Plant-available nutrient dynamics across a gradient of polygonal tundra in Barrow, Alaska (NGEE - Arctic)

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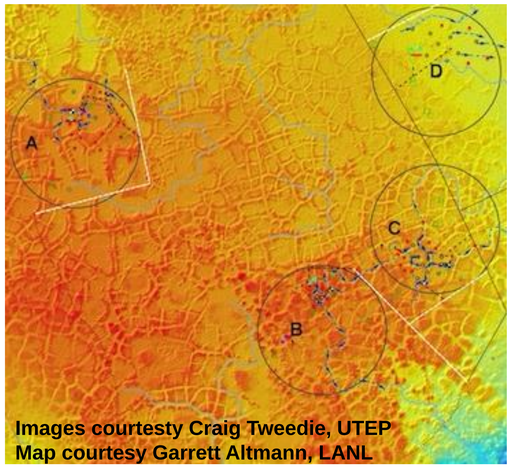


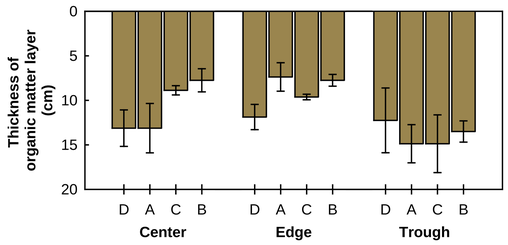
Images courtesy Craig Tweedie, UTEP
Map courtesy Garrett Altmann, LANL

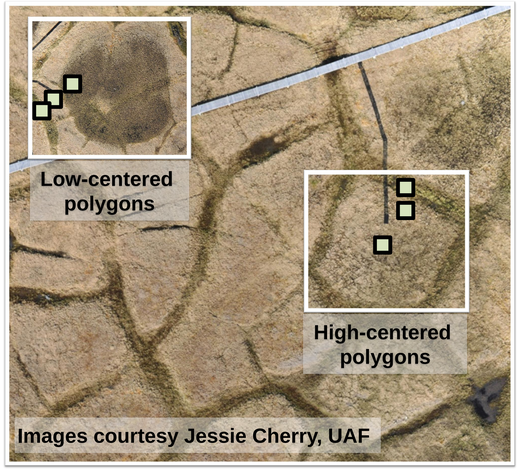
Overview

- The overarching goal of NGEE - Arctic is to advance predictive understanding of the structure and function of Arctic terrestrial ecosystems in response to climate change.
- Permafrost degradation is expected to affect fluxes of CO_2 and CH_4, surface albedo, soil moisture and nutrient availability, and vegetation community composition.
- Sites chosen as the focus of Phase 1 (pictured at left) were located at the Barrow Environmental Observatory (BEO), near Barrow, Alaska, USA on tundra underlain by continuous permafrost.
- The plant community on the BEO is dominated by graminoids, mosses, and lichens (see V. Sloan *et al.* poster).
- **A goal of the Vegetation Dynamics team was to determine differences in soil nutrient availability within and among polygonal features on the tundra to guide modeling and scaling of plant community composition and cover.**

Thickness of soil organic matter

- Soil cores (5-cm diameter) were taken in early August, 2012, to near the bottom of the active layer in C, E, and T microtopography associated with vegetation plots in areas A-D.
- Thickness of the soil organic matter layer was measured before cores were sectioned and frozen for further analysis (soil C, N, and P content, rooting depth distribution, pH, soil C, N and P mineralization). Thanks to Dave McGuire and Eugenie Euskirchen for help in the field.
- The thickness of the organic layer differed across the gradient of polygonal topography. The center of the high-centered polygons (area B) had the least amount of organic matter; troughs in all locations had a thick layer of organic matter.
- Differences in the thickness of the organic layer within and among polygons is likely due to a combination of differences in the amount of plant inputs and the relative saturation of the soil (i.e., anaerobic compared with aerobic decomposition).
- The thickness of the organic matter layer is an important input for models used to project feedbacks from the Arctic to the global carbon cycle (e.g., DOS-TEM).





