SILVA21 ANNUAL GENERAL MEETING

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NOVA SCOTIA, CANADA

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ANNUAL GENERAL MEETING/ ASSEMBLÉE GÉNÉRALE ANNUELLE

Silva21's second Annual General Assembly (AGM) took place from June 27th to 29th at Oak Island Resort & Conference Centre on the Western Shore of Nova Scotia on the ancestral and unceded territory of the Mi'kmaq people.

The AGM brought together a diverse group of over 50 participants from across Canada including graduate students, postdoctoral fellows, research associates, university professors, provincial and federal government researchers, and forest industry partners.

La deuxième assemblée générale annuelle (AGA) de Silva21 a eu lieu les 27 et 29 juin au Oak Island Resort & Conference Centre sur la côte ouest de la Nouvelle-Écosse, sur le territoire traditionnel et non cédé du peuple Mi'kmaq.

L'AGA a réuni un groupe diversifié de plus de 50 participants de partout au Canada, y compris des étudiants diplômés, des boursiers postdoctoraux, des associés de recherche, des professeurs d'université, des chercheurs des gouvernements provincial et fédéral et des partenaires de l'industrie forestière.

GOALS

- Provide an opportunity for researchers, HQP and partners to meet, network and socialize
- Provide of an overview of the projects, results and ongoing programs of work at each research theme and hub
- Allow partners to provide feedback about how projects may help adapt silviculture to changing realities

This year, the three days of events were organized by Silva21's research themes: Observe, Anticipate and Adapt.

OBJECTIFS

- Donner l'occasion aux chercheurs, aux PHQ et aux partenaires de se rencontrer, de réseauter et de socialiser
- Donner un aperçu des projets, des résultats et des programmes de travail en cours à chaque thème de recherche et carrefour
- Permettre aux partenaires de fournir des commentaires sur la façon dont les projets peuvent aider à adapter la sylviculture aux réalités changeantes

Cette année, les trois jours d'événements ont été organisés selon les thèmes de recherche de Silva21 : Observer, Anticiper et Adapter.

OBSERVE // OBSERVER

Collect data using innovative tools to assess the growth and vigor of trees, and thus allow more flexible and adaptive management strategies in the face of climatic stresses and disturbances.

Recueillir des données à l'aide d'outils novateurs pour évaluer la croissance et la vigueur des arbres et ainsi permettre des stratégies de gestion plus souples et adaptatives face aux stress et aux perturbations climatiques.

Liam Irwin, PhD student, UBC (Coops)	OB1a: Advanced remote sensing: free-to-grow to thinning stage
Gabrielle Thibault Completed MSc project, ULaval (Achim)	OB1b: Optimization of the characterization of burn patterns
Sarah Smith-Tripp, PhD student, UBC (Coops)	OB2: Regeneration after catastrophic disturbances
Alexandre-Mortin Bernard Completed PhD project, ULaval (Achim)	OB3b: Early alert systems for forest management
Raphael Pouliot, RA, Université Laval (Achim)	OB3c: From theory to action at the Montmorency Forest
José Riofrio, Postdoctoral Fellow, UBC (Coops)	OB4a: Climate-sensitive mortality models in Ontario
Chris Mulverhill, Postdoctoral Fellow, UBC (Coops)	OB5a: Continuous forest inventory framework
Spencer Shields, MSc student, UBC (Coops)	OB5b: Metrics for silvicultural prescription
Madison Brown, MSc student, UBC (Coops)	OB5c: Metrics of silvicultural prescription: stand condition
Lukas Olson, MSc student, UBC (Coops)	OB6: Metrics of silvicultural prescription: composition and structure

OB1B: *Optimization of the characterization of burning patterns*

Gabrielle Thibault (gabrielle.thibault.4@ulaval.ca)
Étudiante à la maîtrise
Superviseur: Alexis Achim
Collaborateur: Ministère des forêts, de la faune et des parcs

In the context of climate change, the frequency and intensity of fires in Canadian forests will be impacted, leading to an increase in the burned forest areas in the boreal forest. To ensure a supply of wood in a future with more forest fires, harvesting wood from disturbances is both an interesting and necessary approach. To harvest wood with acceptable quality, salvage operations must be carried out within the next 4 years to prevent degradation caused by insects and microorganisms.

In order to quickly harvest the burned areas and assess the impact of the fire on the ecosystem, accurate mapping of the affected area is essential. The passage of fire leaves a distinct pattern on the landscape, affecting stands at different severity levels.

The objective of my project is to optimize the characterization process of the burning pattern used by the Forest Ministry in Québec, utilizing high-resolution satellite images (50cm resolution). The process involves classifying each pixel in the image to identify the extent of fire impact in different areas. To optimize the process, I want to determine which classification model provides the highest pixel classification accuracy.

Three classification models were trained (featureless, KNN, and Random Forest) using a training dataset created by manually classifying over 5000 pixels. After comparing the models, Random Forest demonstrated the highest accuracy, especially when selecting the most relevant training variables. The classification results show an 89% accuracy, differentiating well between burned and unburned pixels.

This process can be applied to classify a large number of images, which is beneficial for quickly characterizing the burning pattern. By using high-resolution satellite images and the optimized Random Forest classification model, we can efficiently analyze and classify images covering extensive areas affected by fire. The speed and accuracy of this approach make it highly valuable for monitoring and characterizing fire patterns over large regions, aiding in better understanding the ecological effects and guiding appropriate interventions.

