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Uranium and Strontium isotopes and major elements revealed signals of increased basalt weathering underneath agricultural fields in Upper Snake-Rock watershed in Idaho, USA

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Agricultural irrigation has changed hydrological cycles by redistributing surface and groundwater, modifying Critical Zone processes, and impacting water and soil quality. Here, we present a study of increased basalt weathering and its impacts on carbonate dissolution/precipitation dynamics in Dryland Critical Zones at the extensively irrigated agricultural Upper Snake-Rock Watershed in south-central Idaho. The Upper Snake-Rock Watershed is a typical and representative basaltic watershed with surface loess deposits, located within the regional Snake River Watershed under intensive agricultural activity that covers Wyoming, Idaho, Oregon, and Washington in northwest United States. We focus on investigating how the subsurface water underneath the agricultural fields reacts in the shallow soil zones and the upper fractured basalt aquifer systems and returns excess water and nutrients back into the Snake River. We collected different types of agriculture-related water samples (Snake River, agricultural irrigation canals, groundwater wells, drains and underground tunnels) along the regional flow paths from both irrigation and non-irrigation seasons (2024 -2025). Water chemistry (salinity, pH, alkalinity, major and trace elements) and $^{87}Sr/^{86}Sr$ and $^{234}U/^{238}U$ ratios were used to identify and quantify the agrohydrological processes. Indeed, $^{87}Sr/^{86}Sr$ and $^{234}U/^{238}U$ ratios showed systematic changes between irrigation to non-irrigation seasons and along the flow paths. Along with the build-up of alkalinity, lower $^{87}Sr/^{86}Sr$ and $^{234}U/^{238}U$ ratios revealed the signals of increased basalt weathering underneath agricultural fields. Furthermore, Mg, Ca, and Na showed higher concentrations during non-irrigation seasons and correlated well with HCO_3, providing evidence of increase chemical weathering and potential carbonate dissolution and precipitation. In addition, trace elements like B, As, Ni, Cu were released into water from the increased weathering of basalt. Low level of agricultural anthropogenic pollutants (P and NO_3) was also observed in these water samples from most likely fertilizer runoff. A long-term dataset of major elements (Ca, Mg, Na, Cl, P, NO_3) from 2016-2024 collected by USDA (Kimberly, ID) also confirms similar patterns of increased basalt weathering and possible carbonate dissolution and precipitation. Our study provides insights into the long-term impacts of the agricultural activities on regional water-rock interactions in agricultural basaltic watersheds that has implications on long term carbon cycles.