Growing an equitable and resilient urban forest

Opportunities to increase tree canopy and enhance green equity in the Downtown Eastside, Vancouver

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Cover photo courtesy of the Downtown Eastside Plan Team

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Executive Summary

The Downtown Eastside (DTES) is one of Vancouver's oldest and densest neighbourhoods, and yet it has the lowest canopy cover and the largest low-income group, making it one of the most vulnerable areas to social changes and climate change impacts. Various city strategies have introduced goals and targets to increase tree canopy and enhance green equity in DTES. Specifically, the Vancouver Board of Parks and Recreation (VBPR) has proposed to double street tree density in below-average blocks of the DTES by 2030. This project aims to support the VBPR in developing a proactive plan to improve canopy cover and increase equitable access to green space for residents in the DTES. This project reviews successful cases of greening dense and vulnerable communities, identifies gaps in the planning and implementation of urban forestry projects in the DTES, and develops recommendations on next steps.

Abbreviations

CoV: City of Vancouver

VBPR: Vancouver Board of Parks and Recreation

DTES: Downtown Eastside

Introduction

Vancouver is often recognized as one of the most livable cities in the world. One of the most important reasons is the beautiful urban landscape of the city. Urban forests play a significant role in forming Vancouver's character and landscape. They are closely intertwined in the development of this city and the lifestyle of its residents. Besides, urban forest provides wildlife habitat, improves air quality, provides shade on a hot day, enhances people's physical and mental health, and makes our neighbourhood more livable and resilient. Research has shown that living in a greener environment can bring various physical and social benefits. Greener areas tend to have better air quality, more recreation opportunity to encourage physical activities, and more social space for neighbours and friends to relax and connect. Urban forest also brings various mental benefits by helping people reduce stress, restore attention, and improve emotional health. In addition, research has found that the benefits of urban forest are more significant for those with lower socioeconomic groups as they are more prone to physical and mental health issues (Hotte et al., 2015). As Vancouver develops, urban forests will play an increasingly important role in maintaining/improving urban resilience and livability.
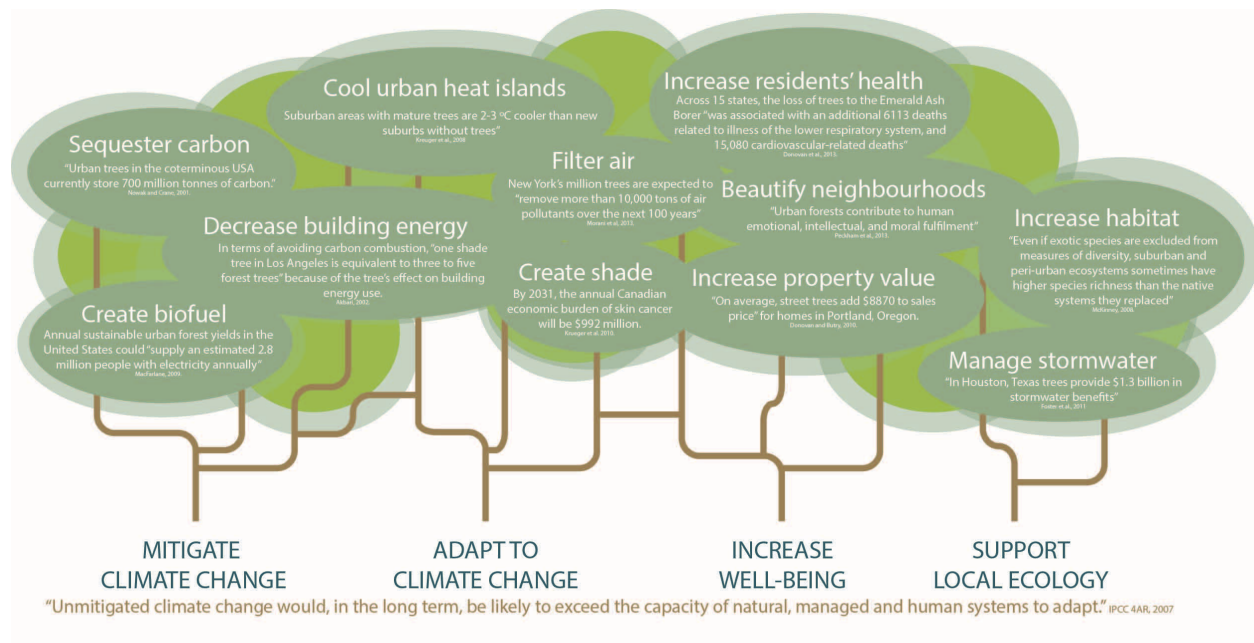
Figure 1 Benefits of urban forests (infographic created by Dr. Sara Barron)

The average tree canopy cover in Vancouver is 18%. Over half of the canopy cover is located on streets, public parks and public properties (City of Vancouver and Vancouver Board of Parks and

Recreation, 2018a). Due to population growth and urbanization, Vancouver has been losing its healthy urban forests in the past two decades, from 23% in 1995 to 18% in 2018, and there is an unequal distribution of tree canopy within the city (City of Vancouver and Vancouver Board of Parks and Recreation, 2018a). Newly developed neighbourhoods tend to have increased density and lower tree canopy cover. The study site for this project, the DTES, is one of the areas with the lowest tree canopy citywide and potentially highest vulnerability to various social and other changes.

Site Description

The DTES in this project refers to the Downtown Eastside community defined by the CoV (Figure 2). As the historic centre of Vancouver, the DTES has very distinctive characteristics. It has a strong tie to aboriginal communities. It also has a rich and diverse international culture due to early settlement from various countries such as Japan and China. Chinatown and Japantown are both located in the DTES (City of Vancouver, 2014).
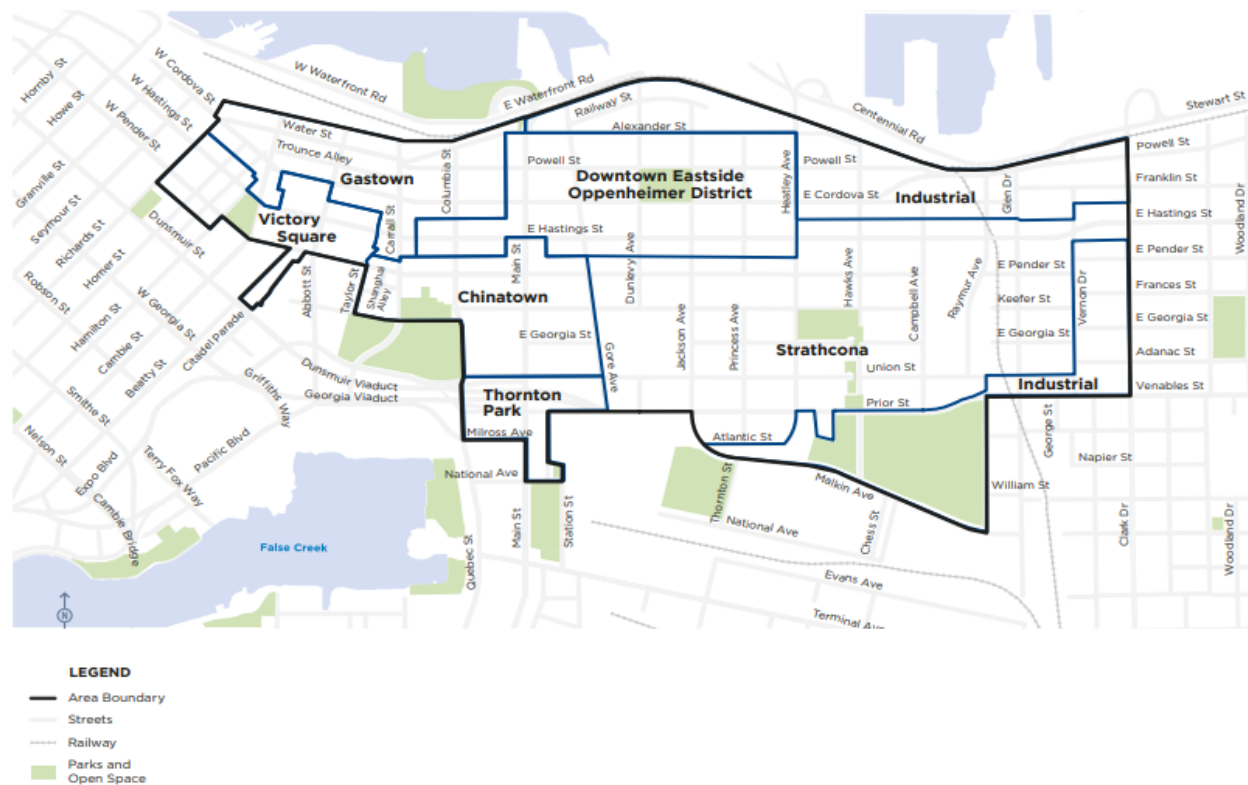
Figure 2 DTES boundary and sub-areas (City of Vancouver, 2014, p. 4)

The diverse nature of the DTES also adds to the complexity of social and environmental issues. It is home to the largest group of the most vulnerable population in the city - homeless people, urban

aboriginal communities, new immigrants, seniors, low-income individuals and families. It is a compact environment with prevalent use of hardscape. The DTES is located across the two neighbourhoods with the lowest tree canopy in the city: Strathcona (5.9%) and Downtown (8.3%) (City of Vancouver and Vancouver Board of Parks and Recreation, 2018b). The north portion of the DTES is estimated to have even less 5% of tree canopy due to industrial land and ports. Less trees and greening exposes already vulnerable communities to urban heat islands and other environmental risks, leading to increased dehydration and heat stroke, reduced quality of life, limited access to nature and cooling shade (Figure 3 and 4). Given the high vulnerability and tree-less environment, it has an excellent potential for improvement and therefore becomes a prioritized area for the implementation of Vancouver's Urban Forestry Strategy.
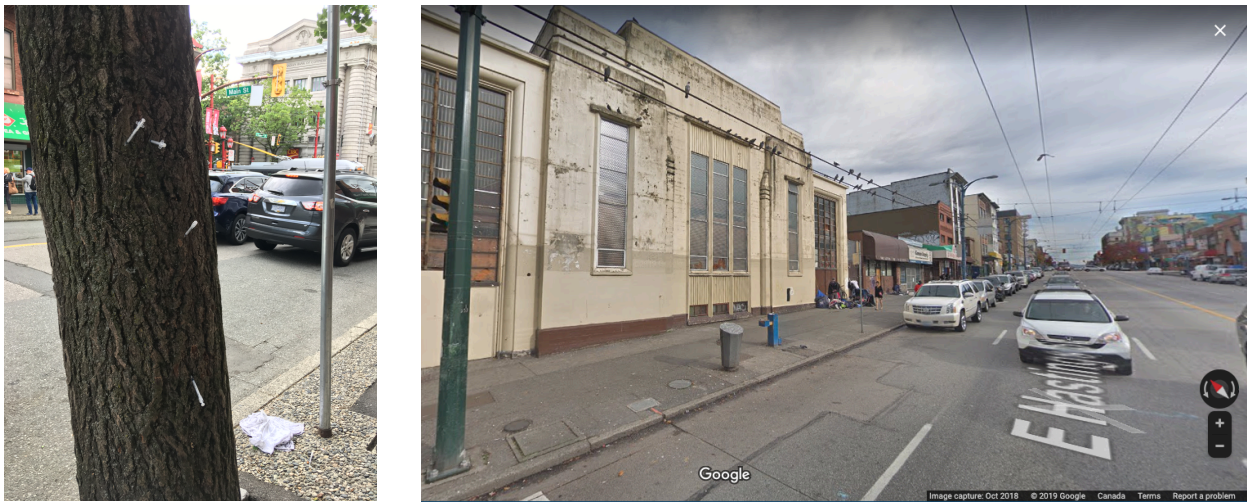
Figure 3 Conditions of the DTES: Used syringes on a tree (left; photo by an anonymous source); people living on East Hastings Street with no shelter or tree shade (right; picture from Google Streetview, 2018 October)
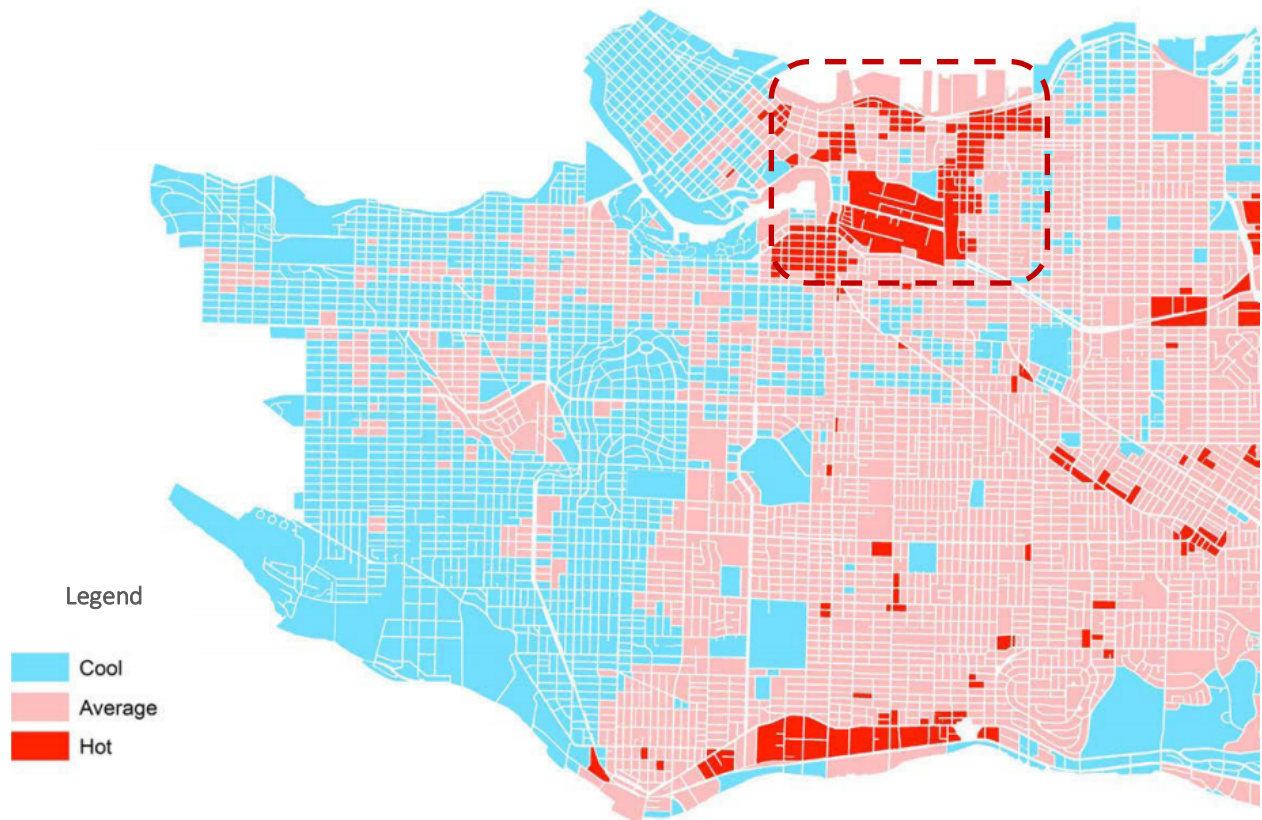
Figure 4 Relative Surface temperature on a summer day. The DTES (within in the boxed area) is extremely susceptible to heats (City of Vancouver and Vancouver Board of Parks and Recreation, 2018b, p. 28)

