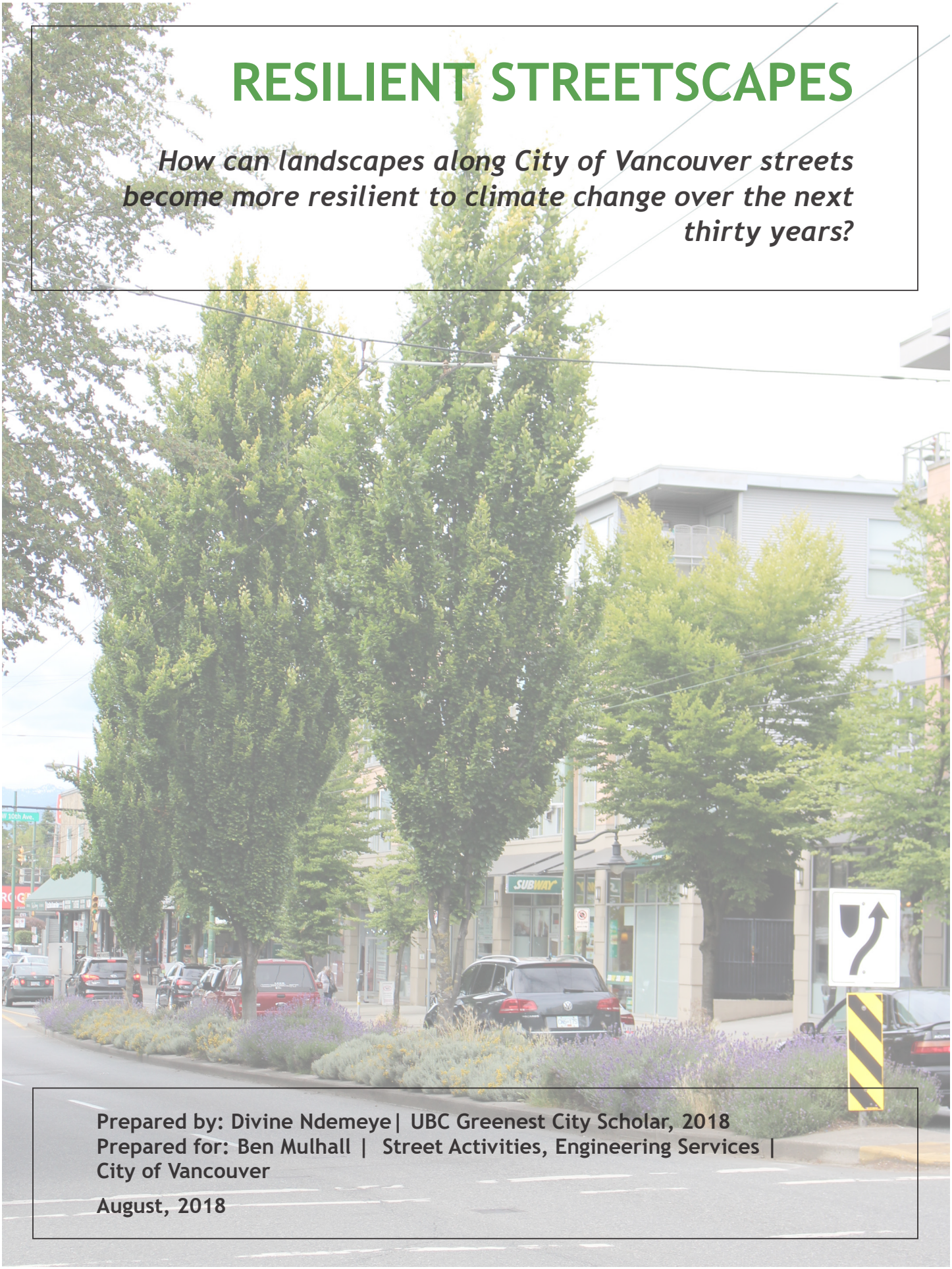
RESILIENT STREETSCAPES

How can landscapes along City of Vancouver streets become more resilient to climate change over the next thirty years?



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This GCS project was conducted under the mentorship of City staff. The opinions and recommendations in this report, and any errors, are those of the author, and do not necessarily reflect the views of the City of Vancouver or The University of British Columbia.

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EXECUTIVE SUMMARY

The Resilient Streetscapes project aims to support the Greenest City Action Plan 2020 goals of increasing access to nature and green transportation by enhancing the resiliency of street planting in the face of climate change over the next thirty years. Climate change projections indicate that Vancouver can expect warmer temperatures, longer summer dry spells, wetter fall and winter conditions and more extreme precipitation events. These changes will put further stresses on street horticulture assets, in addition to the existing harsh street conditions that these plants are subject to such as air pollution, road salt and low soil volumes.

The right selection, installation and maintenance of plant material is necessary to ensure that City of Vancouver streetscapes are resilient to changing climate conditions, while remaining environmentally sound and aesthetically appealing. The Resilient Streetscapes project has the following objectives:

- Improve existing street horticulture planting and maintenance practices in anticipation of the potential effects of climate change
- Improve citizens' access to nature through healthier planted areas in streetscapes
- Provide a reference document for improving street planting guidelines

The recommendations presented in this report are based on findings from a literature review on the effect of climate change on vegetation and City of Vancouver street horticulture conditions of the day. A preferred plant list is proposed with plants that will withstand and help mitigate some of the forecasted effects of climate change. These recommended plants will play an important role in stormwater management, soil stabilization, urban heat island mitigation, habitat enhancement and aesthetic quality; thereby improving the social and environmental quality of streetscapes in the City of Vancouver.

1.0 INTRODUCTION

Shrub and grass plantings along streets, referred to as street horticulture assets, are subject to harsh conditions including extreme temperatures, air pollution, road salt and low soil volumes. The effects of climate change will make conditions more challenging for plants to survive.

In 2011, the City of Vancouver set the goal to be the greenest city in the world by 2020. A number of projects, strategies and policies have been developed and put in place to advance this goal. The Resilient Streetscapes Project aims to support the Greenest City 2020 Action Plan (GCAP) in making Vancouver greener, healthier and more livable by proposing recommendations to enhance the City's street horticultural design and maintenance practices to respond to climate change. Resilience is the capacity of a system to absorb or withstand perturbations such that the system maintains its structure and functions (Holling, 1973). The project aims to answer the following question:

> ***How can landscapes along the City of Vancouver streets become more resilient to climate change over the next thirty years?***

To answer this question, the project included the following research:

- Background review of relevant Greenest City Scholar projects and City policies and initiatives.
- Baseline review of street horticulture conditions today.
- Literature review and grey literature (documents not formally published in academic sources, including government reports, policy documents and websites) review on the effect of climate change on vegetation.

- Questionnaire to select municipalities on street horticulture design and maintenance practices. A questionnaire was sent to eight municipalities, selected based on their comparable biogeoclimatic and plant hardiness zones (current and projected in the next thirty years). Due to the lack of sufficient responses from these municipalities within the timeframe of the project, this research was null within the scope of this report.

The recommendations presented are based on findings from the literature review. A preferred plant list is proposed with plants that will withstand and help mitigate some of the forecasted effects of climate change such as hotter and drier summers, increased intensity and frequency in heavy rain events. These recommended plants will play an important role in stormwater management, flood management, soil stabilization, urban heat island mitigation, habitat enahncement and aesthetic quality; thereby improving the social and environmental quality of streetscapes in the City of Vancouver.

The objectives of this project are as follows:

- Improve existing street horticulture planting and maintenance practices in anticipation of the potential effects of climate change
- Improve citizens' access to nature through healthier planted areas in streetscapes
- Provide a reference document for improving street planting guidelines

2.0 PROJECT BACKGROUND

2.1 RELATED PAST GREEN SCHOLAR PROJECTS

The Greenest City Scholar program is a partnership between the University of British Columbia and the City of Vancouver to advance the goals outlined in the Greenest City 2020 Action Plan. This project builds on past work by Greenest City Scholars. Some of the relevant projects are summarized below.

Green Stormwater Infrastructure (GSI) on City Streets (2016)

This project investigates GSIs on city streets in terms of benefits and challenges, best practices and lifecycle cost. The most common GSI tools found in street horticulture aareas are rain gardens and infiltration bulges and infiltration trenches. An important finding of this study is that the perceived operational and maintenance costs of GSI is the greatest barrier to their implementation.

Connecting to Nature in Vancouver's Urban Landscape- Greenest City Action Plan access to nature strategies in everyday landscapes (2014)

This project is an overview of the City initiatives seeking to increase connections to nature to inform designs for a neighborhood park and a major boulevard, which demonstrate various ways of bringing nature experiences in the urban landscape.

How can city landscaping increase habitat values in our parks and along our streets for urban songbirds and other wildlife? (2013)

This project presents "Bird-friendly Landscape Design Guidelines" that serve as a design guide to increase habitat diversity at different scales and urban habitat types including the following: parks and gardens, residential gardens, green streets, green roofs, community gardens and golf courses.

How will we achieve our target to plant 150,000 new trees by 2020? (2012)

This project recommends the development of a local community-based program aimed at encouraging a higher number of residential tree planting in Vancouver. Informed by four case studies, this project provides key design, funding, and outreach opportunities to enhance tree planting in Vancouver. One of the main findings of this study is that there is a need for a visually engaging, clear and accessible instructional tree planting/care guides and other resources to assist residents in caring for trees on their residential properties.

2.2 SUPPORTING PLANS AND STRATEGIES

The Resilient Streetscapes Project supports many existing City of Vancouver policies and strategies. Some of these documents are summarized below.

Greenest City 2020 Action Plan

In 2011, the City of Vancouver set out the goal to be the greenest city in the world by 2020 and adopted the Greenest City 2020 Action Plan, which outlined eleven goals with measurable targets. The Resilient Streetscapes project primarily supports the following two goals and targets:

#3 Green Transportation
Target: Make the majority of trips (over 50%) by foot, bicycle and public transit.

Between 2010 and 2016, the percentage of walking, biking and transit usage improved from 40% to 50% of trips. Green and beautiful streets can encourage active transportation by making travel by bike or foot more enjoyable.

#5 Access to nature
Target: Ensure that every person lives within a five minute walk of a park, greenway or other greenspace.

Between 2010 and 2016, the percentage of city's land base within a five minute walk to a green space improved from 92.6% to 92.7%. The 2020 target has been set to 95%. Street horticulture can play a role in the availability and accessibility of green spaces in the city of Vancouver where existing park space is limited.

Climate Change Adaptation Strategy

The Climate Change Adaptation Strategy predicts that Vancouver will experience increased annual precipitation and temperatures with hotter, drier summers and sea level rise which will increase the risk of overland and coastal flooding. The goal of the strategy is to ensure Vancouver remains a livable and resilient city, maintaining its values, character and charm in the face of climate change.

