Impacts of land clearing on areas containing permafrost

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Figure 1: An active area of hay cultivation next to an abandoned area that was abandoned due to thaw subsidence and the formation of a pond at a farm in Fairbanks, AK. Note the elevation difference (>1 m) between the pond and the adjacent cultivated area.

Melissa Ward Jones from the University of Alaska Fairbanks explores the impacts of land clearing on areas with permafrost

Potential northward shift of agricultural production

Climate change is simultaneously decreasing yields by pushing crops to their upper-temperature limits while also simultaneously increasing opportunities to grow crops in regions that are currently not climatically suitable. It is estimated that high-latitude regions, containing primarily boreal ecosystems, will gain the highest land area with a suitable climate to grow globally important crops (Hannah et al., 2020). These regions also contain permafrost (perennially frozen ground), whose consideration is essential for agriculture and agricultural expansion in these regions (Ward Jones et al., 2022).

Interactions between permafrost and land clearing

Permafrost within these projected agricultural areas is mainly found within areas of discontinuous permafrost. Discontinuous permafrost describes patchy permafrost conditions, only surviving in areas with environmental protection, such as certain vegetation cover (such as black spruce or peat) and terrain aspect (e.g., more typical on north-facing slopes). Therefore, when these areas are cleared for uses like agriculture, any underlying permafrost will become exposed and begin to thaw.

Understanding the thermal impacts of land clearing and rates of permafrost thaw can aid in developing management strategies and mitigate potential permafrost-related problems. It is important for efforts to account for varying types of ground cover and permafrost conditions (Ward Jones et al., 2022). Therefore, management strategies need to account for farmers who want to thaw permafrost (particularly if it is ice-poor) and those who wish to preserve it (to avoid ground collapse, or thaw subsidence, from thawing ice-rich permafrost e.g., Figure 1). The Permafrost Grown Project works with farmers in Alaska better to understand permafrost-agriculture interactions, such as land clearing.

The following presents preliminary results by team members Melissa Ward Jones, Benjamin Jones, Glenna Gannon, and Mikhail Kanevskiy that were recently presented at the American Geophysical Fall Meeting in Washington, D.C., in December 2024 (Ward Jones et al., 2024). Depth to the permafrost table were measured in variety of ways, including using an electric drill with auger attachment (Figure 2), ground penetrating radar, historic information and borehole data.

Figure 2: Permafrost Grown team members drill to the permafrost table at a farm in Bethel, AK, using an electric drill with an auger attachment. The image shows ~4 m of auger flights pulled from the ground after permafrost was found.

Preliminary results from Bethel, AK (Tundra Ecosystem)

Bethel is a community with over 6,000 people located within the discontinuous permafrost zone in the Yukon-Kuskokwim Delta Region of southwest Alaska. The vegetation cover in Bethel is primarily moist tundra with small areas containing shrub/tree cover (willow, alder, and resin birch).

An agricultural field was cleared in 2011 for vegetable production (e.g., brassicas and potatoes). Depth to the permafrost table (determined by ground drilling) in an area of unclear tundra adjacent to the agricultural field was between 92 cm and 116 cm, while depth to the permafrost table in the cleared area was 396 cm to 408 cm. The approximate rate of permafrost thaw following land clearing was 27 cm/year. Ground temperatures at 15 cm depth varied by ~4 °C throughout the growing season between the cleared and undisturbed tundra.

Preliminary results from Fairbanks, AK (Boreal Forest Ecosystem)

Fairbanks is the second largest city in the state with a population of ~32,000 people. It is located within the discontinuous zone of Interior (central) Alaska with boreal forest vegetation. Agriculture has been ongoing in the region since the early 1900's.

We are assessing a field cleared between 1908 and 1938 at the University of Alaska Fairbanks Agriculture and Forestry Experiment Station (UAF AFES). Comparing the depth to the permafrost table between 1958 (Pewe, 1958) and 2022 (UAF GI Monitoring Borehole) shows that over 7 m of permafrost has thawed at a rate of approximately 11 cm/year. The permafrost table under the cleared field is deep (over 13 m) and is currently not impacting agricultural activities. Ground temperatures at 15 cm depth varied by over 10 °C between the undisturbed and cultivated areas during the growing season.

Another field belonging to a Permafrost Grown collaborating farm was abandoned in 2019 due to problems with thaw subsidence and continues to experience detectable subsidence as recently as the summer of 2024. Up to 1.9 m of subsidence has been measured between 2010 and 2024 using digital surface models collected by repeat LiDAR (Light Detection and Ranging) surveys. Although the depth to the permafrost table is still unknown (drilling efforts and GPR surveys have not found permafrost in the upper 3 to 4 m) in the abandoned field, it was found at 88 cm depth in an adjacent area of undisturbed forest.

Our ongoing work seeks to understand better the rates of thaw and response trajectories (e.g., topographic changes from thaw subsidence) of permafrost following land clearing. This fundamental knowledge supports the development of best practice guides and mitigation strategies for land clearing and agricultural practices in high-latitude regions.

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References

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