Policy Context

Several CoV and VBPR policies support the creation or upgrades of green space in the DTES for easy and equitable access for residents. This project directly supports the following city plans and strategies:

Greenest City 2020 Action Plan

In 2011, Vancouver City Council set 10 overarching goals to layout the roadmap for Vancouver to become the greenest city in the world by 2020. This project directly supports one of the goals that focuses on Vancouver residents' incomparable access to green space. This goal is accompanied by three measurable targets (City of Vancouver, 2019):

- Ensure that all Vancouver residents will live within a five-minute walk of a park, green way or other green space by 2020: 93% of residents have access to nature as of 2018
- Restore or enhance 25 ha of natural areas between 2010 and 2020: 27 ha of natural area has been restored or enhanced

- Plant 150,000 new trees between 2010 and 2020: 125,854 trees have been planted since 2010
- Increase canopy cover to 22% by 2050: updated data will be available in early 2020

Urban Forest Strategy

Introduced in 2014 and updated in 2018, Vancouver's Urban Forest Strategy provides an overview of urban forest status in Vancouver and the priority actions for VBPR to improve Vancouver's urban forest. Building on the existing policies and strategies proposed by other key policies (e.g. the Greenest City Action Plan), the Urban Forestry Strategy sets goals, targets and actions specific to protection and enhancement of urban forest. This strategy also highlights the need to prioritize planting in neighbourhoods with lower tree canopy, such as DTES. It introduces a target to double street tree density in below-average blocks of the DTES and Marpole by 2030 (City of Vancouver and Vancouver Board of Parks and Recreation, 2018a).
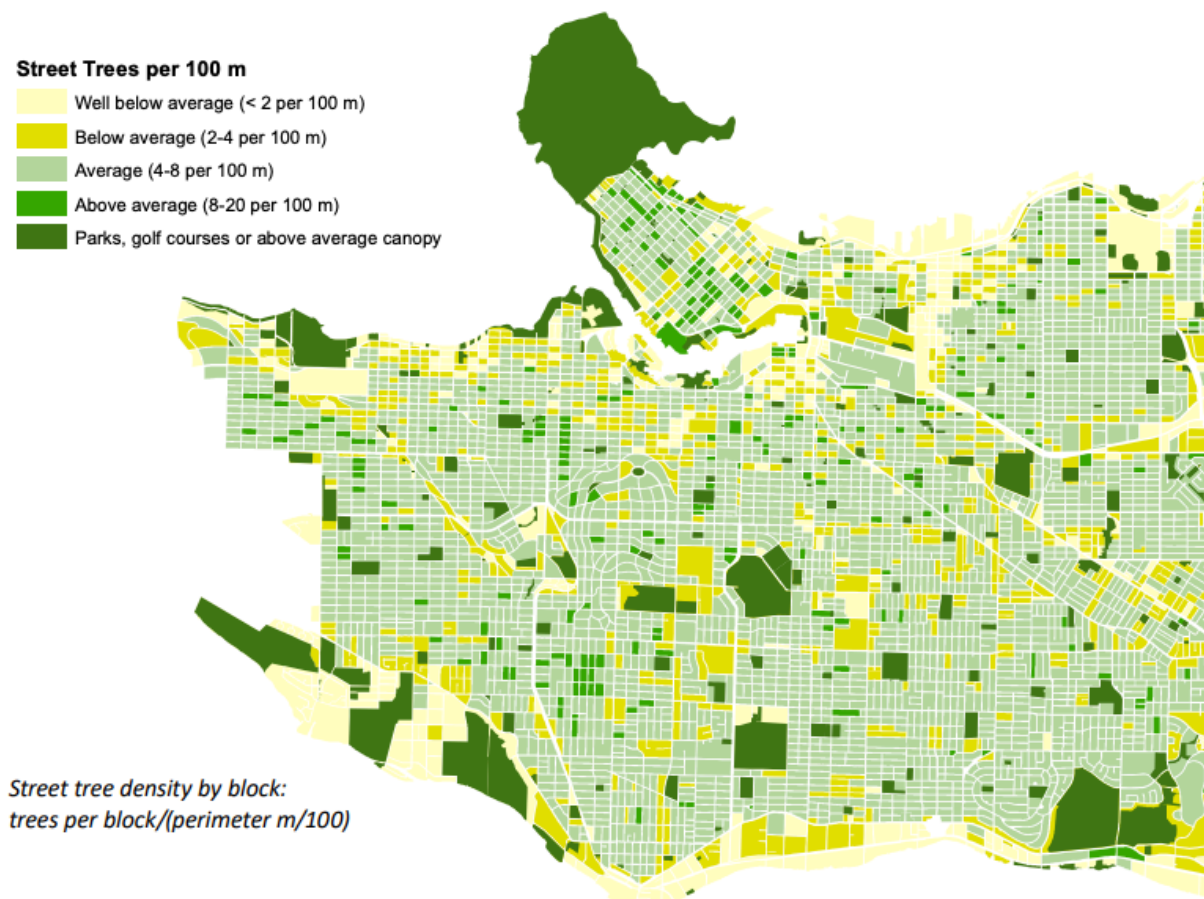
Figure 5 Urban Forest Canopy (City of Vancouver and Vancouver Board of Parks and Recreation, 2018b, p. 23)

Downtown Eastside Plan

The DTES Plan provides a comprehensive overview of the history, existing condition, and long-term vision & planning in the DTES area. The Plan includes parks and public open space as one of their key principals. Specifically, the Plan identifies the need to enhance, expand and create new parks and other green/natural space in this area, especially the northeastern industrial section. As the first step, the Plan proposes to (City of Vancouver, 2014):

- Convert over-paved or under-used areas into mini-parks or plazas where possible
- Review existing street trees to fill gaps and replace ailing trees, and prioritize planting new trees in areas with few or no existing street trees
- Rehabilitate Blood Alley Square/Trounce Alley in conjunction with adjacent development
- Pursue public access to the Canadian Pacific Railway right-of-way to enhance walkability and public amenity

Stakeholder Analysis

Due to the number and complexity level of issues in the DTES, many stakeholders need to get involved in various plans and projects in the DTES. For the purpose of this project, we only focus on stakeholders for planning, design, implementation and maintenance of green space (e.g. creation of new parks, upgrades of existing green space, and planting of street trees in tree-deficit areas). Through the consultation of various teams, we have identified the following 21 stakeholders (teams and units) in five areas of work (as outlined in the Figure 6 and Table 1).

As indicated in Table 1, there are many stakeholders involved in every stage of the urban forestry projects in DTES. Each area of work includes several teams across different departments. There are obvious links between teams responsible for the same area of work. For example, the VBPR's Planning, Policy and Environment team and CoV's Sustainability Planning both are responsible for strategic planning to reach GCAP targets (VBPR is more focused on Goal #5 Access to Nature). Therefore they are more likely to connect and collaborate on GCAP-related projects.

Collaboration across different areas of work is essential in the success of a comprehensive project. For example, it is important for the Planning, Policy & Environment team (VBPR) to work with the Urban Landscape Development (CoV) and the Street team (CoV) to understand each other's work plan, avoid conflicts and ensure feasibility in their planning.

The number of stakeholders involved and the complexity of projects in the DTES requires a central team/person as the coordinator to coordinate/facilitate the interactions between various

stakeholders and to oversee all the urban forestry and other projects in the DTES. The DTES Tech Team, formed by the key stakeholders, is serving a similar role now to ensure on-track & on-time fulfillment of proposed goals and targets. Their presence also ensures that every stakeholder's voice is represented and their work priority is considered in the early stage of each project.

The DTES Tech Team is formed essentially for the planning and implementation of the DTES Plan, which has a much broader focus. Although many focused areas are related to urban forestry (e.g. public facilities, place-making), there might be plans with competing interests, especially for the land and space. Therefore, another big challenge for the DTES Tech Team as well as other stakeholders is to balance between competing priorities and resolve conflicts by effective communication and innovative solutions.

