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Branching Out
from the Canadian Forest Service - Laurentian Forestry Centre

Dendroecology and genomics in support of forest carbon capture

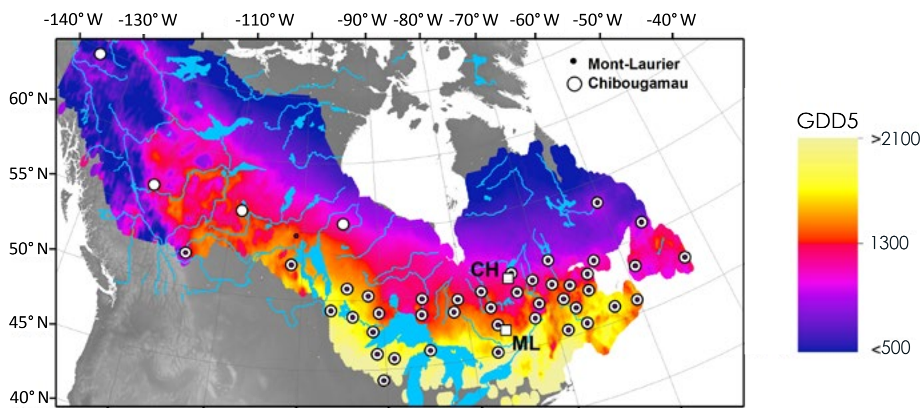
Globally, forests play a significant natural role, as they absorb and sequestrate carbon that would otherwise end up in the atmosphere. This carbon sequestration mitigates the phenomenon commonly known as the greenhouse effect, which helps slow down the rate of climate change. One of the forest management strategies that could promote carbon storage is tree selection through genomics. Trees' genetic information could be used to learn about their carbon uptake potential in order to select the most suitable, diverse and successful offspring to maximize the positive effects of reforestation. Researchers from the Canadian Forest Service are trying to demonstrate that combining dendroecology and genomics could become an effective tool to select trees more quickly according to their carbon sequestration capacity.

Why should carbon be sequestrated?

We are currently witnessing an imbalance between carbon emission and uptake. From an anthropogenic point of view, greenhouse gas emissions result, among other things, from industrialization and the use of fossil fuels at an ever-increasing rate. At the forest level, CO_2 release into the atmosphere occurs naturally during the decomposition process of dead trees or during wildfires. Conversely, CO_2 uptake and sequestration by the forest occur through photosynthesis. As trees grow, they absorb CO_2 from the atmosphere and store it as biomass, both above and below the ground. Although reducing consumption is one of the actions to be taken to lower CO_2 emissions, additional efforts are recommended to capture more carbon, such as planting trees with increased carbon capture potential on new, undeveloped sites.

Studying the black spruce

To investigate the impact of genetics on trees' ability to sequester carbon, researchers used dendroecology to analyze carbon sequestration data from numerous black spruce populations sampled across Canada. Seedlings from 45 populations were established in Quebec in 1974 in two ecologically distinct experimental plantations, one in Chibougamau and the other in Mont-Laurier. Seedlings were grouped under the same growing conditions for comparison with each other within each site and between sites.



Map 1. (Dot) Origin of the 45 sampled black spruce provenances across Canada. (Square) Locations of the common gardens Mont-Laurier (ML) and Chibougamau (CH). Background colors: mean annual growing degree days above 5°C (GDD5).

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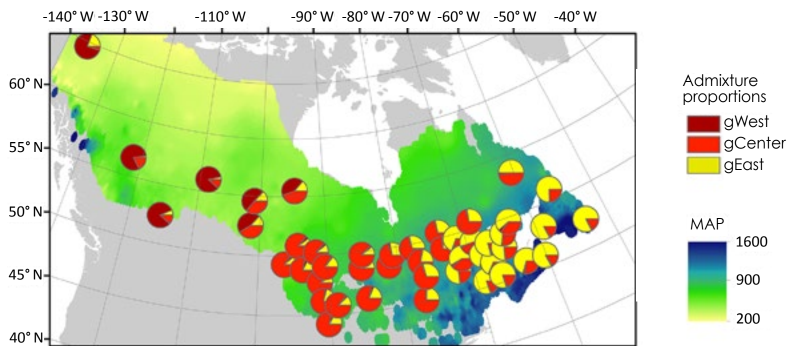
Annual growth rings of a black spruce tree showing the alternation of earlywood (light) and latewood (dark) Photo: NRCan

The usefulness of dendroecology

Dendroecology is the study of the width of the annual growth rings of trees in relation to the environment and other factors at different times of a tree's life. Its use provides a better understanding of the history of tree resilience in terms of adaptation and, among other things, a better idea of carbon sequestration under variable and extreme climates. Data are derived from the analysis of wood density and tree ring width measured on tree samples (cores) taken on the trunk, and the periodic re-measurement of these trees. Dendroecology can also be used to determine the degree of carbon sequestration. It is then expressed in units of carbon/area/year. In this large-scale study, cores were collected from 45 populations of black spruce from more or less different environments. These data made it possible to track the evolution of carbon sequestration on more than 1,500 trees when the plantations were 40 years old.

A climate and genomic model

To determine whether carbon sequestration values are attributable to their geographical origin or to an effect of the environment at the plantation sites, data are evaluated with the number of cumulative degree days, the average annual precipitation of the provenance site of the studied trees and the survival rate of these provenances on the experimental sites. In order to determine the possible influence of genetics on carbon sequestration performance, the data are also analyzed in association with the glacial origin of the trees studied. Indeed, black spruce can be classified into three subgroups of different genomic origin following the recolonization of the territory after the last glaciation, which occurred about 10,000 years ago. This genetic inheritance is stored within each tree cell and can be used to detect genetic variations transmitted from generation to generation. These variations can be expressed differently depending on the influence or not of their environment, which makes it possible to associate certain genetic variations with various climatic events.



Map 2. Pie chart: Each dot location shows the inherited genetic proportion according to three ancestral genomic groups corresponding to Western, Central and Eastern lineages. Background colors: mean annual precipitation in mm (MAP).

Additional effects

The results show that the relationship between carbon sequestration and tree origin is significant in the first 15 years after planting. In the future, dendroecology and genomics could help maximize carbon capture by planted forest species. They are becoming increasingly important tools to mitigate the impact of climate change from a carbon sequestration standpoint.

Useful link

https://www.nrcan.gc.ca/climate-change/impacts-adaptations/climate-change-impacts-forests/forest-carbon/13085

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