The Resilient Streetscapes project supports this vision through the preservation and expansion of planted areas along streets which play an important part in absorbing carbon, groundwater recharge and mitigating flood events, which are likely to increase due to sea level rise and heavy rainfall or storms surge.

Urban Forestry Management Plan

While urban forestry is the study and management of the city's urban forest, comprised of trees, shrubs and other vegetation, the City of Vancouver's Urban Forestry Management Plan and Strategy is focused mainly on tree canopy. Trees provide ecological, social and economic benefits to the community, such as carbon sequestration, air purification, stormwater interception, flood management, habitat creation, biodiversity, and recreation. Locally, Vancouver's urban forest canopy coverage has declined 26%, from 46% coverage in 1972 to 19.7% coverage today. This plan proposes the establishment of a city-wide goal of 28% for tree canopy.
Today, 67.5 % of existing canopy coverage is on private land; 20% on public lands and 12.5% on Rights of Way.

The Resilient Streetscapes project supports the following goals and objectives outlined in the Urban Forestry Management Plan:

1. Tree Resource Protection

1.4 Promote stewardship of native plant communities on private and public property. Provide education about the benefits of native plants and negative effects of invasive and non-native species.

2. Tree Resource expansion

2.2 Increase tree and shrub planting on public property, including parks and natural areas.

Integrated Rainwater Management Plan

The Integrated Rainwater Management Plan seeks to use green infrastructure to improve rainwater management. Strategies include, but are not limited to absorbent landscapes, infiltration swales, rain gardens, infiltration bulges and green roofs. Trees, shrubs, grasses and surface organic matter create absorbent landscapes which play a key role in the reduction of rainfall runoff through crown interception, evapotranspiration, soil water storage and infiltration. Some examples of existing absorbent landscapes include street gardens (part of Vancouver's Green Streets Program), private residential yards, planted boulevards, parks and open spaces. The Resilient Streetscapes project supports the Integrated Rainwater Management Plan through its focus on improving street planting.

Water Wise Landscape Guidelines

The Water Wise Landscape Guidelines aim to reduce the consumption of potable water for irrigation while maintaining the quality of the urban landscape. Water wise landscapes help preserve water quality and availability. They also reduce greenhouse gas emissions, and mechanical and energy inputs related to gas powered equipment used for plants maintenance. In Vancouver, the seasonal patterns results in an abundance of precipitation in the winter months, while the summer months experience a shortage and some drought. Water wise plants such as native and hardy non-native adaptive plants would be able to thrive in these contrasting climatic conditions.

3.0 STREET HORTICULTURE

Cities rely heavily on road networks for the flow of people and goods. The extensive transportation infrastructure made of asphalted roads in cities has resulted in significant soil sealing, whereby “soil is no longer able to perform the range of ecological functions associated with it” such as habitat provision for flora, fauna and micro-organisms, and nutrient recycling (Dolan et al L.et al.,1970, p. 277). Nonetheless, the unsealed roadside provides many opportunities to introduce some ecological functions and benefits through planting. Plantings along streets are subject to harsh conditions including extreme temperatures, air pollution, road salt and low soil volumes. The appropriate selection of plant species is critical to building resilient, environmentally sound and aesthetically appealing streetscapes. The right selection, installation and maintenance of plant material can improve the safety of vehicular and pedestrian traffic, workers, as well as the long term sustainability (social, financial and environmental) of streetscapes. Roadside vegetation, including shrub and grass plantings, can help to mitigate surface runoff, erosion, and can establish some wildlife habitat as well as add aesthetic value to communities. Street planting and green infrastructure play a key role in enhancing the ecosystem services of urban streetscapes. Ecosystem services (see figure 1) are “the material and immaterial goods, services, and benefits that people receive from functioning ecosystems” (Mooney,2014,p.143). Streetscapes can provide regulating (such as climate regulation), supporting (such as nutrient and water cycling) and cultural (such as aesthetic, and recreation) ecosystem services to our communities including the following:

- Air and water purification
- Mitigation of the urban heat island effect
- Flood regulation
- Climate regulation
- Habitat for insects, birds and urban adapted wildlife
- Beautification of streets and the city
- Traffic calming
- Enhancing walkability and visual interest
- Opportunities to engage with neighbors

Figure 1- Four categories of ecosystem services: Supporting, Provisioning, Regulating and Cultural (Thorston et al., 2014)

Combining urban transportation mobility with environmental sustainability can be achieved with the use of street horticulture, which can enhance overall urban ecosystems. Ideally, roadside vegetation does not compromise traffic safety; rather it supports it through buffering uses while protecting sightlines. It can require minimal input in terms of energy and other resources such as water, fertilizers, herbicides and pesticides as well as minimal maintenance services.

3.1 EXISTING PLANTING DESIGN PRACTICES

All street horticulture assets go through a landscaping geometric design process. First, a review of viability of a planting area is evaluated to determine if the planting would thrive considering the site conditions, such as the surface area, water availability, foot traffic, salt spray as well as adjacent uses. Once this has been determined to be viable, a review of sightlines and visibility is conducted to ensure that the planting does not compromise traffic safety and control, and to ensure that existing utilities

are not negatively impacted. A decision is made between a standard grass planting or shrub planting. Plants in traffic circles and plants located close to intersections or where visibility is a concern must be 0.6 m (2 ft) or less. Plants in gardens that are located away from the intersection should be kept to a maximum of 1 m (3 ft). In addition, a review of the traffic control required for ongoing landscape maintenance is conducted to ensure that the area can be maintained with minimal traffic impacts. Further information on design and installation practices are available in the City of Vancouver Boulevard Gardening Guidelines.

3.2 EXISTING MAINTENANCE PRACTICES

Maintenance for street horticulture assets includes pruning, watering, weeding, mowing, litter pick up, as appropriate and required. Maintaining high service levels is challenging due the competing priorities for resources and the inherent challenges in maintaining the variety of assets. Challenges for street horticulture maintenance include the following:

Traffic Control

- Operations workers require a safe work zone to work within when maintaining plantings along roadways, per Ministry of Transportation and Worksafe BC regulations. Work zone requirements typically require closure of a full lane adjacent to the planting for staging and access. On medians, closure of a lane on either side of the median is typically required. Adjacent to bike lanes, closure of the bike lane is typically required.
- Maintenance that requires full road closures, reduction to single lane traffic or impacts to turning movements are often only permitted during evenings and weekends, which brings an increased cost for mobilization, staging and labour.
- Plantings adjacent to bike lanes are difficult to maintain because current policy indicates bike lanes cannot be closed for more than one hour. Longer closures are allowed if there is an alternative route of equal or greater service.

Timing

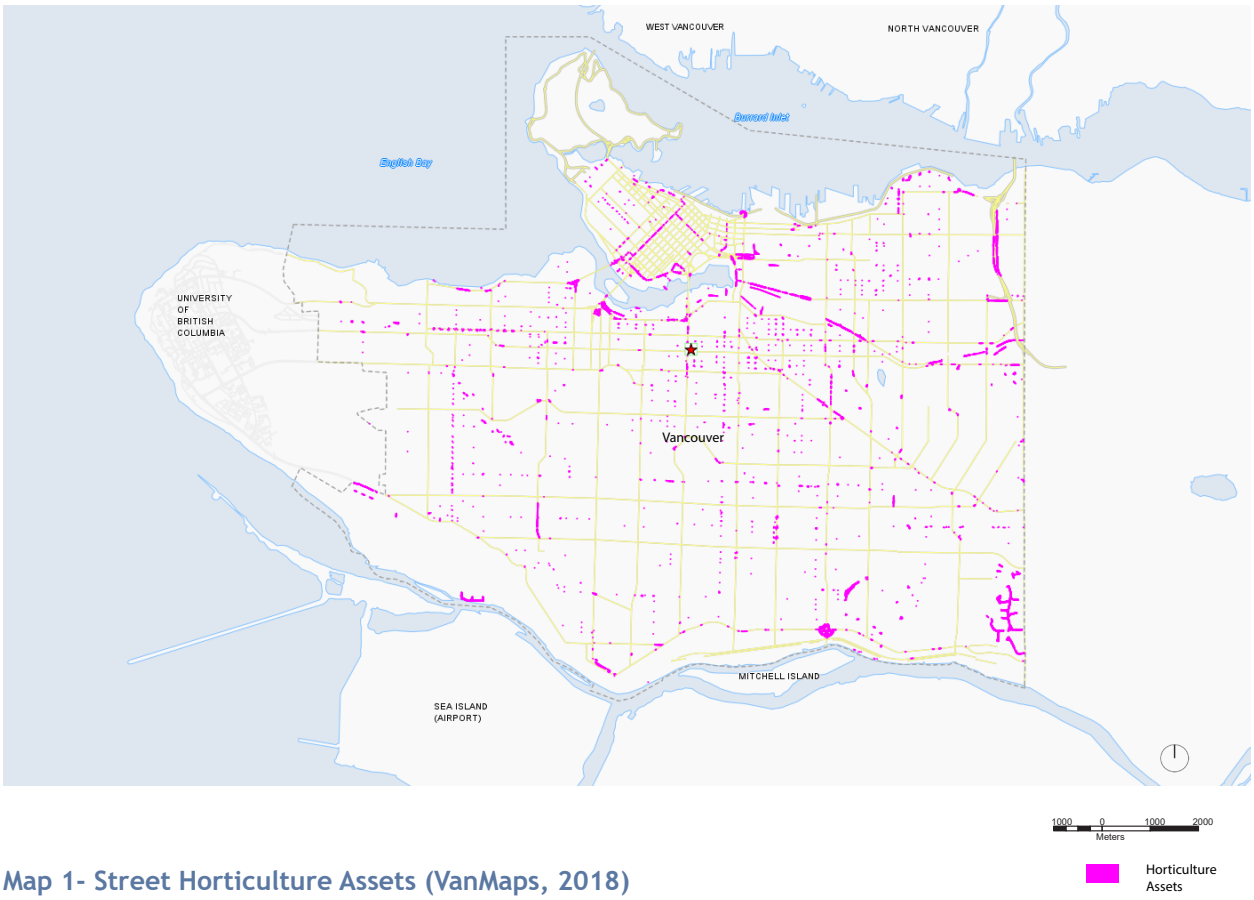
- Landscape maintenance equipment such as hedge trimmers generate sound levels around 100 decibels. The Noise Bylaw restricts times that work can be completed.

Plant Health

- Roadside plantings are subject to harsh conditions from extreme temperatures, air pollution, road salt and low soil volumes. Plant establishment is difficult in these conditions and plant lifespan is often reduced.
- Plant establishment typically requires extra watering. Permanent irrigation systems are not installed in any street horticulture assets.

While all plants require some maintenance, some species establish more quickly, grow slower and require fewer water and nutrients inputs. Plant selection of low maintenance plants is crucial for accomodating the maintenance challenges of street horticulture.

