Nitrous Oxide Production in Agricultural Soil
Linking Biogeochemical Pathways and Drivers

Philipp Schleusner
Institutionen för geovetenskaper
Naturvetenskapliga fakulteten

Akademisk avhandling för filosofie doktorsexamen i naturegeografi, som med tillstånd från Naturvetenskapliga fakulteten kommer att offentligt försvaras fredagen den 1 juni 2018 kl. 10 i Hörsalen, institutionen för geovetenskaper, Guldhedsgatan 5C, Göteborg.

Opponent: Dr. Christina Biasi,
Department of Environmental and Biological Sciences
University of Eastern Finland, Kuopio, Finland

ISBN: 978-91-7833-053-9 (Print)
ISBN: 978-91-7833-054-6 (PDF)
Tillgänglig via http://hdl.handle.net/2077/56067
Abstract

Nitrous oxide (N₂O) is a long-lasting and potent greenhouse gas responsible for depletion of stratospheric ozone. As the atmospheric N₂O concentration reaches all-time highs, emission variability in space and time still leaves unresolved questions. The aim of this thesis is to improve our understanding of the origin of N₂O and its main drivers from the largest anthropogenic source: agricultural soil. Therefore, we investigated agricultural soil from long-term trial field sites in the laboratory and used ¹⁵N-enriched tracers in two main approaches: partitioning of the sources of N₂O production and quantification of the gross rates of microbial processes competing for ammonium (NH₄⁺) and nitrate (NO₃⁻).

The varying relative contribution of NH₄⁺, NO₃⁻ and organic nitrogen (Norg) to N₂O emission highlights the influence of site-specific factors apart from the field management. Without fertilizer, Norg was the dominant N₂O source related to high carbon (C) contents and C:N ratios. High N₂O emissions were caused by increasing contributions of nitrification and denitrification, which was drastically stimulated by mineral nitrogen (N) fertilizer. In addition, N fertilizer application more than doubled N₂O production from native non-fertilizer N compounds, which provides evidence for primed N₂O production. By using the Nitrace model, we quantified gross rates of N cycle processes that compete for substrates and regulate N₂O production. In the long term, cropping systems can shift the balance between denitrification and dissimilatory nitrate reduction to ammonium (DNRA), which determines the fate of NO₃⁻ in soil. A perennial cropping system that maintains high SOM contents and C/NO₃⁻ ratios has shaped the microbial community of dissimilatory nitrate reducers leading to higher N retention by DNRA and lower N₂O emissions. By applying selective inhibitors, we were able to quantify the specific activity of archaeal and bacterial nitrifiers competing for NH₄⁺. While both can coexist and be equally active in agricultural soil with low N supply, bacteria outcompeted archaea with increasing NH₄⁺ concentration, which can be responsible for higher N₂O emissions as well.

This thesis illustrates how human action drives N₂O emission from agricultural soil in a variety of ways since field management affects N cycle processes in the short- and long-term. While N fertilizer application strongly stimulates N₂O production from added- and native N sources, long-term field management can change the soil properties, which shifts the abundance of microbial communities and thereby alters the N cycle processes responsible for N₂O production.

Keywords

Nitrogen, field management, fertilizer, ¹⁵N-tracing, ammonium, nitrate, soil organic matter, priming, denitrification, nitrate ammonification, DNRA, ammonia oxidation, bacteria, archaea