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Microbial N and P mining regulates the effect of N deposition on soil organic matter turnover

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Nitrogen (N) deposition to soils has become a global issue during the last decades. Its effect on mineralization of soil organic carbon (SOC), however, is still debated. Common theories based on Liebig's law predict higher SOC mineralization rates in nutrient-rich than in nutrient-poor soils. Contrastingly, the concept of microbial N mining predicts lower mineralization rates after N deposition. The latter is explained by ceased decomposition of recalcitrant soil organic matter (SOM) as the need of microbes to acquire N from this pool decreases. As N deposition might shift the nutrient balance towards relative phosphorus (P) deficiency, it is also necessary to consider P mining in this context. Due to limited knowledge about microbial nutrient mining, any predictions of N deposition effects are difficult.

This study aims at elucidating the preconditions under which microbial nutrient mining occurs in soil. We hypothesized that the occurrence of N and P mining is controlled by the current nutrient status of the soil. Likewise, soils might respond differently to N additions.

To investigate this hypothesis, we conducted substrate-induced respiration measurements on soils with pronounced gradients of N and P availability. We used topsoil samples taken repeatedly from a site which was up to 7 years under bare fallow (Selhausen, Germany) and up to 4 m deep tropical forest soils (Kalimantan, Indonesia). Additional nutrient manipulations (glucose, glucose+N, glucose+P, glucose+N+P additions) were conducted to study the effect of nutrient additions. Samples were incubated for one month. We further conducted 13C labeling experiments to trace the sources of CO_2 (sugar vs. SOM derived CO_2) for further hints on nutrient mining.

Mineralization of glucose was limited by a lack of available N in the bare fallow soil but microbes were able to slowly acquire N from previously unavailable pools. This resulted in a slightly higher release of native SOM-derived CO_2 compared to N-fertilized treatments. Nutrient additions had no effect on cumulative CO_2 evolution in tropical topsoils. Subsoils of the tropical sites (20 – 100 cm depth) were co-limited by N and P. Here, alleviation of either N or P deficiency was necessary to stimulate the mineralization of glucose. In the deep subsoil (>150 cm depth) only the combined additions of N+P induced any CO_2 release.

Our results reveal that mining of both N and P potentially occurs but is restricted by multiple nutrient limitations, by the absence of potentially accessible nutrients (e.g., in the deep subsoil), and by full nutrient supply (e.g., high nutrient contents make mining unnecessary). The results suggest several implications for N deposition effects: 1) N deposition decreases (recalcitrant) SOC mineralization in former N-deficient soils, 2) N deposition increases SOC mineralization in former co-limited soils as it facilitates mining of the required P, 3) N deposition has no effect in nutrient rich topsoils.