OB2: *New techniques to assess re-establishment after severe disturbance and prioritization for remediation measures*

Sarah Smith-Tripp (ssmithtr@student.ubc.ca)
PhD student, UBC
Supervisor: Nicholas Coops

Monitoring forest recovery in the widespread burned environments of British Columbia is critical. Fires affect forests' carbon sequestration and timber provisions. Post-fire monitoring must capture structural measures relevant to forest managers. Examples of these measures include: height, basal area, stem density, and the composition of deciduous versus coniferous regeneration. Monitoring young forests over large spatial scales (larger than the size of Prince Edward Island) is difficult, expensive, and time consuming. In my research, I develop methods to identify different types of forest structures post-fire using Landsat composite imagery. Landsat imagery measures the colors (or spectra) observed on the landscape. I use temporal measures to identify unique trajectories of different indices, or combinations built from singular Landsat bands. Indices were selected to represent landscape components. Selected indices include the Normalized Burn Ratio (NBR), Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), and four Tasseled cap combinations that capture the brightness, wetness, and greenness on a landscape. I input temporal measures from each index into a K-means clustering algorithm. K-means algorithms classify data into clusters that maximize within cluster similarity and minimizing the similarity to other clusters. The output of the kmeans algorithm was six different spectral types for fires that occurred in 2006. To understand how these different spectral types related to structural measures, I used spatially continuous measurements taken by lidar (light detection and ranging) data collected from Remotely Piloted Aircraft (RPA) in summer 2022. The RPAS lidar flights captured over 400 hectares of data with point densities greater than 200 pts/m2. Using the lidar and co-located field measures, I modeled the important forest attributes, with cross-validation accuracies (R2) of 0.41 for the ratio of coniferous to deciduous stems, 0.52 for stem density, and 0.95 for basal area. Models were then applied to create wall-to-wall, spatially explicit estimates of structural indicators within burn perimeters to relate to unique Landsat clusters. I found the six unique Landsat clusters described structurally distinct forest types. The two most notable clusters for forest managers are (a) a cluster with higher basal areas and conifer regeneration compared to others, and (b) a cluster with lower basal area, higher proportions of deciduous and particularly high stem densities. The accuracy of identifying unique areas in new locations was greater than 80%. My research showcases a method to identify structurally unique forest types using temporal measures of Landsat imagery without a need resource intensive field measurements.

OB3C: *From theory to action at the Montmorency Forest*

Raphael Pouliot (raphael.pouliot.1@ulaval.ca)
Chercheur associé, University Laval
Professeur: Alexis Achim

As an integral part of Silva21 and covering an area of 410 km2, the Montmorency Research Forest is the largest forest for university teaching and research in the world. Its objective is not only to produce wood to meet the society's needs for sustainable materials but also to focus on the development of educational and research activities. Forest planners must organize harvesting activities while considering researchers, students, professors, and teachers who need access to the area.

The availability of lidar-derived products for forest planners dates back a few years, and there are several differences between the data and what is observed during field measurements today. My project aims to implement the framework for near real-time forest inventory using multi-source remote sensing data to update the lidar-derived products and improve decision-making support. We will start off with the lidar acquisition from 2011 and 2015 to conduct an enhanced forest inventory. Subsequently, we will utilize satellite imagery to detect changes that have occurred since those acquisitions to update and futher refine the enhanced forest inventory.

OB5A: *Enhanced forest inventory*

Chris Mulverhill (chrismulverhill@gmail.com)
Postdoctoral Fellow, UBC
Supervisor: Nicholas Coops

Enhanced forest inventories (EFIs) based on airborne lidar data form a fundamental component of forest management in the 21st century. However, due to high cost of both field and lidar data acquisition, EFIs are only updated on 5- or 10-year repeat intervals. A continuous forest inventory framework has been proposed in order to allow EFIs to be updated on a shorter repeat interval. The components of this framework include establishing the initial EFI, continuously monitoring for change using optical satellite data, updating the attributes of changed cells, and forecasting growth in unchanged cells. Manuscripts outlining the framework (1) and detecting changes using satellite data (2, 3) have been accepted in peer-reviewed publications.

Current work on this project is on updating EFI attributes in changed pixels. To do this, pixels are first grouped into strata of similar dominant species and site indices (taken from inventory polygons). Next, models are developed to estimate the difference in forest attributes (such as basal area or canopy cover) as a function of difference in spectral index values. Initial results suggest that attributes such as canopy cover have the highest estimation accuracy ($r2 \approx 0.90$, 10.4 relative root mean square error; RMSE%), while attributes such as basal area are less accurately predicted using optical data ($r2 \approx 0.57$, 14.2 RMSE%). Future work will aim to continue developing these models and test their accuracies in the context of a continuous forest inventory.

OB5C: *Metrics of silvicultural prescription: stand conditions*

Madison Brown (madib98@ubc.ca)
MSc student, University of British Columbia
Supervisor: Nicholas Coops

My research focuses on characterizing and assessing the impact of Non-stand Replacing Disturbances (NSRS) within a near-real-time context. NSRS are events that result in incomplete removal of trees, examples include insect infestation, drought, wind damage, and partial burn. In Quesnel, BC, the hub site location for this project, the dominant NSRs are Mountain Pine Beatle and partial burn. NSRS often occur at a lower intensity over a longer time period. Which often leads to leads to a more variable stand structure and can greatly impact both timber supply and ecosystem services making them critical to consider for future forest management strategies. However, traditional forest inventories created from a combination of ground plots and interpreted aerial images do not provide the detail in stand characteristics or temporally to properly conceptualize the impact of the NSRs.

