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Validation of VSD+ and Critical Loads for Nutrient N

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3.1 Introduction

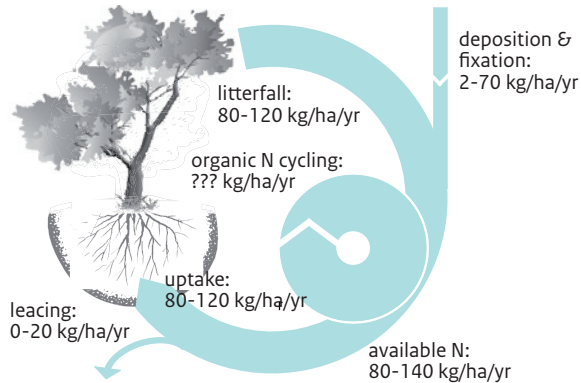
The soil chemistry model VSD+ (Bonten et al. 2009) has been developed from the soil acidification model VSD (Posch and Reinds 2009), to calculate effects of atmospheric deposition on i) nutrient enrichment of the soil and subsequent effects on the vegetation and ii) carbon sequestration in the soil. The reasons for this are the changing objectives regarding the effects of atmospheric deposition on nature areas. Initial objectives were the effects of deposition of sulphur and nitrogen (N) compounds on the acidification of the soil and the effects on forest health and surface water quality. As sulphur deposition has decreased dramatically in most areas in Europe during the last decades, the focus shifted more and more towards the effects of nitrogen deposition on biodiversity (e.g., Hettelingh et al. 2008, Millennium Ecosystem Assessment 2005, EEA 2007), more specifically plant biodiversity, as a higher N deposition generally leads to a lower plant species biodiversity. The increasing awareness of climate change due to greenhouse gas emissions has further lead to the demand to calculate carbon (C) sequestration potentials and the effects of atmospheric deposition on this. To be able to calculate the

effects of N deposition on biodiversity and to include soil carbon sequestration we added an explicit model for organic carbon and nitrogen to the original VSD model, which then became VSD+. This C and N model and the coupling of VSD+ to plant species biodiversity models like Veg (see chapter 4) has been described previously (see Appendix B in Slootweg et al. 2010). In this text we show a first validation of VSD+ results regarding N enrichment in the soil and the potentials of VSD+ to calculate critical loads for nutrient N critical limits.

3.2 Validation

Figure 3.1 shows the N fluxes within a forest ecosystem. The largest fluxes are possibly the internal cycling of N in the soil, i.e. the turnover of soil organic matter and soil microbial biomass. The actual sizes of these fluxes are however hard to measure. Also relatively large is the cycling of N by the vegetation, i.e. litterfall and uptake by the vegetation. Both the N cycling by the vegetation and the soil internal N cycling determine the size of the organic N pool in the soil. A first validation is therefore on these N pools. A second validation is on the leaching of N from the soil. This N leaching is small compared to other N fluxes in the system and is actually the difference of two 'big' numbers: available N and N uptake.

Figure 3.1 Fluxes of N within a forest ecosystem.



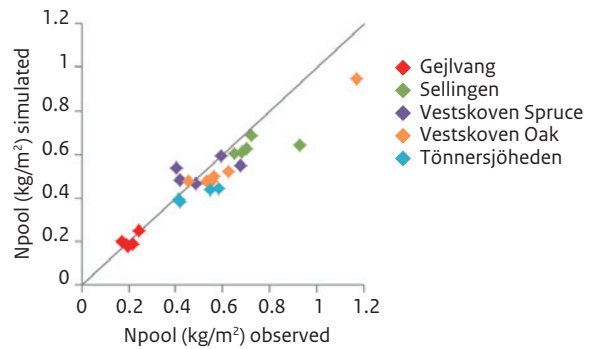
Validation on N pools

Figure 3.2 shows the results on N pools in five chrono-sequences in the Netherlands and southern Scandinavia. Although this is not a true validation because these sites have been used previously in the calibration of VSD+, it is clear that VSD+ can describe changes in N pools with a single parameter set for organic C and N turnover. The figure further shows that changes in organic N pools are small for most sites and that a sound validation requires really long-term datasets.

Validation on N leaching

The calculation of N leaching by VSD+ was tested for two different datasets. First, for a set of 137 Dutch forest sites, for which we used national scale model calculations for N deposition and estimates for vegetation growth and N contents of the vegetation. The second dataset contains two forest sites, one in Solling, Germany (Bonten et al. 2011) and one in the Hardenberg, the Netherlands, with more detailed information. Atmospheric deposition, forest growth and N contents were measured on-site. In both calculations we did not calibrate organic C and N turnover

Figure 3.2 Simulated and observed N pools in the soil for five chrono-sequences.



separately for each site, but we used a single parameter set for organic C and N turnover taken from the calibration on the five chrono-sequences (see above).

Figure 3.3a shows a comparison between observed and calculated N leaching concentrations for the 137 Dutch forest sites. This figure shows that there can be a large deviation between measurements and calculations, although average concentrations seem to correspond. Figure 3.3b shows the frequency distributions of the measured and calculated N concentrations, and these match perfectly. This demonstrates that site-specific N leaching can not be calculated using estimates for N deposition and/or N uptake. As mentioned previously, N leaching is the difference between N availability and N uptake and a small error in one of these can lead to large errors in N leaching. However, average regional scale N leaching can be properly assessed using VSD+.

Figure 3.4 shows the N leaching concentrations for the two forest sites for which more site-specific data are available. The two graphs show that a much better agreement

Figure 3.3 3.3a Simulated and observed N leaching concentrations at 137 Dutch forest sites (left); 3.3b Frequency distributions of observed and simulated N leaching concentrations at these sites (right).

