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Isolated ecosystems on supercooled scree slopes in subalpine environments – interaction between permafrost, soil and vegetation

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In the central European Alps, permafrost can be expected in altitudes above 2300 m a.s.l., where mean annual air temperatures are below -1°C. However, attributed to the thermally induced "chimney effect", isolated permafrost lenses can be found in scree slopes far below the timberline where mean annual air temperature is positive. Usually the supercooled subsurface appears as lenses at the foot of talus slopes, covered by a thick layer of organic material and a unique vegetation composition most obviously characterized by dwarf grown trees ("Hexenwäldli") and azonal plant species. The fact that mean annual air temperature is positive and therefore can be excluded as a driving factor makes these sites unique for studying interdependencies between a supercooled subsurface, plant adaptation and vegetation sociology as well as the soil development.

Three study sites in the Swiss Alps, differing in altitude and substrate (granite, dolomite, limestone) were investigated. Studies covered the permafrost-affected central parts of the slope as well as the surrounding areas. For characterizing distribution and temporal variability of ground ice geophysical methods were applied (electrical resistivity- and seismic refraction tomography). Temperature data loggers were used for monitoring the thermal regime (air-, surface- and soil temperatures). Chemical parameters (pH, C/N ratio) and nutrient contents (N, P, Ca, Mg, Mn, K) were analyzed in different depth levels. Plant communities were analyzed with the Braun-Blanquet method. To characterize physiognomic adaptation of trees, transects have been determined parallel to slope, measuring tree height, diameter and age.

Results show a strong spatial correlation between frozen ground, formation of a thick organic layer (Tangelhumus), azonal plant species distribution and pronounced dwarfing of trees. Surrounding areas with unfrozen subsurface show an – for the particular altitude – expected species and soil composition and normal forest growth. Ellenberg pointer values in central parts of the study sites showed a strong plant adaption to cold temperatures. However, plant sociological analysis did not indicate one clear azonal community, but two different permafrost-plant-communities, one adapted to acidic and the other to calcareous substrates. Dwarf grown trees (e.g. spruce, 63cm high, 122 years old) could be found in permafrost-affected areas of all study sites, while the same species developed normally in the surroundings. Main factor for the physiognomic adaptation seems to be the low temperature in the rooting zone and the correlated shorter vegetation period, as air temperatures and nutrient supplies between the permafrost affected area and its surroundings are comparable.

Pronounced interdependencies between frozen ground distribution, vegetation cover and soil development could be verified for all sites. The supercooled subsurface causes reduced decomposition of organic material as well as dwarfing of trees. In return, Tangelhumus and dwarfed trees positively affect supercooling. Dry organic material thermally insulates the subsurface during summer and prevents/delays thawing, while the high thermal conductivity of the moist or frozen Tangelhumus enhances heat flow and supercooling in winter. In addition, dwarfed trees prevent the formation of a consistent insulating snow cover optimizing thermal fluxes between atmosphere and subsurface.