Enhanced forest Inventories, EFIs for short, are generated in part using advanced remote sensing datasets such as airborne laser scanning (ALS), which to provides managers with a higher level of detail of stand characteristics to quantify NSRs. However, it is economical to update them on a regular enough interval to see fully assess the impact of NSRS. In summary, EFIs, to effectively assess NSRS, there is a need to have an approach to extrapolate ALS metrics over larger temporal scales. Moderate resolution optical satellite data such Landsat, Sentinel-2 and harmonized Sentinel Landsat, updates every ~2-16 days, has driven the push for Continuous Forest Inventories (CFIs) which can help fill this temporal gap. Bringing us to the main outcome goal of this project is to be able to utilize harmonic seasonal change detection algorithms such as BEAST, to be able to identify NSRs based on spectral change and develop a framework extrapolate ALS stand metrics creating an EFI that can be updated in near-real-time.

An EFI that can be updated in near-real-time not only has the potential to aid forest managers to better quantify economic and ecological impacts of NSR. But additionally, by having a more temporally dense visualization of the evolution of NSRs on a particular stand, which has not previously existed, there emerging opportunities for better adaption and mitigation strategies for said disturbance to be implemented.

OB6: *Metrics of silvicultural prescription: composition and structure*

Lukas Olson (lukas.olson@ubc.ca)
MSc student, University of British Columbia
Supervisor: Nicholas Coops

Canadian forests play a significant role in the country's economy and contribute towards ecological stability. Their sustainable management is vital, not only for the many Canadians whose livelihoods depend on the forest industry but also for the global biodiversity which they support. Nevertheless, the tools currently employed to evaluate and ensure the health of our forests leave room for improvement.

Traditional methods for evaluating tree health revolve around visual inspection. These techniques, while reliable, necessitate extensive training, incur substantial costs, and pose challenges for standardization due to their inherent subjectivity. Aerial remote sensing offers an alternative approach. However, it can struggle to penetrate the forest canopy due to occlusion, and hence, capture intracanopy features.

To address these limitations, this research seeks to explore a novel approach to tree health assessment centred on quantitative data. It involves using drones to capture video footage of sugar maples in their entirety. Then, photogrammetry—a technique that uses photographs to create detailed 3D models—would process this footage. These models are used to measure quantitative indicators of tree health, such as branch density and angle, conditions of bark, crown and canopy, and new growth from dormant buds on a tree's trunk or branches (also known as epicormic sprouting).

The primary goal of this research is to establish whether it is feasible to use drones to extensively capture video data of trees and generate accurate 3D models, and further, to determine whether these 3D models can be used to measure 'tree vigour'—an indicator of a tree's overall health, indicated by external signs such as canopy condition, growth rate, branching patterns, and crown density.

The research could result in a method of tree health assessment that is both more efficient and accurate while simultaneously less labour-intensive. This novel approach could help the way we measure tree health and provide a practical tool that could be incorporated into broader forest health management strategies.

A data-driven and economical method for assessing tree health could lead to better protection of the various benefits that forests offer, including economic, ecological, and cultural benefits. Beyond that, it could help ensure the long-term health and productivity of Canada's forests, thereby furthering sustainable forest management and conservation initiatives globally. This not only resonates with Canada's commitment to sustainable development but could also set an example for similar initiatives around the world.

ANTICIPATE PROJECTS

Improve growth models and prediction methods to account for climate reality and synthesize the multiple risks of disturbance that forests face.

Améliorer les modèles de croissance et les méthodes de prévision pour tenir compte de la réalité climatique et synthétiser les multiples risques de perturbation auxquels les forêts sont confrontées.

Catherine Chagnon, RA, Université Laval	AN1a: Climatic drivers of tree growth
Guillaume Moreau, PDF, UToronto (Caspersen)	AN4: Stem vigour and growth of tolerant hardwoods
Amy Wotherspoon, PDF, UBC (Coops)	AN1b: Future climate envelopes
Christina Howard, PhD candidate, UBC (Eskelson)	AN3a: Integration of climate drivers into growth modeling (Quebec focus)
Jamie Ring, MSc student, UBC (Eskelson)	AN3b: Integration of climate drivers into growth modeling (maritime focus)
Florence Leduc, MSc student, ULaval (Achim)	AN1c: Impact of climate change on growth of commercial forest species in Nova Scotia
Sergio Alonso Sanches, MSc student, UBC (Roeser)	AN6a: Thinning as a tool to increase resistance to stressors
Joao Paulo Czarnecki de Liz, PhD student, ULaval (Achim)	AN5: Targeted assisted migration
Catherine Beaulieu Completed MSc project, ULaval (Achim)	AN9: Flexibility in forest management to preserve caribou habitat
Mariliou Yargeau Completed MSc project, ULaval, (Thiffault)	AN7: Tree-level response to thinning
Philippe Riel PhD student, ULaval (Achim)	AN1d: Wood properties as proxies for past climate conditions
Sébastien Dumont, PhD student, ULaval (Achim)	AN1e: Effect of extreme climatic events on boreal and temperate tree growth
Emmanuelle Baby-Bouchard, RA, ULaval (Achim)	AN2: Boreal forest growth dynamics in the face of climate change
Kirk Johnson, PhD student, UBC (Coops)	AN8b: Viability of climate-informed, landscape-level strategies (west focus)

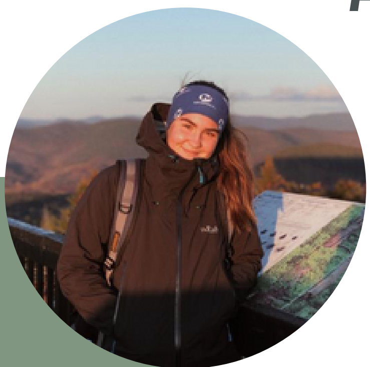
AN1B: *Assessing future climate trends and implications for managed forests across Canadian ecozones*

Amy Wotherspoon (amy.wotherspoon@ubc.ca)
Postdoctoral Fellow, University of British Columbia
Supervisor: Nicholas Coops

Canada's managed forests are changing rapidly due to climate change which is likely to impact harvestable wood volumes, carbon sequestration potential and Canada's forestry industry. Climate interacts with ecological processes that vary depending on forest type that influence biome shifts, biotic and abiotic disturbances, changes to tree and forest growth rates, and shifts in species abundance and composition (Brecka et al., 2018; Gauthier et al., 2015, 2014). Forests' susceptibility and response to one of – or a combination of – these interactions will depend on future climate projections of each ecozone and have significant implications for how Canadian forests will need to be managed in the future.

