An Evaluation of Potential Policy Tools and Frameworks For Urban Tree Canopy Cover Management in North Vancouver

by

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TABLE OF CONTENTS

LIST OF TABLES & FIGURES

Figures

Tables

Glossary

Afforestation: planting trees on land which did not previously contain tree cover

Canopy cover: the extent of a tree's outermost layer of leaves

Combined Sewer Overflows: Combined sewer systems direct domestic sewage, industrial wastewater as well as stormwater runoff altogether towards treatment plants. Periods of heavy precipitation can exceed a sewer system's holding capacity

Deciduous trees: trees that seasonally shed leaves, usually in autumn

Diameter at breast height (DBH): a standard of measuring a tree's diameter thickness, which in most countries is 1.3 m above ground

Evergreen trees: trees that keep their leaves throughout the year and whose leaves remain green

Grey infrastructure: engineering projects that are built with concrete and steel

Green infrastructure: engineering project that implement vegetation, soils and other environmental design elements to restore natural processes

Impervious surface: surfaces which are usually artificial structures and non-porous and therefore impenetrable by water (ie. asphalt, concrete, brick, etc.).

Pervious surface: surfaces which are permeable or porous, allowing for water infiltration

Reforestation: the intentional restocking of existing forests

Urban heat island: phenomenon where urban areas are significantly warmer than surrounding rural areas due to human activity and the increased heat capacity of man-made structures and land cover

Urbanization: the formation and growth of town and cities as greater populations begin living and working in city centres

Watershed: a geographic area which collects and drains rainfall or surface water to a common point. May also be referred to as a catchment area or drainage basin

EXECUTIVE SUMMARY

Urban trees offer a host of benefits both to the environment and to society by having a directly influential impact on physical, biological, and social conditions. Therefore, their appropriate management is critical towards the well-being and resiliency of current and future communities in the face of densification and climate change. A geospatial measurement of canopy cover area was conducted on aerial imagery of single-family detached residential lots between 1992 and 2018 within the City and District of North Vancouver to determine the impact that residential subdivisions have had on canopy cover area over time. Across the 20 individually assessed lots that had been subdivided between 1992 and 2018, an overall average decrease of 76% in canopy cover area was found to have occurred by 2018. These findings have far-reaching implications on the health of the surrounding ecology as well as on community well-being. They also provide grounds to support the notion that a fundamental shift in attitude towards urban trees and their roles in society is required.

A review of policies and frameworks concerning urban tree management and removal was also conducted to determine whether certain frameworks were more effective than others at protecting and encouraging urban canopy growth. Although this project is set within contexts of the City and District of North Vancouver, the evidence used to provide a recommendations framework that supports the maintenance and development of urban canopy cover was synthesized from a variety of local cities and municipalities experiencing similar challenges.

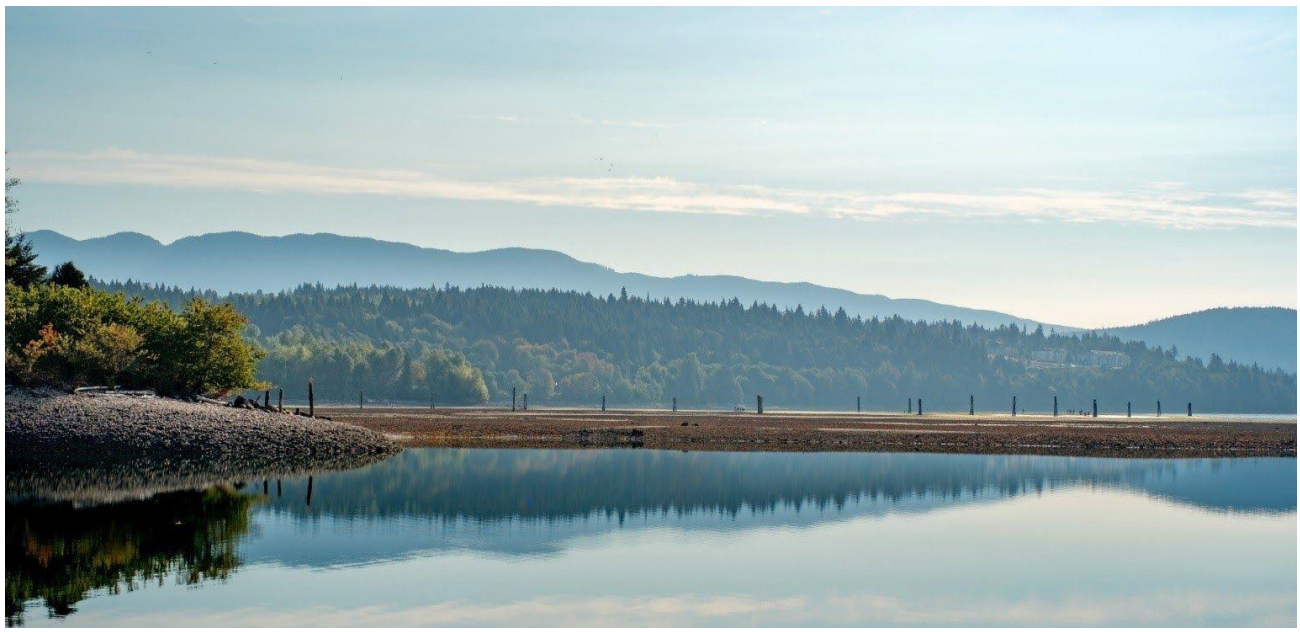


Image source: District of North Vancouver, 2020

INTRODUCTION

Trees are now effectively recognized as a valuable infrastructure in cities, delivering an array of advantages towards multiple systems: economic, social and environmental. From stormwater attenuation (Roy *et al*., 2012), urban cooling, biodiversity provisioning to human health and well-being (Saunders *et al.,* 2020), the ecosystem services, social, and financial benefits of sound urban tree canopy cover management are significant. The Southwest coast of British Columbia is currently experiencing increased urbanization and intensification, which is associated with an increased replacement of naturally pervious surfaces such as forests and vegetation cover with man-made impervious surfaces such as concrete roads, sidewalks, and buildings (Berland *et al.,* 2017). As such, many cities are experiencing a decrease in overall urban tree cover. The body of evidence supporting the beneficial roles that urban trees play has grown significantly in recent years, as has the acknowledgment that densification and development pressures have created competition for space between trees and infrastructure.

These trends are accompanied by impacts from climate change, giving rise to growing environmental and human health pressures. For example, an increased proportion of precipitation has been predicted to fall in the form of rain as opposed to snow in the Pacific Northwest in upcoming decades (Luce *et al.,* 2016). This means that a greater volume of rainwater will require managing within a shorter duration of time which thus increases the risk of flooding, erosion, and water contamination (Olds *et al.,* 2018). In addition, the projected increase in average temperatures for this temperate region elevates the risk of forest fires and associated landslides. On a municipal-wide scale, these elements pose far-reaching ecological implications as it relates to stormwater management, environmental protection and human health (Olds *et al.,* 2018). The conscious management of urban canopy cover has the potential to provide considerable mitigation effects against the challenges posed by climate change.