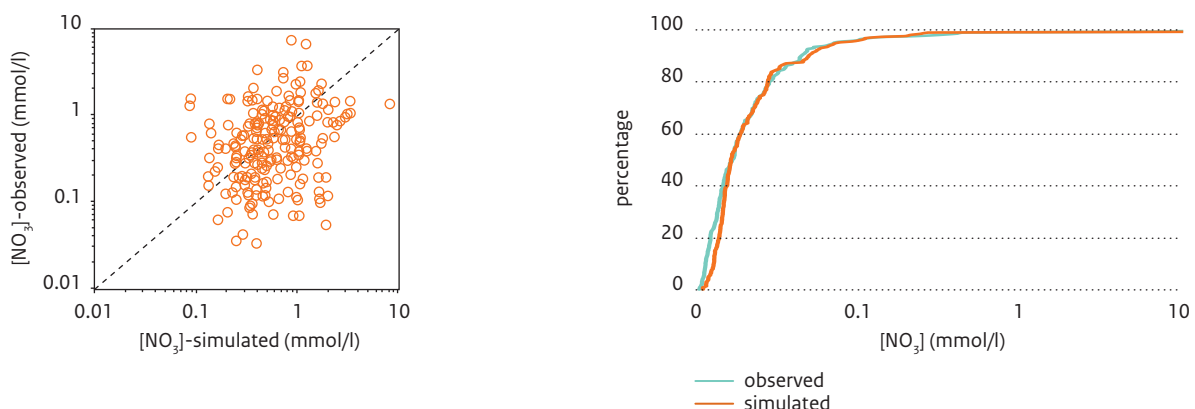
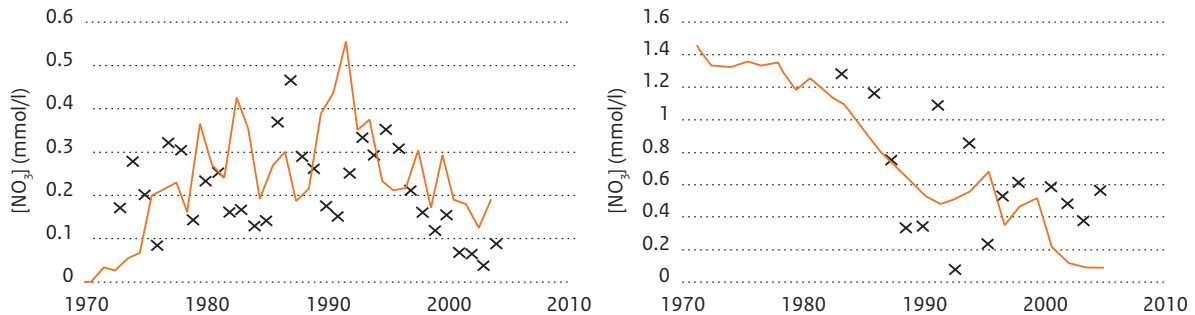


Figure 3.4 Average annual N leaching concentrations at forest in Solling, DE (left) and Hardenberg, NL (right).



between calculations and observations can be achieved using site-specific data on N deposition and N uptake.

is mainly dependent on the NH_3 deposition, because most NO_x will be lost to the atmosphere as N_2 after denitrification.

3.3 Critical loads for nutrient N

The VSD+ model includes the calculation of critical N deposition for criteria of N as a nutrient. Critical loads for N as acidifying compound were already included in VSD. In VSD+ critical loads can be calculated for two different critical limits: i) a maximum N leaching concentrations, and ii) a maximum N availability (defined as the sum of N deposition and N mineralization).

CL for critical N leaching

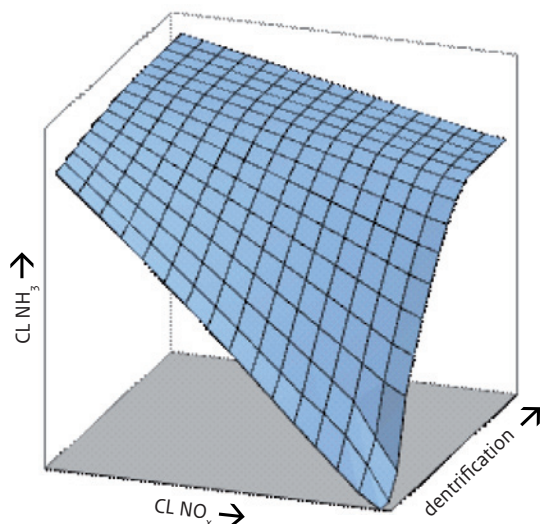
Figure 3.5 shows critical loads of NH_3 and NO_x deposition as a function of denitrification. Denitrification itself is influenced by a number of parameters like moisture, pH, temperature, availability of electron donor. When there is no denitrification all nitrogen deposition that is not taken up will leach. There is no distinction then between NH_3 and NO_x deposition. For high denitrification rates, the leaching

CL for critical N availability

Nitrogen availability has been defined as the sum of N mineralization, N deposition and N fixation. In steady state the N mineralization is equal to the organic N inputs to the soil, i.e. litterfall and fine root turnover. Because of this, critical loads for a critical N availability can be calculated simply as:

$$\text{CL}(\text{N}) = N_{\text{available,crit}} - N_{\text{litterfall}} - N_{\text{root turnover}} - N_{\text{fixation}}$$

Figure 3.5 Critical loads of NO_x and NH_3 for critical N leaching as a function of denitrification.



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