In this study, future climate projections were generated for eight of the 12 forested ecozones that contain managed forests. For the 2071 to 2100 period, SSP3-7.0 scenario shows warming and rising annual precipitation alongside an overall reduction of precipitation falling as snow and the increase in the number of degree-days above 5°C and frost-free days. Temperature-limited forests found in ecozones such as the boreal shield east and Atlantic maritime have the potential to temporarily increase forest growth rates while promoting northeastern migration towards greater resource availability. However, this is likely to concur with and greater risk of pest overwintering success and windthrow. This is similarly true for forests in in wetter than average ecozones such as those in the Pacific maritime, the boreal cordillera and the Atlantic ecozones though with the additional risk of rain-on-snow events that increase vulnerability to flooding, landslides and windthrow due to greater annual precipitation. In moisture-limited forests, such as those in the montane cordillera, boreal plains and taiga plains ecozones of western Canada, warmer future temperatures are likely to reduce growth rates and promote species compositional shifts towards more drought-tolerant species. These climate conditions are likely to increase drought events (and thus drought-induced mortality), as well as forest fires. Of course, projections that are further into the future coincide with reduced accuracy and limits to adaptation (Dessai et al., 2009). However, the cumulative risk of drought, fire and forest pests is undoubtedly to be the largest challenge in maintaining forest productivity against Canada (Boulanger and Puigdevall, 2021).

As biomass of future forests lost to disturbances being to outweigh any beneficial growth as a result of climate change (Dymond et al., 2016; Ma et al., 2012; Seidl et al., 2017), adaptive forest management practices that promote forest resistance and resilience will be key to sustainable forestry practices. These overarching climate trends should be considered in future regional forest management planning and in conjunction with bioclimatic models to map ongoing changes to species distribution (Rehfeldt et al., 2015; Schneider et al., 2016) and growth and yield models (Boulanger et al., 2017) for projections of future wood volumes.



AN1C: *The impact of climate change on growth of temperate and boreal tree species in Nova Scotia*

Florence Leduc (florence.leduc.1@ulaval.ca)
Étudiante à la maîtrise, Université Laval
Superviseur: Alexis Achim
Collaborateur: Nova Scotia Department of Resources and Renewables

In the context of climate change, it is essential to accurately predict the effects of climate on forests, as they play a crucial role in global biogeochemical cycles. Tree growth is determined by a complex combination of factors, and each species reacts differently to environmental conditions, making it difficult to predict how they will behave under increasingly novel climatic conditions. In fact, irregularities in the relationship between climate and growth have already been observed in recent decades in both boreal and temperate forests of Canada. Fortunately, tree-ring networks enable us to characterize climate-growth relationships and their evolution over time. Indeed, since tree growth is regulated by the environmental conditions in which trees evolve, a climatic signal is encoded in the wood they produce each year. The ring widths thus reflect growth, and by extension the climate that influenced ring formation each year. The instability of climate-growth relationships has mainly been studied in boreal forests, and most studies target a single species, without considering the interaction between the various species growing in mixed stands. My research will help better understand climate-growth relationships in mixed temperate forests as I will build and analyse new tree ring chronologies for many species across the province of Nova Scotia. This in turn will enhance our ability to model the effects of future climate, particularly for complex temperate forests that provide a wide range of ecosystem services.

AN1D: *Wood properties as proxies for past climate conditions*

Philippe Riel (philippe.riel.1@ulaval.ca)
Étudiant doctoral, Université Laval
Superviseur: Alexis Achim

Climate change is characterized by global temperature variations and extreme weather conditions, including within the Canadian boreal forest. Over the past few decades, the relationship between tree growth and climate has become less consistent. The width of tree growth rings no longer corresponds to historical climate conditions as they did in the past.

My project aims to find an alternative indicator to characterize climate events such as droughts, different from tree ring width. Certain wood properties are sensitive to the growth conditions in which trees develop, such as microfibril angle, which is particularly sensitive to variations in water availability. Therefore, the objective is to verify whether the microfibril angle in black spruce can serve as a reliable indicator for characterizing droughts. Microfibril angle is measured at the fine scale of an annual growth ring to associate these measurements with annual water availability. The technique used to obtain microfibril angle is the polarized Raman spectroscopy technique, which determines the orientation of crystalline cellulose in the wood cell walls.

Microfibril angle is a crucial wood property as it influences mechanical properties like wood stiffness and can also be used to predict modulus of elasticity of the wood. In our case, we aim to use it to measure the effect of droughts on this wood property, which will allow us to have a better comprehension of how microfibril angle can help characterizing passed droughts.