TABLE 1 KEY STAKEHOLDERS WITHIN THE COV OR VBPR IN PLANNING, DESIGN, IMPLEMENTATION AND MAINTENANCE OF URBAN FORESTRY PROJECTS IN DTES		
AREA OF WORK	**VBPR**	**COV AND OTHER TEAMS**
Planning & Policies	Planning, Policy & Environment	Sustainability Planning DTES Planning Team Engineering Engineering Strategy and Standards -> Engineering Long-Range and Street-Use Planning
Park & Landscape Development	Park Development	Urban Landscape Development
Operations & Engineering	Park Operations	Engineering - Green Infrastructure - Transportation & Street Divisions - Development & Major Projects - Public Space & Street Use
Enforcement	Park Ranger	Vancouver Police Board
Engagement	Recreation - Community Engagement (including Access and Inclusion, Community Youth Development) - Community Centre Services (East Area)	**Engineering**: Public Space & Street Use **Arts, Culture, and Community Services**: Non-Market Housing & Social Operations **BC Housing** (Provincial Crown Agency) **BC Non-Profit Housing Association** (Provincial Organization) **Portland Hotel Society** (NGO)

DTES Planning Team

TABLE 2 SUMMARY OF KEY STAKEHOLDERS FOR URBAN FORESTRY PROJECTS IN THE DTES [UNDER REVIEW BY EACH STAKEHOLDER TEAM]

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
Coordination	Strategic & Long-Range Planning (CoV)	DTES Planning Team	Coordinates and liaises other departments and community groups to facilitate projects related to the DTES. Convenes the DTES Tech Team (formed by staff from across the City)	• Requires effort to **coordinate** between various focuses of work, partners and projects • Needs creative solutions and sustained efforts to tackle social, economic, and environmental issues in DTES
Planning & Policies	Planning & Development (VBPR)	Planning, Policy & Environment	Strategic planning of VBPR's future focus of work, including plans to fulfill the goals in the Greenest City Action Plan, Urban Forestry Strategy, Biodiversity Strategy and other documents (e.g. double street tree density in DTES by 2030)	• Needs improved communication and coordination with other teams in VBPR & CoV • Needs more baseline information and data support in e.g. species selection, climate change mitigation, urban soil enhancement and green equity for planning the next steps.
	Strategic & Long-Range Planning (CoV)	DTES Planning Team	Develops/amends/interprets policies. Collaborates with VBPR and Sustainability group regarding the development and implementation of greening policies in the DTES	• Requires effort to coordinate between various focuses of work, partners and projects • Needs creative solutions and sustained efforts to tackle social, economic, and environmental issues in DTES
	Planning, Urban Design & Sustainability (CoV)	Sustainability Group	Strategic planning for environmental sustainable development, including working across the organization on	• Requires effort to manage various focuses of work and coordinate different partners in making plans,

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
			development and implementation of the Greenest City, Climate Emergency, and Climate Adaptation plans	implementing projects, and tracking the progress
	Engineering Services (CoV)	Engineering Strategy and Standards -> Engineering Long-Range and Street-Use Planning	Long-term infrastructure and street use planning: working with internal and partner agencies to identify opportunities to proactively coordinate construction activities (Dig-once Practice) such that any upgrades or renewal works within a given street segment are completed concurrently to tie together construction impacts while also achieving efficiencies and cost savings through elimination of future re-work	• Needs improved communication between VBPR and Engineering about upcoming projects with other teams • Needs more support & direction on tree-friendly decisions & practices to advise project partners early on during the project initiation phase (scope identification)
Park & Landscape Development	Planning & Development (VBPR)	Park Development	Review of park space for the development of new parks and upgrades of existing parks; Street & ornamental tree planting in collaboration with Operations (VBPR)	• Needs improved communication with teams in the VBPR as well as other involved teams in the CoV (e.g. engineering)
	Planning, Urban Design & Sustainability (CoV): Current Planning	Urban Landscape Development	Processes proposed development submissions, development and non-development related tree removal permit applications	• Lack of policy and/or conflicting policy that could support urban forestry or urban greening values • Requires effort in coordination with Engineering, VBPR, Urban Design in development reviews

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
				• Pressure to streamline and expedite development permits • Responsible for responding to public complaints about tree removal and vetting general enquiries about landscape and open space design in developments
Operations & Engineering	Parks (VBPR)	Operations	Chooses cultivars and plants street & ornamental trees Monitors and maintains public trees (on streets, parks, and other public lands)	• Needs to coordinate with development plans by streets and transportation, sewer & water, utilities and developers to include enough space and suitable planting conditions in the designs going forward. • Existing opportunities to plant are very limited, but new development projects opens up those areas for re-configuration
	Engineering Services (CoV)	Green Infrastructure	Improves water quality, resiliency, and livability Ensures greening projects are able to retain and treat runoff from the right-of-way (48 mm or 90% of annual rainfall) when possible	• Require communication and coordination well in advance (at least 1 year in advance) for stormwater tree trench design and funding • Opportunity exists to implement stormwater tree trench designs (using soil cells or structural soil) to support bigger and healthier tree canopies while capturing stormwater runoff

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
	Engineering Services (CoV)	Street Division: Street Design	Reviews design applications and provide input as required. Works closely with other Engineering branches to help identify public realm improvements on streets and to ensure the public realm is accessible and safe for all users	• Needs to balance between competing priorities with limited budget. Existing infrastructure may require rehabilitation to meet current City standards, but scope of work is limited by available funding. • Needs to select a design that promotes a vibrant public realm and can be maintained with the current citywide maintenance budget.
	Engineering Services (CoV)	Transportation Division: Transportation Design	Leads design of public space in street right-of-way - streetscape improvements including greenways, bikeways and street closures. Works closely with Streets Design to help identify public realm improvements on streets including finding locations for trees and working around existing trees.	• Needs to balance between competing priorities with limited budget • Limited space within the public realm to accommodate different amenities
	Engineering Services (CoV)	Public Space & Street Use Division: Street Activities	Leads design of public space in street right-of-way, including street closures. Reviews development applications for proposed horticulture elements (not trees) in the street right-of-way.	• Faces an increasing competition for green space in street right-of-way from transportation needs and public amenities including gathering spaces, furnishings, and utility accesses.

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
			Reviews/accepts designs of street horticulture assets (not trees) including medians, traffic circles, curb bulges, GI, etc.	
			Responsible for operations/maintenance of street horticulture assets (includes some trees)	
	Engineering Services (CoV)	Development & Major Projects	Provides support such as Engineering-related coordination (with internal stakeholders) and data/information input as needed	• Requires coordination between various Engineering teams and other partners in CoV and VBPR
Engagement & Recreation	Engineering Services (CoV)	Public Space & Street Use Division	Enhances street experience through partnerships, pilots and programs (e.g. through the VIVA Vancouver Program)[1]	• Requires effort to coordinate among various departments for new street programs
	Recreation (VBPR):	Community Engagement	Designs and implements various recreation and engagement programs in community centres and parks	• Needs improved communication and coordination with other teams in VBPR & CoV • Needs creative and engaging programs to create a welcoming and inclusive environment for all user groups

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[1] https://vancouver.ca/files/cov/2018-06-12-2018-upcoming-public-space-initiatives.pdf

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
	Arts, Culture, and Community Service (CoV)	Non-Market Housing & Social Operations	Applies and implements Vancouver's Housing Strategy, provides housing support for local communities	• Needs to balance between the increasing demand for land and equitable provision of services to the communities in need • Needs to consider the needs of various community groups
	BC Housing (Provincial)		Develops, manages and administers a range of subsidized housing options and programs across British Columbia[2]	• Difficult to increase housing affordability with the rapidly increasing land values and housing price in densifying cities in BC
	BCNPHA (Provincial)		A provincial umbrella organization for the non-profit housing sector that provides and manages affordable housing for community members[3]	• Difficult to increase housing affordability with the rapidly increasing land values and housing price in densifying cities in BC
	Portland Hotel Society (NGO)		An NGO based in Vancouver, BC that provides housing, service and advocacy to the poorly served in Vancouver, BC's Downtown Eastside and in Victoria, BC[4]	• Needs effective communication with the public to raise awareness of the issues faced by the homeless, drug addicts and other vulnerable communities

[2] https://www.bchousing.org/about

[3] https://bcnpha.ca/about-us/

[4] https://www.phs.ca/

Area of Work	Department (CoV, VBPR or other)	Team/Branch	Main Responsibilities (in connection with greening projects in DTES)	Main Needs/Challenges
				• Needs effort to advocate on behalf of the marginal & vulnerable groups in the DTES
Enforcement	Ranger Program (VBPR)		Park patrol and routine regulatory enforcement work to ensure a safety environment and a better experience in parks	• Needs an effective system to prevent recurring illegal conducts & stays in parks and urban forests • Needs to balance conflicting needs from different groups (e.g. park users and homeless campers)
	Vancouver Policy Board		Civilian governance, oversight of policing[5] and crime reduction for public safety	• Needs effort to coordinate with other departments and teams in VBPR & CoV • Needs an effective system to prevent recurring illegal conducts & stays in parks and urban forests

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[5] https://vancouver.ca/police/policeboard/index.html

Literature Review

Successful cases in urban greening

This section reviews successful case studies to green dense but socially or climate vulnerable neighbourhoods. The review focuses on cases with a similar population density with DTES (~ 10,000 people per sq. km) and a strong community engagement/empowerment initiative.

DTES (VANCOUVER)
Tree canopy cover: 5.9%
Population density: 18,477/km2

TORONTO
Tree canopy cover: 26.6%-28%
Population density: 4,692/km2

NEW YORK
Tree canopy cover: 24%
Population density: 10,906/km2

MEDELLÍN
Tree canopy cover: ?
Population density: 19,700/km2

SINGAPORE
Tree canopy cover: 29%
Population density: 8,383/km2
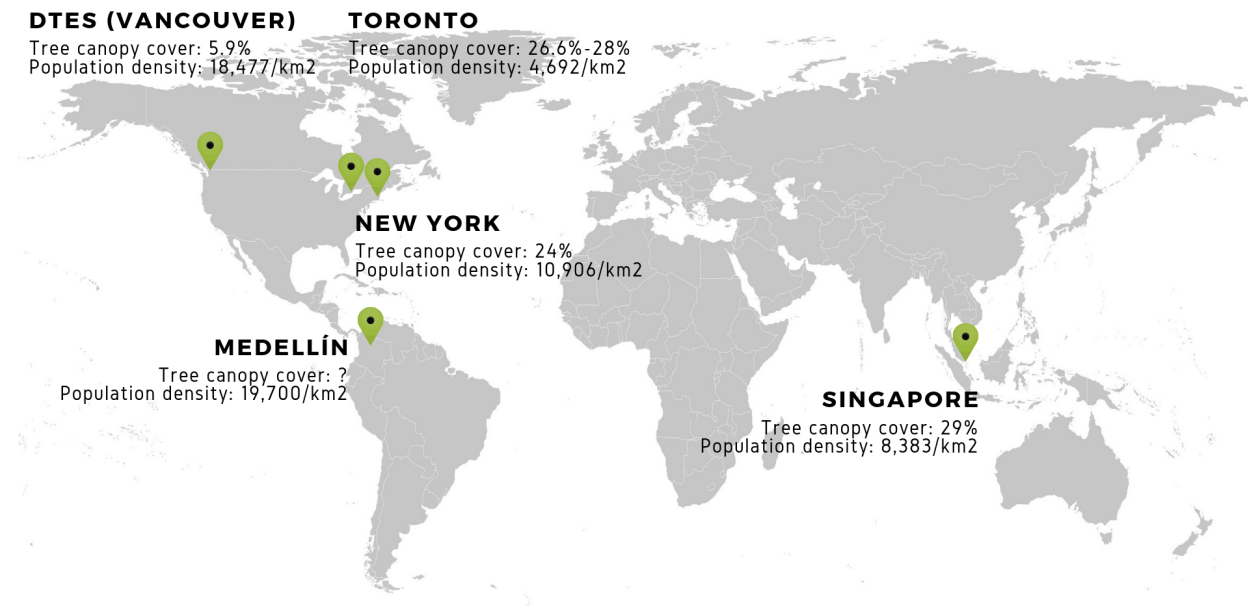
Figure 6 Locations of the selected case studies

TABLE 3 SUMMARY AND COMPARISON BETWEEN REVIEWED CASE STUDIES

Case Study Locations	Reviewed Program / Strategy	Population Density (/km²)	# of Trees	Urban Tree Density (/km²)	Current Tree Canopy	Tree Planting or Canopy Target	Primary Engagement Approach
New York	MillionTreesNYC	10,906	5.2 million	6,632	24%	Plant one million trees in 10 years (achieved)	• Volunteer stewardship program e.g. Citizen Pruners Program • Tree giveaway event • Education workshops and green job training
Singapore	Garden City Vision and associated projects	8,383	2 million	2,817	29%	Plant 250,000 trees/shrubs in nature parks over the next 10 years (till 2029)	• Environmental campaign • Environmental education • Volunteer stewardship programs
Medellín	Green Belt Project (as part of the Urban Revitalization process)	19,700	406,856 in Metropolitan Area of the Aburrá Valley	3,447	Unknown	Unknown	• Community workshops for co-design public spaces • Education workshops
Toronto	Strategic Forest Management Strategy	4,692	10.2 million: - 4.1 million on public lands - 6.1 million on private lands	16,190	26.6%-28%	40%	• Tree giveaway event • Tree planting event • Volunteer stewardship program • Youth training program
Vancouver (as reference)	Vancouver's Greenest City Action Plan; Urban Forestry Strategy	5,539	Over 400,000 trees	Over 3,480	18%	22% by 2050	• Seasonal tree sale • Community workshops • Community garden programs
DTES (project site)	DTES Local Area Plan; Urban Forestry Strategy	18,477	Unknown	Unknown	5.9%	Double street tree density by 2030	• Same as Vancouver

MillionTreesNYC | New York

In 2007, MillionTreesNYC (MTNYC) was introduced as part of PlaNYC, a strategic plan by the former mayor Bloomberg to prepare the city for one million more residents in a sustainable way by 2030. The MTNYC initiative is a collaboration between the New York City Parks Department (NYC Parks) and the New York Restoration Project (NYRP) to plant and care for 1 million new trees in New York, and it aims to finish planting in a decade (from 2007 to 2017). By planting 1 million trees, NYC is estimated to increase its urban canopy by 20%. MTNYC managed to meet this aggressive planting goal two years ahead of schedule, making NYC the first city that finishes planting among others with the same goal (e.g. Los Angeles, Boston and Denver).