3.3 VANCOUVER: STREET HORTICULTURE ASSETS

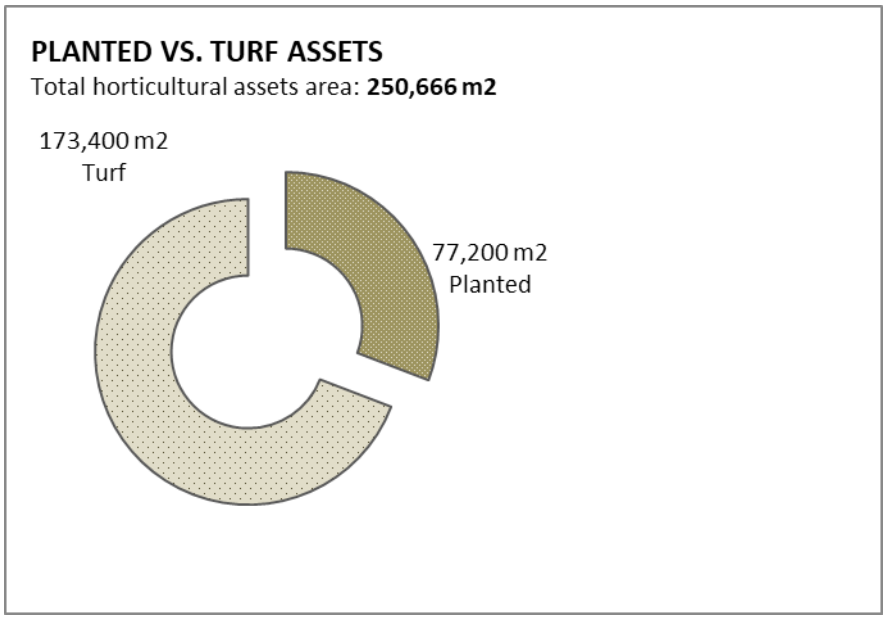


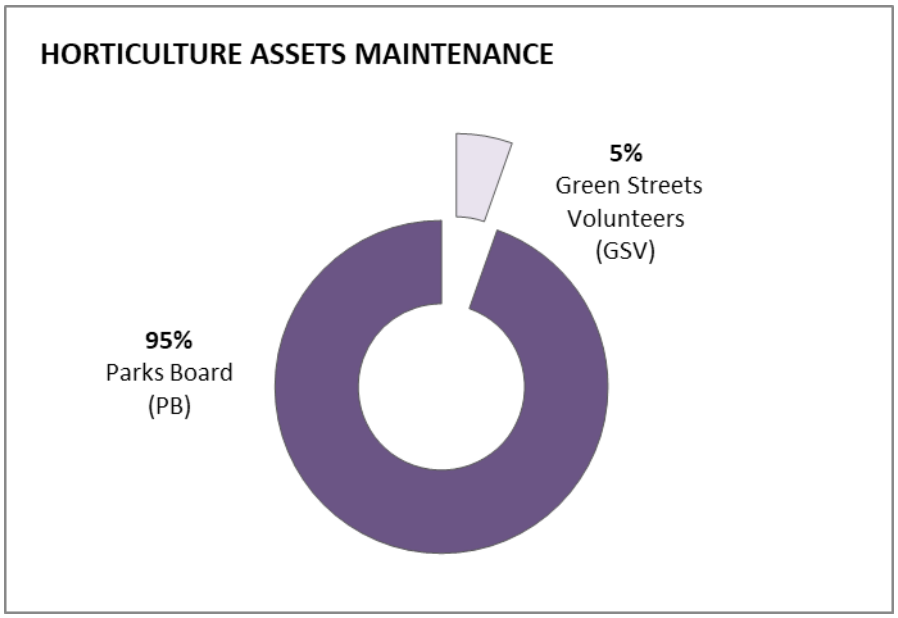
Map 1- Street Horticulture Assets (VanMaps, 2018)

In the City of Vancouver, street horticulture assets make up approximately 250,000 square meters (based on 2018 inventory) and are distributed across the city (refer to Map 1). Street horticulture assets do not include street trees. Assets are categorized between two vegetation types; turf (grass) and planting (shrubs, perennials, and ornamental grasses). Assets are also categorized based on location, either on arterial roads and/or local roads (which includes collector roads). Arterial roads support higher traffic volumes than local roads and therefore have different microclimates and require different maintenance service levels. Asset categorization is further refined by garden type which include the following:

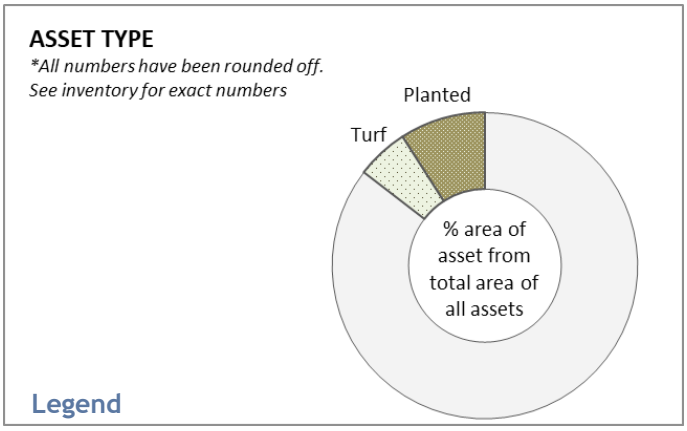
- Bioretention Bulges
- Boulevard
- Bridge/ ramp
- Bulge
- Diverter
- Island
- Median
- Naturalized Area
- Neighborhood Greenway
- Planter
- Street End
- Traffic Circle
- Welcome to Vancouver Signs

The Vancouver Park Board maintains 95% of all existing horticultural assets and Green Streets volunteers maintain the other 5%. Private contractors also maintain several assets. The charts below illustrates the proportion of turf and planted assets and the percentage area maintained by different groups.



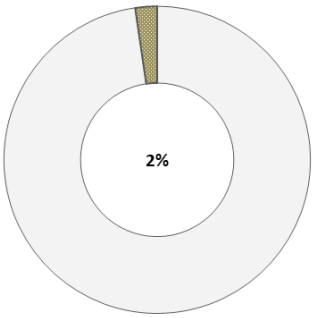


Here is the breakdown of vegetation type and service provider for each garden type (information is based on the 2018 Street Horticulture inventory).



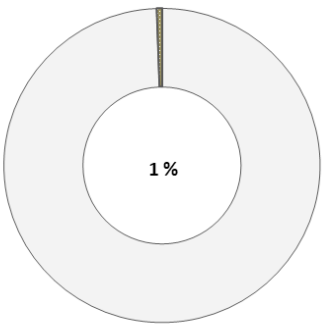
WELCOME TO VANCOUVER SIGN
Number of assets: **7**
Total area: **5,000 m2**
Planted: 100%

Maintenance Provider (% of asset area)
PB: 100%
Not eligible for sponsorship by GSV



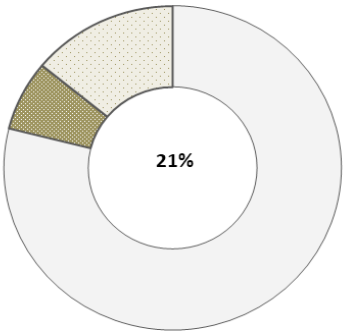
BIORETENTION BULGE
Number of assets: **55**
Total area: **1,400 m2**
Planted: 100%

Maintenance Provider (% of asset area)
PB: 42%
GSV: 58%



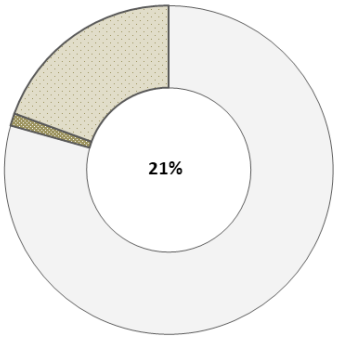
BOULEVARD
Number of assets: **225**
Total area:**52,000 m2**
Planted: 33%
Turf:67%

Maintenance Provider (% of asset area)
PB: 90%
GSV: 10%



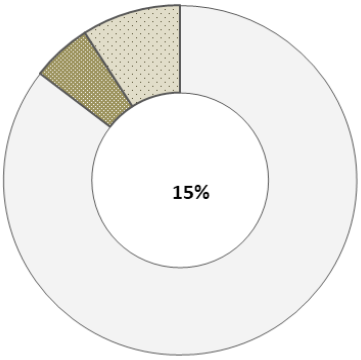
BRIDGE/RAMP
Number of assets: **80**
Total area: **51,700 m2**
Planted: 6%
Turf: 94%

Maintenance Provider (% of asset area)
PB: 100%
Not eligible for sponsorship by GSV



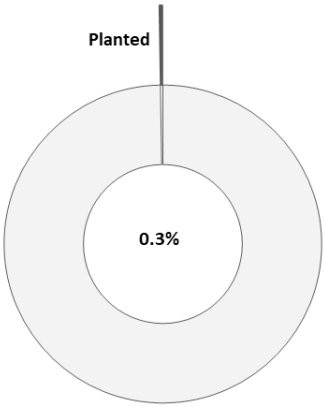
BULGE
Number of assets: **833**
Total area: **36,500 m2**
Planted: 38%
Turf: 62%

Maintenance Provider (% of asset area)
PB: 65%
GSV: 35%



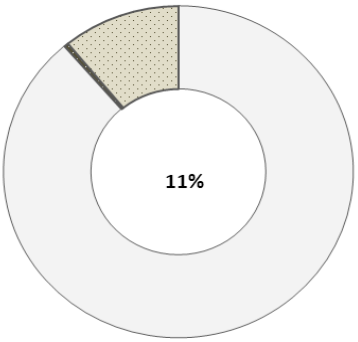
DIVERTER
Number of assets: **59**
Total area: **600 m2**
Planted: 98%
Turf: 2%

Maintenance Provider (% of asset area)
PB: 37%
GSV: 63%



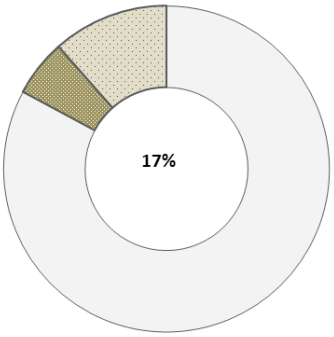
ISLAND
Number of assets: **200**
Total area: 2**8,300 m2**
Planted: 86%
Turf: 14%

Maintenance Provider (% of asset area)
PB: 95%
GSV: 5%



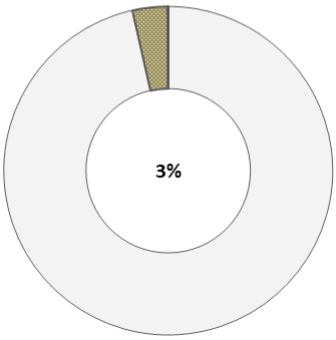
MEDIAN
Number of assets: **244**
Total area: **43,000 m2**
Planted: 33%
Turf: 67%

