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Grazing in the high alpine and implication for slope stability

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During the last centuries, land use in the alpine zone has led to biologically rich, productive, and stable ecosystems (Körner 2002). Presently, the sustainable use of alpine grasslands is endangered due to either reduced management, complete abandonment, or over-exploitation. Changes in land use have complex ecological effects and may induce changes in vegetation composition (biodiversity), productivity, water balance (catchment value), but also change microclimate and soil structures. Vegetation changes in steep slopes are especially critical, since plant roots are the only forces that fasten soil in steep terrain and counteract the strong gravitational forces on slopes. Therefore, intensification or reduction of land use may enlarge erosion potential in mountains. Increased erosion risks are not only of local, ecological significance, but also of socio-economic relevance since settlements in the valleys may become endangered.

The present study focuses on the functional significance of plant diversity in the high alpine zone on water runoff (1) and sediment loss (2) in steep slopes. The study was carried out in the upper end of the Rhone valley (Swiss central Alps) at an elevation between 2050 m and 2500 m (a. s. l.). We simulated 182 single rain events by means of a portable rain simulator in 91 paired grassland plots ($0.0625\ m^2$). Prior to sprinkling, half of the plots were trampled by hoofed shoes in order to quantify the sheep trampling impact. Runoff water was collected and dry weight of washed out soil particles (sediment loss) was determined.

Multiple regression analysis revealed that water runoff was influenced by the topsoil water content (0-5 cm soil depth) as well as by the coverage of higher plants. In plots where upper soil layers were not extremely dry ($>$ 30 % soil water content), increas-

ing cover of vascular plants significantly reduced water runoff. Dwarf shrub cover of >10 % reduced runoff substantially and water infiltration was almost up to 100 % in shrub-dominated plots. Tasser *et al.* (2003) observed that landslides were significantly more frequent in abandoned land with tall shrub encroachment than in alpine pastures under sustainable use. In addition, root diversity and density was highest under low-intensity management underpinning the interrelation between land use and belowground diversity (Tasser *et al.* 2001).

In line with the negative relationship between vascular plant cover and water runoff, increasing vascular plant cover also reduced sediment loss. A substantial reduction of sediment loss was observed when vascular plants covered more than 80 % ('threshold' value). Therefore, we conclude that a dense, species rich vegetation cover protects most efficiently against soil loss and soil degradation. Simulated sheep trampling had no apparent effect on water runoff, and only slightly more soil particles were washed out from trampled plots, illustrating that alpine vegetation is well adapted to moderate, mechanical impacts of grazing animals.

Extensive land use has evolved species rich, attractive plant communities. Here, we are able to show that high plant diversity is also of functional relevance to well-balanced water relations and to soil erodibility in the high alpine ecosystems.

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