During MTNYC, the City planted 70% of trees in parks and other public spaces, leaving the other 30% to private organizations, homeowners and community groups (see Table 1 for more details). NYC Parks was mainly in charge of plantings wihtin its jurisdiction (e.g. public right-of-way and parks), tracking tree planting progresses, and conducting analysis to identify possible planting spaces, whereas NYRP focused on hosting tree giveaway events (where residents received trees for free) and engaging homeowners, land managers, developers, and local community organizations to plant trees on their properties (Lu et al., 2014). The planting has been done through various approaches, including individual effort, block planting, tree replacement (1 to 1 replacement), and green street projects (initiated 80 new Greenstreets with gardens and trees in street medians or traffic triangles). The Initiative also sets up various public education and engagement programs, such as tree giveaway program, volunteer & steward programs, and k-12 education toolkit (Centre for Public Impact, 2016).

TABLE 4 ESTIMATED BREAKDOWN OF TREE PLANTING NUMBERS AND AREAS (MILLIONTREES NYC, 2015)	
PLANTED AREA	NUMBER OF TREES PLANTED
Street trees	220,000
Parks (reforestation and landscape), other agencies, and zoning regulations	480,000
Private partners	300,000
Total	1 Million Trees

Critical Success Factors

Strong Political Will

MTNYC has received strong and continuous support from various NYC mayors since its initiation. As part of the long-term strategic plan PlaNYC, there is a strong inter-agency collaboration for MTNYC.

Various agencies have been involved in MTNYC, including the Department of Environmental Protection (DEP), the Department of Transportation (DOT), the Department of Education (DOE), the Department of Buildings (DOB), and the U.S. Forest Services (Federal) (Lu et al., 2014; Centre for Public Impact, 2016). Trees are considered as a higher priority. Each involved government agency takes it seriously. In addition, strong political will has brought extensive resources. The initiative received over $350 million from the City and $1 million from NYRP's fundraising effort (New York Restoration Project, no date). This would not be possible without strong political will or commitment.

Stakeholder Engagement

MTNYC is co-led by a city agency (NYC Parks) and a nonprofit organization (NYRP). The public-private collaboration enables MTNYC to reach different agencies and organizations and plant trees on various land jurisdictions. NYRP plays a vital role in reaching local communities and private sectors through seasonal tree giveaway events, educational workshops, and small grant programs (Kinney, 2015). By 2012, MTNYC has offered over 1100 tree planting and care workshops and engaged over 12,000 residents. There are other civil groups involved in different stages of the initiative. For example, TreeKIT (http://treekit.org/) is a nonprofit partner in MTNYC that uses innovative mapping techniques to engage citizens for tree monitoring and maintenance (Lu et al., 2014).

MTNYC also sets up an advisory committee and seven subcommittees on various areas. Each subcommittee is comprised of 3 co-chairs (from NYC Parks, NYRP, and an external organization) and members with diverse backgrounds (e.g. business, research, and community) to ensure different voices and opinion are represented (Lu et al., 2014).

Integration of Research and Practice

MTNYC initiated or facilitated a variety of research projects to inform the planning and implementation of the initiative and to evaluate its progress and results. For example, NYC Parks introduced the "Trees for Public Health" program at six neighbourhoods with few street trees but high asthma hospitalization rate for children of 14 years old or younger. Baseline research, such as UTC Analysis, provides better policy support for more informed decision making (Lu *et al.*, 2014). For example, STRATUM and UFORE[6] made a business case for MTNYC (e.g. it proved that every dollar

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[6] STRATUM and UFORE: STRATUM stands for Street Tree Analysis Tool for Urban Managers, and UFORE stands for Urban Forest Effects Models. Both tools are developed by U.S Forest Services to quantify and estimate monetary values of ecosystem services by trees.

investing in street tree planting & care could get $5.6 in benefits in return) and convinced the policymakers to commit capital funding to initiate the MTNYC (Lu *et al.*, 2014).

Criticisms and Challenges

While being considered as a successful model for planting initiative, there have been criticisms and concerns about MTNYC. Although the MTNYC prioritized neighbourhoods with less tree canopy, poorer air quality and higher children asthma hospitalization rate for planting, some studies have shown that environmental equity was not their priority. Their tree planting effort was unequally distributed within the city, primarily due to the unequal distribution of city parks where MTNYC planted most trees (Garrison, 2019).

Many people worry that the initiative is overly focused on quantity over quality. A mature tree delivers much higher ecosystem benefits than a newly planted sapling does. To ensure the newly-planted trees to reach its maturity, we need to plant and care them well (e.g. with adequate soil volume and water, which most city trees don't have). According to a previous study, in New York, 26% of street trees were dead eight to nine years after being planted. Therefore, the key is not planting 1 million trees but keeping them growing healthily in the long term (Marritz, 2012; Pincetl et al., 2013).

In addition, it is hard to replicate the MTNYC model in other cities as there might not be as many resources. MTNYC received about $600 million in funding for planting and caring for 1 million trees. However, many cities are unable to make such a commitment (Pincetl et al., 2013).

Garden City | Singapore

While being one of the densest countries in the world, Singapore has managed to keep 40% of land covered vegetation (as of 2011), a ratio much higher than other cities with similar density. Since its independence, Singapore has managed to successfully transform the largest slum in Southeast Asia to the globally-known Garden City, thanks to the "Garden City" vision. The vision was introduced by Singapore's first Prime Minister Lee Kuan Yew in the early 1960s (4 years after the independence of Singapore). The goal is to resolve various environmental, social and economic issues (e.g. housing, jobs, and environmental degradation) that Singaporeans face through bringing more green space (National Library Board, no date; Tan, 2016).

The implementation of the "Garden City" vision can be divided into three stages. In the initial stage (1963 to mid-1970s), it was implemented through intensive tree-planting along boulevards. It was a big success: by 1970, over 55,000 trees were planted. During this phase, the Parks and Tree Act was initiated to mandate housing & development agencies and private developers to set aside spaces for

trees in residential areas, roadsides, or carparks. The second stage (the mid-1970s to the 1990s) was more focused on the creation of parks and other green space. The Park and Recreation Department was established in 1976 to lead the development of new parks. From 1975 to 2014, the number of parks increased from 13 to 330, and the areas of green space (including parks) increased from 879 ha to 9707 ha. In the final stage (since the 1990s), more effort has gone to connecting green space and preserving natural heritage. In the same time, more public engagement and education programs have been initiated to raise citizen's awareness and improve their experience in green space (National Library Board, no date). The "Garden City" vision has gradually evolved to the "City in a Garden" Plan. Today, Singapore has over 350 parks and gardens, 1300 community gardens, 2 million urban trees, and 3347 ha of natural reserves. Despite pressures from urbanization and population growth, Singapore continues its commitment to promote greenery to become the "City in a Garden" (Han, 2017; Er, 2018).

Critical Success Factors:

Strong and Continuous Political Will

Since the Singapore government is a very top-down system, Lee's personal belief in his "Garden City" vision has brought a lot of attention and support for urban greening projects. In some cases, greening projects could win over development projects with high economic returns because of the strong political will. For example, Gardens by the Bay, a famous waterfront garden in the heart of Singapore, would have been a real estate project if the state government did not have such a strong desire for becoming a garden city. In addition, Lee ensured sufficient resources were available to implement greening work. Despite rapid population growth, the budget allocated for parks and greening per person has increased over 50 times from 1970 to 2010. The percentage of the total government expenditure for parks and greening also doubled from 0.4% in 2000 to 0.85% to 2010 (Tan, 2016).

Early Integration of Environmental Planning and Goals

When the "Garden City" vision was introduced in 1963, an early stage of the nation-building process. Urban greening, as a priority for the "Garden City" vision, was well-integrated with other development goals and the state legal framework. For example, the Park and Tree Act introduced in 1975 enforces a 3-5 meters of "buffer" for tree planting along the side of development project facing a public street, and 2 meters of tree space on the other side of the development to increase tree canopy and to separate from other buildings. This requirement creates more physical spaces for trees. In the mid-1970s, Singapore introduced a regulation to require 2-4 meters of planting space along the road (space requirement varies by the type of road). Because of this policy, roadside greening is

automatically considered in the planning, design and construction of roads in Singapore. Today, over 90% of roads in Singapore have vegetation on the side. A more recent policy, Landscape Replacement Policy, is introduced to enforce developers to replace all the greenery that has been lost due to the development somewhere else within the same site (greening in the building or rooftop also count) (Tan, 2016). This policy applies to all the commercial and residential developments in 19 town centres (including the state public housing project that provides flats for 80% of Singaporeans) (Tan, 2016; Kolczak, 2017). This policy has helped increase 40 ha of green space in the urban core areas from 2009 to 2014. Although 40 ha seems low compared to the area of developments over the past five years, it is the best strategy for Singapore to preserve greenery from extensive constructions and rapid development (Tan, 2016).

Criticisms and Challenges

Lee's vision for the Garden City was based on the "utilitarian values" of nature (e.g. a good environment could attract businesses and tourists and therefore generate economic benefits) (Han, 2017). As a result, development-oriented agencies are usually given more power than environment agencies, which leads to further forest fragmentation and degradation in spite of the increasing number of parks and gardens. The utilitarian framework also results in little attention to ecological concerns (e.g. climate change and habitat loss) that are not usually associated with utilitarian values. In fact, Singapore was ranked lower-than-average for climate change action and almost the lowest for natural habitat protection in the world by the Environmental Performance Index (Han, 2017). Singapore is also known for rapid population growth and densification, which impose a high risk to its urban forest. From 2007 to 2011, its vegetation cover decreased from 47% to 40%, meaning a loss of 1000 ha of vegetation per year. As the country develops, Singaporeans need a new mindset and a participatory process that allow more collaboration and creative methods to preserve their green space from urban development (Tan, 2016).

Urban Revitalization | Medellín

Medellín is the second largest city in Colombia with 4 million inhabitants. It was once known as the most dangerous city in the world, due to rapid population growth[7], deep social inequality, widespread

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[7] Medellín's population increased by ten times in about 40 years since the 1950s. The city could not accommodate the rapid population increase. Therefore, many new immigrants illegally settled on the hillside north of Medellín, which later became the slum area due to lack of proper infrastructure and services (e.g. roads, public services, education) (Villabona, 2017; Echeverri, 2018)

poverty, and unprecedented drug trafficking and violence. In the worst time, over 6000 murders happened every year. Since 1991 when the new constitution[8] was ratified, the City of Medellín introduced new social programs and prioritized redesign of public spaces to address its epidemic violence and inequity issues. Working with architects, planners, and community representatives, the city has built a world-famous mobility system comprised of cable cars, bridges and escalators that links previously disconnected neighbourhoods on steep hills[9] to city centre, redesigned and recreated public spaces (e.g. parks, museums and libraries even in the most deprived areas), created digital maps to understand gang activities, and included marginal communities in the decision-making process (ECPA Urban Planning, 2011; Warnock-Smith, 2016).

As part of the urban revitalization program, Medellín initiated a 75-km greenbelt project on the hill in 2012 with a budget of US$249 million, aiming to create a ring of park space to restore local ecosystems and mitigate landslide risk[10], to set a boundary to limit further sprawling and to provide local residents more green space to gather and relax. The project will connect 3 zones and various projects within them: "protection zone" for ecological preservation, "transition zone" for introducing more recreational and risk management amenities in high-density low-income neighbourhoods, and "consolidation zone" for new parks, housing and transportation services (Parkinson, 2014; Chu, Anguelovski and Roberts, 2017). As of 2016, 70,000 native trees have been planted for this project. In order to help the local community with the transition due to the greenbelt project, the city provides local families with job and education opportunities. Over 300 local households have started their agriculture projects or business, and 1,000 people have been trained through various programs (C40, 2016).

