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Editorial: Ecological impacts of degrading permafrost

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Editorial on the Research Topic
Ecological impacts of degrading permafrost

As one of the major cryospheric components, permafrost covers approximately a quarter of the currently exposed land surfaces of the Northern Hemisphere, extending from the Arctic, Subarctic and Boreal zones at high latitudes to the alpine, high-plateau, and mountainous regions at mid-to-low latitudes. In the meantime, the regions of seasonal frost and the near-surface soil layers that undergo seasonal and annual freeze-thaw cycles account for more than one-half of the world's exposed land surfaces.

In general, the spatial distribution and thermal stability of permafrost are primarily controlled by the balance of geothermal flows and redistribution of solar energy at macro-scales, and at local scales by surface characteristics, such as vegetation and snow covers, hydrology, lithology, and geology. The complicated multi-interactions between permafrost and geo-environmental and climatic factors have attracted generations of scientists and engineers to investigate, monitor, and simulate these processes and mechanisms with various methods. In particular, since the 1980s, the extensive and accelerating degradation of permafrost has been increasingly reported for regions at both high latitudes and high elevations. Recently, under the combined influences of climate warming and increasing anthropogenic activities, the degradation of permafrost has been accelerated as manifested by ground surface subsidence and thaw settlement of permafrost soils, rising ground temperature, thickening active layer, disappearance of isolated patches of permafrost, the emergence, expanding or connecting of taliks, as well as shrinking in areal continuity of permafrost. The degradation of permafrost would extensively, profoundly, and inevitably influence the ecological environment and engineering infrastructures in cold regions. However, so far the ecological impacts of the rapidly degrading permafrost have not yet been sufficiently appreciated and evaluated.

In particular, in the context of continuous climate warming and increasing anthropogenic activities, the degradation of permafrost may pose significant risks to sustainable development because of the key roles of permafrost in regulating the carbon pool and ecosystems and freshwater resources, and the safety of engineering facilities. Permafrost acts as a large organic carbon pool as a result of a very slow decomposition rate and extremely low microbial activity caused by subzero temperatures. The soil organic carbon stored in permafrost regions is approximately 1,672 Pg (Tarnocai et al., 2009), outweighing that in the atmosphere and vegetation. In addition, as a potential freshwater reservoir in solid forms, permafrost stores a large amount of ground ice (Zhang et al., 2008), which is likely to be melted as a result of permafrost degradation. Moreover, the successful construction and safe operation of a variety of engineering infrastructures and foundations, such as the railways, highways, airports, dams, and bridges in cold regions (Hjort et al., 2022), require knowledge about the thermophysical and mechanical properties of the frozen soils.

This research collection provides a forum for researchers to share the latest findings on the ecological and engineering impacts of degrading permafrost. In total, there are 17 high-quality original research papers and one review article on this Research Topic, which are contributed by 112 authors. These papers could be roughly categorized into four aspects: 1), Changes of permafrost; 2), Ecological impacts of changing permafrost; 3) Engineering impacts of degrading permafrost, and; 4) Model studies of permafrost distribution and changes.

This collection includes three papers about permafrost changes. In the past, most studies about the degradation of permafrost were generally characterized by melting of ground ice and deepening of the active layer around the top of active permafrost, Dobiński and Kasprzak proposed a new perspective that permafrost degrades from the permafrost base upwards by presenting a special case of such degradation from Hornsund, Svalbard. Based on continuous monitoring of permafrost temperatures in 2013–2020, Yin et al. concurrently found a bottom-up degradation pattern and a complete disappearance of permafrost in 2018 in one island permafrost near the northern lower limit of permafrost in Xidatan along the Qinghai-Tibet Highway on the interior Qinghai-Tibet Plateau (QTP). This is caused by unusually warm summers in the previous 2 years. The degradation of permafrost could be monitored through surface deformation, Du et al. detected the ground deformation in the eastern Tianshan Mountains, China using the small baseline subset interferometric synthetic aperture radar (SBAS-InSAR). They stated that the areas with elevations of 3,150 to 4,275 m a.s.l., slopes of 15–50°, and aspects of southwest, west, and northwest are geologic hazard-prone regions and should receive more attention and field monitoring.

