Disentangling nitrogen's role as a limiting nutrient and acidifier: how does nitrogen availability affect soil respiration?

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Soil respiration (Rsoil) is the second largest terrestrial carbon flux, vastly exceeding fossil fuel emissions. It is composed of two separate fluxes: autotrophic respiration (Ra), driven by plant respiration, and heterotrophic respiration (Rh), which comes predominantly from microbial decomposition. Many studies have demonstrated that increasing nitrogen (N) availability can suppress Rsoil, but the mechanisms underpinning this response are difficult to discern, because each component flux can respond differently to changes in N availability, through its roles as a limiting nutrient and as an acidifying agent. As a limiting nutrient, increasing N availability could reduce plant belowground carbon allocation to roots (Ra) and microbial symbionts; however, supplying N to nutrient-limited soil microbes inhabiting carbon rich soil layers could offset this effect by increasing saprotroph biomass (Rh). Alternatively, as an acidifying agent, N may decrease soil decomposer biomass and increase belowground carbon allocation if acidification reduces availability of other nutrients. Here, we test these hypotheses by measuring respiration fluxes from fixed collars (Rsoil) and from lab-incubated soils separated by depth (Rh) in a replicated, ten-year N x pH manipulation (+N, +pH; +N, -pH; -pH; control) study in mixed temperate forests in central New York, USA.

Acidifying N additions led to large reductions in Rsoil (19%, 2.2 t C ha-1 yr-1), and decreased forest floor Rh (per unit soil mass). In contrast, acidification alone had no effect on Rsoil, but produced large increases in Rh in mineral soils. De-acidifying N additions did not significantly affect Rsoil or Rh, but effects trended towards suppression rather than enhancement. When considered per unit area, both Rh and Rsoil decreased sharply with increasing soil N availability, but showed little response to soil pH across all treatments. However, within acidification treatments, Rsoil and mineral soil Rh decreased with increasing acidity. We anticipated that acidification would impact Rsoil by reducing Rh and increasing Ra, but surprisingly found that acidification alone stimulated Rh in mineral soil, perhaps reflecting long-term accumulations of carbon in surface mineral soils. Overall, our findings suggest that increased N availability suppresses Rsoil through nitrogen's role as a limiting nutrient for both plants and heterotrophic microbes and that N-driven acidification can contribute to this effect by suppressing microbial activity in surface soil layers.