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Alterations of Nutrient Uptake Depth in the Forest Ecosystem Traced by Radiogenic Strontium Isotopes

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Forests cover around one-third of all land on Earth and play a crucial role in sustaining life. In the context of climate change, understanding the alteration of nutrient flows in forest ecosystems has become increasingly important. In this study we monitored the variations of nutrient (e.g., Mg) concentrations and of radiogenic strontium isotopes ($^{87}Sr/^{86}Sr$) over 20 years at the International Co-operative Programme forests monitoring site Mitterfels, Germany, with the aim to identify possible changes of nutrient cycling in the system.

The nutrient concentrations in the needles of Norway spruce (*Picea abies* L.) tended to increase during the last decades. Among the nutrient elements, Mg concentration showed the strongest increase by ~30% from 1992 to 2014. This suggests either an increasing uptake rate or increased access to a nutrient source that is rich in available Mg. Along with the increase in nutrient concentrations, we also observed an increase in the $^{87}Sr/^{86}Sr$ ratio of spruce needles shifting from 0.71473 to 0.71775 over the years. In comparison with the $^{87}Sr/^{86}Sr$ ratio of the exchangeable fraction in soil, this indicates that the nutrition for the spruce trees was mainly from the forest floor. Over time, the mean uptake depth was shifted from litter horizon to a deeper horizon where the humus was more abundant. We attribute this shift to that over the last decades the increased temperature has accelerated the litter decomposition and mobilization of nutrients which accumulated in the humus layer and mineral soil. Together with the decreased annual precipitation, higher temperature, though only slight, also resulted in faster respiration of the trees and deeper uptake from the water- and nutrient-rich humus horizon. Overall, we demonstrate that monitoring $^{87}Sr/^{86}Sr$ ratio was able to trace nutrient flow alternations over time.