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A new multi proxy approach using trace metal isotopes for more quantitative estimates of climate-human-landscape interactions

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Due to the lack of appropriate analytical methods, high-resolution studies about the frequently non-linear landscape response to climate and human forcing in the geological history have remained challenging until today. To address this issue, novel isotope proxies (uranium and lithium) have been applied to lacustrine sediment successions from deep and large Lake Ohrid (FYROM, Albania), and medium-sized, shallow Lake Dojran (FYROM, Greece) at the Balkan Peninsula. These new, innovative proxies can be applied on the same sediment material, from which the climatic and environmental history of the area has previously been inferred by means of conventional proxy analyses, such as pollen, stable isotopes, sedimentary, and (bio-)geochemical data. Results presented herein demonstrate the great potential of this new approach to obtain more quantitative estimates for landscape evolution in response to climate and human land use.

Uranium (U) isotopes determine the time that has elapsed since physical and chemical weathering have formed detrital grains <63μm (i.e. the so-called comminution age). This provides insights into the "regolith residence time" of detrital matter, which is a measure for catchment erosion, and, as the weathering front in a soil profile continuously moves downwards over time, for erosion depth. Lithium (Li) isotopes fractionate during secondary clay mineral formation and thus, provide insights into soil development and silicate weathering intensities during the time of deposition.

Consistent patterns of soil erosion (uranium isotopes) in response to rapid climate variability could be inferred for both lakes Ohrid and Dojran, with shallower erosion (sheet wash) prevailing during cold and dry periods such as the 4.2- and 8.2- events, and the Younger Dryas. Humid (and warmer) Holocene time intervals are characterized by deeper erosion, such as gully erosion. In contrast to soil erosion, soil development and silicate weathering intensity (lithium isotopes) do not respond to these rapid climate oscillations. Whereas this good agreement underpins the regional significance of the inferred interpretation, the data also reveal local differences of the landscape′s response of both catchments. For instance, almost complete stripping of the landscape in response to anthropogenic land use at Lake Dojran during the Late Holocene is not evident at Lake Ohrid although archeological findings and pollen analyses suggest the early presence of humans in the catchment of both lakes. Much shallower erosion subsequent to the 8.2-event is apparent in the uranium isotope record at Ohrid but not at Dojran.

The results from lakes Ohrid and Dojran underpin the regional significance of the inferred catchment dynamics beyond the respective catchments. In addition, the local differences provide an excellent possibility to gain a general understanding of tipping points in the frequently non-linear response of landscape dynamics under comparable climatic boundary conditions. The underlying mechanism of the local differences can only be unraveled by including additional information such as sedimentary, (bio-)geochemical, and pollen data from the same sample material emphasizing the importance of a multi-proxy approach.