Watershed Health

The decreases in tree canopy cover and increase in impervious surfaces associated with urban densification are correlated with larger volumes of run-off during storm events, as virtually none of the water that lands on impervious surfaces are absorbed into the ground or captured by trees (Jennings & Jarnagin, 2002). The increase in storm flows poses concerns about the frequency of combined sewer overflows and gives rise to notable human health risks through water contamination (Roy *et al.* 2014). Conscious management of the urban hydrological cycles also greatly influences the health of surrounding urban ecosystems. Overflows and flooding have detrimental effects on urban streams, which are particularly susceptible to chemical, biological, and physical degradation due to the high concentrations of pollution loading and variable flow rates associated with urban run-off (Booth *et al.*, 2016). This in turn poses risks for aquatic life and compromises the ecological integrity of surrounding areas. These negative outcomes are a result of a culmination of factors, such as the rate of precipitation, elements of infrastructural design and notably, the prevalence (or lack thereof) of urban forests as green infrastructure.

Urban trees and forests have a great capacity for rainfall retention and the ability to influence the lag time, velocity, and peak flows of stormwater runoff (Kuehler, 2017). In addition to "pre-treating" storm flows and assisting in pollutant filtration, trees also reduce run-off through below-ground root water absorption and transpiration. Traditionally, gray infrastructure systems were solely relied upon for the collection and treatment of storm flows. However, it is increasingly acknowledged that in addition to acting as a more ecologically sound method of managing stormwater, the maintenance and proper planning of urban forests is cost-effective as well. It was published by McPherson *et al.* (2016) that the annual benefit of avoided stormwater treatment and flood control costs associated with rainfall interception of urban trees in California amounted to approximately US$ 41.5 million. In some other US cities, gains in stormwater services are between US$1.37 - $3.09 per dollar that would have otherwise been invested into traditional stormwater management (McPherson *et al.* 2005)

Urban Heat Island Effect

The urban heat island effect is a phenomenon where urban areas experience higher temperatures in comparison to surrounding non-urban areas as city surfaces tend to absorb, hold and radiate large amounts of heat more efficiently than natural surfaces (Rizwan *et al.,* 2008). A study evaluating the heat-related morbidity of extreme heat events in 544 neighbourhoods of Toronto published that the number of heat-related emergency calls was found to be negatively correlated to canopy cover (Graham *et al.,* 2016). Neighbourhoods containing less than 5% total canopy cover (TCC) placed five times more calls than neighbourhoods with greater than 5% TCC and placed about fifteen times more calls than neighbourhoods containing over 70% TCC. This is indicative that a minimal increase in TCC (from <5% to >5%) could greatly affect the quantity of heat-related ambulance calls, among other public health implications. Primarily, the cooling effect of urban forests on cities is provided by evapotranspiration and shading (Jiao *et al.,* 2017), and can reduce building energy use (Nowak & Dwyer, 2007). The importance of urban trees in mitigating urban heat islands within both future local and global climate change contexts has been well documented.

Human Physical and Psychological Well-Being

Urban trees have a great capacity to sequester air pollutants, which are associated with poor health conditions, particularly for those recovering from disease (Cantone *et al.,* 2020). A recent study found that after adjusting for socioeconomic, clinical, and demographic factors, tuberculosis patients undergoing treatment who lived in neighbourhoods with the highest percent of canopy cover experienced a 22% decrease in mortality risk compared to those living in neighbourhoods with the lowest percentage of canopy cover. This suggests that the presence of trees may play a role in bettering tuberculosis treatment outcomes through their pollutant sequestration properties (Blount *et al.,* 2020).

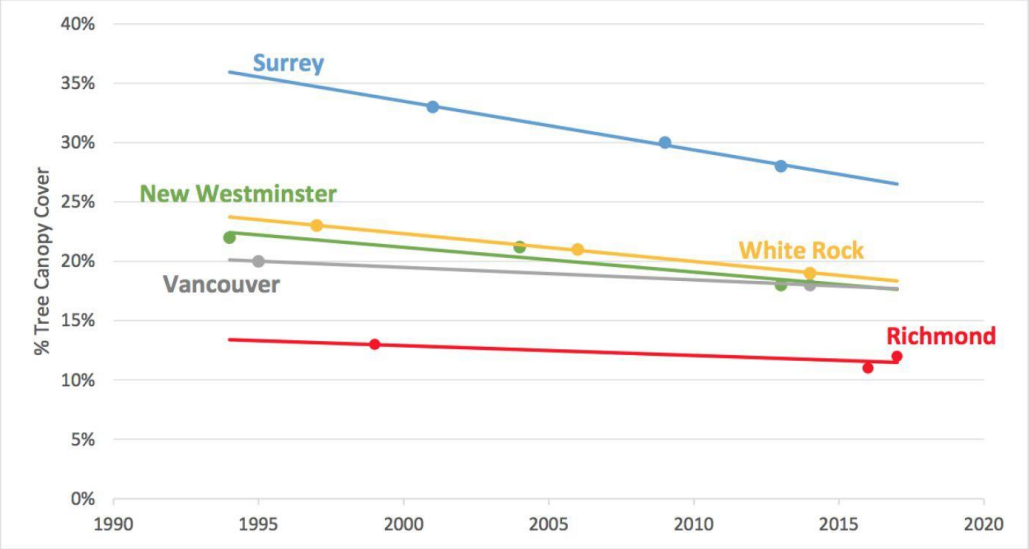
The proximity of treed streets and green spaces encourages physical activity, social cohesion, and stress reduction, therefore improving general happiness and well being (Barton & Pretty, 2010). A study published by Van den Berg *et al.* (2010) demonstrated that residents who were surrounded by more green spaces in their neighbourhoods tended to be less affected by the stress in their lives than those residing in neighbourhoods with less greenery. Moreover, the advent of 2020's COVID-19 pandemic has highlighted the importance of green spaces in cities. As soon as governments began easing physical distancing restrictions, urban residents flocked to

open parks and green spaces to alleviate the cabin fever that had set in while in lockdown (Plummer *et al.*, 2020).

