

Proposal

Christophe Rouleau-Desrochers

March 28, 2025

Climate change is intensifying extreme weather events, posing significant challenges to urban and forest ecosystems. Rising temperatures, heat waves, and increasing wildfire frequency threaten biodiversity and human well-being. In urban environments, tree cover provides critical services that can mitigate these threats. Trees cool local areas to reduce heat waves, sequester carbon, and improve air quality. Additionally, exposure to trees has been linked to substantial mental and physical health benefits. With my Master's research, I aim to identify tree species best suited for warmer and drier conditions in British Columbia, optimizing urban tree planting strategies and reforestation efforts for climate resilience. In 2024, I conducted a large-scale experiment on seven tree species saplings using a full factorial design with spring and fall watering to understand the across-year carry-over effect of the extended growing season. Then, my second chapter will scale up using juvenile and mature tree species by leveraging the data from a common garden and community science program in an urban arboretum. This research has broader implications for both British Columbia forests and for environmental justice. For BC forests, my work could provide insights into selecting tree species that will get their productivity maximized under future climate change. For environmental justice, my work can improve green infrastructure policy to reduce disparities. Currently, green infrastructure is extremely poor in low-income and marginalized communities, but my work could help refine plans to improve this by suggesting the most climate-resilient species. By recommending climate-resilient species for urban planting, my research supports equitable access to green spaces and sustainable forest management practices that integrate both scientific and Indigenous knowledge systems.

Substantive Eligibility

Given the accelerating pace of human-induced climate change, urgent and radical actions are essential to minimize its future impacts. Summers are hotter and extreme events like heat domes and severe drought events are more frequent¹. These phenomena and their consequences on urban environments and forest ecosystems are widely reported^{2,3}. Indeed, cities are forefront victims of climate change^{4,5}. Urban residents are already facing a rise in extreme weather events, such as heat waves⁴. Cities like Vancouver can mitigate the future impacts of climate change. For instance, urban trees provide cooling effects which can save lives during summer heat waves^{6,7}. They also provide carbon sequestration, improve air quality, and increase human health and well-being⁸. This is particularly important, as recent studies show that exposure to trees significantly benefits both mental and physical health^{8,9}. My proposed work will provide valuable insights into selecting tree species best suited to warmer and drier urban environments, optimizing tree-planting strategies for climate resilience.

Beyond cities, climate change is also intensifying wildfire risk.¹⁰ Recent work highlights the crucial role of forest species composition in fire behaviour, with ecosystems containing more deciduous trees experience lower fire severity.¹¹ Increasing the role of deciduous trees in the forestry industry—either through better understory planning or in selective locations ideal for deciduous species—could help reduce fire severity in the future while offering better options for enhancing forest productivity.¹² Increasing the use of deciduous trees—either through better understory planning or in selective locations ideal for deciduous species—could help mitigate fire intensity while increasing

forest productivity. Thus, my research will contribute to strategies that enhance both urban forestry and broader forest management efforts in a changing climate.

EDI and Indigeneity

Bridging the gap between the Western view of science and indigenous knowledge is not simple, but I believe, necessary. BC Indigenous communities have an extremely valuable understanding of the forest ecosystem functioning. One example is their successful wildfire mitigation in ways we have yet to implement in BC forest management. Along with increased wildfires, climate change-driven pest infestations and summer droughts are projected to have severe impacts on BC forests.¹³ Thus, modelling and experimental studies may have the power to better guide decisions on tree species for reforestation, potentially incorporating assisted migration to enhance forest resilience.¹⁴

While I believe my research could help refine the way we do forestry in BC, it could also improve tree species composition in impoverished urban areas. Green spaces in cities are positive. However, the setbacks are more subtle but can have tremendous impacts on people's lives. Low-income communities and people of color often experience climate injustice. One example is through green 'climate gentrification,' where new green infrastructure leads to residential displacement.¹⁵ Consequently, the people living in urban areas poor in tree density are the most affected by increased summer heat waves and future sea level rise and their corresponding lethal toll.^{15,16}

I argue that preserving BC's old-growth forests and ancestral lands, alongside enhancing knowledge of species and genotypes to improve reforestation efforts, will help forests better withstand future environmental changes. Additionally, my research could contribute valuable insights for the precise selection of better drought and heat-resistant trees to be planted in BC cities, ensuring more equitable and inclusive access to trees in urban environments.