Critical Success Factors

Dedicated and Strong Political Leadership

The urgency to resolve the long-standing drug, violence, inequality issues in Medellín was well recognized in the 1990s. When Mayor Farjado was elected later, he started a series of aggressive policies and programs to target at these issues. Many policies introduced a decade ago are still being

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[8] The New Constitution of Colombia gives more power to the locals to elect their leader and plan local development (Warnock-Smith, 2016)

[9] Medellín was not able to accommodate newcomers with proper housing. Therefore illegal settlements were set up on the hills with limited or access to the city centre and public services (Warnock-Smith, 2016)

[10] About 180,000 families are living in an area with a high risk of landslide (Chu, Anguelovski and Roberts, 2017).

used and supported by the successive mayors of Medellín. Because of the mayor's vision and commitment, more municipal budget is allocated for the urban revitalization projects. For example, the city budget for urban revitalization projects doubled from 2004 to 2008 (Warnock-Smith, 2016).

Stakeholder engagement and participatory process

The program involves a wide variety of stakeholders, including government agencies, publicly-owned companies, private companies, and local community members. In order to improve transparency and efficiency, Mayor Farjado established an independent agency called the Urban Development Corporation (EDU) for designing and managing various urban revitalization projects (including the greenbelt project). In addition, there is a strong focus on community engagement. The City sets 5% of its municipal budget for "citizen-defined priorities" (McGuirk, 2012, para. 3). During the design process, the design team often works with a community representative who helps communicate the proposed design with local communities. Mayor Fajardo and his team also held co-design workshops (or "imagination workshops") where residents were given the opportunity to imagine and redesign the public space. Through the participatory process, residents from both slums and wealthy communities become participants and clients who can have a say in different stages of a city redesign project (Warnock-Smith, 2016).

Public-private funding scheme

Many projects in Medellín cost millions of dollars. Without stable funding, these projects would not have been possible. Medellín has a special public-private funding mechanism, comprised of municipal funding, tax revenues from private companies, and contributions from EPM – a city-owned utility company that exports energy to other parts of Colombia and South America. EPM contributes 30% of its profits (US$450 million a year) to municipal uses, which provides a crucial source of funding to fuel the transformative projects (Warnock-Smith, 2016).

Criticisms and Challenges

Medellín is wildly considered as a model for urban revitalization. However, the projects also raised concerns over equity and gentrification issues. People argue that the greenbelt project is targeted at tourists and wealthy residents, while low-income families tend to lose access to the space that they used to use. New stone or concrete paths are being built without considering the nearby communities' needs. In addition, there seems no standard on who can stay and who gets relocated. While many low-income families are told to move to public housing that is further away from the city centre, there is no plan to relocate families in wealthy neighbourhoods in the landslide-prone area. Finally, due to private developers' involvement, local communities have been suffering from increasing housing prices, increasing tax, and changing social dynamics and composition of the community (Chu,

Anguelovski and Roberts, 2017). Although the city has made a tremendous amount of effort to improve the local's quality of life through a series of transformative projects, there are various systemic and chronic issues that the city has to address to become a truly sustainable, equal, and revitalized city.

Strategic Urban Forest Management | Toronto

Toronto aims to sustain and expand its urban forests. Currently, Toronto has approximately 10.2 million trees and a tree canopy cover of 26.6% to 28%[11], providing a total of $28.2 million worth of ecological services every year (e.g. air pollution alleviation, energy conservation, carbon sequestration). Toronto's long-term vision is to build "a healthy and expanding urban forest, incorporating sound urban forestry practices and community partnership" (City of Toronto Parks Forestry and Recreation, 2013, p. viii). In order to achieve this vision, it has introduced a plan called the Strategic Forest Management Plan ('the Plan' in short hereafter) since 2013 to guide the direction of urban forestry efforts in Toronto from 2012 to 2022. The Plan has identified six strategic goals, including increasing tree canopy (to 40%), achieving equitable distribution, increasing biodiversity, increasing awareness, promoting stewardship, and improving monitoring (City of Toronto Parks Forestry and Recreation, 2013). The Plan also identified key challenges and solutions to urban forest management in Toronto. For example, to address adverse impacts of urbanization, the Plan identified key criteria for successful planting designs considering soil volume and space for other urban infrastructure. Based on these criteria, Toronto is implementing three planting designs for healthy tree growth: 1) open planting beds for wide sidewalks with plenty of room for planting; 2) continuous soil trenches with reinforced concrete panels and 3) continuous soil trenches with soil cells for narrower sidewalks to provide shared un-compacted soil for trees and easy access for utility services (City of Toronto Parks Forestry and Recreation, 2013).

Reaching the strategic goals requires collaborative efforts between the city, private sectors, and local communities. Increasing public education and engagement is a crucial action identified for Toronto's urban forestry branch. In addition to the most common activities such as remove invasive species or water plants, Toronto's urban forestry branch organizes an annual tree-planting event called Tree Across Toronto. Thousands of trees are planted by volunteers at this event every year (City of Toronto Parks Forestry and Recreation, 2013). The City of Toronto also partners with the Local Enhancement

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[11] Different canopy cover estimates are generated using different methods. Therefore it shows as a range instead of a number

and Appreciation of Forests (LEAF) and the Toronto Parks and Tree Foundation (TPTF) to organize various community engagement event, such as Tree For Me, where local residents can receive a free tree that is suitable for their planting location (Toronto Parks and Trees Foundation, no date b).

A robust urban forest management plan needs a comprehensive monitoring framework for progress over time. The Plan includes a set of 23 criteria and 23 indicators covering vegetative resources, management of the resources, and community framework. This framework helps the city understand if goals are being reached successfully and which area needs more efforts (City of Toronto Parks Forestry and Recreation, 2013).

Critical Success Factors

Supportive Policy Framework

Protection and enhancement of urban forests are embedded in various city policies. The Toronto's City Official Plan stresses the need to "provide suitable growing environments for trees; increase tree canopy coverage and diversity; and regulate the injury and destruction of trees" (City of Toronto Parks Forestry and Recreation, 2013, p. 11). The City of Toronto also acknowledges the role of urban forests in mitigating climate change impacts, such as heat island effects and more extreme precipitation events, in the Climate Change Adaptation Strategy since 2018. In addition, a comprehensive system of by-laws has been introduced to prevent urban tree loss and encourage tree planting. For example, the Toronto Green Standard includes specific requirements for tree preservation and planting for new private and city developments. It requires that each development site has to have no less than 30 sq. meters of soil volume per planting site and at least one large shade tree for every three parking spaces in the surface parking lot (City of Toronto, no date; City of Toronto Parks Forestry and Recreation, 2013). These regulations and policies provide a legal framework that enforces the protection and enhancement of urban forests in Toronto.

Integration of Research and Science in Decision-making

Before introducing the Plan, the City of Toronto worked with U.S. Department of Agriculture on two major research projects (including UTC2 and UFORE3 analyses that are also applied in the MTNYC) to understand the baseline condition of its urban forest and potential space for planting. The studies help the city and the parks department better understand not only the structure, distribution, health and ecological values of its urban forest but potential opportunities to maintain or enhance the quality and quantity of the urban forest. For example, the research by USDA found that Toronto needs to plant 114,000 trees a year to reach the 40% canopy target by 2060 (assuming the mortality rate is 3% and a similar number of trees are planted on private lands). Another project conducted with the

University of Vermont explores the potential spaces for more tree canopy in the city by comparing existing tree canopy, impermeable surfaces, and open spaces. In addition, as climate change intensifies, the Plan has a strong emphasis on climate change adaptation through urban forestry. In the tree canopy study, Toronto identifies areas that should be prioritized for heat vulnerability (e.g. bare land or turf) and shares the findings with the public and partner organizations to increase awareness and encourage planting in the most vulnerable areas. These research outcomes provide valuable information for the City to take on the most effective action for fulfilling its urban forestry goals (City of Toronto Parks Forestry and Recreation, 2013).

<u>Public-Private Partnership</u>

The public-private partnership with LEAF and TPTF is a critical factor for broader community engagement and smoother policy implementation in Toronto's urban forestry program. As a non-profit charity foundation, TPTF aims to foster city-community collaboration for parks and green space enhancement. Because of the involvement of TPTF, projects that would not have been possible with solely public funding are now implemented in communities, such as Tree for Me initiative and Every Tree Counts Community Grant to encourage planting on private land (Toronto Parks and Trees Foundation, no date a). LEAF is a non-profit organization that runs various programs to protect and improve trees and forest in the city. With the collaboration with the City of Toronto and TPTF, LEAF offers a wide range of programs: Our Backyard Tree Planting Program that provides subsidized tree planting and consultation services for residents; Toronto Community Housing Corporation (TCHC) Planting Initiative to plant trees on TCHC properties and engage TCHC tenants through tree tours and volunteer activities; and Young Urban Forest Leaders (YUFL) Program that offers free training and mentorship opportunity for youth from underrepresented groups (e.g. women, indigenous groups, new immigrants, and visible minorities) (Local Enhancement & Appreciation of Forests (LEAF), no date). The programs offered through the public-private partnership supports the City to achieve its urban forestry goals through more effectively engaging local communities and training local residents (especially youth) as 'citizen urban foresters' to plant and care for trees on public and private lands.

Criticisms and Challenges

Toronto's urban forest is facing various challenges as the city develops and the population grows. It is becoming increasingly challenging to find space for trees in the city. With more than half of urban trees in Toronto being located on private lands, it is important for the City to collaborate with community groups and NGOs for more aggressive engagement and stewardship programs. In fact, according to the Plan, Toronto needs to plant 314,000 trees on private lands annually to achieve the 40% tree canopy target. However, only about 25,000 trees and shrubs are planted on private lands per year, mainly through bylaw enforcement. Moreover, most of the City's efforts focus on

programming on public lands. Therefore, there is an urgent need for broader education and engagement programs targeting at tree establishment and maintenance on private lands (Beacon Environmental Limited and Urban Forest Innovations Inc., 2016; City of Toronto Parks Forestry and Recreation, 2013). In addition, the City has limited resources, given the aggressive urban forestry goals. A possible way to address this limitation is through collaboration with more organizations and other local/regional authorities with existing urban forestry programs to help raise funds for new projects (Beacon Environmental Limited and Urban Forest Innovations Inc., 2016).

Empowering Local Communities:

Community-initiated program | Sustainable South Bronx

Established in 2001, Sustainable South Bronx (SSBx) is a non-profit community-initiated organization in South Bronx, one of the most troubled neighbourhoods in New York with various issues of violence, drugs, and high unemployment rate. SSBx was created to address these issues and promote environmental justice through community greening programs, job training and social enterprise. It led the creation of Hunts Point Riverside Park, the first waterfront park in this neighbourhood over the past 60 years. This project later initiated a series of projects to restore the riverbank - the South Bronx Greenway project, a waterfront park system along the Bronx River.

In 2002, SSBx started a "green-collar" job-training program – Bronx Environmental Stewardship Training (B.E.S.T) Program – to train local residents for essential work skills so they are employable and capable of retaining their jobs (Loria, 2009). This 12-week intensive training program covers various topics, such as tree surveys, landscaping, and shoreline restoration.

The program includes four steps (The HOPE Program, no date a):

1. **Work readiness training** (12 weeks/480 hours) focuses on essential work skills (e.g. occupational safety, landscaping). Participants will receive certificates upon completion.
2. **On-the-job training** (200 hours) provides hands-on training at the workplace
3. **Supported job search and placement** provides participants with networks and support for job searching, interview training, and settling down at the workplace
4. **Job retention and career advancement support** offers on-going support for participants, such as career coaching, tax preparation and additional training

In 2015, SSBx joined a larger non-profit organization - the HOPE Program – that aims to "empower New Yorkers to build sustainable futures through comprehensive training, job, advancement and lifelong career support" (The HOPE Program, no date b). The B.E.S.T. program becomes one of the

three job training programs that focuses on green construction and environmental restoration. So far, 84% of the graduates have secured employment after SSBx training (Sustainable South Bronx, no date).

Government-led program | Community Watershed Stewardship Program

The Community Watershed Stewardship Program (CWSP) in Portland is a partnership between Portland's Environmental Services (BES) and Portland State University (PSU) to help residents improve the health of their watershed and their communities (City of Portland Bureau of Environmental Services, no date a). CWSP was initiated in part to respond to the Bureau of Environmental Services' mandates to prevent stormwater pollution, aiming to provide technical and financial support for community-initiated stormwater management or watershed enhancement projects (Miller et al., 2015).