Maintenance Provider (% of asset area)
PB: 65%
GSV: 35%



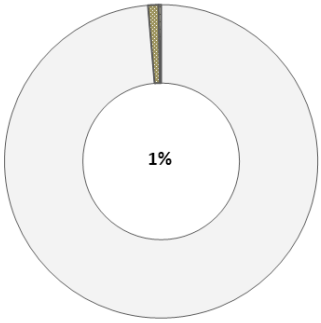
NATURALIZED AREA
Number of assets: **7**
Total area: **8,800 m2**
Planted: 97%
Turf: 3%

Maintenance Provider (% of asset area)
PB: 71%
GSV: 29%



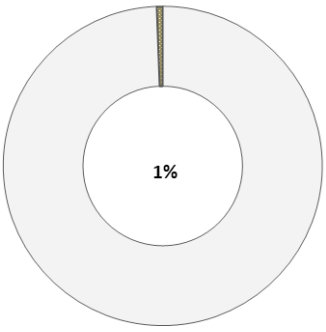
NEIGHBORHOOD GREENWAY
Number of assets: **18**
Total area: **3,300 m2**
Planted: 80%
Turf: 20%

Maintenance Provider (% of asset area)
PB: 50%
GSV: 50%



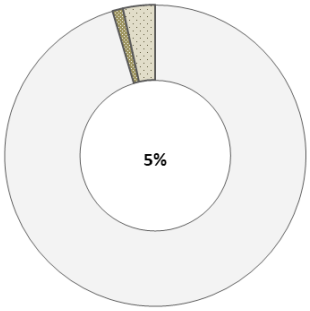
PLANTER
Number of assets: **80**
Total area: **1,400 m2**
Planted: 100%

Maintenance Provider (% of asset area)
PB: 99%
GSV: 1%



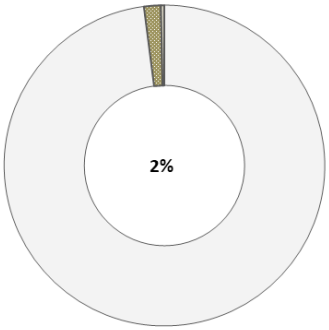
STREET END
Number of assets: **46**
Total area: **11,400 m2**
Planted: 25%
Turf: 75%

Maintenance Provider (% of asset area)
PB: 89%
GSV: 11%



TRAFFIC CIRCLE
Number of assets: **289**
Total area: **5,000 m2**
Planted: 83%
Turf: 17%

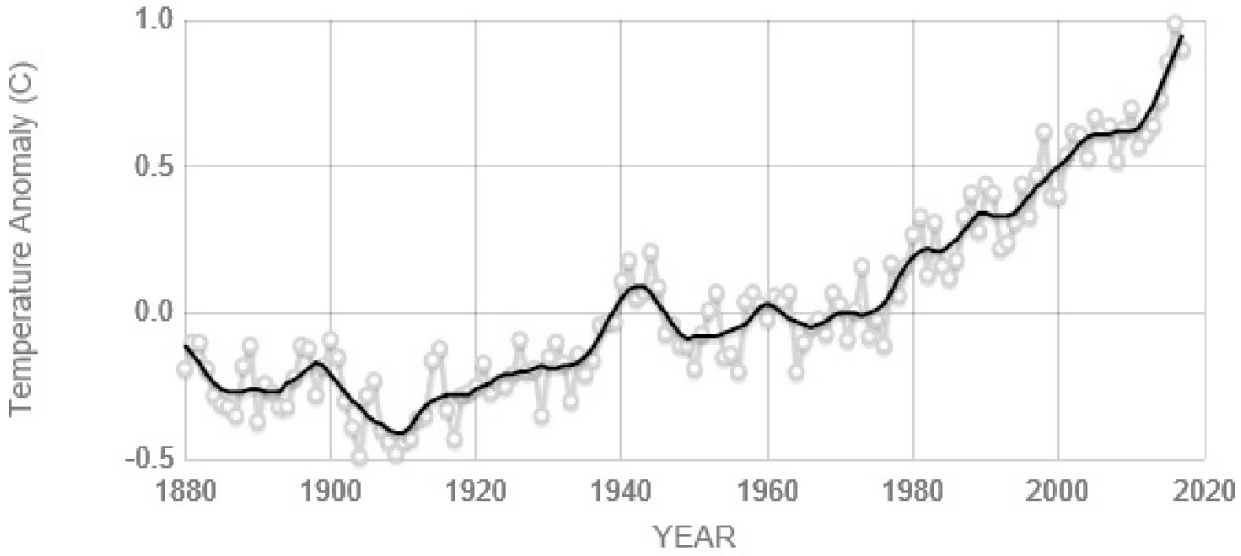
Maintenance Provider (% of asset area)
PB: 46%
GSV: 54%



4.0 CLIMATE CHANGE

4.1 GENERAL CLIMATE CHANGE TRENDS

Human influences on the planet and anthropogenic emissions of greenhouse gases are the highest in history and have led to warming of the climate systems (graph 1 below illustrates increasing temperatures over time) and the rise of sea level (IPCC, 2014). This has resulted in widespread impacts on human and natural systems such as the shift of terrestrial, freshwater and marine species from their geographic range, abundances and migration patterns in response to climate change (IPCC, 2014).



Graph 1- Global surface temperature change- land and ocean, compared to 1951-1980 average (NASA)

Climate change has a significant impact on the vulnerability of urban forests due to increases in stresses as a result of factors such as changing moisture and soil availability, temperature change, extreme weather events and sea level rise.

Plant hardiness zone maps are based on annual extreme minimum temperatures that influence plant survival and growth. The Canadian plant hardiness zone maps show significant shifts from the 1981-2010 period from the 1931-1960 period, whereby there were vegetation shifts northwards, especially in western Canada (See Figure 2).

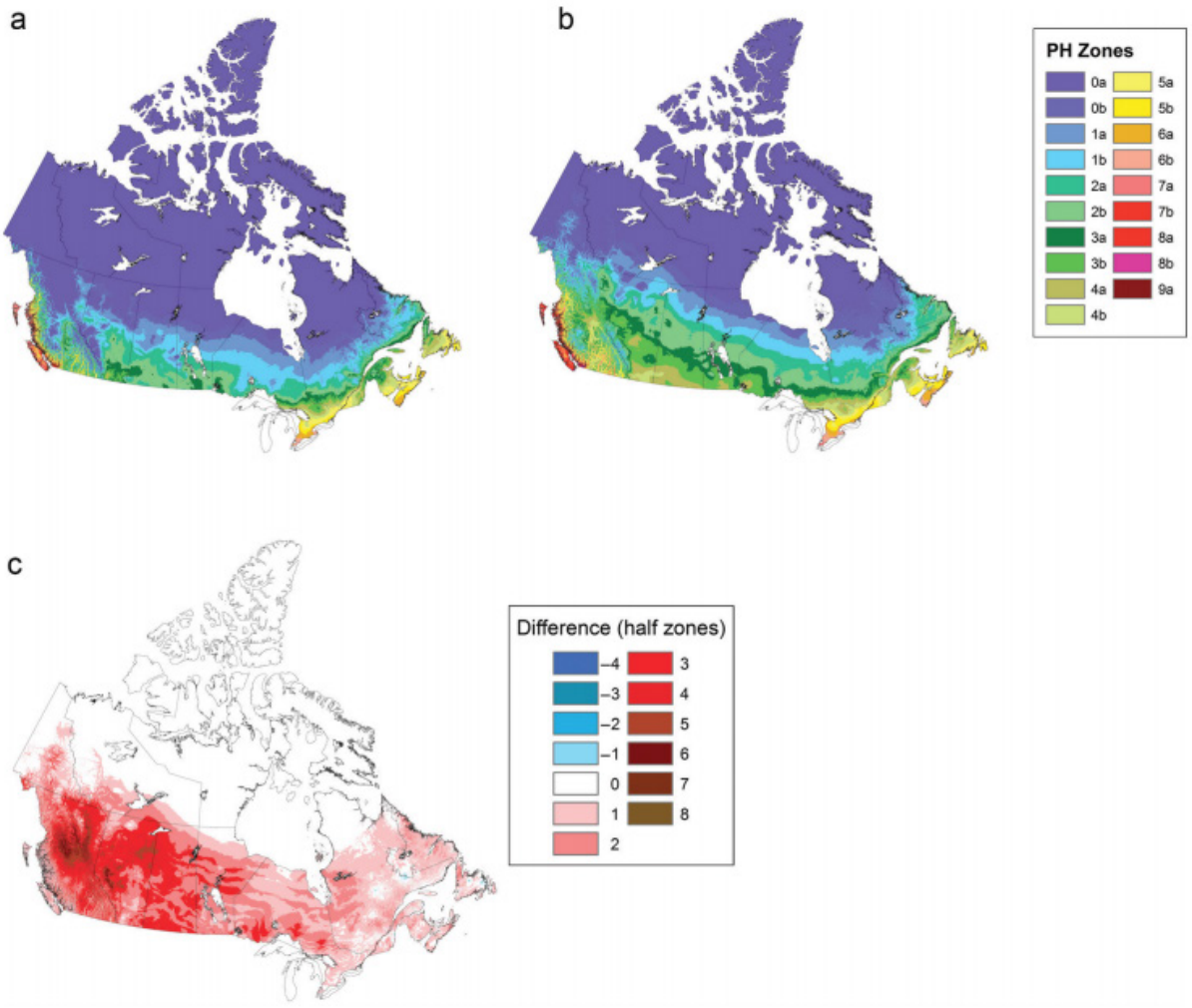
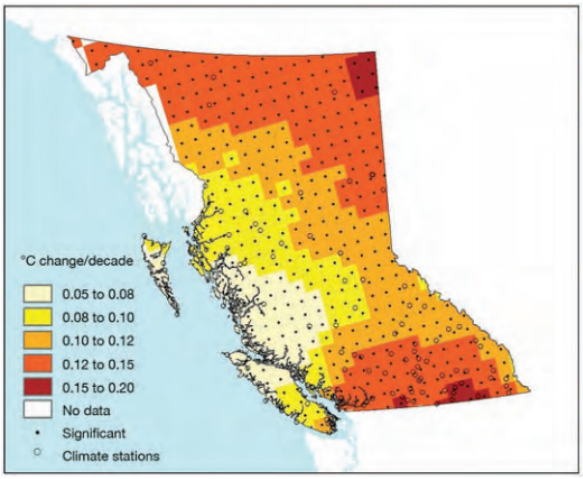
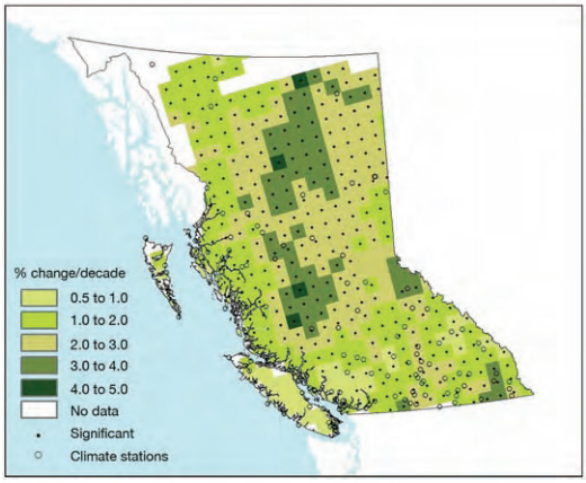


Figure 2- Canadian plant hardiness (PH) zone maps for (a) 1931-1960, (b) 1981-2010, and (c) the difference between the two maps (McKenney, et al. 2014)

On average, all climate variables changed in the direction of increasing the plant hardiness zone. Vancouver experienced a shift from 7a to 8b (McKenney, Daniel W. et al, 2014). British Columbia has been experiencing an increase in temperature and total precipitation since the 1900s as seen in Map 2 and 3, respectively.



