UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Campus Urban Forest Inventory and Assessment: Phase 1B

University of British Columbia

UFOR 101

Themes: Land, Biodiversity, Climate

Date: May 31, 2020

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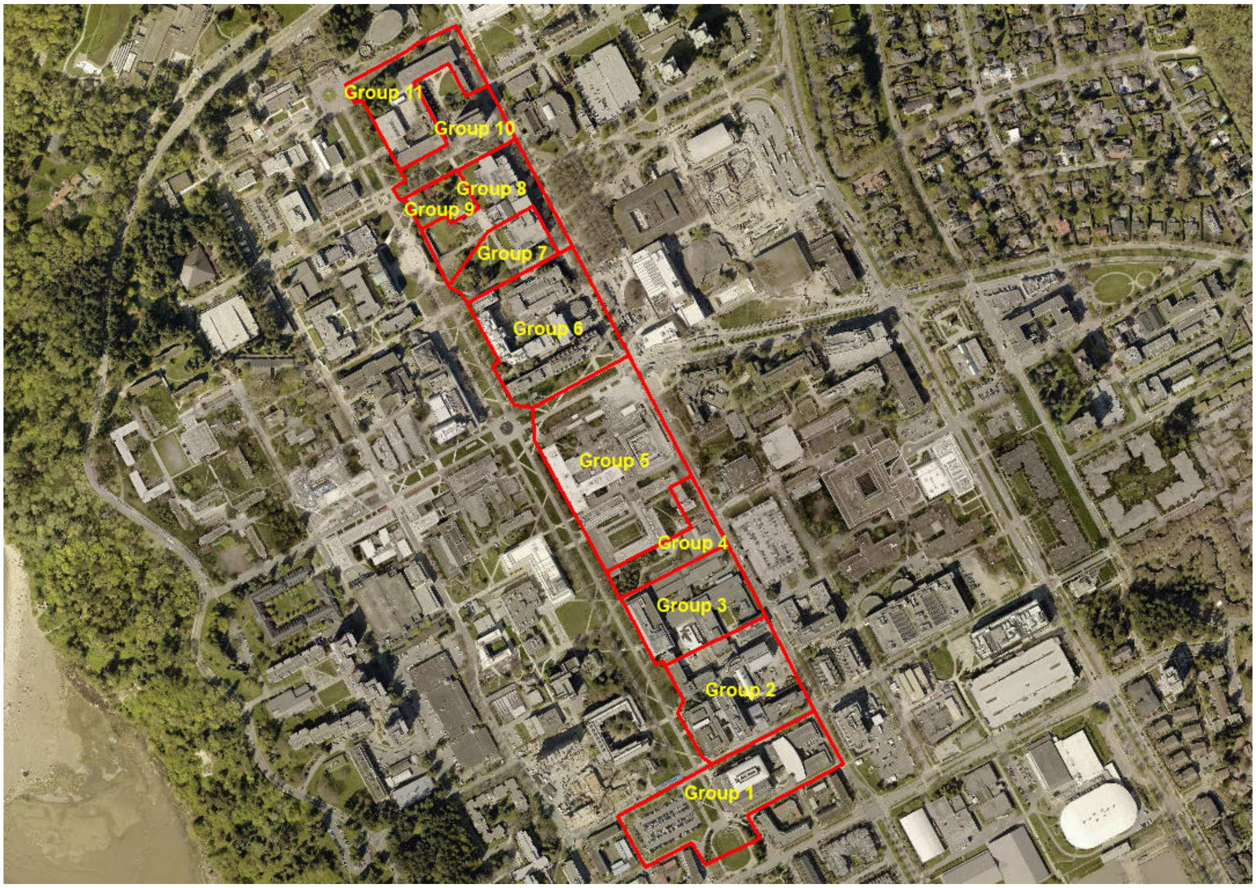
* See next page for a map of every group's site



Map showing eleven student group zones distributed across the Phase 1B area allocated for UFOR 101 in 2020. UBC Campus view retrieved from ArcGIS online basemap.

2020

Urban Forest Inventory & Assessment

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5/31/2020

URBAN FOREST INVENTORY AND ASSESSMENT

EXECUTIVE SUMMARY

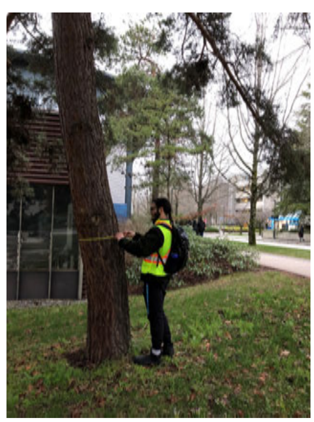
Urban Forest Inventory and Assessment (UFOR 101) addresses 1) the need to teach students about urban forest structure, composition, and distribution, and how these influence the ecosystem services and benefits urban forests provide, and 2) the need for a sound overview and valuation of urban forest resources on UBC campus. UFOR 101 was implemented for the first time in 2019. This year, it involved 62 first-year students in the Bachelor of Urban Forestry program and ran from January 9th to April 8th, 2020. The course introduced the students to a range of methods and tools for urban forest inventory and assessment. Moreover, it discussed how inventories and assessments are integrated into the planning and management of urban forests, with real implications for the urban forests on UBC campus.

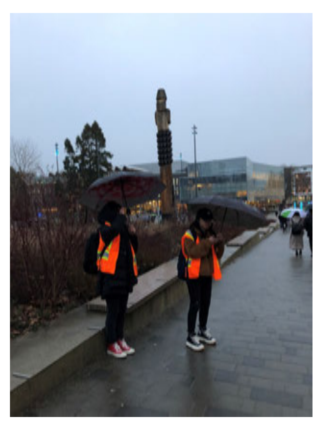
The work conducted by UFOR 101 students provides important information to support the campus greening strategy led by UBC Campus & Community Planning (UBC C&CP). In addition to UBC C&CP, other key stakeholders who contributed to UFOR 101 included UBC Information Technology and UBC Botanical Garden, whose horticulture students, under Egan Davis, contributed accompanying data on the understory. The collaboration was coordinated by the UBC SEEDS program with the intention to repeat this initiative on a yearly basis. During 2020, the work focused on a specific area of campus referred to as Phase 1B (see map below). In subsequent years, students will be working in different areas of campus until eventually urban forest data will have been gathered for the entire UBC campus.

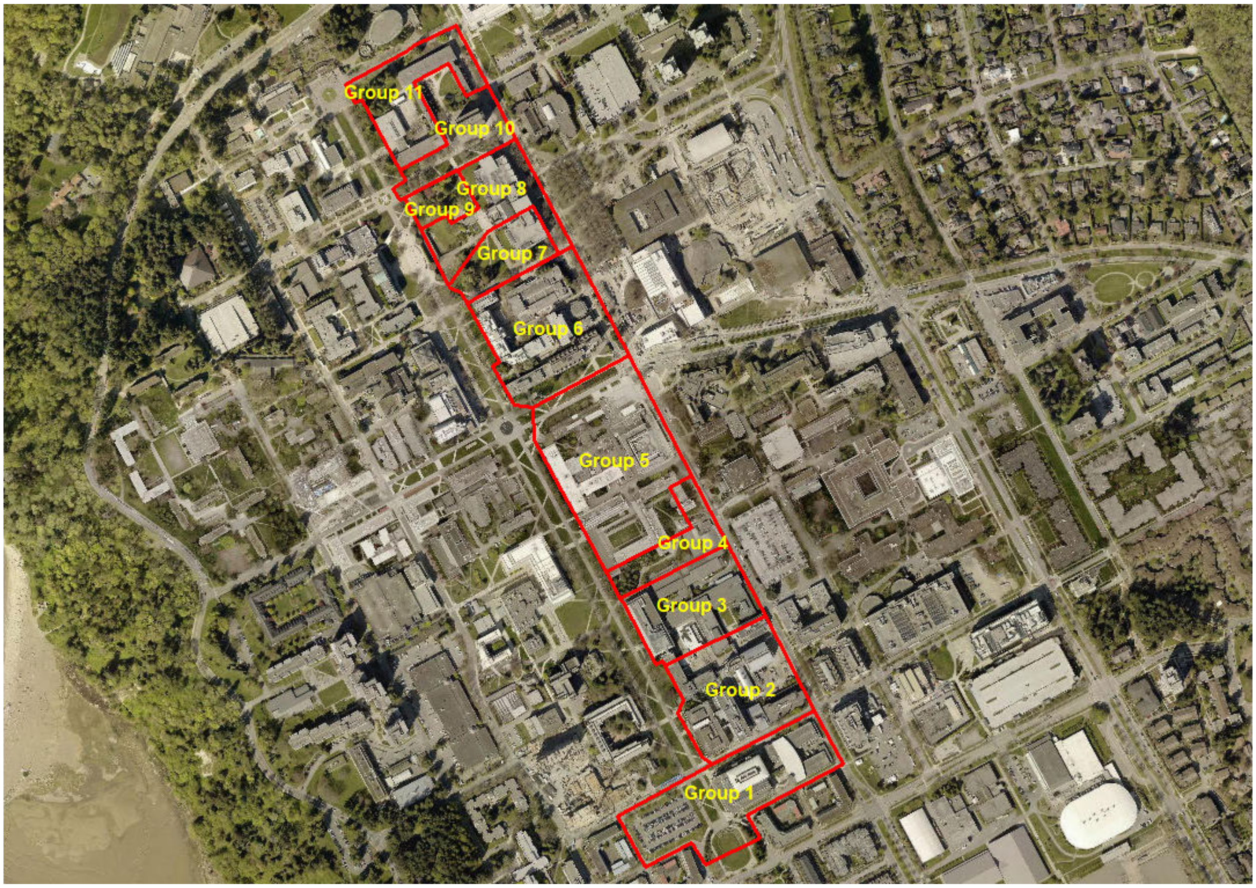
The UFOR 101 course involved four modules, two major group assignments, and final group presentations of all the work. For the first assignment, students planned and implemented a basic urban tree inventory working in small groups of five to six students. The final product of the assignment presents a comprehensive overview of the inventory data, analysis of the data, and the process used to collect it. All eleven inventory reports produced by the students are attached to this document.

The second assignment comprised an ecosystem service assessment. Working in the same groups, students assessed the ecosystem services provided by their selected urban forest area using the inventory data collected in the first assignment. They used different ecosystem services assessment tools and methods, including i-Tree Eco, i-Tree Canopy, and Value Mapping. Findings of the ecosystem services assessments are used to make recommendations to UBC C&CP. The eleven reports of the ecosystem services assessment and planning recommendations are attached to this document.

To access tree and landscape data for UBC, please go to github.com/UBCGeodata







Map showing eleven student group zones distributed across the Phase 1B area allocated for UFOR 101 in 2020. UBC Campus view retrieved from ArcGIS online basemap.

Urban Forestry Inventory Report

UFOR 101

Group 1

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February 12, 2020

Contribution Page

Report content

Introduction: JinRu Chai

Methodology: Ruoxuan Ma; Xiwen Zhang

Site Description: Rebecca Cai

Results: Xiangyue Chen, Viola Zhao

Analysis: Viola Zhao

Final Edit: Viola Zhao

Arrangements: Jinru Chai

Graphs

DBH Graphs: Xiangyue Chen

TTH Graphs: Xiangyue Chen

Species Abundance Graph: Viola Zhao

Data Entry

Everyone

Introduction

This urban forest inventory report investigates a part of the tree inventory at the University of British Columbia campus. The objects are recognizing tree species, measuring tree dimensions, and analyzing collected data. This piece of the selected area is investigated by six students. All the data collected will serve for the UBC campus tree inventory program. A tree inventory is a fundamental stone and meanwhile plays a crucial role as the resource of urban forestry management. The data collected in Zone 1 contributes to the UBC campus tree inventory program by providing assessments of tree growth conditions.

The Zone 1 fieldwork area is assigned in the south end of UBC campus, the block between the East Mall and Thunderbird Crescent, passing forestry science faculty, this area includes the tree species on the sides of Reconciliation Pole and Sopron Gate. The area has a significant purpose of cultural and recreation influence, "it represents the history of Indigenous people in Canada before, during, and after the Indian residential school era." (Kevin Ward, 2019)

The following inventory report will provide overall site information of Zone 1. The site description gives an overall fieldwork area explanation. The methodology will explain in detail the data collection methods and the processing approaches in the third section. The last section will summarize and analyze the results of tree inventory data in graphic and text form.

Site Description

This part of the assignment of site description will illustrate group number one's selected area which is located at the very end of the main mall in Vancouver's UBC campus. The picture shown below with the red-lined square (figure 1) belongs to group one's area with two school buildings, one parking lot, one square of the main mall's lawn and a small park cut in half. Although the picture looks like it only has buildings and lands, there is one Tim Hortons coffee shop inside one of the two buildings. People and students can easily get their coffee without walking a long-distance walk to their "destination" especially during the rainy seasons in Vancouver.

The definition of land use is based on what can be built on it and also what can the land be used for. To determine whether it can be used for community, recreation or business purposes, we need to select a specific type of land according to its uses. Land use can be the way in which people adopt the land to suit their demand and zoning is when the government readjust and regulates the land. In our group's site, lands are being used for recreational, commercial, agricultural and transport purposes.

Two of the buildings on the right side of the box are the Forest Science Center and Centre for Advanced Wood Processing, these two buildings can be listed for commercial land purposes. The land usage of transport design is located on the left side of this graphic, there is one rectangle-shaped pay parking lot for students, visitors, and staff to park their cars. However, at the end of the left side bottom, there are a few different species of fruit plants that are seeded over there and it can be counted as the agricultural use because specific land is used for the growing and harvesting of crops and livestock. Finally, the bottom area is a recreational park for residents and students to come and have some seats to enjoy their time here whether on sunny days or snowy days.

People can not always spend their time in their office or classrooms for 24 hours and they have to come out for a walk at least for a short break so that the forester has designed parks or greenways with seats near office buildings or school buildings just like the one in the pictures. The park in this site is at the perfect location due to its use of percentages because as a group we have seen so many staff and students are having fun in this park. Some of them will come here for a picnic and some people will bring their gym equipment to work out with their friends and also residents living around this area will walk their dogs in this park too.

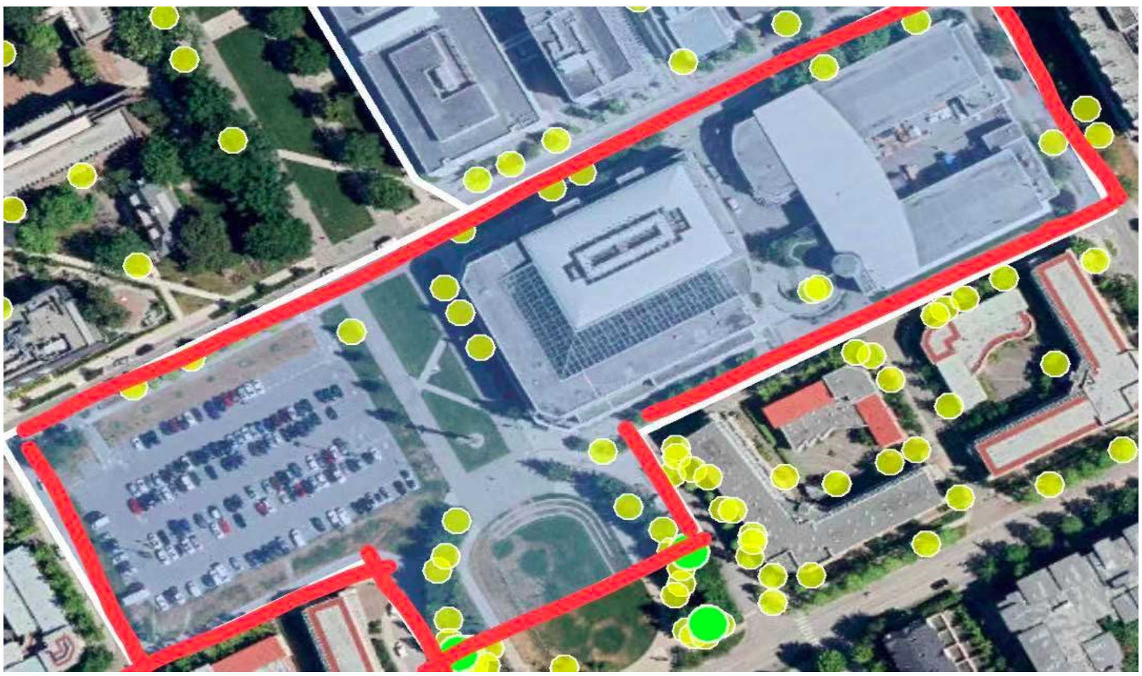


Figure 1. Group 1 Inventory plot

Methodology

The 5 tools that used to collect the raw data are Collector App, Laser rangefinder, Diameter Tape, Distance Tape and Compass. The data contains nine components, which are tree ID, tree species, tree tag, diameter at breast height, total tree height, crown base height, crown width, percent crown missing, and crown light exposure.

The tree tag is a steel plate that is nailed led on the trunk with certain numbers, and not all the trees have a tree tag. When we measure the data, we will check if the tree has it or not. When we find a tree tag, we record the number on the datasheet.

DBH (Diameter at Breast Height)

The diameter at breast height (DBH) will be estimated at 1.37 meters (4.5 feet) above the ground. The DBH for trees with DBH ≥ 2.54 cm (1 inch) will be recorded on the datasheet directly. We use diameter tape to measure the DBH. However, according to different land use, and landscape, there are always trees with irregularities at DBH. For instance, if the tree is grown on a slope, the tree's DBH needs to be measured on the uphill side of the tree. For the trees with swelling at 1.37 meters should be measured at higher than 1.37 meters until there is no swelling on the stem. Also, if trees have branches at 1.37 meters, the method would be similar to swelling trees at 1.37 meters. In this circumstance, the data will be written below the H DBH column. The H DBH is the height at which DBH measurement was taken if not measured at 1.37m above the ground.

TTH (Total Tree Height)

Total tree height is the height from the ground to the top of the tree. Total tree height will be measured with the laser rangefinder, which is a three-point measurement. To measure the total tree height, the first step is to distinguish between living or dead trees. If the tree is still alive, it will be measured from the ground to the top of the crown. For downed living trees or severely leaning trees, height is considered the distance along the main stem from the ground to the treetop. If the tree is dead, only standing dead trees are measured. The height of the living tree is always measured from the ground to the top unless the top of the crown is dead.

The steps of using a laser rangefinder are the first to stand >10 meters from the tree, press the power button on top to turn on the equipment, then use one eye to look through the lens, find the horizon line to the tree trunk, wait until HOR start to flash, and press the mode button. Next, move the equipment up to the top of the tree crown, and click the mode button again. Lastly, move the rangefinder to the bottom of the tree, press the mode button and the height of the tree will present on the left side screen. While getting the exact number, record the data on the datasheet. A reminder is that before measuring, do not forget to adjust the unit of measurement to a meter.

CBH (Crown Based Height)

The distance tape is used to estimate the crown base height and crown width. Crown base height(CBH) is the height from the ground to the base of the live crown. The base of the live crown refers to the lowest live foliage on the last branch in the live crown. However, when it is winter, and trees do not have leaves, CBH can be measured from the lowest branch. If the crown base touches the ground, the CBH is zero as well.

The width of the crown has two directions, which is the long side and the short side. The crown width is the average number of the two measurements. Practically, for the long side, find the outermost branch on one side and straighten the distance tape to find the outermost branch on the other side and record the length. The short side is perpendicular to the long side of the tree. Determine the short side and repeat the steps to measure and record the data.

Percent Crown Missing

Percent crown missing is mainly the crown volume that is not occupied by branches and leaves. To estimate the percentage of crown missing, we need to stand at perpendicular angles of the tree and imagine the trees with fully symmetrical shape and predict what percentage of foliage that is absent. In order to get the accurate data, at least two positions are required to visualize the trees and averaged the data. Number of sides of the tree crown can receive the light refers to crown light exposure. A single tree can count with maximum five sides, the top, and the other four sides dividing the crown vertically into four quadrants. While collecting data, simply counting the number of sides that can receive sunlight and record the data on the datasheet.

Method for analysing data

In the report, based on the distribution of the data, values of tree stem diameter (DBH) were divided into different classes (< 10 DBH, 10-20 DBH, 20-30 DBH, 30-40 DBH, 40-50 DBH > 50 DBH). In further analysis, DBH could help to define the age of trees.
The total height of trees (TTH) were classified into six groups (< 2m, 2-5m, 5-8m, 8-1 m, 11-14m, >14m). The data of TTH was analyzed by using a pie chart to find out the distribution of the trees in zone 1.

In order to measure the variability of variables of trees, standard deviation was used to calculate the bias of the data in the database by using this formula:

$$\mathrm{SD} = \sqrt{\frac{\sum |x - \mu|^2}{N}}$$

In the equation, $\sum$ means the sum; x is the value recorded in the database; μ is the mean of the database; N indicates the population in the data which is the total number of trees.

Furthermore, the allometric equation is a statistical way used to establish quantitative relations between some key characteristic tree dimensions (Almas &Devisscher, 2020). It is created based on DBH and TTH in order to measure the biomass and volume of aboveground trees (Kebede & Teshome, 2018). Firstly, by using the value from the database to graph the relation. Secondly, applying different models for regression analysis until the best fit is found. Finally, for completing the prediction by the allometric equation.

Result

The data includes DBH, total tree height, species abundance, each of the data will be shown in the table.

Total Tree height

Tree height is the vertical distance between the base of the trees and the tips of the highest branch on the tree. For this tree inventory, we used a laser tool to measure the tree height, and the date of the tree height in zone 1 is shown in table 1.

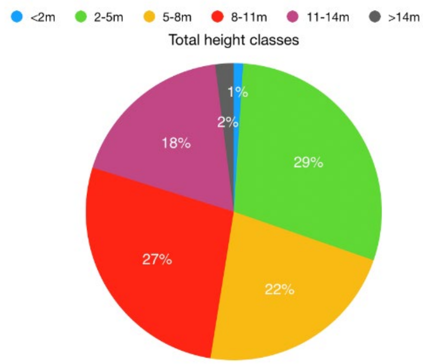
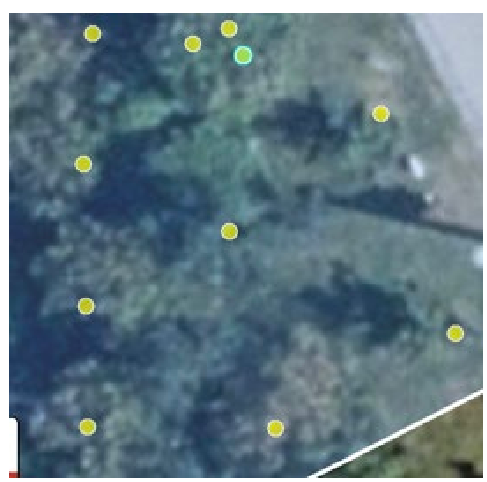


Table1:

Total height	Trees
<2m	1
2-5m	29
5-8m	22
8-11m	27
11-14m	18
>14m	2

The majority of the trees are within the height around 2 meters to 5 meters, which accounts for 30% of total trees in zone 1. Next come trees with height about 8 meters to 11 meters, whose percentage is slightly lower than that of small trees (2-5m). Trees with the height around 5 meters to 8 meters and 11-14 meters tall trees take up 20% of the total trees respectively. The two lowest proportions are taken up by 2 big trees with more than 14 meters and one tree lower than 2 meters. Besides the 3 trees with the remarkable tree height, the total height classes of zone 1 is evenly distributed. The evenly distribution of trees total height in zone 1 might be triggered by two main reasons. First of all, most of the measured trees in zone 1 are street trees, street trees are planted to provide shade and beautify our landscapes. Most of the street trees are usually required to be the same specie with the similar height, so that can create beautiful and uniform streetscapes. For example, plenty of Japanese cherry were planted in UBC, as one of the most beautiful street trees, those Japanese cherry have the similar height and similar crown width. Secondly, most of the trees with similar total height are planted in the same area, so they have similar growing conditions. For instance, the trees in figure 2 are Pacific madrones, and they were densely planted, these Pacific Madrone absorb the similar nutrients from soil, meanwhile, they accept the same sunlight



and rainfall, hence, they have the same growing condition. Overall, due to the similar growing condition and same tree species selection, the total height classes of zone 1 are evenly distributed.

Figure 2 Pacific Madrone Distribution

Landmark trees

Cherry Trees are the landmark trees in this inventory site because they produce beautiful and attractive sceneries along Agronomy Street. Cherry blossoms are always referred as the symbol of beauty and rebirth. (Krasnick, 2018).

Figure 3: UBC cherry blossom season, from google picture

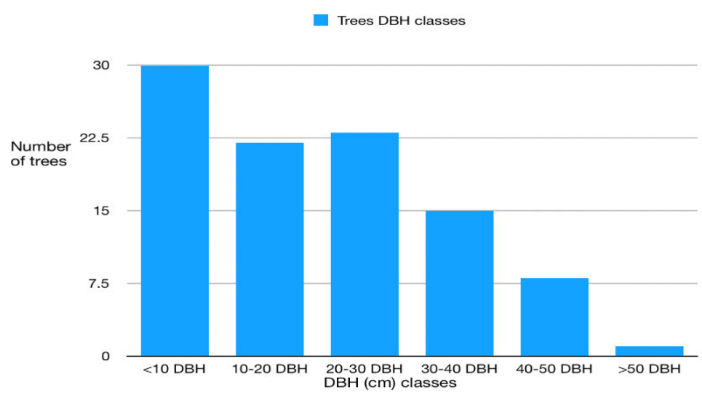
Figure 4: Taki-nioi cherry tree during winter season

DBH

DBH is a standard method of expressing the diameter of the trunk of a standing tree, it is typically measured at 1.37m above the ground. We used steel tape ruler to measure the DBH. The specific data is shown in table 2.

Table2:

DBH (cm)	Trees
<10 DBH	30
10-20 DBH	22
20-30 DBH	23
30-40 DBH	15
40-50 DBH	8
>50 DBH	1



One thirds of the trees DBH classes is made up by trees with DBH smaller than 10 cm, there are 30 trees with more than 10 centimeters DBH; 22 trees with 10-20 cm DBH; 23 trees with 20-30 cm DBH , 15 trees with 30-40 cm DBH, 8 trees with 40-50 cm DBH, only one trees with 59.95 cm DBH. The bar chart illustrates a trend which is the negative relationship between DBH and the number of trees. With the increasing of DBH, there is a downward general trend in the number of trees. In other wards, trees with large DBH is relatively rare in zone 1.The trees with DBH from 1cm to 30 cm, this group of trees takes up 75% of all trees, additionally, these trees are mainly made up by native trees like Douglas fir and pacific red cedar.

Species abundance

There are more than 18 different tree species found in zone 1, species abundance is shown in Figure 4.

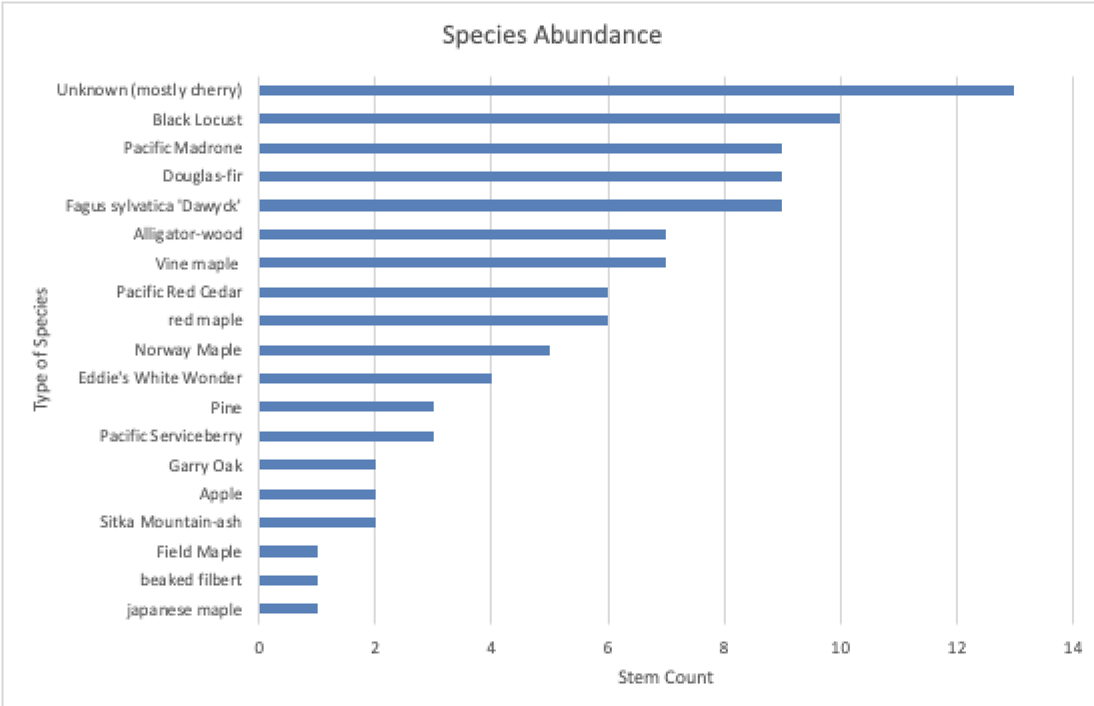


Figure 4 Species Abundance at Inventory Site

Analysis

The inventory site included the forestry science building and a parking lot, as well as half of the grass lawn in front of the Old Barn Community. The land use of our site varies, but can mainly be categorized in four groups: Institutional, residential, transportation, and park. Therefore, the choice of tree species and function of trees in this area varies.

Canopy Coverage

Overall the total canopy coverage at the inventory site is very loose, according to low mean DBH. The main reason for this result is attributed to land uses. First, most of the spaces are occupied by buildings, roads, and a parking lot. There is not enough space for planting too many trees. Second, at this inventory site, a large amount of canopy coverage is not required due to the purpose of this place. Trees along the street function as a barrier that separates constructions from the street. These trees should not be planted too closely next to each other because they should not block the pedestrians' ways to cross the street. At the Totem pole area, the focal point is centered at the pole. The main function of those trees is to highlight the totem pole, therefore trees that have large canopies (decurrent trees) should not be chosen to plant there. In the parking lot area, trees are only planted around the parking lot but not in it, because The function of those trees is similar to those trees along the street. They separate the parking lot from the Thunderbird Residence, and at the same time not blocking the cars from parking.

Species Abundance

The inventory site is dominated by deciduous tree species, for example, Black Locust. Since the site contains roads and many walkways, the shades provided by trees are crucial for pedestrians, especially in summer. Deciduous trees usually have decurrent branching patterns, and thus they have wider crowns and are able to produce sufficient shade. This site also has wide shrub coverage. Shrubs, in urban forest, sometimes are responsible for "filling the gaps" between trees. Shrubs also soften lower level urban sites by adding natural features. At some specific places in the inventory site, shrubs are the main urban forest components. For example, there are some benches that are surrounded by shrubs in front of the Tim Hortons in the Forest Science Building. These shrubs function as a "barrier" for the benches, separating the seats from the streets. Because the benches are very close to each other, planting trees next to them would be inappropriate as the spacing is not enough for the trees.

Total Tree Height

Total tree heights (TTH) of the species surveyed range from 1 to 14 m. Most of the data clustered at 5 to 11 m. Tree heights vary, primarily based on the variety of species. For instance, Douglas-fir can grow up to 30 meters while Cherry Trees usually grow up to 7 meters. Another reason is the different growing environment for each tree. For example, trees that are planted closely next to each other will have distinctive vertical diversity as some trees are outcompeted by others for sunlight. Sometimes, trees have a certain height due to artificial reasons. Some pine trees, especially in gardens and parks, are pruned to a certain height for aesthetic purposes. For instance, the pine trees right beside Tim Hortons are pruned into less than 2 m tall so that they will not block people's sights.