Development Impacts

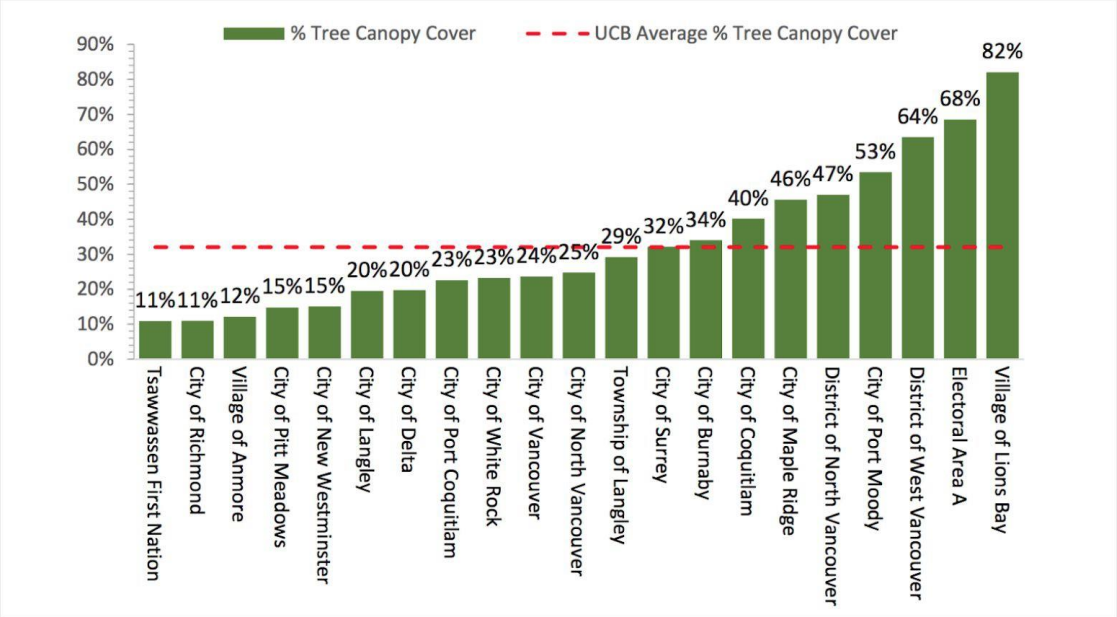
Despite the growing list of recognized utilities that urban trees offer, a consistent annual decline in canopy cover area has been observed across all reported districts by Metro Vancouver (2019), (Figure 1). Figure 2 provides an indication of where each district stands in relation to Metro Vancouver's average % canopy cover.

Figure 1: Reported change in % Tree Canopy Cover in Surrey, New Westminster, Vancouver, White Rock, and Richmond



Source: Regional Tree Canopy Cover and Impervious Surfaces, Metro Vancouver, 2019

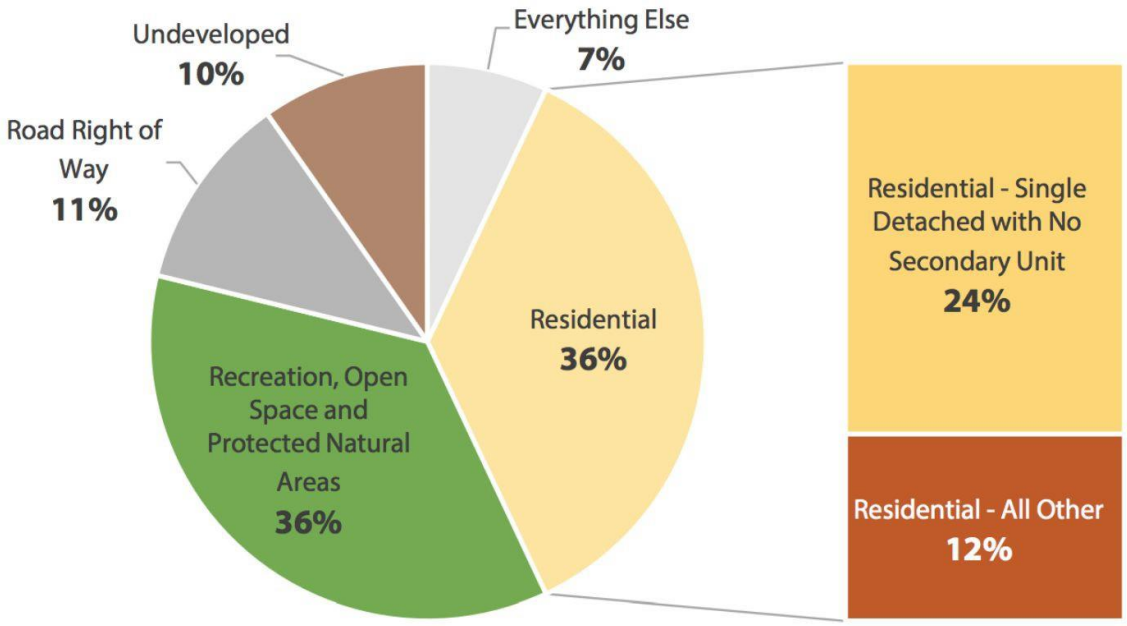
Figure 2: % Tree Canopy Cover within the Urban Containment Boundary (UCB)



Source: Regional Tree Canopy Cover and Impervious Surfaces, Metro Vancouver, 2019

Of particular interest to this study is the proportional significance that residential canopy cover can have on shaping a municipality's overall percentage canopy cover. Illustrated by Figure 3, a significant proportion of the Metro Vancouver Area's total canopy cover area is found within residential land use types (36%). Furthermore, 24% of all of canopy cover in Metro Vancouver is found on one particular type of residential area—single-family detached lots.

Figure 3: Distribution of tree canopy cover among land use types within Metro Vancouver



Source: Regional Tree Canopy Cover and Impervious Surfaces, Metro Vancouver, 2019

Nearly all of the 1.5% in yearly canopy cover decline measured in New Westminster (2004 - 2013 data) has occurred on private land where tree protection and replacement policies were non-existent (City of New Westminster, 2016). Since then, the municipality has implemented tree protection programs directed towards private land as an essential part of maintaining and growing future urban forests.

For these reasons, homeowners and those tasked with landscaping decisions have a significant influence on a city's overall canopy cover. Victoria, BC is a great example of a nearby city that is actively working to increase its percentage canopy cover from approximately

18% to 40% (City of Victoria, 2013) by capitalizing on the fact that the majority of their canopy cover is also found within residential areas. From information released by municipalities of this region, it is apparent that sustaining and expanding urban forests on private lands must be capitalized upon as that is where the greatest opportunities to do so lay. This notion is foundational towards this study's focus on residentially contained canopy cover.

Thoughtfully designed landscaping with the effective use of urban forests can take on biomimicry-like functions and have incredible potential in maintaining the integrity and resilience of ecologically sensitive areas in urban settings or implemented as part of wider regional restoration initiatives (Zari, 2018). It can also be shown that urban forests represent much more than design concepts. Rather, they are becoming accepted as part of a larger societal agenda and philosophy that serves as a basis for sustainability management and planning (Benedict *et al*., 2012). Only once equipped with a greater understanding of the degree to which urbanization impacts urban forests and innovative policy tools and frameworks that can be adopted to counter these trends, may municipalities feel more empowered to steward the implementation of ecologically conscious growth and development policies.