Map 2- Trend in annual mean temperature in BC, 1900- 2004 (Lemmen et al. 2008)



Map 3- Trend in annual total precipitation for BC, 1900- 2004 (Lemmen et al. 2008)

Research findings from McKenney et al (2014) "suggest that the Canadian land base has generally become hospitable to a wider range of perennial plant species over the past 50 years"(p 345), especially in Western Canada. In British Columbia, decreased summer precipitation and soil moisture deficit could mean that more irrigation will be required for horticulture. "Most plant species cannot naturally shift their geographical ranges sufficiently fast to keep up with current and high projected rates of climate change in most landscapes" (IPCC, 13). British Columbia is expecting large shifts in species to occur which will result in vegetation communities that may not resemble current communities. Hamann and Wang (2006) conducted a study simulating future ecological zones and tree species distributions for British Columbia (see figure 3). This was done through a bio-climate envelope study, which uses climate data as independent variables and biological data as dependent variables to generate a predictive model for species. These studies generally show that temperate tree species will expand their range northward and lose suitability from their original distribution in the face of climate change (Hamann and Wang 2006). While climate change is not the only determining factor in the shift in climate vegetation, it plays a major role, in addition to soil, topography, groundwater level and other factors. In addition, different plant species have various levels of adaptation to climate change as well as different capacities of migration to different habitats (Lemmen et al, 2007).

The maps below show changes in biogeoclimatic ecological distribution in BC for the periods of 211-2040 (2025), 2041-2070 (2055) and 2071-2100 (2085). The observed elevation and north shifts are measured as averages of ecological zones in BC, relative to averages modeled under 1961-1990 climate.

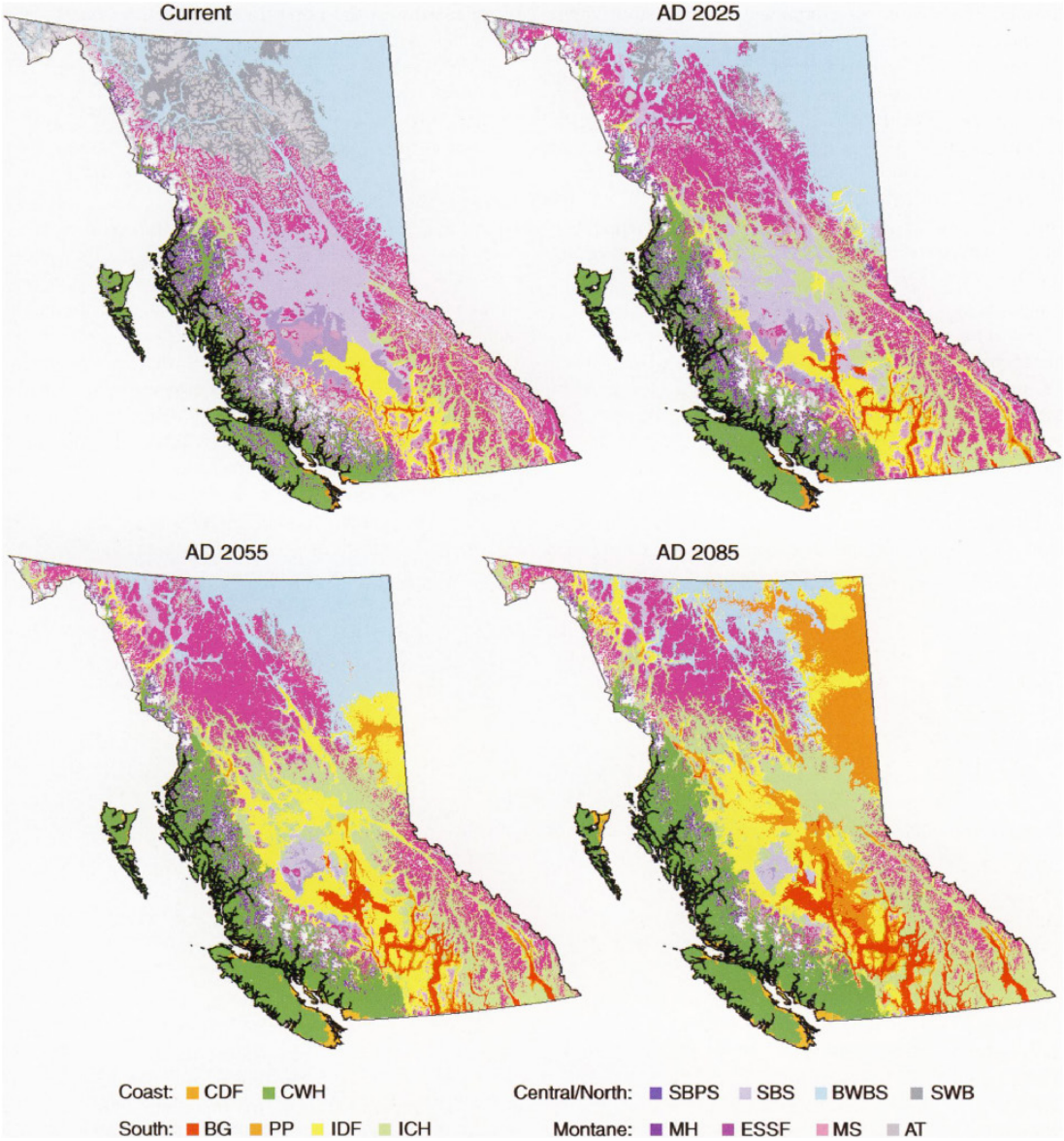


Figure 3- Shift of the climatic envelope of ecological zones based on the ensemble simulation CGCM Igax for the normal periods 2011-2040 (2025), 2041-2070 (2055), and 2071-2100 (2085) (Hamman and Wang, 2016)

The ecological zones are: CDF, Coastal Douglas-fir; CWH, Coastal Western Hemlock; BG, Bunchgrass; PP, Ponderosa Pine; IDF, Interior Douglas-fir; ICH, Interior Cedar-Hemlock; SBPS, Sub boreal Pine and Spruce; SBS, Sub-boreal Spruce; BWBS, Boreal White and Back Spruce; MH, Mountain Hemlock; ESSF, Engelmann Spruce-Subapline Fir; MS, Montane Spruce; SWB, Spruce-Willow-Birch; AT, Alpine

In general, the majority of climatic envelops will be shifting north, including the Coastal Western Hemlock where Vancouver is situated. The Coastal Western Hemlock region will experience a 27% area change in 2015, 40% area change in 2055 and 50% area change in 2085. Nonetheless, the response to climate change will not be uniform for the plant communities within the region. While this study focuses on changes in forest ecosystems and tree species distribution, it provides useful information in understanding the biological changes of plant communities in relation to climate change. Information on emerging conditions and plant communities in the region can be used in plant selection for street horticulture planting.

4.2 VANCOUVER: CLIMATE PROJECTIONS

The Report on Climate projections for Metro Vancouver (Metro Vancouver) highlights the following anticipated changes in climate by 2050:

- ***Increase in intensity and frequency of heavy rain events***
    - 5% increase of total annual precipitation
    - 11 % increase of fall precipitation
    - 19% decrease of summer precipitation

- ***Sea Level Rise***
    - Increase in shoreline erosion affecting natural environments and public amenities such as parks, trails and access to the water.
    - The Province of B.C recommends using 0.5m global mean sea level increase to 2050

- ***Increased frequency and intensity of storms and weather extremes***
    - A daily rainfall event that occurred once every 35 years in the past is expected to occur almost 2.5 times as frequently.
    - A daily rainfall event that occurred once every 25 years in the past is expected to occur almost 3 times as frequently.

- ***Hotter, drier summers with more heat waves***
    - Annual average increase of 1.7°C by the 2050s
    - Summer days above 24°C are projected to occur more than twice as frequently in the 2050s

Climate Variable	Season	Projected Change from 1961- 1990 Baseline	
		Ensemble Median	Range (10th to 90th percentile)
Mean temperature (˚C)	Annual	+1.6 ˚C	+1.0 ˚C to +2.4 ˚C
Precipitation (%)	Annual	+5%	+0% to +11%
	Summer	-10%	-19% to +1%
	Winter	+6%	-4% to +14%
Snowfall (%)	Winter	-22%	-38% to -7%
	Spring	-51%	-72% to -13%

Table 1- Summary of climate change for Vancouver Coast in the 2050s (Pacific Climate Impact Consortium, 2012)

The table above shows projected changes in average (mean) temperature, precipitation from the baseline historical period (1961- 1990) to the 2050s for the Vancouver Coast region (Pacific Climate Impact Consortium, 2012).

EFFECTS OF CLIMATE CHANGE ON STREETSCAPES: VANCOUVER

As the climate shifts and temperature and precipitation patterns change, our local ecosystems will change. Certain plant species may migrate to find more suitable temperature and precipitation conditions and invasive species may start to out-compete native species as they may thrive in these changing conditions. Existing trees and shrubs may be lost due to climatic stresses. The Resilient Streetscapes project looks to adapt to the forecasted changes by suggesting improvements to street horticulture assets and practices that can mitigate the effects of climate change. Some street planting and adaptation benefit opportunities include:

- Stormwater management
- Air pollution reduction
- Wind buffering
- Slope and soil stabilization
- Shade and cooling
- Carbon sequestration
- Urban Heat Island effect mitigation

HORTICULTURE ADAPTATION TO CLIMATE CHANGE

One of the greatest risks to street horticulture assets from climate change is the potential long-term change in soil moisture availability. This will compromise plants' growth, regeneration rates and establishment success. The projected seasonal moisture deficits, extended droughts and heat waves as a result of climate change will impact plants survival as the optimal climate niches for some plants will change and fail to be suitable to sustain them. This will compromise the ecosystem services rendered by these plants. Climate variability and shifts will alter our urban environment in significant ways, resulting in modified vegetation phenology. In the long run, novel ecologies and species are likely to arise as a result of climate change, while some might disappear. Historically, there has been a change in the plant hardiness zone in Vancouver (Table 2), due to a changing climate. Further shifts in the climate affecting vegetation can be expected.

