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Gross rates of soil N_2O emission and uptake and denitrification gene abundance in temperate cropland agroforestry and monoculture systems

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Monoculture croplands are considered as major sources of the greenhouse gas, nitrous oxide (N_2O). The conversion of monoculture croplands to agroforestry systems, e.g., integrating trees within croplands, is an essential climate-smart management system through extra C sequestration and can potentially mitigate N_2O emissions. So far, no study has systematically compared gross rates of N_2O emission and uptake between cropland agroforestry and monoculture. In this study, we used an in-situ $^{15}N_2O$ pool dilution technique to simultaneously measure gross N_2O emission and uptake over two consecutive growing seasons (2018 - 2019) at three sites in Germany: two sites were on Phaeozem and Cambisol soils with each site having a pair of cropland agroforestry and monoculture systems, and an additional site with only monoculture on an Arenosol soil prone to high nitrate leaching. Our results showed that cropland agroforestry had lower gross N_2O emissions and higher gross N_2O uptake than in monoculture at the site with Phaeozem soil ($P \leq 0.018 – 0.025$) and did not differ in gross N_2O emissions and uptake with cropland monoculture at the site with Cambisol soil ($P \geq 0.36$). Gross N_2O emissions were positively correlated with soil mineral N and heterotrophic respiration which, in turn, were correlated with soil temperature, and with water-filled pore space (WFPS) ($r = 0.24 – 0.54$, $P < 0.01$). Gross N_2O emissions were also negatively correlated with nosZ clade I gene abundance (involved in N_2O-to-N_2 reduction, $r = -0.20$, $P < 0.05$). These findings showed that across sites and management systems changes in gross N_2O emissions were driven by changes in substrate availability and aeration condition (i.e., soil mineral N, C availability, and WFPS), which also influenced denitrification gene abundance. The strong regression values between gross N_2O emissions and net N_2O emissions ($R^2 \geq 0.96$, $P < 0.001$) indicated that gross N_2O emissions largely drove net soil N_2O emissions. Across sites and management systems, annual soil gross N_2O emissions and uptake were controlled by clay contents which, in turn, correlated with indices of soil fertility (i.e., effective cation exchange capacity, total N, and C/N ratio) (Spearman rank's rho = -0.76 – 0.86, $P \leq 0.05$). The lower gross N_2O emissions from the agroforestry tree rows at two sites indicated the potential of agroforestry in reducing soil N_2O emissions, supporting the need for temperate cropland agroforestry to be considered in greenhouse gas mitigation policies.