Citation

Almas, Andrew, & Tahia, Devisscher. 2020. "Analysis of tree inventories." Presented at University of British Columbia, 2020, Vancouver. Retrieved February 6, 2020. (https://canvas.ubc.ca/courses/38878/files/6979173?module_item_id=1658226)

Kebede, Birhanu, and Teshome Soromessa. 2018 "Allometric equations for aboveground biomass estimation of Olea europaea L. subsp. cuspidata in Mana Angetu Forest."*Ecosystem Health and Sustainability*, 4(1), 1-12.

Krasnick, Hannah. (2018, April. 3) A guide to cherry blossoms at UBC. Retrieved from https://events.ubc.ca/a-guide-to-cherry-blossoms-at-ubc/

Tahia, Devisscher. 2020. "Introduction to Assignment 1." Presented at University of British Columbia, 2020, Vancouver. Retrieved January 23, 2020. (https://canvas.ubc.ca/courses/38878/files/6809909?module_item_id=1635153)

What is the Reconciliation Pole? (2019, April 8). Retrieved from https://students.ubc.ca/ubclife/what-reconciliation-pole

Assignment 1: Inventory Assessment of UBC

Urban Forestry 101

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UFOR 101: Urban Forest Inventory and Assessment

Dr. Tania Devisscher and Dr. Andrew Almas

February 13th, 2020

Contributions page

Adra Al-Shakarji was responsible for introduction and summary suggestions
Oakley Kang was responsible for methodology
June Lam was responsible for tree inventory table and summary analysis
Kaysha Reeder was responsible for the summary of tree inventory data
Britany Wu was responsible for tree inventory table and site description
Border Yin was responsible for the summary of tree inventory data and notable trees

Introduction

The following urban forestry inventory report was completed by six students from University of British Columbia (UBC) on the Vancouver campus. Its objective was to collect data concerning a particular area on campus. The following report concerns the tree data collected around UBC's Department of Computer Science building.

The purpose of the tree inventory ground-based field survey is to provide suggestions for UBC's urban forest management plans and to contribute to the campus' data archives. We began by setting clear goals and objectives, then developed a methodology by following a systematic plan. With the right equipment and active teamwork, we completed a partial tree inventory on campus, conducted ecosystem service assessment of trees, analysed and presented the data of our results, all in efforts to improve the urban forestry on campus.

The end users of the inventory data include the students of this class, and the UBC campus. Students were not only able to learn important urban forestry knowledge and skills in class, but were also given the opportunity to apply their knowledge during the field work.

With special thanks to Egan Davis, most of the tree species were already identified and documented into the Collector for ArcGIS app, making it easy to find and inventory. However, some trees were either misplaced or missing from the application and have been recorded at the end of this report.

Site description

Our group assessed the area enclosed by Agronomy Road, Main Mall, and East Mall; the buildings consisted of the MacLeod Building, UBC Department of Computer Science, and the Engineering Student Centre. Most of the land was used institutionally while a portion was also utilized for transportation as we saw many cars and parked trucks at the centre of the road during the inventory (red line in *Figure 2*). Since there is a restaurant, there are several trash bins located in the area (blue squares in *Figure 2*). To support the energy use in buildings, a number of power generators were located in the area enclosed by the yellow square in *Figure 2*. Most of the activities observed in this area were students or staff members walking, biking, or skate-boarding between classes, cars driving pass Agronomy Road and East Mall, and trucks parking in the back of the buildings to unload. Agronomy Road and Main Mall became even more crowded compared to the other lanes in the area when classes ended.

Figure 1. Map of the area from the Collector app.

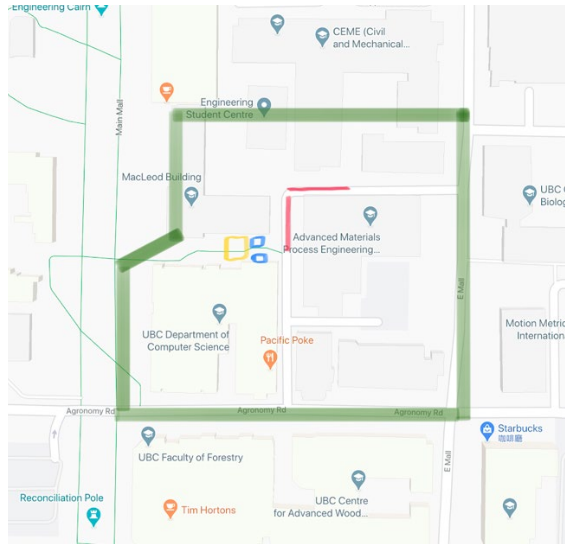


Figure 2. Map of the area from Google Map.

Methodology

On-the-ground data collection methods

The variables measured in our UBC Vancouver campus site partial inventory include: (1) tree ID, (2) tag ID, (3) living status, (4) species, (5) land use, (6) tree stem diameter at breast height or 'DBH', (7) tree height - which consists of (a) total tree height or 'TTH', (b) live crown height or 'LCH', and (c) crown base height or 'CBH', (8) crown width, (9) percentage crown missing, and (10) crown light exposure or 'CLE'.

1. Tree ID: (code) retrieved from ArcGIS Collector Classic app
2. Tag ID: (number) documented if the tree features a tag
3. Living status: indicates trees as 'live' or 'dead' from visual observation
4. Species: retrieved from ArcGIS Collector Classic app
5. Land use: chosen from i-Tree Eco categories
6. DBH (cm): the tree stem diameter height at 1.37 m from the ground and measured from the uphill side of the tree (an alternate height indicated if faced with these following irregularities: swelling of the stem, branches at 1.37 m, tree on a slope, leaning trees, or trees on the ground). With a multiple-stemmed tree, the six most dominant stems were measured to calculate an overall diameter. Stems were omitted if their DBH were less than 2.54 cm. Tool used: diameter-tape

7. Tree height (m):
    a. TTH: the height of a standing tree from bottom to top or along the main stem if the tree is severely leaning (regardless of whether alive or dead). In a situation where the tool was unable to function, estimations were made relative to previous measurements. Tool used: laser rangefinder (three-point measurement)
    b. LCH: equal to TTH and omitting any dead crown height. Tool used: laser rangefinder (three-point measurement)
    c. CBH: the height from the ground to the base of the crown with live foliage. Tool used: measuring tape
8. Crown width (m): the average of the crown widths taken from two directions (long side and short side). Tool used: measuring tape
9. Percent crown missing (%): the unoccupied crown volume that lacks expected branches or leaves and is estimated from two sides by visual observation. Tools used: none
10. CLE: the number of sides that a tree receives sunlight from (top and four sides) and is concluded by visual observation. Tool used: none

Advantages and disadvantages of an on-the-ground/field survey inventory

Advantages: provides the most precise and reliable data (Nielsen, Östberg, & Delshammar, 2014). Disadvantages: the most time-consuming and labour-intensive due to direct measurements and/or visual inspection (Nielsen, Östberg, & Delshammar, 2014).

Advantages and disadvantages of partial inventory

Advantages: an equal accuracy level as a complete inventory as all trees in an area are measured (Morgenroth & Östberg, 2017). Disadvantages: multiple inventories required for greatest accuracy and is more time-consuming in comparison to a sample inventory.

Data analysing methods

With our inventory data, we analysed the relationship of species frequency with its corresponding basal area, crown area, crown cover, seasonality, and origin. Additionally, we also took note of the number of trees per DBH and height. Using Excel as our primary software device, we visualized our data into bar graphs and circle charts. With these comparisons, we were able to draw conclusions regarding possible reasons for tree growth, size, and population dominance within our site, along with the ecosystem services provided from them.

Summary of tree inventory data tables

As seen in *Figure 3,* the zone has 75 trees that were surveyed in total. 19 unique species were identified among 12 different genera. 5 species belonged to the maple (*Acer*) genus. Over 40% of the trees were maples with 18% of total trees belonging to one species, Japanese maple (*Acer palmatum*). The other species are relatively evenly distributed among the 11 genera. The monoculture is not ideal for biodiversity or ecosystem resilience but creates a visual quality that people enjoy.

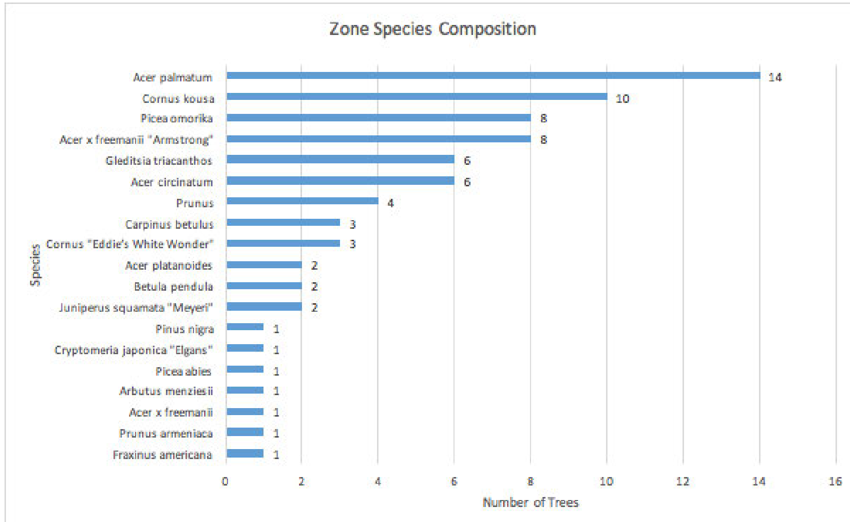


Figure 3. Zone Species Composition

In *Figure 4,* the highest basal area is occupied by the Serbian spruce *(Picea ormorika).* It is the third most abundant tree but has significantly larger basal area due to its high average basal area per tree. In *Figure 5,* the most abundant tree, Japanese maple *(Acer palmatum)*, is surprisingly not the dominant species in basal area due to its thin trunks. The more abundant species tend to be relatively smaller in basal area, kousa dogwood *(Cornus kousa)* is a good example of this.

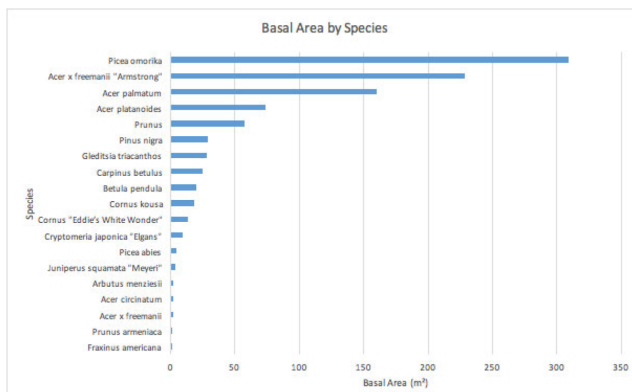


Figure 4. Basal Area by Species.

Of the 19 species present within our survey zone, only 6 are evergreen species. The remaining 13 deciduous species make up 80% of the stem count with 60 individuals. The remaining 15 evergreen trees represent 31% of the species but only 20% of the total trees in our area.

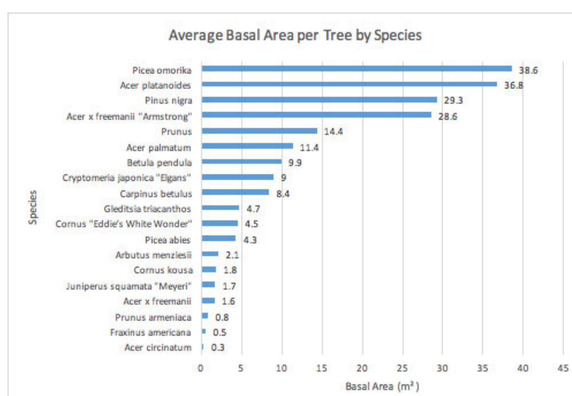


Figure 5. Average Basal Area per Tree by

Our zone has 2567.36 m^2 of canopy cover. Only 16% of the canopy is evergreen, with the remaining 2166 m^2 being deciduous. This means over 84% of the canopy cover in our zone is absent for a portion of the year.

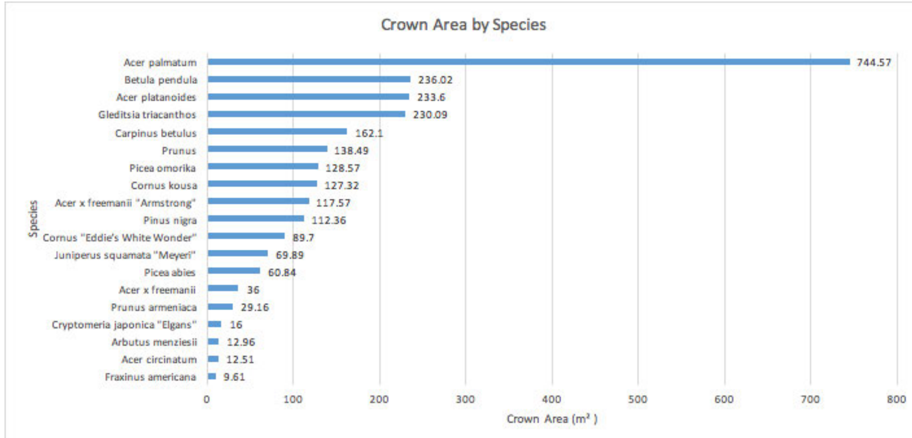


Figure 6. Crown Area by Species.

Of the 19 unique tree species in our zone, only 2 are native species. The strong majority of tree species are non-native with two species which are debatable in origin. The two present native species are the vine maple (*Acer ciricinatum*) and the arbutus tree (*Arbutus menziesii*). The species with questionable origin is the *Cornus* "Eddie's White Wonder" and the genus "*Prunus*". Without the species listed in our GIS database, the most accurate species we are able to determine is the cherry genus, *Prunus*. There are cherry trees native to BC such as the choke cherry *(Prunus virginiana*), pin cherry *(Prunus pensylvanica*) and the bitter cherry *(Prunus emarginata*), even though most trees planted in the Vancouver area are not native (Roberta, 1948). There is a possibility of the trees being a native species, but we were not sure. The dogwood cultivar "Eddie's White Wonder" is a hybrid species of the native pacific dogwood (*Cornus nuttallii*).

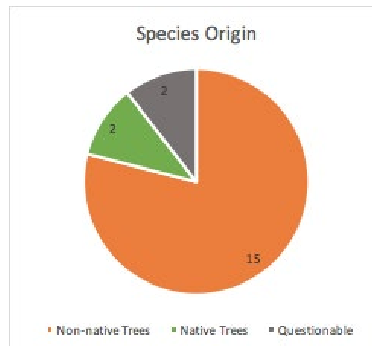


Figure 7. Species Origin.

This regression analysis in *Figure* 10 shows the general growth trend of the trees to have a 1 m height increase for every 2 cm of DBH increase. There are very few trees above 15 m so the height growth per centimetre of DBH decreases as total height increases.

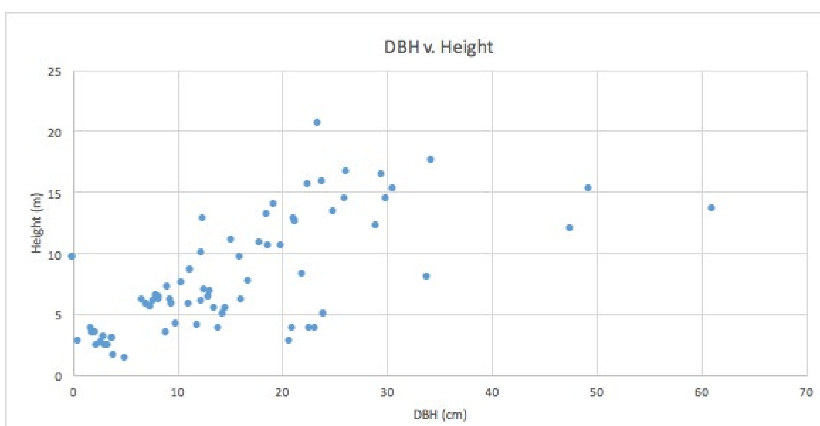


Figure 8. DBH v. Height.

Our zone has the most trees with a DBH less than 5 cm, meaning that there are a lot of thin trees. Trees with a DBH of between 0 and 15 cm are well distributed with about 14-15 tress per 5 cm difference. Our zone has relatively less trees in the DBH classes of 15-20 cm, and 25 cm or higher in our area. The total average DBH in our zone is 15.388 cm and the bar graph show that our area has more trees with DBH lower than the average.

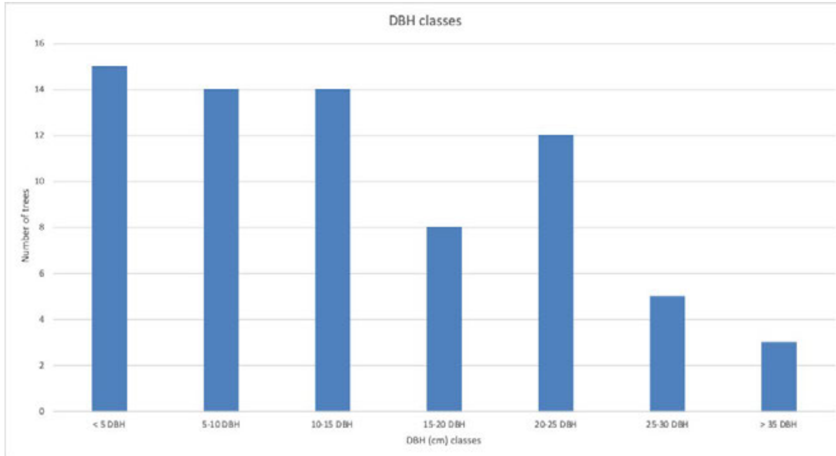


Figure 9. DBH classes.

Most of our trees have a total tree height between 5 m and 10 (*Figure 12*). The average TTH in our zone is 7.919 m. The number of trees starts to decrease as the total tree height goes over 10m.

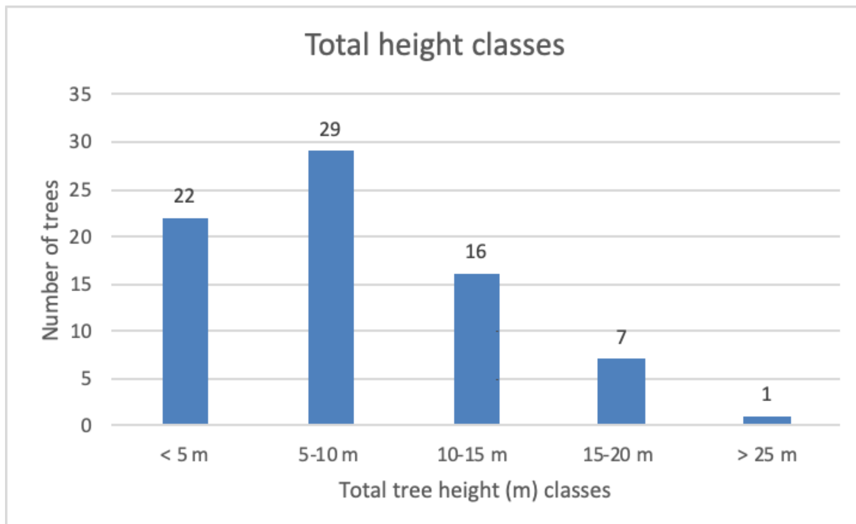


Figure 10. Total height class.

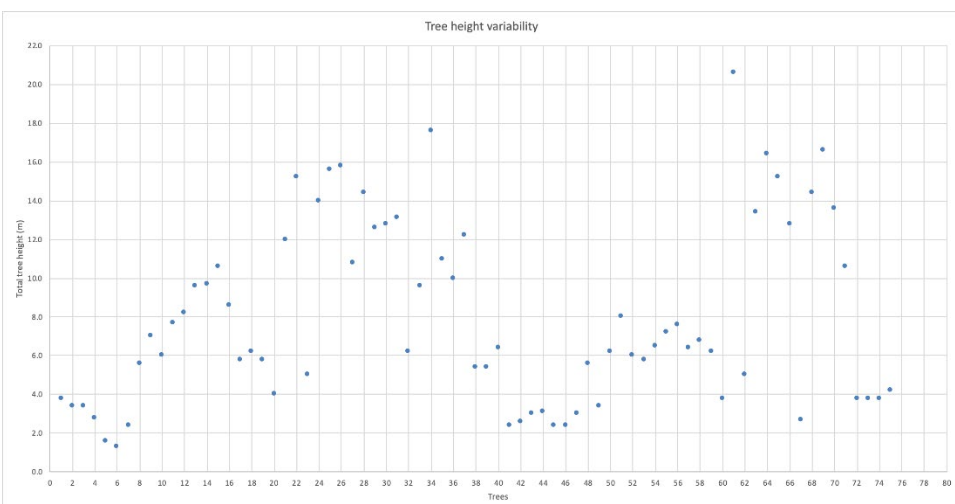


Figure 11. Tree height variability. The average height of all the 75 trees is 7.919 m, as indicated by the orange line.

Row Labels	Average of DBH	StdDevp of DBH	Average of TTH	StdDevp of TTH	Average of CBH	StdDevp of CBH	Average of CW	StdDevp of CW
Acer circinatum	2.609	1.460	2.717	0.946	0.600	0.000	1.404	0.290
Acer palmatum	10.199	6.388	6.943	2.205	1.489	0.746	7.125	1.436
Acer platanoides	48.400	0.900	13.600	1.600	3.670	0.330	10.800	0.400
Acer x fremani	14.400	0.000	5.000	0.000	1.720	0.000	5.950	0.000
Acer x fremani armstrong	21.319	2.592	13.638	1.556	1.935	0.156	3.663	1.051
Arbutus menziesii	16.200	0.000	6.200	0.000	1.200	0.000	3.550	0.000
Betula pendula	25.167	9.167	13.600	4.000	1.775	0.225	10.075	4.025
Carpinus betulus	18.864	7.262	11.067	0.899	1.900	0.071	7.250	1.128
Cornus "Eddie's White Wonder"	13.800	0.668	5.733	0.471	1.467	0.094	5.450	0.122
Cornus Kousa	4.830	2.566	3.410	1.293	1.192	0.166	3.213	1.487
Cryptomeria japonica "Elgans"	33.900	0.000	8.000	0.000	0.900	0.000	3.950	0.000
Fraxinus americana	7.800	0.000	6.000	0.000	2.400	0.000	3.085	0.000
Gleditsia triacanthos	10.033	1.767	6.717	0.579	2.317	0.308	6.107	0.968
Juniperus squamata "meyeri"	10.350	3.650	5.000	1.200	0.700	0.700	5.850	0.850
Picea abies	23.500	0.000	20.600	0.000	2.500	0.000	7.750	0.000
Picea omorika	24.800	5.626	12.063	4.932	1.738	0.992	3.691	1.529
Pihus nigra	61.100	0.000	13.600	0.000	2.200	0.000	10.600	0.000
Prunus	21.400	1.759	5.500	2.944	1.383	0.346	5.813	0.828
Prunus armeniaca	9.900	0.000	4.200	0.000	0.300	0.000	5.400	0.000
Grand Total	**15.388**	**11.648**	**7.919**	**4.628**	**1.654**	**0.758**	**5.211**	**2.622**

Table 1. Grouped species with calculated standard deviation (StdDevp).

Since we are dealing with a sample, the formula used for finding the standard deviation (StdDevp) uses n-1 instead of N (number of data points in the dataset). In *Table 1,* the lower the standard deviation is, the closer the values are to the mean value, and the higher standard deviation is, the greater the deviation is from the mean value.

Standard deviation for Freeman's maple *(Acer x freemanii),* Pacific madrone *(Arbutus menziesii),* Japanese cedar *(Cryptomeria japonica "Elgans"),* American ash *(Fraxinus Americana),* Norway spruce *(Picea abies),* black pine *(Pinus nigra),* and Siberian apricot *(Prunus armeniaca)* are not included as there is only one tree per species. The standard deviation of DBH is 11.648 m, which is the highest compared to standard deviations of other values. Silver birch *(Betula pendula)* has the highest DBH standard deviation at 9.167 m. Flowering dogwood *(Cornus* "Eddie's White Wonder") has the lowest DBH standard deviation at 0.668 m.

The standard deviation of total tree height (TTH) is 4.628 m, which is in the midrange compared to other standard deviation values. Serbian spruce *(Picea omorika)* has the highest TTH standard deviation at 4.932 m. Flowering dogwood *(Cornus* "Eddie's White Wonder") has the lowest standard deviation, 0.471, in TTH.

The standard deviation of crown base height (CBH) is 0.758 m, which is the lowest compared to other standard deviation values. Serbian spruce *(Picea omorika*) has the highest CBH standard deviation at 0.992 m. Common hornbeam *(Carpinus betulus)* has the lowest CBH standard deviation with 0.071 m.

The standard deviation of crown width (CW) is 2.622 m, which is in the mid lower range compared to other standard deviation values. Silver birch *(Betula pendula)* has the highest CW standard deviation, 4.025 m. Common hornbeam *(Cornus* "Eddie's White Wonder"*)* has the lowest CW standard deviation, 0.122 m.

		SD
Trees	75.000	
species	19.000	
DBH mean (cm)	15.390	(±11.648)
BA mean (m^2)	27.589	(±71.152)
Total height mean (m)	7.920	(±4.628)
Crown base mean (m)	1.650	(±0.758)
Crown width mean (m)	5.210	(±2.622)

- The basal area (BA) has the highest standard deviation, ±71.152, meaning that the value of BA greatly deviates away from the mean value
- The crown base mean has the lowest standard deviation, ±0.758, meaning that the values of crown base are close to the mean value.
- Standard deviation value: BA > DBH > total height > crown width > crown base

Canopy missing	
0-10%	0
10-20%	15
20-30%	17
30-40%	19
40-50%	12
50-60%	3
60-70%	1

- The majority of trees has a canopy miss of between 10-50% and most of the trees, 19 out of 75, has a canopy missing of 30-40%
- There are only 4 trees out of 75 that has a canopy miss more than 50%
- There were no trees missing a canopy cover less than 10%

Crown light exposure	
0	0
1	1
2	16
3	17
4	35
5	6

- The majority of trees, 35 out of 75, has crown light exposure on 4 sides.
- All of the trees have at least one side of light exposure
- The average of the crown light exposure is 3.387, close to 4 sides.

Summary analysis

Tree structure is shaped by many factors including built infrastructure, phylogenetic constraints, development patch constraints (Almas & Devisscher). Some of our trees were constrained by the pre-built infrastructure. For instance, there were a line of six vine maples (IDs: 3848-3853) that were constantly trimmed, two of which were looked like shrubs, as to avoid damaging windows or cars that drove on the vertical red line in *Figure 2.*

Most of our trees were rather thin in nature when compared to the trees on Main Mall. This is perhaps due to the need to ensure adequate walking space for pedestrians (mostly students going to their next class). However, these thin trees usually had a large CW, which may provide adequate shading and cooling during the summer. This may also be beneficial during the winter due to the large amount of glass windows in the buildings of our zone. In the colder months of the year, after the trees undergo senescence, more sunlight is allowed through canopies and into the buildings. Moreover, the most populous species in the zone, Japanese maple *(Acer palmatum)* has thin trunks and branches that allows for even more sunlight to enter and warm buildings while creating different visual experiences.

The trees around the buildings provide mostly cultural services as they bloom during specific times of the year like the cherry trees (cherry blossoms in March) and the Japanese maple (bright red leaves). Most of the trees planted are tall enough to receive adequate sunlight (a CLE of 4) despite being near or next to the building with an average height of 7.917 m.

The amount of non-native species in our zone is not especially surprising considering how developed the site is. Many urban sites like this have conditions so far from BC's native edatopic conditions, that there are no guarantees if our native trees will perform better than non-native species. In addition, with such high human traffic, the aesthetic qualities and maintenance demands surely takes precedence over native species and ecosystem functions in tree selection.

Notable Trees

The Japanese cedar (C*ryptomeria japonica "Elgans,"* ID. 1985) is located in front of the ICICS building, it is a notable tree due to its cultivar, Elgans. It is bred to retain its juvenille purple foliage through maturity. Another *cryptomeria japonica* specimen located in an adjacent zone displays the normal mature foliage colour. It is visible from the position of the Elgans cultivar. These Japanese cedars are not native to BC but are a good example of genetic variance within a species.

Another interesting tree is the arbutus (*Arbutus menziesii)*, tree ID 3854. There are only a few arbutus trees on UBC campus. They are generally uncommon due to the small habitat range within 8 km of the ocean. They are also the only evergreen broadleaf tree native to Canada

(Roberta, 1948). The leaves are waxy and the bark is distinct in reddish colour and its ability to peel.

There are three dogwood trees *(Cornus* “Eddie’s White Wonder”) with IDs 1967, 1968, and 1972 are notable for being a hybrid of the pacific dogwood (*Cornus nuttallii*) and the flowering dogwood *(Cornus florida*). The pacific dogwood is native to the Pacific Northwest (Holmes, n.d.) and has been the provincial flower of British Columbia since 1956 (B.C. Symbols, n.d.). BC’s provincial flower has six petals while the dogwood cultivar often bears only four broad striking white but distinctly dogwood petals. There is also the kousa dogwood (C*ornus kousa*), in our zone; however, they are non-native and only exhibit four acuminate petals on each flower.

Summary Suggestions

One main suggestion would be to plant a variety of different trees in the same areas. While aesthetics plays an important role in beautifying the campus, it would be costly if many of the trees were wiped out at once due to pests or diseases. As seen on the map and from the graphs there are many trees in the *Acer* genus, specifically *Acer palmatum*.

Due to the continuous pruning of the six vine maples (*Acer circinatum)* (IDs: 3848-3853) trees and the limited growth space, it may be better if they were replaced with either smaller trees or shrubs. Since that area is primarily used for transportation, it may be better to transport the trees elsewhere so they can grow to their full potential. This could improve the overall ecosystem services benefits the trees may provide. For example, aesthetics, habitat for little creatures, and general benefits trees provide. The growth area is limited and would overall limit the ecosystem services the trees may provide. It would potentially inhibit root growth (unless there are Swales or other types of structure that promote root growth).

The arbutus tree (ID. 3854) holds a strong cultural value; however, it is currently cornered between a tall concrete building, other trees, and hidden behind a large shrub, leaving it a CLE of two. While most arbutus are able to stand tall with their crown stretching wide, this tree is unable to due to its current location. Compared to the other arbutus on campus, there is a strong visible difference. Either the arbutus or the trees that surround it closely should be removed.

Appendix

Missing/misplaced tree coordinates

- Misplaced tree on app along Agronomy road: X: 482001.25; Y: 5454534.73
- Image 1, tree with red berries: X:481892.42; Y: 5456592.62
- Image 2, missing tree in front of Pacific Poke: X: 481936.68; Y: 5456496.83
- Image 3, missing cherry at the start of Main Mall: X: 481887.10; Y: 5456468.12
- Image 4, missing tree behind missing cherry: X: 481888.29; Y: 5456475.53

Image 1. Tree with red berries.

Image 2. Missing tree in front of Pacific Poke.

Image 3. Missing cherry at the start of Main Mall.

Image 4. Missing tree behind missing cherry (*Image 3*).

References

Almas, A., & Devisscher, T. (n.d.). UFOR 101: Analysis of tree inventories. Vancouver, BC.

B.C. Symbols. (n.d.). Retrieved from British Columbia: https://www2.gov.bc.ca/gov/content/governments/celebrating-british-columbia/symbols-of-bc#flower

Holmes, R. (n.d.). *Plant of the Week*. Retrieved from U.S. Forest Service: https://www.fs.fed.us/wildflowers/plant-of-the-week/cornus_nuttallii.shtml

Morgenroth, J., & Östberg, J. (2017). Measuring and Monitoring Urban Trees and Urban Forests. In F. Ferrini, C. C. Konijnendijk van den Bosch, & A. Fini, *Routledge Handbook of Urban Forestry* (pp. 33-48). Routledge.

Nielsen, A. B., Östberg, J., & Delshammar, T. (2014). Review of Urban Tree Inventory Methods Used to Collect Data at Single-Tree Level. *Internation Society of Aboriculture*, 96-111.

Roberta, P. (1948). *Tree Book: learning to recognize trees of British Columbia.* British Columbia.