Research Statement

Introduction: In temperate and boreal forests, temperature plays a crucial role in setting the boundaries for seasonal physiological activity. Thus, with rising temperatures from anthropogenic climate change, the climatically possible growing season has lengthened in many ecosystems worldwide by up to 11 days.^{17,18} Plants have tracked this through shifts in phenology—the study of recurring life history events—which are expected to continue with increasing temperatures¹⁹. In particular, trees have shifted earlier in the spring and later in the fall. They may use these extra days to fix more carbon and increase growth during the current growing season.^{20,21} This is a long-lasting assumption that was supported both by ecosystem-scale studies and warming experiments. This phenomenon could potentially have global consequences by partially offsetting anthropogenic warming, but could also affect trees on the individual level because longer seasons would push them to increase growth.²² However, recent research challenges this assumption, suggesting that factors such as drought stress and internal growth limitations may counteract the expected benefits.^{23,24}

Research objectives:

In my first chapter, I aim to assess tree species' potential to prolong or stretch their activity schedule and if increased carbon pools translate into greater growth increments in the following growing season. I will also investigate potential variations in these responses across deciduous and evergreen species, to test whether different patterns emerge within these distinct groups.

Recent research has shown that phenological traits are critical in regulating tree growth in urban ecosystems.²⁵ Thus, my first chapter will be complemented by two smaller projects, leveraging the data from a common garden and community science program to investigate how the timing of phenological events affects growth across years for juvenile and mature deciduous trees within an urban arboretum.

Research methods:

To investigate the impact of manipulated spring and fall temperatures on phenological responses,

I successfully conducted experiments in 2024 across seven different tree species under controlled conditions, including species that span both fast and short-life strategies (e.g., *Populus balsamifera*) and slow growth and longer lifespan species (e.g., *Quercus macrocarpa*) and including both deciduous and evergreen species.²⁶ I used a full factorial design of spring and fall warming with two levels each (control/warmed), resulting in four treatments plus an additional two treatments to test fall nutrient effects, using 15 replicates each for a total of 630 individual trees. Throughout the growing season of 2024, I tracked phenological events weekly from the start of the spring treatments through the end of the fall treatments. During the growing season of 2025, the same measurements will be performed. In fall 2025, after the trees have grown in ambient temperatures for the season, I will assess growth on the individual (total biomass) and the cellular level (number of cells and their characteristics), using dendrochronological methods.

With two projects forming my second chapter, I aim to draw a more complete picture of the underlying mechanisms driving tree growth and its relation to growing season length and temperature. For my first project, I will use five years of leaf phenology data and tree cross-sections that were collected at the common garden study. Then, I will analyze how the tree ring width relates to leaf phenology and how these traits vary across years. Then, for my second project, I will use the phenological data collected for the past 10 years by a citizen science program called the Treepotters on 53 mature deciduous trees. To relate these observations to growth, I will collect tree cores from these individuals.

By identifying future climate-resilient species, my work can directly inform municipal and provincial reforestation strategies. For instance, many trees planted in Metro Vancouver are native to North America, including (e.g. Red maple (*Acer rubrum*), River birch (*Betula nigra*), Yellow birch (*Betula alleghaniensis*), Northern Red Oak (*Quercus rubra*). These four species are among the eleven I will be studying in this project and are widely planted across the Greater Vancouver area. By using experimental and observational data to demonstrate the impact of growing season length on tree growth—considering both urban-planted juvenile and mature trees—my research has the potential to improve city green architecture and inform reforestation efforts following forest disturbances.

Methods of dissemination: I plan to communicate my research through usual academic means, such as peer-reviewed publications and dissemination in scientific events. More specifically, I will present my results and findings to local and international scientific conferences, such as Ecological Society of America (ESA), Eco-Evo, the International Phenology Conference to share the importance of preserving and improving tree planting policies in cities. However, I am convinced that reaching beyond the scientific community is paramount. Communicating scientific results to citizens is crucial, especially for such vital issues as urban green infrastructure which has the potential to bring tremendous positive effects by informing policymakers about new scientific insights. In turn, these insights could lead to better and faster changes in the living environment of the most marginalized communities in Vancouver. To challenge scientific echo chambers, I plan to share my insights through webinars and talks at events organized by the Invasive Species Council of BC, the Vancouver City Parks Restoration Group, and Green Teams Canada. By disseminating my research in these spaces, I can more effectively address climate injustice in Vancouver as suggested by Triffo's (2022) work.¹⁶ Beyond public presentations, I also intend to create accessible, engaging versions of my research. These will integrate the perspectives of those most impacted by climate injustice, alongside insights from interdisciplinary experts, for publication in science magazines and Vancouver neighbourhood newspapers.

