

The greenhouse gas exchange responses to forest change in Europe

Gundersen P.¹, Alberti G.², Brüggeman N.^{3,9}, Christiansen J.R.¹, Gasche R.³, Kitzler B.⁴, Klemetsson L.⁵, Lobo do Vale R.⁶, Moldan F.⁷, Rütting T.⁵, Weslien P.⁵, Schleppi P.⁸

1) *Forest & Landscape, University of Copenhagen, Denmark*

2) *CNR-IBIMET, Italy*

3) *Karlsruhe Institute of Technology, Institute of Meteorology and Climate Research, Atmospheric Environmental Research (IMK-IFU), Kreuzeckbahnstraße. 19, D-82467 Garmisch-Partenkirchen, Germany*

4) *Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW), Austria*

5) *Department of Plant and Environmental Sciences, University of Gothenburg, Sweden*

6) *Universidade Técnica de Lisboa, Portugal*

7) *Swedish Environmental Research Institute, Sweden*

8) *WSL Birmensdorf, Switzerland*

9) *Present address: Forschungszentrum Jülich GmbH, Institute of Bio- and Geosciences, Agrosphere (IBG-3), D-52425 Jülich, Germany*

pgu@life.ku.dk

Rationale

Currently, the forested area in Europe is increasing annually by 0.3% and is expected to continue to increase. Thus, the importance of forests for the European greenhouse gas (GHG) balance will increase. However, current and future management of forests, such as replacement of coniferous with broadleaf species, restoration of natural hydrology, altered management strategies and intensity towards use of wood for bioenergy and to conserve and foster biodiversity, will also alter the GHG balance of forests. External drivers, such as climate change (i.e. temperature increase and precipitation changes) and air pollution with N compounds, interact with the altered forest management to shape forests changes in Europe with currently unpredictable impacts on the forest greenhouse gas (GHG) balance. To gain new insight into the magnitude of changes of GHG fluxes we primarily studied the response of N₂O and CH₄ but also of CO₂ exchange from coniferous and broadleaf forest soils at twelve manipulation or natural gradient sites across Europe.

Approach

This is the first study to undertake a quantitative assessment and comparison of the expected future changes in GHG dynamics and balance for a wide range of European forests. The studies were conceived to manipulate mainly the external drivers. The types of manipulations of external drives included changes in N deposition (4 sites), climate (temperature at 1 site and precipitation at 3 sites), hydrological condition (3 sites), harvest intensity (1 site), wood ash addition (1 site) tree species (1 site) and afforestation of arable land (2 sites). Forest sites ranged from Sweden to Italy and covered both coniferous and broadleaf forests.

Results

At all sites soil hydrology dynamics was found to control the temporal and spatial variability of N₂O fluxes (Fig. 1A). Increasing soil temperatures also lead to elevated N₂O emissions by up to 73% compared to non-warmed plots (Fig. 1B). Generally, the emissions of N₂O were positively related to mineral soil N status (Fig. 1C), but responses of N₂O fluxes to N addition were negligible at a C:N ratio > 25 in the mineral soil. For organic forest soils soil pH and groundwater dynamics were found to be most important for N₂O and CH₄ dynamics. The main factor controlling CH₄ emission was soil moisture with hydrological manipulations affecting emissions the most (Fig. 1A). The uptake rate of CH₄ showed a negative relationship with soil water content and inhibition of CH₄ oxidation by

increased N levels in the soil was indicated. Increased soil temperatures decreased CH_4 uptake rates by 10-20% compared to non-warmed plots (Fig. 1B).

The changes of N_2O and CH_4 fluxes from external drivers on undisturbed forests are expected to occur on a decadal scale. However, management practices such as clear cuts can have immediate effects on GHG fluxes through changes in soil hydrology, soil temperature and N status. In aggrading forests fluxes of N_2O and CH_4 are of little importance for the GHG balance since much CO_2 is sequestered in biomass, but as the forest mature and soil drivers (N status, pH etc.) favour GHG exchange, the importance of N_2O and CH_4 for the forest GHG balance increase. The synthesis (Fig. 2A and B) of forest change on N_2O and CH_4 fluxes across NitroEurope forest manipulation sites will provide us with new knowledge on the impact of forest ecosystems on both the process level in the soil as well as long term implications of forest change on the GHG balance of Europe.

