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Testing Mg stable isotopes as a potential geochemical tool in agronomy

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A sustainable use of soil resources is urgently required to cope with the increasing demand for agricultural products during climate change. Advanced soil cultivation methods like subsoil management were suggested but analytical tools to measure changes in the nutrient use efficiency of crops are still missing. Here we tested the applicability of Mg stable isotopes as novel evaluation tool in agronomy. To this end, we conceptually demonstrated under which conditions changes in the Mg isotope composition (δ^{26}Mg) of crops and the bioavailable fraction of Mg in soils containing low, middle, and high inventories of exchangeable Mg could be resolved from analytical uncertainty, when simulating subsoil management. We found that shifts in δ^{26}Mg values are only detectable if i) the crop uptake-related Mg isotope fractionation factor is at the upper end of hitherto published fractionation factors, ii) a high Mg uptake flux of crops is matched by a low Mg supply from the exchangeable fraction, and iii) subsoil management causes a considerable deepening of the rooting system.

We tested our concept on field trials, where deep loosening with and without the incorporation of compost was conducted on Luvisols. Shifts in δ^{26}Mg values of crops and the exchangeable fraction of Mg in soil were mostly unresolvable from the analytical uncertainty, which positively tested the Mg isotope concept for well nurtured soils. Yet, systematic shifts in δ^{26}Mg values among crops cultivated on and beside a melioration strip were found and attributed to the uplift of isotopically distinct compost-derived Mg on the melioration strip and root restricting layers beside the melioration strip. Also, field-based crop uptake-related 'apparent' Mg isotope fractionation factors of winter wheat and spring barley were determined, which differed from one another. However, the quantitative approach of Mg isotopes was violated when lime or Mg-carbonate containing fertilizer were applied to the field. In these cases, the isotope-derived difference in the Mg use efficiency were likely caused by the uneven distribution of lime-derived Mg with soil depth. Hence, using Mg stable isotopes as a new geochemical routine for agronomy will require further work to allow low-demanding, minimally invasive sampling of the soil-plant system.