Carbon storage in phosphorus limited grasslands may decline in response to elevated nitrogen deposition: a long term field manipulation and modelling study

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In ecosystems where nitrogen (N) limits plant productivity, N deposition can stimulate plant growth, and consequently, promote carbon (C) sequestration by increasing input of detrital C and other forms of plant C to the soil. However, other forms of nutrient limitation such as phosphorus (P) limitation and N-P co-limitation are widespread and may increase in prevalence with N deposition. Our understanding of how terrestrial ecosystem C, N and P cycling may be affected by N deposition when N is not the sole limiting resource is fairly limited. In this work, we investigate the consequences of enhanced N addition on C, N and P cycling in grasslands that exhibit contrasting forms of nutrient limitation.

We do so by collecting data from a long-term nutrient manipulation experiment on two N-P co-limited grasslands; an acidic grassland of stronger N-limitation and a calcareous grassland of stronger P limitation, and integrating this into a mechanistic C, N and P cycling model (N14CP). To simulate the experimental grasslands and explore the role of P access mechanisms in determining ecosystem state, we allowed P access to vary, and compared the outputs to plant-soil C, N and P data. Combinations of organic P access and inorganic P availability most closely representing data were used to simulate the grasslands and quantify their temporal response to nutrient manipulation.

The modelled grasslands showed contrasting responses to simulated N deposition. In the acidic grassland, N addition greatly increased C stocks by stimulating biomass productivity, but the same N treatments reduced the organic C pool in the calcareous grassland. Nitrogen deposition exacerbated P limitation in the calcareous grassland by reducing the size of the bioavailable P pool to plants, reducing biomass input to the soil C pool. Plant acquisition of organic P played an important role in determining the nutrient conditions of the grasslands, as both simulated grasslands increased organic P uptake to meet enhanced P demand driven by N deposition. Greater access to organic P in the acidic grassland prevented a shift to P limitation under elevated levels of N deposition, but organic P access was too low in the calcareous grassland to prevent...
worsening P limitation.

We conclude that grasslands of differing limiting nutrients may respond to N deposition in contrasting ways, and stress that as N deposition shifts ecosystems toward P limitation, a globally important carbon sink risks degradation.