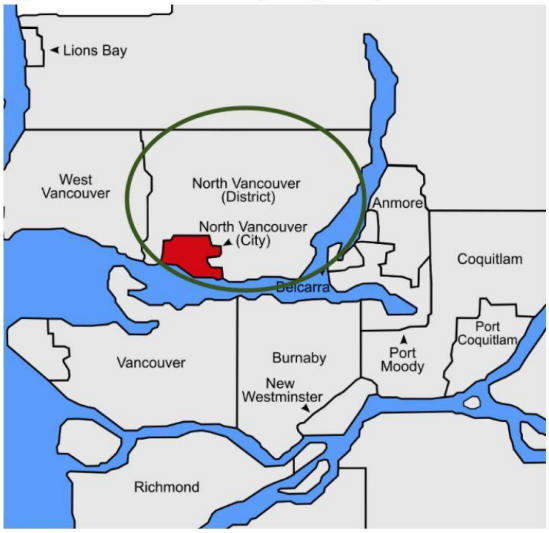
STUDY SITE

The study site of North Vancouver (Figure 4) comprises the City of North Vancouver (CNV) and the District of North Vancouver (DNV) and is contained within the region of Metro Vancouver. The CNV's 25% canopy cover falls just below Metro Vancouver's average of 30%, while the DNV's 47% canopy cover is significantly greater. Although two separate municipalities are responsible for policy governance within the study region of North Vancouver, they collaborate closely together on community and infrastructure planning as they are subject to nearly the same challenges that accompany their shared climatic, geographic and topographic characteristics. This study's investigation occurs amongst nine different blocks, indicated in Figure 5.

North Vancouver lies in a temperate rainforest zone, where the climate is largely influenced by the Pacific Ocean and mountain ranges to the East. Characterized as having a mild climate year-round, summers in this region are warm with daytime temperatures hovering around 20 °C.

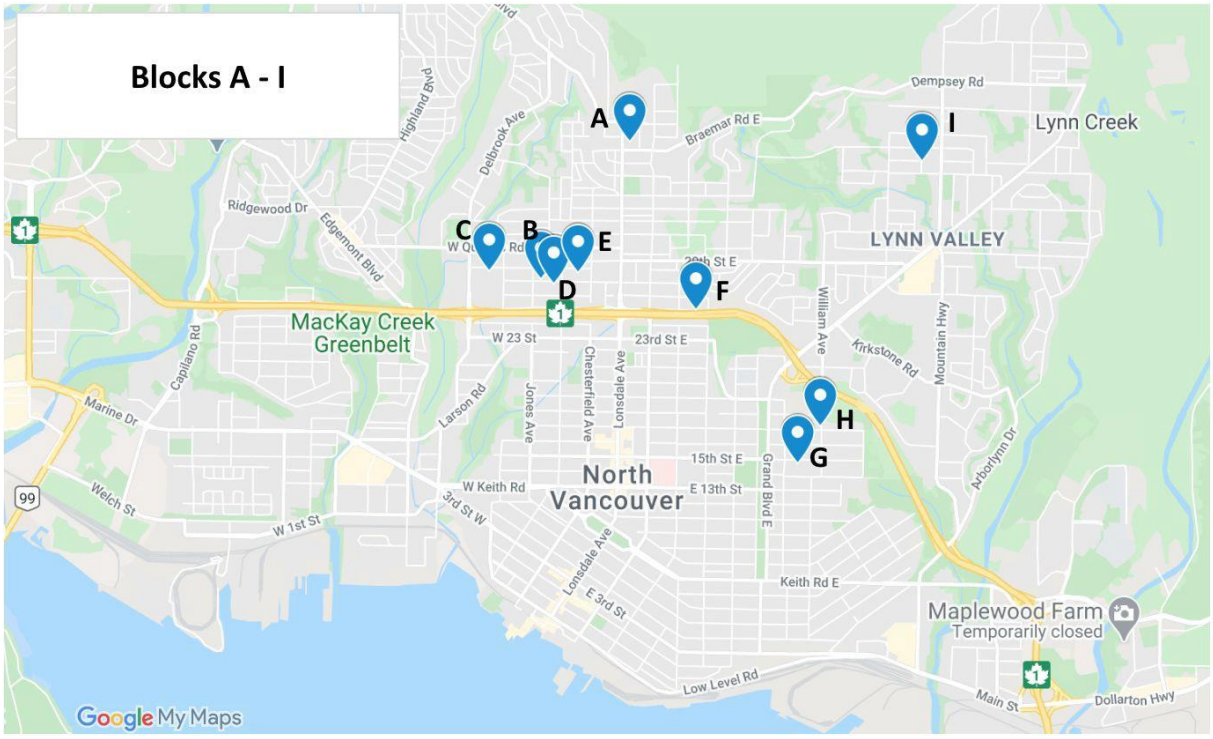
This region also experiences the mildest winters in all of Canada, with temperatures that rarely drop much below freezing at sea level. Precipitation rates vary widely due to BC's rugged and mountainous coastline. However, the region can be characterized as being "rainy", with average rainfall amounts falling approximately within the 1,400 mm range annually (Climate Data, 2012).

Figure 4: North Vancouver study area (circled)



Source: Wikimedia Commons contributors, 2014

Figure 5: Locations of nine study blocks (A - I)



Source: Google maps

PROJECT OBJECTIVES

The objective of this project is to review and supplement the City and District of North Vancouver's existing efforts to manage urban canopy cover by providing a scientific basis from which to support the incentivization of ecologically sound urban forest management practices. This includes providing statistics regarding trends in canopy cover from single-family detached residential lots that have been recently subdivided, as well as conducting a review of nearby municipal urban forestry best management practices reports to synthesize policy recommendations in an effort to further bridge the gap between science and policy. These two components are addressed as follows:

I. Residential case study: Determine the impact that subdivisions of single-family detached residential lots have on total canopy cover between 1992 and 2018

- *Measure* and *compare* canopy cover (sq m) found between residential lots in 1992 and 2018 (after subdivision developments have occurred) to determine the degree of canopy cover loss.
- Determine the total area of tree canopy cover changes between 1992 and 2018 over time within the lots as a percentage and in square meters.

II. Provide a policy recommendation framework based on scientific evidence for the City and District of North Vancouver to complement their existing urban canopy cover management objectives and activities.

- Provide a recommendation framework and policy tools to educate, as well as to increase public and industry awareness, about the importance and value of maintaining canopy cover

With a greater understanding of how the thoughtful design of urban forest landscape planning can contribute positively to climate change mitigation strategies and in addressing human health concerns, this project will be of value to several stakeholders. This serves as an additional resource that municipal governments can utilize to support the maintenance and ecologically sound management of urban canopy cover. The assessment will also inform both residents and the industry about the benefits of maintaining canopy cover. The normalization of ecologically sound landscape designs provides the opportunity for "green" or "sustainable" marketing strategies for construction and developing companies.

I. North Vancouver Residential Case Study

The case study component of this project was conducted through a geospatial measurement of canopy cover (m sq) of single-family detached residential lots amongst various neighbourhoods in the City and District of North Vancouver. Twenty lots were randomly chosen on the basis that they existed as individual lots in 1992, and were subdivided into two lots between 1992 and 2018. The twenty lots were selected from nine different residential blocks (Figure 5). The historic aerial imagery used for analysis was provided by the District of North Vancouver from their extensive records database.

