Future productivity of the balsam fir boreal forest

Experimental interactions of climate change and nitrogen deposition

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Background

Most recent simulations of the future climate from the Canadian Regional Climate Model for the eastern boreal forest of Canada suggest an average annual temperature increase of 3°C by 2050 whereas precipitations should increase by 5 to 20%. Such changes will certainly have a major impact on the growth of the boreal forest.

But climate is not the only important factor: nitrogen is also a major growth-limiting factor in such biome. In fact, more and more studies show that the response of plants to climate change is strongly influenced by the availability of inorganic nitrogen, although this aspect is largely ignored in today's predictive growth models.

Objective and hypothesis

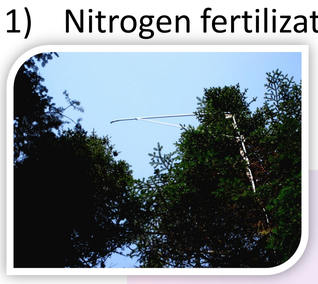
The main objective of this project is to measure the effect of three key parameters on tree growth in boreal biomes by integrating, within the same study, an experimental manipulation of the climate (precipitations, soil temperature) and nitrogen additions directly on the tree canopies.

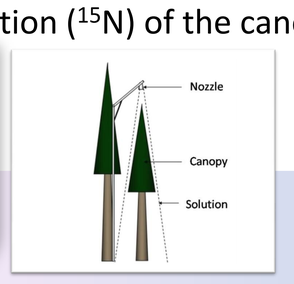
Forest canopies typically act as sinks for inorganic N, taking up approximately 40% of incoming N from precipitations. Also, soil warming generally results in an increase of N mineralization and immobilization. Since boreal forests are generally N-limited, an addition of N in the system, through soil warming and N fertilization, should increase radial growth.

Experimental design

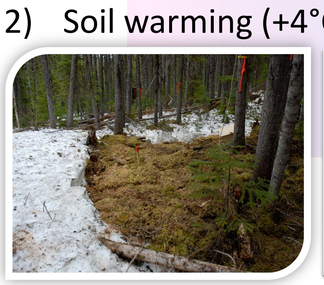
The experiment takes place in a mature balsam fir stand of the Eastern Canada boreal forest. The two treatments (N and soil warming) were nested in a randomized block split-plot design with 12 plots, each with a single tree.

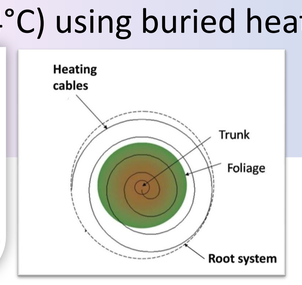
1) Nitrogen fertilization (^{15}N) of the canopy

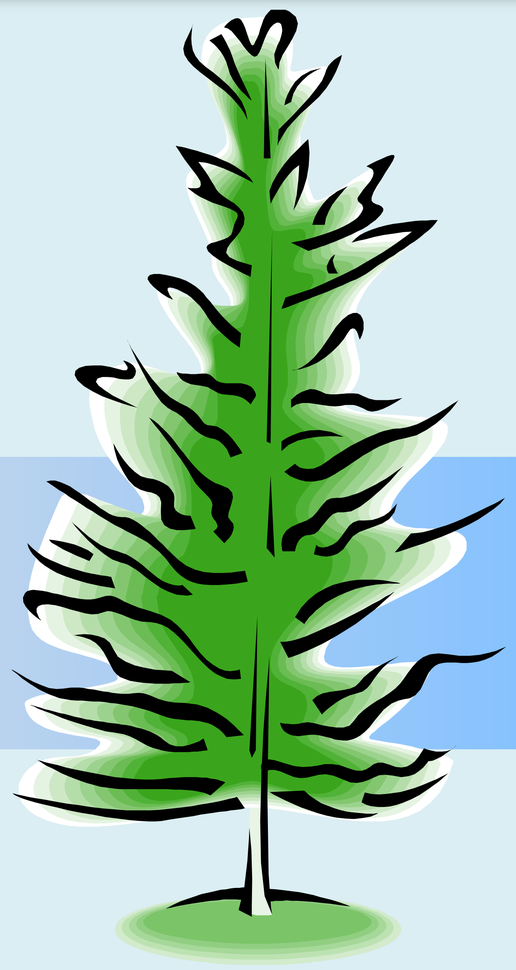




2) Soil warming (+4°C) using buried heating cables



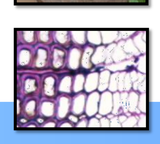




Data sampling

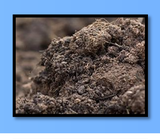
Analysis of leaf and wood nutrient content, including ^{15}N.

Continuous measurement of stem radius variation using highly accurate dendrometers.

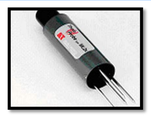


Weekly extraction of wood micro-cores for cambial activity and xylem formation.

