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# Past Holocene soil erosion modeling as a new way to decipher human-climate-environment interactions on natural geo-ecosystem over long time-scale.

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Soil erosion is a global phenomenon dealing with both environmental, societal and economic issues. Soil erosion is also one of the key processes when it is a matter of Human-climate-environment interactions [1, 2] since if mechanical erosion of continental surfaces initially results from climatic forcing, it can be largely amplified by anthropogenic activities. Using multi-scalar datasets to model long-term (Holocene) erosion fluxes in contrasted areas, where human pressure is well documented by geoarchaeology, we address how landscape evolution, geomorphological processes, ecosystem response and human impacts have been connected over time. Beyond that, such interdisciplinary and integrative approach allow (1) to locally date, qualify, and in particular quantify, both climate variability (rainfall) and impacts of human activities on soils, and (2) to discuss of potential feedback mechanisms and the legacy of past socio-cultural systems on actual geo-ecosystems.

Lacustrine sediment represents one of the more relevant natural archives in order to reconstruct environmental or climatic variability and human activities over the past thousand years. Over the last 50 years, the edges of lakes Paladru (low altitude site, 640 m a.s.l.) and Blanc Huez (high-altitude site, 2250 m a.s.l.), both located in Western French Alps and therefore sensitive to the same climatic influences, have been deeply studied by archaeologists who documented and dated periods of enhanced human pressures (agriculture, mining [3, 4]). In these two case-studies, we were therefore able to confront the specific calendars of local human activities with past landscape evolution (vegetation cover, 5) and soil erosion fluxes reconstituted from specific organic tracers quantified into the lacustrine sediments [3, 6]. Results demonstrated that, over the Holocene, climatic forcing, and more particularly glacial fluctuations, influenced human accessibility to high-altitude sites (lake Blanc Huez) and therefore regulated the anthropogenic impacts on the geo-ecosystem; whereas none feedback was identified at lower altitude (lake Paladru) at least after the Bronze Age period. Independent soil erosion modelling performed on the two sites add more information. Between 10,000 and 5500 cal years BP, annual rainfall estimations are the same for the two sites (around 300 mm per year), demonstrating that for both sites, soil erosion was only dependent of climate variability and rainfall intensity over this period. After 5500 cal years BP, the two models clearly differ, with a systematic overestimation of the sediment budget delivered into lake Paladru; and this time-interval matches the beginning of agricultural practices in the vicinity of this lake [3]. It suggests that human-induced soil erosion could be effective since the Neolithic period. Indeed, according to models, agrarian activities would explain up to 50% of soil erosion within the catchment area of lake Paladru between the Bronze Age and the Middle Age, suggesting that the actual geomorphology of the drainage basin is inherited from several millenary and not only from modern activities.

[1] Dearing et al., 2006
[2] Ojima et al., 1994
[3] Simonneau et al., 2013, JAS
[4] Garçon et al., 2012
[5] Doyen et al., 2016
[6] Simonneau et al., 2014, QSR