Shallow erosion in grassland areas in the Alps. What we know and what we need to investigate further

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Introduction

Loss of soil through shallow erosion in steep grasslands is a common problem in mountain areas. Researchers point to an increase in shallow erosion across the Alpine Space within recent decades (see for instance, Blechschmidt 1990; Meusburger & Alewell 2008; Schauer 1975; Tasser et al. 2005a, b). The partial loss of soil is accompanied by a degradation of its numerous ecosystem services. In addition to its performance in agriculture and forestry, the soil provides important functions as buffer and filter of pollutants from water and air, as carbon sink and as archive of natural and cultural history. Soils in the Alps provide such functions in varying degrees and take a long time to develop because of the limiting conditions in the sometimes extreme locations. Often the soils are shallow and more severely threatened by various morphodynamic processes (Geitner 2007).

The Alpine Convention recognized the special situation of alpine soils and the threats to their performance. It included soils as a resource that deserves protection in the Soil Conservation Protocol and demanded concrete conservation measures (CIPRA 2005). Tasser et al. (2005b) relate the apparent increase in shallow erosion to the changes in land use as a result of changes in the socio-economic framework within the Alpine Space.

Fig. 1: Shallow landslide near Brandberg, Tyrol. Photograph by Clemens Geitner 2010.

Changes in agricultural use take the form of extensive management and abandonment of inaccessible and thus unprofitable mountain grasslands or of an intensification of easily accessible areas. Measures to manage areas extensively go along with a reduction of mountain pasture staff and a concomitant reduction of maintenance activities on the mountain grasslands. This leads to untended grazing if not the complete abandonment of mountain pasture activities, leaving these areas open to natural succession processes. In contrast, more easily accessible areas are grazed more intensively or mown several times a year, increasing the yield through fertilization. In either case, the species composition of the vegetation cover changes and, with a certain time lag, effects the soil and its stability via changes in the litter composition (Tasser et al. 2005a).

This contribution takes stock of selected case studies and raises several questions. What processes are involved? What are the key parameters controlling the phenomenon? How do changes in climate or land use affect this form of erosion?

Shallow erosion (*Blaiken*) formation in the Alps

Various types of shallow erosion are subsumed under the term *Blaiken* in the German-speaking part of the Alps. The etymology of the term *Blaike* [also *Plaike*: from *blaicken*, *blecken* = to reveal something naked or white] points to areas on sloping ground, free of vegetation or only sparsely covered and formed by erosions (cf. Fig. 1) or other damages to the ground cover (Stahr 1997: 8). The term itself does not say anything about any geomorphologic processes involved. The extent of such erosion phenomena is often confined to a few square metres (2 to 200 m^2), the thickness tends to be only a few decimetres, with a maximum depth of two metres (Schauer 1975: 1; Tasser et al. 2005b: 195). Compared with large rock falls or landslides, each event moves only small amounts of material. Affected areas, however, usually show several eroded patches, with considerable overall loss of soil and unconsolidated material (Fig. 2).

Relevant processes and parameters

Various processes are attributed to the morphologically distinct phenomenon of the *Blaike*. On the one hand, they are seen as the result of shallow landslides and as such as a form of gravitational mass movements (Laatsch & Grottenthaler 1975; Schauer 1975: 1). On the other hand, *Blaiken* may be caused by snow-gliding processes and as such are a form of superficial erosion (Blechschmidt 1990; Stahr 1997). Trampling by heavy grazing animals also damages the sward and contributes to superficial erosion and may trigger further erosion (Laatsch & Grottenthaler 1972: 331).

Shallow erosion of the mass movement type usually occur as shallow landslides, i. e. the clods of the sliding mass move downhill along an often plane, preformed gliding horizon in the substratum (Laatsch & Grottenthaler 1975: 317). The gliding horizons are determined by weak or inhomogeneous zones in the substratum. Such a weak zone may be oriented along changes of material and consolidation, e.g. along the boundary between unconsolidated material and contiguous bedrock or within differently structured layers of unconsolidated material, a common occurrence on slopes in the Alps (Fig. 3). In addition, gliding horizons can emerge between soil horizons which are often oriented on such boundaries between layers of unconsolidated material. Biogenic factors may also contribute to destabilizing a slope, for instance if certain kinds of land use lead to a vegetation cover with a homogenous root horizon that is clearly set apart from the substratum (Schauer 1975: 14). For a landslide to occur, it usually takes a critical disposition plus a trigger event, be it heavy rain, snow melt, earthquake or similar.

