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Development of soil in heterogeneous landscapes of a high alpine catchment in the Central European Alps

Svenja Müller[1], Katharina Ramskogler[2], Bettina Knoflach[1], Johann Stötter[1], Brigitta Erschbamer[2], Paul Illmer[3], and Clemens Geitner[1]

[1]University of Innsbruck, Institute of Geography, Innsbruck, Austria (svenja.mueller@uibk.ac.at)
[2]University of Innsbruck, Department of Botany, Innsbruck, Austria
[3]University of Innsbruck, Institute of Microbiology, Innsbruck, Austria

In high mountain environments with harsh weather conditions, soil development and its limitations strongly depend on topography and morphodynamics, both leading to heterogeneous landscape patterns of different geological substrate, vegetation, (micro)relief, and (micro)climate. In addition, as glaciers currently are retreating disproportionately strong, a large area is exposed to initial soil development, enabling to study time related issues of soil formation.

These mosaic-like patterns are particularly intensified within the high-alpine and nival zone, due to the dominating influence of cryospheric elements, such as ice (e.g. retreating glaciers), snow (e.g. snowbeds; shallow self-deepening sinks with snow accumulation at altitudes above 2500 m a.s.l.), and frost (e.g. causing solifluction, controlling physical weathering, changing permafrost dynamics, increasing the probability mass movements and sediment transport). The high-alpine environment with its site diversity therefore represents a perfect study area to analyze soil-vegetation-interactions at various microsites within a single catchment.

To study the influence of time, the glacier foreland of Zufall- and Fürkeleferner (Martelltal, South Tyrol) was found to be excellent for an interdisciplinary chronosequence study. Large amounts of historical maps, aerial orthophotos, and remote sensing data are available, enabling reconstructed glacier retreat with a high spatial and temporal accuracy. Study sites of different soil age were chosen for the analysis of various soil and vegetation parameters. The influence of temperature and soil water availability were determined by installing temperature and soil matric potential data loggers.

Furthermore, to study soil development as a function of geological substrate, microrelief, altitude, slope, and microclimate, an additional transect along an altitudinal gradient (Martelltal, South Tyrol, within the maximum extent of Egesen) was sampled and analyzed regarding central soil properties, vegetation, and microclimate. Directly bordering to those sites, heterogeneous and morphodynamically active microsites were investigated. These special sites were characterized by different morphological features, in particularly: soil sinks of different genesis, hilltops, and scree-dominated sites with initial soil development after primary plant succession.

As expected, we found clear trends of soil development with changing altitude and/or time. However, the small-scaled special sites differed distinctly from the reference sites regarding basic soil properties such as soil pH or soil organic matter content, and also remarkably in plant-available NH4-N, microbial activity, and microbial biomass. This was especially true where the water regime was strongly affected by the microrelief.

The observed distinct changes in soil properties within small scales of sometimes only several meters help to better understand and predict soil formation and diversity as well as soil-plant-interactions in high alpine environments of the European Alps.