Permafrost Grown: Cultivating convergence between farmers and researchers to foster sustainability for intensifying permafrost-agroecosystems

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Collaborating Farms: Ice Wedge Art and Farm, Goosefoot Farm, Boreal Peonies, Porcupine Ridge Farms, Offbeet Farm, Polar Peonies, Meyers Farm, Roughcut Farm, Slimtree Farm, and Gardens in the Arctic

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Introduction: The rapid degradation of near-surface permafrost is widespread (e.g. Nitze et al., 2018), being driven by a warming Arctic as well as changes in land-surface disturbances with cascading effects on high-latitude ecosystems and communities. Most research is currently focused on the biophysical changes of the Arctic system and understanding how these biophysical changes are affecting northern economies and industry sectors is still in its infancy (Alvarez et al., 2020). With increasing summer air temperatures and growing season length (Figure 1), new agricultural opportunities are expected to emerge in the discontinuous permafrost region, where suitable area to grow globally important crops (for example, wheat, potato, and maize) is predicted to increase (Hannah et al., 2020). While agricultural activity has long been practiced in areas of discontinuous permafrost, the interactions between cultivation and permafrost has received little attention to date and the potential impact to the future of critical crop production from climate-driven thaw following land clearing is not yet understood. *We present an overview of the Permafrost Grown project, including our conceptual scenarios of permafrost degradation (Figure 2) for boreal and subarctic regions (modified from Ward Jones et al., 2022). We present our co-production of knowledge framework (Figures 3 and 4) and discuss how co-producing knowledge between researchers and the Arctic farming community can support adaptable, resilient, and sustainable permafrost-agroecosystems. Finally, we present preliminary data including remote sensing observations of measured subsidence of an abandoned field in the Fairbanks area, AK, USA (Figure 5), a normalized difference vegetation index image of a farm in Two Rivers, AK (Figure 6) and thermal data showing the thermal impact of plastic mulches and crop type (Figures 7 and 8).*

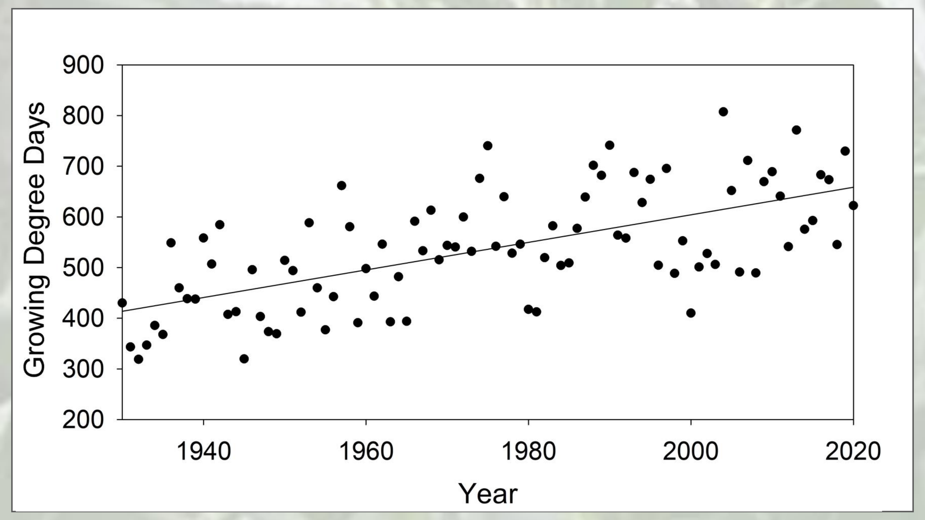

Figure 1: Climate warming is currently benefitting certain aspects of agriculture, such as increasing growing degree days (GDD; a cumulative unit added during the growing season to estimate the heat needed for plants to develop and reach maturity). The GDD for sweet corn (base temperature of 10°C) has increased by 59 % between 1930 and 2020. The ability to consistently grow corn in Interior Alaska has only been possible the last few decades. The background image of corn grown in UAF vegetable trials in 2021.

