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Changing controls of soil water retention in an alpine watershed: integrating sedimentological and ecological processes

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Soil water retention (SWR) is a critical soil hydraulic property which governs soil water storage, redistribution, availability and potential evaporation, and thus has profound influence on hydrological processes and ecological functions in terrestrial ecosystems. Many soil properties have an effect on SWR, and several of them such as particle size distribution, soil organic matter content and bulk density have been widely used to build pedotransfer functions (PTFs) at different scales to predict SWR. However, the effects of these soil properties on SWR are not independent from each other, which underlines the dependence of all PTFs on the respective dataset and scale dependency. This causes inadequacy of most hydrological models and a dilemma for watershed hydrological modeling in regions with high spatial heterogeneity of soil properties.

The Qilian Mountains on the northeastern Tibetan Plateau represent such situation. Soils across the Qilian Mountains show a high degree of spatial variability. Sedimentological and pedological studies indicate that the soils vary mainly as a function of sedimentological and biological processes, both of which are largely determined by geomorphological settings. To inspect how SWR is affected by these processes, we analyzed 27 soil horizons from 11 profiles in a typical alpine watershed of the Qilian Mountains. These soils were distributed in three geomorphic settings. Three soils were on floodplains, four on alluvial fans and four on hillslopes. Three major sediment types, i.e., aeolian sediments, fluvial sediments and periglacial slope deposits were identified. Among them, aeolian sediments were rather uniform in texture (silt loam), while fluvial sediments were more diverse and were further subdivided into silty, sandy and gravelly fluvial deposits. Periglacial slope deposits were excluded in this study because large-size rock fragments hindered sampling them with steel cylinders. The parent materials of 13 soil horizons were identified as fluvial sediments (three silty fluvial deposits, eight sandy fluvial deposits and three fluvial gravels), and 14 soil horizons had formed in aeolian sediments (all aeolian silts). For each soil horizon, soil water contents were measured at saturation (SAT), -33 kPa (field capacity) and -1500 kPa (wilting point) by use of a pressure plate apparatus. Principle component analysis and correlation analysis revealed strong correlations between SWR (SAT, field capacity and wilting point), soil organic carbon (SOC) content and (clay+silt) content. However, the controlling factor for SWR differed for aeolian and fluvial sediments. In fluvial sediments, (clay+silt) content largely determined SAT (r^2=0.55), field capacity (r^2=0.94) and wilting point (r^2=0.97). In aeolian sediments, due to their homogeneously high silt contents, no significant influence on SWR was found. In these sediments, the accumulation of SOC significantly increased SAT (r^2=0.75), field capacity (r^2=0.66) and wilting point (r^2=0.72). Also in the fluvial sediments, SOC showed significant correlations with SAT (r^2=0.54), field capacity (r^2=0.74) and wilting point (r^2=0.67). These results underline the importance of the enhancing effect of SOC on SWR in ecosystems limited by fine particles (clay and silt).

In conclusion, integration of geological, sedimentological, pedological and biological processes lead to a better understanding of SWR and eco-hydrological feedbacks at the watershed scale.