Canopy cover measurements were made on ArcGIS by drawing polygon layers overtop georeferenced aerial imagery, for both 1992 and 2018 maps. As this case study is interested in tree canopy cover, shrubs and other vegetation cover were not included in the analysis.

II. Policy Review and Synthesis

Many cities across North America have published canopy cover target reports and subsequent urban forestry best management practices in response to the measured decline of urban tree canopy cover. Although a plethora of information and literature is available for distillation, only municipal reports relevant to the Pacific Northwest context were examined to synthesize recommended policies and steps to be taken to meet stated canopy cover objectives. The Cities of Victoria, Vancouver, New Westminster, Surrey, Portland, and Seattle were therefore selected as they are found within the same geographic region, have similar characteristics and face similar challenges. Furthermore, reports could be identified that met the following criteria:

- published no earlier than 2012 for the purposes of relevancy
- outlined % canopy cover targets
- outlined monitoring and tracking protocols
- outlined public outreach and educational initiatives
- outlined policy recommendations and actionable items

A literature review was also performed to explore other notable drivers of change towards changes in urban canopy cover.

The City and District of North Vancouver have also released various documents pertaining to the management of their urban trees in the form of by-laws, official community plans and various management and strategy plans[1]. These documents were surveyed for current in-use practices, programs, and policies that dictate the management of their urban forests. Based on an assessment of their current management framework and the assembled collection of additional policies and practices that other municipalities have adopted, a framework of policy recommendations was determined in policy areas where there could be further developed. They were formulated based on actionability and relevance to the local context, and in considering the following six dimensions (Morestin, 2012): effectiveness, unintended effects, equity, cost, feasibility, and acceptability (Figure 6). These dimensions were selected following a review of other frameworks related to areas of environmental policy formulation. Despite being non-exhaustive, the evaluation illustrates general tendencies and focuses attention on key contributions made to the complementary recommendations provided in this study.

Figure 6: Dimensions for analyzing public policies

Effects	Effectiveness	What effects does the policy have on the targeted problem?	Durability
	Unintended effects	What are the unintended effects of this policy?	
	Equity	What are the effects of this policy on different groups?	
Implementation	Cost	What is the financial cost of this policy?	
	Feasibility	Is this policy technically feasible?	
	Acceptability	Do the relevant stakeholders view the policy as acceptable?	

Note: Adapted from "A Framework for Analyzing Public Policies: Practical Guide" by Morestin, F., 2012, *National Collaborating Centre for Healthy Public Policy (NCCHPP), 1636, p. 2.*

[1] District of North Vancouver Climate Change Adaptation Strategy (2017), City of North Vancouver Adaptation Plan (2013), District of North Vancouver Tree Protection Bylaw 7671 (2012), and City of North Vancouver Tree Policy (2011)

RESULTS

North Vancouver Residential Case Study

There was a significant decrease in canopy cover measured on lots in 2018, compared to their unsubdivided 1992 counterparts. From the subdivisions that occurred over 26 years, the overall average decline in canopy cover experienced by all sites was 74 % (Table 1). This notable decrease was the result of the complete removal of all trees on some lots, whereby the remaining canopy cover is solely overlapping growth from neighbouring lots. The total measured change in canopy cover from 1992 to 2018 was a decrease of 81%, translating to a total decline of 3,710 square metres of canopy cover across all sites over this time (Table 2). This is consistent with findings published in Metro Vancouver's Report[2], which indicated a decrease in canopy cover of housing stock parcels built in the 70s from 36% to 18%, a 50 percent loss, for those built in the early 2000s.

Table 1: Canopy cover measurement results

Blocks # A - I	Subdivision Sites # 1- 20	Subdivided Addresses (2018):	1992 Canopy Cover (sq m)	2018 Canopy Cover (sq m)	% Change Canopy Cover
A	1	3782, 3790 LONSDALE AVE	551	125	-77%
B	2	352, 350 W 27TH ST	318	78	-75%
C	3	562, 560 W 28TH ST	197	141	-28%
	4	558, 556 W 28TH ST	169	23	-86%
	5	563, 561 W 28TH ST	104	41	-61%
	6	549, 541 W 28TH ST	258	25	-90%
	7	529, 527 W 28TH ST	81	26	-68%
D	8	322, 318 W 26TH ST	175	35	-80%
	9	316, 314 W 26TH ST	28	8	-71%
	10	319, 317 W 27TH ST	201	10	-95%
E	11	2728, 261 W 28TH ST	448	10	-98%
	12	241, 239 W 28TH ST	147	30	-80%
	13	235, 233 W 28TH ST	49	13	-73%
	14	205, 2741 W 28TH ST	81	53	-35%
F	15	328, 330 E 25TH ST	663	0	-100%
G	16	786, 788 E 17TH ST	207	28	-86%
H	17	721, 723 E 15TH ST	410	5	-99%
	18	729, 731 E 15TH ST	82	18	-78%
I	19	1196, 1197 CROFT RD	182	123	-32%
	20	1199, 3633 CROFT RD	242	90	-63%

[2] Metro Vancouver, Regional Tree Canopy Cover and Impervious Surfaces, 2019

Table 2: Change in canopy cover between 1992 and 2018

Average decrease in canopy cover across all lots (%)	**74%**
Total decrease in canopy cover (%)	**81%**
Total decrease in canopy cover (sq m)	**3,710**

Following the development of subdivided sites, an overall decrease in pervious surfaces is evident, as there are now double the number of structures when compared to its pre-development state (two homes, garages and driveways). A growing desire for Canadians to live in larger homes is also apparent. In 1975, the average Canadian house was 98 sq m (1050 sq ft). By 2010, the average new homes being built were double in size (Banerjee, 2012). When it comes to garages, buyers are also favouring properties with structures capable of storing two vehicles (Salandro, 2018). With a larger number of buildings being built that are also increasing in size, escalating pressure is placed on the removal of trees.

Review of North Vancouver's Urban Forest Management Strategy

Between 2011 and 2016, the DNV saw a population increase of 1.8% (translating to approximately 1,500 new residents). The remaining North Shore region saw a population increase of 5.1% (over 5,000 residents) during the same period (Statistics Canada, 2017). As populations climb steadily, so too have expectations of an influx of development permits and rezoning applications.

The comprehensiveness of North Vancouver's existing urban canopy cover management planning is documented through the implementation of their Living City Tree Planting Program (2019), Tree Protection Bylaw Policies (2012), Climate Change Adaptation Strategy (2017), Official Community Plan (2018), and Integrated Stormwater Management Plan (2016). They are framed through the lens of climate change mitigation and adaptation, which are informed by the primary risks identified by reviewed municipalities in Table 3. Overall, the published resolutions to support the long-term health of urban trees and forest ecosystems over the last decade is evident, and key policies and programs outlined in their reports have been consolidated in Table 4.