Progress of thesis/dissertation and preliminary results:

For my main experiment, I conducted all treatments in 2024, and preliminary results suggest that the replicates subjected to spring and autumn warming experienced longer seasons and growth increments. I will measure trees until the completion of their growing seasons, after which I will assess their biomass. I will complete data collection, results and discussion in early 2026. I will write the introduction, methods and abstract in April 2026, and the paper will be sent for peer-review revision in June 2026.

Regarding my second chapter, I processed tree cross-sections for dendrochronological measurements and measured tree ring widths. Additionally, I cleaned and processed Treepotters data and will be collecting tree cores at the end of April 2025. Preliminary analyses of the phenological measurements indicate longer seasons when spring is early and fall is warmer. I will complete data collection and analyses by August and write the paper from September to November 2025. Once the paper has been finalized, it will be sent for peer-review revision in December 2025. While the projects I am undertaking are large, I am leveraging existing data for my second chapter and have successfully completed most of my large experiments. I am therefore confident I will complete my thesis with time for full dissemination as a Wall's Award holder.

Outline for completion of thesis and feasibility: Being seven months into my Master's, I have already completed the majority of the work for my first chapter. Chapter 2 is also well underway and I am currently building robust statistical models with colleagues for the tree cross-sections and Treepotters tree-core data. I am very positive that I will complete my thesis by August 2026. Since a significant portion of my data collection is already finished and my statistical analyses are progressing well, I expect to complete the chapter writing between November 2025 and April 2026. These two chapters will then be submitted for revision by my supervisor and committee in April 2026, with the defence scheduled for around that time. I anticipate submitting the final version of my thesis in July 2026.

Conclusion: British Columbia's forests and cities are already experiencing a small fraction of the future impacts of climate change. Therefore, I believe that my proposed work could offer valuable insights into tree species composition to select in BC's reforestation efforts following disturbances. By primarily focusing on deciduous trees, my findings have the potential to inform tree species selection in reforestation efforts and urban areas, ensuring that both affluent and underserved communities can benefit from the numerous advantages trees provide to people.

References

1. Zhang, X., Zhou, T., Zhang, W., Ren, L., Jiang, J., Hu, S., Zuo, M., Zhang, L., and Man, W. Increased impact of heat domes on 2021-like heat extremes in North America under global warming. *Nature Communications* **14**(1), 1690, March (2023).
2. Allen, C. D., Macalady, A. K., Chenchouni, H., Bachelet, D., McDowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D. D., Hogg, E. T., Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S. W., Semerci, A., and Cobb, N. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. *Forest Ecology and Management* **259**(4), 660–684, February (2010).
3. McCarthy, M. P., Best, M. J., and Betts, R. A. Climate change in cities due to global warming and urban effects. *Geophysical Research Letters* **37**(9), 2010GL042845, May (2010).
4. Das, S., Choudhury, M. R., Chatterjee, B., Das, P., Bagri, S., Paul, D., Bera, M., and Dutta, S. Unraveling the urban climate crisis: Exploring the nexus of urbanization, climate change, and their impacts on the environment and human well-being – A global perspective. *AIMS Public Health* **11**(3), 963–1001 (2024).
5. Corburn, J. Cities, Climate Change and Urban Heat Island Mitigation: Localising Global Environmental Science. *Urban Studies* **46**(2), 413–427, February (2009).
6. Ettinger, A. K., Bratman, G. N., Carey, M., Hebert, R., Hill, O., Kett, H., Levin, P., Murphy-Williams, M., and Wyse, L. Street trees provide an opportunity to mitigate urban heat and reduce risk of high heat exposure. *Scientific Reports* **14**(1), 3266, February (2024).
7. Zandler, H. and Samimi, C. Cooling Potential of Urban Tree Species during Extreme Heat and Drought: A Thermal Remote Sensing Assessment. *Remote Sensing* **16**(12), 2059, June (2024).

