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Topographic control on soil depth and chemical weathering in subtropical Brazil

Liesa Brosens (1), Benjamin Campforts (1), Jérémy Robinet (1), Veerle Vanacker (2), Yolanda Ameijeiras Mariño (2), Jean Minella (3), and Gerard Govers (1)

(1) Division of Geography, Department of Earth and Environmental Sciences, KU Leuven, Leuven, Belgium (liesa.brosens@kuleuven.be), (2) Earth and Life Institute, Georges Lemaître Centre for Earth and Climate Research, Université Catholique de Louvain, Louvain-la-Neuve, Belgium, (3) Institute of Hydraulic Research (IPH), Federal University of Rio Grande do Sul (UFRGS), Porto Alegre, Brazil

Soil thickness and residence time are regulated by a dynamic interplay between soil formation and lateral transport of soil particles and solutes. Geochemical variables and soil physical properties have widely been used to infer soil development and chemical weathering. The spatial variation in soil thickness along slope gives information on soil transport mechanisms, whereas chemical depletion indices are a measure of the weathering degree of the soil. We propose the use of an integrated approach to analyze the topographic control on soil depth and chemical weathering. In this paper, we applied this framework to well-developed subtropical soils, and derived quantitative information on soil physical and chemical properties from field measurements. In a subtropical region in southern Brazil, we sampled soils at 100 mid-slope positions having slope gradients between 2.5 and 41°. The weathering degree was determined using three chemical weathering indices: the ratio of iron oxides to total iron (Fed/Fet), the chemical index of alteration (CIA) and the total reserve in bases (TRB). Our results show that soil depth and weathering degree decrease with increasing slope steepness. The residence time, defined as the average transit time of soil particles since their detachment from the bedrock, was constrained between 1.1 and 197 Myr. Residence times exponentially decrease with increasing slope steepness. Combining information from the weathering degrees and soil residence time allowed us to derive soil chemical weathering rates, which decrease from 8.38e-7 to 4.89e-9 kg m-2 yr-1 (for the change in total bases) with increasing residence time and decreasing slope steepness. Our approach suggests that soil weathering rates can be very low and might vary by two orders of magnitude depending on topographic position. Notwithstanding the model assumptions and uncertainties on the measured data, we demonstrate the potential of an integrated approach, where field data are integrated in a numerical model to unravel the complex journey of soils over hillslopes.