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Zn isotope geochemical fingerprint for diverse land utilizations: Evidence from soil profiles in a karst area

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Under the “Grain–for–Green” program in China, large amounts of arable land have been converted to natural land in the past 20 years. However, the effects of agricultural activities can last over long periods, particularly in karst areas, owing to their high ecological fragility and environmental sensitivity. Zinc (Zn) isotopic tracing is an efficient tool for identifying anthropogenic disturbances and geogenic processes in terrestrial ecosystems. Soil Zn dynamics for different land utilizations can imprint the linkages between soil evolution and ecosystem management on a regional scale. To reveal how land use affects the transformation of Zn, soil profile samples were collected from abandoned cropland, grazing shrublands, and natural forest land in a typical karst area. The Zn content and isotopic composition were analyzed. Both soil Zn contents and δ^{66}Zn compositions showed the largest variation in the forest land (Zn: 72.50 ~ 131.20 mg/kg, δ^{66}Zn: -0.26‰ ~ 0.04‰) than those in the abandoned cropland (Zn: 74.53 ~ 112.20 mg/kg, δ^{66}Zn: -0.14‰ ~ -0.02‰) and shrubland (Zn: 48.26 ~ 82.57 mg/kg, δ^{66}Zn: -0.18‰ ~ 0.00‰). Rock weathering was the main contributor to soil Zn. Differences among profiles arose from partially assimilative Zn returning to the forest through plant debris, whereas leaching processes coupled with the consumption of crop production and livestock led to Zn loss. After the decomposition of plant debris, vegetation preferentially assimilated lighter δ^{66}Zn from the soil solution while retaining heavier δ^{66}Zn in the surface soil. Additionally, the soil solution contained lighter δ^{66}Zn that leached downward. Animal excrement unintentionally supplied heavier δ^{66}Zn during grazing, which indirectly disturbed soil Zn behavior under the effect of vertical leaching. The assimilation of crops exhausted lighter δ^{66}Zn during cultivation, and heavier δ^{66}Zn continued to be lost by leaching after stopping tillage. Agricultural lands possibly experience Zn loss through dissolution due to anthropogenic disturbances. The lower level of soil Zn found in the karst area may suggest a risk of soil degradation, which has been previously ignored. This study reveals a potential feedback mechanism for soil Zn isotope behavior during agricultural disturbances, which will help optimize land management measures in karst areas.