	Plant Hardiness zone	Hardiness index
1961- 1990	8a	82
1981-2010	8b	88

Table 2- Index change in plant hardiness zones for Vancouver, BC (Natural Resources Canada)

5.0 RECOMMENDATIONS FOR VANCOUVER

The following steps are recommended to ensure the survival and resiliency of street horticultural assets in the anticipation of the potential effects of climate change.

- **Inventory** of all existing horticultural assets and their existing condition (health and lifespan)

- **Vulnerability assessment** to identify priority areas to address: rate existing assets to assess suitability to the changing climate. This could be completed by inspecting the microclimate of plants (such as soil and moisture availability, sun exposure); plants' health and degree of acclimatization to climate change; and maintenance cost of assets.

- **Adaptation strategy**: Identify adaptation strategies based on risk of horticultural assets. Develop schedule for tactical and strategic adaptation strategies:
    - **Tactical adaptation**: adjusting day by day maintenance of plants such as pruning, watering and weeding.
    - **Strategic adaptation**: Installation of new horticultural assets more suitable to climate change. Suggested use of plant material that will prosper in the expected new climate. This includes looking at urban areas south of B.C. as Vancouver's weather will resemble these areas by 2050s.

- **Consider reducing turf assets by replacing them with more plantings to enhance biodiversity**

  Currently, turf assets make up 70% of the total surface area of all street horticulture assets. Turf areas require more resources to maintain and sustain during their growing season, such as the frequency of mowing. In addition, turf eliminates potential biodiversity that can be enhanced by other planting.

- **Introduce more xeriscaping designs**

  Xeriscaping landscape designs require little to no additional water beyond the natural precipitation of their specific location. Xeriscaping designs focus on planting drought-tolerant plants that are well adapted to the local climate and on decreasing the need for water through methods such as efficient irrigation, proper weeding, mowing, pruning and fertilization (Tyman, 2011). This is more ecologically and financially sustainable as it emphasized the use of plant material suited to local soil and climate conditions.

- **Adopt the following planting design guidelines:**
    - Plant material should be chosen for their tolerance to drought and urban conditions, and their ability to enhance streets' aesthetic quality, habitat value and the overall biodiversity of the city
    - Choose both deciduous and evergreen plants to maintain foliage and interest all year long.
    - Select drought-tolerant plants to create a waterwise streetscape
    - Plant shorter plants on the edges and taller plants in the middle of gardens
    - Consider leaving sufficient setback space from the road for maintenance and safety purposes, reduced salt damage from the road and containment of plant material and soil.
    - Maintain a similar planting aesthetic with surrounding vegetation and landscape for character continuity for an integrated streetscape design
    - All planting must abide by transportation sight lines requirements, sidewalk width, automobile and pedestrian traffic and other adjacent road conditions.

- **Follow standard planting installation guidelines that encourage healthy root growth and plant establishment.** Preparing an area for planting is critical to the long term success of plants. Appropriate growing medium properties and depth will allow plants to thrive and reduce the amount of maintenance needed. Below are examples of grass and shrub planting guidelines.

    - **Grass Areas:** Remove existing road base/base material to 300mm below finished elevation and scarify existing sub-base using a toothed bucket 100mm below excavated grade. Supply and install 100mm of growing medium and mix well into scarified sub-base. Add remaining 200mm on top. Compact growing medium lightly with a roller. Install additional growing medium to ensure finished level is flush with adjacent paving/curbing. Broadcast seed or hydroseed grass according to standard details and specifications.

    - **Shrub Planting Areas:** Remove existing road base/base material to 450mm below finished elevation and scarify existing sub-base using a toothed bucket 100mm below excavated grade. Supply and install 100mm of growing medium and mix well into scarified sub-base. Add remaining 350mm on top. Compact growing medium lightly with a roller. Install additional growing medium to ensure finished level is flush with adjacent paving/curbing. Install shrubs and groundcover according to standard details and specifications

      Refer to the Vancouver Board of Parks and Recreation Development Standards.

RECOMMENDED PLANTS LIST

This project presents a recommended plants list for street horticulture that would perform well in an anticipated climate of warmer temperatures, longer summer dry spells, wetter fall and winter conditions and more frequent extreme precipitation events.

The recommended plants list (see Appendix A) has been chosen based on the following criteria:

- Resilient species based on projected climate trends
- Low maintenance
- Drought resistant plants or requiring minimum watering after establishment
- Weed suppressing plants
- Ability to withstand wear and tear from pedestrian and vehicular traffic
- Ability to withstand salt, sand, grit, gravel (from adjacent road)
- Low growing plants that follow traffic safety sight line requirements

6.0 CONCLUSION

The Resilient Streetscapes project aims to support the Greenest City Action Plan 2020 goals of increasing access to nature and green transportation by enhancing the resiliency of street planting in the face of climate change in the next thirty years. Climate change projections indicate that Vancouver can expect warmer temperatures, longer summer dry spells, wetter fall and winter conditions and more extreme precipitation events. These changes in climate will lead to changes in vegetation. In an effort to ensure that street planting can be more resilient to these climate change in the next thirty years, a study on the effects on vegetation informed the suggested plant material to be used on streetscapes. The recommended plants will play a key role in ensuring the continued viability, beauty and ecological services provided by streetscapes in Vancouver.

Looking ahead, this project could be enhanced by the following :

- Conduct benchmarking research: connect with other municipalities about their respective horticulture street design and maintenance practice and plans for adaptation to climate change to inform a baseline of best practices.
- Develop a community toolkit for street gardens planting design and maintenance guidelines.
- Provide detailed planting design guidelines for each type of street garden.
- Investigate turf alternatives such as ground covers, micro clover, sedum mats, wild flower mixes and/ or no mow plantings.

Appendix A - Recommended Plants List

SCIENTIFIC NAME	COMMON NAME	TYPE	POLLINATOR	HEIGHT (m)	SPREAD (m)	BLOOM TIME	BLOOM COLOR	WATER REQUIREMENTS	SUN REQUIREMENTS	FOLIAGE TYPE
Acanthus spinosus	Bear's breeches	Perrenial	Yes	0.5	0.6	Late spring	White and Pink	Drought tolerant	Full sun	Deciduous
Achillea ‘Moonshine’	Yarrow	Perrenial	Yes	0.6	0.5	Summer	Yellow	Low	Part sun	Deciduous
Agastache ‘Blackadder’	Giant hyssop	Perrenial	Yes	0.9	0.6	Summer	purple	Low	Full sun	Deciduous
Agastache ‘Blue Fortune’	Hybrid hyssop	Perrenial	Yes	0.6	0.5	Summer	Lavender	Low	Part sun	Deciduous
Agastache cana	Hummingbird's mint	Perrenial	Yes	0.6	0.6	Summer	Pink	Low	Full sun	Deciduous
Allium cristophii	Star of Persia	Bulb	Yes	0.6	0.5	spring	purple	Drought tolerant	Full sun	Deciduous
Allium karataviense	Turkestan Onion	Bulb	Yes	0.2	0.2	Winter, spring	pink	Drought tolerant	Full sun	Deciduous
Allium karataviense ‘Ivory Queen’	White turkestan onion	Bulb	Yes	0.2	0.2	Winter, spring	white	Drought tolerant	Full sun	Deciduous
Allium senescens	German onion	Bulb	Yes	0.3	0.6	Summer	pink	Drought tolerant	Full sun	Deciduous
Allium senescens ssp. Glaucum	German onion	Bulb	Yes	0.3	0.3	Summer	pink	Drought tolerant	Full sun	Deciduous
Allium ‘Globemaster’	Ornamental onion	Bulb	Yes	0.9	0.8	Summer	purple	Drought tolerant	Full sun	Deciduous
Allium ‘Summer Beauty’	Summer beauty ornamental onion	Bulb	Yes	0.5	0.3	Summer	purple	Drought tolerant	Full sun	Deciduous
Anemone blanda	Wildflower	Bulb	Yes	0.2	0.3	Summer	Lavender	Drought tolerant	Full sun	Deciduous
Anemone nemorosa	Wood anemone	Perrenial	Yes	0.2	0.9	summer	pink, white, lavender	Drought tolerant	Full sun	Deciduous
Aquilegia caerulea 'Dragonfly'	Columbine	Perrenial	Yes	0.6	0.6	Spring	Blue & white	Medium	Part sun	Deciduous
Arabis procurrens	Rock cress	Perrenial	Yes	0.08	0.3	spring	white	Drought tolerant	Full sun	Evergreen
Armeria maritima	Sea thrift	Perrenial	Yes	0.5	0.5	spring	pink to white	Drought tolerant	Full sun	Evergreen
Artemisia ‘Sea Foam’	Curlicue sage	Perrenial	No	0.5	0.6	Summer	Yellow (insignificant)	Drought tolerant	Full sun	Evergreen
Artemesia arborescens 'Powis Castle'	Wormwood	Perrenial	No	0.6	1	Summer	Yellow (insignificant)	Drought tolerant	Full sun	Evergreen
Artemesia stelleriana 'Boughton Silver'	Hoary mugwort 'Boughton Silver'	Perrenial	No	0.5	0.5	Summer	Yellow (insignificant)	Drought tolerant	Full sun	Evergreen
Aster divaricatus	White wood aster	Perrenial	Yes	0.5	0.9	Summer	white	Low	Shade	Deciduous
Aster × frikartii ‘Jungfrau’	Frikart's aster	Perrenial	Yes	0.9	0.9	Summer, fall	purple	Medium	Full sun	Deciduous
Aster × frikartii ‘Mönch’	Frikart's aster	Perrenial	Yes	0.9	0.5	Summer, fall	Lavender	Medium	Full sun	Deciduous
Aster × frikartii ‘Wunder von Stäfa’	Frikart's aster	Perrenial	Yes	0.9	0.5	Summer, fall	Lavender	Medium	Full sun	Deciduous
Aster lateriflorus ‘Prince’	Calico aster	Perrenial	Yes	0.9	0.9	Spring, summer	pink, white	Medium	Full sun	Deciduous
Astrantia major	Great Masterwort	Perrenial	Yes	0.9	0.6	Spring, summer	green, white	Medium	Full sun	Deciduous
Astrantia major ‘Claret’	Astrantia	Perrenial	Yes	0.5	0.5	Spring, summer	red	Medium	Full sun	Deciduous
Baptisia ‘Purple Smoke’	Wild indigo	Perrenial	Yes	0.9	0.6	spring	purple	Drought tolerant	Full sun	Deciduous
Berberis buxifolia ‘Nana’	Dwarf boxleaf barberry	Shrub	Yes	0.6	0.6	Autumn	Yellow	Drought tolerant	Full sun	Evergreen
Berberis thunbergii f. atropurpurea ‘Bagatelle’	Dwarf purpleleaf japanese barberry	Shrub	Yes	0.3	0.5	Autumn	Yellow	Drought tolerant	Full sun	Deciduous
Berberis thunbergii f. atropurpurea ‘Concorde’	Dwarf purpleleaf japanese barberry	Shrub	Yes	0.6	0.8	Spring to fall	Yellow	Medium	Full sun	Deciduous
Berberis thunbergii ‘Goruzam’ GOLDEN RUBY®	Dwarf golden-edged japanese barberry	Shrub	Yes	0.3		Spring to fall	Yellow	Medium	Full sun	Deciduous
Bergenia cordifolia	Pigsqueak	Perrenial	Yes	0.4	0.6	Spring	Pink	Medium	Part sun	Evergreen
Buxus microphylla japonica 'Winter Gem'	Winter Gem boxwood	Shrub	No	0.9	0.9	N/A	N/A	Medium	Full sun	Evergreen
Buxus sinica var. insularis 'Winter Gem'	Korean boxwood	Shrub	No	0.9	0.9	N/A	N/A	Medium	Full sun	Evergreen

