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Effects of soil and vegetation development on surface and subsurface hydrological properties and processes on moraines in the Swiss Alps

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Overland flow (OF) and subsurface flow (SSF) are key processes that determine the streamflow response to precipitation, as well as water quality, but are affected by the land surface and soil characteristics. They can also modify the shape of our landscape. However, our understanding of the evolution of OF and SSF characteristics and the feedback mechanisms between hydrological, pedological, biological and geormorphological processes that affect OF and SSF during landscape evolution is still limited.

We used a space-for-time approach and studied 3 plots (4m x 6m each) on four different aged moraines (several decades to ~13.500 years) on the Sustenpass near the Steinglacier and in the karstic glacier foreland of the Griessfirn near Klausenpass (total of 24 plots) to determine how OF & SSF change during landscape evolution. We used artificial rainfall experiments with high rainfall intensities to determine runoff ratios, peak flow rates, timing and duration of OF & SSF. The addition of tracers (^{2}H and NaCl) to the sprinkling water and sampling of soil water allowed us to determine the degree of mixing of the applied rainfall with water in the soil. Measurements during natural rainfall events helped to determine the impact of the rainfall volume and intensity on the runoff generation. In addition, the runoff samples and sensor-based turbidity measurements of OF provide an estimate of the erosion rates during extreme events. In order to link the differences in runoff generation with the pedological and biological characteristics of the slopes, vegetation cover, root density, soil texture, soil aggregate stability, and the saturated hydraulic conductivity (K_{sat}) were measured as well.

The results show that K_{sat} at both study areas decreases with moraine age and soil depth and is mainly driven by the increase in silt and clay content. Despite the high K_{sat} values, local OF occurs frequently on the youngest moraines due to the large rock and stone cover. Sediment flux and the related erosion rates are largest for the young moraines, since vegetation cover and soil aggregate stability are small. Soil and vegetation development change major OF and SSF characteristics during landscape development, such as the mixing processes and the pre-event water fraction in OF & SSF, which both increase for the older moraines. However, the rate of these changes during landscape evolution is controlled by the parent material. These results can be used to inform landscape evolution models and help us to understand processes within the critical zone during the first millennia of soil development.