The CWSP provides two grant programs for residents: Stewardship Grant (up to $12,000) and Native Plant Mini-Grant (up to $500). Applicants can use the Stewardship Grant for various projects such as youth leadership and job skill programs, park and river restoration, and neighbouthood safety and livability projects, whereas the Native Plant Mini-Grant only funds the purchase of native plants. CWSP prioritizes equity in its review and granting process by considering the locations and beneficiaries of the applications. The application specifically asks details about how the project contributes to equity and community partnerships (City of Portland Bureau of Environmental Services, no date a). PSU also plays an active role as a partner of CWSP. Every year, CWSP hires two graduate students from PSU to help BES staff coordinate the program (including recruit applicants, support application process, coordinate grant delivery, and support project implementation). PSU faculty members are involved too. They incorporate CWSP projects into their teaching and research to support CWSP projects, help supervise student interns and review grant applications (Miller et al., 2015).

As of 2017, CWSP has provided over $1.4 million to 275 projects, engaged more than 51,000 volunteers with 369,000 volunteer hours (City of Portland Bureau of Environmental Services, no date b). From 1996 to 2012, CWSP projects planted over 325,000 native trees and plants, restored 10.4 miles of stream, installed over 300,000 sq. feet of eco-roofs and other stormwater management infrastructure (Miller et al., 2015).

CWSP is an excellent example of how the city and university can collaborate for better results, and how the city can empower communities through a relatively small program. Here listed three featured CWSP projects that enhanced stormwater/watershed management and empowered marginalized communities:

1. **Green Team** was founded by the Groundwork Portland (an NGO) to provide training for youth from communities of colour for job skills and knowledge of environmental and social justice. Besides, the Green Team works closely with local communities to advocate for environmental and social justice and implement rain gardens and bioswales (Miller *et al.*, 2015).

2. **JOIN project**: JOIN is a group that provides day services to homeless community members and assist them in locating permanent homes (also include support for job search and health referral). With CWSP's help, in 2008, JOIN removed 7,000 square feet of asphalt and created a garden to produce food for the homeless community (City of Portland Bureau of Environmental Services, no date b).

3. **Johnson Creek Clean Up Project** is a collaboration of multiple community organizations and businesses to clean the Johnson Creek in 2015. The project recruited houseless people who were seeking stable housing and people with stable housing to clean trashes in the Johnson Creek to promote better communication and understanding within the community (City of Portland Bureau of Environmental Services, no date b).

Conditions for Trees Growing in Urban Areas

In urban areas, trees are facing constant competitions with people, vehicles, and other grey infrastructure (e.g. roads and utilities). Common challenges and limitations for successful tree establishment and growth include limited soil volume, inadequate soil quality, unsuitable location or species, constant disturbances from other urban infrastructure and people, improper planting design and practices, and limited caring and support (Jim, 2017). These challenges are usually a direct result of densification and population growth (Diamond Head Consulting Ltd., 2017b).

OPTIMAL	COMPROMISED

Below ground :
adequate soil volume + adequate soil quality

At ground level:
high permeability

Above ground:
no conflict

Below ground :
low soil volume + poor soil quality

At ground level:
low permeability

Above ground:
clearance pruning + mechanical damage to stem and branches

m²

m³

TARGET SOIL VOLUME
0.6 cubic meters of soil for every square meter of crown projection

ABOVE-GROUND STRESSORS
conflict with utilities + structures

GROUND-LEVEL STRESSORS
decreased permeability

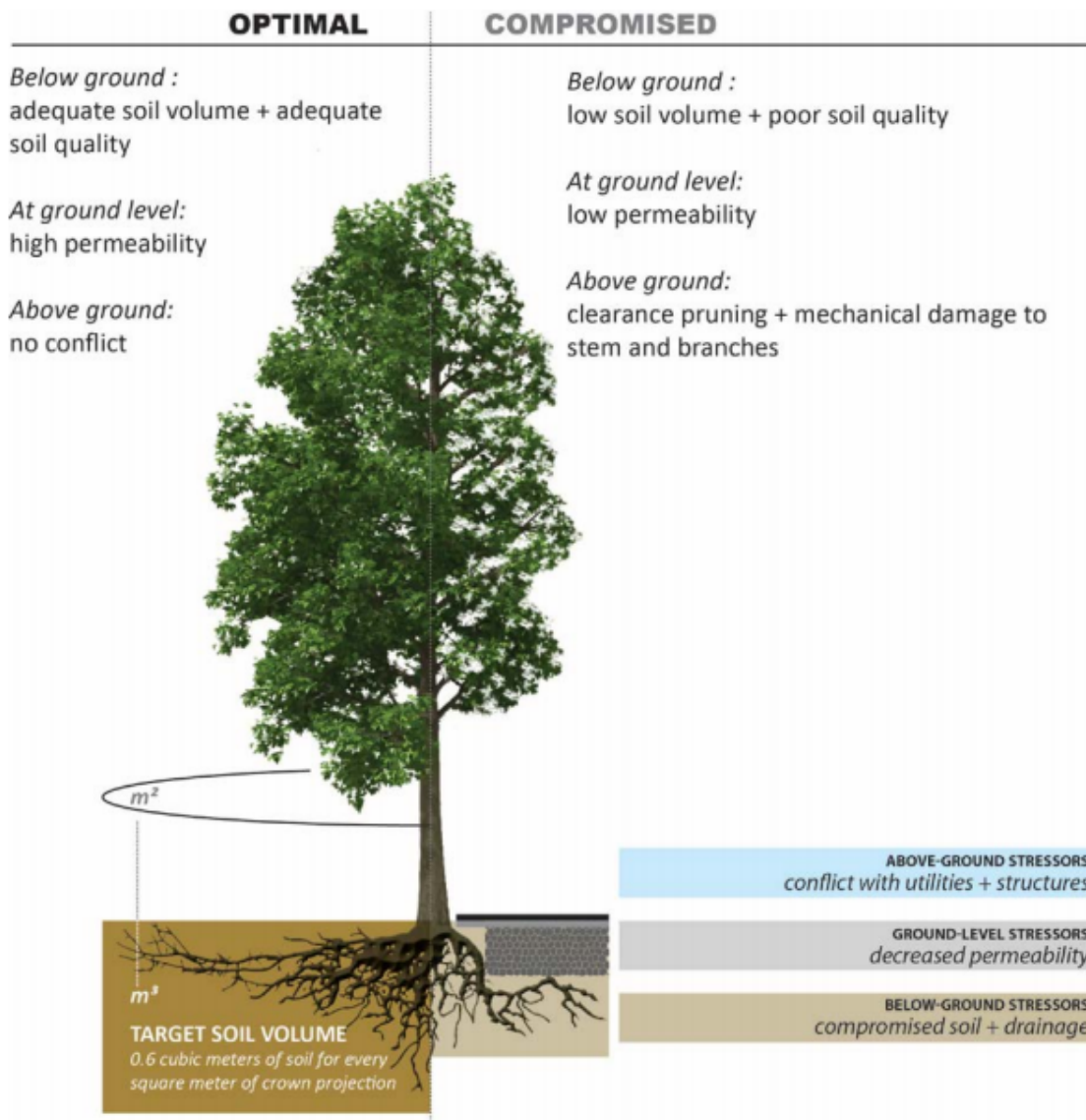**BELOW-GROUND STRESSORS**
compromised soil + drainage

Figure 7 Optimal growing condition for a tree (on the left) and stressors it faces in an urban environment (on the right) (Diamond Head Consulting Ltd., 2017b, p. 10)

There are several key factors to consider in order to mitigate the challenges and enhance the growing condition for trees (for a full list, please see the Design Guidebook – Maximizing Climate Adaptation Benefits with Trees by Metro Vancouver):

Soil volume and quality

Soil is essential for tree health as it enables tree roots to expand and obtain water and nutrients for growth. Many suggest that the soil pit needs to be no less than 1 meter in depth (can be reduced for small trees) and the soil volume needs to be at least 0.3-0.6 m³ for 1 m² of tree crown area (Jim,

2017). Ideally, a mature tree with a canopy spread of about 9 m (30 ft) (considered as a medium-sized tree) needs about 28 m^3 (1000 ft^3) of soil (Casey Trees, 2008; Diamond Head Consulting Ltd., 2017a).

As for soil quality, it is hard to define the ideal level as it varies by the purpose. In general, good soil is defined as "uncompacted, well aerated, and moist" (GreenBlue Urban, 2015, para. 1). Specifically, soil with good quality would have:

- An adequate level of drainage or water holding capacity (about 10 cm per hour) (Trowbridge and Bassuk, 2004, as cited in Bassuk, 2017, p. 300)
- More clay (that typically hold more nutrients) (Bassuk, 2017)
- Good aggregate stability (50% of stable aggregates or higher)[12] (Gugino et al., 2009, as cited in Bassuk, 2017, p. 300)
- Soil pH: the ideal range of soil pH is between 6.5 and 7.0 when nutrients in the soil are the most available for trees. Most urban soil is alkaline due to leaching from building materials. Soil pH amendments can be applied with caution. It is also important to select species that have a wider adaptability of alkaline soil (Lukes and Kloss, 2008; Bassuk, 2017)
- Uncompacted condition: The soil compaction level [13] is commonly measured by $\frac{weight\ of\ an\ undisturbed\ soil\ sample\ (g)}{its\ volume\ (cc)}$. There is a threshold range for tree root growth, which varies by soil texture (Daddow and Warrington, 1983, as cited in Bassuk, 2017, p. 302) -
  - Clayed soil: 1.0-1.4 g/cc
  - Sandy soil: 1.0-1.65 g/cc
  - Pure sand: 1.0-1.7 g/cc

Urban soil is usually highly disturbed and polluted. To restore the soil to the best state to support tree and plant growth, several techniques can be adopted, such as soil rehabilitation or mulching to restore soil, and use soil cells to avoid compaction and maximize soil volume.

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[12] This can be measured by the aggregate stability test: in a lab environment, lay a known weight of soil comprised of particles between 0.25 and 2.0 mm on a 0.25 mm sieve, drop water on it to simulate a heavy thunderstorm using a rainfall simulator for five minutes, collect and measure the soil that falls through (unstable aggregates) and soil that stays on the sieve (stable aggregates), calculate the percentage of stable aggregates by: $\frac{weight\ of\ stable\ aggregates}{weight\ of\ unstable\ aggregates} \times 100\%$ (Bassuk, 2017, p. 300).

[13] There are other ways to measure soil compaction, such as bulk density measurement (dry weight of an undisturbed soil sample divided by its volume) and soil penetrometer (i.e. the force to push through soil, measured by pounds per square inch) (Bassuk, 2017, p. 302).

Surface permeability

High surface permeability allows air and water exchange, which is essential for healthy soil and robust root (Diamond Head Consulting Ltd., 2017b). Leaving the soil area open is the easiest way to ensure surface permeability. If the soil area has to be covered, there are different paving techniques available, some of which are already applied in Vancouver (e.g. metal grates, cobble or granite paving, and permeable paver blocks (Casey Trees, 2008). Another good alternative to increase permeability while allowing easy access for underground utilities is to lay concrete slabs with small holes on soil cells or structural soil. This design has been tested and applied in Toronto (Lukes and Kloss, 2008; City of Toronto Parks Forestry and Recreation, 2013).

Conflicts with nearby infrastructure

Utilities create space constraints for tree growth. Underground utilities are usually buried very shallow under the sidewalks for easy access, which limit soil volume and introduces disturbances (Jim, 2017). Overhead utilities and buildings also post a constraint on the horizontal expansion of tree crown and upward growth of tree due to lack of overhead space and sunlight (Jim, 2017). It is essential to understand the constraints and conflicts with nearby infrastructure (including utilities) and consider the limitations in planting design and tree species selection. Major street redesign or new street design projects would include the introduction of a utility tunnel to avoid conflicts or reposition utility lines away from tree pits (Jim, 2017).

The selection of factors above is for the optimal tree growing condition in a dense urban environment (e.g. DTES). In the actual implementation, more factors should be considered, such as the level of maintenance, conflict of use, and sight-lines (Diamond Head Consulting Ltd., 2017a). Some examples of good street tree designs are provided in the final section – Challenges and Recommendations (page 40).

