Climate, decomposition and carbon feedbacks of tundra shrub expansion

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Objectives of project

Climate change is expected to dramatically alter tundra ecosystems[1]. The abundance of different plants such as shrubs and grasses increasing[2], life events such as the green up and flowering of plants are thought to be shifting at some tundra sites[3]. These changes in the plants could affect important ecosystem processes such as carbon storage[4]. In the last 50 years, rapid shrub expansion has been documented in Alaska, Yukon and NWT, including in the Kluane Lake region[5]. However, vegetation is not changing uniformly across all regions of the tundra biome[2], in part due to differences between vegetation communities. For example, a shift towards greater shrub abundance could change the quantity and quality of leaf and wood litter inputs to tundra soils, and thus is expected to alter decomposition and carbon storage[6].

The objectives of this project are:

1. To investigate growth rates of tundra shrubs in warmer growing conditions using a common garden experiment
2. To measure plant traits (the characteristics of the plant, leaves and stems) and plant phenology (the timing of leaf and flower development over the growing season)
3. To measure decomposition rates (how quickly plant material rots) of tundra vegetation
4. To measure site influences on decomposition along altitudinal and moisture gradients

Progress and current findings

1. Common Garden Experiment

The common garden experiment was established in 2013 at the Kluane Lake airstrip near Silver City and now contains over 800 cuttings of three common willow species (*Salix pulchra* - Diamond-leaf willow, *Salix richardsonii* - Richardson's willow, and *Salix arctica* – *Arctic willow*). This experiment allows us to directly compare the growth of willow shrubs from two populations (Arctic and subarctic), testing whether responses to warming could be constrained by genetic adaptation to local growing conditions. In 2017, we continued existing monitoring of plant growth, but added new protocols to include the measurements of leaf characteristics such as size and thickness. We also set up five time-lapse cameras in the common garden to more accurately capture change in the timing of bud burst and leaf yellowing across the growing season.

The common garden experiment is still an on-going experiment, but we are now developing a clear picture of the differences between willow populations. Initial results indicate that:

1. Willows are continuing to grow very rapidly as they experience warmer conditions. In 2016 we recorded over 1m of new growth recorded in one individual, far above the highest observations in tundra sites. This high growth rate continued in 2017, with some four year old willows now over 1m in height and 2m in width.
2. We have recorded very large differences in growth between willow populations, with southern individuals growing much faster, with larger leaves and longer stems, than northern individuals. Differences in growth are increasing over time.
3. Differences in growth are driven in part by the timing of life events, which appear to more closely follow 'home' sites than the common garden site. Southern species drop their leaves later in the season than northern species and therefore experience a longer growing season.

2. Plant Traits

We continued to collect leaf, seed and stem cuttings (plant traits) from the alpine tundra in the Kluane Region, which provide information on the different growth strategies and environmental responses of species. The information from this research has now informed three large studies looking at variation and change in plant traits across the tundra.

Collecting and measuring leaf characteristics to understand plant response to climate change

Our results indicate that:

1. Most plant traits, such as height or leaf area, correlate well with temperature and soil moisture across the biome, indicating strong links between how plants grow and their environment. We can use this to predict how vegetation might change in the future.
2. Plant communities increasing in height as the tundra warms, but many other characteristics are remaining surprisingly stable such as those associated with plant leaves.
3. The relationship between different traits (e.g. tall plants tend to have large leaves) is the same in the tundra as the rest of the world, despite cold and harsh conditions. We can use this information to predict how a wide variety of characteristics (e.g. seed / berry size) might change, or which species might do better as the climate warms.

3. Decomposition – different plants

In 2017, we dug up the second of two 'litter beds' created in summer 2015. These contained leaves, stems and flowers from a range of tundra species. Measuring the differences in how fast different species decompose allows us to predict whether vegetation change will speed up or slow down decomposition overall.

The results of this experiment are being combined with information on leaf and stem traits, and on vegetation change across the tundra to investigate whether plant communities are becoming more or less decomposable over time.

Our initial results indicate that:

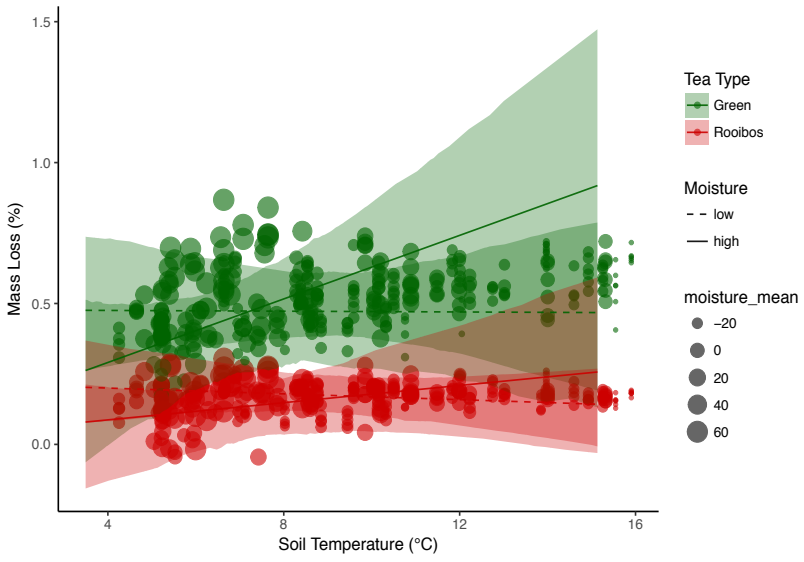
1. There are clear patterns over space, with more decomposable plant communities at warmer sites.
2. There are no net change in decomposability over time, despite warming and vegetation change, suggesting that vegetation change is neither helping to lock up nor release carbon in leaf litter.
3. The amount of wood (e.g. shrub stems) is likely the most important factor controlling decomposability.

4. Decomposition – different sites

We recovered a final set of tea bags buried at three locations in the Kluane Lake region to test for how temperature and soil moisture affect decomposition.

Our results indicate that:

1. Temperature and moisture drive how fast things decompose (the hotter and wetter the better).
2. Moisture is more important in determining how fast things decompose than temperature.
3. There are large differences in decomposition across sites, but these are small compared to the differences in what is decomposing (i.e. differences in litter quality).



Additional information:

Team Shrub at the University of Edinburgh https://teamshrub.wordpress.com/

The Tundra Tea Bag Experiment https://tundratea.wordpress.com/

References:

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