Table 3: Risks to urban trees and ecosystems in the DNV due to climate change

Increased risk	**Negative effects on tree health and mortality**
Warmer and drier climate	Inability of native species to sufficiently adapt to changing conditions
Wildfire	Death of trees or stands
Insect outbreaks	Increase in diseased trees
More intense precipitation and wind storms	Higher soil saturations = tree blowdowns
Sea level rise	Coastal flooding, erosion, saltwater intrusion Habitat loss

Table 4: North Vancouver's key urban tree management policies and programs

Tree Protection[3]

- Only personnel authorized by the municipality may undertake any activity that may affect the health and welfare of a tree.
- Trees may only be considered for removal under a strict set of criteria, such as posing visibility impediments to traffic or other safety concerns.
- Consent from surrounding property owners must be provided before applications to prune or remove trees by residents can be considered.
- Where trees are removed from city property, replacements are to be planted where budget constraints allow.
- Development applications must have significant trees noted on submission for consideration of retention.
- That tree protection barriers surround any retained tree(s) during development
- Under certain circumstances, stringent conditions are placed upon the removal of significant trees. Ex. if the subject lot is 420 square metres or greater, three replacement trees are required for every large-diameter tree removed or damaged
- Severe penalties may result from offences contrary to the provisions outlined by municipal bylaws

Climate Change Adaptation[4]

- Development of an Urban Forest Management Plan focusing on growing resilient trees and improving urban canopy cover.
- Strengthens public communication, education and outreach about the economic, ecological, and social benefits of proactive urban canopy cover management.
- Partners with regional First Nations to gain more insight into various approaches for understanding and managing forested areas.
- Invests in the professional review of the region's forested areas, and the monitoring of post-treatment areas to assess the efficacy of management approaches.
- Supports the health of fire disturbance regimes.
- Development of an administration to deliver incentives (e.g., waived permit fees, fast-tracked applications, a rebate program) for property owners, developers, and architects who are making resilient development choices.
- Development of an education and incentive program to encourage more resilient choices for the design, maintenance, and renewal of private development.

[3] District of North Vancouver Tree Protection Bylaw 7671 (2012), and City of North Vancouver Tree Policy (2011)

[4] District of North Vancouver Climate Change Adaptation Strategy (2017) and City of North Vancouver Adaptation Plan (2013)

Community Planning[5] ● Promotes the protection of the region's forested character. ● Recognizes the value of ecosystem services provided by urban trees and encourages tree retention and replacement as guided by the region's development permit requirements and tree protection bylaws. ● Supports the appropriate maintenance of trees and hazard tree removal. ● Strives to improve species diversity and mitigate risks of disease and hazards ie. wildfire and windfall. ● Seeks to retain soils, prevent soil compaction, erosion and instability during development, and ensure adequate soil depth for rainwater infiltration and tree growth. ● Integrates of trees, plants and natural elements for shade, sensory and health benefits. ● Acknowledges that mature trees shade and cool homes in the summer, absorb CO2 and trap dust particles, provide habitat, aid with energy conservation and absorb rainwater, reducing stormwater run-off into creeks.
City of North Vancouver Living City Tree Planting Program (2019) ● Promotes the planting of street trees in residential areas within the City of North Vancouver. ● Residents on blocks selected for planting receive a Notice of Tree Planting, species fact sheet and additional information about the program.
City of North Vancouver Integrated Stormwater Management Plan (2016) ● Underground soil cells in city boulevards which support the health of street trees and provide stormwater control. ● Investigating wildlife relationships between forest patches of higher density and/or of particular designs. ● Inclusion of street trees for canopy connection to capture and treat stormwater.

It should be noted that among the reviewed documents, some progressive and sustainable construction standards exist, pertaining to building designs and infrastructure, and flood and fire protection. Such policies are accompanied by enforcement systems. One of the most clearly identified areas whose scope can be further developed is in public outreach, seeing that there is currently a "limited number of educational and incentive initiatives to encourage more resilient choices for the design, maintenance, and renewal of private development" (District of North Vancouver, 2017).

Review of Other Municipal Urban Forest Management Strategies

A review of additional urban canopy cover target reports published by surrounding municipalities of this region was conducted. Findings pertaining to objectives were obtained and are given in Table 5.

[5] District of North Vancouver Official Community Plan (2018) and City of North Vancouver Official Community Plan (2018)

Table 5: Various canopy cover targets of surrounding municipalities

City	Urban tree canopy cover target
Vancouver, BC	Increase canopy from 18% to 22% by 2015[6]
Victoria, BC	Increase canopy from 18% to 40%[7]
New Westminster, BC	Increase canopy to 27% by 2035, with a long term goal of 40%[8]
Surrey, BC	Maintain canopy at 30%[9]
Seattle, WA	Increase canopy from 23% to 30% by 2037[10]
Portland, OR	Increase canopy from 26% to 33%[11]

Several programs were noted as being of central importance to their respective cities' objectives. For example, in 2009, the City of Seattle established The Urban Forestry Commission to advise and strategize for the Mayor and City Council regarding urban forest management and governance policies (City of Seattle, 2013). The Urban Forestry Commission is responsible for holding open meetings every month, implementing programs and sanctioning canopy cover assessments. Similarly, in 2014, Vancouver's Urban Design and Sustainability Department implemented processes to facilitate alternative design solutions through collaboration during all scales of the development processes (City of Vancouver, 2018). The Protection of Trees Bylaw was also amended to no longer permit the removal of one tree/year on all private properties. Furthermore, the City of Vancouver holds two subsidized tree sales annually, where residents can purchase fruit, flower, shade, or conifer trees in the range of $10/tree, which normally cost upwards of $75 (City of Vancouver, 2020). Events like these offer great opportunities for educating families and youth about the important roles trees play in urban ecosystems and could be a worthwhile program to adopt within North Vancouver.

[6] Vancouver Board of Parks and Recreation, Urban Forest Strategy, 2018 Update
[7] City of Victoria, Urban Forest Master Plan, 2013
[8] City of New Westminster, Tree planting master plan 2020-2030, 2019
[9] City of Surrey, Tree Canopy Dataset page, 2015
[10] City of Seattle, Urban Forest Stewardship Plan, 2013
[11] City of Portland, The Portland Plan, 2012

DISCUSSION

Findings from this project's temporal canopy cover assessment have significant implications. The large decline in canopy cover measured for the 2018 period from 1992's baseline has consequences on both the health of the City's watershed as well as on the region's efforts to mitigate the effects of climate change (Jim *et al.,* 2018). To illustrate how crucial the maintenance of canopy cover is in this region, Asadian & Weiler (2009) investigated the rainfall interception rates of Douglas Fir (*Pseudotsuga menziesii)* and Western Red Cedar (*Thuja plicata)* trees within the DNV. It was found that on average, the interception rate of Douglas Firs was 49.1%, and Western Red Cedars' was 60.9%. Considering the abundance of trees within the DNV, the significant proportions of rainfall that are captured and evaporated rather than contributing to urban storm flows have significant implications on flood protection (Alila *et al.,* 2009). The additional utilities provided by urban forests are also compromised as canopy cover decreases.