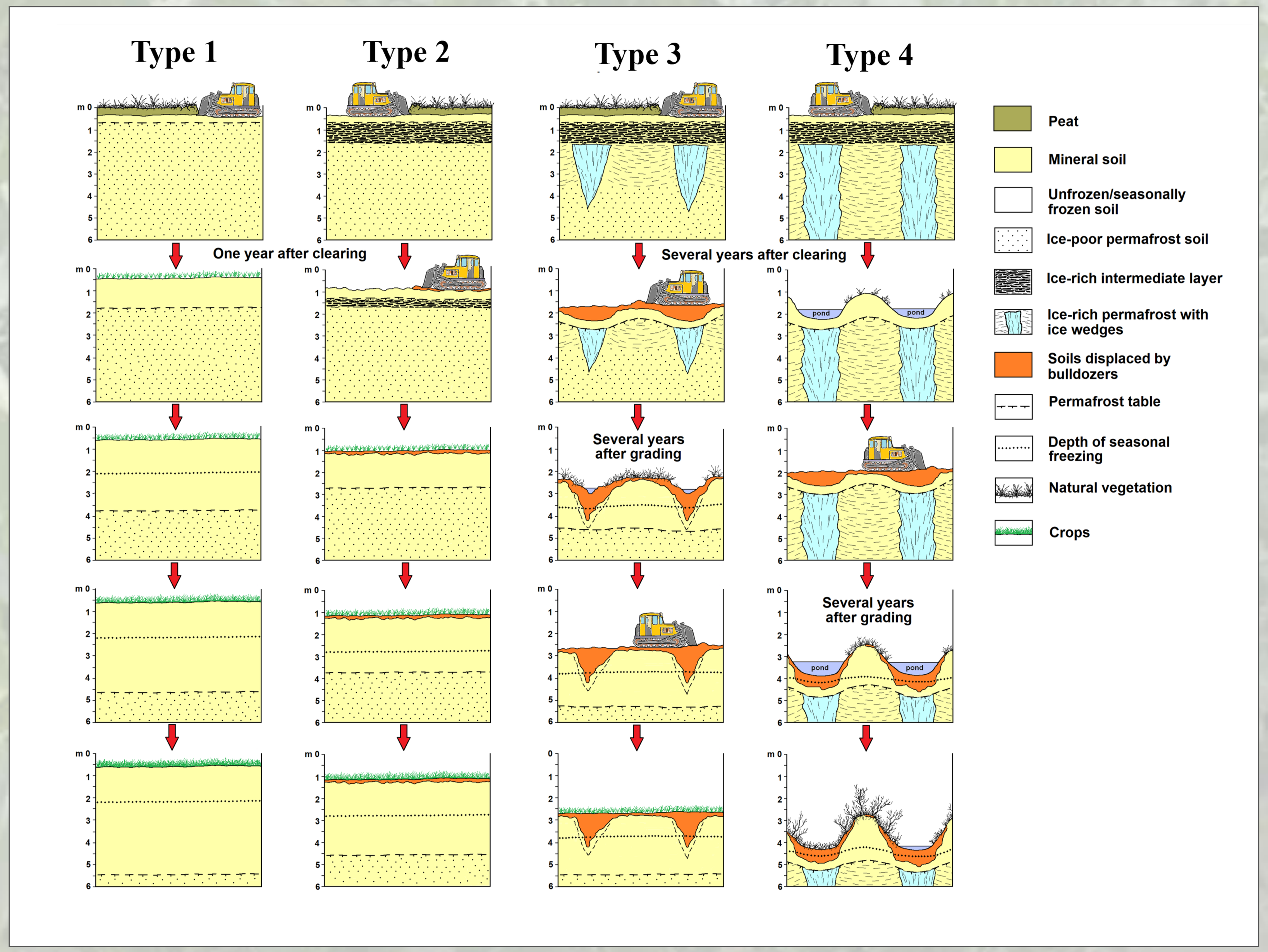

Figure 2: Permafrost degradation scenarios in agricultural fields based on ground ice content and the common practice of surface grading to manage subsidence (modified from Ward Jones et al., 2022).

