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Soil organic carbon dynamics and non-CO_2 gas fluxes from agricultural soils under organic and non-organic management - results of two meta-studies

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It is anticipated that organic farming systems provide benefits concerning soil conservation and climate protection. Therefore, meta-studies on soil organic carbon (SOC) and soil-derived greenhouse (GHG) fluxes, respectively, were conducted to proof this assumption. Datasets from 74 studies from pair wise comparisons of organic versus non-organic farming systems were subjected to meta-analysis to identify differences in soil organic carbon (SOC). We found significant differences and higher values for organically farmed soils of 0.18±0.06 % points (mean±95% confidence interval) for SOC concentrations, 3.50±1.08 Mg C ha-1 for stocks, and 0.45±0.21 Mg C ha^{-1} a^{-1} for sequestration rates compared to non-organic management. Meta-regression did not deliver clear results on drivers, but differences in external C inputs and crop rotations seemed important. Restricting the analysis to zero net input organic systems, i.e. without nutrient inputs from outside the system, and retaining only the datasets with highest data quality (measured soil bulk densities and external C and N inputs), the mean difference in SOC stocks between the farming systems was still significant (1.98±1.50 Mg C ha^{-1}), while the difference in sequestration rates became insignificant (0.07±0.08 Mg C ha^{-1} a^{-1}). The SOC dataset mainly covers top soil and temperate zones, while only few data from tropical regions and sub soil horizons exist.

For the second meta-study measured soil-derived nitrous oxide and methane flux data from soils under organic and non-organic management from 19 farming system comparisons were analysed. Based on 12 studies that cover annual measurements, it appeared with a high significance that area-scaled nitrous oxide emissions from organically managed soils are 492±160 kg CO_2 eq. ha^{-1} a^{-1} lower than from non-organically managed soils. For arable soils the difference amounts to 497±162 kg CO_2 eq. ha^{-1} a^{-1}. However, yield-scaled nitrous oxide emissions are higher by 41±34 kg CO_2 eq. t^{-1} DM under organic management (arable and use). To equalize this mean difference in yield-scaled nitrous oxide emissions between both farming systems, the yield gap has to be less than 17%. Emissions from conventionally managed soils seemed to be influenced mainly by total N inputs, whereas for organically managed soils other variables such as soil characteristics seemed to be more important. This can be explained by the higher bioavailability of the synthetic N fertilisers in non-organic farming systems while the necessary mineralisation of the N sources under organic management leads to lower and retarded availability. Furthermore, a higher methane uptake of 3.2±2.5 kg CO_2 eq. ha^{-1} a^{-1} for arable soils under organic management can be observed. Only one comparative study on rice paddies has been published up to date. All 19 retrieved studies were conducted in the Northern hemisphere under temperate climate.

Summarizing, the two meta-studies show that organic farming has the potential to accumulate soil carbon and to reduce soil-derived nitrous oxide and methane fluxes.