Feature Articles

Is Snow Gliding a Major Soil Erosion Agent in Steep Alpine Areas?

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Snow cover is a key hydrological characteristic of mountain areas. Nevertheless, a majority of studies focused on quantifying rates of soil erosion and sediment transport in steep mountain areas has largely neglected the role of snow cover on soil erosion rates (Stanchi et al., 2014). Soil erosion studies have focused almost exclusively on the snow-free periods even though it is well known that wet avalanches can yield enormous erosive forces (Freppaz et al., 2010; Korup and Rixen, 2014). This raises the question whether annual snow cover and particularly the slow movement of snow packages over the soil surface, termed ‘‘snow gliding’’, contribute significantly to the total soil loss in these areas.

Three different approaches to estimate soil erosion rates were used to address this question. These include (1) the anthropogenic soil tracer ^{137}Cs, (2) the Revised Universal Soil Loss Equation (RUSLE), and (3) direct sediment yield measurements of snow glide deposits. The fallout radionuclide ^{137}Cs integrates total soil loss due to all erosion agents involved, the RUSLE model is suitable to estimate soil loss by water erosion and the sediment yield measurements yield represents a direct estimate of soil removal by snow gliding. Moreover, cumulative snow glide distance was measured for 14 sites and modelled for the surrounding area with the Spatial Snow Glide Model (Leitinger et al., 2008).

The mean measured snow glide distances varied from 2 to 189 cm in the fourteen investigated sites (Figure 1). Most of this variability can be explained by the slope aspect and the surface roughness determined by land use/cover. With increasing surface roughness, the snow glide distance decreases. The modelled snow glide rates from the Spatial Snow Glide Model compared reasonably well with the snow glide measurements and revealed that snow gliding is not a punctual phenomenon but an extensive process especially at the south facing slopes (Figure 1).

The soil erosion rates estimated from the sediment yields of the snow glide deposition ranged from 0.03 to 22.9 t ha^{-1} yr^{-1} with a mean value of 8.4 t ha^{-1} yr^{-1}. The 2012/2013 winter precipitation of 407 mm was quite representative of the long-term average (i.e. 430 mm). However, to verify the effectiveness of snow gliding for a longer temporal scale, the authors additionally used an indirect quantification approach. It was assumed that the difference between total net erosion rate (estimated by the ^{137}Cs approach) and the water soil erosion rate (estimated by RUSLE), termed excess RUSLE erosion rate, corresponds to snow glide triggered soil erosion.

The mean ^{137}Cs based soil erosion rates of 17.8 t ha^{-1} yr^{-1} are four times higher than the average RUSLE estimates. Congruent with RUSLE the ^{137}Cs-based average soil erosion rate on the north facing slopes is lower than on the south facing slopes (by 8.7 t ha^{-1} yr^{-1}). The observed excess RUSLE erosion rate that could be interpreted as snow glide triggered soil erosion is correlated to the measured snow glide distance (Figure 2). With increasing snow glide rates an increase of soil loss is observed. The excess RUSLE erosion rate corresponds well with erosion rates estimated from the sediment yield measurements.

The combined use of RUSLE and ^{137}Cs showed the relevance of the snow glide process for a longer time scale (as compared to the snow glide deposition measurements of one single winter). Additionally, it has highlighted that for an accurate soil erosion prediction in high mountain areas, it is crucial to take into account the erosivity of snow movements. The Spatial Snow Glide Model might serve as a tool to evaluate the spatial relevance of snow gliding for larger areas.

Both approaches indicated that snow gliding is a major soil erosion factor in steep snow-covered mountain grasslands. Surface roughness may reduce snow glide rates particularly on the south facing slopes which are generally more intensively used. This is a key finding with respect to soil conservation since surface roughness can be modified and adapted through an effective land use management.

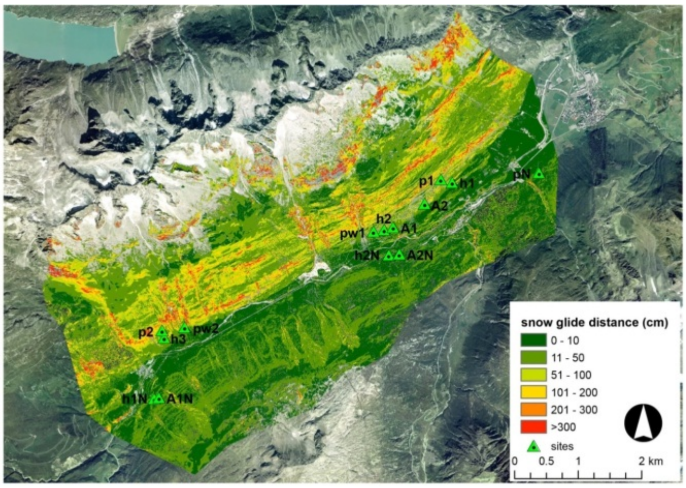

Figure 1. Map of the potential snow glide distance (m) modelled with the Spatial Snow Glide Model of Leitinger et al. (2008).

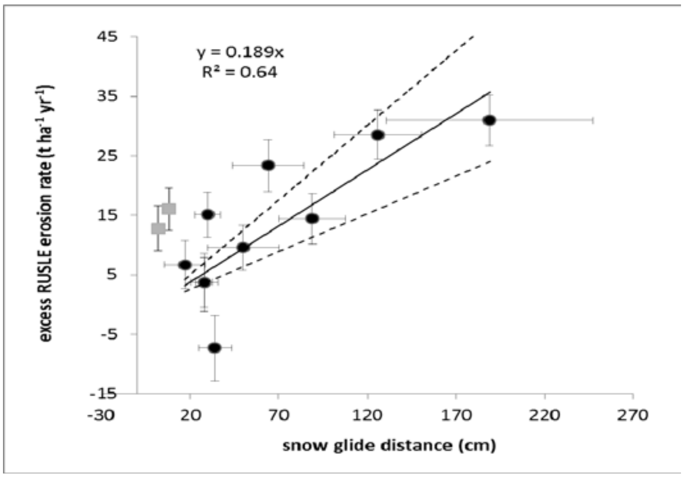

Figure 2. Correlation of the cumulative measured snow glide distances (cm) versus the difference of the ^{137}Cs and RUSLE soil erosion rate (t ha^{-1} yr^{-1}) for the grassland sites (dots, n=10) and the Alnus viridis sites A1N, A2N (squares, n=2). Y-error bars represent the error of both the ^{137}Cs and RUSLE estimates. X-error bars represent the standard deviation of replicate snow glide measurements at one site. Solid line represents a linear regression and the dotted lines the 95% confidence interval.

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Factors Affecting Water Dynamics and Their Assessment in Agricultural Landscapes

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The intensification and extension of agriculture have contributed significantly to the global food production in the last five decades. However, intensification without due attention to the ecosystem services and sustainability of soil and water resources contributed to land and water quality degradation such as soil erosion, decreased soil fertility and quality, salinization and nutrient discharge to surface and ground waters. Land use change from forests to crop lands altered the vegetation pattern and hydrology of landscapes with increased nutrient discharge from crop lands to riverine environment. Global climate change will increase the amount of water required for agriculture in addition to water needed for further irrigation development causing water scarcity in many dry, arid and semi-arid regions. The water and nutrient use efficiencies of agricultural production systems are still below 40% in