AN3B: *Integration of climate drivers into growth modeling (Nova Scotia focus)*

Jamie Ring (jamie.ring@novascotia.ca)
MSc student, University of British Columbia
Supervisor: Bianca Eskelson
Collaborator: Mathieu Fortin

Existing tree-list growth and yield models for the Acadian forest region use climate normals (among other physiographic and topographic variables) to estimate site productivity, but currently lack the ability to account for temporal changes in climate. To support climate-sensitive growth and yield modelling in the Acadian Forest Region, an evaluation of Forest Vegetation Simulator - Acadian Variant (FVS-Acadian) and Open Stand Model (OSM) is being completed. The results from this evaluation will then be used to inform what model components are a priority (diameter increment, height increment, mortality, ingrowth) for incorporating climate sensitivity to allow for temporal adjustments to climate during model simulations. The model evaluations are underway, and a comprehensive summary is being created with model projections from approximately 3,000 permanent sample plot measurements.

AN5: *LiDAR-derived topographic variables to help find suitable sugar maple sites for assisted migration efforts*

Joao Paulo Czarnecki de Liz (joao-paulo.czarnecki-de-liz.1@ulaval.ca)
PhD student, Université Laval
Supervisor: Alexis Achim

Climate change poses uncertainties and challenges for forestry practices, necessitating adaptive measures to protect forests and their services. Assisted migration (AM) has emerged as a potential adaptation strategy to conserve ecosystems and maintain forest production. Implementation of AM requires a comprehensive analysis considering various factors. Spatial distribution models (SDMs) incorporating multivariate approaches and topographical factors have become increasingly important in assessing habitat suitability and planning species management. High-resolution terrain data derived from LiDAR facilitates the characterization of terrain microrelief, aspect, slope, and other topographical indexes, enabling a finer-scale representation of ecological processes. While previous research efforts have aimed to support the implementation of AM at an operational scale through various studies and experiments, a more comprehensive characterization of potential sites at the stand level is essential to mitigate risks of failure.

This study focuses on the sugar maple (*Acer saccharum*), a commercially valuable species in North America expected to shift its range northwards in response to climate change. The objective of this work was to examine the extent to which topographical factors can enhance SM distribution modeling and the degree to which these factors determine sites that are suitable for SM under different future climate scenarios. By examining the responses of sugar maple to biotic and abiotic factors, particularly in its northernmost range, we aim to gain insights into its ecological requirements and develop effective management strategies for its survival and growth.

Our findings suggest that topographical position and aspect are the most significant topographical variables with the potential to enhance sugar maple distribution modeling and explain its presence in the study region. Furthermore, when evaluating climate projections, our results suggest that the species is likely to migrate downslope occupying the valleys through relatively small increases in annual averages of temperature and precipitation. The study area would shift from a small percentage of suitable areas to a small percentage of unsuitable only within the first 30 years of changes under the most optimistic climate scenario (SSP126). These results can support the implementation of AM at stand level scale and with the spatially explicated representations it can provide practical references for practitioners to guide their actions in the field. The results also highlight that certain changes in specific areas are likely to occur more rapidly than expected, necessitating swift response measures.

AN8B: *Viability of landscape-level management strategies under climate change*

Kirk Johnson (kmj1@student.ubc.ca)
PhD student, University of British Columbia
Supervisor: Nicholas Coops

Climate change is anticipated to influence how forests grow, shift major forest ecosystems, and amplify forest disturbances like wildfire and insect attacks. In central British Columbia, substantial insect attacks have already reduced sustainable harvest levels. Furthermore, increasingly warm and dry conditions are expected to pressure sub-boreal pine and spruce forests in the future, slowing growth, increasing disturbances, and encouraging a transition to Douglas-fir dominated ecosystems. Currently, the sustained yield models that inform forest management in British Columbia do not include climate change or climate-based disturbances when estimating future growth. In addition, these sustained yield models do not consider adaptive forest management practices that could reduce climate stress or preferentially encourage drought resistant species like Douglas-fir.

This project will incorporate climate change and adaptive silviculture into the sustained yield models of central British Columbia. To accomplish this, climate sensitive growth modifiers will be developed using the forest growth models 3-PG and MGM-Climate. Adaptive silvicultural regimes will be modeled using targeted thinning, enhanced mixed-species planting, and the aggressive planting of drought resistant Douglas-fir. Finally, sustained yield outcomes will be simulated at the landscape-level relative to climate risk, considering factors such as site-level doughtiness, wildfire and insect potential, and tree species suitability under climate change.

These modifications to sustained yield models will allow a better assessment of long-term sustainability under climate change, particularly in areas that are expected to experience drought, reduced growth, or major disturbances. These modifications could also encourage the implementation of targeted thinning, targeted harvesting, and targeted reforestation to reduce climate stress and support climate change adaptation. This approach could also inform how sustained yield modeling is performed in British Columbia and across western Canada. Modeling forests under climate change poses a significant and difficult challenge. However, to ensure the sustainable management of our forests, climate change and adaptive forest management need to be considered in future sustained yield modeling.

AN9: *Flexibility in forest management to preserve caribou habitat in Newfoundland*

Catherine Beaulieu (catherine.beaulieu.14@ulaval.ca)
Étudiante à la maîtrise, Université Laval
Superviseur: Alexis Achim
Collaborateur: Kruger Inc.

The boreal ecotype of woodland caribou (Rangifer tarandus caribou) is particularly sensitive to habitat fragmentation caused by forest harvesting. Indeed, previous studies have demonstrated that forest operations can impact their space use, habitat selection, predation risk, and foraging behavior. While caribou populations in North America are declining due to habitat disturbance, the population in Newfoundland, which is not exposed to wolves (Canis lupus), appears to be faring better. The dominant forest management company responsible for operations on the island aims to implement a flexible management plan that can ensure the species' preservation while maintaining wood supplies, thus preventing it from reaching critical population levels.

