ranges in northern Europe. Glacier erosion steepens mountains slopes, and when de-glaciated they tend to become unstable and can fail. Permafrost stabilises steep slopes as water in crevasses and in sediments covering the slopes is frozen and therefore fixed. Thawing permafrost and melting ice in cracks and sediments favours instability, more frequent slope failures and greater impact on society and human activity. Recently, landslides were observed rapidly transporting frozen material downslope, indicating the failure of frozen bedrock and sediments. A warmer climate will certainly affect thaw of steep mountain slopes and the possibility of increased risk for slope failures in the future. ○

Finland

By STEPHEN D. GURNEY and JUKKA KÄYHKÖ

MEASURING OVER 1000 km from south to north, the mean annual air temperature (maat) in Finland ranges from +5°C to -2°C. Unlike neighbouring Sweden and Norway, Finland is relatively low-lying, with only occasional summits reaching 1000 m elevation. These factors produce a 'seasonal frost' climate so that much of the country is not affected by permafrost. The northernmost regions of the country (the communes of Enontekiö, Inari and Utsjoki), however, have some areas of 'sporadic' permafrost – isolated pockets of permanently frozen ground underlying less than 30% of the ground surface.

Sporadic permafrost in Finland generally takes one of two forms. The first is found at higher elevations on the fells ('tunturi' in Finnish). In this case, the temperature of the bedrock some metres below the surface is continuously below 0°C. Loss of this type of permafrost will not necessarily result in land surface change or in the generation/release of greenhouse gases.

The second form of sporadic permafrost is found in the palsa mires ('palsa-suo') of northernmost Finland. Palsas are mounds up to 7 m high with a frozen core, which grow in the thick peat of mires due to deep penetration of frost in winter, which does not thaw in the intervening summers (given the insulating effects of the overlying peat). In this setting, only the cores of the palsa mounds actually constitute permafrost and are surrounded by mire, which is only seasonally frozen. Should this type of permafrost be lost, land surface change and greenhouse gas production are likely to ensue.

WITH A WARMING CLIMATE THERE WILL BE AN INCREASE IN THE NUMBER OF DECAYING PALSAS

Globally, areas of 'warm' permafrost are most vulnerable to decay. This 'warm' permafrost is typically sporadic, as discussed above. Since it is found in regions with a maat of between 1.0°C and -2.9°C, just a small shift in mean temperatures can lead to its loss. At present, the majority of permafrost in Finland is found only in Utsjoki and Enontekiö. Utsjoki is the most northerly region, but Enontekiö has, on average, higher elevations and hence the maat are similar, although snow cover differences also play a role.

The sporadic permafrost on the northern fells of Finland has a thickness of at least 50 m. The lower limit has been observed at an altitude of around 300 m in the Utsjoki region, but without geoelectrical soundings it is difficult to map. The active layer (the uppermost part which thaws each summer) above such permafrost is several metres thick. Some have speculated that this permafrost does not reflect the current climate. Further warming will certainly lead to the loss of this permanently frozen ground.

The sporadic permafrost in the frozen cores of the palsas is a rather special case. Here the permafrost occurs in a particular landform (the palsas) and the peat in which they develop. Palsas have a 'life-cycle' and decay when the layer of peat covering their frozen core becomes thin through stretching to accommodate the growth of the core and cracks open, leading to melting. When palsas collapse some of the peat decomposes, which produces greenhouse gases such as methane. With a warming climate there will be an increase in the number of decaying palsas and perhaps an absence of new palsas. This may form part of a positive feedback cycle, whereby warmer conditions lead to enhanced palsa decay, which in turn leads to greater greenhouse gas production.

Although permafrost degradation is a concern, other impacts of climate change on things such as winter snowfall (and hence the period of snow cover) may well have a much greater influence on the lives of people and the native fauna than thawing permafrost, at least in the short term. ○

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