N-losses from Austrian forest ecosystems. A modelling approach using climate change and N-deposition scenarios

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Rationale:

In this study, we are exploring possible future changes in forest N cycling and associated N-losses until 2080 as influenced by different N deposition and climate change scenarios.

Introduction:

The net effect of N deposition and climate change on N losses from soils remain largely unknown. In forests, large amounts of N are related to N - gas production by soil microbes. The gases nitric oxide (NO), nitrous oxide (N_2O) and molecular nitrogen (N_2) are produced by microbial processes in soils and are perhaps the least well-understood components of the N cycle. Large uncertainty in N balances i.e. "missing N" has led to increased interest in soil N-gas production as an important N loss component.

Material and methods:

Long-term data from 8 forest ecosystem monitoring stations in Austria (ICP forests; Tab. 1) were used to calibrate the process oriented ecosystem model LandscapeDNDC with detailed plant and soil process descriptions. In the model all forests were "planted " in 1950 to guarantee comparable results.

LandscapeDNDC is a model designed to simulate ecosystem C and N turnover and losses including associated changes in the C and N stocks of soils for forest, arables, and grasslands at local and regional level. LandscapeDNDC was evaluated to represent the water, C and N cycling of various forest ecosystems under different weather and soil conditions and used successfully to simulate nitrate leaching for forest sites. Tree growth, DBH and height measured since 1996 at the sites was used for validation of the model. Additionally year round in-situ measurements (since 2001) at KL09, AK22 (and ZB00) of N_2O and NO were compared with modelled baseline fluxes.

Climate scenarios: A1B, A2X, and B1X scenarios were based on the global circulation model ECHAM5. The A1B scenario was also available from the HadCM3 model (A1B_H).

Deposition scenarios: Daily total dry and wet N deposition for 1950-2080 was derived from retrospective modelling and considered three future scenarios: the current legislation (CLE) scenario with revised Gothenburg Protocol emissions and the technically maximum feasible emission reduction scenario (MFR). A baseline scenario was defined by the 2010 deposition values with no further reductions (B10).

Table 1: Site characteristics of the 8 study sites. ([1] all horizons; [2] mean value in mineral soil ($CaCL_2$)).

Site code	Site name	Altitude [m.asl]	Air temp. [°C]	Precip. [mm y^{-1}]	N_{dep} [kg N ha^{-1} y^{-1}]	Tree species [1/10]	Soil type	Humus type	soil C:N[1]	soil pH[2]
AK22	Achenkirch	896	7	1454	15.5	PIAB (9); FASY (1)	shallow Chromic Cambisols and Rendzic Leptosols	mull	17	6.5
JO17	Jochberg	1050	7.3	1200	6.6	PIAB (10)	Eutric Stagnic Episkeletic Fluvisol	moder (mull)	13.9	4.6
KL09	Klausenleopoldsdorf	510	8.7	689	12.5	FASY (10)	Endostagnic Endoskeletic Luvisol	mull	13.2	4
MG15	Mürzzuschlag	715	7.6	1148	9.4	PIAB (10)	Eutric Calcaric Endoskeletic Cambisol	moder	25.6	6.9
MO11	Mondsee	860	9.7	1568	16	PIAB (10)	Hyperdystric Endoskeletic Cambisol	moder	20.4	3.6
MU16	Murau	1540	4.2	1155	4.2	PIAB (8); LADE (2)	Hyperdystric Endoskeletic Cambisol	moder	23.7	3.7
UP02	Unterpullendorf	290	10.8	631	17.8	QUEP (5); QUEC (5)	Eutric Stagnic Vertic Cambisol	mull	12.8	3.9
ZB00	Zöbelboden IP1	900	8	1565	27.9	PIAB (7.5); FASY (2.5)	shallow Chromic Cambisols and Rendzic Leptosols	mull (moder)	16.8	6.7

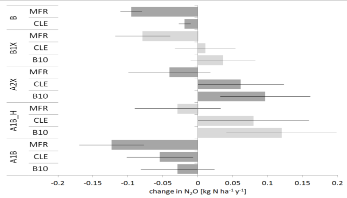

Fig. 1. General trend of N_2O changes (baseline – scenario) in the future at the site AK22.