Despite all the innovative programs and initiatives that have been implemented by regional municipalities thus far, canopy cover continues to decline as a result of the construction of new buildings across Metro Vancouver (Metro Vancouver, 2019). It is conceivable that since awareness surrounding the topic of urban forest management has only relatively heightened within the last decade, perhaps an insufficient amount of time has passed to enable the positive effects of recently implemented programs and outreach initiatives to be measurable, considering the slow growth of trees. Nevertheless, increasing development pressures are sure to persist, and thus, urban forest management frameworks should be constantly evaluated and adapted to be as relevant and effective as possible, with monitoring systems in place to track progress.

A holistic framework needs to be implemented in the procurement of such a framework. It has been established that housing developments are a primary driver of canopy cover loss in many communities (Croeser *et al.,* 2020). However, additional factors constitute notable influence and key players are described in the next section.

Other Drivers of Canopy Cover Change

The purpose of this project was to quantify the degree to which increased urbanization affects canopy cover. However, it is also important to acknowledge that additional complex drivers are also at play, including the significance of "local context" regarding the social and economic heterogeneity of cities. Each municipality varies in its location, climate, demographics, size, and other circumstantial factors (Saunders et al., 2020). Therefore, the complex relationship between each city's tree canopy cover and its socio-economic characteristics will differ.

While the vast majority of North Vancouver residents value street trees (District of North Vancouver, 2020), the overall attitude towards them can vary significantly. City trees can be perceived as a burden when they cause property damage, impose hazards or impede views. Some residents also consider trees to be a costly nuisance to maintain, when dropped fruit, flowers, and leaves cause sidewalk slipping hazards and clog gutters (Rollins, 2008). As such, one of the roles that community outreach programs can adopt is to shift negative public perceptions. Thoughtfully placed residential trees can also have economic advantages. A Canadian study found that amongst certain neighbourhoods, the presence of mature trees on residential properties can raise their value by 10-15% (Thériault *et al.*, 2002).

Green spaces can sometimes be distributed unevenly based on income, ethno-racial characteristics and (dis)abilities (Wolch *et al.*, 2014), and lower-income and non-home owning groups often face barriers to participation in reforestation programs (Dawes *et al.*, 2018). Homeownership and the wealth, education, cultural, and racial composition of communities can also be deterministic with respect to influencing forest structure such as diversity and stem density (Fan *et al.*, 2019). These findings highlight the importance of allocating funding more consciously towards public green spaces and for designing future urban developments that allow equitable access to trees on both public and private land. The benefits of ecosystem services should be distributed equally amongst all socio-economic and ethno-racial groups. As urban forests are generated and cared for by people, the human factor component of urban forest

systems provide

a great opportunity to include city residents through citizen science programs. These programs will offer the added benefit of increasing awareness surrounding the relationships between society and urban forests (Fan *et al.,* 2019).

Urban Canopy Health

The general health of canopy cover is another aspect of urban forest management that requires attention. For instance, the City of Toronto has seen a 1.8% increase in canopy cover over the last 10 years, but the overall health of their urban forests has declined. A decrease in average tree size was observed, as well as an overall reduction of its forests' structural value due to the prevalence of invasive species and a higher proportion of younger trees (City of Toronto, 2018). In addition to species diversity, size and age heterogeneity is also necessary for maintaining a stable forest population over time. Based on a study published by Richards (1983), the 40:30:20:10 guideline, now commonly known as "Richards' guideline", can be generally followed, using size as a proxy for age. The rule suggests that a population of trees with the following size distributions is considered well-balanced: 40% of individuals have a diameter breast height (DBH) <20 cm, 30% with a DBH between 20-40 cm, 20% with DBH between 40-60 cm and 10% with a DBH > 60 cm. Despite this guideline, there are notable advantages of planting large, longer-lived trees: reduces the number of trees requiring planting and removal at the end of its lifespan, as well as lowers the long-term costs and fuel consumption required of maintenance. Distinctions between deciduous and evergreen (conifers) trees are also important to recognize. Because evergreen trees keep their foliage year-round, they have a greater ability to attenuate rainfall throughout the year, tend to be longer-lived and grow to larger sizes (Chen *et al.,* 2017).

Climate change is another player requiring consideration in developing policy frameworks. The University of Washington's School of Environmental and Forest Sciences reported that the characteristics of the bioclimatic condition to seed transfer zones surrounding the Puget Sound region (where Seattle is located) for western red cedar, western hemlock and Douglas fir are likely to reduce in size, shift North, or disappear within the next 80 years (Kim *et al.,* 2012). This is indicative that seed sources used for urban reforestation and afforestation need to diversity and consider novel bioclimatic habitats as climates shift. Not only do the appropriate

species have to be selected, appropriate site-specific conditions for planting also require consideration.

Public Policy

Public policy is defined as "a strategic action led by a public authority to limit or increase the presence of certain phenomena within the population" (National Collaborating Centre for Healthy Public Policy, 2012). For public policy to be effective, an understanding of system components and their complex interactions must be achieved to adequately manage urban canopy cover to maximize its benefits to society. Policies should be tangible and feasible, where management opportunities are appropriately matched with management challenges. For example, the projected increase in precipitation, runoff and flooding may lead to heightened tree stress and mortality. This can be mitigated by the thoughtful selection of native species adapted to extreme events for planting or provide insight to support the planting of new species (Brandt *et al.*, 2016).

A holistic approach needs to consider land, water, economic, built, and invisible social systems, as well as by incorporating the most up-to-date ecological knowledge. Unintended consequences of policy decisions can be avoided by refraining from assigning "too-narrow definitions of problems and processes," which can only be done by effectively "engaging in systems thinking" (Cairney, 2019). This is an optimal approach through which to be able to change, manage, or influence the system. For example, most public sector accounting guidelines currently categorize urban trees as biological assets along with animals (City of Victoria, 2013). By increasing the asset status of forests as green infrastructure and tangible capital assets, more effective resource management and planning can occur as improved integration into the City's asset management system and improved access to infrastructural funding is made possible.

Applications Elsewhere

Beyond local contexts, the majority of people live in cities worldwide. The migrational trend of populations moving towards urban centres is growing (Mouftah et al., 2018), and land conversion rates are therefore steadily increasing as cities of both high and low-density populations worldwide continue to expand at increasing rates (Schneider & Woodcock, 2008).

As such, the health of urban environments is sure to pose significant policy challenges in the near future.

Humans are living in an era of extreme planetary degradation (Gulistan *et al*., 2020). Work done by city planners and residents themselves, which are bound by the confines of municipal policies and by-laws, can be increasingly recognized as remedial if properly advised by scientific, socio and economic variables relevant to their regional contexts. Indeed, this form of urban ecological restoration could be a vital contributor to the effects of climate change (Ingram, 2008). Through outreach and education, tooling communities with skills to enhance the resilience of their communities can have far-reaching implications: in particular, communities experiencing, or projected to experience rapid growth in housing and commercial development. Universally, municipal tree by-laws and policies that regulate the maintenance and expansion of urban trees and forests are a critical component towards upholding the ecological integrity of urban environments as well as serving important functions towards human health and well-being.

