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Plant diversity effects on leaching of nitrate, ammonium, and dissolved organic nitrogen from an experimental grassland

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Leaching of nitrogen (N) from soil represents a resource loss and, in particular leaching of nitrate, can threaten drinking water quality. As plant diversity leads to a more exhaustive resource use, we investigated the effects of plant species richness, functional group richness, and the presence of specific functional groups on nitrate, ammonium, dissolved organic N (DON), and total dissolved N (TDN) leaching from an experimental grassland in the first 4 years after conversion from fertilized arable land to unfertilized grassland.

The experiment is located in Jena, Germany, and consists of 82 plots with 1, 2, 4, 8, 16, or 60 plant species and 1-4 functional groups (legumes, grasses, non-leguminous tall herbs, non-leguminous small herbs). Nitrate, ammonium, and TDN concentrations in soil solution in the 0-0.3 m soil layer were measured every second week during 4 years on 62 plots and DON concentrations were calculated as difference between TDN and inorganic N. Missing concentrations in soil solution were estimated using a Bayesian statistical model. Downward water fluxes (DF) per plot from the 0-0.3 m soil layer were simulated in weekly resolution with a water balance model in connection with a Bayesian model for simulating missing soil water content measurements. To obtain annual nitrate, ammonium, and DON leaching from the 0-0.3 m soil layer per plot, we multiplied the respective concentrations in soil solution with DF and aggregated the data to annual sums. TDN leaching resulted from summation of nitrate, ammonium, and DON leaching.

DON leaching contributed most to TDN leaching, particularly in plots without legumes. Dissolved inorganic N leaching in this grassland was dominated by nitrate. The amount of annual ammonium leaching was small and little influenced by plant diversity. Species richness affected DON leaching only in the fourth and last investigated year, possibly because of a delayed soil biota effect that increased microbial transformation of organic N to inorganic N in species-rich mixtures or because of complementary resource use of amino-acid DON of species-rich mixtures. Nitrate and TDN leaching generally decreased with increasing species richness likely because of more exhaustive resource use of more diverse plant mixtures. Functional group richness did not have a significant effect on nitrate, ammonium, DON, and TDN leaching. Legumes increased and grasses decreased nitrate, DON, and TDN leaching because of their N-fixing ability and their extensive rooting system, respectively. TDN leaching was highest in the first year after conversion from arable to grassland which can be related to former fertilization. Quantitative differences in nitrate leaching between plant diversity treatments were also highest in the first year after conversion. However, the percentage reduction of nitrate leaching by species richness, the presence of grasses, or the presence of small herbs increased with time since land-use change possibly because of a strengthening of diversity effects with time. We conclude that especially shortly after land-use change from fertilized arable land to unfertilized grassland, N leaching, in particular nitrate leaching, can be reduced considerably if highly diverse mixtures without legumes are established.