Soil nutrient supply rate within each plot measured with exchange membranes (PRS^{TM}-probes) .



Soil nutrient content, including ^{15}N.



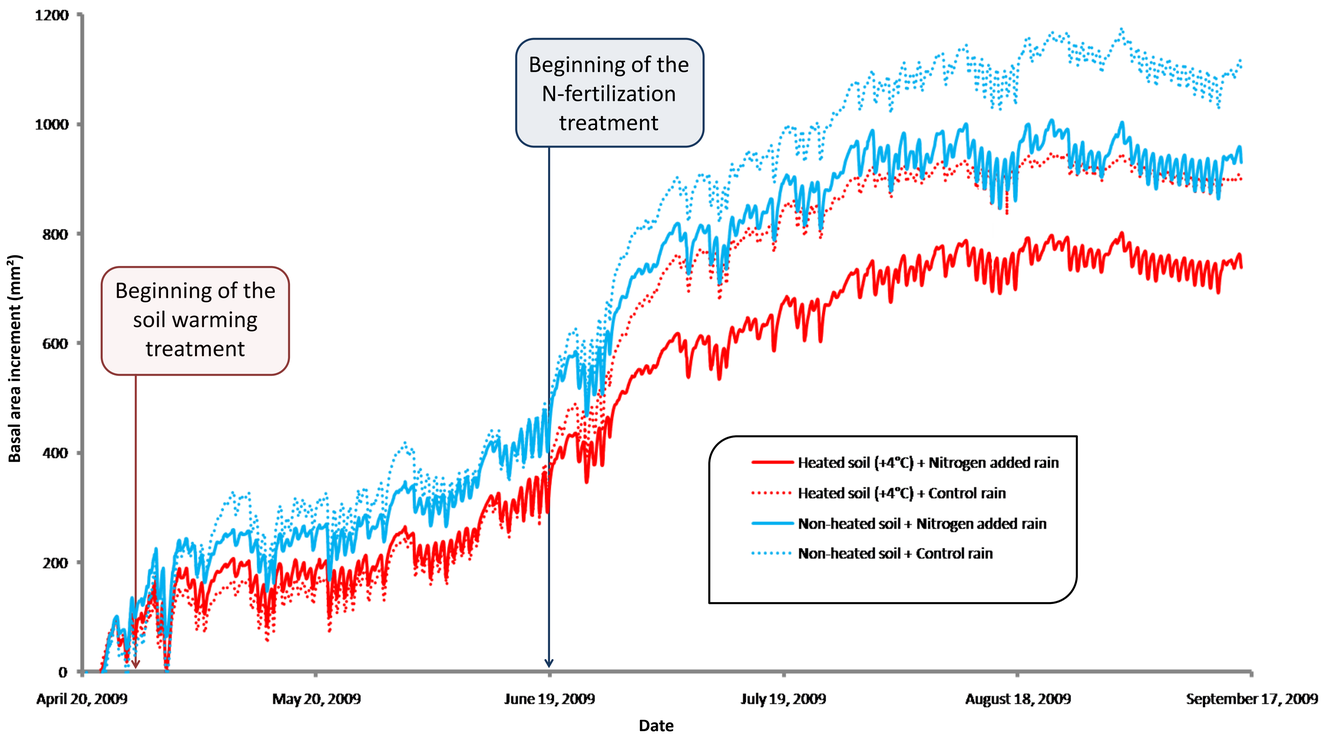
Weekly measures of soil and wood water content.

Preliminary results

- Trees with higher soil temperature, as well as extended growing season, tend towards a lower annual radial growth.
- Trees with nitrogen addition through precipitation events tend towards a lower annual radial growth.
- Trees with soil warming and nitrogen addition grew the slowest, and fastest growth was achieved by control trees.
- Soil moisture was not significantly affected by soil warming (results not shown).

Some hypotheses...

- Results suggest that the trees are not N-limited. However, in mature trees, a large proportion of N and other mobile nutrients required for growth are drawn from storage tissues. Thus, coming years could yield different growth response.
- The tendency towards reduced growth observed with N addition could be linked with NH_4NO_3 interactions with the canopy. High atmospheric deposition generally leads to leaching of base cations. Given the low exchangeable cations reservoirs of this site, this mechanism could impact tree nutrition.
- An excessive warming of the tree roots in contact with or too close to the heating cables could have killed the roots and/or inhibited nutrient uptake. Also, the root system could be migrating away from the heating cables, temporarily limiting nutrient translocation to the stem.



Soil warming and nitrogen deposition effects on balsam fir radial growth

- Leaching of soil base cations and associated nutrient deficiencies are not likely involved in the growth reduction effect at this stage of the study. Previous fertilization studies, using larger amounts of added N over longer periods, noted no sign of N saturation with the associated NO_3 and base cations leaching that are characteristic of such a condition.
- Results from cellular analysis will enable us to standardize individual growths in regard with previous annual growths.