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A new framework for the quantification of the hydrological connectivity of vegetated slopes

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Lateral preferential subsurface flow is a dominant process in many forest catchments during intense and short rainfall events. Recent studies and field observations indicate that roots increase the hydrological efficiency of preferential-flow path networks, directly and indirectly. This leads to the proposed new framework which is based on the hypothesis that root distributions at hillslopes are influenced by the structure of vegetation cover and the species composition. Thus, under various antecedent soil moisture conditions, the composition and structure of the canopy impacts the root distribution, the network of preferential flow paths, and ultimately the drainage efficiency of vegetated slopes.
In Switzerland protection forests are considered important in mitigating flood risks. Their increased root density increases both, water storage and preferential flow paths leading to rapid flow accumulations that prominently reduce peak-flow. Protection forests are subject of national management programs and their flood-mitigation effects are recognized in the national guidelines (NaiS) which consider both, soil types and stand characteristics. However, the guidelines include only the water storage capacity, while methods for the quantification of the forests' protective power are poorly developed and frequently subject of controversy.

The objective of this work is to quantify the impact of the connectivity of preferential-flow paths on the hydrological response of vegetated hillslopes on one hand, and the impact of the structure and species composition of the canopy on the connectivity on the other hand.
Sprinkling experiments simulating extreme rainfall events are used to characterize the relationship between preferential subsurface flow and root distributions at soil profile scale within plots 0.5 m long and 0.5 m deep. Root distributions at 30 profiles were analyzed and 20 sprinkling experiments were performed in a forest dominated by spruce (Picea abies L.) in the northern foothills of the Swiss alps (canton of Bern). A validated root-distribution model is used to characterize the spatial distribution of roots, from which networks of preferential flow paths are inferred at the scale of the forest stand. The spatial distributions of flow paths were applied to a simple model that quantifies the hydrological connectivity of vegetated hillslopes of various forest structures and soil conditions.
The theoretical investigations shed light on the impact of silvicultural measures on runoff behavior of vegetated slopes. The investigations' goal is to demonstrate the relationships between silviculutral interventions on one side and the modifications of the hydrological network on the other side. Of main interest is how the mechanisms influence the dynamics of the areas contributing to runoff during rainfall events and thus the magnitude of peak-flow.