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Soil organic carbon and nitrate leaching loss in organic and conventional farming systems for the current and near future climate

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In Finland, nitrate (N) leaching loss and soil organic carbon (SOC) decrease are current environmental threats. The aim of the study is to simulate soil C dynamic and N leaching loss for conventional (C) and organic (O) farming systems producing either crops or livestock in South Savo (Finland). Simulations were carried out by using the process-based model ARMOSA for both current (1999-2018) and near future climate scenarios (2020-2040, RCP 6.0: annual change + 0.8 °C, –70 mm). Daily meteorological data from Mikkeli station, and the statistical data in the region during the last 20 years served as model inputs.

Five-year crop rotations were simulated on loamy sand soil (C 3.5 %, C/N ratio 17, pH 6.2). In crop farm, rotations included cereals (with fodder pea in the organic farm), oilseed rape and grass, while in the livestock farm, the rotation consisted of two years of cereals followed by a 3-year fescue and timothy meadow (with clover in the organic farm). In the crop farm, we simulated three conventional cropping systems: mineral fertilizer with either crop residues removed (C1–R) or incorporated into soil (C1+R), mineral fertilizer + slurry, residues incorporated (C2+R); and two organic systems: green manure (O1+R) or meat and bone meal-based commercial organic fertilizer, Ecolan Agra® (O2+R). In the livestock farm, we simulated conventional and organic cropping systems: mineral fertilizer + slurry with either residues removed (LC–R) or incorporated into soil (LC+R); slurry with either residues removed (LO–R) or incorporated (LO+R).

The results showed that conventional crop production systems led to relevant SOC decline of 500-750 kg $ha^{-1}yr^{-1}$ at 0-30 cm soil depth, while organic systems showed either less SOC decline (120 kg $ha^{-1}yr^{-1}$) as in O1+R, or slight SOC increase (55 kg $ha^{-1}yr^{-1}$) as in O2+R. Under the future climatic conditions, the model estimated a faster degradation of SOC for all the cropping systems, except for O2+R that still resulted in a negligible SOC increase. Annual N leaching predicted to be about 10 kg NO_3-N ha^{-1} yr^{-1} for conventional crop farm, while 3 kg NO_3-N ha^{-1} yr^{-1} for organic crop farm with green manure. Under the future climate scenario, conventional cropping systems are prone to an increased N leaching loss, up to 20 kg NO_3-N ha^{-1} yr^{-1}, but organic systems do not.

The simulation of livestock farm showed a loss of SOC about 25-160 kg $ha^{-1}yr^{-1}$ in LC–R, LC+R and LO–R, while a small SOC increase of 20 kg $ha^{-1}yr^{-1}$ in LO+R. Annual N leaching loss varied between 6 and 9 kg NO_3-N ha^{-1} yr^{-1} with very little differences between organic and conventional systems due to use of perennial grass in rotation and slurry as N-fertilizer. In the future climate, the model forecasted an overall increase of SOC losses for all systems, and the larger N loss in organic livestock farm, up to 15 kg ha^{-1} yr^{-1}.

In conclusion, the modelling results suggest that organic crop production farms can be more environmentally friendly per unit area compared to conventional farms, particularly under the future climate scenario.