Assessment of nutrient availability in ice-wedge polygon successional stages in a coastal Arctic tussock tundra in Jago, Alaska

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Introduction

Nutrient availability – predominantly Nitrogen availability – strongly influences plant productivity and distribution in Arctic environments. Recently, the Arctic has experienced warmer winter temperatures and has exhibited varying responses to warming in the face of climate change. Permafrost thaw along the coastal Arctic tundra causes ground subsidence, ponding, and the release of solutes and nutrients, affecting vegetation distribution and leading to various possible positive or negative permafrost thaw feedback loops.

In patterned ground (polygon) permafrost systems, nutrient cycling can vary substantially throughout ice-wedge polygon successional stages. Successional stages of ice-wedge polygons range from undegraded polygons with dry, vegetated, high or flat centers, to heavily degraded ice-wedge polygons with subsided and inundated low centers. As nutrients are released due to thaw and ponding, however, subsequent plant biomass and litter accumulation may play a role in re-vegetating and re-stabilizing the ice wedge polygon. A better understanding of fine-scale spatial and temporal nutrient cycling among these ice-wedge polygon trajectories will improve the ability to predict tundra response to warming.

This study aims to identify and quantify plant-available inorganic nitrogen and total dissolved nitrogen in the soil, water tracks, and ponds of various successional stages of ice-wedge polygons, and to quantify %N and C:N ratios in plant biomass in each successional stage.

Methods and Materials

Sampling took place July 27th – August 2nd in 2018, at a 250m transect in coastal tussock tundra in Jago, Alaska. Six successional stages of ice wedge polygons were identified: tussock tundra (TT), undegraded (UD), degraded initial (DI), degraded advance (DA), stabilized initial (SI), stabilized advanced (SA). There were 3 replicate sites of each successional stage along the transect, and two subset samplings were taken from each site.

- Water samples were taken from various stages of degraded, inundated or water-logged ice-wedge polygons and analyzed with a Lachat Quikchem 8500.
- In order to assess NO_3^- and NH_4^+ uptake in the ice-wedge polygon successional stages, buried bag experiments were buried for a duration of 7 days (data not shown; in progress) and supplemented with AgWestern ion probes. (Buried bags and probes were not possible for heavily degraded, wet sites.)
- Clippings of the common tussock-forming sedge *Eriophorum angustifolium* was also taken from each ice-wedge polygon successional stage to analyze for C:N and use as a benchmark species to compare C:N ratios across site types.

Statistical analyses not yet complete

Site Description

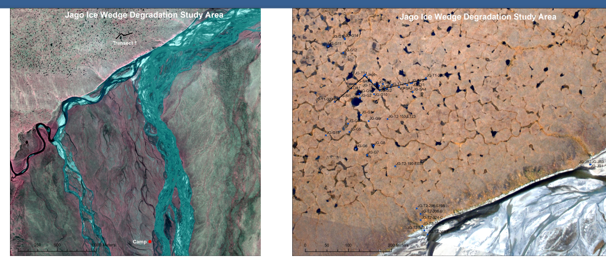

Figure 1. Two aerial shots of the 250m sampling transect on coastal tussock tundra in Jago, Alaska, featuring various successional stages of ice-wedge polygons. (Photos provided by Torre Jorgenson.)

Results

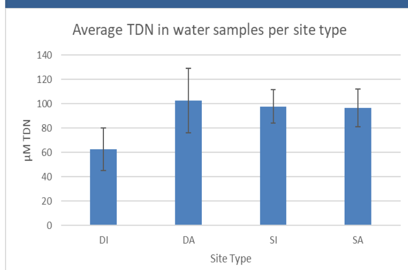

Figure 2. Averaged total dissolved nitrogen (µM) in water samples from successional stages of ice-wedge polygons. Standard deviation reported. (DI = degraded initial; DA = degraded advanced; SI = stabilized initial; SA = stabilized advanced.)

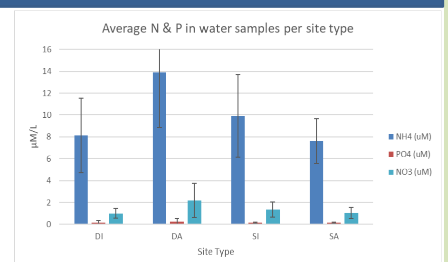

Figure 3. Averaged concentrations (µM/L) of forms of N & P present in water samples from successional stages of ice-wedge polygons. Standard deviation reported. (DI = degraded initial; DA = degraded advanced; SI = stabilized initial; SA = stabilized advanced.)

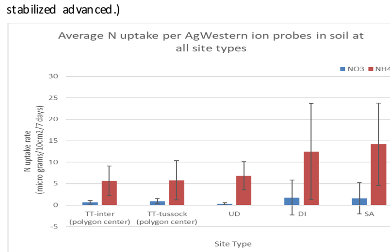

Figure 4. Averaged N uptake (micrograms/10cm2/7 days) of forms of N in soil per AgWestern soil ion probes in successional stages of ice-wedge polygons. Standard deviation reported. (TT = tussock tundra; UD = undegraded ice-wedge; DI = degraded initial; SA = stabilized advanced.)

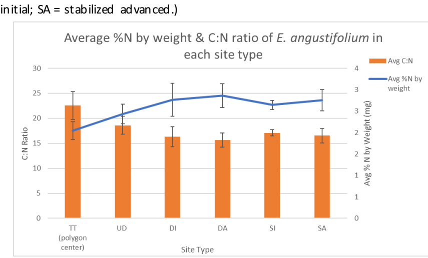

Figure 5. Averaged C:N and %N by weight (mg) in plant tissue of *E. angustifolium* in successional stages of ice-wedge polygons. Standard deviation reported. (TT = tussock tundra; UD = undegraded ice-wedge; DI = degraded initial; DA = degraded advanced; SI = stabilized initial; SA = stabilized advanced.)

Preliminary water sample results show that though total dissolved nitrogen (TDN) is relatively low at all sites, and though there are relatively small concentrations of NH_4^+ and especially NO_3^- at all sites sampled, there is a greater availability of NH_4^+ and TDN in sites that are experiencing ponding, advanced degradation, or initial stabilization, i.e. sites that are waterlogged or inundated. This suggests that permafrost thaw and subsequent release or increase in water at a site may increase N availability to plants. A one-way ANOVA found significant differences in NH_4 ($p = 0.0046$), TDN ($p = 0.00026$), and DON ($p = 0.0002$; data not pictured) among sites.

%N by weight of plant tissue from *E. angustifolium* increases slightly across successional sites, and the AgWestern soil ion probes suggest greater N uptake at sites experiencing some form of degradation. Greater average C:N ratios in *E. angustifolium* are found in tussock tundra (polygon center) and undegraded ice-wedge polygon sites.

Conclusions

When permafrost thaws, the soil organic matter and minerals within the permafrost become available for remobilization and uptake, and the resulting increase in water may play a key role in the storage and transport of nutrients, influencing vegetation response to the warming Arctic.

Future work includes statistical analyses on soil, water, and plant biomass data; completing the assessment of the buried bag incubations to compare with the data from the AgWestern ion probes; analysis of biomass clippings from each ice wedge polygon successional stage to compare functional group composition, mass, and C:N ratios; and further assessment of nutrient availability and plant functional groups in various successional stages of ice-wedge polygons in additional coastal Arctic tundra sites in northern Alaska.

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References

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