Appendix A - Recommended Plants List

SCIENTIFIC NAME	COMMON NAME	TYPE	POLLINATOR	HEIGHT (m)	SPREAD (m)	BLOOM TIME	BLOOM COLOR	WATER REQUIREMENTS	SUN REQUIREMENTS	FOLIAGE TYPE
Camassia cusickii	Cusick's quamash	Bulb	Yes	0.6	0.6	Spring, summer	Lavender	Low	Full to part shade	Deciduous
Camassia quamash	quamash camas	Bulb	Yes	0.6	0.5	Spring, summer	purple	Low	Full to part shade	Deciduous
Campanula rotundifolia	Harebell	Perrenial	Yes	0.3	0.2	Spring	Lavender	Drought tolerant	Full sun	Deciduous
Carex buchananii	Leatherleaf Sedge	Grass	No	0.6	0.6	N/A	N/A	Medium	Full to part shade	Deciduous
Carex flacca	Blue Sedge	Grass	No	0.3	0.45	N/A	N/A	Medium	Full to part shade	Deciduous
Carex morrowii 'Aurea variegata'	Japanese Sedge	Grass	No	0.45	0.6	N/A	N/A	Medium	Full to part shade	Deciduous
Carex morrowii 'Ice Dance'	Japanese Sedge	Grass	No	0.3	0.45	N/A	N/A	Medium	Full to part shade	Deciduous
Centranthus ruber	Red valerian	Perrenial	Yes	1	0.5	Spring to fall	Crimson, pink, white	Medium	Full sun	Deciduous
Ceratostigma willmottianum	Chinese plumbago	Shrub	Yes	1	1.5	Summer	Blue	Medium	Full sun	Deciduous
Cistus x corbariensis	Rock Rose	Shrub	Yes	0.9	1.2	late spring	white	Drought tolerant	Full sun	Evergreen
Cistus 'Silver Pink'	Silver Pink Rock Rose	Shrub	Yes	0.9	0.9	late spring	pink	Drought tolerant	Full sun	Evergreen
Colchicum autumnale	Autumn crocus	Bulb	Yes	0.3	0.2	Autumn	Lavender	Drought tolerant	Full sun	Deciduous
Colchicum autumnale ‘Alboplenum’	White double-flowered autumn crocus	Bulb	Yes	0.2	0.06	Autumn	white	Drought tolerant	Full sun	Deciduous
Colchicum autumnale ‘Album’	White double-flowered autumn crocus	Bulb	Yes	0.2	0.06	Autumn	white	Drought tolerant	Full sun	Deciduous
Colchicum ‘The Giant’	Autumn crocus	Bulb	Yes	0.3	0.1	Autumn	Rose	Drought tolerant	Full sun	Deciduous
Colchicum ‘Waterlily’	Double-flowered autumn crocus	Bulb	Yes	0.2	0.2	Autumn	Pink	Drought tolerant	Full sun	Deciduous
Coreopsis rosea 'American Dream'	American Dream Tickseed	Perrenial	Yes	0.5	0.5	Summer	Rose	Medium	Full sun	Deciduous
Coreopsis verticillata 'Moonbeam'	Threadleaf coreopsis	Perrenial	Yes	0.5	0.5	Summer	Creamy yellow	Drought tolerant	Full sun	Deciduous
Cotoneaster dammeri	Bearberry Cotoneaster	groundcover	Yes	0.3	1.8	Spring	White	Drought tolerant	Full sun	Evergreen
Cotoneaster glaucophyllus	Gray-leaf Cotoneaster	Shrub	Yes	0.9	1.8	Spring	White	Drought tolerant	Full sun	Evergreen
Cotoneaster procumbens ‘Queen of Carpets’	Ground-hugging Cotoneaster	groundcover	Yes	0.2	1.8	Spring	White	Drought tolerant	Full sun	Evergreen
Crambe maritima	Sea kale	Perrenial	Yes	0.9	0.6	Summer	white	Drought tolerant	Full sun	Deciduous
Crocus tommasinianus	Tommasini's crocus	Bulb	Yes	0.1	0.03	Late winter	lavender, purple	Drought tolerant	Full sun	Deciduous
Crocus tommasinianus ‘Barr's Purple’	Tommasini's crocus	Bulb	Yes	0.1	0.1	Late winter	purple	Drought tolerant	Full sun	Deciduous
Crocus ‘Blue Pearl’	Snow crocus	Bulb	Yes	0.1	0.2	Late winter	lavender	Drought tolerant	Full sun	Deciduous
Crocus ‘Flower Record’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Late winter	purple	Drought tolerant	Full sun	Deciduous
Crocus ‘Jeanne d'arc’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Spring	white	Drought tolerant	Full sun	Deciduous
Crocus ‘King of the Striped’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Late winter	lavender	Drought tolerant	Full sun	Deciduous
Crocus ‘Pickwick’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Late winter	lavender	Drought tolerant	Full sun	Deciduous
Crocus ‘Spring Beauty’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Late winter	purple	Drought tolerant	Full sun	Deciduous
Crocus ‘Yellow Mammoth’	Large-flowering crocus	Bulb	Yes	0.1	0.2	Late winter	yellow	Drought tolerant	Full sun	Deciduous
Digitalis grandiflora	Large yellow foxglove	Perennial	Yes	0.8	0.5	Summer	yellow	Drought tolerant	Full sun	Evergreen
Dracocephalum grandiflorum	Dragon's head	Perennial	Yes	0.3	0.3	Summer	Blue	Drought tolerant	Full sun	Deciduous

Appendix A - Recommended Plants List

SCIENTIFIC NAME	COMMON NAME	TYPE	POLLINATOR	HEIGHT (m)	SPREAD (m)	BLOOM TIME	BLOOM COLOR	WATER REQUIREMENTS	SUN REQUIREMENTS	FOLIAGE TYPE
Echinacea purpurea 'Kim's Knee High'	Dwarf Purple Coneflower	perennial	Yes	0.6	0.6	Summer	Pink	Drought tolerant	Full sun	Deciduous
Echinops ritro	Globe flower	perennial	Yes	1	0.5	Summer	blue	Drought tolerant	Full sun	Deciduous
Epimedium × rubrum	Bishop's hat	perennial	Yes	0.3	0.4	spring	yellow	Low	Full to part shade	Deciduous
Erica x darleyensis 'Kramer's Rote'	Darley heath	groundcover	Yes	0.4	0.6	Winter	violet pink	Medium	Full sun	Evergreen
Erysimum 'Bowles Mauve'	Wallflower	perennial	yes	1	1	Spring	Purple	Drought tolerant	Full sun	Deciduous
Eryngium planum 'Sapphire Blue'	Sea Holly	perennial	yes	0.7	0.6	Summer	blue	Low	Full sun	Deciduous
Erodium chrysanthum	Heronsbill	perennial	Yes	0.2	0.4	Spring to autumun	Cream	Drought tolerant	Full sun	Evergreen
Eryngium agavifolium	Agave-leaf sea holly	perennial	Yes	0.6	1.2	Summer	White	Drought tolerant	Full sun	Evergreen
Eryngium alpinum	Alpine sea holly	perennial	Yes	0.7	0.4	Summer	blue	Drought tolerant	Full sun	Evergreen
Eryngium amethystinum	Blue sea holly	perennial	Yes	0.7	0.7	Summer	lavender	Drought tolerant	Full sun	Evergreen
Euphorbia x martinii	Martin's Spurge	perennial	Yes	0.6	0.6	Spring, summer	yellow	Drought tolerant	Full sun	Evergreen
Euphorbia characias ssp. characias 'Humpty Dumpty'	Dwarf mediterranean spurge	perennial	Yes	0.6	0.6	Spring	green	Drought tolerant	Full sun	Evergreen
Euphorbia myrsinites	Donkey-Tail Spurge	perennial	Yes	1	0.6	Winter	Yellow green	Drought tolerant	Full sun	Evergreen
Euonymus fortunei 'Emerald 'n' Gold'	Spindle 'Emerald 'n' Gold'	groundcover	Yes	1	1.5	N/A	Not significant	Medium	Full sun	Evergreen
Genista pilosa 'Vancouver Gold'	Creeping broom	groundcover	No	0.2	0.8	Late spring	yellow	Drought tolerant	Full sun	Evergreen
Geranium macrorrhizum	Hardy geranium	perennial	Yes	0.3	0.4	Late spring	pink	Low	Full sun	Evergreen
Geranium 'Philippe Vapelle'	Cranesbill	perennial	Yes	0.3	0.4	Late spring	Lavender	Low	Full sun	Deciduous
Helenium 'Moerheim Beauty'	Sneezeweed	perennial	yes	0.9	0.6	Summer to autumn	red	Drought tolerant	Full sun	Deciduous
Helictotrichon sempervirens	Blue oat grass	grass	No	0.6	0.6	autumn	brown	Drought tolerant	Full sun	Evergreen
Helleborus argutifolius	Corsican hellebore	perennial	No	0.9	1.5	Late winter	cream	Drought tolerant	Full sun	Evergreen
Helleborus foetidus	Stinking hellebore	perennial	No	0.5	0.8	Winter to spring	green	Drought tolerant	Full sun	Evergreen
Helleborus × sternii	hybrid hellebore	perennial	No	0.8	0.6	Winter to spring	green, mauve	Drought tolerant	Full sun	Evergreen
Hemerocallis stella d'oro	Daylily	perennial	Yes	0.3	0.6	Summer to autumn	Yellow	Drought tolerant	Full sun	Evergreen
Heuchera micrantha 'Palace Purple'	Palace Purple Coral Bells	perennial	Yes	0.6	0.4	Summer	pink, white	Medium	Full sun	Evergreen
Ilex crenata 'Dwarf Pagoda'	Dwarf japanese holly	shrub	No	0.6	0	N/A	N/A	Drought tolerant	Full sun	Evergreen
Ilex crenata 'Green Thumb'	Green thumb holly	shrub	Yes	1	0.6	Spring	white, yellow	Drought tolerant	Part sun	Evergreen
Leucanthemum x superbum	Shasta daisy	perennial	Yes	1	0.9	summer	white	Drought tolerant	Full sun	Deciduous
Liatris spicata 'Kobold'	Blazing Star	perennial	Yes	0.5	0.5	Summer to autumn	purple	Medium	Full sun	Deciduous
Liriope muscari	big blue lilyturf	grass	Yes	0.5	0.4	Summer	Lavender	Drought tolerant	Full to part shade	Evergreen
Lonicera pileata	Box-lead honeysuckle	shrub	No	0.6	2.4	Spring	Creamy wihte	Low	Full to part shade	Evergreen
Mahonia aquifolium 'Compacta'	Compact oregon grape holly	shrub	No	0.8	1	Spring	yellow	Medium	Full sun	Evergreen
Mahonia nervosa	Cascade oregon grape	shrub	No	0.6	1.2	Spring	yellow	Drought tolerant	Full sun	Evergreen
Muscari latifolium	Grape hyacinth	bulb	No	0.3	0.2	Spring	blue	Drought tolerant	Full sun	Deciduous
Narcissus poeticus var. recurvus	Pheasant's eye daffodil	bulb	No	0.5	0.2	Late spring	white	Drought tolerant	Full sun	Deciduous
Narcissus 'February Gold'	Miniature daffodil	bulb	No	0.3	0.3	Late winter	yellow	Drought tolerant	Full sun	Deciduous
Narcissus 'Jack Snipe'	Miniature daffodil	bulb	No	0.3	0.1	Late winter	white	Drought tolerant	Full sun	Deciduous
Narcissus 'Mount Hood'	White trumpet daffodil	bulb	No	0.5	0.2	Late winter	white	Drought tolerant	Full sun	Deciduous
Narcissus 'Saint Keverne'	Golden trumpet daffodil	bulb	No	0.5	0.2	Spring	yellow	Drought tolerant	Full sun	Deciduous
Narcissus 'Thalia'	White orchid daffodil	bulb	No	0.3	0.1	Spring	white	Drought tolerant	Full sun	Deciduous
Narcissus 'Tête-à-tête'	Miniature daffodil	bulb	No	0.3	0.3	Late winter	yellow	Drought tolerant	Full sun	Deciduous
Nepeta racemosa'Walker's Low'	Walker's Low Catmint	perennial	Yes	0.8	0.8	Summer	Violet-blue	Low	Full sun	Deciduous