UBC Inventory Report

2020-02-13

Group 3

K., Finn D., JP O., Lukas M., Nick H., Daniel H., Rowan

I. Introduction

This study is part of an ongoing cumulative class project aimed at providing a detailed tree inventory and report to the University of British Columbia (UBC)s Point-Grey campus. Tree characteristics such as DBH, CBH, and total tree height will be measured and analyzed to determine ecosystem services derived from the assigned plot. The project, when completed, will integrate individual reports, submitted by different groups to create a full tree inventory of UBCs urban forest. The whole process of the complete campus inventory will be collected by small individual plots assessed over the course of multiple terms and student groups yielding multiple reports. These documents provide an integral contribution towards the completion of the UBC Urban Forest Management Plan. Once complete, the inventory data will be used by urban planners, engineers, designers, sustainability experts, etc. involved in UBC campus planning to make changes and design plans moving forward. The tree inventory will also act to provide a baseline of the universitys natural assets, which will play a vital role in its protection and management and help in creating a holistic system approach to address the ecological, cultural and regulating values of UBCs urban forest. This project has been organized by Campus and Community Planning and the faculty of forestry to provide students with applicable field work and bring additional value to the inventory as it is relied upon as an educational resource for UBC students.

Throughout the project, assessing the inventory has provided students with hands-on learning experiences that can be directly applied to an urban forester's work load. This year, the students will be completing phase 1B of the full UBC tree inventory. Students have gained an understanding of standard surveying tools, including laser range finder, DBH tape, measuring tape, and the ArcGIS collectors app. With these tools, students have collected a variety of attributes such as light exposure, DBH, total tree height, crown width, and percent crown missing, among others.

II. Site Description

A. *Selected Area of Campus*

Group 3 had been preassigned an area in Phase 1 Figure:1 partially bound by Main Mall and East Mall, and which dissects several departments Figure: 2. Overall, the buildings located in the area include:

- Fred Kaiser Building
- Civil Engineering and Mechanical Engineering (CEME) Building
- Civil and Mechanical Engineering Structures Lab
- Macleod Building
- Engineering Student Centre

B. *Land-Use*

Land-use type is a combination of institutional, minor commercial, and transport infrastructure with generous areas of open-space between buildings. Buildings offer a vast array of educational facilities including but not limited to, lecture halls,

Fig. 1. Group overviews

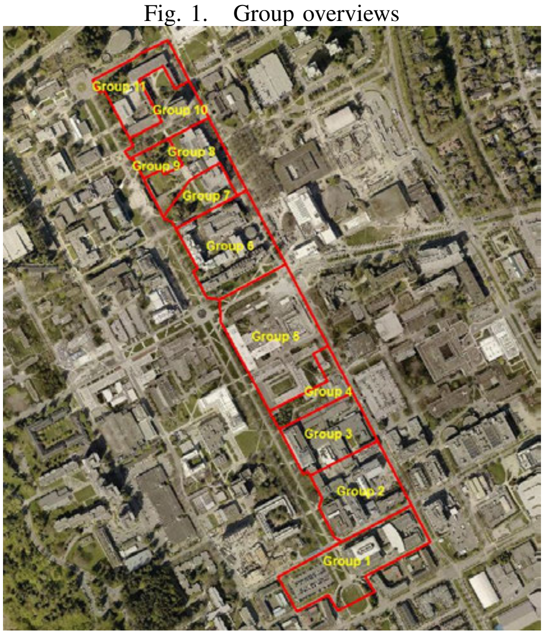
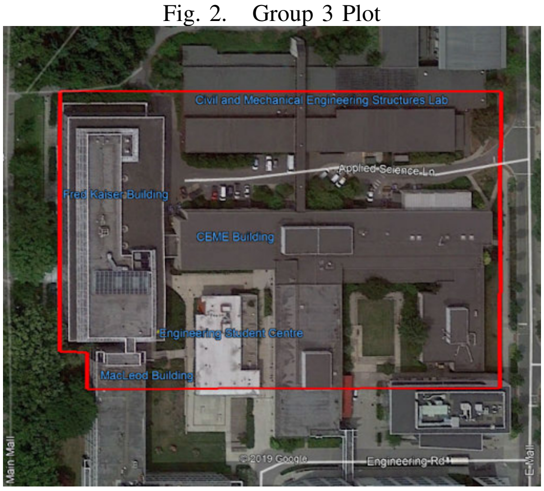


Fig. 2. Group 3 Plot



classrooms, labs, study spaces, student centers, and cafeterias hosting food services. Likewise, primary users of the area are students, lecturers, professors, and researchers with secondary users being recreationalists, visitors, and operations staff. Engineering Road, East Mall, and Applied Science Lane are legal traffic roads within the study area, meaning motorized vehicle presence is not uncommon.

C. Stand Composition

The vast majority of trees on the site were planted in stands or groups. The first group measured was a row of Vine maple (*Acer circinatum*) along the north side of the Fred Kaiser building. These vine maples are next to the stand of Red cedars (*Thuja plicata*), douglas-firs (*Pseudotsuga menziesii*), and spruce (*Picea sitchensis*). This combination serves as a sort of representation of the composition found in Pacific Spirit Park. The row of vine maples, a plant growing multiple stems, is used to cover the side of the building by having a very broad, covering canopy. Next up on the southern side of the Civil and Mechanical Engineering Structures Lab, beginning on the west with a row of 7 common hornbeam (*Carpinus Betulus*). These trees are planted, similar to the vine maples, along the wall but also have a planted hedge in front of them. Suspected to have a similar, view blocking, purpose as the row of maples. On the other side of the corridor, on the the north side of CEME is a small, 3 tree stand, comprised of a serbian spruce (*Picea omorika*), english holly (*Ilex aquifolium*), and a Japanese maple (*Acer palmatum*). This group of trees is special due to the physiology of the leaves. In this area, one can find an evergreen needleleaf (spruce), evergreen broadleaf (holly), and a deciduous broadleaf (maple) boasting a nice variety in shapes and colors. East of this group, 5 more Japanese maples are planted, accompanied by 2 katsura trees (*Cercidiphyllum japonica*), and 1 additional Serbian spruce with dense understory vegetation. Additionally one can find a weymouth pine (*Pinus strobus*) planted alone in the alley. At the edge of the plot along east mall there are 2 sweet gums (*Liquidambar styraciflua*) planted along the road side of the sidewalk. On the building side of the path theres a Scots pine (*Pinus sylvestris*) and north of it there are 2 other needleleaf trees that arent registered on the collector app/inventory list. Continuing down east mall, planted along the street, are 3 European smoke trees (*Cotinus coggyaria*), more Japanese maples, a manna ash (*Fraxinus ornus*), and another weymouth pine. Another group of trees can be found in the courtyard west of the Engineering Student Centre. It entails a very large western hemlock (*Tsuga heterophylla*), Norway maples (*Acer platanoides*), more vine maples, a laurustinus (*Viburnum tinus*), and multiple katsura trees. Also, the passage built by the Engineering Student Center is comprised of additional vine maples and multiple Japanese stewartia (*Stewartia pseudocamellia*). Lastly, there is a single tree that falls into the assigned plot along Main Mall in front of the MacLeod building. It is a large Japanese-cedar or sugi (*Cryptomeria japonica*).

III. Methodology

Our aim for this project was to complete a full tree inventory of plot 3 phase 1B (Figure 2) of UBC's Point-Grey campus. This took place as a multi day field survey from January 30th to February 6th 2020 totalling approximately 10 working hours. A quantitative approach was used in the tree inventory to gather the following information: tree ID number, tag number, living or dead, tree name, land use, height of dbh, total tree height, live crown height, crown width, crown base height, percent crown missing, and crown light exposure. Satellite-based imaging via the Collector app was referred to for each trees location, ID number, and species. With this information, ground-based field surveying was performed using a variety of equipment provided by the UBC Forestry Department. Equipment such as D-tape, measurement tape, and a rangefinder were used to gather the required data outlined above. All data collected was recorded on field inventory cards which later was compiled into an excel workbook for further analysis. It should be noted that 2 trees (with ID tags) on the corner of East Mall and Applied Science Lane were not listed in the collector app; however, the locations and other information was recorded, pending species confirmation.

IV. Summary of Tree Inventory Data

A. Interpretation

Figure 6 shows the species abundance of trees located on the plot. Vine maple (*Acer circinatum*) is the most abundant tree found on said plot, with a total of 19 Vine maples measured. In contrast, 8 tree species appeared only once on our plot. This displays a relatively strong tree species diversity throughout the plot. Also, there is a negative exponential trend from gradient of highest to lowest abundance. Meaning that species diversity decreases exponentially, possibly causing vine maples abundance to appear as an outlier. Vine maple may have become such a popular urban planting around UBCs campus due to its remarkable adaptability, and ability to grow in full sun to deep shade, clay to sand soils, and moderate to dry conditions "Acer circinatum," 2020. The species also produces aesthetic colors in the fall, and its relatively small branches and medium height makes maintenance less challenging. Scots pine (*Pinus sylvestris*), which only was found on the plot once, is most avoided as an urban tree planting due to its high pest and disease susceptibility in combination with its large size "Scots Pine," 2020. If the individual tree were to become afflicted it would pose a large risk to citizens and infrastructure.

Of the 75 trees, the majority fell (around 32 trees) within the 3-6 m height class, with 10 trees being greater than 9 m tall (Figure 5). This suggests that our study area contains relatively small trees, but does not necessarily mean this is due to young age. Many of our trees were inventoried in highly developed areas with minimal greenspace. This type of environment may impede a tree's growth by exposing it to greater stress, minimizing the availability of nutrients and water, and by not providing enough space for grow.

a) Tree Allometry: Figure 4 displays the relationship between the diameter at breast height (DBH) of individual trees and their average crown width. The DBH of the trees on plot 3 were measured at the height of 1.37 meters from the bottom of the ground up the trunk. However, some trees presented physical barriers from measuring at that height (i.e. location, swelling, irregular branching); therefore, DBH for those individuals was modified and the altered DBH height was noted in the data sheet. Average crown width was calculated by taking the long and short side measurements from the bottom of the crown and averaging them. A linear trendline was added to the graph in order to see a more clear relationship between the two. The data shows a clear increasing linear relationship between DBH and average crown height. Meaning, a tree found on plot 3 with a relatively large DBH is also going to have a relatively larger average crown width. This is mostly due to a trees physical makeup and its wood properties. In general, a tree must have enough sapwood available to support water transport to the foliage, and in the process of producing this necessary wood type the tree grows and diameter increases Pretzsch et al., 2015.

Fig. 3. DBH Vs. Basal Area Vs. Tree Count

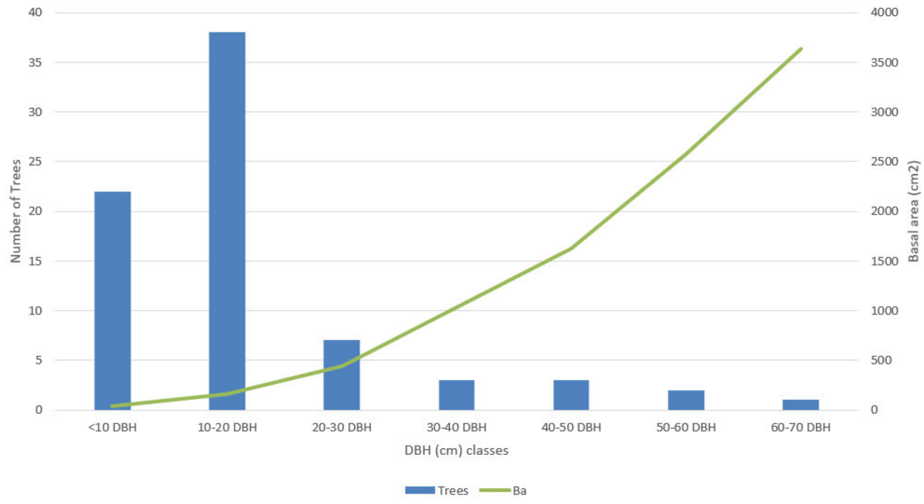


Fig. 4. Average DBH Vs. Crown Width

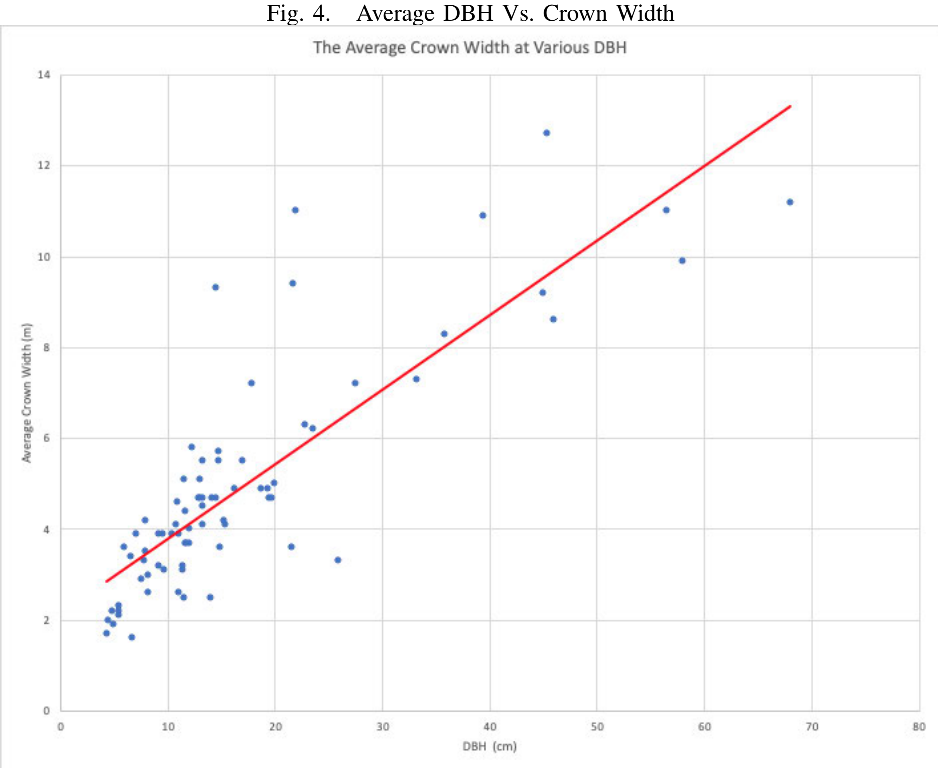
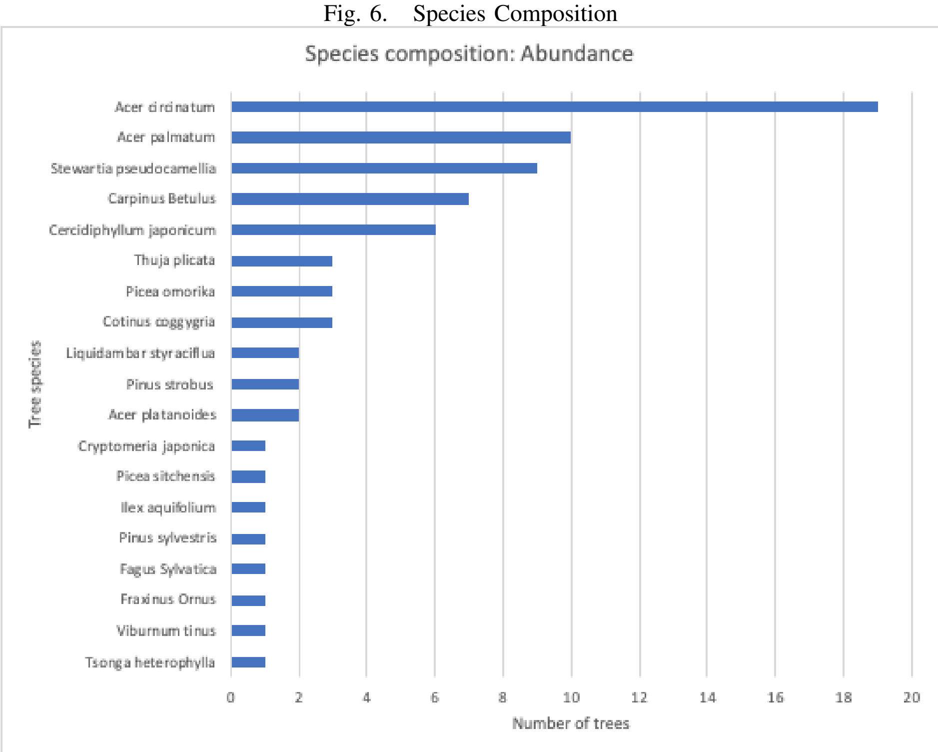


TABLE I

DBH Class (Cm)	Number of Trees	Ba (Cm)
0-10 DBH	22	41.77
10-20 DBH	38	158.92
20-30 DBH	7	440.62
30-40 DBH	3	1031.16
40-50 DBH	3	1623.72
50-60 DBH	2	2574.63
60-70 DBH	1	3631.68

Fig. 5. Tree Height Classes

Fig. 6. Species Composition



The majority of the trees surveyed fell between a range of 0-20 centimeters for DBH, and 2-6 meters for average crown width. This is most likely the result of limited campus spacing for larger trees, the greater risk big canopy trees pose, the lower maintenance costs for smaller trees, and their aesthetic ability to shield attractive infrastructure Bassuk, 2000.

V. CONTRIBUTIONS

Overall, all team members contributed equally to all tasks including report writing, field data collection, report formatting, graph making, and graph interpretations. For field work, all team members rotated between tasks to have exposure to field data measuring and data recording. For desktop tasks, each member was initially assigned a header (Introduction, Tree Inventory, Interpretation, etc.) to start and throughout the assignment, any member added, formatted, and/or removed information to other sections. Our group performed optimally, consistently arranging our schedules and never had any conflicts with time management or contributions. If one member was unable to make a meeting, they always volunteered to work further on other aspects to compensate. A rough breakdown is listed here but due to the complex nature of recording and the large overlap of tasks performed by all members, this list should not be taken as exhaustive.

- 16% K., Finn 87777421:
  - Various measurements
  - Wrote most of ”selected area” and plot descriptions
  - Helped with other tasks
  - Created a graph
- 16% D., JP 72750003:
  - Initiated writing for the introduction, site description, tree inventory, and methodology.
  - Contributed towards interpretations and headings
  - Recorded some field note inventory
  - Primarily measured tree canopy width and length, Crown basal height, and estimated percent missing.
- 16% O., Lukas 20982393:
  - Data tabulation and data recording
  - Document formatting and Bibliography
  - Editing
  - Overall document contribution
  - Helped with tree canopy width and height
  - percent crown missing
  - Navigation
  - Text consolidation
  - Odd Jobs
- 16% M., Nick 49225063:
  - Collected field data
  - Made graphs in excel
  - Edited report
  - Group management
  - Contributed to all sections
- 16% H., Daniel 53154514:
  - Field data collection
  - Formatting
  - Report writing: intro, methodology
  - Data collection
- 16% H., Rowan 91443960:
  - Collected data
  - Performed all field tasks - mainly DBH, short/long width
  - Recording and app navigation
  - Helped clean up tabulated data
  - Contributed to writing
  - Graph Interpretation

REFERENCES

Acer circinatum. (2020). Retrieved from http://www.greatplantpicks.org/plantlists/view/30

Bassuk, N. (2000). *Recommended urban trees: site assessment and tree selection for stress tolerance*. Cornell University.

Pretzsch, H., Biber, P., Uhl, E., Dahlhausen, J., Rfffdfffdtzer, T., Caldentey, J., … Pauleit, S. (2015). Crown size and growing space requirement of common tree species in urban centres, parks, and forests. *Urban Forestry Urban Greening*, *14*(3), 466–479. doi:10.1016/j.ufug.2015.04.006

Scots Pine. (2020). Retrieved from https://www.mortonarb.org/trees-plants/tree-plant-descriptions/scots-pine-not-recommended

Assignment 1:
Urban Forest Inventory & Assessment
Group 4: Phase 1E3

Submission Date: February 13, 2020

<u>Contributions Page</u>

1. Alerik Wang

-Field: Measured total tree height, live crown height & crown base height

-Written Report: Methodology (Analysis)

2. Kirsty Rude

-Field: Measured Crown Width

-Written Report: Summary (Results, Figures, Interpretation)

3. Maria Luna Santacruz

-Field: Measured CLE & Crown % Miss

-Written Report: Summary (Results, Figures, Interpretation)

4. Odelia Law

-Field: Measured Crown Width, Recorded & inputed all collected data

-Written Report: Methodology (Collection)

5. Rebecca Liu

-Field: Measured Crown Width & CLE

-Written Report: Introduction

6. Roberta Gonzalez

-Field: Measured total tree height, live crown height & crown base height

-Written Report: Summary (Results, Figures, Interpretation)

7. Zahra Sow

-Field: Measured DBH & took pictures of trees not listed in the ArcGIS Collector -Written Report: Site Description

1. Introduction

A complete inventory was conducted on the site assigned and focused on, phase 1E3, within the larger area, phase 1B. The purpose of this inventory is to gain valuable skills in fieldwork as urban forestry students, but also to collect data that will be saved, and later used, in the management and protection of UBC trees. Variables measured include crown light exposure, tree height and DBH.

End users of phase 1E3 encompass those who wish to take a shorter route from Main Mall to the UBC hospital and surrounding areas, as well as drivers of vehicles. Within our site are two distinctive types of areas; a dense, forested area found in between pathways, named Fairview Grove, and an area in which the trees line the sides of the pathway in a relatively organized fashion. Fairview Grove provides less social value to end users due to its density and location in between paths, as the trees are less visible and harder to access. This area, however, warrants an increased possibility of pest damage, from the closeness of each tree to another. The latter area has an increased social value by end users from the clearer visibility of the trees, giving this area a more aesthetic purpose than the previous one.

2. Site description

Most of Group 4's, Phase 1E3's site location is situated in the area on the UBC campus called Fairview grove. It is located in a small area between the Beaty Biodiversity Museum and the Fred Kaiser building. A grove as recognized by Gill in the case of study of Nagele, is identified in modern landscape architecture as "an independent spatial type in which trees are grouped densely relative to their surroundings and has been used in addressing deficiencies of form, function and experiential quality in contemporary cities" (Gill, 2018). In this context, the grove that was analyzed on campus serves the purpose of enhancing aesthetics for the surrounding buildings, increasing greenery as well as promoting physical activity.

The trees present in the grove vary from Douglas fir, Pacific red cedar, Red alder, American sweetgum and many others. In addition to the grove, the location for group 4, phase 1E3 extended to an alleyway alongside the Beaty Biodiversity Museum and Civil and Mechanical engineering structures building, reaching all the way onto trees bordering the sidewalks of East Mall. This area of the plot however vastly differs from the grove in the sense that the trees along the sidewalks have wider spaces between each other. The tree species are more uniform as well as the majority consist of American Sweet Gum.

Figure 2.1 Fairview grove

Figure 2.2 View of East Mall

3. Methodology (Collection)

The site location for Group 4, Phase 1E3, was first analyzed visually through the use of the application, ArcGIS Collector Classic, to determine where our plot started and ended and which trees were included in our section. The group started from the densely forested area, called Fairview Grove, and continued measuring heading northeast towards East Mall. Since the grove was relatively dense in trees and was difficult to keep track of, a sketch of that grove was created. The trees were then approached and measured systematically.

The basic tree description was conducted including: the ID number of the tree, the tree tag number, whether the tree is alive or dead, the species of the tree, and the land use where the tree is situated. The ID number of the tree was determined through ArcGIS Collector, which provided an unique identifier for the particular tree (indicated by a green dot) based on the GPS location on the map. The tree was checked to determine if there was tag, if there was, the tag ID number was recorded. The species of the tree was determined through the ArcGIS Collector and whether or not the tree was alive or dead was also indicated. If the species of the tree listed on ArcGIS Collector did not match the tree, a comment was made on the plot inventory table. The land use of the tree location based on i-Tree Eco categories was determined; in this instance, all trees were considered to be institutional (I).

The tree stem diameter at breast height (DBH) was measured using the diameter tape. Only trees that had a DBH greater than 1 inch were included in the inventory, unless that particular tree was already identified on the ArcGIS Collector. The measurement was taken at 1.37 meters above the ground from the uphill side of the tree. The height at which it is measured is recorded (HT DBH) only if the DBH was not measured at 1.37 meters. If the tree has multiple stems, the DBH of up to the 6 largest stems is measured and calculated using the following equation: Overall DBH= the square root of the sum of all squared stem DBHs.

The laser rangefinder is used to estimate the tree height using the three-point measurement method by standing at least 10 meters away from the tree on a level area. The total tree height (height from the ground to the top of the tree), height of the live crown and crown base height (height from the bottom of the live crown to the ground).

The crown width is measured in two directions: the long side and the short side. The crown percentage missing is the percent of the crown volume that is not occupied by branches and leaves. The crown percentage is recorded as a range in increments of 5%, for example, 5-10% and 25-30%. The crown light exposure (CLE) is the number of sides of the tree's crown that is receiving light from above or the side. This measurement is determined by dividing the tree into 5 quadrants: the top of the tree and dividing the crown vertically into 4 sections. The number of sides that would receive sunlight will be the CLE.

Methodology (Analysis)

Figure 3.1 Tree id tag: 11.030

Figure 3.2 Tree id: 4906

Figure 3.3 Tree id tag: 11.034

The quantitative data collected can be presented and analyzed in many ways and used to show the relationships between different variables. We can track plot cover, Species abundance, Species Dominance, etc. While also comparing the relationship between missing crown % and light exposure or look at how the size of dbh is directly correlated with the total tree height. We also pointed out some trees of interest in our qualitative data. Cultural importance, and other ecosystem services, as well as future growth were points of interest here. There were some issues when it came to the collection of our quantitative data. Trees with the id tag 11.030, and 11.034 were not on the app, so we needed to take GPS coordinates for them. Tree 17 turned out to not be a tree, but it was actually a shrub. GPS in general was inconsistent in the denser areas and some trees were mislabelled. Measurement using the laser rangefinder was difficult in denser areas as well, and at times it simply wasn't possible to confidently get an accurate reading of the tree heights. Some other minor obstructions included weather, however that did not impact the data collection significantly.

4. Summary (Results, Figures, Interpretation)

Plot Land Cover

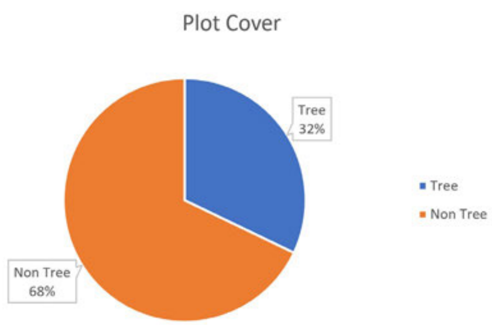


Figure 4.1

As mentioned, plot 1E3 has multiple land types and uses within its borders. To break this down into simple, easy to use data, we have presented a pie chart and a table displaying this. The percent data has been determined using i-Tree Canopy estimates. We used 110 sample points in our i-Tree analysis to obtain the most accurate data possible. Land cover was broken down into 5 categories when identified, the categories are as follows: Trees, Shrubs, Grass, Buildings, and Walkways / Roads. Tree cover was identified as being less than half of our plot area, at a value of 32.1% (please keep in mind that this data has an error range, this range can be viewed in the accompanying table (figure 4.2), while building cover came in at 42.2%. The remainder of the area is covered by 15.6% walkways and roads, 3.67% shrubs, and 6.42% grass. However, because this data has been determined with the use of i-Tree Canopy, this is the coverage of the land at a birds-eye view, it does not account for anything that is under the canopy of a tree, or covered by any other object.

Land Type	Trees	Shrubs	Grass	Buildings	Walkways & Roads
Percent Cover (%)	32.1 ±4.47	3.67 ±1.83	6.42 ±2.43	42.2 ±4.73	15.6 ±3.48

Figure 4.2

Species Composition

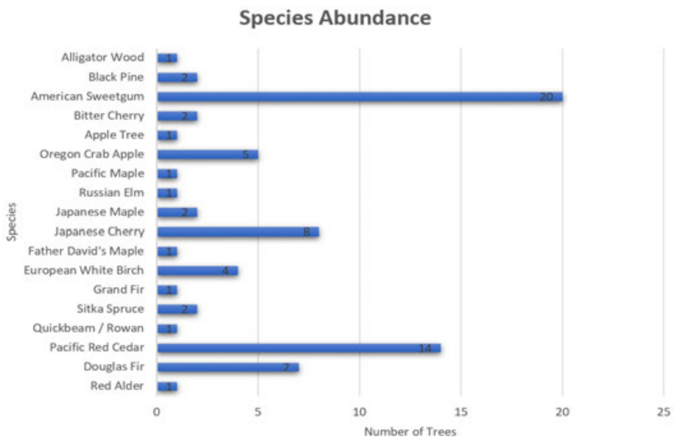


Figure 4.3

Figure 4.3 showcases the species abundance in our plot. This was completed by taking a tally of the number of trees that belong to each species listed in the attached Inventory Data Table. This representation includes live and dead trees. As can be seen in the graph, the most abundant species were the American Sweetgum with 20 trees, the Pacific Red Cedar with 14 trees, and the Japanese Cherry with 8 trees.

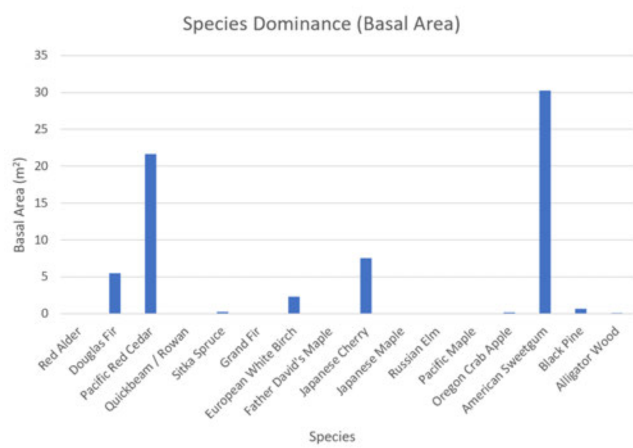


Figure 4.4

Figure 4.4 shows the basal area of each tree species. The basal area is the area of the plot that is covered (in m^2). This graph was constructed by totaling the DBH for each species, then inserting that into a simplified basal area equation - $BA = pi(DBH)^2/40{,}000$ where BA represent the basal area, the DBH represents the total DBH of each species (in cm), and the division by 40,000 includes a conversion factor to convert cm to m^2. To summarize the result of this graph, the two most abundant species, the American Sweetgum and the Pacific Red Cedar cover the most basal area due to their large quantity. It can be seen here that, in general, basal area increases with species abundance.

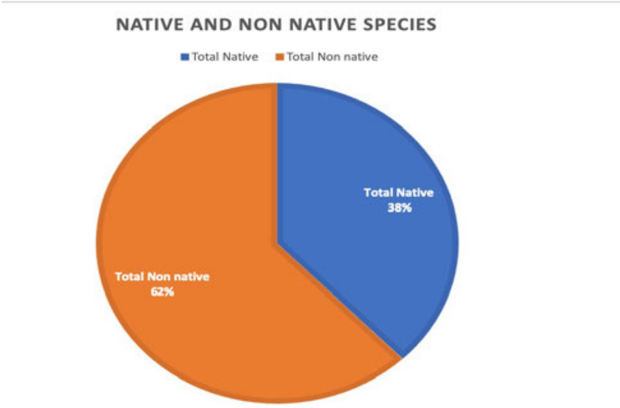


Figure 4.5

Figure 4.5 displays the ratio of native trees to non-native trees. This was done by counting the frequency of tree species that are native and non-native. According to a BC Nature report on native and non-native species, the Native portion is comprised by: Grand Fir, Red Alder, Sitka Spruce, Bitter Cherry, Pacific Red Cedar, Douglas Fir, and Pacific Maple. While non- native species include: Quickbeam / Rowan, European White Birch, Russian Elm, Japanese Cherry, Japanese Maple, Father David's Maple, Apple Tree, Alligator Wood, Black Pine, American Sweetgum, and Oregon Crab Apple.

