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Modelling soil structure dynamics and nitrous oxide emissions in compacted soils by animal treading

Alejandro Romero-Ruiz[1], Kevin Coleman[1], Carmen Segura[2], Laura Cardenas[2], Alice Milne[1], and Andrew Whitmore[1]

[1]Sustainable Agricultural Sciences, Rothamsted Research, Harpenden, United Kingdom (alejandro.romero-ruiz@rothamsted.ac.uk)

[2]Sustainable Agricultural Sciences, Rothamsted Research, North Wyke, United Kingdom

Soil compaction is a form of soil degradation that adversely impacts soil mechanical and hydraulic properties, potentially affecting productivity and is often linked to increases in nitrous oxide emissions. However, we lack a quantitative understanding of the extent and environmental impacts of soil compaction. This is partially due to gaps in our knowledge of how compaction impacts soil physical properties spatially and temporally, how it impacts soil's hydrological functioning and how these impacts ultimately modify nitrification and denitrification in the soil. We propose to address this challenge by embedding a new? model of soil structure dynamics into an agro-ecosystem modelling framework to explicitly account for soil compaction impacts on soil functions such as soil moisture dynamics, plant growth and GHG emissions. We tested this model to assess the effect of soil compaction by animal treading in livestock-grazing systems. We considered random movement of cattle in a confined area that is discretized in square cells with given soil bulk density and saturated hydraulic conductivity. Changes in these properties in response to animal treading are then inferred using a soil rheology model based on Bingham's law. We modeled five two-month long grazing seasons in consecutive years using 18 years of weather data from the North Wyke experimental platform in Devon, United Kingdom. Our model predicts an increase of bulk density of up to 20% and a decrease in hydraulic conductivity of up to 95% due to animal treading. Such compaction-induced changes in soil pore space and related hydraulic functions led to a relative increase in N_2O emissions from the compacted areas of up to 200% and a related decrease in yield of up to 15%, which is in agreement with ranges reported in the literature. By providing a mechanistic framework that calculates the impacts of soil management on soil properties and functions, our work advances the ability to test management strategies that might help to ameliorate the environmental impact of animal treading in grasslands.