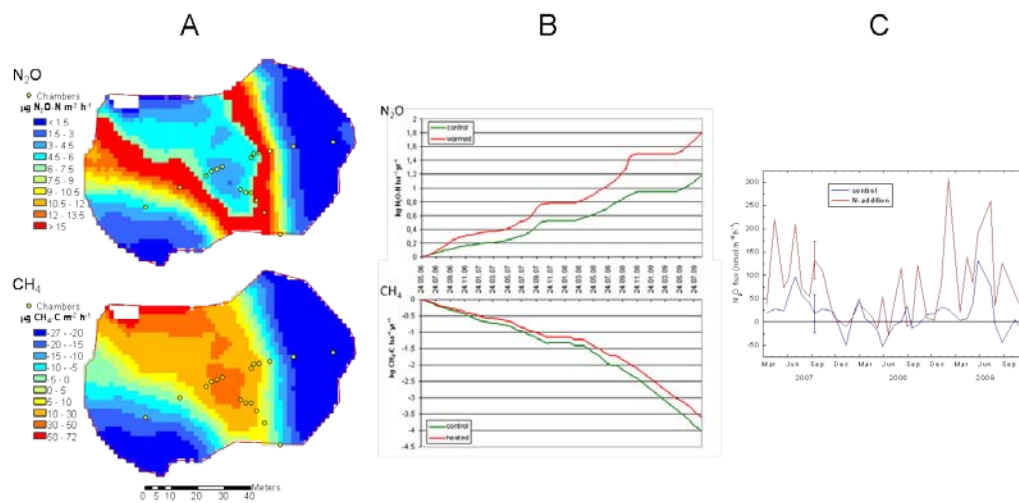


Fig. 1. A) Spatial distribution of N_2O and CH_4 as controlled by hydrological conditions in a small beech forest catchment at Strødam (Denmark), B) Effects of soil warming by 4°C at Achenkirchen, Austria. The graph shows accumulated fluxes of N_2O (kg $\text{N}_2\text{O-N ha}^{-1} \text{ y}^{-1}$) and CH_4 (kg $\text{CH}_4\text{-C ha}^{-1} \text{ y}^{-1}$) in the period 2006 – 2009, C) Effects of long-term nitrogen addition on N_2O fluxes from the soil at Alptal, Switzerland

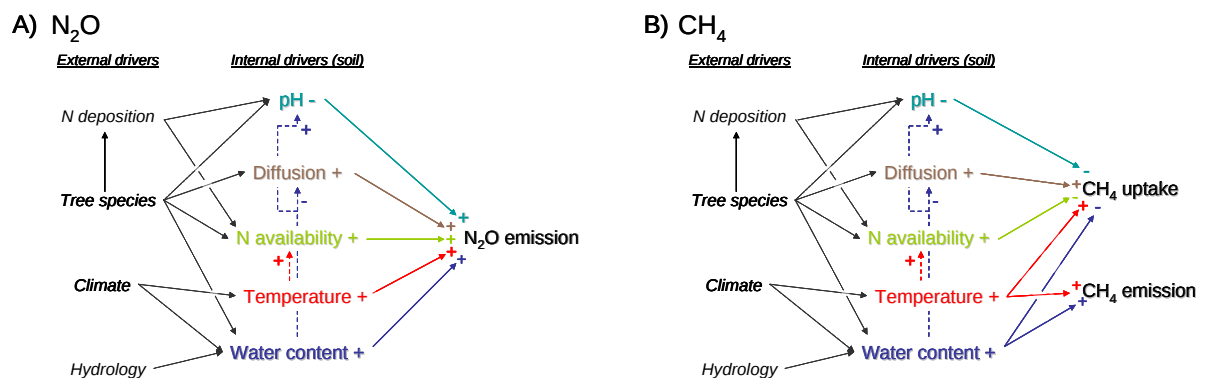


Fig. 2. The synthesis of the effect of forest change on A) N_2O emission and B) CH_4 uptake and emission. External drivers in unmanaged or undamaged forests act on a decadal time scale, consistently changing the state of the soil environment in the forest ecosystem. Arrows with + or - signs at the end mean increase or decrease, respectively, of the outcome in question.