The occurence of material displacement as superficial erosion through gliding snow has the effect of removing the vegetation cover and parts of the litter layer and the uppermost soil horizons. The emergence of tussock forming species of grass in the wake of abandoned land use encourages erosion as the gliding snow can have a deeper impact on the soil as it hits the rigid tussocks. In most cases, however, the dislocation of material cannot be clearly attributed to a particular process. Rather, this type of erosion is the result of an interaction of the processes described above. Gliding snow, for instance, may initiate further sliding processes as tension fissures the slope and surface water penetrates into the openings. The water then flows off along the weak zones, destabilizing them further. Eventually the mass resting on top slides off (Fig. 4).

Key parameters that influence the emergence of shallow erosion are the geological, topographical and climate framework of the area as well as its soils and vegetation. In addition to natural impact factors, land use plays a decisive role as it is a key determinant of vegetation and soils and thus of the local water balance.

Terrain-related factors

The fundamental geological conditions of a location affect the emergence of shallow erosion primarily through the composition of the unconsolidated sediments. The petrographic composition does not seem to be decisive as this kind of erosion occurs in the whole of the Alpine Space. The characteristics of the solid rock do influence the emergence of erosion events indirectly via their role

Fig. 2: Shallow erosion slope near Brandberg, Tyrol. Photograph by Christoph Wiegand 2010.

in shaping the terrain. The composition and sequence of weathered layers and the soil characteristics are also related to the geological framework conditions.

Decisive topographical-geomorphologic factors include slope inclination, exposition, altitude above sea level and the shape of the terrain. Inclination is most influential as mass movements only occur on surfaces of a certain inclination. Various studies state a minimum incline of 20°, with the majority of shallow erosion events documented at inclinations of 25–45° (e.g. Blechschmidt 1990: 36; Rickli & Graf 2009: 40; Stahr 1997). At inclinations of more than 45°, dislocation occurs less frequently because it is rare for unconsolidated material to remain in such steep locations and consequently no soil or vegetation cover can develop there. Exposition plays a role mainly via the number of sunshine hours, which determine the timing of snow melt, snow gliding and soil water balance, all of which is relevant for the emergence of shallow dislocation. However, there are no documented preferred expositions for the occurrence of shallow erosion. Vertical temperature and precipitation gradients mean that altitude too has a major effect on the water balance and with it on weathering and soil formation. Most important in this respect seems to be the snow situation, since gliding snow and erosion by snow are major factors in the emergence of shallow material displacement. The majority of documented erosion events is situated at altitudes between 1200 and 2500 m (Blechschmidt 1990: 37; Stahr 1997). In addition to the situational features of a location, the concrete shape of the relief also plays a role. Unevenness, for instance microterracing caused by trampling, offers an increased resistance to gliding snow, so that despite the relevant inclination there is no