It is worth mentioning that the Pacific Red Cedar constitutes 50% of the native trees in the plot. Furthermore, this species is recognized due to its ability to grow at an extremely fast pace, this is likely to be one of the reasons why this species is so abundant in this plot. Given that 15% of the plot are walkways and roads, shade is an important ecosystem service that can improve the experience of the users of this area, not to mention that shade is one of the characterizing features of this species, as it can grow up to 60 m tall. Thus, rapid growth is a Figure 4.5 desirable feature in the planted trees. Another abundant species is the Douglas Fir. These trees comprise 25% of the native trees present in the plot. This species shares many qualities with Pacific Red cedars in terms of the amount of shade they provide, however, this species has the added benefit that they have good soil-binding roots. This is a desirable quality since it helps reduce risk of erosion in soil, which the soils in this plot are highly prone to given the high traffic of pedestrians, especially around areas such as Fairview grove.

Crown Fullness

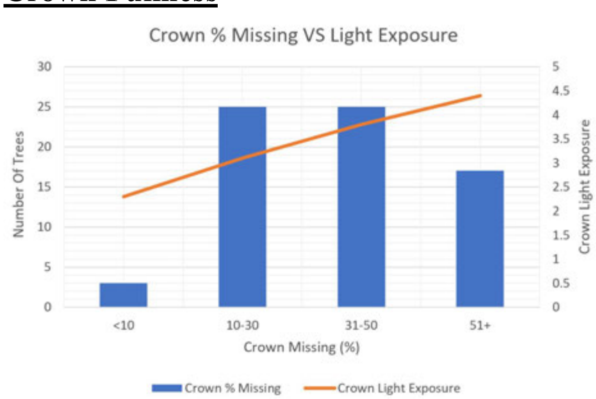


Figure 4.6

Figure 4.6 shows the data for the number of trees that have a certain percent of crown missing, as well as the number of trees that have a certain crown light exposure. The percent of the crown missing and the crown light exposure are also compared on this graph. Most trees have an intermediate amount of the crown missing, being between 10% and 50%. As can be seen, there is a direct relation between the amount of crown a tree is missing, and the amount of light exposure it receives; the more crown a tree is missing, the more light exposure. This graph was constructed by creating classes of the percent of crown missing, then totaling the number of trees that reside within that class. Then, the trees in each class's crown light exposure was totaled and averaged for each class of percent crown missing (this is the reason for the crown light exposure being to one decimal place).

DBH & Total Tree Height

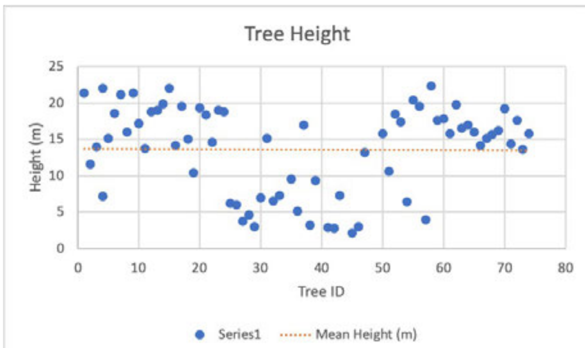


Figure 4.7

The mean height for the trees in this plot is 13.74m. The Standard deviation for this data set is 5.982m. This means that there is considerable variation in the heights of trees from the mean height. Such heterogeneity may be due to a) age of tree or b) species of tree. The grouping of the data into clusters (as shown in figure 4.7) is most likely due to species characteristics rather than age.

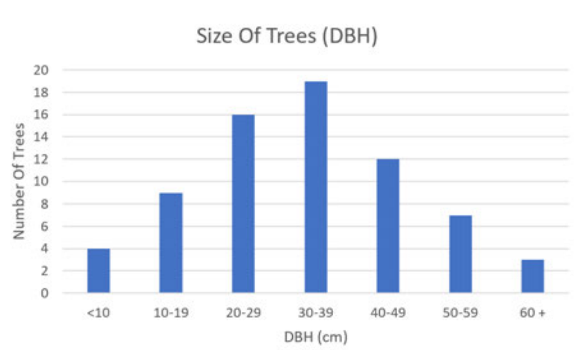


Figure 4.8

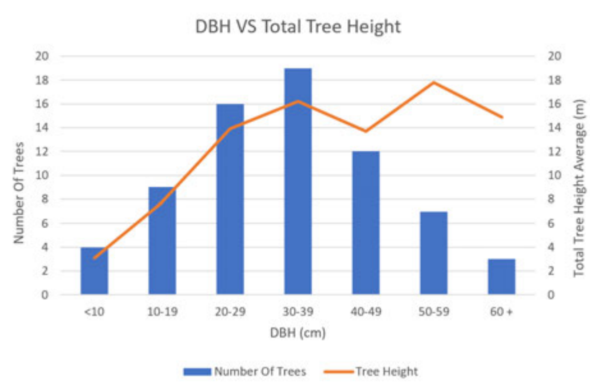


Figure 4.9

The DBH of the trees in our plot is shown in figure 4.8. This graph shows the relationship between the DBH and the abundance of trees. From this graph, it is seen that the most common DBH of a tree in our plot is 30-39cm. Trees on the extreme ends (<10 DBH and 60+ DBH) of this spectrum are considerably less common. Although, it may be worth noting that DBHs less than 10cm are slightly more common than those with 60+ cm DBH.

This graph (figure 4.9) is showing the relationship between the DBH of trees and their total height. The blue bars represent the DBH classes and the number of trees they contain, and the orange line represents the average tree height of each class. This was done by totaling the total heights of all of the trees in each DBH class, then averaging it. Generally, the larger the DBH of a tree, the taller it is. Two exceptions of this on the graph are at the DBH class of 40-49cm and the DBH class of 60+cm. The total height of the trees in these classes is smaller than that of the lower class. This is possibly due to the species that dominates each DBH class. Perhaps most of the species in the 40-49cm DBH class are of a species that commonly has that DBH associated with the graphed height (13.7m). It is also possible that this DBH class has a large rage of tree heights associated with it, leading to an intermediate average.

Trees Of Interest

Scientific name: Acer davidii, commonly known as Father David's maple is a species of maple belonging to the snakebark group (see figure 4.10).
It brought to our attention its remarkably green pigmented trunk and branches, which are assist in the process of photosynthesis. This photograph was taken during our data collection which was carried out in winter season, where all its leaves had fallen. However, after further research, we found that not only its bark has aesthetic attributes, but also its dark green leaves (Emery, 2019) amongst other more commonly lighter coloured maples.

Figure 4.10

In the plot we assessed the tree with most cultural importance would most likely be the great Western Red Cedar which held many attributes and uses to the First Nations Indigenous communities of the Musqueam peoples which used it to make canoes, baskets with its inner trunk, accessories, art and several other items.

References

Appreciation: - Peter Gregory's Maple Profiles: Father David's Maple, Acer davidii. (n.d.). Retrieved from https://forums.botanicalgarden.ubc.ca/threads/peter-gregorys-maple-profiles-father-davids-maple-acer-davidii.96530/

BC Nature. (n.d.). PDF. Retrieved from https://www.bcnature.ca/wp-content/uploads/2015/03/Appendix2.pdf

Kamni Gill (2018) The grove as an urban tree planting type: The case of Nagele, Studies in the History of Gardens & Designed Landscapes, 38:4, 269-292, DOI: 10.1080/14601176.2018.1465273

The Plant List - A working list for all plant species. (n.d.). Retrieved from http://www.theplantlist.org/tpl1.1/record/kew-2615577

Inventory Report

Group 5

February 13, 2020

Contribution page

Anna Tian [redacted]
-Introduction; the specific northern red oak in front of UBC bookstore
Hui Chen [redacted]
-Methodology; DBH Analysis; Crown Width Analysis
Yiqi Yan [redacted]
- Site description; Species Analysis; Potential Future Growth of Trees
Yongfei Pan [redacted]
- Methodology; DBH Analysis; Crown Width Analysis
Yufei Zhu [redacted]
-Site description; Species Analysis; Potential Future Growth of Trees
Zhiyi Lin [redacted]
-Site description; Height Analysis; Potential Future Growth of Trees

1. Introduction

The purpose of tree inventories can vary due to multiple uses of different areas. Management of any resource begins with an inventory of that resource. The planning of inventories can break down into three categories: schedule planting, maintenance and removal activities; Prioritize tree work to be done such as risk managing; Last but not least, developing plans, strategies, and budgets. These assessments help identify urban forest conditions such as species and diseases, as well as evaluating tree performances including their biological factor. Inventories can also assess ecosystems services like the benefits we get from trees, which is mainly the reason why we do all these works of planting the trees and evaluating them.

The results of the inventories lead to different end-users and interest. Obviously, the authorities have highly use of these data in order to improve management, make better economic decisions, and to inform future plans. Researchers also play a role in assessing the environment, focusing on the social and economic aspects the trees provide. Lastly, citizens that are directly affected by these urban forests are also one of the end-users because they form micro-communities within the urban area which contribute to the formation of the linkage between forests and urban areas.

2. Site Description

Our inventory zone is roughly located at the middle of the UBC, and is surrounded by the University Blvd, Main Mall, East Mall and south of the Beaty Biodiversity Museum. North corner of this zone is the intersection of the University Blvd and East Mall within the school.

In this area, there are some representative facilities and buildings. UBC Bookstore (Figure 1) is a commercial place for supporting students' success by providing innovative products and services. Furthermore, this area includes Corner Store and Starbucks, where visitors can purchase souvenirs as well as enjoying the sceneries with a warm cup of beverage in their hand. Beaty Biodiversity Museum (Figure 2) is a fascinating building containing spectacular biological collections for visitors and students to acknowledge of biodiversity. Some buildings standing here are for academic research for students and professors, including Biological Sciences Building, Michael Smith Laboratories, Aquatic Ecosystems Research Laboratories and Food, Nutrition, and Health Building. AbCellera is a biotechnology company mainly for experts working.

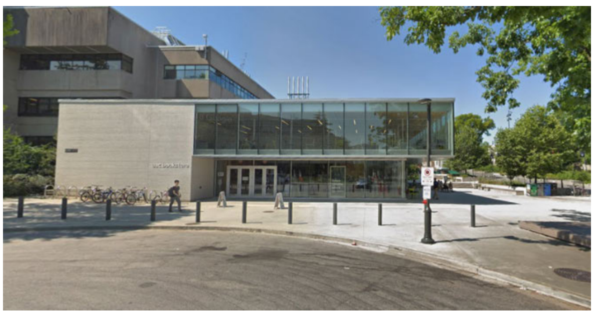


Figure 1 UBC Bookstore. ("Google Maps", 2020).

Figure 2 Beaty Biodiversity Museum. ("Google Maps", 2020).

With the help of i-Tree Canopy, Table 1 presents the cover assessment of this zone. We conclude that the major area of our zone is for institutional services, which accounts for about 50.0%. The green space covers about 22% of the whole zone, of which trees, shrubs and lawns accounts for about 8.00%, 7.33% and 6.67% respectively. They are mainly planted around the buildings and along the streets, providing aesthetic and ecological values. The transportation area accounts 11.3%, including roads and parking lots. University Blvd (East Mall to Main Mall) as one of the most important roads with a large population flow in this zone was renovated in the summer of 2019. As for commercial area (2.33%), UBC Bookstore, Starbucks and Corner Store are the main components.

Cover Class	Points	%Cover
Trees	24	8.00±1.57
Shrubs	22	7.33±1.51
Lawns	20	6.67±1.44
Commercial	7	2.33±0.88
Institutional	150	50.0±2.89
Transportation	34	11.3±1.83
Other	43	14.3±2.02

Table 1 Cover Assessment

3. Methodology

There are two types of inventory that can be classified by different ranges in our research. As for the whole campus, we did a partial inventory which measures all trees in a particular area of the campus. It creates a complete inventory and provides accurate data, but just for a specific area. However, it is a complete inventory which provides comprehensive data for all of the trees' situation within this zone.

We selected a ground-based field survey method to collect the inventory data. We inspected the trees and did direct measurement with different kinds of tools because the position data was supported by a GPS navigation app (Collector), it was also an Urban vegetation Survey (Nielsen, Östberg, & Delshammar, 2014). The Collector app provided tree species and numbers. We used the diameter-tape at 1.37 m above the ground on the uphill side of the tree to measure the DBH. We measured the DBH of up to six largest if there are multiple stems separately. For the tree height, we used the laser rangefinder to estimate it, standing more than 10 meters away from the trees. Then we used tape measure to gauge the long and short length of the crown width. i-Tree was the tool that helps us to estimate the percentage of trees and shrubs in the zone.

Figure 3 Laser rangefinder

https://www.monumentaltrees.com/en/content/measuringheight/

Figure 4 Diameter-tape

https://www.midwestarboristsupplies.com/product/diameter-tape-fabric-20/

Figure 5 i-Tree

https://www.itreetools.org/

After we finished the collection of data, we used Excel to organize the data and draw the graphics. The bar charts compare the amounts of trees, while the line chart illustrated the trends of the data. In order to predict the growth of trees in this zone, we used the urban tree database and allometric equations from United States Department of Agriculture (USDA). We calculated the variables including height, crown base height and crown width by the given coefficients and equations, such as quad, cub, loglogw1 (McPherson, van Doorn & Peper, 2016). As for the reference region, the pacific northwest region with the environmental conditions which are the most similar to Vancouver's, is the optimal choice. However, because in this region, we could not find the relevant data about the tree species we chose to make prediction, eventually we made the northern California coast as the secondary choice.

The following variables are what we recorded: Tree ID, Tag ID, living status, species, land use, diameter at breast height (DBH), tree heights, crown width, crown missing and crown light exposure (CLE).

4. Summary of Tree Inventory Data

4.1 Species Analysis

Figure 7 presents the amount of each tree species and their main basal area in this zone. From the statistics, the number of trees and their basal area are not directly proportional or inverse ratio. However, we can clearly find that Black Pine and Japanese Maple are the two most abundant species with the highest number of trees and largest basal area, reflecting that they are the dominant species in this zone. As dominant species, they might be more competent in extracting resources, resisting diseases or deterring competitors or predators than other species ("Dominant Species in a Diverse Ecosystem," n.d.). Norther Red Oak, as a native species, its number is much smaller than the former two invasive species. We assume several reasons to explain why UBC urban forestry management planners have decided more non-native species in this zone. Firstly, some cases show that non-native species are better at providing desired ecosystems in urban environments (2011). Secondly, they can grow quicker and require minimal maintenance (2010).

Figure 6 Northern Red Oak ("Google Maps" ,2020)

However, Northern Red Oak still has representative effect and historical meaning because of its a large basal area (0.261m^2). For example, in front of UBC Bookstore, a huge Northern Red Oak (Figure 6) surrounded by wooden blocks that created a resting area with large canopy for people. What's more, this oak tree provides aesthetic value within the focal point in this area. As we did more research of this specific tree, we found out that this tree was named in recognition of Raymond Lee's support to UBC. Lee has spent a lot of time and finance on finding methods to develop and protecting environments. He donated about $5 million to support UBC and about half of the money was used on enhancing this square. Just a little touch on the fact that he graduated from UBC and is one of Hong Kong's leading philanthropists, donating more than ¥110 million to charities in China, and devoted his time and skills to promoting the government committee and non-profit sectors.

Cornelia-Cherry has the smallest basal area, assuming the life of this species is younger comparing with other trees, and there is only one Black Tupelo, one European White Birch and one Quick Bean.

Species	Number	Basal Area
Northern Red Oak	2	1.51
Alligator-Wood	2	0.32
Cornelia-Cherry	5	0.02
Robinia Pseudoacania Frisia	4	0.05
Black Tupelo	1	0.03
European White Birch	1	0.02
Black Pine	16	2.87
Japanese Maple	16	2.23
Tulip poplar	2	0.17
Quick Bean	1	0.01
False Acacia	3	0.05
Three-Thon Acacia	5	0.05
Flowering Dogwood	2	0.02
London Plane	6	0.24

Table 2 Species Analysis

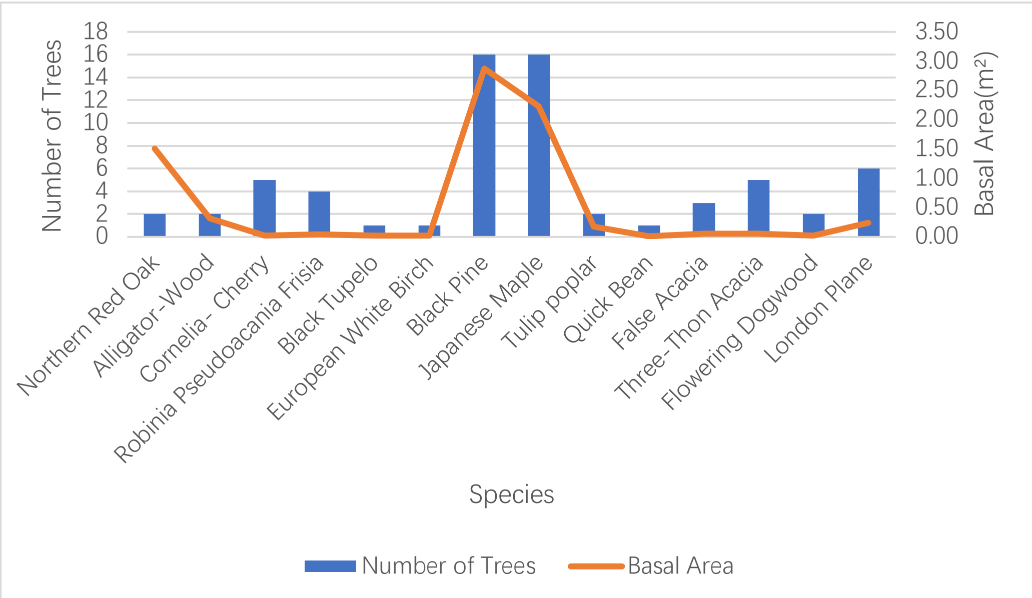


Figure 7 Species Analysis

4.2 DBH Analysis

Figure 8 illustrates that the number of trees whose DBHs are between 10cm and 30cm is the largest, while there are only two trees whose DBHs are between 70cm and 90cm. The number of trees with a DBH between 10cm and 30cm stands a larger quantity than the former one. The basal area of the trees with a DBH between 30cm and 50cm is the largest, and the smallest groups are the trees with a DBH less than 10cm.

We can discover that the number of trees with a DBH between 50cm and 70cm is few, as well as the categories of trees with 70cm to 90cm DBH. However, both have relatively large basal area. We suppose the cause of this situation is that these two categories of trees have long DBH so that each individual tree has a larger basal area comparing with other categories. With the same reasoning, although the number of trees with DBH less than 10cm is more than those two categories mentioned above, their basal area is the least because of their short

DBH.

DBH (cm)	Trees	Basal Area (m^2)
<10	9	0.04
10-30	41	1.22
30-50	11	1.33
50-70	3	0.95
70-90	2	1.10

Table 3 DBH Analysis

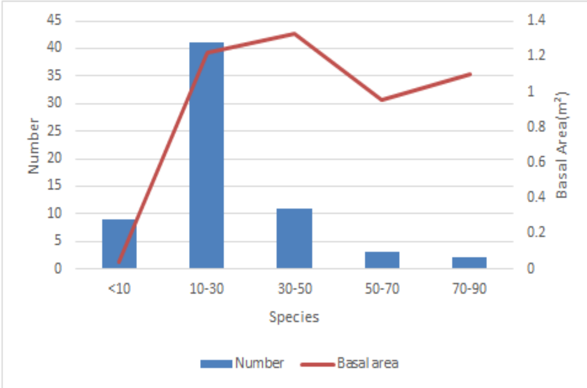


Figure 8 DBH Analysis

The average of DBH is 24.5 cm, and the standard deviation is 17.2 cm. According to Figure 9, we can find out that the DBH of trees were mainly around 10cm-30cm, except for some thick, old trees.

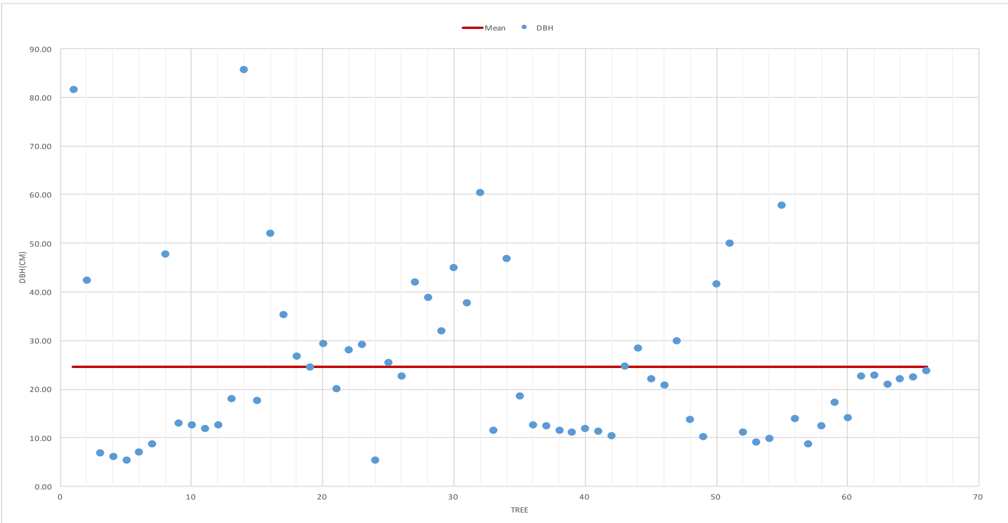


Figure 9 DBH and Mean Line

The DBH of Northern red oaks are around 80 cm, which are relatively larger than other species in this zone. There were some Cornelia- Cherry trees near the bookstore. We assume that these trees were planted not long ago due to the small DBH which was less than 10 cm. Robinia Pseudoacania Frisia trees' DBH are around 10 cm. We think these trees were planted at the same time with the Cornelia-Cherry because their DBH are similar. Noticing more, we consider the trees (Three-Thon Acacia) near the Beaty Biodiversity Museum were also planted at the same time due to their similar DBH. In general, same tree species was planted synchronously in a specific area.

4.3 Height Analysis

By analyzing the data, we get that the average height of all the trees in this zone is 9.7 meters, and the deviation is 5.5 meters. According to Figure10, it simply shows that the height of most trees is between 5 and 10 meters, and only 3 trees are more than 20 meters high. It illustrates that the trees in this zone are generally in small and medium height. The trees whose mature heights are less than 30 ft. (about 9 meters), are often recommended to be planted in downtown area where soil and space is limited (Gilman & Sadowski, 2007). It can be considered as a rational reason to explain the result, because the area where we conducted the inventory is the core zone of UBC campus. It's a highly functional zone with institutional and commercial buildings and arterial roads. The high density of constructions and the large cement surface area resulted in trees with small to medium height an appropriate choice for planting in this zone. On the other hand, planting high trees within this area with a large population flow will increase the risks of falling branches, workload and difficulties of pruning.

Height (m)	Number of Trees
<5	14
5-10	27
10-15	11
15-20	11
20-25	2
25-30	1

Table 4 Height Analysis

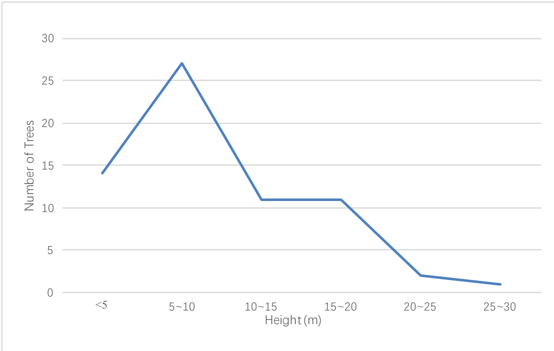


Figure 10 Height Analysis

However, combining the species and location of trees with our observation during the inventory, we find that some trees are still in juvenile stage, which might be another factor for our result. For example, the London planes is a species that can grow to 20-30 meters, exceptionally over 40 meters tall (Wikipedia contributors, 2020), but the row of London planes on the UBC Blvd, all of them are about 11 meters tall. They are not mature, and still in the crucial growth period. Besides, we find that other groups of trees, such as the London planes on the UBC Blvd. and three-thon acacias near Aquatic Ecosystems Research Laboratory (AERL), grown evenly with a relatively small deviation of height. It can be

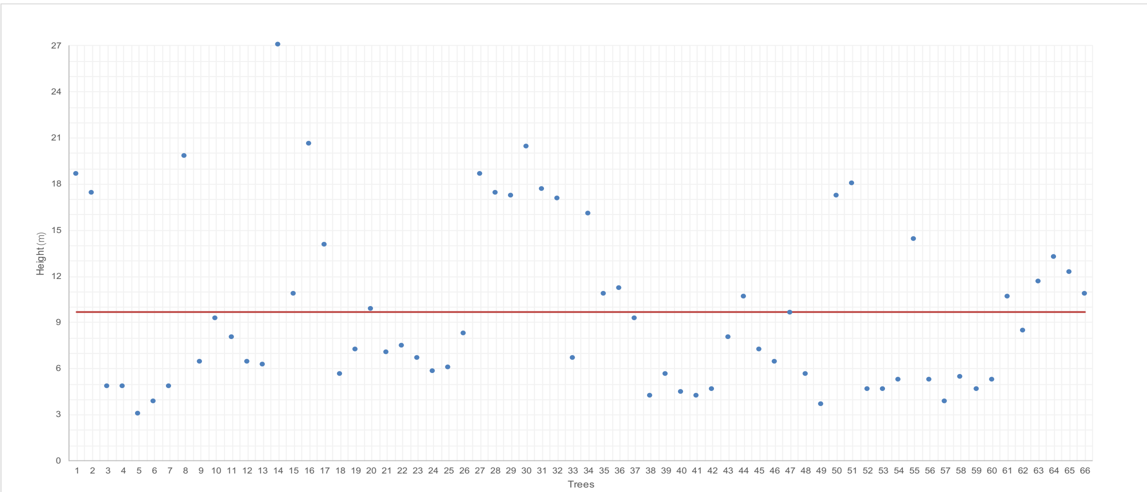


Figure 11 Tree Height and Mean Value

inferred that these trees in one group were planted at a same time and grows at a similar rate, which can provide people with a sense of unity and harmony. There are still a few relatively tall trees in this zone, like the northern red oak at the conjunction of Biological Sciences Road and E Mall (the highest one) and some near the UBC bookstore. These trees are usually considered as a landmark, planted separately rather than densely with other trees.

4.4 Crown Width Analysis

We used volume equation (1)("Tree crown measurement", n.d.) and crown shape ratio equation(2)(Martin-Ducup, Schneider, & Fournier, 2018) to calculate the volume of every species with their crown width.

Crown volume=($\frac{\pi \cdot (\text{crown shape ratio})^2}{4}$)×(crown thickness)×(average minimum crown spread)^2 (1)

Crown shape ratio (Cr%): Crown length /tree height (2)

As the result, the volume of Northern Red Oak is the biggest, which is 9340.86(m³), while the volume of Flowering Dogwood is the smallest, 24.57(m³), in this zone.

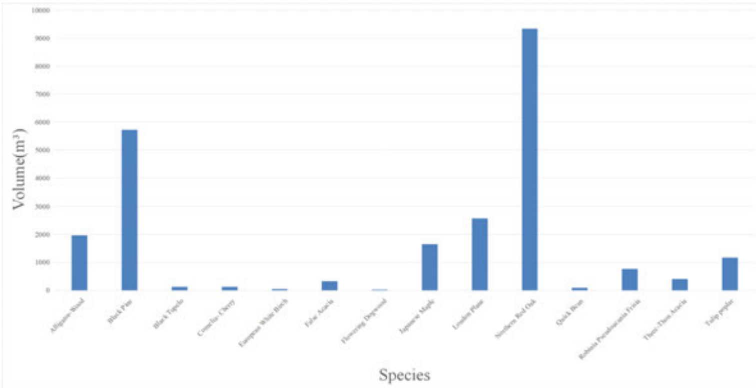


Figure 12 Crown Volume

4.5 Potential Future Growth of Trees

Using the the urban tree database and allometric equations, we made the analysis and prediction of the growth of the trees. However, because of the limited subjects and data, we can not make an overall future scenario and propose strategic methods to manage the green space.

In terms of specific species, there are six London Plane located on the University Blvd, we combine with the limited data, and conclude the future growth of these trees. The average height of these trees is 11.13m, and based on the Figure 13, we can estimate their age is 17 and in their adult. After the seventeenth year, the increase rate of crown base height is getting lower, which means that the current nutrient, space and soil are enough for them to grow.

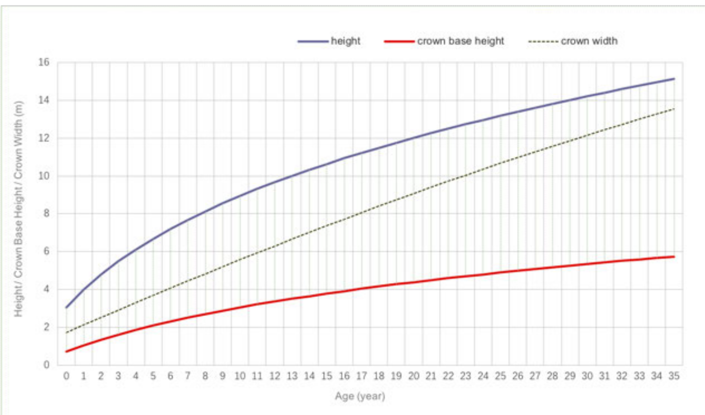


Figure 13 Future Growth of London Plane

There are four Robinia Pseudoacania Frisia on the East Mall (Figure 16), their average height is 7.5m, according to figure 15, their age is around 12 and in their juvenile. They will grow fast after several years according to the curves. However, we find the spaces between these trees are narrow that will impede their future growth. And the roads will be cracked by underground root.

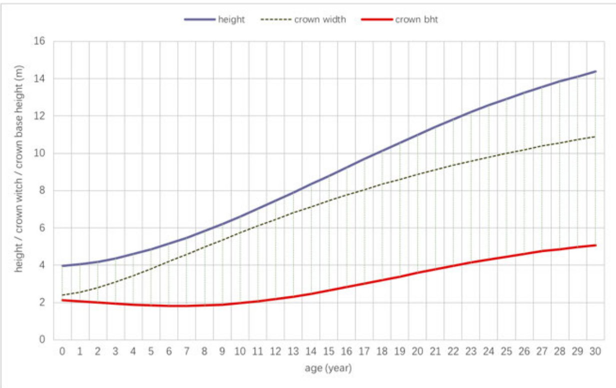


Figure 14 Future Growth of Robinia Pseudoacania Frisia

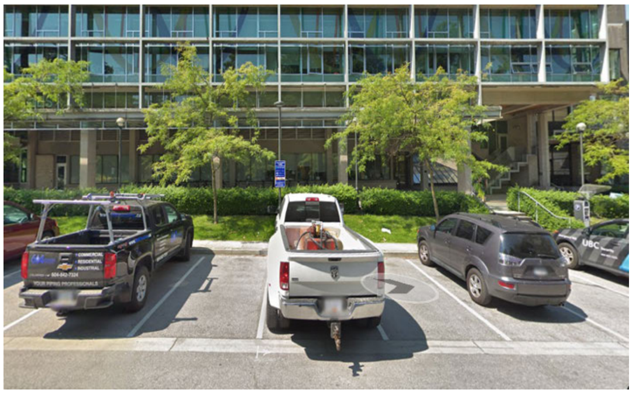


Figure 15 Robinia Pseudoacania Frisia ("Google Maps",2020)

Because of the lack of data in the database, we cannot calculate to get predicted height data of five Cornelia-Cherries. However, according to their growing environment we find some challenges that they may face in the future. Because of planted densely, we assume that they will compete each other for more soil, nutrition and spaces. This dysfunctional competition will be detrimental to their growth.