The objective of this project is to evaluate the impact of forest fragmentation on caribou's habitat selection. To achieve this, a cost surface will be modeled in conjunction with graph theory to describe the connectivity between the various high-quality patches (i.e., large patches of old-growth forests or other types of land covers with a high abundance of available resources and low predation pressure). Current work is on analyses that have to be carried out prior to running resource selection functions (RSFs). First, collar data was cleaned up to ensure a consistent time interval between consecutive locations throughout the data and to remove implausible speeds for a caribou. Then, the yearly 100% Minimum Convex Polygon (MCP) was calculated for each animal ID. These polygons will be used to extract covariates that may influence caribou habitat selection. One of these covariates is lichen volume, which will be estimated using the Lichen Volume Estimator developed by Falldorf et al. in 2013. The estimation will be verified through ground truthing activities planned for this summer.

ADAPT PROJECTS

To test innovative silvicultural treatments and forest management strategies adapted to the new socio-environmental reality, thus working to ensure the sustainability of the fiber supply across Canada.

Tommaso Trotto, PhD candidate, UBC (Coops)	AD2: Learning from the past: key stand attributes linked with resilience
Rover Liu, MSc student, UBC (Roeser)	AD3a: Silvicultural scenarios to promote resilient stand structures
Ethan Ramsfield, PhD student, UAlberta (Pinno)	AD1: Revisiting existing trials
Jacob Ravn, PhD student, UNB (D'Orangeville)	AD9b: Assisted migration trials: early response
Mario Stolz, MSc student, UBC (Roeser)	AD3b: Silvicultural scenarios to promote resilient stand structures
Chloe Larstone-Hunt, MSc student, UNB (D'Orangeville)	AD3c: Rainfall exclusion experiment: the effect of thinning
Laurence Boudreault, PhD student, ULaval (Achim)	AD6: Culturally important species
Anne Bernard Completed PDF project, ULaval (Achim)	AD8a: Silvicultural practices at the page of global changes: a public policy challenge
Sandrine Paquin Completed MSc project, ULaval (Flamand-Hubert)	AD5b: Climate change and adaptive silviculture: playing to collaborate with a serious game
Dane Pedersen, PhD student, UBC (Hagerman)	AD5a: Deliberative-analytic framework to engage public and stakeholders

AD1: *Revisiting existing legacy trials*

Etham Ramsfield (eramsfie@ualberta.ca)
PhD student, University of Alberta
Supervisor: Brad Pinno
Collaborators: Wayne Bell

Silviculture intensification is being used across the boreal forest to increase productivity. However, there are concerns about increased silviculture intensity reducing the complexity and heterogeneity of stands. This concept is based on the management of monocultures, with few studies looking at how silviculture intensification impacts mixedwood forests. Mixedwoods play a crucial role in the boreal forest ecosystem, comprising a substantial portion of the landscape and providing numerous ecological benefits. In the Canadian boreal forest, mixedwoods are typically a mix of trembling aspen and white spruce. They provide numerous benefits over monocultures, including higher biodiversity, productivity, resilience to pests and pathogens, and are expected to respond better to climate change. The purpose of this study is to examine how increased intensity of silviculture treatments, while attempting to maintain a mixedwood forest type impacts the structural diversity and homogeneity when regenerating mixedwood stands. To answer this question data from the Timmins NEBIE site will be used. NEBIE, which stands for natural disturbance, extensive, basic, intensive and elite (referring to the intensity of silviculture), is a long term study across northern Ontario looking at the impact intensive silviculture has on a variety of criteria and indicators. Of the eight sites across northern Ontario, data gathered from the Timmins site, which is a boreal mixedwood, will be used to answer the above question. Metrics that will be used to assess structural diversity and heterogeneity will be diameter distributions, species composition, and spatial arrangement of trees. As more intensive management may be needed to regenerate intimate mixtures and mixedwoods are naturally structurally diverse, it is expected that increased intensity may result in more structurally diverse stands compared to stands with little or no intervention. Initial results suggest that the treatments were effective at maintaining multiple species, with the higher intensity treatments having higher proportion of large trees. It was also found that the higher intensity treatments had a more even size classes distribution. Additionally, it was found that the higher intensity did not have a negative impact on tree species diversity, with the extensive treatment having the lowest species richness. The next steps in this study will be to conduct spatial analysis using the pair correlation function to assess the spatial heterogeneity.

AD2: *Learning from the past: key stand attributes linked with resilience*

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Natural disturbances have a significant impact on forest structure at varying spatial and temporal scales. Forests may experience abrupt changes caused by stand-replacing disturbances like severe wildfires or more subtle and pervasive modifications due to non-stand replacing (NSR) disturbances. NSR disturbances, such as moderate insect defoliations, may affect various aspects of forest structure, including base crown height, canopy shape and complexity, canopy density, spatial arrangement of tree patches, and growth dynamics. The complex response of forest structure to NSR disturbances poses challenges for developing approaches that can accurately capture temporal and spatial changes for informed forest management. However, the application of active remote sensing tools, such as aerial laser scanner (ALS), may offer valuable insights into forest structural changes resulting from NSR disturbances when repeated acquisitions are available.

This study aims to investigate forest structural changes at a fine scale using a bitemporal ALS dataset acquired in the southern portion of the Lac St-Jean region, Quebec, Canada. Change detection on ALS data was performed via a raster differencing approach, which is widely adopted for change detection tasks given its robustness in handling data acquisition inconsistencies, such as varying ALS system specifications. This approach involves regularizing 3-dimensional ALS information onto a two dimensional grid.

