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Modelling soil carbon stocks in semi-natural and agro-ecosystems – quantifying national scale impacts of the Anthropocene

Victoria Janes-Bassett[1], Jessica Davies[1], Richard Bassett[1], Dmitry Yumashev[1], Ed Rowe[2], and Edward Tipping[3]

[1]Lancaster University, Lancaster Environment Centre, Lancaster, UK (v.janes@lancaster.ac.uk)

[2]Centre for Ecology and Hydrology, Bangor, UK

[3]Centre for Ecology and Hydrology, Lancaster, UK

Throughout the Anthropocene, the conversion of land to agriculture and atmospheric deposition of nitrogen have resulted in significant changes to biogeochemical cycling, including soil carbon stocks. Quantifying these changes is complex due to a number of influential factors (including climate, land use management, soil type) and their interactions. As the largest terrestrial store of carbon, soils are a key component in climate regulation. In addition, soil carbon storage contributes to numerous ecosystem services including food provision. It is therefore imperative that we understand changes to soil carbon stocks, and provide effective strategies for their future management.

Modelling soil systems provides a means to estimate changes to soil carbon stocks. Due to linkages between the carbon cycle and other major nutrient cycles (notably nitrogen and phosphorus which often limit the productivity of ecosystems), models of integrated nutrient cycling are required to understand the response of the carbon cycle to global pressures. Simulating the impacts of land use changes requires capacity to model both semi-natural and intensive agricultural systems.

In this study, we have developed an integrated carbon-nitrogen-phosphorus model of semi-natural systems to include representation of both arable and grassland systems, and a range of agricultural management practices. The model is applicable to large spatial scales, as it uses readily available input data and does not require site-specific calibration. After being validated both spatially and temporally using data from long-term experimental sites across Northern-Europe, the model was applied at a national scale throughout the United Kingdom to assess the impacts of land use change and management practices during the last two centuries. Results indicate a decrease in soil carbon in areas of agricultural expansion, yet in areas of semi-natural land use, atmospheric deposition of nitrogen has resulted in increased net primary productivity and subsequently soil carbon. The results demonstrate anthropogenic impacts on long-term nutrient cycling and soil carbon storage, and the importance of integrated nutrient cycling within models.