Geophysical Research Abstracts
Vol. 19, EGU2017-17828, 2017
EGU General Assembly 2017
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Simulating soil greenhouse emissions from Swiss long-term cropping system trials

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There is an urgent need to identify and evaluate management practices for their bio-physical potential to mitigate greenhouse gas (GHG) emissions from agriculture. The cost and time required for direct management-specific GHG measurements limit the spatial and temporal resolution and the extent of data that can be collected. Biogeochemical process-based models such as DayCent can be used to bridge data gaps over space and time and estimate soil GHG emissions relevant to various climate change mitigation strategies. Objectives of this study were (a) to parameterize DayCent for common Swiss crops and crop-specific management practices using the Swiss long-term experimental data collected at four sites (Therwil, Frick, Changins, and Reckenholz); (b) to evaluate the model's ability to predict crop productivity, long-term soil carbon dynamics and N2O emissions from Swiss cropping systems; (c) to calculate a net soil GHG balance for all treatments (except for bio-dynamic) studied in long-term field experiments in Switzerland; and (d) to study the management effects and their interactions on soil GHG emissions at each experimental site. Model evaluation indicated that DayCent predicted crop productivity (rRMSE=0.29 r2=0.81, n=2614), change in soil carbon stock (rRMSE=0.14, r2=0.72, n=1289) and cumulative N2O emissions (rRMSE=0.25, r2=0.89, n=8) satisfactorily across all treatments and sites. Net soil GHG emissions were derived from changes in soil carbon, N2O emissions and CH4 oxidation on an annual basis using IPCC (2014) global warming potentials. Modelled net soil GHG emissions calculated for individual treatments over 30 years ranged from -594 to 1654 kg CO_2 eq ha-1 yr-1. The highest net soil GHG emissions were predicted for conventional tillage and slurry application treatment at Frick, while soils under organic and reduced tillage management at Reckenholz acted as a net GHG sink. The statistical analyses using linear MIXED models indicated that net soil GHG emissions were influenced by the farming system x tillage interaction at Reckenholz (p<0.01) and the type of organic fertilization at Frick (p<0.01). The contribution of N2O to net soil GHG emissions was higher (approximately 60% on average) than that of soil CO_2 emissions. Soil N2O emissions were also more sensitive to studied managements than soil CO_2 emissions. At Therwil, the level of soil N2O emissions was influenced by the farming system x level of fertilization interaction (p<0.001), at Reckenholz by cover cropping (p<0.001) and the farming system x tillage interaction (p<0.001), at Changins by tillage (p<0.0001) and soil texture (p<0.0001), and at Frick by the type of organic fertilization (p<0.0001). Overall, the highest N2O emissions were predicted for the conventional farming system at 100% fertilization, and the lowest for the non-fertilized farming system, both at Therwil. Changes in soil carbon and associated CO_2 emissions were mostly influenced by farming system (at Therwil), the farming system x tillage interaction (at Reckenholz), and by the type of organic fertilization (at Frick). The results from this study suggest that organic farming in combination with reduced tillage has the highest potential to mitigate soil GHG emissions from Swiss cropping systems, mainly through the reduction in soil CO_2 emissions.