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Effects of landslides on terrestrial carbon stocks with a coupled geomorphic-biologic model: southeast Alaska, United States

ADAM M BOOTH[1], BRYCE VASCIK[1], BRIAN BUMA[2] AND SONIA NAGORSKI[3]

[1]Portland State University
[2]University of Colorado-Denver
[3]University of Alaska Southeast

Presenting Author: boothad@pdx.edu

Landslides are an important driver of the global carbon (C) cycle because they transfer terrestrial C in biomass and soil from hillslopes to channels, where it can subsequently be transported to depocenters and sequestered for geologic time scales. Landslides also redistribute C across the landscape, transfer it among pools with different residence times, and therefore likely affect the size of the terrestrial C reservoir itself. Such feedbacks have been quantified for surficial erosion, primarily on agricultural lands, but have not for landslides in natural, forested settings, which contain a disproportionately high amount of global terrestrial C. In this study, we use data on C stocks and landslides in temperate rainforests of southeast Alaska, United States, to derive a novel model that explicitly couples stochastic landsliding with the terrestrial C cycle. Landsliding determines lateral C fluxes, while a pool-and-flux model for living biomass, dead biomass, and soil C governs vertical C fluxes. Compared to a base case of no landslides, modeling landslides at the historically observed rate of 0.002-0.02 landslides/km^2/yr increases total terrestrial C stocks by 2-7%. This boost primarily results from landslides deeply burying biomass and soil C on the foot slopes of steep-walled, glacially-sculpted valleys, where it has a longer residence time. The characteristic response times for the living biomass, dead biomass, and soil C pools in the base case are 100, 150, and 3,900 yrs, respectively. Landsliding negligibly increases the response time of the living biomass C pool, but consistently decreases the response time of the dead biomass C pool by 3-5% and that of the soil C pool by 9-17%. These results imply that relatively frequent landsliding in forested southeast Alaska perpetually elevates the flux of C from biomass to soil, thereby boosting total terrestrial C stocks and shortening the overall terrestrial C reservoir's response time. A sensitivity analysis shows that the landslide-induced boost in terrestrial C increases monotonically with landslide frequency. This implies a negative feedback between increases in atmospheric carbon dioxide, which is predicted to increase landslide frequency via increased precipitation extremes in many parts of the forested world, and the landslide-induced terrestrial C sink.