Type 1 represents ice-poor permafrost where thaw does not lead to significant land surface subsidence.

Type 2 represents an ice-rich intermediate layer of the upper permafrost with thick ice lenses overlaying ice-poor permafrost, where thaw leads to some subsidence that will stop once all the ice lenses have melted; cleared lands do not require significant grading after termination of thaw settlement.

Type 3 and Type 4 represent ice-rich soils with ice wedges of varying vertical extents immediately below an ice-rich intermediate layer; thaw results in thermokarst as shown in Figure 5. Such land is suitable for farming after complete degradation of ice wedges, and lands may be arable after several cycles of grading (Type 3). Continued surface subsidence caused by thawing of deep ice wedges (Type 4) is the most unfavorable for farming because agricultural fields are not navigable, and land surface changes become disruptive to farming activities. Attempts at cultivation of this permafrost type commonly result in abandonment, and additional mitigation techniques need to be developed to cultivate on ice-rich permafrost soils.

Project Methodology and Preliminary Results

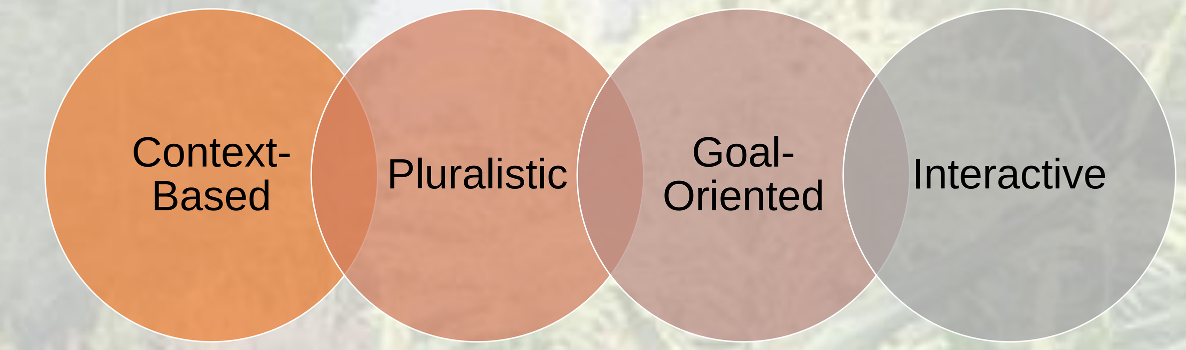

Figure 3: Co-production of knowledge framework principles by Norström et al., 2020.

Figure 4: Example of consultation meetings with farm-collaborators. A Google Earth print out of the farm property was utilized to discuss farm activities, learn about subsidence issues as well as plan for sensor placement and agricultural experiments.

Co-production of Knowledge Framework:

We based our framework from Norström et al., 2020 and Carolan, 2006. Norström et al. (2020) provides four principles that we apply::

a) Context-based: Our research aims to achieve convergence between the social and physical sciences by contextualizing the economic, political, social, and ecological histories surrounding permafrost-agroecosystems.

b) Pluralistic: We recognize there are multiple ways of knowing and doing. We have recruited collaborator farmers that offer a range of perspectives, demographics, skills, types of knowledge, and expertise.

c) Goal-oriented: Our farmer collaborators have been part of the research since proposal development and have and will continue to help guide research questions that define meaningful goals and set project milestones. Furthermore, their early participation will help guide the development of data products that are useful for their needs and the needs of the greater agricultural community.

d) Interactive: We intend a high level of engagement from partner farms, holding bi-annual meetings in addition to workshops and fostering an open two-way communication with frequent interactions and repeated conversations.