Appendix A - Recommended Plants List

SCIENTIFIC NAME	COMMON NAME	TYPE	POLLINATOR	HEIGHT (m)	SPREAD (m)	BLOOM TIME	BLOOM COLOR	WATER REQUIREMENTS	SUN REQUIREMENTS	FOLIAGE TYPE
Pachysandra terminalis	Japanese spurge	groundcover	No	0.2	0.8	N/A	N/A	Drought tolerant	Full to part shade	Evergreen
Penstemon 'Purple Haze'	Purple Haze Beardtongue	perennial	Yes	0.8	0.5	Spring	Lavender, purple	Drought tolerant	Part sun	Evergreen
Perovskia atriplicifolia ‘Little Spire’	Compact russian sage	perennial	No	0.6	0.6	Summer	violet blue	Drought tolerant	Full sun	Deciduous
Polystichum munitum	Sword fern	fern	No	0.9	0.9	N/A	N/A	Drought tolerant	Full to part shade	Evergreen
Rhodiola pachyclados	Afghani sedum	perennial	No	0.2	0.3	Summer, fall	White	Drought tolerant	Full sun	Deciduous
Rosmarinus officinalis ‘Salem’	Rosemary	shrub	No	0.9	0.9	N/A	N/A	Drought tolerant	Full sun	Evergreen
Rosa 'Meineble' Red Meidiland	Shrub rose	shrub	Yes	0.9	1.5	Spring to fall	red	Medium	Full sun	Deciduous
Rosa meidiland 'White'	Shrub rose	shrub	Yes	0.9	1.5	Spring to fall	red	Medium	Full sun	Deciduous
Rudbeckia fulgida 'Goldsturm'	Orange coneflower	perennial	Yes	0.7	0.6	Winter	Yellow	Drought tolerant	Full sun	Deciduous
Santolina chamaecyparissus	Lavender cotton	shrub	No	0.5	1	Summer	yellow	Drought tolerant	Full sun	Evergreen
Sarcococca hookeriana var. humilis	Sweet box	shrub	Yes	0.8	1	spring	white	Medium	Full to part shade	Evergreen
Sedum cauticola ‘Lidakense’	Stonecrop	perennial	No	0.2	0.3	Summer to fall	pink	Drought tolerant	Full sun	Deciduous
Sedum cyaneum	Blue stonecrop	perennial	No	0.2	0.3	Summer to fall	purple	Drought tolerant	Full sun	Deciduous
Sedum ewersii	Sedum stonecrop	perennial	No	0.1	0.3	Summer to fall	pink	Drought tolerant	Full sun	Deciduous
Sedum kamtschaticum	Kamtschaticum stonecrop	perennial	No	0.2	0.3	Summer to fall	yellow	Drought tolerant	Full sun	Deciduous
Sedum kamtschaticum var. ellacombeanum	Japanese stonecrop	perennial	No	0.2	0.2	Summer to fall	yellow	Drought tolerant	Full sun	Deciduous
Sedum kamtschaticum ‘Variegatum’	Variegated kamtschaticum stonecrop	perennial	No	0.2	0.3	Summer to fall	yellow	Drought tolerant	Full sun	Deciduous
Sedum kamtschaticum ‘Weinstephaner Gold’	Kamtschaticum stonecrop	perennial	No	0.2	0.3	Summer to fall	yellow	Drought tolerant	Full sun	Deciduous
Sedum selskianum	Amur sedum	perennial	No	0.2	0.3	Summer to fall	yellow	Drought tolerant	Full sun	Deciduous
Sedum sieboldii	October daphne sedum	perennial	No	0.2	0.3	Summer	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Doctor John Creech’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Fuldaglut’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	red	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Green Mantle’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	yellow	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Pearly Pink’	Two-row stonecrop	perennial	No	0.2	0.3	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Pink Jewel’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Purpurteppich’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	purple	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Raspberry Red’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	red	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Ruby Mantle’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	red	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Salmoneum’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Schorbuser Blut’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘Tricolor’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	pink	Drought tolerant	Full sun	Deciduous
Sedum spurium ‘White Carpet’	Two-row stonecrop	perennial	No	0.2	0.6	Autumn	white	Drought tolerant	Full sun	Deciduous
Sedum ‘Bertram Anderson’	Stonecrop	perennial	No	0.2	0.3	Summer to fall	pink	Drought tolerant	Full sun	Deciduous
Sempervivum arachnoideum ssp. tomentosum‘Stansfieldii’	Houseleek	perennial	No	0.1	0.3	Summer to fall	pink	Drought tolerant	Full sun	Deciduous
Sesleria autumnalis	Autumn moor grass	grass	No	0.5	0.5	Autumn to winter	white, brown	Drought tolerant	Full sun	Evergreen
Spiraea japonica 'Gold Mound'	Japanese spiraea 'Gold Mound'	shrub	yes	1	1.5	Summer	pink	Medium	Full sun	Deciduous
Stachys byzantina 'Silver Carpet'	Lamb's ears	perennial	No	0.2	0.5	N/A	N/A	Low	Full sun	Evergreen
Thymus pseudolanuginosus	Wooly thyme	perennial	yes	0.08	0.3	Spring	pink	Drought tolerant	Full sun	Evergreen
Zauschneria septentrionalis ‘Select Mattole’	California fuchsia	perennial	Yes	0.3	0.6	Summer to fall	orange	Drought tolerant	Full sun	Deciduous

REFERENCES

Campbell, Michele (2013). How can city landscaping increase habitat values in our parks and along our streets for urban songbirds and other wildlife?

City of Vancouver (2016). Citywide Integrated Rainwater Management Plan

City of Vancouver (2012). Greenest City Action Plan 2020.

City of Vancouver (2009). Water Wise Landscape Guidelines

City of Vancouver (2007). Urban Forestry Management Plan

City of Vancouver. Climate Change Adaptation Strategy

Dolan et al, L.M.J. & van Bohemen, H.D. & Whelan, P & Akbar, khalid F. & O'MALLEY, V & O'LEARY, G & J. KEIZER, P. (1970). Towards the sustainable development of modern road ecosystem. The Ecology of Transportation: Managing Mobility for the Environment. 275-331. 10.1007/1-4020-4504-2_13.

Fryett, Lindsey (2014). Connecting to Nature in Vancouver's Urban Landscape- Greenest City Action Plan access to nature strategies in everyday landscapes.

Hamann, Andreas, and Tongli Wang. "Potential Effects of Climate Change on Ecosystem and Tree Species Distribution in British Columbia." Ecology, vol. 87, no. 11, 2006, pp. 2773–2786. JSTOR, JSTOR, www.jstor.org/stable/20069297.

Holling, C. S. 1973. Resilience and stability of ecological systems. Annual Review Ecology System 4:1-23.

Hsieh, Jason (2012). How will we achieve our target to plant 150,000 new trees by 2020?

IPCC (2014). Climate Change 2014 Synthesis Report

Jin, Jessica (2016). Green Stormwater Infrastructure (GSI) on City Streets

Lemmen, D.S, Warren, F.J., Lacroix, J., and Bush, E., editors (2008): From impacts to Adaptation: Canada in a Changing Climate 2007, Government of Canada, Ottawa, ON
https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2007/pdf/full-complet_e.pdf

McKenney, Daniel W., et al. "Change and Evolution in the Plant Hardiness Zones of Canada." BioScience, vol. 64, no. 4, 2014, pp. 341–350. JSTOR, JSTOR, www.jstor.org/stable/90006669.

Metro Vancouver. Climate 2050- discussion paper. April 2018

Metro Vancouver. Climate Projections for Metro Vancouver.
http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjectionsForMetroVancouver.pdf

Mooney, P. (2014). A systematic approach to ecosystem services. Landscape Journal, 33(2), 141-171.

Natural Resources Canada. 2017. Plant Hardiness Zone by Municipality.
http://www.planthardiness.gc.ca/?m=22&lang=en&prov=BritishColumbia&val=V

Pacific Climate Impact Consortium. 2012. Biogeoclimatic zones.
http://www.plan2adapt.ca/tools/