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Spatial dynamics of soil erosion impacts on food, water and energy security in a large Andean river basin, Chile

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The Rapel Basin (ca 14,000 km^2), Chile, provides a wide range of ecosystem services from mining activities and water supply from its Central Andean headwaters to mixed agricultural food production and hydropower generation in the Central Valley. The breadth of ecosystem service provision, range of land use and wider anthropogenic pressures makes the Rapel system an ideal natural laboratory in which to evaluate tools to support soil erosion mitigation in the context of enhancing food, water and energy security.

Taking a distributed approach to encompass geological variability plus superimposed land management and natural process variability, replicate tributary sediment samples (n = 10± per tributary, total number of sediment samples= 313) were collected from across the system to characterise sediment inputs from the major potential sediment sources : (a) natural sediment production in steep Andean headwaters driven by (i) glacial retreat and (ii) seasonal snow melt, (b) sediment inputs from major copper mining operations in the Andes, (d) soil erosion on agricultural land in the Central valley basin area and (e) soil erosion on agricultural land in the Coastal Mountain Belt bordering the hydropower reservoir, Lake Rapel. Samples of river bed sediment from two main sub-catchments (north: Cachapoal River, South: Tinguiririca River) were collected at the outlet to the upper Andean catchment, below the central valley agricultural zone and downstream of a major tributary confluence above the reservoir. In addition, 12 surficial sediment samples were collected from the main arm of the reservoir. All materials were analysed for major and minor element geochemistry by Wave-length Dispersive X-Ray Fluorescence (44 elements).

Mixtures were compared in terms of their source material groups in a series of nested MixSIAR mixing model runs after selection of appropriate tracer groups following established procedures. In the northern tributary to the reservoir, mining effluent dominated the sediment supply in upper reaches (78%) with the reminder from natural landscape denudation plus a small proportion of glacial-derived sediments (5%). The influence of the mine was diluted by significant inputs of sediment from agricultural sources (fruit orchards and grain production) in the central basin (agriculture 53%, mining 25%) but given the scale of the system, mining remained a major contributor to the reservoir sediment column, with high Cu concentrations (ca 450 mg kg^{-1})

observed in reservoir sediment. In the southern tributary, in the absence of mining, natural erosion upstream was dominated by snow melt processes (70%) compared to glacial melt (30%). In the lower reaches downstream of agricultural land, agricultural inputs dominated (53%) with natural erosion in mountain headwaters still contributing (45% overall). Evaluation of reservoir sediment against main geological, natural and anthropogenic tributary-based classification demonstrated significant inputs of sediment from Coastal Mountain agriculture (41%) where steep hillslopes are being actively converted from natural vegetation to plantations (olives, avocados etc). Moreover, sediment contribution coming from mining activities were still considerable (31%).

Future land-management decisions require quantification of soil erosion hotspots for targeted mitigation measures. Natural science results are discussed in the context of parallel participatory approaches to developing stakeholder consensus on future actions.