Reconstructing the transition of hillslope denudation in granite watersheds using cosmogenic nuclides: quantifying the anthropogenic impacts on soil coverage in the Tanakami Mountains, central Japan

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We quantify the anthropogenic acceleration of hillslope denudation by cosmogenic ^{10}Be measurements in detrital sand from watersheds with different hillslope coverage. We then reconstruct the anthropogenic environmental change through the detailed analysis of sediment cores obtained at the outlet of the watershed where significantly affected by human impact on hillslope coverage.
The investigated granite watersheds are located in the Tanakami mountains, about 20 km to the southeast of Kyoto, Japan. The present watersheds can be categorized into three types: 1) kept forested and naturally soil-mantled watersheds without significant human impact, 2) devastated and still bedrock-exposed watersheds, and 3) artificially reforested and thin soil coverage watersheds. The ^{10}Be concentration in forested watersheds indicates higher varying values (4.8×10^4–8.9×10^4 atoms g^{-1}). Assuming steady-state denudation, the non-impacted natural watersheds in this area have been denuded at rates ranging from 1.4×10^2–2.6×10^2 g^{-1} m^{-2} yr^{-1}. Whereas ^{10}Be concentration in devastated or reforested watersheds show lower constant values (1.9×10^4–4.0×10^4 atoms g^{-1}). Once the soil layer on hillslope have been thoroughly removed, the current fluvial sediment originates from the uppermost part of the saprolite. The ^{10}Be concentration in sample can not recover in the 10^2–10^3 yr timescale. Thus, the difference in ^{10}Be concentration can be explained by mass loss from hillslope due to the human impact. In the case of Tanakami Mountains, the thickness of removed material from hillslopes should have reached from 0.57±0.14–2.04±0.31 m for the past few hundred years since initiation of overexploitation on the forest resources.
Sediment that was washed away from hillslope due to the anthropogenic impact is widely distributed and filled the channel around the outlet of Tenjin watershed which is located in west side of Tanakami mountain. The depth profile of ^{10}Be in the sediment core collected at the point show gradually degrease forested watershed level (5.8×10^4 atoms g^{-1}) at bottom (2723–2490 cal BP) to devastated watershed level (2.6×10^4 atoms g^{-1}) at surface, changeling as repeatedly increases and decreases. The tendency emerged at the layer dated around 918–793 cal BP. The upper layer of that, charcoals that dated older than the lower samples were included in the layers (3000–2426 cal BP, 4289–4091 cal BP). Once the sediment produced from the upper part of the saprolite by freeze and thawing in winter and eroded by surface erosion in monsoon, ^{10}Be concentration in sediment should be getting lower. While, during heavy rainfall events, the remaining soil layers with organic material in watershed should be eroded, resulting in a temporary increase in the ^{10}Be concentration with reversals in ^{14}C age in the sediment. The anthropogenic deforestation must have progressed from the front to the interior. Our results indicate that if we continue to overexploit forest resources to a tipping point that vegetation recovery can not keep up the condition, the soil mantled on hillslope will be completely removed and will not be able to return to its original state.

Keywords: physical geography, human impact, tipping-points, cosmogenic nuclide, radiocarbon dating

