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A Wet Layered Sloping Sponge? The Role of Volcanic Ash Soils in Water Transport and Tracer Mixing at a Tropical Hillslope

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Hillslope soils developed on volcanic ash (Andosols) provide key hydrological services such as water storage and streamflow regulation in montane environments. Yet, little is known about how they influence subsurface water flow paths and flow transport and mixing dynamics. To fill this knowledge gap, we analyzed a unique 3-year dataset of hourly precipitation, soil moisture, and groundwater level and weekly precipitation and soil water stable isotope data collected along a steep hillslope transect underlain by Andosols. In combination with a detailed characterization of soil properties, we investigated how these soils influence water transport and tracer mixing in the subsurface. Our results indicate that the high organic matter (33-42%) and clay (29-31%) content of the soils' organic horizon and an abrupt change in hydraulic conductivity between the highly conductive rooted soil layer and a low conductive underlying layer results in a perched water layer that remains near saturated year-round. Despite the formation of the latter, our isotope-based water age estimations depict that water resides within the organic horizon of the soils for short periods (2-4 weeks). The dynamics of soil moisture suggest a fast transfer of hydraulic potentials (few hours) along the entire soil profile in response to rainfall events. This hydraulic response is explained by the exponential shape of the soils' water retention curves that facilitate a rapid vertical mobilization of water through the porous soil matrix. These findings indicate that the hydrological behavior of volcanic ash soils resemble that of a "layered sponge" in which vertical flow paths are dominant despite the formation of a perched water layer.