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Continental scale climate, land-use and geological controls of soil P cycling and relations with soil C and N

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Despite the importance of phosphorus (P) as a nutrient for all life, its availability is highly constrained in terrestrial ecosystems. The availability of P to plants and microbes is regulated by abiotic processes (e.g. P sorption/desorption, precipitation/dissolution) and biological activities (microbial P immobilization/organic P mineralization). Due to the strong geochemical component of the P cycle, it can be expected that soil C, N and P cycling may differ in terms of effects of geology, climate and management. Despite advances in our understanding of physico-chemical controls on P availability, there is still little mechanistic understanding of large scale controls on soil P cycling and its relation to soil C and N cycling, due to a lack of broad scale studies using common methodologies.

Here we aimed to investigate soil physicochemical and biological factors that drive soil P cycling and may cause a (de)coupling of C, N and P processes. We therefore sampled mineral topsoils (0-10 cm, n=95) across a continental transect in Europe (Southern Spain to Northern Scandinavia), covering major geological, climatic and land use gradients. The soils derived from different land uses (cropland, grassland, forest/woodland) and bedrock types (silicate, sediment, calcareous). We analyzed a wide range of potentially relevant physico-chemical and biological properties and measured gross rates of soil N and P processes by short term (24 h) incubations of soils with ^{33}P and ^{15}N following isotope pool dilution approaches.

(i) Across the whole transect land-use effects on soil P pools and processes exceeded those of geology, reflecting the accumulation of fertilizer P in soils of managed ecosystems. Cropland (and grasslands) had higher values of soil total P and soil inorganic P (Pi), available Pi (Olsen P), and gross Pi mobilization rates by abiotic and biotic processes compared to forests. Soil phosphatase activity did not vary between land-uses. Soils on silicate bedrock had significantly higher total and labile P than calcareous soils.

(ii) Climate differentially affected P pools and processes. Soil total P, dissolved organic P, and gross Pi desorption decreased with mean annual temperature (MAT; these properties were not sensitive to mean annual precipitation - MAP), while soil phosphatase activity and gross total Pi mobilization

through abiotic and biotic processes increased with MAP but were insensitive to MAT. This clearly points to adverse climatic controls of biotic and abiotic soil P processes.

(iii) We found strong interlinkages between soil C, N and P pools (soil organic matter and microbial biomass) and soil enzymes (beta-glucosidase, chitinase, phosphatase) but not in related gross processes (respiration, N and P mineralization). Interestingly the slopes of C-P and N-P relations of pools and enzymes differed systematically between land-uses, indicating that land management causes a partial decoupling of P from C and N cycles, reflecting the P-richness of croplands.