The raster differencing was conducted on a set of 15 uncorrelated ALS-derived metrics, which were rasterized at a 10 m spatial resolution for both ALS acquisitions and subtracted over time (t2 – t1, hereafter delta metrics). Metric selection included height metrics, canopy cover, light interception metrics (e.g., leaf area index), and shape metrics derived from covariance matrix eigende composition. To identify regions of pixels exhibiting similar response patterns to NSR disturbances (i.e. ecological regions), a two-stage clustering approach was applied to the delta metrics. This approach involved an initial KMeans pass, followed by multivariate agglomerative clustering, resulting in the identification of 9 ecological regions.

Next, a cumulative severity map of NSR disturbances in the region was produced. The cumulative severity map provided a summary of the spatial interactions of NSR disturbances on an annual basis, incorporating data from the Provincial forest resource inventory and Landsat time series. This map was used to determine the separability of the ecological regions as a function of cumulative disturbance severity. Additionally, these regions are being validated in terms of their structural response to different NSR disturbance severity levels. To do so, aerial photos of the study area, collected in 2020, are currently being interpreted for signs of decoloration, defoliation, and gaps across a network of 900 locations.

In conclusion, this ongoing study provides the foundation for the detection and characterization of NSR disturbances in a boreal forest context, leveraging the availability of a bitemporal ALS dataset. This research aims to provide valuable insights into the implications of NSR disturbances on forest structure.

AD3: *Irregular Shelterwood as a tool to promote wildfire resistance in the lodgepole pine forest in interior BC*

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Record-breaking fires continue to be seen in interior BC, threatening the livelihood and economy of local communities. As a forestry-oriented town, Quesnel has experienced incredible loss in the 2017 and 2018 fire season. Concerns regarding the current forest management methodology and future wildfire regimes have been raised among stakeholders in the Timber Supply Area (TSA).

Despite the long history of forestry practices, very few silvicultural systems but clearcut has been widely implemented provincially. Among the scarce alternative silvicultural applications, few of them were well inventoried nor set up systematically following experimental design. Consequently, the interactions between wildfire and alternative silviculture systems remain unknown province wise.

Both evidence-based and conceptual methodologies will be employed to understand the interactions between the stand structure and wildfire, using an irregular shelterwood treated stand in Quesnel TSA as a case study. The stand was partially burnt in the wildfire season in 2017 and categorized into four stand types: Treated-Burnt (A), Treated-Unburnt (C), Untreated-Burnt (B) and Untreated-Unburnt (D). In the first research question, timber cruising, ground fuel and crown fuel data was collected from 40 randomly located plots, which was then analyzed in R to compare the fire behaviour differences in the burnt comparison pair (A&B) and the pre-fire conditions in the unburnt comparison pair (C&D). In the second research question, a stand of same characteristic will be generated using the field data and burnt in fire model. The model outcomes will be compared to what has been observed in the field. A sensitivity analysis will be done to identify the significant variables that contribute to severe fire behaviour.

The objective of this study is to investigate the interactions between the stand structure created by irregular shelterwood and wildfire. The hypothesis is that the treated stand will have an increased resistance to wildfire compared to an untreated natural stand. Preliminary results have suggested that a ground fire with lower intensity was observed in the treated stand, in contrast to a passive crown fire in the untreated stand. It is expected that the fire type, fire intensity and fire behaviour in the two stands differ as well, as data being run through the fire models.

The result will likely propose a new silvicultural prescription that is more resistant to wildfire as they become increasingly frequent in the light of ongoing climate change. The sensitivity analysis will provide guidance as for at what timing should thinning be implemented to mitigate potential stand replacing fires.

AD9B: *Assisted migration trials: early response*

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Collaborators: JD Irving

Drought is expected to increase in severity under current climate change projections which will have negative impacts on forest stands. As a result, silvicultural techniques in the Acadian forest must adapt to the expected change in drought regimes. Current literature suggests that reducing stand density by pre-commercial thinning (PCT) has been shown to reduce vulnerability of stands to drought. However, knowledge on optimal stand density and its effects on white spruce plantations is still lacking. New Brunswick heavily relies on thinning as a silviculture technique, therefore the results form this drought experiment can better inform the ways in which PCT treatments are applied and the forestry sector in general.

The objective of the drought experiment is to quantify the effects of PCT on the vulnerability of white spruce stands to increasing drought. To test this, a fully crossed two-factor factorial drought experiment has been set up in Black Brook, New Brunswick, where we test three levels of artificial drought by means of transparent eaves troughs (0, 25, and 50% coverage), and three levels of PCT (2800-3200 trees ha-1, 1500-2000 trees ha-1, and 1000 trees ha-1). The combinations of treatments is replicated in two blocks for a total of eighteen 20x20m plots.

A combination of permanent and portable soil moisture probes are used to measure the treatment effects on available moisture. Biweekly measurements of xylem water potential serve to compare the level of tree water deficit between treatments, while a combination of manual and electronic dendrometers will track the impact of this water deficit on stem moisture content and seasonal radial growth. Finally, needles will be collected at the end of the season for C isotope assessments that integrate seasonal gas exchanges.

AD5A: *Deliberative-analytic framework to engage the public and stakeholders*

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Collaborators: Nazko First Nation

Communities and governments across Canada are struggling to respond to the rapidly increasing impacts of climate change. The threat of climate-induced ecological change is particularly acute in forest-dependent communities where the livelihoods of citizens are intimately connected to the landscape. As climate adaptive responses in forest management advance from the natural sciences, it is critical to simultaneously advance knowledge of the extent to which and how new policies and management approaches can better reflect the interests, values, and perspectives of stake- and rightsholders. Such efforts also require close attention to understanding the complex governance systems in which these forests are historically embedded. Failing to rise to this challenge risks perpetuating the longstanding injustices relating to decision-making for resource-based development that has, both past and present, benefited some groups and disadvantaged others.

