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Patterns in C:N:P stoichiometry and relations to soil microbial function as affected by climate, bedrock, and land use across a continental transect in Europe

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Introduction. Ecological stoichiometry has allowed important insights into the coupled/decoupled cycling of C, N and P in terrestrial environments, at scales from local, regional, to continental and global ones. Important findings from these studies and meta-analyses were on differences in the homeostatic behavior of heterotrophs and autotrophs, on climatic/latitudinal effects on plant stoichiometry linked to large-scale changes in nutrient availability, and more recently on microbial elemental imbalances and their effect on microbial element use efficiencies and soil biogeochemical processes.
Study design. In this study we investigated the C:N:P stoichiometry of different ecosystem compartments (leaf litter, roots, soils, soil microbial biomass, soil extractable pool) across 95 sites differing in climate, bedrock and management, ranging from South Spain to Northern Sweden. Stoichiometric patterns were then linked to microbial community composition and function. Sampling was performed in Mai-August 2017, from 43 forest, 28 grassland and 24 cropland sites. Sites ranged in mean annual temperature from -3.4 to 17.8 °C and in mean annual precipitation from 415 to 1396 mm. Soils covered a pH (H_2O) range from 3.6 to 8.9. We used this dataset to test for large scale effects of land use, climate and bedrock on continental C:N:P stoichiometry and microbial community composition and function.
Results. (1) C:N and N:P ratios in plant litter, roots, bulk soil and microbial biomass showed clear land use (cropland<grassland<forest) and soil horizon effects (organic horizons>mineral horizons). (2) Bedrock effects were weaker than land use effects, but influenced soil extractable and microbial biomass C:N and N:P, and had little effect on plant root and litter stoichiometry, indicating relatively little geochemical effects on plant C:N:P ratios. (3) Climate explained relatively little of the overall variation in C:N:P stoichiometry across this transect, with the exception of MAT (inverse to latitude), being negatively related to soil C:N. (4) We found strict C:N and N:P homeostasis of soil microbial communities, but weak homeostasis of plant roots relative to soils (R2=0.12-0.46), the response being uniform across land uses. (5) Microbial community structure (bacteria: fungi or Gram+/Gram- ratios based on PLFA analyses) was neither related to land use and climate, nor to their biomass stoichiometry, or to their elemental imbalances or element use efficiencies, but microbial groups such as Gram+ and Gram- bacteria decreased with MAT. (6) Microbial C:N imbalances increased from agricultural land to forests, triggering microbial nitrogen use efficiency (NUE) to increase, according to stoichiometric reasoning, but at the same time also microbial carbon use efficiency (CUE) increased, hinting at co-regulation of microbial CUE and NUE in terrestrial ecosystems. (7) Linked to decreases in microbial element use efficiencies due to agricultural land use, microbial respiration and gross N mineralization increased along the same line.
Conclusion: This study highlights major strengths and weaknesses of ecological stoichiometric patterns when applied to terrestrial ecosystems at the continental scale and when discerning land use and climate effects on microbial community composition and function, but allows identifying causal pathways linking biogeochemical processes.