Equal yield-scaled and lower area-scaled nitrous oxide emissions in organically managed soils

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Abstract

Despite the increase in organic cropland, knowledge on the impact of organic farming on soil-derived nitrous oxide (N_2O) and methane (CH_4) emissions is rather limited. To improve the knowledge base, N_2O and CH_4 fluxes were investigated in a 571 day lasting cropping sequence in the "DOK" field trial. Two organic and two non-organic farming systems and an unfertilized control were chosen. For the whole monitoring, the two organic systems combined emitted 40% less N_2O than the two non-organic ones cumulated on area-scale. Yield-scaled cumulated N_2O emissions were nearly 10% lower for the organic systems combined, despite the yield gap of 27%. We found that besides N input, management induced soil quality properties drive differences in N_2O emissions between farming systems as well. This supports the effort to invest in soil quality by ecological intensification not only to lower the environmental burden of agriculture but also to mitigate greenhouse gases.

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Introduction

There is a weak knowledge basis regarding greenhouse gas (GHG) fluxes in organically managed soils. Based on the evaluation of 18 farming system studies Skinner et al. (2014) determined lower area-scaled nitrous oxide emissions and higher methane uptake in organically compared to conventionally managed soils. Related to crop yield it turned out that organically managed soils emitted more N_2O than conventional based on the evaluation of 7 comparative studies. In this study, we aim to show evidence that ecological intensification through organic farming does not necessarily lead to higher yield-scaled nitrous oxide emission in soil. Therefore we conducted GHG flux measurements in conventional and non-fertilized farming systems under the same crop rotations in the DOK long-term trial in Therwil/CH, one of the oldest and best characterized farming system trials, worldwide.

Material and methods

GHG flux measurements and accompanying soil and agronomic analyses were conducted in the DOK Farming Systems Trial established in 1978 in Therwil, CH. The GHG monitoring was performed with the closed chamber method based on weekly gas samplings over the cropping sequence: grass-clover/maize/green manure. The 571 day lasting monitoring period encompassed the four farming systems – two organic ones, bio-dynamic, BIODYN (composted manure and slurry) and bioorganic, BIOORG (rotted manure and slurry); a conventional one (with staple manure and mineral fertiliser) CONFYM - that all are cultivated in a fully (1.4 livestock units), and

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the second conventional one (exclusively mineral fertilisation) CONMIN. An unfertilised control, NOFERT, complemented the comparison.

Results

The GHG flux measurements within this monitoring campaign enabled a worldwide unique dataset over a time period of 571 days. For all investigated farming systems the lowest N_2O emissions were determined during the grass-clover phase and the highest during the maize period, when the grass-clover ley was ploughed followed by soil preparation, maize seeding and fertilization. Over the whole observation period the cumulated mean N_2O emissions ranged from 3.73 (BIODYN) to 8.21 kg N_2O-N ha^{-1} (CONFYM). We found a farming systems effect, showing that the area-scaled N_2O emissions of the two organic systems (BIODYN and BIOORG) were lower than the emissions from the two conventional systems CONFYM and CONMIN. Also during the 117 days lasting maize cropping phase, the same tendency was observed, lowest emissions from the organic systems. Unexpected high N_2O emissions were determined for the unfertilized system NOFERT. There the emissions of 4.19 kg N_2O-N ha^{-1} were as high as from the fertilized systems BIORG, CONFYM and CONMIN.

Equal yield-scaled N2O emissions between the two organic and two conventional systems were found for maize for which we have a complete data recording. There the highest values were determined in NOFERT and the by far lowest yield-scaled N_2O emissions were observed in BIODYN.

Discussion

In accordance to the meta-study by Skinner et al. (2014) we found the lowest area-scaled N_2O emissions in the two organically managed systems. This can be explained by the lower N inputs applied to grass-clover and maize. The yield-scaled N_2O emissions revealed a different picture. Skinner et al. (2014) reported a higher yield-scaled N_2O emission for organic arable systems based on the evaluation of 7 studies. Our own measurements in the DOK trial, how-ever, showed no difference in the yield-scaled emissions between organic and conventional farming systems. This might be due to the fact that the 7 studies included in the meta-study by Skinner et al. (2014) showed a larger yield gap between organic and conventional cropping systems.

Unexpected and interesting results were obtained by including the NOFERT system in the monitoring campaign. There we found relatively high area-scaled and the highest yield-scaled N_2O emission and a lack of CH_4 uptake despite of any fertiliser N inputs. The rationale behind is because of mineralisation of the grass-clover N and loss of soil organic matter. This goes along with an earlier meta-study from the US, showing that historical intensification in agriculture contributed to GHG mitigation, whereas zero fertilisation cannot be considered as a mitigation option (Burney et al., 2010). Remarkable as well are the surprisingly low N_2O emissions in the BIODYN system of the DOK. Investigation of the reasons is ongoing; the kind of applied manure, that is composted as well as the denitrifier communities are in the focus.

References

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