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Climate change impairs processes of soil and plant N cycling in European beech forests on marginal soil

Javier Tejedor (1), Rainer Gasche (1), Silvia Gschwendtner (4), Martin Leberecht (5), Carolin Bimüller (3), Ingrid Kögel-Knabner (3), Andrea Pole (5), Michael Schloter (4), Heinz Rennenberg (2), Judy Simon (2), Marc Hanewinkel (6), Andri Baltensweiler (6), Silvija Bilela (2), Michael Dannenmann (1,2)

(1) Institute for Meteorology and Climate Research, Atmospheric Environmental Research (IMK-IFU), Karlsuhe Institute of Technology (KIT), Garmisch-Partenkirchen, Germany, (4) Department for Terrestrial Ecogenetics, Helmholtz Zentrum München, Oberschleissheim, Germany, (5) Abteilung Forstbotanik und Baumphysiologie, Büsgen-Institut, Büsgenweg 2, Georg-August Universität Göttingen, 37077 Göttingen, Germany, (3) Lehrstuhl für Bodenkunde, Department für Ökologie und Ökosystemmanagement, Wissenschaftszentrum Weihenstephan. Technische Universität München, Freising-Weihenstephan, Germany, (2) Institute of Forest Botany and Tree Physiology, Chair of Tree Physiology, University of Freiburg, Freiburg, Germany, (6) Research Unit Forest Resources and Management, Swiss Federal Research Institute WSL, Zuercherstrasse 111, CH-8903 Birmensdorf, Switzerland

Beech forests of Central Europe are covering large areas with marginal calcareous soils, but provide important ecological services and represent a significant economical value. The vulnerability of these ecosystems to projected climate conditions (higher temperatures, increase of extreme drought and precipitation events) is currently unclear. Here we present comprehensive data on the influence of climate change conditions on ecosystem performance, considering soil nitrogen biogeochemistry, soil microbiology, mycorrhiza ecology and plant physiology. We simultaneously quantified major plant and soil gross N turnover processes by homogenous triple 15N isotope labeling of intact beech natural regeneration-soil-microbe systems. This isotope approach was combined with a space for time climate change experiment, i.e. we transferred intact beech seedling-soil-microbe mesocosms from a slope with N-exposure (representing present day climate conditions) to a slope with S exposure (serving as a warmer and drier model climate for future conditions). Transfers within N slope served as controls. After an equilibration period of 1 year, three isotope labeling/harvest cycles were performed.

Reduced soil water content resulted in a persistent decline of ammonia oxidizing bacteria in soil (AOB). Consequently, we found a massive five-fold reduction of gross nitrification in the climate change treatment and a subsequent strong decline in soil nitrate concentrations as well as nitrate uptake by microorganisms and beech. Because nitrate was the major nutrient for beech in this forest type with little importance of ammonium and amino acids, this resulted in a strongly reduced performance of beech natural regeneration with reduced N content, N metabolite concentrations and plant biomass. These findings provided an explanation for a large-scale decline of distribution of beech forests on calcareous soils in Europe by almost 80% until 2080 predicted by statistical modeling. Hence, we question the sustainability of such forests under projected climate change conditions, but also discuss potential mitigation and adaptation options.

Important comment: The topic of this abstract is subject to a press embargo, because it is in review at a Nature Journal