8. Wolf, K. L., Lam, S. T., McKeen, J. K., Richardson, G. R., Van Den Bosch, M., and Bardekjian, A. C. Urban Trees and Human Health: A Scoping Review. *International Journal of Environmental Research and Public Health* **17**(12), 4371, June (2020).
9. Turner-Skoff, J. B. and Cavender, N. The benefits of trees for livable and sustainable communities. *PLANTS, PEOPLE, PLANET* **1**(4), 323–335, October (2019).
10. Wasserman, T. N. and Mueller, S. E. Climate influences on future fire severity: a synthesis of climate-fire interactions and impacts on fire regimes, high-severity fire, and forests in the western United States. *Fire Ecology* **19**(1), 43, July (2023).
11. Park, J., Moon, M., Green, T., Kang, M., Cho, S., Lim, J., and Kim, S.-J. Impact of tree species composition on fire resistance in temperate forest stands. *Forest Ecology and Management* **572**, 122279, November (2024).
12. Mack, M. C., Walker, X. J., Johnstone, J. F., Alexander, H. D., Melvin, A. M., Jean, M., and Miller, S. N. Carbon loss from boreal forest wildfires offset by increased dominance of deciduous trees. *Science* **372**(6539), 280–283, April (2021).
13. Williams, D. W. and Liebhold, A. M. Climate change and the outbreak ranges of two North American bark beetles. *Agricultural and Forest Entomology* **4**(2), 87–99, May (2002).
14. Aitken, S. N. and Bemmels, J. B. Time to get moving: assisted gene flow of forest trees. *Evolutionary Applications* **9**(1), 271–290, January (2016).
15. Anguelovski, I., Connolly, J. J. T., Pearsall, H., Shokry, G., Checker, M., Maantay, J., Gould, K., Lewis, T., Maroko, A., and Roberts, J. T. Why green “climate gentrification” threatens poor and vulnerable populations. *Proceedings of the National Academy of Sciences* **116**(52), 26139–26143, December (2019).
16. Triffo, T. L. Green infrastructure planning in Vancouver : addressing environmental justice with participatory resident workshops. **PhD Thesis** (2022). Publisher: University of British Columbia Version Number: 1.
17. Körner, C. and Basler, D. Phenology Under Global Warming. *Science* **327**(5972), 1461–1462, March (2010).
18. Menzel, A. and Fabian, P. Growing season extended in Europe. *Nature* **397**(6721), 659–659, February (1999). Number: 6721 Publisher: Nature Publishing Group.
19. Wolkovich, E. M., Cook, B. I., Allen, J. M., Crimmins, T. M., Betancourt, J. L., Travers, S. E., Pau, S., Regetz, J., Davies, T. J., Kraft, N. J. B., Ault, T. R., Bolmgren, K., Mazer, S. J., McCabe, G. J., McGill, B. J., Parmesan, C., Salamin, N., Schwartz, M. D., and Cleland, E. E. Warming experiments underpredict plant phenological responses to climate change. *Nature* **485**(7399), 494–497, May (2012). Number: 7399 Publisher: Nature Publishing Group.
20. Keenan, T. F., Gray, J., Friedl, M. A., Toomey, M., Bohrer, G., Hollinger, D. Y., Munger, J. W., O’Keefe, J., Schmid, H. P., Wing, I. S., Yang, B., and Richardson, A. D. Net carbon uptake has increased through warming-induced changes in temperate forest phenology. *Nature Climate Change* **4**(7), 598–604, July (2014). Number: 7 Publisher: Nature Publishing Group.
21. Wang, H., Wang, H., Ge, Q., and Dai, J. The Interactive Effects of Chilling, Photoperiod, and Forcing Temperature on Flowering Phenology of Temperate Woody Plants. *Frontiers in Plant Science* **11** (2020).
22. Grossiord, C., Bachofen, C., Gisler, J., Mas, E., Vitasse, Y., and Didion-Gency, M. Warming may extend tree growing seasons and compensate for reduced carbon uptake during dry periods. *Journal of Ecology* **110**(7), 1575–1589, July (2022).

23. Dow, C., Kim, A. Y., D'Orangeville, L., Gonzalez-Akre, E. B., Helcoski, R., Herrmann, V., Harley, G. L., Maxwell, J. T., McGregor, I. R., McShea, W. J., McMahon, S. M., Pederson, N., Tepley, A. J., and Anderson-Teixeira, K. J. Warm springs alter timing but not total growth of temperate deciduous trees. *Nature* **608**(7923), 552–557, August (2022).
24. Green, J. K. and Keenan, T. F. The limits of forest carbon sequestration. *Science* **376**(6594), 692–693, May (2022).
25. Simovic, M., Mueller, K. E., McMahon, S. M., and Medeiros, J. S. Functional traits and size interact to influence growth and carbon sequestration among trees in urban greenspaces. *Functional Ecology* **38**(4), 967–983, April (2024).
26. Jönsson, A. M., Eklundh, L., Hellström, M., Barring, L., and Jönsson, P. Annual changes in MODIS vegetation indices of Swedish coniferous forests in relation to snow dynamics and tree phenology. *Remote Sensing of Environment* **114**(11), 2719–2730, November (2010).