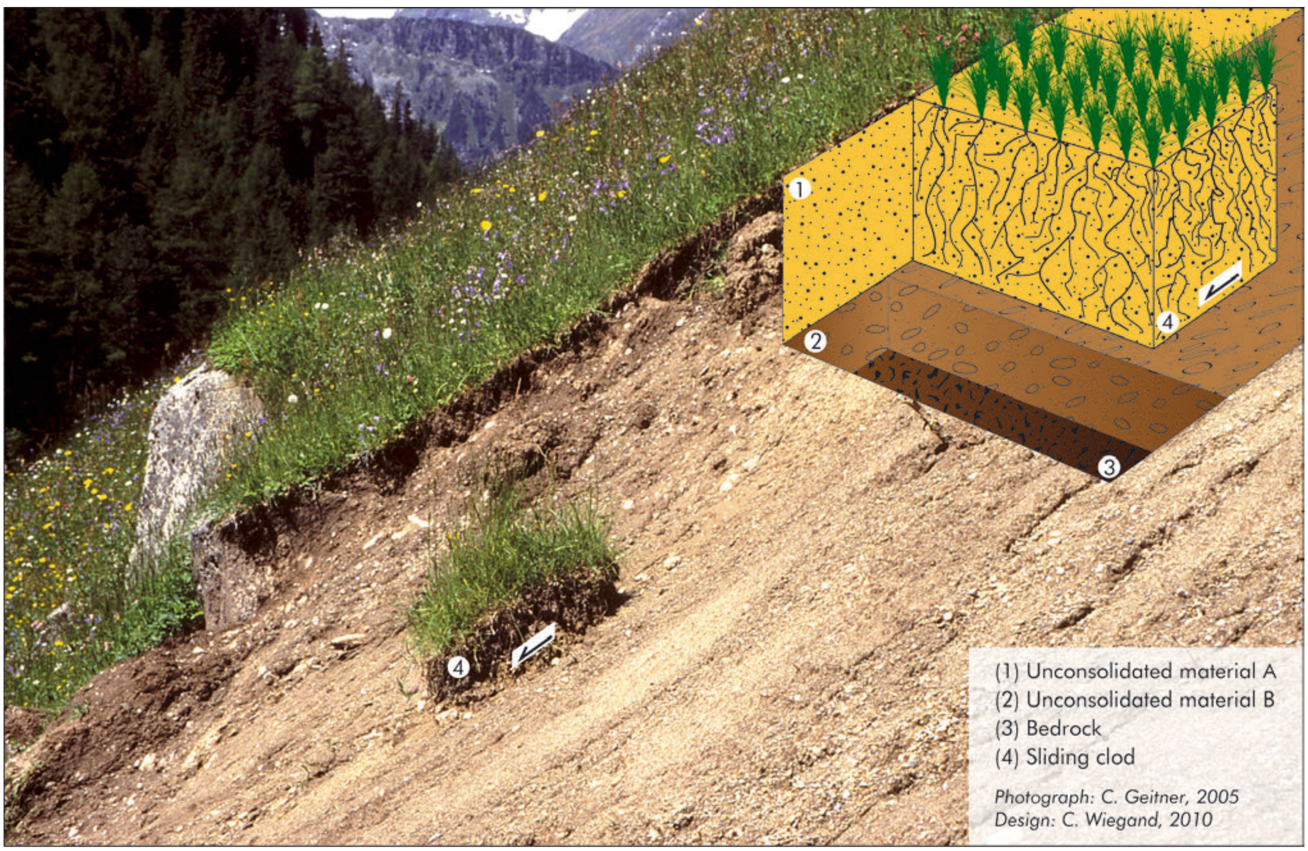

Fig. 3: Schematic diagram and photograph of a shallow landslide near Niederthai, Tyrol.

erosion by snow gliding and no related tension fissures (Blechschmidt 1990: 44; Schauer 1975: 18) (Fig. 4).

The factor soil is highly significant, not least because the majority of shallow erosion in the Alps emerges in the stratum of soil formation. The physical characteristics of a soil, such as stone content, grain size distribution, structure, density and pore distribution, with their capacity for infiltration and water storage have a major impact on stability. Soil chemistry, characterized by lime content, pH value and proportion and quality of organic substances, also controls stability. Humus, for instance, is an essential factor in aggregate formation (clay-humus-coupling) and water balance. The pH value influences mass transfer within a profile, which can lead to badly draining horizons forming, as well as the activity of soil organisms and with it the extent of bioturbation.

Land use and related factors

Vegetation is the result of land use and other local conditions. It influences shallow erosion to some extent via the litter, which controls the biological-chemical soil

