EGU General Assembly 2022

EGU22-4855
https://doi.org/10.5194/egusphere-egu22-4855
EGU General Assembly 2022

Long-term forest soil warming decreases soil total P pools and negatively affects biotic P processes by promoting abiotic P sorption processes

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Phosphorus (P) is an essential element for all organisms, received increasing attention in global change research. Current P-related climate warming studies have mainly addressed warming effects on soil and plant P pools, but how soil P cycling processes respond to elevated temperatures has remained largely uncertain. In this study we investigated the effect of soil warming on both, soil P pools and P cycling processes (applying the ^{33}P isotope pool dilution technique) across different soil depths (0-10 and 10-20 cm) and seasons (spring, summer, autumn) during the 15th year of soil warming (+4 °C) in a mature temperate mountain forest, in Achenkirch, Austria. Long-term warming decelerated the gross rates of phosphate (Pi) mobilization by 21%, reducing the soil Pi input. The decreased gross Pi mobilization was in part attributed to substantial losses of soil total P pools (substrates), which likely was caused by increased dissolved organic P leaching to deeper soil layers in the warming treatment. Abiotic immobilization increased in the warming treatment, due to increased sorption of Pi to iron oxyhydroxides and clay, further reducing soil Pi availability. Moreover, warming decreased biotic Pi immobilization and microbial biomass P, and as a response, microbial communities allocated more energy and nutrients into the production of acid phosphatase, indicating a strong shift in microbial carbon and nutrient allocation in response to the decreased P availability. According to linear mixed-effects models, most of the responses of the measured P pools and processes showed no interactions between warming and soil depth and/or season, indicating consistent effects of long-term soil warming on the P cycle across different soil depths and seasons. Overall, this study highlights for the first-time how long-term soil warming affects (biotic and abiotic) soil P processes and their interactions with soil P pools. Besides, it also indicates the potential of how P constraints can affect other

biogeochemical cycles in response to warming.