Geophysical Research Abstracts
Vol. 18, EGU2016-1238, 2016
EGU General Assembly 2016

The C:N:P:S stoichiometry of soil organic matter

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The formation and turnover of soil organic matter (SOM) includes the biogeochemical processing of the macronutrient elements nitrogen (N), phosphorus (P) and sulphur (S), which alters their stoichiometric relationships to carbon (C) and to each other. We sought patterns among soil organic C, N, P and S in data for c. 2000 globally distributed soil samples, covering all soil horizons. For non-peat soils, strong negative correlations ($p < 0.001$) were found between N:C, P:C and S:C ratios and % organic carbon (OC), showing that SOM of soils with low OC concentrations (high mineral matter) is enriched in N, P and S. The results can be described approximately with a simple mixing model in which nutrient-poor SOM (NPSOM) has N:C, P:C and S:C ratios of 0.039, 0.0011 and 0.0054, while nutrient-rich SOM (NRSOM) has corresponding ratios of 0.12, 0.016 and 0.016. The trends hold across a range of ecosystems, for topsoils and subsoils, and across different soil classes. The major exception is that tropical soils tend to have low P:C ratios especially at low N:C. We suggest that NRSOM comprises compounds that have been selected for their strong adsorptive properties towards mineral matter, the enrichments in N and S being due to preferential adsorption of proteins and other N- and S-rich compounds, while P enrichment may mostly be due to the adsorption of inositol phosphates. The stoichiometric patterns established here provide a new quantitative framework for SOM classification and characterisation, and provide constraints to conceptual and process-based models.