Proposal

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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 to reduce further climate change, 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 warming 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 Colombia 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 refining urban forestry strategies and incorporating climate-resilient species, my research aims to support equitable access to urban green spaces while promoting sustainable forest management practices that align with 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 such as heat domes and severe drought events are more frequent[1]. 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 waves[4]. Cities such as 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-being[8]. This is particularly important, as recent studies show that exposure to trees significantly benefits both mental and physical health[8,9]. My proposed work could offer valuable insights into selecting tree species best adapted to warmer and drier urban environments.

Regarding forest ecosystems, recent evidence suggests that wildfires will increase with ongoing climate change[10]. Additionally, recent work shows the critical importance of forest species composition on fire intensity where ecosystems with a higher proportion of deciduous tree species usually have lower chances of burning[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 This highlights another crucial aspect of my research: increasing the use of deciduous trees in the

forestry industry could help reduce fire severity while offering better options for enhancing forest productivity.

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.[12] 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.[13]

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. The positive impacts of green spaces in cities are obvious, 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 green 'climate gentrification,' where new green infrastructure leads to residential displacement.[14] 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.[14,15]

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 that everyone can enjoy the benefits of 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.[16,17] Plants have tracked this through shifts in phenology—the study of recurring life history events—which are expected to continue with increasing temperatures[18]. 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.[19,20] 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.[21] However, recent research challenges this assumption, suggesting that factors such as drought stress and internal growth limitations may counteract the expected benefits.[22,23]

Research objectives:

Chapter 1. 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.

Chapter 2. Recent research has shown how critical phenological traits are in regulating tree growth in urban ecosystems.[24] Thus, in my second chapter, I will investigate how the timing of phenological events affects growth across years for juvenile and mature deciduous trees within an urban ecosystem. This chapter will be split into two projects. The first one consists of a common garden study of trees grown from saplings of four different provenances. I will investigate growth patterns for juvenile individuals at similar life stages to the trees that are often planted in urban landscapes.

For my second project, I will use the citizen science phenological data on mature trees to better understand how phenological stages and growth are related for trees at advanced life stages.

Research methods:

Chapter 1. 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.[25] 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.

Chapter 2. 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 5 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 Treespotters 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 both of my chapters through usual academic means. I aim to get my second chapter sent to peer-review revision before the end of 2025 and my first chapter by the end of 2026. Additionally, I will present my results and findings to local and international scientific conferences, such as ESA, Eco-Evo, the international phenology conference, etc. However, I strongly believe that reaching beyond the scientific community is paramount. Communicating scientifc results to citizens espicially for such vital issues like urban forests has the potential to have tremendous positive effects by informing policymakers of the new scientific insights which could lead to better and faster changes in our life environment. In order to break the scientc echo chambers, I plan on sharing my insights in webinars and talks in events organized by Invasive Species Council of BC, Vancouver City Parks Restoration Group, Green Teams Canada My first chapter should be written and ready to be sent for revision in mid-2026. I aim to present my experiments at the annual international phenology conference in 2026. The second chapter, which consists of two projects, will be condensed into one scientific article in which I investigate how the timing of phenological events affects growth across years for juvenile and mature deciduous trees. Once this publication is sent for revision, I will present my results at the 2025 edition of EcoEvo, in Squamish (BC) and at the 2026 conference of the Ecological Society of America to share the importance of preserving and improving tree planting policies in cities. Thus I aim dissemite my research through the work from Triffo (2022), who recommends that green infrastructure to fully address climate injustive in Vancouver needs to be done with the involment of the groups concerned throughout the whole process to adjust the implementations to their needs.[15]

Progress of thesis/dissertation and preliminary results:

Chapter 1. All treatments have been conducted in 2024 and preliminary results suggest that the replicates subjected to spring and autumn warming experienced longer seasons and growth increments. Trees will be measured until the completion of their growing seasons, after which their biomass will be assessed. Data collection, results and discussion will be completed in early 2026. The introduction, methods and abstract will be written in April 2026, and the paper will be sent for peer-review revision in June 2026.

Chapter 2. Tree cross-sections have been processed for dendrochronological measurements. Tree ring widths have been measured, and model development is ongoing. I already cleaned and processed Treespotters data. Tree cores will be collected at the end of April 2025. Preliminary analyses of the phenological measurements indicate longer seasons when spring is early and fall is warmer. Data collection and analyses will be completed in August 2025. The paper will be written from September to November and be sent for peer-review revision in December 2025. While the projects I am undertaking are large, I am levereging existing data for my second chapter and have successfully completed most of my large experiments. I am therefore confident I will complete this with time for full dissemination as a Wall's Award holder.

Outline for completion of thesis and feasibility: Being 7 months into my Master's, I have already completed the majority of the work for Chapter 1. Chapter 2 is also well underway and I am currently building robust statistical models for the tree cross-sections and Treespotters 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 Colombia'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.

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