5.Summary Data

	Number	Mean	SD
Tree	66		
Living tree	66		
Dead tree	0		
Species	14		
DBH (cm)		24.5	(±17.2)
BA (m^2)		0.07	(±0.11)
Total height(m)		9.7	(±5.5)
Crown base(m)		2.3	(±1.6)
Crown width(m)		6.7	(±3.0)
Canopy missing			
<10%	36		
10-30%	20		
31-50%	8		
>51%	2		
Crown light exposure			
0	2		
1	9		
2	8		
3	20		
4	2		
5	0		

Note: DBH: diameter at breast height; BA: basal area

Table 5 Summary Data

Reference:

Dominant Species in a Diverse Ecosystem. (n.d.). Retrieved from https://education.seattlepi.com/dominant-species-diverse-ecosystem-3936.html.

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental Pollution,*159(8-9), 2078-2087.

Gilman, E. F., & Sadowski, L. (2007). Choosing suitable trees for urban and suburban sites: site evaluation and species selection. University of Florida, IFAS Extension.

Martin-Ducup, O., Schneider, R., & Fournier, R. (2018). Analyzing the vertical distribution of crown material in mixed stand composed of two temperate tree species. Forests, 9(11), 673. doi:10.3390/f9110673

McPherson, E. G., van Doorn, N. S., Peper, P. J. (2016). *Urban tree database*. Fort Collins, CO: Forest Service Research Data Archive.

Nielsen, A. B., Östberg, J., & Delshammar, T. (2014). Review of urban tree inventory methods used to collect data at single-tree level. *Arboriculture & Urban Forestry*, *40*(2), 96-111.

Naming Report 3.4 Money Raymond MC Lee Square. (n.d.). Retrieved from. https://pdfslide.net/documents/naming-report-34-money-raymond-mc-lee-square.html

Sjöman, H., & Nielsen, A.B. (2010). Selecting trees for urban paved sites in Scandinavia – A review of information on stress tolerance and its relation to the requirements of tree planners. *Urban Forestry & Urban Greening,* 9 (4), 281-293.

Tree crown measurement. Retrieved from https://en.wikipedia.org/wiki/Tree_crown_measurement

Wikipedia contributors. (2020). Platanus × acerifolia. Retrieved from https://en.wikipedia.org/w/index.php?title=Platanus_%C3%97_acerifolia&oldid=939407956

Tree Inventory Report

Group 6

Keith Chau, Mattesen Moore, Molly Kim, Jared Rusheleau, Marcus Nikolovski

February 13, 2020

Group Member Contributions

Name	Contributions
Marcus Nikolovski	
Mattesen Moore 43723535	Present for all fieldwork, Completed Methodology
Keith Chau 29567450	Present for all fieldwork, completed introduction,
Molly Kim 28101632	Present for most fieldwork, Completed site description, part of summary (figure 1 and 2)
Jared Rusheleau 33944323	Present for large majority of fieldwork, summary of tree inventory data

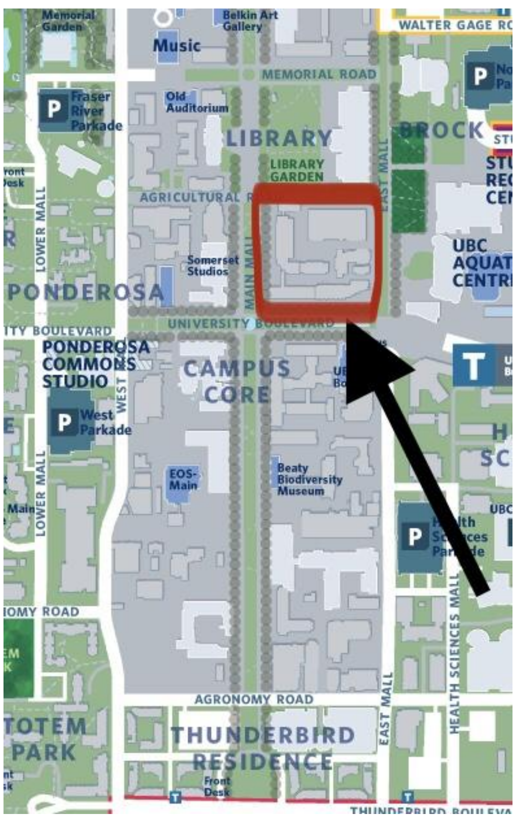
Introduction

Increasing the biodiversity around campus to maintain ecological integrity is one of the major visions in the UBC Green Building Action Plan (2018). As the University continues to improve its campus through the addition of new facilities and improvements to existing structures, the acknowledgement

The purpose of this tree inventory is to establish an accurate inventory of all trees within a given plot on the campus and to assess the health of trees within the area.

The data collected through the tree inventory will be beneficial for new research opportunities such as evaluating biodiversity on campus, average canopy cover, or amount of carbon sequestration by trees. Particularly, the acquired data can further assist shareholders and partners such as UBC Campus and Community Planning in creating a more biodiverse and open community for students, professors, and visitors alike.

As of 2018/2019, UBC Vancouver currently has a total of 54,863 students, and 15,705 staff members, in addition to numerous visitors each year. Along with the complete inventory of other plots, UBC and other stakeholders can use the data to improve flora management strategies and increase biodiversity around the campus.



Site Description

The site is located at the corner of the intersection of Main Mall and University Boulevard. The trees are located around and in-between buildings. For this site the land use type is institutional (Chemistry and HEBB buildings). This area is usually accessed by people who enter and exit the buildings. In-between buildings are mostly shade and slight sunlight can be accessed in that area. There are benches under large canopy covered tall trees so people can attain shade. In addition, there are bike parking areas, including a bike lock-up cage located within the center of the outdoor area within the Chemistry buildings area.

Methodology

The methods for measuring and collecting the data for the inventory were all on-the-ground, besides the use of the "Collector Classic" app, which was used to gather some of the tree species, as well as geographical location within the plot. We started measuring trees at the corner of University Blvd. and Main Mall, going in a counter-clockwise direction around the chemistry and HEBB buildings. The tools used included; a laser rangefinder/hypsometer, a diameter tape, open-reel tape measures, a clinometer, a smartphone, as well as a metal clipboard with *Rite-in-the-rain* paper. The laser rangefinder/hypsometer was used to find the total tree height of all the trees, as well as being used for measuring the canopy base height of the taller trees. The diameter tape was used to find the diameter at breast height (1.37m) of all the trees measured. The open-reel tape measure was used to find the canopy cover of trees, and occasionally used to find the canopy base height of the tree with lower hanging branches or young trees. The clinometer was unused by our group, as the laser rangefinder/hypsometer was used in most situations, but this tool would be used in conjunction with the open-reel tape measure to find the height of trees. The metal clipboard, *Rite-in-the-rain* paper, as well as standard HB#2 pencils were used in the collection and documentation of the data. One of our most useful tools were smartphones, used in the communication between our group members, finding the location and species of trees that were mapped on the *Collector Classic* app, as well as to find the coordinates of the trees that were unlisted on the app. To find the location of the unmapped trees we used google maps, dropping a pin on the location of the unmarked tree, and recording the coordinates onto our data collection sheet. The variables and values we were measuring for included; if the tree have a tag issued by the *University of British Columbia*, if so, what that tag was, the identification number of the tree within the *Collector Classic* app, if the tree was alive, dead or removed, species, the land use of the area the tree was located within, diameter at breast height (if there was multiple branches or stems of the tree at this height we measured up to 6 of them and averaged them to get the average diameter), total tree height, live canopy height, canopy base height, crown width (second measurement taken perpendicular from the initial measurement), crown percent missing, crown light exposure, as well as any comments we felt were necessary to include in the data collection of these trees. We manually input all of our data collected for our trees into a Microsoft Excel spreadsheet. This tool was used to neatly sort all of the data collected, averaging DBHs, as well as to create graphs and other visual instruments to help interpret our collected data.

Summary

DBH (cm)	Trees
<10 DBH	21
10-30 DBH	53
30-50 DBH	12
50-80DBH	20
80-100 DBH	3
>100 DBH	2

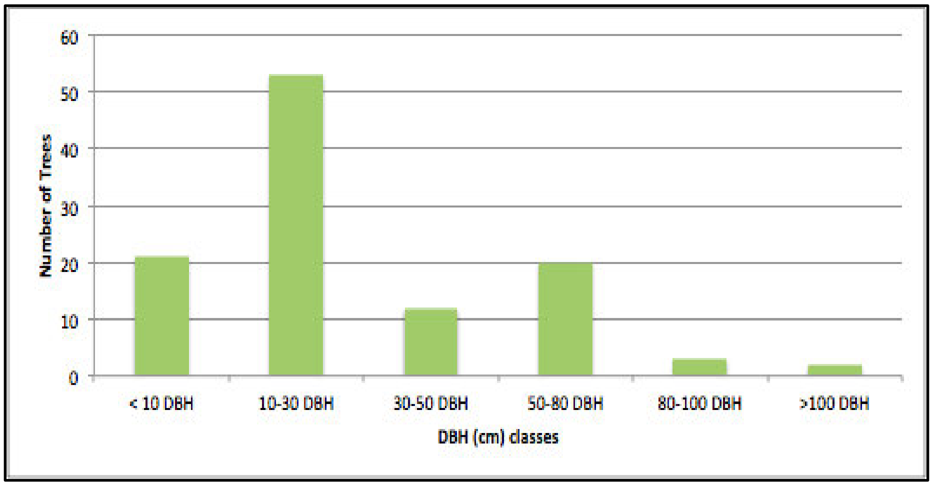


Figure. 1 Total number of trees relative to DBH classes.

Total Tree Height (m)	Trees
< 10 m	71
10-20m	27
20-30m	14

Figure. 2 Total number of trees relative to total tree height classes.

Summary of tree inventory data

Throughout the fieldwork we came across thirty species that were identified (one or two species were not previously catalogues on ArcGIS) among the 100 odd trees that we catalogued. The majority of the trees were around ten meters tall, however there were a few much larger trees that stood almost thirty meters tall. The closest to that, was an Acer griseum that stood at twenty-eight and a half meters tall. This tree was about twenty centimeters taller than the second tallest tree, an Ulmus americana. Looking over the data this proved to be quite interesting as the Acer griseum is native to China, where the Ulmus americana is native to eastern North America. The Ulmus americana is pretty par from home, however in a similar coastal climate. Moreover, the Acer griseum is much further from home, being from a different continent entirely. This proved to be the case for most of the trees we found in the Cupressaceae family, as they were part of the Chamaecyparis genus or ‘false cypress’, such as the Chamaecyparis pisifera and the Chamaecyparis obtusa. Both of which are native to eastern asia. As it turns out, very few species on our site were native to western North America, or North America as a whole for that matter. Maybe that is for good reason. Our moderately tempered, coastal climate gives tree species the ability to reach their full potential. Going back to our tallest tree, the Acer griseum is a mid sized tree that ranges from six to nine meters tall in its native territory. Out here, it tripled that. Another interesting find on our site was a Larix. Larix is a very interesting species as it is native to North America and is prominent in the Canadian boreal forests. Although they are coniferous, they are a deciduous tree. Quite a marvel to see in Banff National Park during the fall as they turn a golden yellow before losing their needles. One final marvel that we noticed on our site was the Ilex aquifolium. Not necessarily the tree itself, but the manor that the tree was growing was interesting. The four Ilex aquifolium on our site were trimmed to stand tall (around seven meters) and act like a canopy to two walkways. Just from looking at the tree, we could tell that this was not in this tree's nature. Knots are visible only a few inches apart from where branches had been limbed all the way up the trunk of these trees. That being said, these trees served their purpose as canopies and beautiful accents to some walkways quite well, while reaching well over it’s expected height of three meters.

References

(2020) *Wayfinding at UBC Vancouver*: http://www.maps.ubc.ca/PROD/index.php

Bielka, C. Larix occidentalis. Retrieved from http://blogs.ubc.ca/conifersubc/?page_id=70&fbclid=IwAR1wOEsgWNtxQLbzu8HJnYJ5vymVBzVpnIxzYLlpDjktGnGDbBYGIVYKt-U

Inventory Assessment
Group 7

Submission date: 2020/2/13

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Table of Contents (contribution)

Introduction

A tree inventory focuses mainly on the attributes of the trees(individual) such as the number of trees in a given area, the species of tree, the condition etc. The tree inventory we conducted focuses strictly on Phase 1C2.

The data we collected for our tree inventory focuses on the following data: The UBC tree ID setup by UBC, whether or not there was a tag and if there was what number was on the tag. We also looked for the species of the tree, the land use, DBH, the circumference of the tree, the actual height of the tree and the crown width. This was all measured using a clinometer, tape measure etc.

The purpose of this tree inventory was not only to identify the trees but also find out the condition and health of the trees, live or dead as well as to see if any of the trees needed maintenance and such. This tree inventory was also conducted so that we could identify any trees that have not been identified or tagged by UBC, so that we could tag them and record their existence. Because UBC is an ever growing institute that inspires education one of the other purposes of this tree inventory is to use the new information and plan for the future, knowing how many trees in an area and the characteristics like size and such as well as density of the tree population in a given area can help prevent overcrowding and if it is currently overcrowded, a plan can be made to resolve it. All of these details help UBC plan and decide where to not only put trees but other important monuments and such. With clear information and detail of UBC's urban forest community this makes initiating and implementing a management plan much easier.

This tree inventory was conducted by student groups. The end users of this small scale project would not only be UBC itself since all of this data helps planning for the future and organization much easier, it also benefits anyone that attends this world class university. Students and professors alike get to enjoy the spiritual and aesthetic benefits of our urban forest. Since this inventory helps identify trees, any trees in poor condition, health or are in the way of students can be taken care of which may be a small detail but can change people's perspective of the school entirely. Ecosystem services such as cultural services can be deprived from this tree inventory in the long run. Although it may seem like a small scale project planned by a forestry class to give forestry students field work experience in their respective careers, it actually plays a significant impact in the wellbeing for many of those who attend the University of British Columbia.

Site Description

The area we measured is located in the east of Main Mall, the north of Chemistry Building and the south of Ladner Clock Tower. The longitude and latitude coordinates are about 49.15 ° N, 123.15 ° W.

In the western part of this area is a small campus botanical garden (Figure 2), which is rich in tree species diversity and tree density, with a narrow stream passing through (but there is no water at present). The main users here are pedestrians, tourists and students resting there. The middle of this area is a triangular lawn and the main road leading to the IKB Learning Centre. The eastern part consists of IKB building and its surrounding open rest area, a grove and road (shown in Figure 1).

Figure 1: The distribution of each plot cover

Figure 2: small campus botanical garden

According to the classification of land use type in i-Tree eco, the western area is Park and the eastern area is Institutional. Also, this plot is mainly covered by grasslands (27%), roads (25%), trees (23%), buildings (22%) and shrubs (3%).

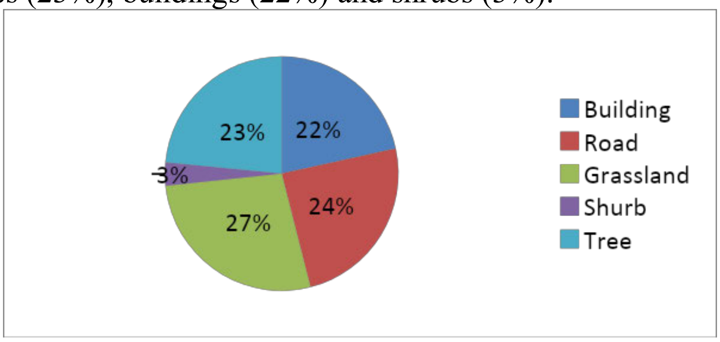

Figure 3: The percentage of each plot cover

Methodology

To do an inventory properly, one must standardize the methods used to measure and record different attributes of the trees. With uniform procedures, errors can be minimized while efficiency is increased.

In the inventorying process, ArcGIS is used to more accurately locate the where about of each tree, to make sure the measurement aligns with its Tree ID. It also allows for the planning of routes, which made data collection much more clear and organized. Data collection took two days to finish, which are sectioned off and planned differently as the following map:

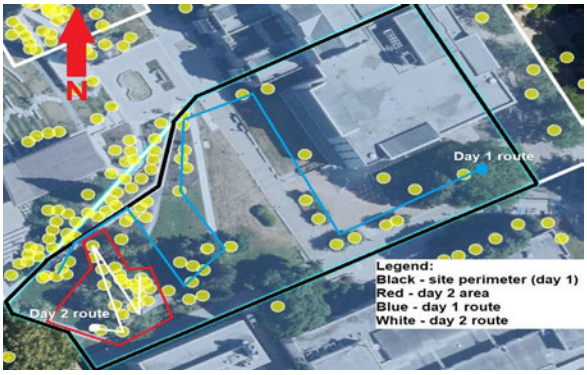

Figure 4: map of phase 1C2

Measurements such as tree heights (DBH, TTH, LCH, CBH) and crown width are measured using both a laser rangefinder and tape measures. Crown % miss and crown lighting exposure (CLE) are estimated in respect to the projection key.

DBH (diameter at breast height) is measured with a tape measure at the height of 1.4m. A reference of 1.4m is first measured and established on a groupmate, then the measurement is taken against the reference on the groupmate. A tape measure is then wrapped around the stem at the referenced height, getting the measurement for circumference. For multiple stemmed trees, all stems are measured unless over 6 stems, which then takes the measurement of the 6 thickest stems. The aggregated DBH is calculated through the formula (MacDicken et al., 1991):

Overall DBH = the square root of the sum of all squared stem DBHs

However, the measurement and calculations above are in terms of the circumference of the stem(s). To get the diameter, simply divide the circumference by **π**, since circumference=**π**d.

All calculations are done post recording and tabulation using excel functions to ensure efficiency and accuracy.

TTH (total tree height) and CBH (crown base height) are measured primarily through the usage of a laser rangefinder. To properly operate the rangefinder, a 3-point measurement method is used (point to horizontal, top, then base of matter being measured). In addition, a tape measure is used when the tree is too short for any meaningfully efficient use of a rangefinder. The tape measure is held at the top of the tree by hand, by letting the tape fall onto the ground by gravity allows the tape measure to be more or less perpendicular to the ground, thus obtaining a more accurate reading.

LCH (live crown height) is largely the same as the TTH throughout the inventory. Most trees are alive and there is a good amount of new trees planted. Thus, the TTH is equivalent to the LCH for a healthy, living tree.

Crown width is measured by taking the average of the longest and shortest length through the centre of the crown. This is done using a tape measure, where two people grab both ends of the tape measure and walk to the ends of the crown. It is important to keep the tape measure as horizontal as possible, to minimize the extra length measured.

Crown % miss and CLE (crown light exposure) are estimated in respect to the projection key handout. Since everyone has different projections on how a full crown of a tree would look like, varying in shapes and sizes, it can be quite subjective despite having a systematic key. Thus, to minimize the deviation in this set of data, the task of evaluation is kept to one groupmate each day.

To analyze the data, two general categories are considered: species composition and urban forest structure. Species composition can be approached from abundance (numbers of each species), diversity (number of species) and basal area (cross-sectional area of a stem at DBH). Urban forest structure can be approached from DBH classes, TTH classes, and CBH classes to assess an urban forest in terms of what purpose it serves, and its ecosystem services. Plotting data from both categories together can reveal possible correlation or new insights, such as plotting DBH against numbers of trees against basal area.

Allometric equations are also used to establish a mathematical estimate of future growth. By quantifying relations between different variables within or across categories (e.g. DBH against TTH, basal area against CBH), it allows plausible future projections which can help in developing an ever-adapting management plan for the urban forest.

Summary of tree inventory data

This area is rich in species. We measured 63 trees and 23 species. The largest number of species are Japanese maple, Pacific red cedar and Magnolia hybrid. In addition, the species with the largest floor area are Pacific red cedar and American elm(Figure5).

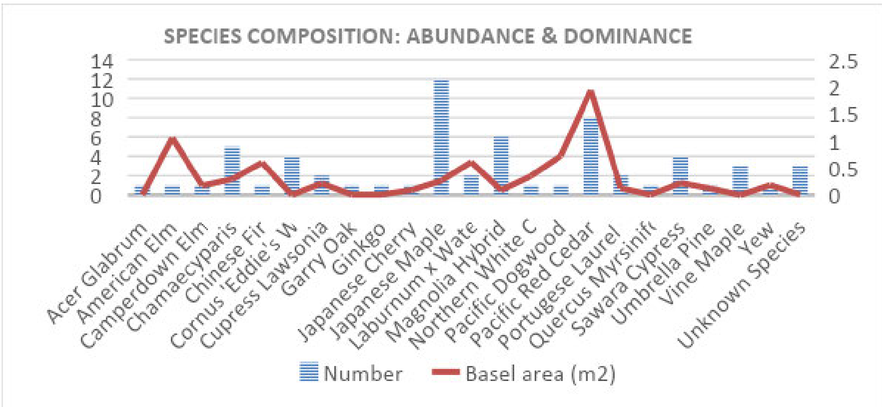

Figure 5: Species composition

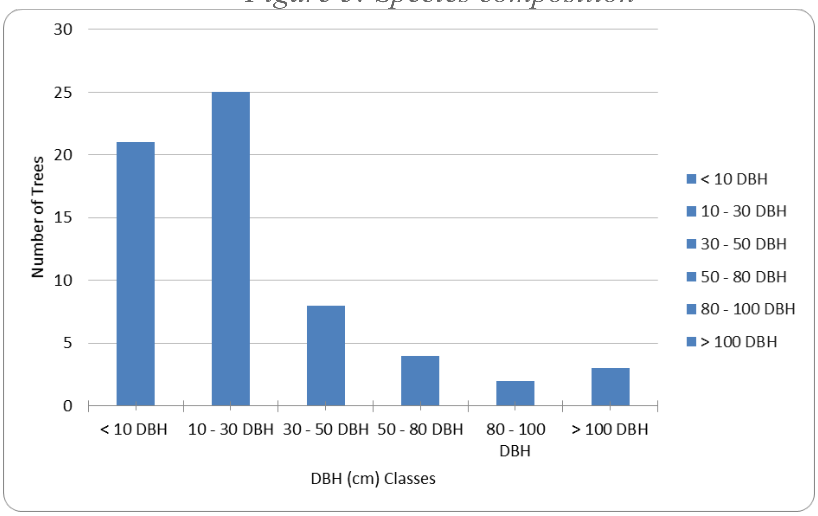

Figure 6: DBH classes

There is a big gap between the height of trees in our zone. The highest trees are more than 30 meters, while the shortest trees are less than 5 meters. The average TTH of these trees is 7.3, and the height of 18 trees in 63 exceeds the average (Figure 7).

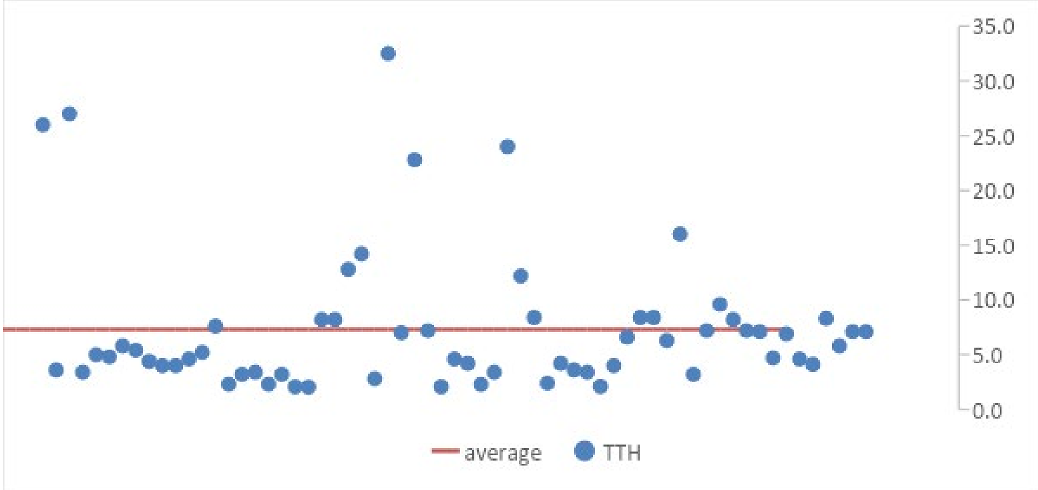

Figure 7: Estimating mean of the total tree height

The DBH of trees in this zone also vary a lot. The largest one is about 120cm, the smallest one is about 1cm. The average DBH of these trees is 25.17cm, and the DBH of most trees are lower than the average (Figure 8).

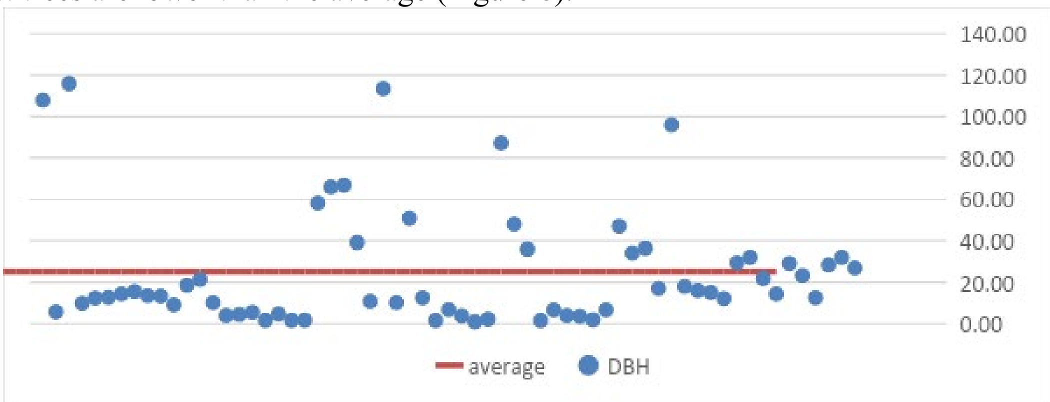

Figure 8: Estimating mean of the DBHs

Summary Table

	Live	SD	Death
Trees	63		0
Species	23		
DBH mean (cm)	25.17	28.2933	
BA mean (m^2)	0.11258	0.2375	
Total height mean (m)	7.297	6.4064	
Crown base mean (m)	33.277	72.3346	
Crown width mean (m)	5.0698	4.0851	
Canopy missing			
<10%	5		
10%-30%	34		
31%-50%	17		
51%-80%	7		
>80%	0		
Crown light exposure			
0	1		

1	1		
2	11		
3	18		
4	16		
5	16		

Special species

The tallest tree:

The Pacific Red Cedar at the east end of the small botanical garden is the tallest tree in the area, with a total height of 32.5m and a DBH of 113.5cm (which is the second largest). It can be regarded as a landmark tree in this area, corresponding to the bell tower in the north. Because of its existence, it blocks the sunshine that can be received by the trees next door, making the surrounding trees not grow very well, and a Cupress Lawsoniana in the south needs to grow obliquely around its branches.

Figure 9: The Pacific red cedar

Interesting Trees:

In this area, we found a tree with very scattered branches. It belongs to Pacific dogwood. Its branches are scattered and extend to the West wildly, with an average crown width of 14.3m. And it has a very low branch position; also its DBH is larger than that of its other counterparts. We think the main reason for this phenomenon is that there is enough growth space in the West

Figure 10: Pacific dogwood

There are also some trees with multiple stems, such as the Northern Western Cedars with five stems and the Chinese Fir with three stems.

Figure 11: Northern Western Cedar & Chinese Fir

The last tree we want to introduce is Camperdown Elm, which has a "twisted branch head" and is very curious. During our measurement, we even met several tourists who took photos with him and had questions about its strange shape. By consulting the data, we find that the grafted Camperdown Elm slowly develops a broad, flat head that may eventually build as high as 4 m, and a commensurately wide crown with a weeping habit (More & White, 2003).

Figure 12: Camperdown Elm

Forecasting of Tree Growth in the Area

In the designated area, tree species and ages vary by a significant amount. There are newly-planted trees around the Irving K. Barber Building, as well as old, multi-stemmed trees around the small botanical garden area.

There are 5 multi-stem trees that have 4 stems or more in the designated area. After several years of growing, we believe the split between the stems will be further apart. Since all 5 trees are near paths around the building that a large number of people walk on every day, they have a potential threat to the community in that area.

Figure 13

For the newly-planted trees around the building, we believe they will continue to grow as usual. However, for some trees, they might block the window of the building after several years of growth.

Figure 14

Works Cited

Mac Dicken, K.K., Wolf, G.V. and Briscoe, C.B. (eds.) (1991). Standard research methods for multipurpose trees and shrubs. International Research Centre for Agroforestry (ICRAF) and Winrock International publication (multipurpose tree species network research series; manual no. 5).

More, D., White, J. (2003). Cassell's trees of Britain & Northern Europe. London: Cassell.

Tree Inventory Report

Irving K. Barber Learning Center

&

Indian Residential School History and Dialogue Centre

Group 8

Date of Inventory: 2020-02-01

Date of Submission: 2020-02-13

Executive Summary

Acknowledgment
We acknowledge that the UBC Vancouver campus, including Site C3, is situated on the traditional, ancestral and unceded territory of the Musqueam people (University of British Columbia, 2018a, p. 12).

Abstract
This inventory report focuses on a study site included in Phase 1 of the UBC Vancouver campus urban forest tree inventory as part of the larger Urban Forest Management Plan (Naveau et al., 2017). The inventory site described is labelled on the UFOR101_TreeSurvey map file system as “Phase 1C3” (Burton, 2020). The site will hereafter be referred to as “Site C3”, acknowledging that the site C3 is part of Phase 1 of the tree inventory, as described by Burton (2020).

The inventory report of Site C3 was conducted by UFOR 101 Group 8 during the Winter 2020 term. The total area included in the inventory report is 1.5 hectares in size (Burton, 2020). This inventory report includes three sections: Site Description, Methodology, and Summary of Tree Inventory Data. The Site Description section provides a general description of Site C3. The Methodology section describes the tools and techniques used in the inventory and analysis of the data. The Summary of Tree Inventory Data (Analysis) reports on the results and findings of the tree inventory, including a subsection regarding the landmark trees included in Site C3.

An excel spreadsheet with the recorded measurement of variables in the tree inventory is included as an electronic submission.

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Introduction

"The forests around UBC are valuable ecological assets"

- UBC Green Building Action Plan, 2018b, p. 77

In a time marked by climate activism and an increased green-approach to development, the value of the University of British Columbia (UBC) Vancouver campus' urban forest cannot be understated. Beginning in the 1930s, a rapid development on the UBC Vancouver campus has resulted in a significant decrease in the size of the urban forest on campus (Du et al., 2016). In an effort to increase housing and construct new faculty buildings, the urban forest on the Vancouver campus has notably diminished (Du et al., 2016). Although the UBC Vancouver campus is known for its green landscape design, a publication in 2017 by Lompart & Thomas indicated the crucial importance of a "complete and maintained tree inventory" (p. 6) for the UBC Vancouver campus (2017).

The establishment of a tree inventory for the UBC Vancouver campus began in the summer of 2017 (Lompart & Thomas, 2017). Once completed, this tree inventory will allow for the "proper implementation and enforcement of tree policies and procedures on campus" (Lompart & Thomas, 2017, p. 6). An inventory of the urban forest will allow for systematic management decisions, including scheduled arboriculture maintenance, planting, and pest management (Lilly, 2010). Tree management plans can be drafted using the information discovered in the tree inventory, as well as determining future budgetary needs (Lilly, 2010). Through the development of a tree inventory, repeated measuring will allow the tree managers to monitor the condition of the urban forest on campus, including successful and vulnerable tree species.

The inventory report is useful to a number of users. Most notably, the urban forest managers might use this tree inventory to inform their management and budgetary decisions and limitations, mitigate risks relate to trees, inform integrated pest management practices, monitor changes to the urban forest, and determine future strategies and policies (Ferrini et al., 2017). As a post-secondary institution with a notable forestry department, researchers might use the inventory data and reports to assess changes to the urban forest, as well as noting current benefits that the urban forest provides (Ferrini et al., 2017).

The urban forest inventory can be considered a crucial aspect in the long-term management of the urban forest.

Site Description

Preface: This section describes the structures located within the inventory site and provides a brief overview of their history. The Site Description section also provides information regarding the boundaries of the site described. The section concludes with a review of the available services offered within the inventory site.