RECOMMENDATIONS

The recommended points provided are guidelines to be used as a framework that complements the CNV and DNV's existing efforts, initiatives and programs to wholly optimize the benefits that can be obtained by society through increasingly thoughtful urban canopy cover governance. Naturally, this list is non-exhaustive. The suite of possible actionable items is indefinite. These submissions provide attention to areas of opportunity within the City and District of North Vancouver that could be developed further, despite challenges that currently exist.

The recommendations have been assigned into the following five categories: 1) Preserving existing trees, 2) Promoting afforestation and reforestation, 3) Incentivization strategies, 4) Public education and outreach, and 5) Monitoring and progress tracking.

1. Preserving existing trees

- Implementing systems during the development process which facilitate alternative design solutions, that retain healthy, mature trees at all scales of development.
- Implementing policies restricting residents' ability to deny street tree planting adjacent to their property, supported through improved notification, education and engagement efforts.
- Focusing on evergreen species which keep their foliage year-round: better rainfall attenuation, CO2 absorption and air pollutant processing capacity. They tend to also have longer lifespans and greater size potential.
- Providing free tree care for certain homeowners who house significant tree ecosystems on their properties, or for residents qualifying for elderly assistance.

2. Promoting afforestation and reforestation

- Upholding mindfulness about equality. Providing particular attention towards neighbourhoods with below-average canopy cover and ensuring that the distribution of ecosystem services are delivered equitably.
- Implementing annual subsidized tree sales or nursery rebate programs.
- Partnering with local school boards and other groups to support planting on private and institutional lands.
- Increasing planting with mindfulness to the location of streets and parks where vulnerable populations are at increased risk from the urban heat.
- Increasing planting with mindfulness of the locations of major truck routes and arterial streets to ameliorate air quality and to act as a buffer.
- Working together with local First Nations groups to identify culturally appropriate ways to support reconciliation through urban forestry, and to enhance or restore cultural values associated with treed landscapes.
- Developing a species biodiversity strategy to account for regional climatic changes projected to occur over the next century.
- Selecting the right tree for the right place: paying mind to size and longevity.

3. Incentivization strategies

- Fast-tracking development applications whose designs are ecologically conscious and retain urban canopy.
- Providing opportunities for departure from certain building codes to preserve existing trees during development. This enables creative building designs.
- Enabling development companies to capitalize on ecologically conscious design as a marketing strategy through the normalization and widespread acceptance of urban forest stewardship.
- Establishing utility bill rebates with certain criteria, based on a property's total canopy cover. This promotes properties with greater stormwater management and shade-cooling potential.
- Creating well-designed and beautiful urban landscapes with ecosystem function in mind, to set examples and provide inspiration.

4. Public education and outreach

- Providing industry outreach with an emphasis on the arboricultural and design communities (landscape architects, architects, planners and engineers) to guide the way towards more innovative design solutions for tree retention and landscape planning.
- Initiating outreach initiatives with various community groups to enhance planting design and tree selection to reflect BC's diverse cultural values.
- Developing a program that implements strategies to engage the public in urban forest guardianship.
    - Provides education and support to understand the benefits and value of trees and how to maintain them.
    - Encourages attendance to urban forest outreach events that are accessible, understandable and coordinated.
    - Develops and delivers outreach tools and materials.
    - Engages with residents in planting and stewardship activities.
    - Leverages funding through volunteer programming.

5. Monitoring and progress tracking

- Conducting regular (bi-annual) land cover change analysis with a particular focus on urban canopy cover. Publishing findings in a report available to the public with recommendations and next steps.
- Developing neighbourhood specific targeted planting strategies to address succession, planting impediments and opportunities.
- Tracking pre- and post-development canopy cover statistics throughout the rezoning and permit application process.
- Implementing an Urban Forestry Commission made up of a knowledgeable and diverse group of professionals to oversee and advise the mayor and municipal branches regarding urban forest programs, policies and governance based on sound science.

SCOPE & LIMITATIONS

A constraint of this project was the time limitations surrounding the review of municipal documents, information synthesis and report preparation periods. However, this report highlights the major concerns, challenges and potential approaches to address urban forests positively. Ideally, geospatial analysis of urban canopy cover can be conducted over the entire North Vancouver region over a similar time scale. This could provide insight into trends of canopy cover. The number of municipalities whose by-laws and urban forestry management strategies were assessed was also limited by time constraints.

The geospatial analysis did not intend to:

- Advise how development may inform the spatial structure and patterning of tree canopies within neighbourhoods.
- Determine the health of trees present.

Future Research

The spatial patterning and structure of urban vegetation is important for determining ecosystem service flows (Dobbs, Escobedo, & Zipper, 2011), and could be studied under a similar temporal context. Similarly, mapping the spatial distribution of changes in canopy cover with respect to residents' access to public green spaces would provide valuable information for regional and community planning, as would investigating general trends of canopy cover on public and non-residential land within North Vancouver.

Potential exists for future MLWS students to build upon this study. The literature and policy review, and provision of recommendations, can be used as a foundation to explore policy formulation regarding the management of other urban ecosystems topics such as soil depth and quality regulation, or water usage and conservation.

CONCLUDING REMARKS

The ecological, and human health well-being potential that urban tree restoration can have are remarkable within urban areas (Kroeger *et al.*, 2018). Of particular significance is that the sound management and planning for increased urban canopy cover remains one of the most effective approaches towards proactively preparing for climate change (Norton *et al.*, 2015) and thus, should be amply prioritized. Although changes in urban canopy cover have consistently been on a steady decline in many municipalities (McGee et al., 2012), a newfound earnestness from municipal governments to counter this trend has been palatable within the last decade, particularly within the Pacific Northwest. The discussion points and recommendations provided resolve to also serve cities beyond North Vancouver, as urban canopy cover management stands as a widely appurtenant topic.

In the end, the success of urban forest management objectives will involve paying mind to credible ecological science, socioeconomic and demographic factors that drive trends in development, as well as the social values that ultimately underpin all decisions pertaining to urban forest planning. Policy frameworks strategically designed to incentivize the preservation and promotion of urban canopy cover will have the greatest chance at being effective,

particularly with the rate of urbanization that the region is experiencing, as well as in anticipation of the changes that are expected alongside climate change.

The vision is such that planning objectives will continue to evolve in a direction that attempts to pack as much ecosystem function into urban environments as possible, where tree landscaping will no longer be an afterthought in the planning process. As such, the recommendations strive to encourage more movement towards attitudes in support of community-based environmental stewardship. Additionally, for landscape design approaches to migrate from its current place of reactively adding green spaces to existing grey infrastructure, to a position of proactively designing landscapes that benefit society and the environment —a paradigm shift which will more quickly enable the healing of humans' relationships with the urban forest and greater environment.

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