Table 2: Mean annual N losses at baseline conditions.

site	NO_3 leach	NO	N_2O	N_2	NH_3	**N loss**
	kg N ha^{-1} yr^{-1}					
AK22	9.8	0.1	0.5	0.4	0.66	**11.4**
JO17	0.2	0.1	0.3	0.6	0.01	**1.2**
KL09	0.5	0.1	0.7	3.3	0.03	**4.6**
MG15	0.6	0.1	0.3	1.8	0.35	**3.1**
MO11	7.2	0.3	0.5	0.1	0.02	**8.0**
MU16	1.5	1.3	0.1	0.0	0.00	**2.9**
UP02	4.7	0.2	0.6	3.4	0.03	**8.9**
ZB00	19.4	0.2	0.7	1.1	0.13	**21.5**

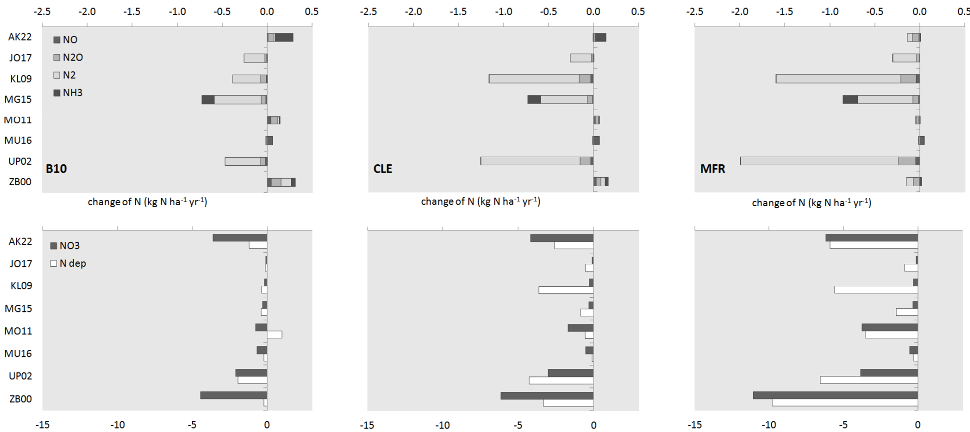

Fig. 2: Mean future (2060-2080) changes in soil NO, N_2O, N_2 and NH_3 fluxes (upper part), N deposition and NO_3 leaching (lower part) at the 8 forest sites. Values for the N-deposition scenarios (B10, CLE, MFR) include results from all climate scenarios and show the difference to the baseline scenario.

Results:

- At baseline conditions (Tab. 2) N_2O fluxes range from 0.7 to 0.1 kg N ha^{-1} yr^{-1} at ZB00 and MU16, respectively. Highest NO emissions were calculated at the acidic soil at MU16. N_2 losses were highest at the deciduous forests KL09 and UP02, whereas highest NO_3 leaching was found at shallow soils with high N-input and high annual precipitation (AK22, ZB00).
- A1B_H model and A2X scenarios predicted higher values (Fig. 1).
- At climate change scenarios with no future N deposition reductions (B10) gaseous N losses increased at high N input and high precipitation sites ZB00, AK22 and MO11 (Fig. 2).
- Sites with low precipitation but high N-input (UP02, KL09) or sites with high precipitation but low N-input (MG15, JO17) had the highest potential to decrease soil N gases.
- The two deciduous forests with low precipitation but high N-input (UP02, KL09) have the highest potential to decrease N emissions under CLE and MFR scenarios.
- At all sites a reduction of N emissions can only be achieved at the MFR scenario at all sites.

Lessons learned:

In future (2060-2080) N-losses from forest soils are mainly controlled by actual N-deposition. High N input sites will still emit more N to the atmosphere compared to sites with low N input. Deciduous forests receiving lower precipitation have the highest potential to reduce N-emissions in future. If no further reduction in N input occurs climate change will lead to higher N emissions. Only at MFR scenarios N losses to the atmosphere and to the groundwater will be reduced significantly at all sites. N-losses will possibly alter during the forest succession stages and will be investigated in a further step.

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