Site Boundaries

Site C3 in Phase 1 of the UBC Vancouver campus urban forest tree inventory encompasses much of the land surrounding the University of British Columbia's Irving K. Barber Learning Centre (IKBLC) and the Indian Residential School History and Dialogue Centre (IRSHDC). The site is defined by the following road boundaries: Memorial Road to the north, East Mall to the east, Agricultural Road to the south, and Main Mall to the west (Burton, 2020). Areas within this boundary but not included in this inventory consist of the northwest quadrant between Learner's Walk, the Ladner Clock Tower, Memorial Road, and Main Mall, as well as the heavily vegetated region in the southern section of the plot bounded by the side walk connecting Learner's walk to Main Mall, and the sidewalk along East Mall (Burton, 2020). All street trees within the boundaries along East Mall are included in this inventory. Figure one provides a visual reference of the boundaries, indicated by a white border line along the perimeter of the coloured area, and a visual reference of the site, coloured blue. Areas in black and white are considered outside the scope of this inventory and are not included in this report.

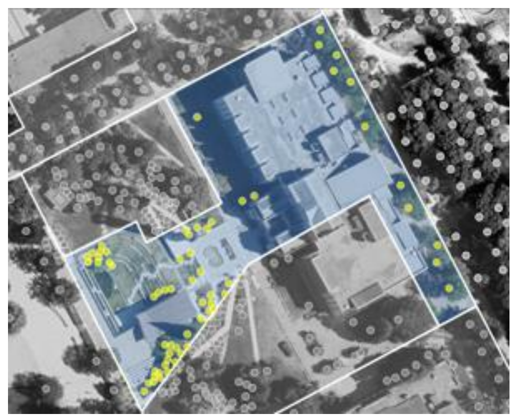

Fig. 1: Site C3 indicated in colour (Burton, 2020)

Site History

Construction of IKBLC began in 1922, following the Great Trek protest in which thousands of students marched to Point Grey calling for a better university campus (University of British Columbia, n.d.). In response to this march, the library and two additional buildings were constructed; construction was completed in 1925, with recent renovation to the building occurring 2002 (University of British Columbia, n.d.). This renovation included a 200,000 square foot addition paid for by a 20-million-dollar donation from UBC Forestry alumnus Irving K. Barber (University of British Columbia, n.d.). In 2009, the Learner's Walk was constructed in front of the library; this construction included adding benches, tables, and new landscaping in the area closest to the building (Syncra Construction, 2015). The Library Garden to the west of the building received new landscaping in 2017 (Situ, 2016). This area includes many of the trees reviewed in the inventory.

Services Provided

IKBLC provides many services to the UBC community including lecture halls, study spaces, the Music, Art & Architecture Library, a small cafe, and the Rare Books and Special Collections archive (University of British Columbia, n.d.). The Library Garden provides even more study spaces and an abundance of greenery creating a peaceful and calming atmosphere.

Methodology

Preface: This section reviews the methods and techniques used to collect inventory data. Measuring refers to determining the number of trees and their structure, condition and other quantitative or qualitative characteristic, yielding data for a single point in time (Ferrini et al., 2017). For accurate results and consistency, the group followed the metric system. All group members are referred to as "surveyors" in this section.

Inventory Type

The inventory conducted on Site C3 was a complete ground-based inventory for all trees located in the site area, but is a partial inventory contributing to the larger UBC tree inventory project. A partial inventory is measuring "all trees meeting a particular condition" (Ferrini et al., 2017, p. 41).

Tree ID, Species

The tree identification number and indicated species were retrieved using the information available on the *UFOR101_TreeSurvey* map file system on Collector for ArcGIS (Burton, 2020).

Tag, Tag ID

If a tag was present on the tree when it was being measured, the presence of a tag would be indicated with a "Y" for yes in the Tag section of the spreadsheet and the identification number on the tag would be recorded under Tag ID. If no tag was present, the tag section would be marked as "N" for no. There were fourteen trees with a tag and tag identification number.

Condition (Live/Dead)

When measuring the condition, the surveyor determines whether the tree is alive or dead. A method to determine the livelihood of the tree is look for "healthy branches covered with new leaves or leaf buds" (Spengler, 2019). Trees found to be alive were indicated as "L" for live in the Live/Dead section. No trees measured during field work were found to be dead, however one tree was found to be removed and is indicated as "D" for dead in the Live/Dead section.

Land Use

There are thirteen default land use classes that are recorded by i-Tree Eco (i-Tree Eco., 2019). The surveyors used descriptions from i-Tree Eco to determine the land use classification as Institutional (I).

Diameter at Breast Height (DBH)

The diameter at breast height (DBH) measures the circumference of the stem of a tree (i-Tree Eco, 2019, p.37). The measurement is conducted with a diameter tape, which "divides the linear scale by pi" (Ferrini et al., 2017, p.38), yielding a diameter measurement in millimeters. It is important to identify the height of DBH. The diameter is "estimated at 4.5 feet or 1.37 meters above the ground" (i-Tree Eco, 2019, p.37).


fig. 2: measuring DBH

When measuring DBH, it is important to note that not all trees in the plot had a single cylindrical stem, such as the *Sequoiadendron giganteum* shown in figure 2.

Certain growth characteristics (tree height, growth form) limit the ability to measure DBH at exactly 1.37 meters. In measuring multi-stem trees, DBH should be measured for "up to six stems" (i-Tree Eco, 2019, p.37). The measurements were inputted into an Excel spreadsheet that calculated DBH of the multi-stem trees. For trees with irregular swellings, bumps or depressions at DBH, measurements would occur at a height "above the irregularity at the place it ceases to affect normal stem form" (i-Tree Eco, 2019, p.38). When working on a slope, surveyors recorded DBH on the "uphill side of the tree" (i-Tree Eco, 2019, p.38).

Tree Height

There were three required tree height measurements, total tree height (TTH), live crown height (LCH) and crown base height (CBH). *Figure 3* illustrates the total tree height and live crown height. Crown base height can be found by subtracting the crown depth from the LCH.

A Nikon laser range finder was used for this tree inventory to record TTH, LCH and CBH. Trees with CBH less than two meters (height) were measured with the open-reel tape measure. To measure the TTH and LCH using the laser range finder, the surveyor would shoot the laser at the basal region and the highest point of the tree (TTH) or the highest live point of the tree (LCH). The range finder would then calculate the angle between these two measurements and produce a height measurement.

Crown Width

Crown width measures the lateral length of the crown of the tree, including all foliage and branch structure (i-Tree Eco, 2019). For this inventory, crown width is documented in two lengths, noting the long and short widths. Measurements were conducted by two surveyors using an open-reel tape. The surveyors would stand on opposite sides of the tree and measure from the edge of the widest dripline, yielding the long length. This would be repeated for the shortest dripline, yielding the short length. The excel spreadsheet would calculate the average crown width using these two measurements. If the tree was planted on a slope, the measuring tape would be leveled to ensure the accuracy of the measurements.

Percent Crown Missing

Percent crown missing is an estimation of the percentage of absent foliage and branch structure (i-Tree Eco, 2019). Using rough estimations and comparisons to normal growth patterns of the species, the percent crown missing could be estimated for each tree on Site C3.

Crown Light Exposure (CLE)

Crown light exposure (CLE) is the "number of sides of the tree's crown receiving light from above or the side" (i-Tree Eco., 2019, p.36) The crown is divided vertically into four quadrants, with the fifth side referencing the tree top; thus, the largest possible CLE value is 5 (i-Tree Eco., 2019). Figure 6 will be used as a field example of CLE determination. Noting the building behind the *Sequoiadendron giganteum* in figure 3, one side of the tree might have a lack of exposure to sunlight, whereas all other sides were free of light obstruction. Thus, the CLE was determined to have a value of four.

fig. 3*: Sequoiadendron giganteum*

Summary of Tree Inventory Data

Preface: This section provides a summary and analysis of the tree inventory data collected and how the findings relate to the future management of the site. Trees of interest are identified in a brief section following the implications of the findings section. It should be noted that averages for this data were affected by 14 trees located on the northeast side of Site C3 (along East Mall), which are all presumed to be *Quercus robur*, although four trees are not identified in the app. These 14 trees are of considerable size in diameter at breast height, tree height, and crown width. Their influence on the calculated averages are further noted within this section.

DBH

The average total DBH on Site C3 was 16.1 centimeters, with a minimum DBH of 1.3 centimeters and a maximum DBH of 78.5 centimeters. The average total DBH of single stem trees was 22.1 centimeters, with a minimum DBH of 1.3 centimeters and a maximum DBH of 78.5 centimeters. The average total DBH of multi-stem trees was 6 centimeters, with a minimum DBH of 2.22 centimeters and a maximum DBH of 16.75 centimeters. In reviewing figure 4, there are no multi-stem trees with DBH greater than 30 centimeters. This average total DBH and average DBH of single stem trees were increased by the 14 *Quercus robur* located on East Mall, which have a significantly larger DBH than most of the other single stem trees found on Site C3. Another notable species that influenced the single stem DBH average was *Sequoiadendron giganteum*. There are two *Sequoiadendron giganteum* located on Site C3; their DBHs are: 39.60 centimeters (tree ID: 4317) and 60.10 centimeters (tree ID: 3070, tag ID: 9599).

DBH Classes			
DBH (cm)	Trees		
	Single Stem	Multi-stem	Total
<10 DBH	33	27	60
10-30 DBH	0	2	2
30-50 DBH	3	0	3
50-70 DBH	6	0	6
> 70 DBH	6	0	6
Avg.	22.1	6	16.1
Min.	1.3	2.22	1.3
Max.	78.5	16.75	78.5

fig. 4: DBH classes by growth form

Differences in DBH might be due to different planting time, different tree species and different growth forms (i.e. single stem and multi-stem trees).

Growth Forms

The multi-stem and single stem tree distribution data is shown in figure 5. *Acer circinatum* tends to grow as a multi-stem tree structure, as opposed to *Thuja plicata*, which were only observed as single stem trees. The other tree species observed with multi-stem growth were *Acer glabrum, Malus fusca,* and *Acer palmatum.* All species in the *Acer* genus located within Site C3 grew predominantly as multi-stem trees. All coniferous trees had single stem growth forms. *Quercus robur* and *Sequoiadendron giganteum,* the two tree species with the largest tree height and DBH, are single stem trees.

Multi-stem and Single Stem Tree Distribution			
Tree Species	Single Stem	Multi-Stem	Total
Acer circinatum (Vine Maple)	7	23	30
Quercus robur (Pedeunculate Oak)	10	0	10
Thuja plicata (Pacific Red-Cedar)	8	0	8
Malus fusca (Oregon Crab Apple)	4	1	5
Acer glabrum	1	3	4
Abies (Fir)	2	0	2
Acer palmatum (Japanese Maple)	0	2	2

Cornus 'Eddie's White Wonder' (Dogwood)	2	0	2
Picea sitchensis (Sitka Spruce)	2	0	2
Sequoiadendron giganteum (Giant-Sequoia)	2	0	2
Abies grandis (Grand Fir)	1	0	1
Cornus nuttallii (Pacific Dogwood)	1	0	1
Cupressus nootkatensis (Yellow Cyprus)	1	0	1
Pinus contorta (Lodgepole Pine)	1	0	1
Pseudotsuga menziesii (Douglas-Fir)	1	0	1
Quercus garryana (Garry Oak)	1	0	1
*Species not identified, not included in totals	(4)	(0)	(4)
**removed *Thuja plicata* (Pacific Red-Cedar), not included in totals	N/A	N/A	(1)
Totals	**46**	**29**	**73**

fig. 5: Multi-stem and single stem tree distribution by species

Potential implications of a large multi-stem tree population include increased likelihood of failure, as multi-stem trees with similar DBH size between the multi-stems have weaker attachments and increased stress on the tree crotches (Dunster et al., 2017). This is of note for site management as a regimented pruning schedule might be recommended to better train young trees into desirable forms (Lilly, 2010).

Tree Height

This section analyzes tree height measurements on Site C3. The term “tree height” will be used in replace of “total tree height” to describe the total height of the tree. Only one tree was identified in Site C3 to have a difference in “total tree height” and “live crown height” (*Quercus robur,* tree ID: 3194; tag ID: 5784). The difference was one meter or 10%. For overall calculations, this difference was considered marginal.

The average tree height in Site C3 is 4.9 meters, the minimum tree height is 1.2 meters, and the maximum tree height is 20.2 meters.

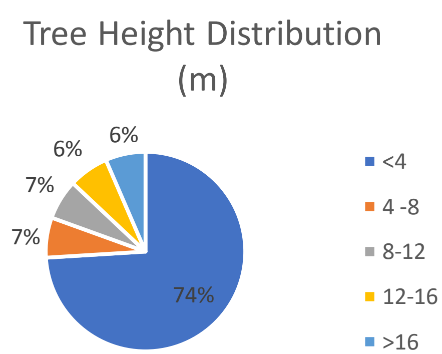

fig. 6: Tree height distribution

Figure 6 indicates that a majority of the trees (74%) on Site C3 are a smaller height at less than four meters. There is little diversity in tree height on Site C3. No trees were measured at a height that fell directly at the intervals (i.e. a height of 8 or 12 meters). The time of planting can be estimated using the tree heights and the average annual growth rate of certain tree species. Based on the overall data however, the statement can be made that this is a predominantly young section of the Vancouver campus' urban forest.

Crown Width

The average crown width for Site C3 was 3.9 meters, with a minimum crown width of 0.5 meters, and a maximum crown width of 19.6 meters. The average crown width long measurement was 4.3 meters, and the average short measurement was 3.6 meters. Based on the data, it is discovered that the majority of trees on Site C3 have a small crown width, as 60 trees have an average crown width between 0.6 to 4.2 meters.

Crown Light Exposure (CLE)

The average crown light exposure value for Site C3 was 4 (rounded from 3.8), with a minimum CLE value of 2, and a maximum CLE value of 5. No trees had a CLE value of 1 or 0. Figure 7 displays the CLE value for each tree in the order in which they appear on the excel spreadsheet data tabulation.

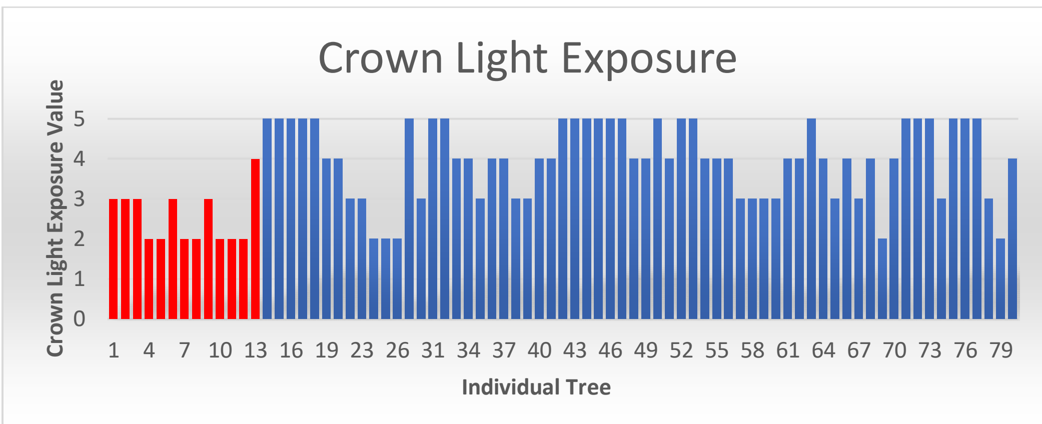

fig. 7: Crown Light Exposure by individual tree

Figure 7 reveals that 46 of the trees on Site C3 have a crown light exposure on 4 or 5 sides. Therefore, the results show that many trees have open space around them, sufficient for further growth. However, it is also evident that there are trees with a CLE value of 3 or less. The red section of figure 7 indicates the *Quercus robur* on East Mall, which have a notably lower average CLE value than the overall CLE value for Site C3. A major cause of the restricted CLE is a result of the IKBLC, although other trees contribute to shading. Trees in the remaining areas of the plot are predominantly obstructed by other trees, as opposed to structures. However, certain trees on Site C3 have a lower CLE value as a result of the IRSHDC shading one side.

Structures that shaded sides of the tree can be considered static, therein a constant obstruction and non-movable. Some trees shaded other trees, resulting in a lower CLE value for the shaded tree. One tree was noted to have a pronounced phototropic lean on Site C3 (*Malus fusca*, tree ID: 4385).

Tree Diversity

The highest number of individual trees per species (abundance) on Site C3 is *Acer circinatum* with a total of 30. The species with the largest basal area (m^2) is *Quercus robur*, as indicated by the red graph line on figure 8. Though the relative abundance of *Acer circinatum* is greater than *Quercus robur*, DBH per individual tree is greater in *Quercus robur. Acer circinatum* and *Thuja plicata* have low basal area values and a large abundance value. Because of the abundance of the two species, it can be determined that the two species are beginning to dominate the area, limiting the overall diversity. This information is something to note in future planting efforts where tree diversity might be a goal. The two *Sequoiadendron giganteum* measured have large basal areas, accounting for the spike in the middle of the graph in the Basal Area logarithmic axis.

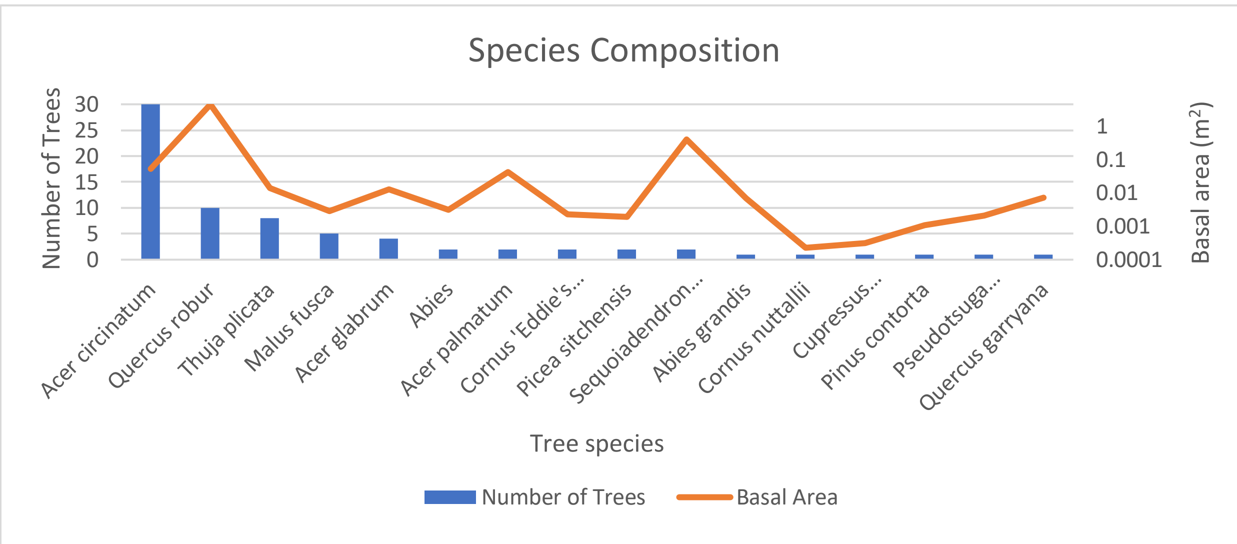

fig. 8: Species composition, noting number of trees (blue) and basal area (red)

Figure 9 shows that deciduous tree species (yellow) are more abundant than coniferous tree species (green) on Site C3. Figure 10 show the distribution of deciduous and coniferous tree species throughout Site C3. Deciduous tree species (yellow) are predominantly distributed on the East Mall strip and adjacent to the IRSHDC. The coniferous trees (green) were more diversely distributed. The two *Sequoiadendron giganteum* are separated on Site C3, with the largest being adjacent to IRSHDC and the other being situated on the northwest corner of IKBLC. The other conifers are distributed among the deciduous trees.

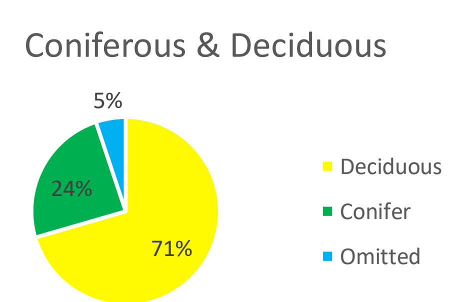

fig. 9: coniferous and deciduous tree abundance

fig. 10: coniferous and deciduous tree distribution

DBH and Tree Height Comparison of the Three Predominant Species

This section reviews the diameter at breast height (DBH) and total tree height (TTH) comparison of the tree most abundant species on Site C3 (*Acer circinatum, Quercus robur,* & *Thuja plicata*). DBH (X axis, measured in centimeters) is compared to the tree height (TTH, measured in meters) to determine how the three predominant species allocate growth to the basal area compared to tree height. A limitation of the regression analysis is a small sampling size. There is not adequate diversity in age to create a dependable growth pattern. Additionally, growth form (single vs multi-stem) might impact the trendline and the R^2 value. The three tree species and their trendline cannot be compared as the species samplings are not the same age.

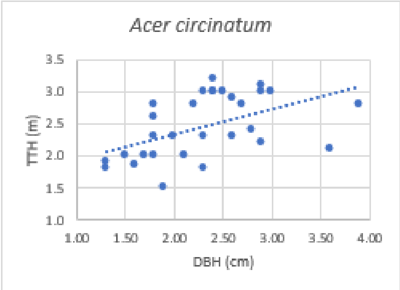

fig. 11*: Acer circinatum* DBH and TTH

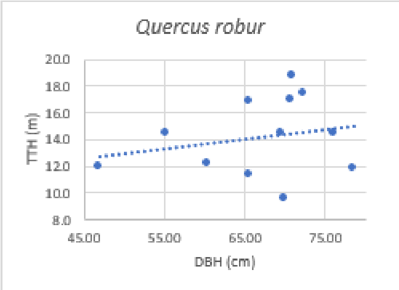

fig. 12*: Quercus robur* DBH and TTH

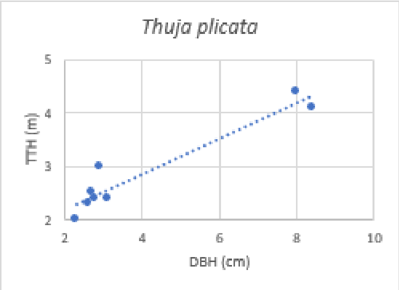

fig. 13*: Thuja plicata* DBH and TTH

In figure 11, *Acer circinatum* (Vine Maple) has a steady growth of both TTH and DBH. The trees have previously been noted to be a younger age, so this is relevant to the species' young growth patterns. Figure 12, *Quercus robur* has a trendline that indicated continued growth in DBH does not have the same correlated TTH growth as is evident among the other species. The *Quercus robur* is thus hypothesized to have reached mature height, growth is likely allocated towards basal increase. The trendline for figure 13 of *Thuja plicata* indicate a more predictable correlation of TTH and DBH. If this model proves correct under more specimens and the R^2 value remains close to 1, the model could be accurately used to predict the species' correlation of DBH and TTH.

Conclusion

The data and findings indicate a diversity in tree DBH, height, and age on Site C3. Tree species diversity is limited, as three species make up 64% of the tree species on Site C3. Based on crown width measurements, a potential concern is distribution, as there is limited space for growth.

Notable Trees

The *Sequoiadendron giganteum* (tree ID: 3070) located next to the IRSHDC is part of a UBC art project titled *Millennial Time Machine* by artist Rodney Graham (Morantz, 2017). An image of the *Sequoiadendron giganteum* is projected by a camera obscura located in a pavilion between IKBLC and the Walter C. Koerner Library (Morantz, 2017).

The *Sequoiadendron giganteum* (tree ID: 4317) located next to IKBLC was planted as a commemorative tree for UBC's centennial year, as seen on the stone plaque beside the tree (figure 14).

fig. 14: Commemorative Plaque

References

Burton, J. (2020). *UFOR101_TreeSurvey* [map file system]. Retrieved from Collector for ArcGIS.

Du, D., Sangha, T., Smith, I., & Yu, H. (2016). *Urban Forestry Visioning Project*. Vancouver, BC: University of British Columbia. Retrieved from https://urbanforestry.sites.olt.ubc.ca/files/2016/09/URBAN-FORESTRY-VISIONING-FINAL.pdf

Dunster, J. A., Smiley, E. T., Matheny, N., & Lilly, S. (2017). *Tree Risk Assessment Manual*. Champaign, IL: International Society of Arboriculture.

Ferrini, F., Konijnendijk van den Bosch, C. C., & Fini, A. (2017). *Routledge Handbook of Urban Forestry*. Abingdon, OX: Routledge Handbooks.

i-Tree Eco. (2019). *i-Tree Eco Field Guide, v. 6*. Retrieved from https://www.itreetools.org/support/resources-overview/i-tree-manuals-workbooks

Johnson, S. E., & Abrams, M. D., (2009). Age class, longevity and growth rate relationships: protracted growth increases in old trees in the eastern United States. *Tree Physiology*, *29,* 1317–1328. doi: 10.1093/treephys/tpp068

Lilly, S. J. (2010). *Arborists' Certification Study Guide*. Champaign, IL: International Society of Arboriculture.

Lompart, J. & Thomas, I. (2017). *Urban Forestry Management Plan: Recommendations for the University of British Columbia Vancouver Campus.* Vancouver, BC: UBC Social Ecological Economic Development Studies (SEEDS). doi: 10.142881/1.0356640.

Morantz, E. (2017, October 18). Hidden in Plain Sight: A place of learning. *The Ubyssey.* Retrieved from https://students.ubc.ca/ubclife/hidden-plain-sight-place-learning

Naveau, A., Miao, A., Bellis, E., & Ikeda, T. (2017). *UBC 2017 Stadium Neighborhood Tree Inventory Project.* Vancouver, BC. Retrieved from https://sustain.ubc.ca/sites/default/files/seedslibrary/UBC%202017%20Stadium%20Neighbourhood%20Tree%20Inventory%20Project_0.pdf

Situ, B. (2016, September 13). Construction under way for Indian Residential School History and Dialogue Centre. *The Ubyssey.* Retrieved from https://www.ubyssey.ca/news/construction-underway-for-indian-residential-school-history-and-dialogue-centre/

Spengler, T. (2019). *Is My Tree Dead Or Alive: Learn How To Tell If A Tree Is Dying*. Retrieved from https://www.gardeningknowhow.com/ornamental/trees/tgen/tree-scratch-test.htm

Syncra Construction. (2015). *UBC Learners' Walk.* Retrieved from https://syncraconstruction.com/projects/ubc-learners-walk-4/

UBC Properties Trust. (n.d.). Irving K. Barber Learning Centre. *UBC Properties Trust.* Retrieved from https://www.ubcproperties.com/projects/irving-k-barber-learning-centre/

University of British Columbia. (2018a). *Indigenous Peoples: Language Guidelines.* Vancouver, BC. Retrieved from https://assets.brand.ubc.ca/downloads/ubc_indigenous_peoples_language_guide.pdf

University of British Columbia. (2018b). *UBC Green Building Action Plan: Pathway to a New Positive Campus.* Vancouver, BC. Retrieved from https://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_Green_Building_Action_Plan_Full.pdf

University of British Columbia. (n.d.). Building history and highlights. *Irving K. Barber Learning Centre.* Retrieved from https://ikblc.ubc.ca/spaces/building-history-and-highlights/

Group Contributions

Group members participated in the group project in the following ways:

Alexander Martin: Group leader, author of Introduction, co-author of Summary of Tree Inventory Data (Analysis) section, excel data tabulation, final edits

Anya Rueter: Author of Site Description section, final edits

Eakin Sawada-Tse: Co-author of Summary of Tree Inventory Data (Analysis) section

Han Yan: Co-author of Summary of Tree Inventory Data (Analysis) section

Yunshu (Lily) Du: Co-author of Summary of Tree Inventory Data (Analysis) section

Karman Phuong: Author of Methodology section

All group members participated in two days of inventory collection.

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Group 9

__UFOR 101 Assignment 1__

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Contribution Page

Introduction: Sophia Brunoro and Sophie Damian

Formating: Sophia Brunoro and Sophie Damian

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Site Description: Tanner Wick

Methods: Mitchell Wong

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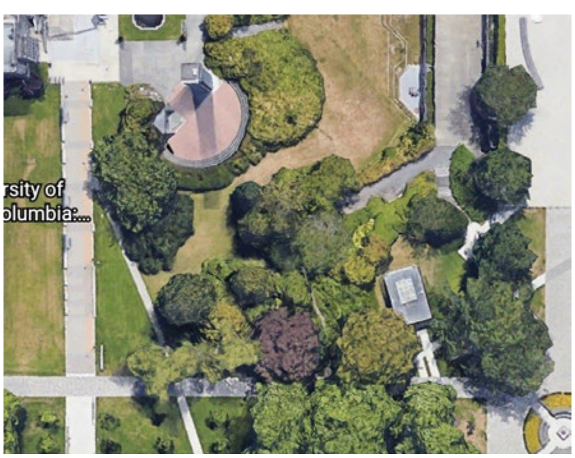
Introduction

The purpose of tree inventory and assessment is to determine the characteristics of the trees in a given area, as well as monitor their growth and development over time. The information that we collected will be used by SEEDS, UBC operations, and help execute the UBC master plan. From this experience our group was able to develop real world tree inventory and assessment skills which can be applied to future jobs. This was extremely beneficial to be given this opportunity, which allows us to practice using tools and hands on learning. Our team learnt the key importances on how to conduct a basic tree inventory and assessment report. This was completed by: using a laser rangefinder to estimate height, determining diameter breast height, crown width, crown percent missing, and tree species. All of this information is critical when completing a proper tree inventory assessment.

Tree monitoring is an important skill set because the data which we collect over time can be compared to that of future data, demonstrating changes within the surveyed trees, which could be significant to development and growth for the UBC community as a whole. Without the teamwork from each member of the group this assignment would not be possible. Throughout the entire process, everyone was given a different specific task to help complete the data effectively and to be more time efficient. With the help of each group member doing their part, we were able to collect data from approximately 55 trees in our area.

Our zone was located in-between the clock tower and Buchanan. The cultural significance of these trees in this area are important for students and faculty members walking from class to class. Where we were surveying, there was a well established path, in which students used to cut through from their classes in Buchanan and then to study at IKB. Walking through the trees and nature allows people a break from reality of stressful everyday classes and assignments. The change of scenery, gives a sense of relief from the constant strain in which a classroom can cause and allows for personal reflection in the unhindered



movement in our plotted area. Not only was there a path for walking, there were also benches set up along the path for people to sit and relax, as well as a small pond. Ultimately, incorporating nature within a modern concrete jungle allows for members of the community, a chance to debrief and connect with nature.

The data that we collected on campus will benefit the students and faculty within the area of our plot by showing the data of specific individual tree species that represents the style and configuration of the layout of the area. The information gives us insight on the ecosystem services intertwined within our zone. The information we collected will be used by SEEDS, UBC management services and with the completion of the UBC master plan.

Site description

Plot 9 is located on the north side of campus between Irving K. Barber Library and Koerner Library, beside the Ladner Clock Tower. It's official title is the Library Garden, however plot 9 does not fully encompass the garden, only the northern portion. The plot has an overall crown cover of approximately 50%. The trees are not spread out very much making them overlap, otherwise the coverage could be even larger. The shrub layer is approximately 35%, as the plants reside underneath the trees in an orderly fashion because they have been maintained and not allowed to grow wildly (the lawns were excluded from the shrub layer). The gardens themselves have undergone recent landscape redesign as of 2016 (Shanel, 2015). The updated version has been designed to have the space feel more natural with its dense tree positioning, compared to other areas on campus.

This space also has been altered to pay homage to the Musqueam People's history within the unseeded territory that is UBC, and the library gardens can even be considered as UBC's Central Park since this renovation has beautified the area (Shanel, 2015). It is classified under the land use types as an Institutional park zone. The area resides within the University of British Columbia as a place to relax under a grove of trees. However, it can also be classified under its other function, therefore it also can reside within the 'other' category. Despite the land title being mainly referred to as an institutional area, students, faculty, and community members utilize this space for a variety of different purposes.