Challenges and Recommendations

The DTES is a very complicated site with various limitations and issues for increased urban forestry. Below is a list of recommendations that specifically focus on enhancing urban forests in the DTES, based on a literature review and consultation with city staff:

1. Improve communication between key stakeholders in planning, design, implementation and maintenance of future urban forestry projects in the DTES

Communication is one of the critical components for a successful collaboration. Timely, effective, and inclusive communication between all the stakeholders is crucial because it ensures mutual understanding, avoids work conflicts, brings opportunity for cooperation and increases overall work efficiency. However, good communication is often a challenge, especially for comprehensive large-scale projects that involve various stakeholders. Through our conversations with different teams, we have found that urban forestry projects in the DTES usually involves multiple stakeholders and it is challenging to keep everyone well informed on relevant ongoing or upcoming projects. The following items are proposed as ways to improve communication:

a) Continue the stakeholder analysis

Over 20 stakeholders have been identified in CoV and VBPR so far, but we have not included stakeholders from other levels of government, local communities or non-governmental organizations (NGOs). It is vital to identify all the stakeholders for the urban forestry projects in the DTES to ensure inclusive and efficient conversations.

b) Partner with Business Improvement Associations (BIAs) and NGOs

Although the VBPR already has an extensive network with community groups (e.g. neighbourhood matching fund program) and NGOs (e.g. Environmental Youth Alliance and EartHand Gleaners Society), there is room to expand the network with other groups within Vancouver communities and at other levels (e.g. provincial or national). Urban forests are mostly considered as the municipality's responsibilities in Canada, but there is an opportunity for different cities to collaborate as a regional network. Currently, Vancouver is a member of the regional urban forestry network, coordinated by Tree Canada (a national charity group dedicated to tree planting and preservation). VBPR can collaborate with the other members of the regional network and Tree Canada to more actively engage federal, territorial and provincial governments in various urban forestry programs. VBPR can also partner with community groups or charity organizations that already have ongoing engagement programs for enhancing community resilience and connection at the community level, such as the Neighbourhood Lab and Portland Hotel Society (PHS). PHS has two service sites in the DTES on urban greening and agriculture (Hastings Folk Garden and Hastings Urban Farm, highlighted in blue in Figure 6). Research has shown that urban forest can have a positive impact on local business (Hotte et al., 2015). VBPR could collaborate with local businesses and BIAs for innovative projects that are mutually beneficial to the local businesses and residents.

c) Develop and maintain an up-to-date database of all the relevant projects

Either developing a new database or building on the VanMap or GIS tree inventory system already in use by VBPR (ideally with the geo-referencing feature) that can be shared with all the stakeholders to keep every team informed. It will be a great tool to initiate collaborations across groups and increase the efficiency of work (e.g. by avoiding conflicts of time or space).

d) Identify a central team or person to coordinate the communication and track overall progress

Coordinating effective communication between various stakeholders can be challenging. Therefore it requires a dedicated team or person as the initiator and coordinator. The DTES Planning Team has initiated a Tech Team with members from each stakeholder team to fulfill this role. However, the Tech Team's focus is not limited to urban forestry projects but all the priorities identified in the DTES Plan (e.g. infrastructure, housing affordability). Hence, a dedicated team or person is needed to coordinate urban forestry and related projects. The newly initiated Team UP! at VBPR could be a good candidate – it is an interdisciplinary team of staff members from various VBPR teams to collaboration on initiatives for park cleanliness, programming and access, community engagement, and park activation and programming. Ideally, there should be more communication and cooperation between Team UP! and the Tech Team, given their common interested areas – the DTES.

2. Update urban forestry regulations and guidelines to support tree planting and protection

Space limitation is one of the biggest challenges to tree health, partially because the current regulation requires the developers to leave minimal room for trees. As the city develops and climate change intensifies, it is crucial that updates are made to planting techniques, procedure and regulations in Vancouver. To address the issues, we propose the following future actions:

a) Update street tree guidelines to reflect the latest information

Since 2011, there has been more research and better practices for street tree planting and maintenance, which needs to be reflected in the guidelines. For example, Metro Vancouver and Diamond Head Consulting Ltd. released three documents regarding urban forest and climate change adaptation, including an Urban Forest Climate Adaptation Framework, a Design Guidebook, and a tree database for species selection (Metro Vancouver, 2019). The documents include useful information that can be applied to Vancouver. For example, climate change impacts and tree species selection criteria that reflect the tolerance to projected climate change impacts in Vancouver. There are suggested criteria of street tree selection for arterial streets in DTES (e.g. East Hastings Corridor) as an example on page 40. The criteria are based on the existing Street Tree Guidelines and Metro Vancouver's urban forests documents.

b) Develop guidelines for tree planting in parks and other naturalized areas

Planting in parks and naturalized areas is very different from street tree planting. It requires more consideration of ecological aspects of trees and forests and the relation to wildlife. It will be crucial for the planting and maintenance crews to have suggestions on planting and care for trees in these areas as well.

c) Develop additional regulations for reserving space for trees and preventing tree loss

Space limitation is one of the biggest challenges to tree health, partially because the current regulation requires the developers to leave minimal room for trees. This issue can be resolved by introducing a requirement for more building/road set backs for trees in the re-zoning process. A compensation mechanism can also be developed for larger setbacks, such as allowing developers to build one floor up. Vancouver can learn from Singapore's model to preserve and restore urban forests by asking developers to either replace all the greeneries lost due to the development or pay into a fund for every m^2 of "green space" displaced. The City and VBPR can use the fund later for other greening projects. Ideally, more aggressive regulations can be applied to ensure that urban forest and trees are considered in every stage of a city or development project.

3. Update and digitalize tree data for a broader audience and organize the data by sub-areas for more functionality and flexibility

We can access street tree information online through VanMap, VanTree (internal use only), or the city's open data catalogue now, but there is not yet a complete dataset for trees in private properties or naturalized areas. VBPR is developing various methods to collect tree information in these areas. It will be very beneficial for efficient planning and implementation of planting projects once the data is collected and available. In addition, CoV and VBPR are using a few different platforms to manage its dataset for various purposes, which could create barriers to efficient work or information sharing.

Additionally, the current tree inventory system can only sort by neighbourhood. It cannot organize tree inventory data by sub-area. Therefore, there is no easy way to sort the tree information for the DTES area, as the DTES does not follow the traditional neighbourhood boundary (it is a combination of sub-areas across different neighbourhoods). To tackle the issues, the following action items are proposed:

a) Initiate a tree inventory program in naturalized areas

Tree inventory data allows us to understand our tree resources better, such as, getting a more accurate estimate of ecosystem services these trees are providing each year. It also enables us to develop plans

and apply practices that are most needed in different areas. For example, the city staff can better identify trees/forests that need more intensive attending or requires a different management practice.

b) Upgrade the existing VanMap system for better interface and functionality

VanMap is a useful tool for various purposes. However, it may not be user-friendly for analyzing tree data. Improving the user interface of VanMap may encourage more city staff to use it as the standard platform for storing, sorting, and analyzing data. Having all the data (such as tree inventory data, mortality rate, and maintenance records) available on the same platform will also help with information sharing and communication across teams. Upgrading the VanMap to allow navigation and analysis for sub-areas (instead of for traditional neighbourhoods) and will be beneficial for areas like DTES that do not fall under one neighbourhood. It is a crucial step to track the progress towards the street tree density target in DTES (i.e. to double street tree density in DTES by 2030).

4. Engage and empower local communities through innovative approaches

The Planning, Policy & Environment Team at the VBPR has done a great job engaging with local communities on various topics such as urban forests, urban agriculture, wildlife and biodiversity. This engagement occurs during various community events including seasonal tree sales, community workshops, volunteer stewardship program, and community garden program. However, there has not been an approach to track trees and tree planting on private lands. As the summer becomes hotter and drier (one of the major projected climate change impacts), the VBPR will need more help from citizens to care for the urban forests. Potentially, two community engagement program ideas that can be applied to the DTES or citywide are noted below:

a) Initiate a more comprehensive private planting program

Vancouver could introduce a program similar to Toronto's "Our Backyard Tree Planting Program". This program focuses on collaboration with NGOs and charity foundations to offer homeowners and renters two options for tree planting on their properties: do-it-yourself program or a full-service program (including an in-person consultation with an arborist, tree delivery, and tree planting). VBPR has completed a survey to understand home owner's interest in full-service planting program. If it is of people's interest, this program can be an excellent opportunity to encourage more private tree planting and help the city to achieve the tree canopy target (reach 22% by 2050).

b) Establish urban forestry training & work programs for low-income & homeless communities

There are many successful examples of work & training programs in other cities (such as New York and Portland), where free training and career support are provided to the most marginal population

to help them re-establish. Some programs also offer paid jobs for registered members. Vancouver can establish similar programs in the DTES through a collaboration of CoV, VBPR and NGOs (where CoV and VBPR provides funding and technical supports while NGOs like Portland Hotel Society with established network and programs can deliver training and provide career support). The position and training can be designed to fit the needed areas of urban forestry work (e.g. tree inventory and maintain park space). It can be of great help and effect, especially in the DTES, as it not only brings potential incomes but skills and opportunities.

c) Establish urban forestry youth programs for future leaders

Currently, there are various youth leadership programs, but there is none focused specifically on urban forestry. Building an urban forestry youth program could be a great opportunity to engage, train and mentor keen youth to become the future "tree guardians". It can possible have a ripple effect to influence the adults (e.g. parents, grandparents, teachers). Some precedents exist in Toronto including the Young Urban Forest Leaders Program, offering free training and mentorship for youth who are interested in urban forestry and/or from underrepresented groups (e.g. indigenous groups, visible minorities).

d) Initiate more citizen urban forester programs

Many cities now run adopt-a-tree programs (e.g. New York, Toronto, Ottawa). By adopting a tree, people can establish a more intimate connection with the adopted tree and therefore take better care of it. The program usually works better with an online tree map where people can check where the available trees and update their adopted tree information. If the online tree map is available in Vancouver in the future, this can be a feasible and effective program to encourage citizens' involvement in caring for our urban forest.

An incentive mechanism with the tree-adopting program can further encourage residents to take care of trees, e.g. water trees in a dry season. For example, the Brewing a Better Forest (BBF) in Minneapolis rewards citizens free beer from local breweries (partners of this project) if they adopt & water street trees (Brewing a Better Forest, no date). Similarly, VBPR can partner with local businesses such as breweries, coffee shops, or bakeries and provide small incentives to encourage planting or watering trees.

Citizen urban forester programs can also be a good opportunity to promote communication and interaction between different groups of residents (including homeless people) in Vancouver through planting events, workshops, and other social gatherings. The Johnson Creek Clean Up Project in Portland is an example of successful citizen engagement project to encourage local residents to talk

and work with homeless members during a river restoration event to enhance understanding of each other.

5. Create or redevelop green space for equitable and compatible access and use

One of the biggest concerns for the DTES community is the gentrification effects after greening and redevelopment. This concern has been well recognized in various city documents, such as the Greenest City Action Plan and the DTES Plan. However, there is not yet a dedicated action plan or strategy by CoV or VBPR to address the concern and actively prevent it from happening. The DTES community is probably the most vulnerable group in Vancouver to various gentrification effects (e.g. raising house price and rent, changing social composition of the community), developing an action plan with specific steps to minimize the impacts on them is crucial.

a) Establish and integrate work-readiness training and job opportunities for vulnerable communities into the green space development/redevelopment projects

Creating or redeveloping green space (e.g. parks, street trees) can create various job opportunities, such as tree planting, watering, surveying. These projects can prioritize the hiring of local community members, especially the most vulnerable, low-income individuals or families as mentioned in the previous page (under the second recommendation under the fifth action item). The aforementioned programs already exist in other cities such as New York, Portland and Washington D.C. that have been running work training or hiring programs for greening projects.

b) Collaborate with BC Housing, BC Non-Profit Housing Association and other NGOs

VBPR can partner with BC Housing and other organizations that run affordable housing programs in the DTES to co-create and co-manage green space on their properties. Research has shown that greenery can help increase people's mental and physical health (Hotte et al., 2015). Having green space nearby their units can be very beneficial to their residents, especially to people who are suffering from physical or mental illness (Hotte et al., 2015). In addition, innovative housing and greening projects can be piloted through the collaboration of VBPR, CoV, BC Housing and other organizations that provide social support to increase equitable access and use of green space as well as mitigate gentrification effects on local communities, such as building tiny house villages (a program originated in Seattle) comprised of social housing units and public green space (e.g. community gardens and parklets).