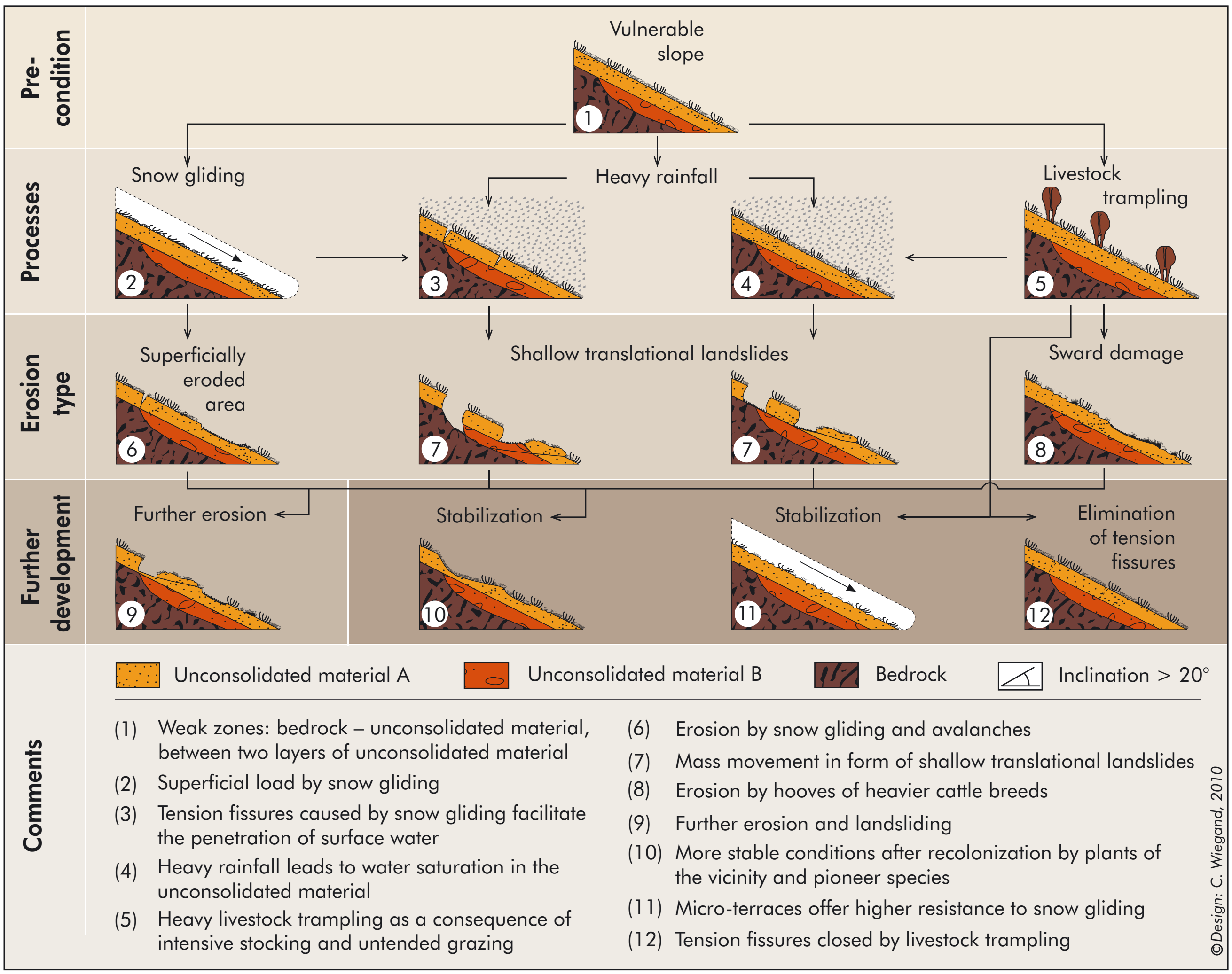

Fig. 4: Simplified overview of processes, types of erosion and possible subsequent developments of shallow erosion.

Fig. 5: Emerging erosion after land abandonment on a slope near Brandberg, Tyrol. Photograph by Christoph Wiegand 2010.

characteristics such as pH value, C / N ratio and humus quality, which in turn affect soil stability. Aspects of root penetration (root forms, density and depth of root penetration) have a considerable impact on the consolidation of the soil material. As a result of interception and evapotranspiration processes, forests exert a positive hydrological influence on slope stability. In addition, they provide mechanical protection by their root penetration (Rickli & Graf 2009: 41).

Once trees had been cleared on the slopes in the montane and subalpine levels to gain land for farming, the forests lost their erosion-reducing effect. The grasslands created in this fashion were used for centuries in a traditional, usually sustainable, way for grazing and meadow culture including the labour-intensive maintenance of the areas. With changes in land use, the maintenance measures are given up first, the vegetation cover changes towards the natural climax state for that location. Below the tree line, this means closed forest cover and above it alpine grassland. Such changes affect soil chemistry and can have a negative impact on soil stability and increase vulnerability to shallow erosion (Fig. 5).

Normally, it is not sufficient to trigger a dislocation of material if one of the factors described is in a critical state, rather it takes a critical combination of these factors. In many cases, an additional trigger is needed to start the erosion process.

Conclusion and outlook

Some studies suggest that the occurrence of shallow erosion is a process complex that has intensified in recent decades and is combined with the loss of soil, an already endangered resource within the Alpine Space. The increased occurrence appears to be caused by progressive changes in land use as regional climate changes show no coherent trends and the other parameters can be considered stable for the period of a few decades. Although we know about the processes and impact factors involved, a number of open questions remain. As yet it is unclear in what way and to what extent changes in land use affect the soil, which characteristics they influence and how these impact on soil stability. Nor are the effects of climate change on the emergence of shallow erosion sufficiently investigated. Long-term effects in particular are poorly understood. The weighting and combination of the individual parameters involved are not entirely clear. Questions remain also on the influence of the substrate. Exact information on distribution and composition of the unconsolidated material is lacking. This is also true of data on the relief where older studies in particular were working with poor resolution.

Although there are numerous local studies, much additional research is needed, in particular in:

- pooling existing case studies (identifying common features and relevant differences)
- deducing superordinate rules on the process and the controlling factors
- examining, comparing and critically assessing the data basis for regional studies
- applying newer methods of remote sensing and geophysics for a more detailed capture of relief and substrate composition
- expanding the soil-scientific data basis on the montane and subalpine grasslands for selected areas

- setting up a database combined with a GIS to capture shallow erosion in certain reference areas
- applying dating methods for an assessment of the landscape-historical dimension of redistribution processes
- developing and setting up a monitoring system to standardize future data for more targeted analyses.

If we want to protect the important resource of soils adequately, we need to improve our understanding and handling of these erosion phenomena. The authors are carrying out additional investigations within the Tyrolean Alps in an effort to reduce the listed information deficits.

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