The plot is not only used by people around campus, but also acts as an ecosystem for certain urban wildlife. The most common resident within the area would be squirrels and birds such as robins and crows. The small pond also acts as another mini-ecosystem as it houses bacteria and other microorganisms. The trees and shrubs act as shelter for animals within the park area and the pond provides water and a bathing area. Although most animals were not extremely present while we were conducting the survey and as students were walking through. As the sun went down though and student traffic died down, more wildlife was present in the area.

The plot itself is not very large and has a high number of trees in the confined space. There are two main gravel paths, one of which borders the south end of the plot and allows students to quickly walk from one library to the next or take shortcuts. The other path branches into multiple sub-pathways through the trees and allows for the enjoyment of nature. The North, East and West sides of the plot are bordered by large cement walkways for students to walk to class. Since the plot is beside such high traffic pathways, it is often used by students as a shortcut to class, or a rest stop to catch their breath in the small patch of trees. Students are the dominant users of this area as it is ideal for an outdoor meeting area when the weather is nice. It is often used for picnics or study sessions, alone or with a group. Faculty and local community members also use this space for similar activities, in addition to simple walks under the trees.

We also observed a photographer using the area for numerous nature shots around the small pond in the northernmost corner of the plot. The plot is also used as an evaluation area for students, like ourselves, to learn and practice their tree inventorying skills.

The reason it is also classified in the land type use index as 'other' is because of the modern art piece in the northwest corner. This art piece is within a glass box under a cement slab. Inside this glass box is an old-fashioned carriage, with an old-fashioned camera inside it. The piece, designed by Rodney Graham, uses the camera to focus on a tree within plot 8, and create a wondrous image. When you go into the carriage and look through the camera the tree appears to be growing from the sky instead of the ground. Though our plot 9 is small there are many wonderful trees along with an amazing art piece allowing plot 9 to stand out from the rest of the gardens in UBC earning its title of central park. It is very impressive that such a small sight has so many significant purposes to multiple different groups of people.

Methods

During the inventory data collection, our group (group 9) did a complete field inventory collection of our plot. For each tree, there were many measurements that we had to do. The measurements that we did for each tree were diameter at breast height (DBH), total tree height (TTH), lowest crown height (LCH), crown base height (CBH), crown width (long side, short side, and average), percentage of crown missing, and crown light exposure (CLE).

We were also given the arcGIS phone application to help us determine the tree ID, species name, and if that tree is dead or not. We found that a few trees had died before we surveyed the plot, but their tree ID was still on the arcGIS application. When doing the data collection, each person in the group had one designated job to do. We completed all the measurements for one tree before moving onto the next one so that we don't get the data numbers mixed up between two or more trees.

For the total tree height (TTH), we were given a rangefinder tool to help us measure the big trees when we could not measure the TTH with the measuring tape. To use this tool, we would have to stand a minimum of 10 metres away from the tree. We had to try to stand as horizontal as possible with the tree without standing downhill or uphill. First, the tool will be blinking Hor, this indicates that you must aim the laser at the tree stem horizontally and click the power button. Once you click the power button, it will then be blinking Hgt1, and this indicates that you must aim the laser at the tip of the tree and click the power button once you find it. Then it will be blinking Hgt2, and this indicates that you will point the laser at the bottom of the tree trunk and click the power button. The screen on the side of the tool will then show the angle of the tree and the TTH.

When measuring the lowest crown height (LCH), you are measuring where the foliage stops on the tree (not including the base of the tree where there are no leaves). To measure LCH, we either measured how tall the base of the tree was and subtracted that with the TTH, or we used the tool for TTH and instead of using the bottom of the tree as Hgt2, we would scan the base of the crown. We only used this tool if the tree was very big and we were unable to measure with the measuring tape.

For crown base height (CBH), we measured from the ground to the base of the live crown height with a measuring tape. For most of the trees within our plot, we were able to use the measuring tape, however, there were a few trees that the CBH was too tall, so we used the rangefinder tool to measure.

When measuring the diameter at breast height (DBH), we kept the height at 1.37m for every tree so that we receive consistent and accurate data. Some trees had multiple stems growing from the ground so we had to measure the DBH for every stem unless when there were more than six stems, we would measure the six largest stems.

Measuring crown width required two people to hold the measuring tape (one on each end), and measure the longest width of the tree. Once we measured the longest width, we would then measure the shortest width of the tree. After recording both of the measurements, we calculated the average crown width.

When measuring the crown percentage that is missing, we looked at the tree at 2-3 different angles and estimated how much of the crown is missing. To measure the crown light exposure (CLE), we first looked at the trees in person at the plot and made an assumption of what the CLE was, then we looked at the arcGIS app to confirm our CLE guess.

Summary

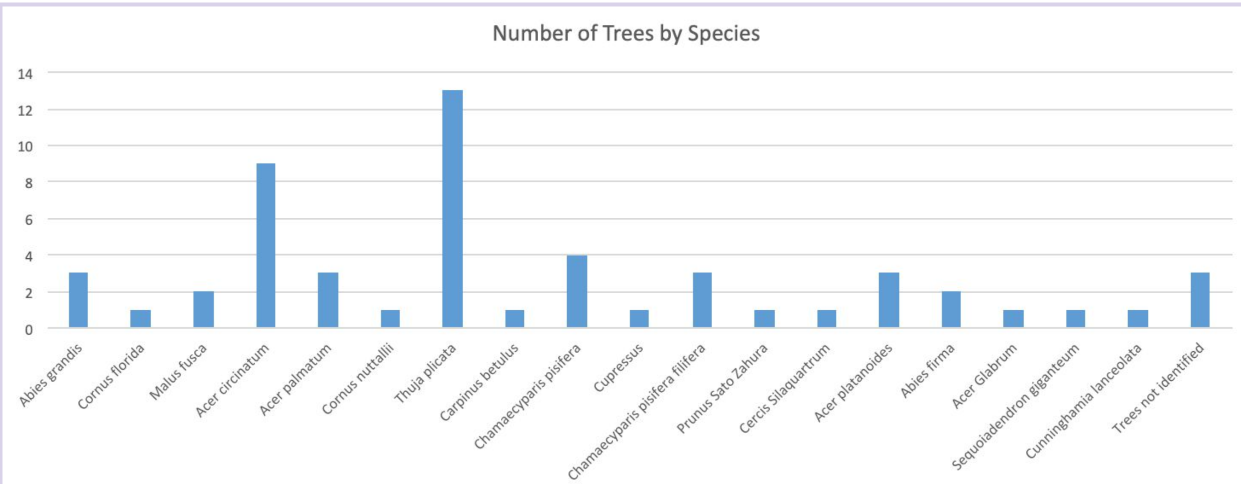


Figure 1: Graph showing the abundance of trees in Plot 9. The Pacific Red Cedar shows to be the most abundant within plot 9 by stem count. Many of the Pacific Red Cedars that we inventoried have been specifically chosen and planted in their locations because they are native to the British Columbia coast. Comparatively, many of the other species with small stem counts are not native (as shown in *Figure 2*).

Figure 2: Simple pie chart showing the percentage of native species versus non-native species. Within our plot, 55% of the species are native while 45% of the species are non-native.

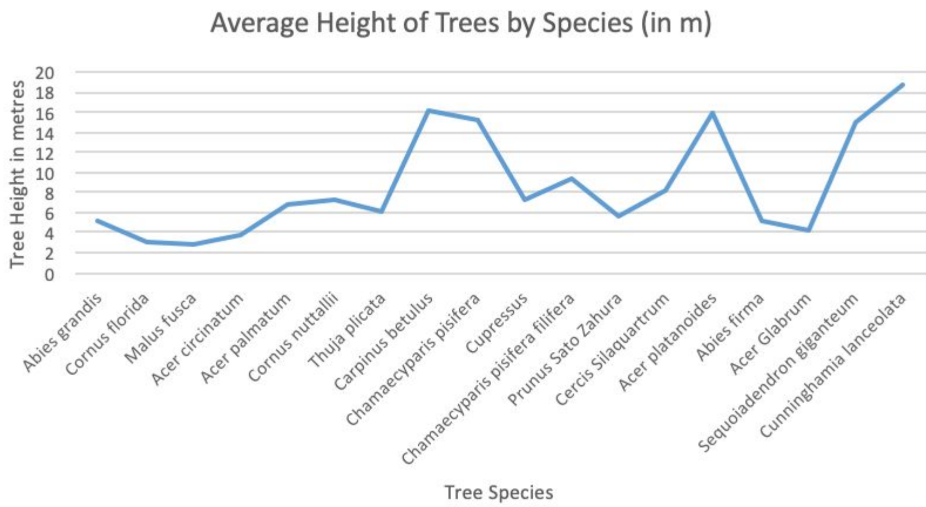


Figure 3: This graph is slightly deceiving as some of the averages are brought down due to recently planted trees. For example, Pacific Red Cedars were some of the largest trees but the average shows to be lower because multiple trees recently planted are under four meters tall.

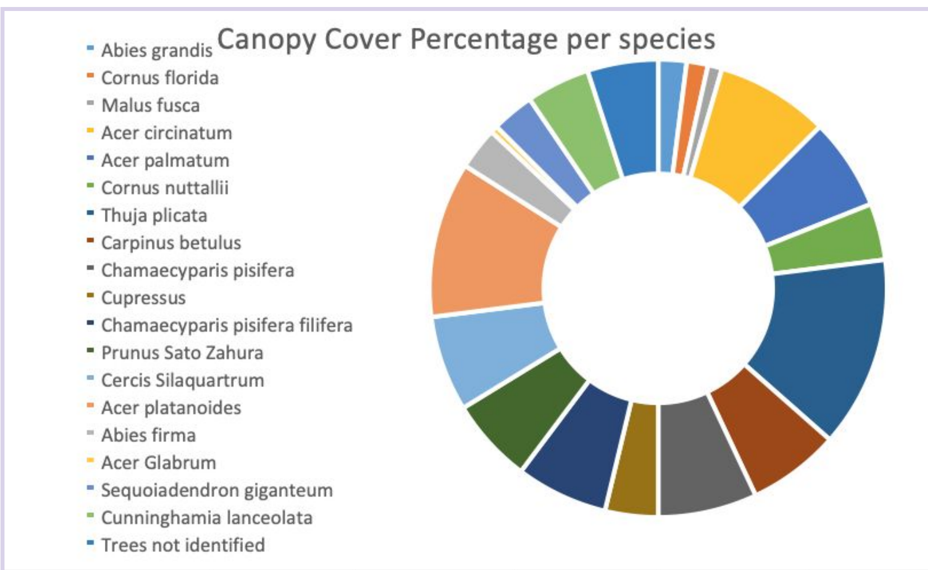


Figure 4: This chart shows the canopy cover percentage within plot 9 per species based on average crown width. We estimated the total canopy cover of plot 9 to be 50%.

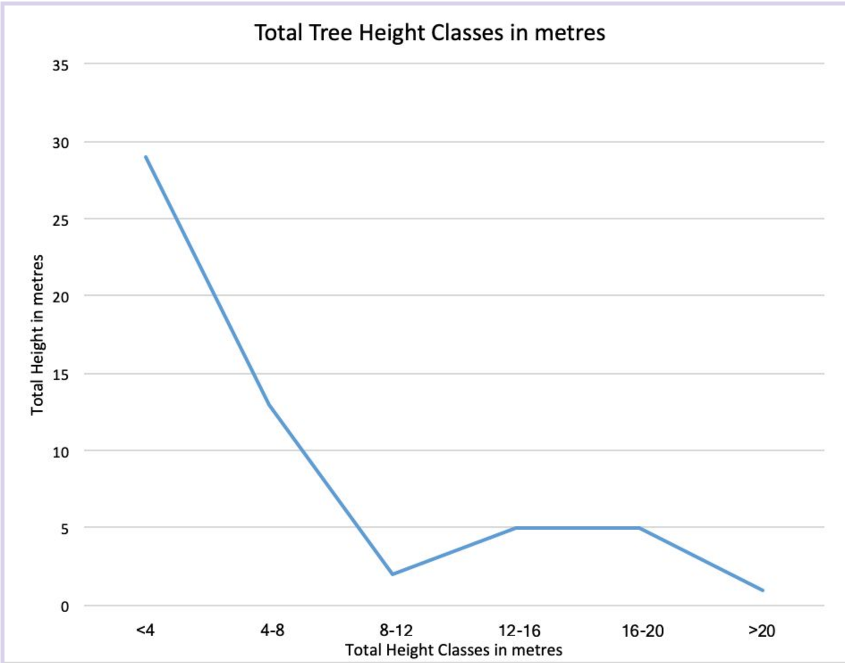


Figure 5: This graph simply shows the heights of trees in our plot broken into six different classes regardless of species and strictly on height. Many of the trees in our plot were under four meters which shows to be a good indicator that many of the trees planted in our plot are in their youthful age.

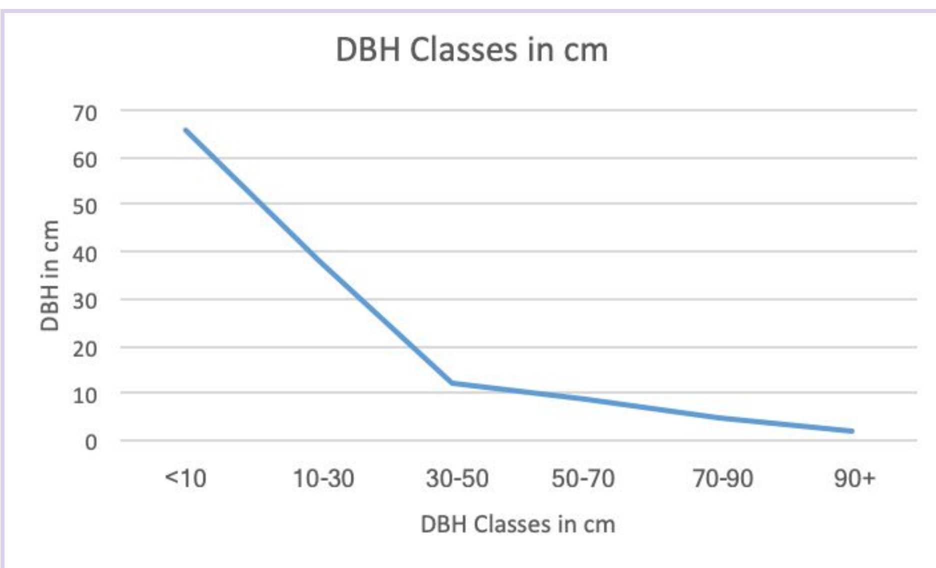


Figure 6: To show the DBH throughout our plot we broke up the data into six different classes that represent the various DBH's that are present within our plot. Similar to *figure 5*, many of the trees with small DBHs correspond to smaller trees.

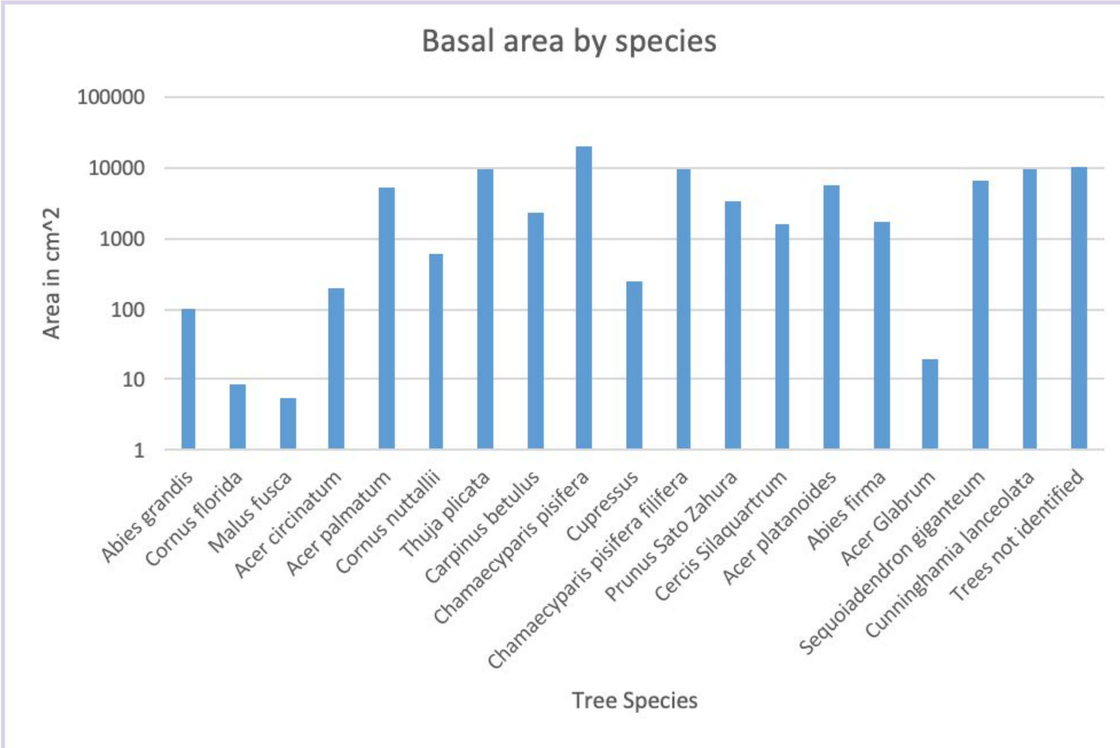


Figure 7: Graph showing the Basal area within plot nine based on tree species. Note that the area on the y-axis is logarithmic to allow our data to be read easier in contrast to using a linear scale.

Ecosystem Services

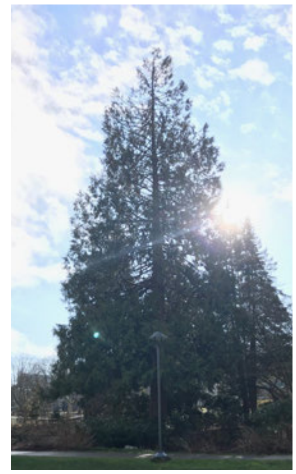
Monitoring the ecosystem services of an area is crucial for measurement of success of an area. Documenting the success at this point of time in this plot will allow future inventories to compare the status of ecosystem services at that point to current conditions.

The supporting services which this plot provides is difficult to place exact value on as much of this kind of ecosystem service is its ability to provide support to other services. In order to ensure the younger trees to grow, and mature trees to continue to prosper in this plot, supporting services such as the ability for the soil to cycle nutrients, maintain water cycles, and photosynthesize nutrients must be intact. The success of supporting services can be seen in the success of other services, such as the regulating and provisioning services.

Having this forested area in the campus allows for climate control by providing shade and by adding to the process of evapotranspiration, a way in which plants can release water into the atmosphere producing a heating or cooling (Selin & Mann, 2019). Observing canopy cover age of the area, which currently is around 50% in winter, is a good estimate of the success of a regulating ecosystem service such as this. Cultural ecosystem services include non-material benefits that people may gain from the environment around them. In this area there is a lot of aesthetic value, with a small path running through many of the trees as well as an area to rest. Having areas that provide cultural ecosystem services have been linked to improved mental health and increased physical fitness (Wolf, 2017).

As the goal of this urban forest is most likely for cultural and regulating services, there are few to no provisioning services, which are the raw or material products that can be consumed or used by people.

Overall the ecosystem services provided by this area are currently doing well, and can be expected to provide even greater services to people as the younger trees mature, and increase canopy coverage.



Tallest Tree

Landmark trees

Tallest Tree: The tallest tree (ID 3091) is a Pacific Red Cedar that stands at around 30m tall. This tree also boasts the widest DBH, at 108.4cm. While Pacific Red Cedars generally can grow to around 60m, it is possible this particular one will not reach that due to factors such as limited root space in its urban environment.

Largest crown width: European Hornbeam (id 4402) has the largest crown width, at an average diameter of 19.2m.

Interesting/rare tree: The interesting tree we chose was a Chamaecyparis pisifera filifera group (ID 4413) that appeared to be multiple trees, however, was found to be a single tree with multiple stems coming out of the same root network..

Interesting Tree

Predictions and forecasting

Area of young trees near clock tower: Within the plot for group 9, there were a significant number of young trees especially towards the (direction ie nw)that had just been planted, many of which were Red Cedars or Vine Maples, two species native to coastal British Columbia. According to Michael Dirr's "Manual of Woody Landscape Plants," Red Cedars have a medium to fast growth rate, which means they can anywhere from 12 to over 25 inches per year, depending on conditions. Vine Maples can grow 12-18 inches per year when they are young, however, they will slow with maturity and age (Miller Foundation, 2020). In ideal conditions these trees will grow rapidly in the next few years, creating areas equally dense to those in this plot that are more mature. Vine Maples in particular are known for being able to thrive in urban environments as they can adapt to many soil textures and amounts of light (Miller Foundation 2020).

Canopy growth and coverage predictions: The canopy itself will see the biggest growth from the young trees that will come into maturity in the next few years, as a significant number of the trees inventoried are too young to contribute a lot to canopy coverage. As this inventory was taken during the winter season, the percent of canopy missing in the trees, especially those that may not be native to the coast or that are deciduous, was not representative of what it would be in the warmer months.

References

Alessio, F. (n.a) How Fast do Cedar Trees grow? *Hunker.* Retrieved from https://www.hunker.com/13428627/how-fast-do-cedar-trees-grow

Elizabeth Carey Miller Foundation. (2020). *Great Plant Picks.* Retrieved from http://www.greatplantpicks.org/plantlists/view/30

Leah Ballin. (2019). *Sustainable ecosystems and Economic Development strategies.* Retrieved from Leah Ballin - Sustainable Ecosystems and Economic Development Strategies - UBC Forestry

Selin, H., Mann, M. (2019). Global warming - land-use change. Retrieved from https://www.britannica.com/science/global-warming

Shanel, D. (2015, December 5th). Library Garden to be redesigned. *The Ubyssey.* Retrieved from https://www.ubyssey.ca/news/library-garden/

UBC. (2019). *See what grows.* Retrieved from https://www.seewhatgrows.org/programs/ubc-logo-2018-crest-blue-rgb3

Wolf, K. (2017). Social aspects of urban forestry and metro nature. *Routledge handbook of urban forestry* (pp. 65-70)

UFOR 101 Urban Forest Inventory

Group number: 10
Date: 13. 02. 2020

Group Members:
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Contributions

Part	Name
Introduction: Explanation of the inventory purpose	Qiao Wang
Site description	Yizhen Zhang
Description of the methodology	Angela Jiang
Data analysis	Xingcan Cao
Landmark Trees and Prediction	Qian Li
Conclusion	Erin Liang

1. Introduction

The urban tree inventory our team implemented is the selected area of zone 10 on campus. This zone is located on the west side of the UBC campus and includes the Buchanan Tower and part of the Buchanan building. After our research, we counted a total of 62 trees in the zone, which were distributed on both sides of the road and around the buildings. Most are older mature trees, but there are also some late planting of smaller size trees.

A tree inventory can be conducted for many purposes. Firstly, with a clear tree identification and an inventory list, we can better plan the tree's maintenance content and schedule intervals. Regular maintenance of trees is crucial for the campus street trees because it is not only a matter of aesthetics, but also a matter of safety for students and faculty passing by. For longer purposes, tree inventories are designed to better assess the benefits to people of ecosystem services provided by the trees on campus. Also, it offers the detailed information of special trees, like memorial trees. Through the analysis of various data and variables in the inventory, the approximate value of a given ecosystem service can be estimated. For example, the width of a tree's canopy can be used to predict the cooling effect in summer. What’s more, the tree inventory can also contribute to informing urban forest vision and master plan on a large scale. Because parts of the tree inventory data are composed of the entire urban planning database of Vancouver, which helps the database to have wide coverage and integrity.

As for the end users, the tree inventory can meet different kinds of interests of different groups. First, authorities such as City of Vancouver are important end users of inventory data. For example, the tree inventories are the basis of the inform management, urban planning, budgeting negotiation, monitoring and so on. Besides, the inventory can also provide materials for the researchers. What’s more, the data provided by the inventory can benefit the Vancouver citizens as well. It can be used to link community to accessible urban trees in forms of apps, which can help with improving the mental and physical well-being of citizens. In addition, it can also play roles in improving nature stewardship, developing citizen-science and so on.

Besides, the Buchanan Tower and Buchanan building in the zones have a long history. The original Buchanan building was designed and built by Thompson, Berwick and Pratt between 1956 and 1958. This 5-wing building was influenced by the Modern Movement and the architecture of Mies Van der Rohe, Walter Gropius, and the master plan of Illinois Institute of Technology (chen, n.d.). So, the building only has stark concrete frame and light-grey enamelled brick . And about the Buchanan Tower, it was built during the 1970s as part of the brutalist movement (Vescera, 2017). Therefore, the tower was typically drab and aimed to incarnate functionality rather than beauty. Besides the purpose above, the campus trees around the buildings truly soften and light the lifeless atmosphere around this area.

2. Site Description

As the map shows, the selected area measured is irregularly shaped, located in the northwestern part of the campus, consisting of Buchanan Block Buildings, related roadways, and small-sized garden. This area covers quite green space, including tree-lined boulevards on Memorial Road, plantings and trees in front of Buchanan Block avenue, sidewalk trees on East Mall, and a small garden surrounded by three separated Buchanan Block Buildings (as shown in figure 1). The Buchanan Block Buildings located in this area are mainly used for the daily courses and examination places. So, the majority of users in the selected area are students and staff on the campus. Meanwhile, the building of the UBC Faculty of Arts is also located in this area, so there are many students of Arts taking courses in the buildings.

Figure 1 Source form Google Map

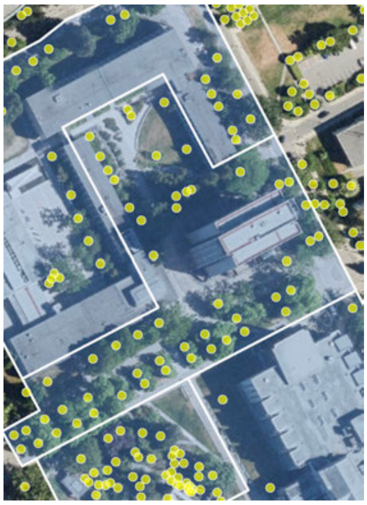


Figure 2 Source from: ArcGIS Collector

The main purpose of this area is for institutional land use, as the provision of class and other learning activities places. The components of teaching buildings include the Buchanan Block B Building, Buchanan Block C Building, Buchanan Block D Building, Buchanan Block E Building, and a Buchanan Tower. There is a broad boulevard on the Memorial Road, with a large stream of people. Since it is adjacent to the library and teaching buildings, many students pass by the boulevard for classes. The large green spaces and wide roadways also attract many neighbors and residents. In addition to the students rushing to and from classes, some residents also take a walk, do jogging and walk a dog on this road (as shown in figure 3), especially on the weekend morning. And some benches placed on the road also offer seating areas for pedestrians. After class, students and staff can take a break on these seating areas. besides, the small garden, surrounded by Buchanan Block Buildings also provides passersby an area for restoration, where place a small-sized open lawn, several trees, a small stream, and some benches.

Figure 3

The main facilities in the area are buildings, featured on connected buildings and a separated tower. In the middle of the Memorial Road, two rows of trees and a wide grassy land make up a boulevard, giving a sense of nature for pedestrians. As figure 4 shows, some infrastructure settled on the roadways (like stone-paved road, benches, lightings, and blue phones, etc.) can also be found.

Figure 4

In the small space surrounded by connected buildings, in addition to trees and bushes, we can also see some benches and a small stream featuring pebbles settled for rest (figure 5). Some facilities with a specific use or special significance can also be seen in this area. For instance, at the end of Memorial Road, there is a stele erected to commemorate the generous actions of student bodies (figure 6). And on the one side of the road, a place of refuge featured on benches and a wood sign is set up (figure 7) under a large tree. These facilities, combined with green trees and some design elements, provide users of this area with a practical and comfortable experience.

Figure 5

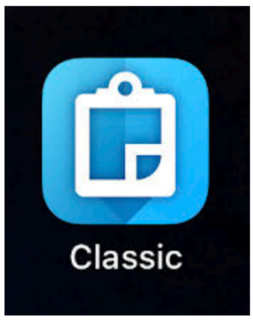
Figure 6

Figure 7

3. Description of the Methodology

During our inventory process, we used all the pieces of equipment that were provided to us. Six of our group members were all selected to do at least one measurement during the process. We measured trees along Memorial road between Irving K. Barber Learning Centre and Buchanan building B, as well as some trees located in the garden beside Buchanan Tower.

Initially, two of the group members downloaded the app to see where our plot and trees were located. The app also told us the trees' species and other useful information. Then, we put on the safety vest and we walked from north of Memorial road to south and gathered the information of the trees one by one beside the Buchanan building B. Moreover, we used the given sample plot sheets to write down the information that we collected.



The six of our group members were divided into three small groups each with two students. One of our small groups measured long crown width and short crown width. The second small group measured trees' DBH. The third small group measured trees' heights. After all, we took turns to observe the percentage of crown missing.

Figure 8

Figure 9

Figure 10

During our tree inventory process, we used a Nikon Forestry Pro to measure tree heights which required us to stand at least 10m away. The Nikon Forestry Pro is a simple surveying device for forestry. It offers simple measurements on exact distance, horizontal length, height, angle and vertical separation. We also used a diameter tape to measure the DBH and the widths of each tree. One of our group members first measured where 1.37 meters is at on her body, then the other student helped her to hold one side of the tape while she walked around the tree in order to measure each trees' DBH. Such steel tapes have a rewind spool fitted with a spring and contain measurements on both sides of the tape in varying combinations.

Numbers and excel are the applications that we used to record the data we collected. While analyzing, we could see that in our zone, there is evidence that the trees are diverse. The app provided us with most of the species types. Indian-Bean is the one that has been planted most in our zone, and it could grow to 15 m in optimal conditions with a highly branched head spreading wide. In the graph of DBH classes, we recognize that most of our trees have large DBH, which means there are plenty of old trees in our zone. In the graph of total height classes, it is easy to see that the tree height in our zone is quite average. I assume they were planted in batches.

4. Summary

4.1 Data analysis

Throughout the measurement and assessment, we recorded 62 trees' status. In our plot, tree species are relatively affluent. Except for unrecognized tree species, there are 14 species of tree (as shown in chart 1). In these trees, Indian-Bean occupies over half a number. They mainly grew on the Memorial road and planted in two columns of tree-lined boulevards. It is a medium-sized deciduous tree with handsome, broad leaves. Among these Indian-Beans we measured, there are some old mature trees. The heights can reach 20 meters, and DBHs are nearly 2.5 meters. These old mature trees have an average crown width of more than 10 meters. Due to the measurement in winter, so the canopy cover is quite low, which means they would have a higher shade cover in summer. Five Pedunculate Oaks is growing on the sidewalk of the E Mall. Pedunculate Oak is a large deciduous tree as well as a long-lived tree, with a large wide-spreading crown of rugged branches. These trees are quite tall, the tree heights range from 10 to 20 meters, and DBHs are around 2-4 meters, the largest tree's average crown width is 20 meters long, but the percent of crown missing is pretty high. Sawara-cypress is a large evergreen tree with a fastigiate crown. All five of Sawara-cypress planted in a small grove that is surrounded by three separated Buchanan Block Buildings. The grove located in front of the tall Buchanan Tower, ideally this area is perfect for rest because it makes the place under the shade all year round and less exposed to sunlight. Their tree height already have reached around 20-25 meters, but the crown width range have been 7-8 meters. The DBH and crown width are not significant compared to their giant height. We found five Bowhall red maples are arranged neatly along with the Buchanan Block C building. They are the late plant of smaller size trees, with the crown is about 5 meters wide, and heights are less than 10 meters. Four Alligator-Wood trees along the Memorial road have a relatively large-scale canopy. Besides the five tree species mentioned above, this area also covers Japanese Maple, Northern Red Oak, Beech, Ornäs birch, Midland Hawthorn, Katsura-Tree, Plus nigra, Western Hemlock, Trochodendron aralioides.