Opportunities to plant in the DTES

After site visits and consultations with stakeholders, the following locations have been identified as the immediate action areas to increase tree canopy in the DTES. These areas are streets with low or no street tree canopy (e.g. some sections of East Hastings Street) and parks with open space for more trees or an upcoming redevelopment plan. Planting in the identified areas can be especially helpful to increase tree canopy in the northern section with the least tree canopy and a limited number of parks and green space.
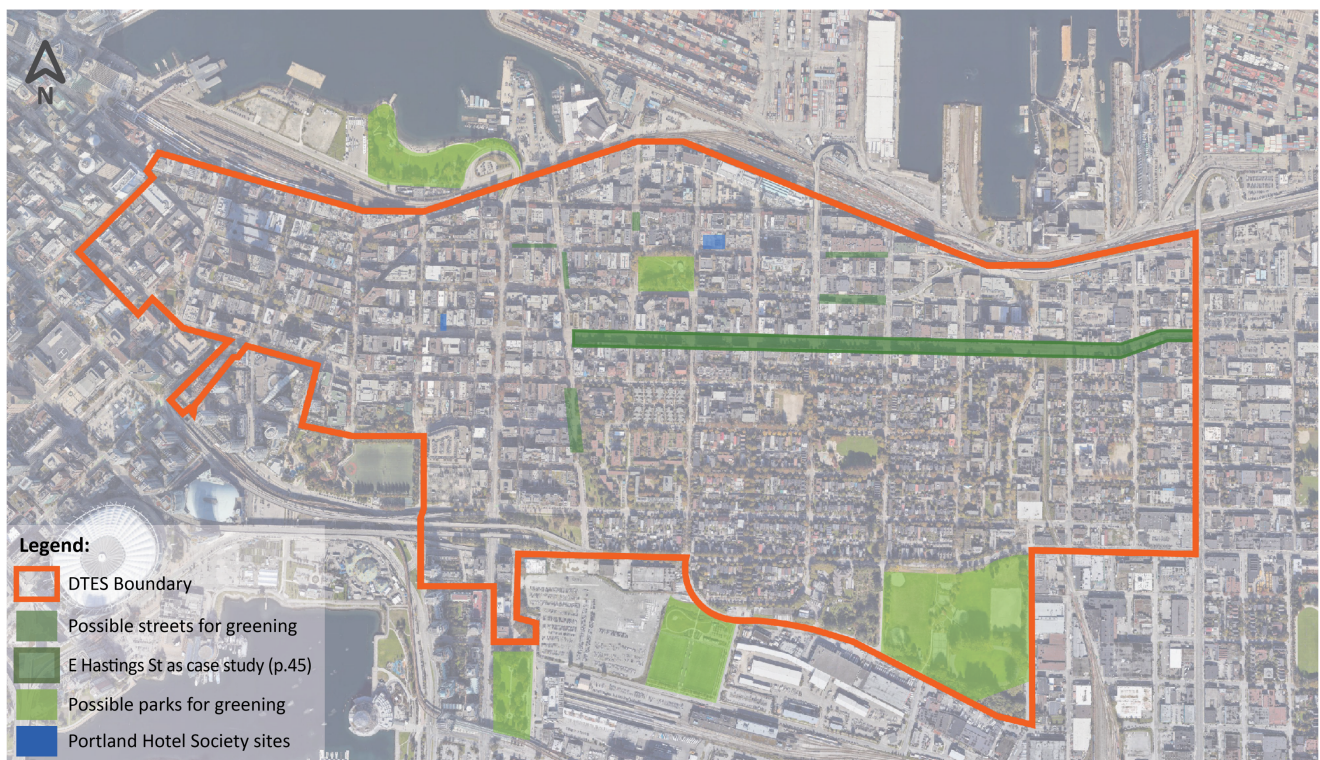

Figure 8 Locations of possible urban forestry projects in the DTES

Besides planting on streets and in parks, opportunities also exist for more long term greening initiatives. These are general suggestions without specific locations. Therefore they are not indicated in the Figure 8.

Create public space along wider streets

Some streets in the DTES are wide and enough to support more mature trees than currently exist (e.g. some parts of East Hastings Street). There is room to improve the tree canopy and social functions of

these streets by increasing street planting and adding elements such as benches and small public art features to create resting areas and small public space for communities to enjoy.

Figure 9 Before and after photos of roadside planting on Princess St. Vancouver (Photo by D. Miller)

Figure 10 Resting areas on streets: University Village in Seattle on the left; 7th Ave. (between Lenora St. and Blanchard St.) in Seattle on the right. Photo credit: Zhaohua Cheng, 2019.

Street closures for parklets

Some quiet and small streets can be closed off and turned into parklets/miniparks. Multiple features can be installed to create a green and inclusive environment for the local community. There are

already some successful examples in Vancouver, such as the Lilian To Park on Yukon Street and 17th Avenue (Figure 11).

Figure 11 Lilian To Park, turned from a small section of closed street by Yukon St. and 17th Ave., Vancouver. Picture credit: Vancouver Park Board facebook account, 2017 (left), Google Maps Streetview, 2019 (right).

Planting on parking lots

Current trends suggest that Vancouver will experience hotter and drier summers, increasing tree canopy in the surface parking can offer various benefits, such as provide shade and cool the air temperature (Diamond Head Consulting Ltd., 2017b). Tree planting can be integrated into parking lot design to allow more tree shade for vehicles. In addition, as Vancouver progresses toward the Green Transportation goal, more travels will be made by foot, bike or public transit, instead of driving. The demand for driving and parking may be significantly less. The under-utilized parking lots will become opportunities for converting to community spaces, such as parklets or community gardens.

Figure 12 An example of a surface parking lot that could have more trees on site (left, Google Streetview, n.d.) and possible installation (right, visualization by GreenMax, n.d.; bottom, Diamond Head Consulting Ltd., 2017a)

Case Study – Planting on East Hastings Street

The project selects one of the identified priority areas (Figure 8), East Hastings Corridor, as an example to illustrate possible planting designs for arterial streets with heavy foot and vehicular traffic. Below is a list of suggested criteria to consider for selecting tree species on East Hastings:

- Size class: small to medium (minimal soil volume requirement less than 50 m^3)
- Shade density in leaf: moderate to high
- Suitable location: streets with tree pits/boulevard < 2m
- Drought tolerance: moderate to high
- VOC (emitted by tree itself): low to moderate
- Wind breakage: low
- Noted public sources of complaints: none
- Suitable for present and future climate: Yes
- Conifers: No
- Available in local nursery: Yes
- In tree form: Yes
- Ability for protracted growth: Yes
- Shade tolerance: medium to high
- Vandalism tolerance: high
- Insect and disease tolerance: high
- Tolerance to poor soil aeration/extended water saturation: Yes
- Aggressive rooting: Low or no

Based on the criteria, 11 species of small- to medium-sized trees from the tree database are suitable for East Hastings Street. Please see the Appendix for the list.

Planting Suggestions:

1) Place structural soil or soil cells under sidewalks and bike lanes to maximize soil volume (Figure 13 and 14). If this is not possible, consider to plant in strips of soil to allow more sharable soil volume between trees (Figure 17).
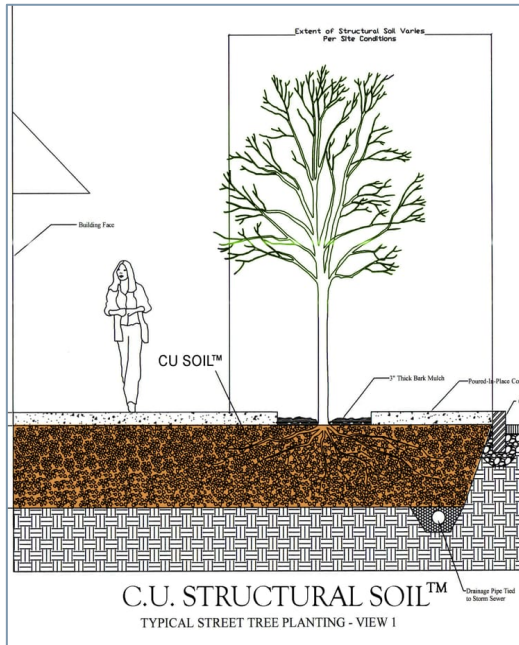

Figure 13 Soil extension to sidewalks (illustration from Casey Tree, 2008)

Figure 14 Soil cells for planting in soil strip by curb (illustration by City Green, 2016)

2) Due to the heavy foot traffic on the street, consider to implement designs that prevent pedestrians from stepping on the soil pits, e.g. raised planting bed that also allows people to sit, gravel or low metal fence by the tree pits, apply mulch or plant understories to protect the soil surface, and cover the pit with permeable paving (Figure 15 and 16).
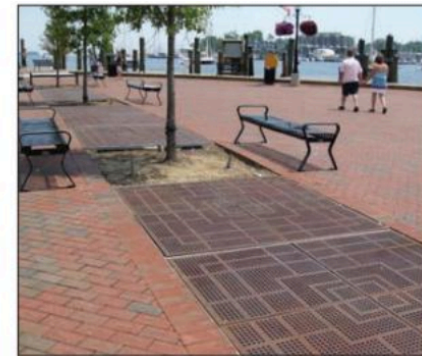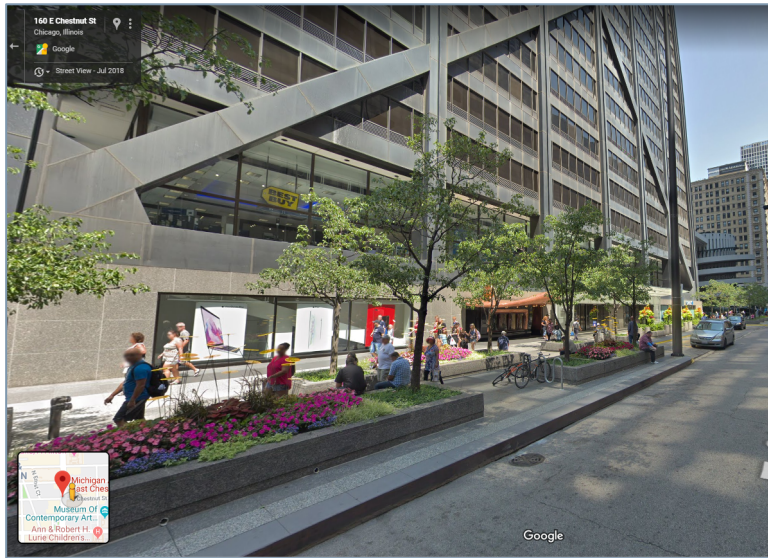
Figure 15 Raised planting bed along the East Chestnut Street, Chicago (top left, Google Streetview, 2018)

Figure 16 Permeable rubber paving (top right, Zhaohua Cheng, 2019)

Figure 17 Various permeable paving on connected tree pits (bottom, Casey Tree, 2008, p. 5)

Conclusion

This project is the first step that approaches DTES's various issues from the perspective of urban forestry. As the city densifies, the population grows, and climate change intensifies, urban forest's role will become more vital in the city, as it is an essential element to create a healthy, resilient and equitable environment. This project helps the VBPR identify key stakeholders that they need to involve, possible partnerships that they can develop, and prioritized action items that they need to take in the near future to progress toward the urban forestry targets citywide and for the DTES.

Looking ahead, the project (if continued) can resume the stakeholder analysis and extend it to external stakeholders. Many of the recommendations in this report are based on the conversations

with different stakeholders. It will be beneficial if the VBPR can continue the communication and even organize regular meetings with all the stakeholders. The DTES is a complicated area with distinctive characteristics and problems. A better understanding of the area is crucial in order to provide solutions. More importantly, clear direction and sustained efforts to support the local community is essential to the success of future initiation. It will also be helpful to conduct a baseline analysis to understand where we are (e.g. identify blocks with below-average tree density) and work out a pathway for the GCAP and other planting targets.

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Appendix A Tree Species for Planting on East Hastings Street

TABLE X. SELECTED SPECIES FOR STREET TREES ON EAST HASTINGS STREET		
Common Name	**Scientific Name**	**Size**
Field Maple	*Acer campestre*	Medium
Bigtooth maple	*Acer grandidentatum*	Small
Paperbark maple	*Acer griseum*	Small
Miyabe's maple	*Acer miyabei*	Medium
Amur maple	*Acer tataricum*	Small
European hornbeam	*Carpinus betulus*	Medium
Japanese hornbeam	*Carpinus japonica*	Medium
Cornelian cherry	*Cornus mas*	Small
Kentucky coffeetree	*Gymnocladus dioicus*	Large
American hop hornbeam	*Ostrya virginiana*	Medium
Burr oak	*Quercus macrocarpa*	Large
Japanese snowbell	*Styrax japonicus*	Small