There are nine papers concerning the ecological influences of permafrost, mainly referring to vegetation dynamics, hydrology, dissolved organic carbon (DOC), as well as methane emissions. Carbon storage in the permafrost region is an important component of ecosystem services, attracting a wide range of concerns recently. Li et al. demonstrated tremendous changes to land use/land cover (LULC) induced by climate warming and human activities, and the changes in the LULC accelerated permafrost degradation, leading to obvious changes in the total carbon storage in Heilongjiang Province, Northeast China. Yang et al. clarified that the decomposition and leaching of DOC from organic soil layers and surrounding permafrost sediments were the important carbon sources in ground ice at the top of permafrost. Ma et al. concluded that the permafrost dynamics dominated the aquatic DOC distribution, and permafrost thaw would alter aquatic DOC budgets, eventually adding to atmospheric carbon emissions. Yang et al. examined the cumulative methane emissions under simulated diurnal freeze-thaw cycle (FTC) scenarios, and highlighted the importance of FTCs in stimulating methane emissions and the export of DOC for peat soils collected from the Zoîgé peatlands, the largest peatland complex on the QTP. Regional degradation of permafrost results in many eco-environmental problems under a persistently warming climate and increasing human activities. Jin et al. comprehensively reviewed climate changes, and the distribution and degradation of alpine permafrost, and permafrost degradation-induced changes in hydrology, wetlands, thermokarst lakes, ponds, and vegetation in the source area of the Yellow River, a key water tower of China, and further described the relationship between the lowering permafrost table and succeeding alpine vegetation. To clarify the relationship between permafrost degradation and ecosystem implications, Hu et al. modeled the variations of net primary productivity (NPP) in the Three-River Headwaters Region (TRHR) and found that the increase of NPP in permafrost regions (1.43 g C m^{-2} yr^{-2}) is much higher than that in regions of seasonal frost (0.67 g C m^{-2} yr^{-2}). Wang et al. confirmed the importance of climate and permafrost regimes on vegetation phenological processes by correlating the dynamics of vegetation phenology (the start of the growing season, the end of the growing season, and the growing season length) and freezing index for the three parallel rivers region (TPRR) on the eastern QTP. The surface characteristics cause varied influences on the hydrothermal processes of near-surface soils. Ma et al. emphasized that vegetation acted as a thermal buffer, had a good thermal insulation effect on the ground surface, and was conducive to rainwater infiltration, which were evidenced by the larger annual range of surface temperature and the ground-air temperature difference at denser vegetation sites in regions of seasonally frozen ground. Ni et al. identified adverse/hazardous impacts of the thawing permafrost on human activities on the QTP in the background of climate warming and concluded a doubled human activity index in regions of seasonally frozen ground in comparison with that in the permafrost region.

There are four papers about the engineering impacts of permafrost degradation. Mao et al. evaluated the engineering stability of the National Highway 214 in Qinghai province, China by categorizing permafrost wetlands on the QTP into 15 types in terms of engineering characteristics, permafrost type, waterlogged area ratio, meadow development degree, and then evaluated the engineering stability of the National Highway 214 in Qinghai province, China. Niu et al. proposed the mitigative methods for frost hazards, including strict control of fine grains content and soil moisture content, prioritizing the use of poorly graded filling, and timely and proper drainage of locally accumulated water in the filling layer for the high-speed railbed along the Harbin-Dalian route in Northeast China. Shang et al. found that the cast-in-place pile foundation enhanced the heat exchange between the atmosphere and soil, expanded the annual range of the surrounding ground temperature, and raised the permafrost table. Using the COMSOL model, He et al. quantitatively studied the influencing factors of thermal recovery after backfilling the coal mine pits and suggested that a composite configuration of organic soil, crush-rock layer, and proper re-vegetation measures could effectively cool the backfilled ground and even offset the climate warming at the Gulian Strip Coal Mine near Mo'he in Northeast China.

Permafrost modeling has attracted a wide range of concerns in the past, as the monitoring of permafrost is insufficient to account for the impacts of permafrost changes on the eco-environments. There are two papers about permafrost modeling in this research collection. Peng et al. developed a thermal calculation model and analyzed the thermal impact of water accumulation on the underlying and ambient permafrost. Yang et al. reviewed the modeling progress of the groundwater-surface water interactions under the influences of snow cover and frozen soil and summarized the current status of hydrologic models suitable for cold environments.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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References

Hjort, J., Streletskiy, D., Doré, G., Wu, Q., Bjella, K., Luoto, M., et al. (2022). Impacts of permafrost degradation on infrastructure. *Nat. Rev. Earth Environ.* 3, 24–38. doi:10.1038/s43017-021-00247-8

Tarnocai, C., Canadell, J. G., Schuur, E. A. G., Kuhry, P., Mazhitova, G., Zimov, S., et al. (2009). Soil organic carbon pools in the northern circumpolar permafrost region. *Glob. Biogeochem. Cycles* 23, GB2023. doi:10.1029/2008gb003327

Zhang, T., Barry, R. G., Knowles, K., Heginbottom, J. A., and Brown, J. (2008). Statistics and characteristics of permafrost and ground-ice distribution in the Northern Hemisphere. *Polar Geogr.* 31, 47–68. doi:10.1080/10889370802175895