In a region heavily impacted by annual forest fires and the effects of climate change, effective and inclusive forest management in British Columbia's interior has never been more important. The study area for this project is the Quesnel Timber Supply Area (QTSA), located on the traditional territory of four First Nations: Lhoosk'uz Dene (Kluskus Band), Lhtako-Dene (Red Bluff Band), ?Esdilagh (Alexandria Band) and the Ndazkhot'en First Nation (Nazko Band). The overarching aim of my research is to analyze shifting society-nature relationships as forest-dependent communities seek to adapt forest management practices to the impacts of climate change amidst the backdrop of efforts towards collaborative governance, meaningful reconciliation, and potentially, transformative change. This overarching aim will be operationalized the following three objectives:

1) Analyze the historical context and development of the current governance regime (e.g., actors involved, use of different forms of knowledge, processes of decision-making, perceived threats) and evaluate the presence or absence of known key factors for enabling collaborative governance in the QTSA.
2) Driven by the goals of First Nations partners, co-design a deliberative process for the identification of key values, visions, and priorities as they relate to land management and future forests, and develop a policy/legislative roadmap for supporting transformative change.
3) Assess levels and logics of support for climate adaptive management interventions in the QTSA, including testing the extent to which decision heuristics are or are not shifting toward a greater sense of "anthropogenic responsibility" in response to climate change.

My project crosses epistemological boundaries by braiding together traditional Western (Objective 1, 3) and decolonial (Objective 2) research approaches. Braiding multiple worldviews or methodologies together does not mean combining them, but recognizing each as unique and travelling parallel "down the River of Life together", like the rows of dark beads on the Haudenosaunee Two-Row Wampum Belt. This methodological braiding mirrors the changes taking place within British Columbia's policy landscape, including the adoption of the United Nations Declaration on the Rights of Indigenous People (UNDRIP) in 2019, and the representation of Indigenous governments in the development of Forest Landscape Plans. Detailed methodology still to come

AB5B: *Climate change and adaptive silviculture: playing to collaborate with a serious game*

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Collaborators: Alexis Achim

Multiple barriers are preventing the adaptation process of silviculture to climate change. These include uncertainties such as the impacts of climate change, the lack of knowledge transfer between scientists and professionals, the lack of governance with regard to these strategies and, in particular, the lack of social cohesion between professionals and the various stakeholders in forest management. The latter was the main focus of the present study and was addressed using an innovative tool: the serious game.

This novel approach allows experimenting serious stakes in a non-realistic and playful environment to address the potential of collaboration in the context of adaptive silviculture. With Catastrophe, the serious game designed and based on the real contexts in silviculture and climate change, the interactions between the players were recorded. In total, four sessions took place across Canada, including the participation of 20 actors of the Canadian forestry sector. During the debriefing that followed each of the game session, the insights from the players were also collected and analyzed to evaluate the potential of this new tool for decision support and stakeholder discussions. During the 10 rounds that completed each game session, the players were comfortable to quickly establish collaboration to win as a team.The debriefings also revealed that the players were able to transpose the collaborative learnings they acquired during the game to their reality. The game also demonstrated its ability to facilitate collaboration through a fun atmosphere and a clear common goal.

Overall, the serious game approach appears as a facilitating tool to establishing collaboration in the decision-making processes and could be used as public participation's tools in the forestry sector.

AD6: *Culturally important species*

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The environment and resources had always supported First Nations and are linked to their well-being. Some tree species are considered as cultural keystone species, since they occupy a very important place in Indigenous culture, spirituality and identity. As such, they are deemed irreplaceable, as the various benefits they provide cannot be derived from other species. Hence, the loss of such species can severely affect the cultural integrity of an Indigenous people. Indigenous people, experience disproportionate impacts from social and environmental changes.

In recent years, the W8banakiak have been concerned about black ash future, a cultural keystone species, use among other things for basketry. The spread of the emerald ash borer (*Agrilus planipennis*; EAB), an invasive wood-boring beetle from Asia that was first detected in North America in 2002, raises general concerns about black ash survival. In addition to the EAB, W8banakiak has experienced a decline in the quality of ash stems for basketry. By limiting the access to black ash stands, the privatization of the traditional land and the associated development of forest management and agriculture, have limited the Nation's access to black ash trees. These external pressures are threatening ecosystem basketry activities, and therefore all the traditional knowledge associated with it that have been previously weakened by colonization.

This participative action research is based on a partnership with the W8banaki Nation. The general goal is to support and participate to the adaptation process regarding black ash that was initiated by the W8banakiak and to provide additional knowledge regarding the species survival and W8banaki basketry future. To do so, the first objective is to document and better understand the importance of the species and its values from the w8banakiak perspectives and knowledge. Then, we will be able to better understand black ash wood properties and quality associated with traditional basketry. In order to ensure that conservation and adaptation efforts are culturally relevant, the third objective of this study will be to document the effect of black ash growth condition on its wood quality for basketry. Finally, we aim, at the end of this collaborative process, to propose culturally relevant management methods for black ash. Stewardship strategies that promote black ash growth and « quality » for basketry will be based on W8bankiak knowledge and needs. To do so, efforts and research have to be locally tailored and engage artisans–gatherers as partners and research process will be. Black ash and basketry are playing a key role for the well-being and the cultural heritage.

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