SUSALPS
Internationale Grünland-Konferenz 2025

Contribution ID: **55** Type: **Poster presentation (4:40 PM - 6:30 PM)**

Mechanistic insights of coupled C-N-P cycling in Bavarian soils

Tuesday 15 July 2025 16:40 (1h 50m)

In the context of climate change and declining mineral phosphorus (P) fertilizer reserves, understanding carbon (C), nitrogen (N), and phosphorus (P) biogeochemical cycling under contrasting land uses is essential for sustainable climate-smart management. This study provides a comprehensive assessment of coupled C-N-P cycling within a hillslope-flood plain system in Bavaria, Germany. It investigates soil biogeochemical processes under long-term grassland and cropland management and evaluates how these processes are altered by an enhanced rock weathering (ERW) strategy aimed at CO2 removal.

The findings show that grassland soils exhibit higher organic carbon (OC), N, and organic phosphorus (OP) stocks compared to cropland soils. Although total P stocks are comparable across both land uses, cropland soils have a greater proportion of inorganic phosphorus (IP). Both OC and OP are predominantly enriched in fine soil fractions (<20 µm). Stoichiometric assessment combined with direct NanoSIMS observations suggests two distinct P retention pathways linked to OC and N. Grassland soils have a stronger coupling of C-N-P cycles driven by microbial processes, whereas cropland soils show weaker coupling due to abundant direct P-mineral complex formation without biological processes involved. The addition of ERW materials significantly influences OC cycling. Fresh ERW materials accelerate OC decomposition due to elevated soil pH, while weathered ERW materials sustain existing OC stocks and enhance new OC retention from plant residues.

This study gives mechanistic insights into C-N-P cycling dynamics under contrasting land uses and demonstrates how climate-smart strategies, such as ERW, can influence soil carbon sequestration and nutrient dynamics.

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Session Classification: Poster Session & Get-Together (including Beer & Pretzels)

Track Classification: Day 1: Science (English) / Tag 1: Wissenschaft (Englisch): Biogeochemical processes in grassland soils