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150 years of macronutrient change in unfertilized plant-soil ecosystems: Observations vs simulations

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Understanding changes in plant-soil carbon and nutrients using data alone is difficult due to the linkages between carbon, nitrogen and phosphorus cycles (C, N and P), and multiple changing long-term drivers (e.g. climate, land-use, and atmospheric N deposition). Hence, dynamic models are a vital tool for disentangling these drivers, helping us understand the dominant processes and drivers and predict future change. However, it is essential that models are tested against data if their outputs are to be concluded upon with confidence. Here, a simulation of C, N and P cycles using the N14CP model was compared with time-series observations of C, N and P in soils and biomass from the Rothamsted Research long-term experiments spanning 150 years, providing an unprecedented temporal integrated test of such a model. N14CP reproduced broad trends in soil organic matter (SOM) C, N and P, vegetation biomass and N and P leaching. Subsequently, the model was used to decouple the effects of land management and elevated nitrogen deposition in these experiments. Elevated N deposition over the last 150 years is shown to have increased net primary productivity (NPP) 4.5-fold and total carbon sequestration 5-fold at the Geescroft Wilderness experiment, which was re-wilded to woodland in 1886. In contrast, the model predicts that for cropped grassland conditions at the Park Grass site, elevated N deposition has very little effect on SOM, as increases in NPP are diverted from the soil. More broadly, these results suggest that N deposition is likely to have had a large effect on SOM and NPP in northern temperate and boreal semi-natural grasslands and forests. However, in cropped and grazed systems in the same region, whilst NPP may have been supported in part by elevated N deposition, declines in SOM may not have been appreciably counteracted by increased N availability.