The Central Canadian Treeline Transect

Introduction

The area of transition between forest and tundra in arctic and alpine regions – referred to as the 'forest-tundra' ecotone and punctuated by the upper limit of tree growth, known as 'treeline' – is expected to exhibit some of the most extensive changes of any component of the global vegetation system as a result of continued climate warming **[1,2]**. Significant positive feedbacks to the global climate system are anticipated as the ecotone advances, as are local and regional impacts to biodiversity resulting from habitat change **[3]**. However, sparse empirical data on recent treeline dynamics in many northern regions has left considerable uncertainty about the rate, extent, and mechanisms of change. Moreover, data indicates substantial variability around the globe. In some areas treelines have advanced in response to recent warming, while in other areas no advance has been observed. In some areas an infilling of the forest-tundra has been more typical. At still other locations the only detectable change has been changes in the growth or growth form of individual trees **[4]**.

In Canada, most studies of northern treelines have been conducted in mountainous areas of the Yukon **[e.g. 5,6]** and in northern Quebec and Labrador **[e.g. 7,8]**. Because it is remote and difficult to access, there is a conspicuous absence of field studies from central Canada, despite the fact that treeline in this region spans a distance greater than 2000 km. In addition to the direct influence of climate change, north central Canada has experienced significant land use change associated with mineral exploration and development, widespread forest fires, and rapid decline of migratory caribou herds in the last two decades **[e.g. 9]**. Research on forest-tundra dynamics in this region is therefore critical for improving forecasts of global change and for understanding its ecological consequences at local, and regional scales.

Research Goal and Objectives

The goal of this research project is to investigate the patterns and processes associated with contemporary vegetation dynamics across the forest-tundra ecotone of central Canada. The project is centered around establishment of a 200 km latitudinal transect spanning treeline in central Northwest Territories. The transect will be traversed from north to south via canoe during July and August 2016. Six base camps will be established along the transect and multiple sampling excursions will be made from each base camp. The principal investigator is Dr. Ryan Danby, Associate Professor in the School of Environmental Studies and Department of Geography and Planning. Additional team members include Post-doctoral Fellow Dr. Greg King (Geography and Planning), MSc student Mitchell Bonney (Geography and Planning, co-supervised by Dr. Paul Treitz), and BSc student Stuart Thibert (Mechanical Engineering). No roads exist in the region; team members along with all gear and scientific equipment will be dropped off and picked up on either end of the transect by float plane. Three primary objectives guide the research project:

1. Conduct a set of dendrochronological investigations to characterize population dynamics of trees across the forest-tundra ecotone, and assess trends in annual growth (King & Danby)

Forest-tundra ecotones respond to climate warming in three ways: (1) increased growth of individuals, (2) infilling of the ecotone, and (3) range extension **[10,11]**, referred to here as Type 1, 2, and 3 responses. The over-arching hypothesis associated with this objective is that all three response-types have occurred over the last half century, but that their extent varies locally in relation to soil and topography. Type 1 responses will be quantified using dendrochronological techniques. Trees (white (*Picea glauca*) and black (*P. mariana*) spruce) will be cored and sectioned from upper and lower treeline zones in both xeric and mesic environments. Ring-width indices will be derived and compared to available climatic data in order to determine the specific influence of these variables on plant growth and to assess change through time. The extent of Type 2 and 3 responses will be assessed using dendroecological stand reconstruction. Plots with a minimum of 50 live individuals will be established and all trees will be sampled and dated to yield age distributions **[e.g. 6]**. All dead individuals in each plot will also be sampled and cross-dated. Local variability will be assessed by sampling 3 plots at each latitude, each separated by several kilometres. Plot location will be guided by documented fire history of the region. Particular attention will be placed on identifying episodic establishment events, which could suggest an important role of seed mast events in treeline dynamics **[12]**.

2. Map recent vegetation changes across the forest-tundra ecotone and analyze their pattern using GIS-based modeling (Bonney, Treitz, & Danby)
Increases in remotely-sensed measures of vegetation productivity have been observed at high latitudes over the past several decades; a phenomenon known as 'arctic greening' **[13]**. A concurrent decrease has been observed in northern forests of North America; termed 'boreal browning' **[13]**. The overarching hypothesis associated with this objective is that change across the forest-tundra ecotone of central Canada has been highly variable over the last three decades, both temporally and spatially, and that this variability is strongly linked to physical landscape variables and disturbance history. To test this, a time-series of Landsat images (30m resolution) is being used to map change in the normalized difference vegetation index (NDVI), a measure of phytomass, over the last 35 years **[e.g. 14,15]**. One hundred 30x30m plots will be established across the length of the ecotone and canopy cover of each major plant functional group will be obtained from each plot. This will provide the data necessary for image calibration and map validation. Changes in landscape metrics will be quantified within a GIS environment and statistically related to a mapped set of independent biophysical variables including topography, geomorphology, permafrost, and fire history, to assess the relative importance of these variables in facilitating or inhibiting vegetation change.

3. Quantify the regeneration niche of tree species at their northern range edge, particularly as it relates to the influence of tall shrubs (Danby & Thibert)
Several studies have demonstrated increased establishment and growth of tall deciduous shrubs in many Arctic and subarctic regions over the last two decades **[11]**. This proliferation of shrubs is likely to have a profound effect on interspecies interactions and provides a compelling reason to explore the biotic interactions between trees and shrubs and their role in structuring the forest-tundra ecotone **[16]**. The overarching hypothesis is that the influence of shrubs on conifer establishment at treeline can be both facilitative and inhibitive, and that the relative contribution of positive and negative effects varies significantly across the ecotone. Deciduous shrubs can inhibit germination, establishment, and recruitment of conifers because of a competitive advantage of angiosperms in the high light environment beyond treeline **[17]**. However, shrubs may also provide suitable microenvironments for the early stages of conifer seed germination and establishment **[16,18]**. To test this, 100 spruce seedlings will be located at each of the three major ecotone boundaries (tree species line, treeline, forestline). An additional 100 points will be located where seedlings are not present. Variables related to deciduous shrubs will be measured at each point, including shrub height and density, species composition and canopy cover. Additional variables including soil depth, moisture, and temperature, distance to nearest adult tree, and metrics of seedling growth, will also be measured. Logistic models will be developed to quantify the influence of the different predictor variables on seedling presence and growth at each latitude.

Impact and Significance

The forest-tundra ecotone is considered a sentinel of climate warming impacts on arctic and alpine ecosystems **[1]**. Research on processes that influence its dynamics, as well how the ecotone has responded to past climate change, is essential for improving forecasts of change and understanding its consequences. This research project will fill an important geographic gap in the network of global studies on forest-tundra dynamics. The multiscale approach being utilized (i.e. plant-population-landscape) is also important. The influence of scale is increasingly being recognized in the study of ecotones **[2,19,20]** and there is a growing recognition that both ecological patterns and processes need to be considered to gain a fuller understanding of their dynamics **[54]**. Linking investigations conducted at the same location, but at different scales and using different methods, is critical to achieve this **[55]**.

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