Are German Forest Soils a Source or Sink for reactive Nitrogen? Model-aided Evaluation of Large-Scale Ground-based Observations

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Abstract

The nitrogen dynamics of German forest soils is derived from recurrent National Forest Soil Inventories (NFSI: around years 1990 and 2007) on roughly 1800 points. While observed increases in the upper mineral soil can be explained by an interaction of environmental changes, measured N losses from the deeper mineral soil raised questions and were not confirmed by observations on Intensive Forest Monitoring (IFM) plots. The plot-specific N-budget calculation identifies German forest soils as nitrogen sinks and is consistent with observed N stock changes in the topsoil. Results are discussed in the context of current forest dieback effects on soil N retention.

Keywords: National Forest Soil Inventory, Level II, Monitoring, N budget, nitrate leaching, gaseous emissions

1. Processes explaining measured N stock changes

Forest soils comprise about 32% of the territory of Germany and were assessed across a systematic grid of roughly 1800 points in the National Forest Soil Inventory (NFSI I around the year 1990 and resampled in the years 2006 – 2008 (NFSI II)). Soil nitrogen stocks of the forested area during NFSI II amounted to 72 Mt (6.2 t/ha). In the depth range from organic layer to 30 cm of the mineral soil average (median) stock changes of +6.2 kg/ha/a were observed between NFSI I and II. We explain the observed dynamics of soil nitrogen as largely driven by slowly decreasing atmospheric deposition, still increasing tree nutrition far beyond demand, liming activities, decreasing soil acidity, increasing activity of decomposition, and changes in climatic conditions. A comparison to observations from 47 German IFM plots (ICP Forests Level II) supports this interpretation – but it also reveals substantial uncertainties in the measurements from the subsoil (30 – 90 cm depth) that are characteristic for measurements of soil nitrogen and strongly affect the interpretation of soils as sources or sinks for nitrogen.

2. Elements of modelled forest soil N budget

In order to identify possible sources or sinks for nitrogen stock changes of German forest soils, a plot-specific nitrogen

budget calculation was performed, comprising assessments of atmospheric deposition, gaseous emissions, nitrate leaching, and N uptake into the growing biomass according to three different harvest scenarios for all NFSI plots

3. The majority of forest soils are still N sinks

The positive total soil N budget between NFSI I and NFSI II (+2.9 to +7.0 kg/ha/a, depending on harvest intensity, Fig. 1) reveals that German forest soils in general act as N sinks, though N losses occur on one third of the plots. The N retention from N budget calculations confirms the magnitude of observed stock changes in the topsoil. N stock changes in the subsoil seem to be very uncertain. Since there were only marginal changes in soil organic carbon of these deeper layers, it may be concluded that organic matter including soil organic N remained stable. This conclusion was also confirmed by spot checks on reanalysed soil samples.

4. N deposition poses forest ecosystems at risk

The NFSI shows that German forest ecosystems are still able to retain reactive nitrogen and mostly continue to accumulate nitrogen stocks in soil organic matter and biomass, even though much higher amounts than needed are entering the system via atmospheric deposition. However, the nitrogen surplus leads to nutrient imbalances and higher water requirements of trees, which poses the whole ecosystem at risk under drought stress and climate-induced biotic stress. The most recent forest dieback of the last two summers shows a high vulnerability of above and belowground nitrogen storage under conditions of climate change. Forest dieback induces severe economic and ecological losses: Nitrogen released from decomposition cannot be assimilated by dead forest stands and will most probably be leached to groundwater aquifers or surface waters (thereby further deteriorating nutrient availability by base cation export from soils) or emitted in gaseous form. Therefore, further reductions of N deposition are getting increasingly important to stabilize forests and their nitrogen pool under manifesting climate change.

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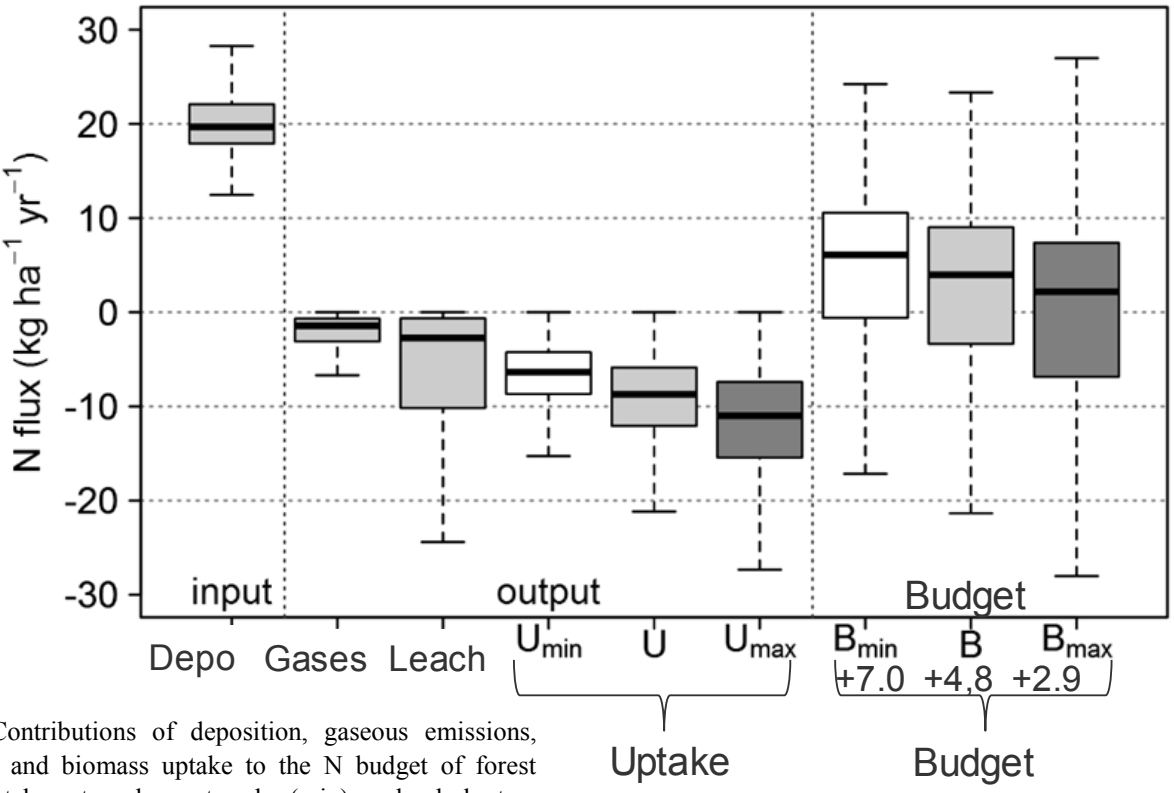

Fig 1: Contributions of deposition, gaseous emissions, leaching, and biomass uptake to the N budget of forest soils. Uptake: stem harvest only (min) and whole tree harvest (max) scenarios