Carolan (2006) specifies the differences between **contributory knowledge** and **interactional knowledge**. Contributory knowledge recognizes that all research participants have meaningful knowledge to contribute to a research project however interactional knowledge is needed (on part of the research team) to ensure that knowledge is shared, gained, and understood between all research participants.

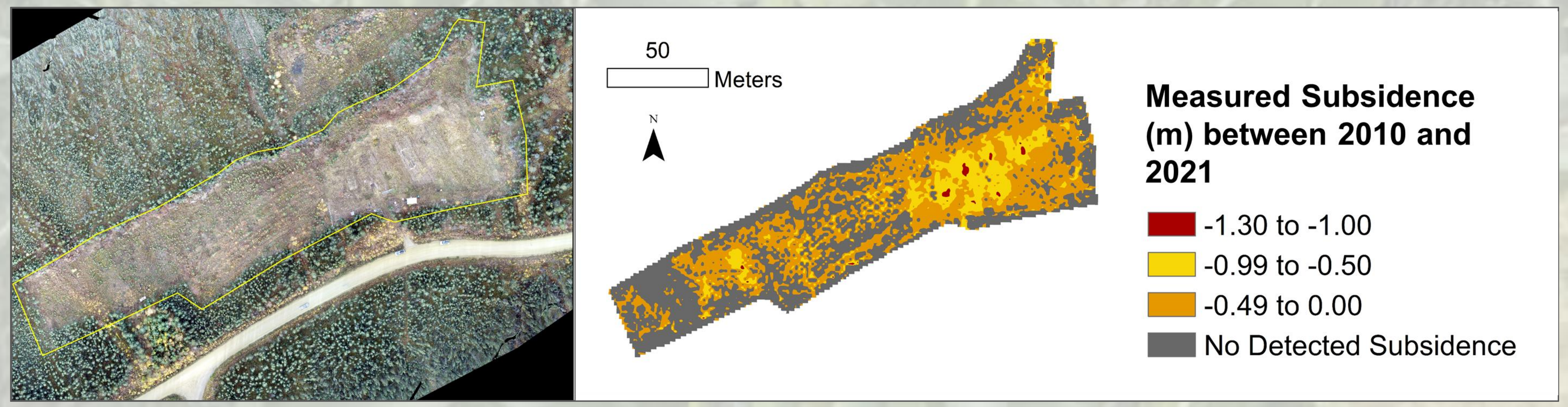

Figure 5: Measured subsidence (thermokarst) of a field that was cleared in 2001, cultivation began in 2002 and was abandoned in 2019. Elevation data used in differencing is a 1.2 m resolution LiDAR digital surface model (DSM) dataset collected in 2010 and a 3 cm resolution DSM collected with a UAV in September 2021. Image on the right shows a mosaic image collected during the Sept. 2021 UAV survey and yellow outlining the field.

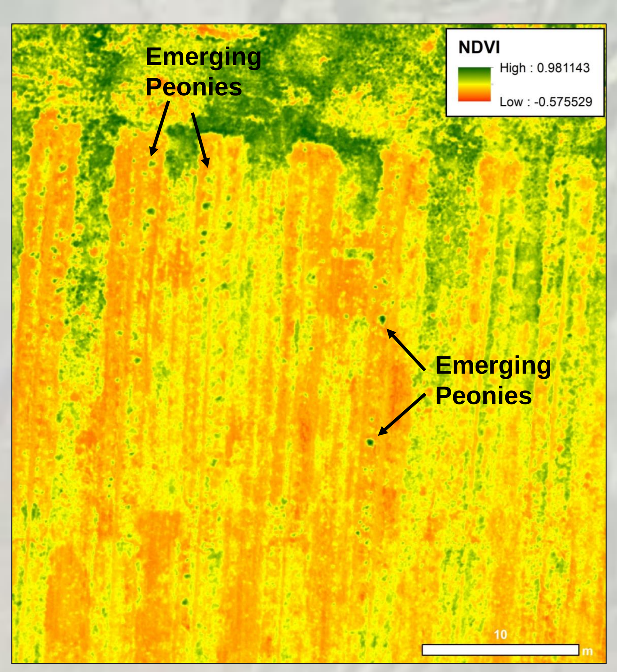

Figure 6: Early season normalized difference vegetation index (NDVI) image of a peony field collected with a UAV. Image is showing recently emerged peony plants. Repeat surveys throughout the growing season can identify areas where permafrost is potentially negatively impacting crop growth.

