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Significant impacts of nutrient enrichment on High Arctic vegetation and soils despite two decades of recovery

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We re-visit a unique field manipulation study in Svalbard to assess the long-term recovery of plant species composition, leaf tissue chemistry and total ecosystem carbon storage from nutrient enrichment.

The experiment was established in 1991. The original aim was to quantify the ‘critical load’ of nitrogen (N) for tundra; that is, the minimum rate of N deposition affecting ecosystem structure and function. Dissolved N was applied to heath vegetation, both alone and in combination with phosphorous (P), during the growing season over three years. The rates of N addition were lower than in most other nutrient manipulation studies, and were designed to represent typical rates of deposition in the Scottish highlands (50 kg N ha^{-1} yr^{-1}) and maximum deposition rates experienced in the Arctic (10 kg N ha^{-1} yr^{-1}). Significant changes in shrub cover, the greenness and N content of the moss layer, and the extent of ecosystem N saturation had occurred by the end of the treatment period.

After 18 years of recovery without further treatment, we assessed primary productivity using CO_2 flux measurements, and the ‘greenness’ of vegetation using the Normalised Difference Vegetation Index. We made destructive measurements of above- and below-ground carbon and nutrient stocks, quantified species composition and sampled leaf tissue for chemical analysis.

Total carbon storage in organic soils and vegetation was c. 40 % lower in the plots treated with 50 kg N ha^{-1} yr^{-1} compared to controls. Species composition in N treated plots also differed significantly, but there was no clear treatment effect on primary productivity. Where 50 kg N ha^{-1} yr^{-1} was applied in combination with P (at 5 kg P ha^{-1} yr^{-1}), organic carbon storage was c. 70 % greater than controls, the vegetation was greener, and primary productivity higher. Effects of the treatments were also still clearly apparent in moss tissue nutrient status, even at the lower nitrogen application rate.

Our results imply that the effects of nutrient enrichment on High Arctic ecosystems are not readily reversible, and that short-term addition of N can result in long-term carbon losses. We show that mosses perform an important role in retaining deposited N aboveground. Our results also highlight the importance of P in mediating carbon cycle responses to increased N availability.