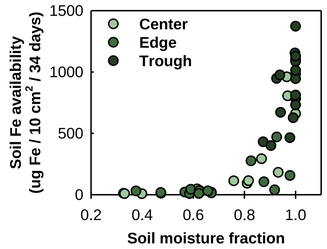
Images courtesy Jessie Cherry, UAF

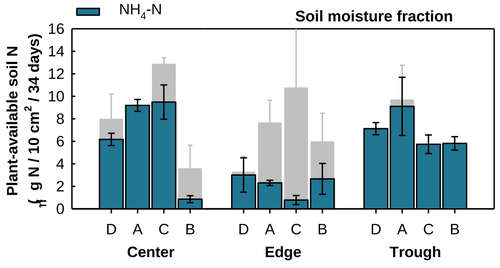
A gradient of permafrost degradation

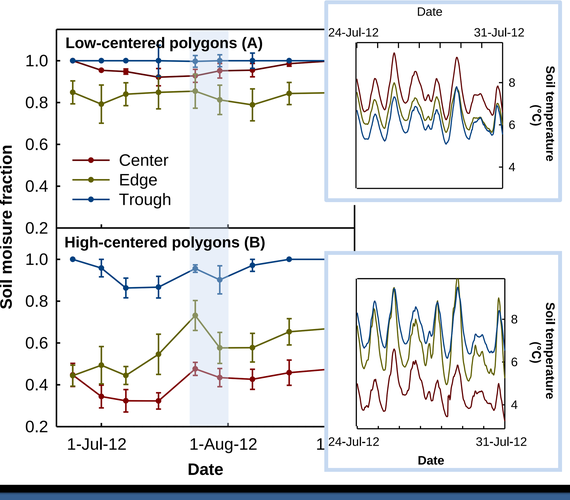
- Four areas of the BEO were chosen for observations associated with Phase 1 of NGEE - Arctic. The areas encompassed polygonal topography of varying age and soil moisture.
- The polygonal gradient (pictured above and at left), in order of increasing dryness, ranged from poorly-defined, low-centered polygons (Area D), walled, low-centered polygons (Area A), flat-centered polygons (Area C), and high-centered polygons (Area B).
- Each area exhibited some degree of microtopography, including a center (C), edge (E), and trough (T), related to the degradation of underlying ice wedges.
- In spring, 2012, the Vegetation Dynamics team placed 1 m × 1 m plots in C, E, and T microtopography in four replicate polygons in each area (48 plots total; e.g., green boxes at left). Data described here were collected adjacent to these plots.

Plant-available nutrients

- Cation- and anion-exchange membranes (Plant-Root Simulators, PRS™) were inserted to 5-cm depth adjacent to vegetation plots on June 23, 2012. Probes were removed, and fresh probes were installed, on July 27, 2012, and again on August 28, 2012. Data shown are from the early growing season (June-July, 2012).
- Nutrients were extracted from probes using 0.5 M HCl, and the extractant was analyzed for multiple nutrients, including NH_4^+, NO_3^-, PO_4^{3-}, and Fe^{3+}.
- Soil moisture was an important factor controlling the availability of Fe, which can influence anaerobic C cycling; Fe availability was greatest in the nearly-saturated troughs.
- Early in the growing season (June-July), total soil inorganic N availability (NH_4-N + NO_3-N) was least in the centers of the high-centered polygons (area B). Patterns were similar later in the growing season (July-August; *data not shown*).
- The relative amount of NH_4^+ and NO_3^- depended on microtopographic position. NO_3^- availability was least in saturated, anaerobic soil in the troughs and low-centered polygons, and greatest in the drier edges.





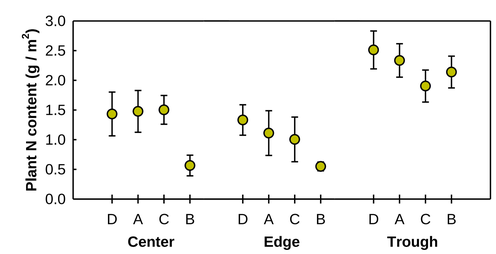


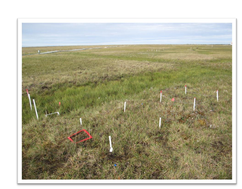
Soil temperature and moisture

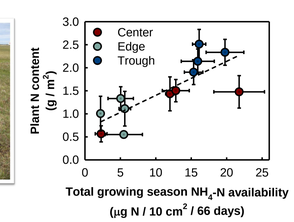
- Soil temperature was measured every 30 minutes throughout the 2012 growing season using HOBO data loggers (Onset Computer Corporation, Inc., Pocasset, MA) installed to 5-cm depth near two replicate vegetation plots in areas A-D.
- Soil moisture fraction was measured weekly using an SM300 Soil Moisture Sensor (Cambridge, UK; 'organic' setting) at 5-cm depth near four replicate vegetation plots in areas A-D. Thanks to Jonathan Brooks for assistance in the field.
- Low-centered polygons tended to be wetter, on average, than high-centered polygons (only areas A and B are shown for comparison), but trough microtopography was near or at saturation (fraction = 1.0) in all locations.
- The wet centers of low-centered polygons tended to be the warmest (1 week in late July is shown for comparison). In contrast, the dry centers of the high-centered polygons were coldest, perhaps because of moss/lichen cover. There were surprisingly strong diurnal fluctuations in soil temperature.
- Differences in soil moisture and temperature within and among the gradient of polygonal topography are expected to affect plant-available nutrients, and therefore plant production.

Plant nutrient content

- Plant biomass, including leaves, stems, and inflorescences, was harvested from small clip plots (0.25 m × 0.25 m) near each permanent vegetation plot in early August, 2012.
- Plants were sorted by species and organ, dried at 70°C, ground into a powder, and analyzed for [N] on an elemental analyzer (Costech Analytical Technologies, Inc., Valencia, CA). Nitrogen content of the vascular plant community (mosses and lichens have not yet been analyzed) was calculated as the product of plant biomass and [N]. Thanks to Jonathan Brooks for assistance in the laboratory.
- Vegetation N content was greatest in trough microtopography, in large part because plant biomass was greatest in the troughs. N content was least in the center and edges of the high-centered polygons (area B).
- Vegetation N content was well-correlated with soil NH_4-N availability (summed over early and late growing season), but not with soil NO_3-N availability (*data not shown*).
- Relationships among vegetation nutrient content and soil nutrient availability could prove useful for modeling plant community dynamics.







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