Figure 7: Preliminary results of determining the thermal impacts of mulches and crop type. 7a shows the carrot trial that had temporary IRT plastic in the early season and 7b shows squash that contained UV resistant plastic.

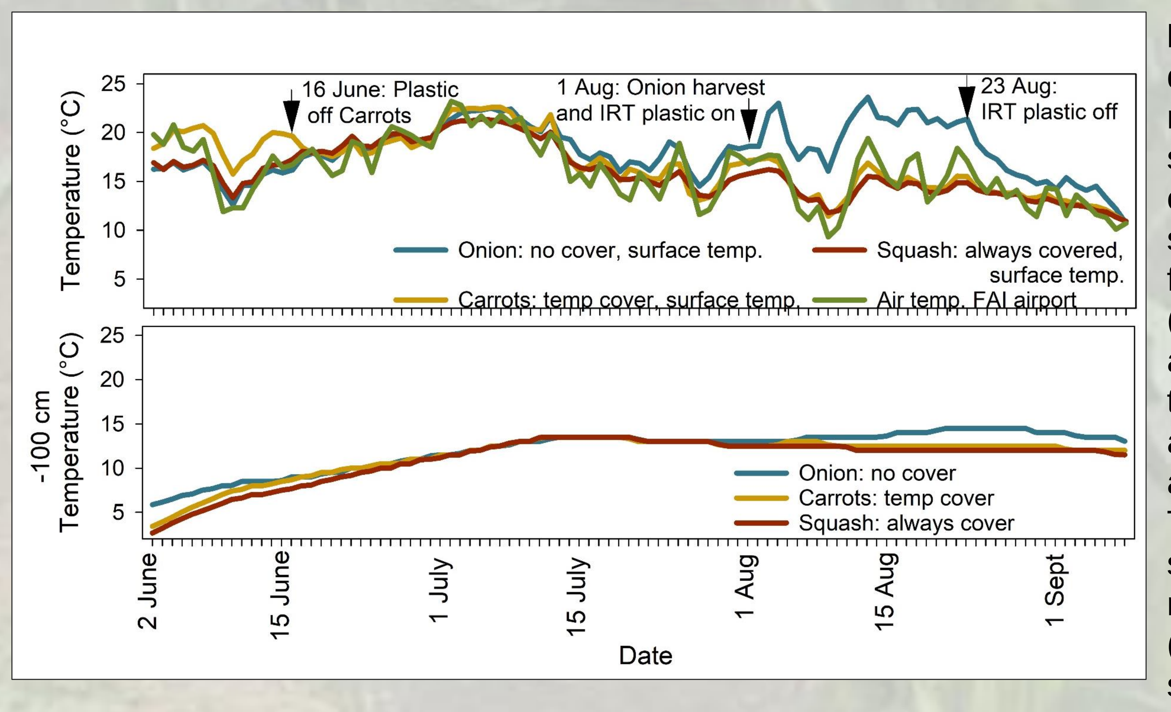

Figure 8: Preliminary results of determining the thermal impacts of mulches and crop type. Temperatures sensors were installed at the surface, 15 cm, 50 cm and 100 cm depths (only surface and 100 cm results are shown) for three crops: onions that had no plastic (however plastic was installed in August after harvest to manage weeds), carrots that had plastic for the first two weeks and squash that was always covered with a UV-resistant mulch. Mean July Surface Temperatures were 19.0 °C (onions, small crop footprint), 18.2 °C, (carrots, moderate crop footprint), and 17.5 °C (squash, largest crop footprint), suggesting crop choice could potentially mitigate potential thaw.

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