

Runoff water compared to 3 sources during a rain event



Measured nitrate concentrations were compared to EMMA predictions. There was a close correlation between them, confirming the analysis.

A further question

The slowly increasing nitrate leaching in the treatment years three and four, however, points to a mechanism with a completely different reaction time than the signal observed already after a few weeks. It may, in this case, be a progressive N saturation. Most of the added N, indeed, remains in the forest soil and can slowly enrich the soil with N, some of it available for micro-organisms and plants. The question remains open if the vegetation (trees, herb layer) is going to show long-term effects from the artificially increased N deposition.