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Modeling the global carbon-nitrogen-water cycle in natural systems, the effect of global change on nitrogen leaching

Karin Rebel (1), Maarten Braakhekke (2), Stefan Dekker (1,3), and Martin Wassen (1)

(1) Utrecht University, Copernicus Institute of Sustainable Development, Environmental Sciences, Utrecht, Netherlands (k.t.rebel@uu.nl), (2) The Netherlands Environmental Assessment Agency, Netherlands, (3) Faculty of Management, Science & Technology, Open University, Heerlen, Netherlands

Over the last decades, nitrogen (N) emissions have increased strongly due to increased industrial activity, transport, and fertilization. As N is an important resource for plant growth, this increased N availability can lead to enhanced productivity. However, too much N can cause N saturation as well, leading to a decline in productivity and increased N leaching, since several forms of N are mobile. Combined with other recent global changes, including CO_2 fertilization, and changes in climate, the net effect on ecosystem productivity and nitrogen leaching needs to be analysed.

We used the global vegetation model LPJ-GUESS to study N cycling in natural ecosystems under global change. We simuated the effects of N deposition, climate, and CO_2 on C sequestration and N leaching, using a factorial simulation experiment. We found that N deposition is globally the strongest driver of N leaching—rising N deposition by itself causes an increase in leaching of 88% by 1997–2006 relative to pre-industrial conditions. Changing climate led globally to a 31% increase in N leaching, with spatially variable size and direction of change. Rising atmospheric CO_2 generally caused decreased N leaching (33% globally), with strongest effects in regions with high productivity and N availability, due to the CO_2-fertilization effect. Including N deposition, climate as well as increased CO_2 concentration resulted in a rise of N leaching by 73% with strongest increases in regions where N deposition rates are highest.

Ecosystem N status (quantified as the reduction of vegetation productivity due to N limitation) shows large spatial variability, which is more strongly related to vegetation type than N input. Grasslands and high-latitude ecosystems show strong N-limitation, while temperate forests are closer to N-saturation. From here we conclude that ecosystem N-status, along with fire frequency, has a large effect on the relationship between N-input and N-leaching per biome.