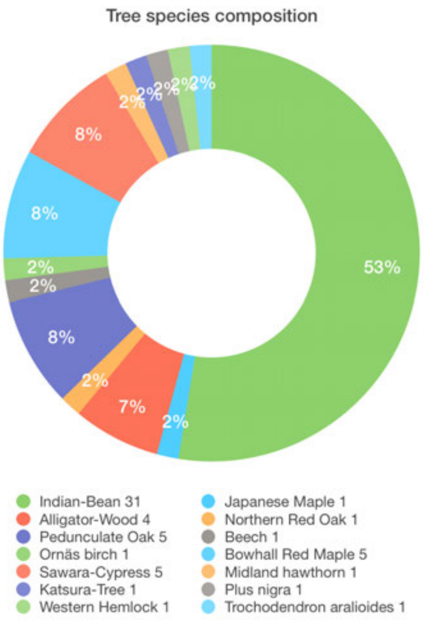


Chart 1

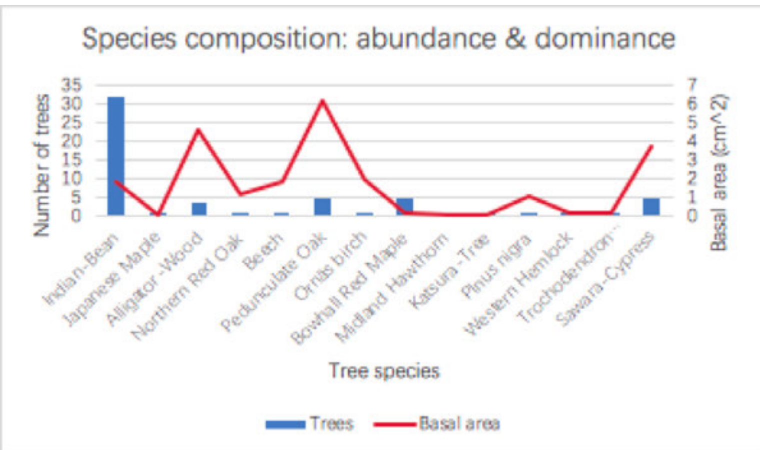


Chart 2

According to measuring DBH of trees and after calculation, we would be able to gain data of the basal area. From the Basal area guide, we know that the basal area is vital for studying forest-wildlife habitat. The canopy cover is in direct proportion to the basal area. Therefore, less sunlight hits the ground as both increases (Basal area, 2020). The basal area of a range of tree species has a significant impact on ground biomass because of sunshine. Also, the high basal area may increase competition among crown space, nutrients and moisture that is not beneficial for tree growth (Basal area, 2020). Consequently, balancing the basal area in a specific area is essential. From the data we collected (as shown in Chart2), we knew that the Pedunculate Oak, Alligator-wood and Sawara-cypress are the top three tree species that own large basal area. Also, Pedunculate Oak and Alligator-wood are the two tree species that have the most far reaching crown.

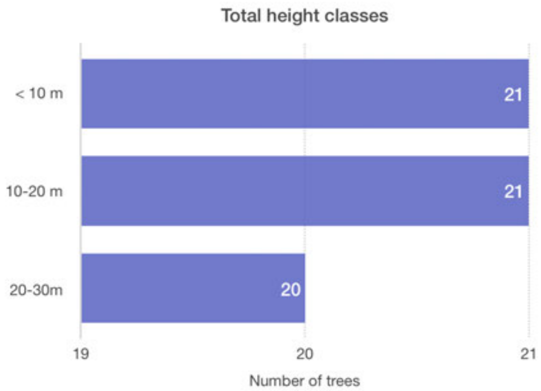


Chart 3

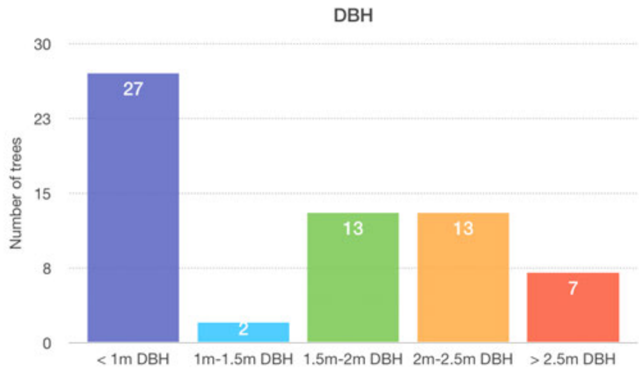


Chart 4

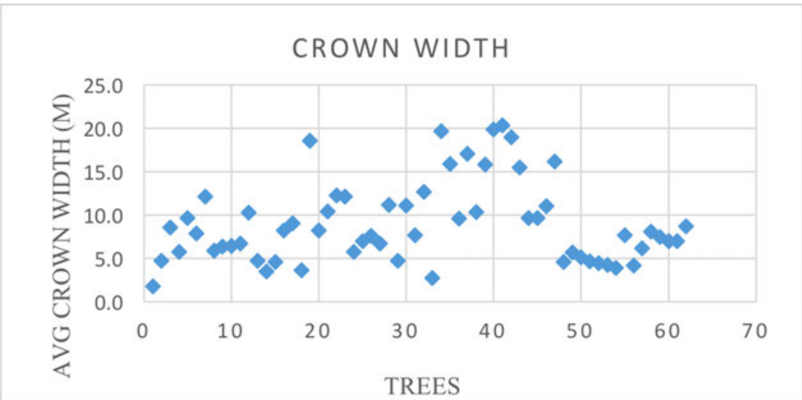


Chart 5

Amidst analyzing the entire data set, we focus on the discussion of total height classes, DBH classes and crown width. For total height classes (as shown in Chart3), all tree heights have even distribution in three ranges. There are 21 trees below ten meters, and 20 trees' heights are between 20 to 30 meters. The remaining 21 trees are between 10 to 20 meters. We learned that about the DBH classes from chart4, nearly a half number of trees have the DBHs that are less than one meter, and only two trees amid 1 to 1.5 meters. Meanwhile, 13 trees in the range of 1.5-2 meters and 2-2.5 meters, and the rest of 7 trees are above 2.5 meters. From chart 5, we found that the crown width range of 5-10 meters covers around half trees. There is nearly one in six trees that have an extremely wide crown lager than 15 meters.

4.2 Landmark Trees and Prediction

Our plot consists of some mature trees and some newly planted trees. Some of them are special because of some exceptional historical, cultural, or aesthetic value and so on. Landmark trees mainly refer to trees that have special historical, cultural, or aesthetic values because of their age, shape, rarity, or connection with important events or people, such as memory trees (Swiecki & Bernhardt). For instance, there have two prominent memory trees in our plot with a sign or stone tablet with messages about related people.

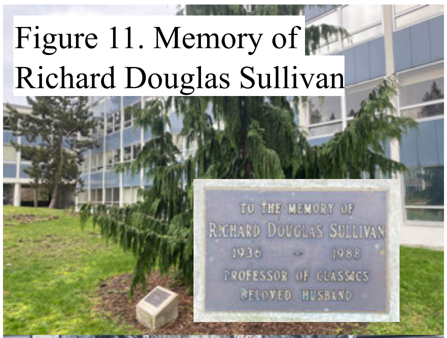


Figure 11. Memory of Richard Douglas Sullivan

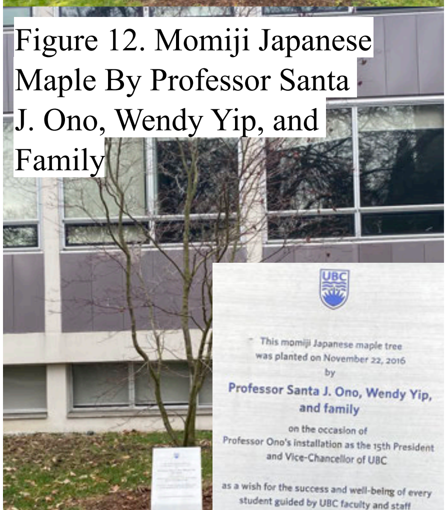


Figure 12. Momiji Japanese Maple By Professor Santa J. Ono, Wendy Yip, and Family

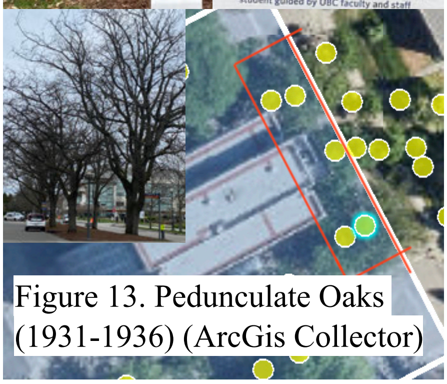


Figure 13. Pedunculate Oaks (1931-1936) (ArcGis Collector)

"Memory tree" means that the tree species planted or selected in honour of someone or something. Figure 11 is the most common type of tree for memory, which is planted in honor of someone already passed away. Apart from that, there is another type of common "memory tree" that can be noticed is for celebrating. For example, we can read from the sign of Figure 12 that this Momiji Japanese Maple are planted by the Professor Santa J. Ono and his family for celebrating Professor Ono would be in charge of the 15th President and Vice-chancellor of UBC. Besides, this tree also represents the best wish of Professor Ono to all UBC students and staff.

However, some trees may also have some sense of history or culture without any well-marked sign or stone tablet. According to an article named "*The Original f UBC's Graduating Classes Trees*" (Wodarczak, 2014) that we found in the magazine of UBC which call Trek, it mentions that there have six Pedunculate Oak (Quercus robur) planted by the graduating classes in 1931-1936. These six Pedunculate Oaks also called English oaks are located on the boulevard of East Mall between Buchanan Tower and Brock Hall which we can see from Figure 13 and we only collected data for the five that labelled in the ArcGis APP. According to Wodarczak's article, he mentions that the "memory tree" which also known as the "commemorative tree", originated from common customs in USA universities and basically aims to contribute to the landscaping of the campus (Wodarczak, 2014). From the first group of commemorative trees to now, this traditional ceremony has continued at UBC for over a hundred years. Moreover, this type of memory tree not only serves to landscape the campus environment but also celebrates and commemorates those graduation classes. It is worth mentioning that this ceremony also played a significant role in promoting the beautification and protecting the campus environment at UBC.

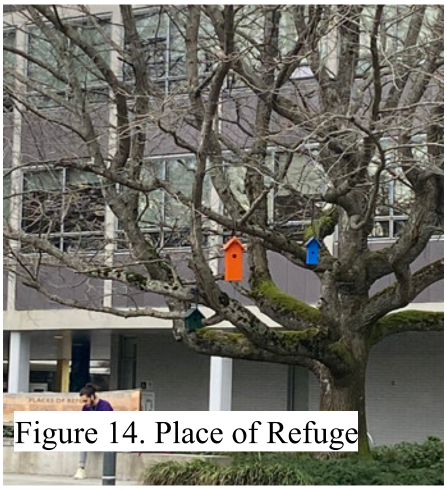


Figure 14. Place of Refuge

In addition to the memory trees mentioned above, we also noticed that there is a significant difference between one tree and other trees here. We mentioned that there is a bench under a tree in the row of trees next to the Buchanan building in the site description. We noticed that the tree beside the bench not only a street tree in a tree pit or parterre, but also works as a decoration tree here. We can see there have some colorful metal birdhouses on the branches just above the bench from Figure 14. Therefore, the reason why this tree is special as a landmark tree is that it is not just a street or tree planted for the beatification of campus, it is also a part of urban landscape design.

Since we emphasized many times that our plot consists of some mature trees and some newly planted trees. The size or the shape of the trees here are mostly concentrated in two extreme range. Hence, there are no obvious tree is bigger or strange-shaped tree here can be a landmark tree. The landmark trees here are mainly noticed by their different historical and cultural backgrounds.

Additionally, we assumes a prediction of the tree by combining some rough calculations and estimation based on the data we collected. We can see from Chart 6 that the growth trends of different tree species in our plot have obviously differences. The growth trends of some species are more obvious, and some are more flat. As mentioned earlier, the ages of the trees in our plot range are not evenly distributed. In addition, approximate 50% trees in our plots are Indian-Bean, thus, the prediction results are relatively accurate with Indian-Bean. However, the number of other tree species is about 1-5 for each, and the prediction of their growth trend is just based on data we only have. In general, we find that the growth rate and range of newly planted trees such as Western Hemlock are dramatically changing; on the contrary, the growth of more mature trees like Northern Red Oak will be more stable.

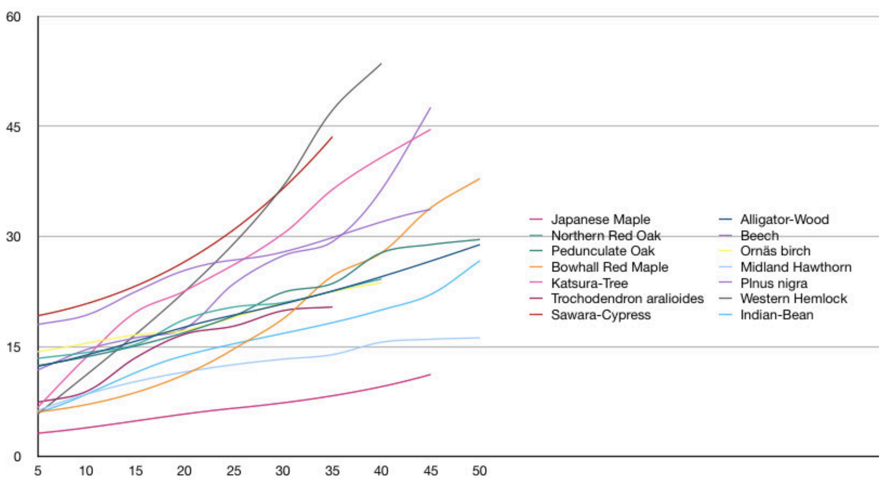


Chart 6. The Growth of Trees

5. Conclusion

In conclusion, the different aspects of tree inventory data analysis illustrate various information of urban forestry condition in our ploy. Above all, many trees are the small to median size based on the datum from DBH (diameter at breast height, breast height= 1.37m), TTH (total tree height) and CW (Crown width). The standard deviation of those datum are considerable to indicates the high-level variation of individual trees. Meanwhile, the light exposure and tree growing space are affected by the arrangement of planted trees and buildings. In our site, most of tree are able to exposed to sunlight, because most the trees are well organized in a relatively open area. There are few trees has low tree light exposure might because the light are blocked by the higher trees or building.

The diversity of tree species is pretty good. However, most of trees are Indian Bean tree *(Catalpa bignonioides)*. Over 50% trees are Indian Bean Tree and aggregate on the main road in our plot in campus. As deciduous tree, Indian Bean tree has big crown to provide shield to people and provide many ecosystem services of urban forest such as climate regulating (e.g., decreasing temperature in hot summer) for the campus. Otherwise, plant the deciduous trees on the campus road is more safety and prevent the snow to break the branch or hurt people in winter. Other species' trees are mostly close to the building or plant to the area between the buildings, some deciduous trees such as northern red oak (*Quercus rubra)*, Japanese maple (*Acer palmatum)*, etc., and some evergreen trees such as sawara-cypress (*Chamaecyparis pisifera)*, plnus nigra *(Austrian Pine)*and western hemlock. Those trees provides the cultural services and other ecosystem services to the campus.

Overall, tree plant planning in this plot is in line with the strategic planning and management of urban forestry which is committed to plant more trees and greening the campus. Meanwhile, it provide multiple ecosystem services and benefit from urban forestry to the people and campus.

References

Basal area. (2020). A guide for understanding the relationships between pine forests and wildlife habitat. Retrieved 13 February, from https://www.mdwfp.com/media/4194/basal_area_guide.pd

Chen, J. The Architecture of van der Rohe. Retrieved 13 February 2020, from http://www.people.vcu.edu/~djbromle/modern-art/02/Ludwig-Mies-van-der-Rohe/index.htm

Swiecki, T. J., Bernhardt, E. A. Guidelines for Developing and Evaluating Tree Ordinances. Phytosphere Research, Vacaville, CA. Retrieved 13 February, from http://phytosphere.com/treeord/index.htm

Wodarczak, E. (2014). The Origins of UBC's Graduating Class Trees. Trek Magazine. Retrieved 13 February, from https://trekmagazine.alumni.ubc.ca/2014/february-2014/features/campus-roots-the-origins-of-ubcs-graduating-class-trees/

Vescera, Z. (2017). Buchanan Tower doesn't care what you think about it. Retrieved 13 February 2020, from https://www.ubyssey.ca/culture/in-defense-of-buchanan-tower/

Urban Forest Inventory

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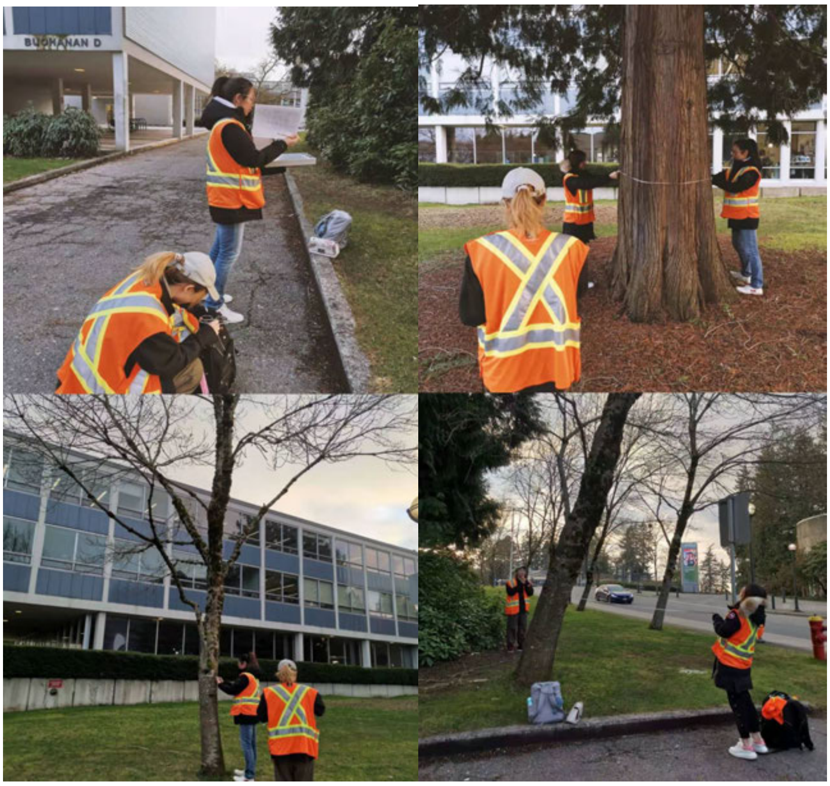
February 13, 2019



For UFOR 101, UBC Winter term 2, 2020

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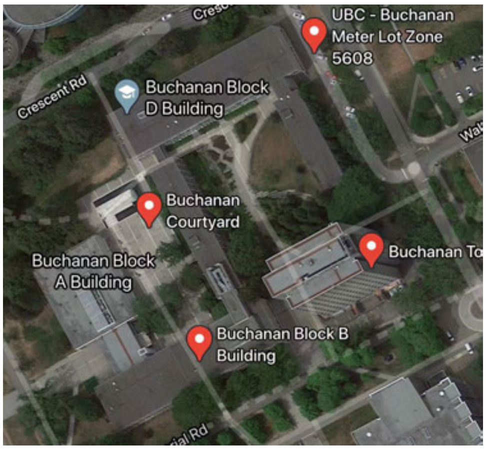
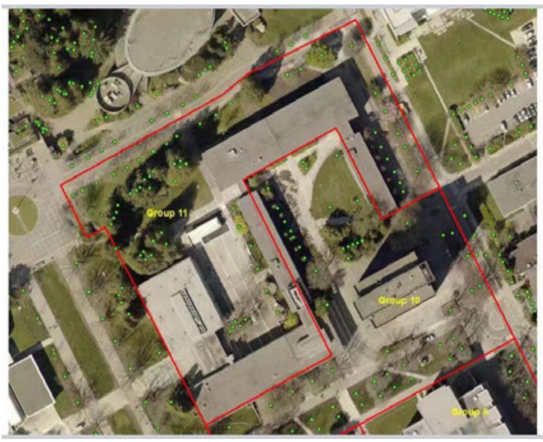
1 Introduction

1.1 Purpose of tree inventory

Tree Inventory Zone in the UBC Campus: Buchanan Building Blocks A to E





In this assignment we are put onto the task of making a tree inventory of a section of the UBC (University of British Columbia) campus.From the course and personal point of view, we have mastered the basic measurement methods and understood the measurement process. When after we clearly understand our current situation. It is significant to the management of tree distribution and future assessment and their development. How to observe the tree concentration can give us the keys that can assure that the biological distribution of these biological forms have to be maintained in the areas where they are standing. The idea of a tree inventory is mostly to understand and to construct the form on why there are significant concentrations or distributions of trees inside the UBC campus.

There, with any other type of tree inventory that is made in other urban spaces, is to assess what species are accessible, and where they can be relocated in the case of a massive renovation or expansion of buildings. The idea of a tree inventory is more akin to the same issues that it derived from the idea of inventories of other items inside the campus, these data collections, shows us what is the state of the trees around us. How valuable and how important trees for the campus as living spaces.

By taking into consideration where are distributed, the concentration of any specific species, that can be made in the terms of making their maintenance easier, the campus can actually expand the other types of trees that can be available, as well as to understand where exactly where there are more specific concentrations of trees, and where are they less prone to appear or develop by specific circumstances. Another of the benefits of a tree inventory inside the campus, can be considered in the terms of making a proper concentration of trees that can allow the campus to be a balance between buildings and biological structures, that can really allowed the development of green policies, an substance of the local ecology that it is done in the spaces.

Not only this type of assignment is necessary but gives us a wider view of it as a campus beyond an academic space for studying and research. The campus is an extension of buildings where people interact and exchange, and many amenities like the vegetation helps to increase the value of the buildings, but also their intrinsic value where they are located.

So, that is why that the main goal of this index is not only knowledge of the trees, but also platforms to understand how much is the vegetation developed in an University campus, how can be renewed or improved and how the campus themselves are acting accordingly to their maintenance an expansion according to green spaces policies that are adopted by campus policies, all the way to the federal government considerations.

1.2 Site description

Now, regarding the assigned building for the study and creation of the tree inventory inside the UBC campus, our group has been assigned the block related to the Buchanan buildings inside the campus. This complex of buildings located in the most northern part of the campus between Crescent and Memorial Rd. These are several buildings in which accounted the Buchanan blocks form a complex and also included the Buchanan tower. This is one of the most important complexes inside the campus, because many cultural activities among other types of meetings inside the campus are made frequently. Also, in the history of the entire campus, is one of the buildings that were constructed during the period of considerable structure expansion after World War Two.

The Buchanan Buildings started its construction in 1956, their intention was to have inside the location of the Faculty of Arts and Science and the main idea was to locate in one of each building assigned with a letter. Many of the classrooms and meeting places that were going to be established, mostly to expand the campus and start developing more areas we are more characteristic and contemporary architecture that will reflect the new idea behind the development of this type of buildings inside the campus.

The University of British Columbia, by itself in its distribution inside the city of Vancouver, offers enough space and comforts in the terms of its biological diversity, that these studies are very important to be made to see if the campus is already complying with many of the politics of the Canadian government regarding ecological balance, and sustainability of the environment in the area where the campus is standing. We live in an age where these concerns are important and taken into consideration every day, so by making these inventories, we are not only securing the main documentations about the trees on the campus. We are also securing the idea that the campus is constantly improving, and it is a place that not only serves for educational purposes, but also for the students to enjoy the ecology present in the area of Vancouver.

As well that one of the most important values of our time is the ecological balance it is more than important it is essential and the norm, and to know nature is to better known ourselves, to understand and to take into consideration this type of indexes. We are also making it possible to make current and future generations aware of the types of trees that are available for the proper maintenance and the better distribution in the buildings of the campus.

2 Methodology

2.1 A list of variables

Tree Description	Tree ID (code)	Unique identifier given to each tree
	TAG (Y/N)	Verify if the tree has a tag already
	TAG ID (number)	If the tree has a tag, add the number
	LIVE/DEAD (L/D)	Tree is alive or tree is dead
	SPECIES	Species of tree in App
DBH	H DBH (m)	Height at which DBH measurement was taken if not measured at 1.37 meters
	DBH (cm)	Tree stem diameter at breast height (DBH) measured at 1.37 meters above the ground
Tree Height	Total Tree Height (m)	Height from the ground to the top of the tree (alive or dead)
	Live Crown Height (m)	Height from the ground to the live top of the tree
	Crown Base Height (m)	Height from the ground to the base of the live crown
Crown Width	Long (m)	The longest width of the crown
	Short (m)	The shortest width of the crown
Other	CROWN %MISS (%)	Percent of the crown volume that is not occupied by branches and leaves
	CLE (0 to 5)	Crown light exposure (CLE) indicates the number of sides of the tree's crown receiving light from above or the side

Table 2.1 List of variables measured

2.2 The methods used for inventory data collection

This section aims to describe how to use common tools for urban forest measurement during tree inventory. Before undertaking the inventory data collection, Dr. Tahia Devisscher introduced the class to an auxiliary tool, an app called ArcGIS Collector Classic. When we sign-in with ArcGIS login, the information of current campus tree data with plots and zones for W2020 term would be showed in the App. Each tree is presented on the 2019 orthophoto as base map as a yellow translucent dot for clicking and further viewing of the detailed data. Each group was assigned to a backpack full of measuring tools, and each group member in turn received their own measuring vest. According to the list of variables, the tools used are as follows: diameter-tape, laser rangefinder, telemeter tape, compass, and inventory table. For each tree in our responsible zone, our team measured it in the order of tree description-- tree stem diameter-- tree height-- crown width-- other.

In the first place, after matching the ID number of trees on Classic, we then copied the identified tree species and checked whether any tree tags on trees. It is worth mentioning that all the trees tested were alive except one that had been destroyed (cut down) near the exit of Buchanan Block A Building. In the second place, diameter-tape was used to measure tree stem diameter at breast height. This number is often abbreviated as DBH. Our practical way to measure DBH is to hold the diameter-tape up to the height of the chest (about 1.37m), which is the standard used in many countries. DBH is usually measured on the uphill side of the tree to avoid measuring the butt swell of the tree. This term refers to the area where the root of the tree is thicker than the rest of the tree, more accurate measurements can be gain if we measure above it (Cris, 2009). However, we experienced to measure trees which are not monophyletic. In these special cases with multiple stems, DBH of up to six stems must be measured separately (ignoring the smaller stems and choosing the larger ones). The overall DBH of a multiple stem tree is equal to the square root of the sum of all squared stem DBHs (I-Tree Design, 2019). In the third place, using a laser rangefinder to measure Total Tree Height (TTH), Live Crown Height (LCH), and Crown Base Height (CBH) separately. The group let a member stand ten meters away from the target tree and estimated the height of the tree by observing the horizontal point, the top and the base of the tree (Three-point measurement). Figure 2.2 shows the ranges of these variables. Notice that CBH refers to the height from the ground to the lowest living crown on the last branch, not from the ground to the point where the branch intersects the main bole (Randolph, 2009).

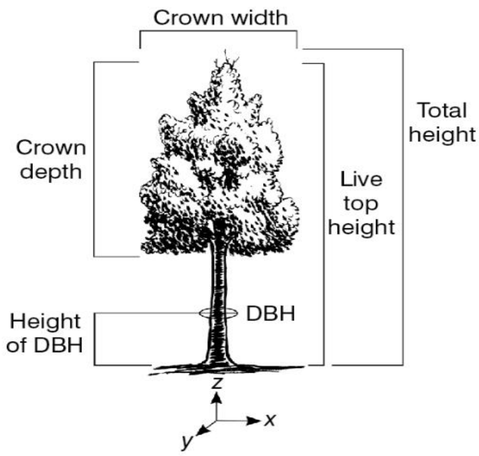


Figure 2.2 Common variables that are measured to describe a tree's structure

On the other hand, two group members were required to measure the crown width with a telemeter tape and a compass. They need to grab both ends of the telemeter tape to stand on opposite sides with the trunk as the axis to record the width of the crown from two directions. The average value is calculated after measurements on both long side and short side are obtained. Last but not least, the measurements of Percent Crown Missing and Crown Light Exposure could be compared by a standard called projection key cover estimation and visual. Both of these measurements need to be observed from multiple angles to obtain more accurate results.

2.3 Methods used to analyse your data in class

To analyse collected datas of abundance trees, different graphing and charting methods can be applied. To describe the species composition, two charts can be shown. One is the general tree species composition chart, according from species and quantities of the tree. Another one is the dominance of the tree species, which demonstrates by basal area verse tree species. Combine both charts, the dominance and abundance of species can be perfectly summed up. The equation of tree basal area in m^2 equals to pi times square of DBH in cm divided by 40000. To demonstrate the structure of the urban forest, can be shown by two graphs. The first one is about the DBH classes, as number of trees verse DBH classes. Beside, the basal area can also including in this graph by connecting the points to a line. This graph illustrates the main species and the relationship between DBH and the basal area. The second one is the total height classes, shown by number of trees verse total tree heights classes. All the dots connected by an uneven line. The differences between all the variables can be solved by calculate the mean and estimate the variance. The method uses to calculate the mean is by taking the sum of the measured values in the dataset and dividing by the total number of values. The method uses to estimate variance is called standard deviation which calculates the deviation of the data around the mean of that dataset by equation:

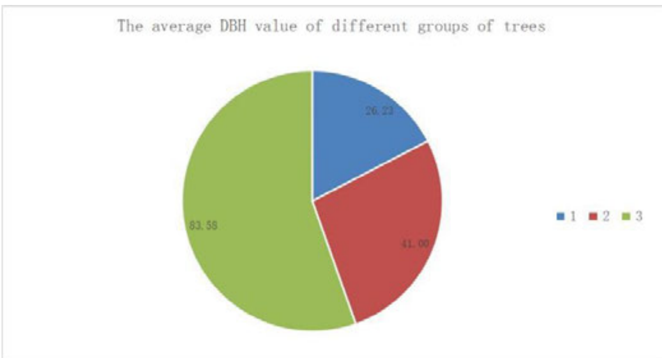
Standard deviation (SD): $\mathrm{SD} = \sqrt{\frac{\sum \lvert x-\mu\rvert^2}{N}}$	$\sum$ = sum of X = a value in the dataset μ = mean of the dataset N= number of data points in the dataset (population)

After calculated all the numbers, sum all the datas and numbers up in a summary table.

3 Summary of tree inventory data

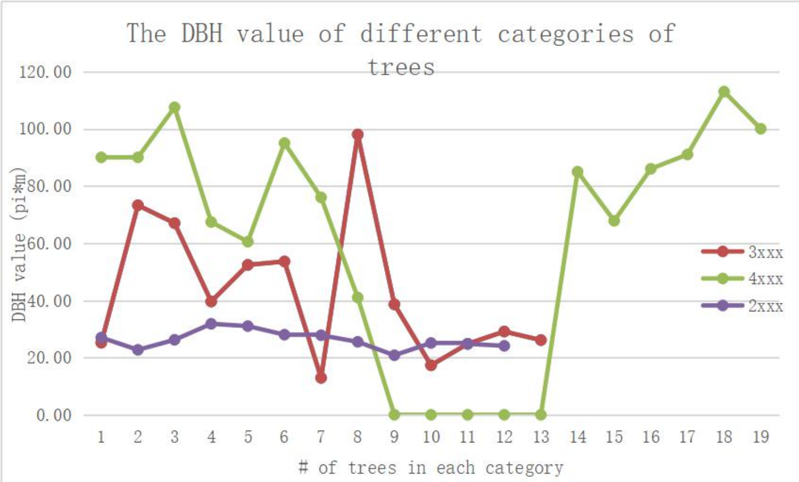
In conclusion of our measurement, the rarest tree seen in our area is Japanese cherry. The tallest tree is Pacific red cedar, it has an average TTH around 22 m. The tree we measured that has the longest branch distance is Northern red oak, it has a distance of 26.2 m.

3.1 Summary of results



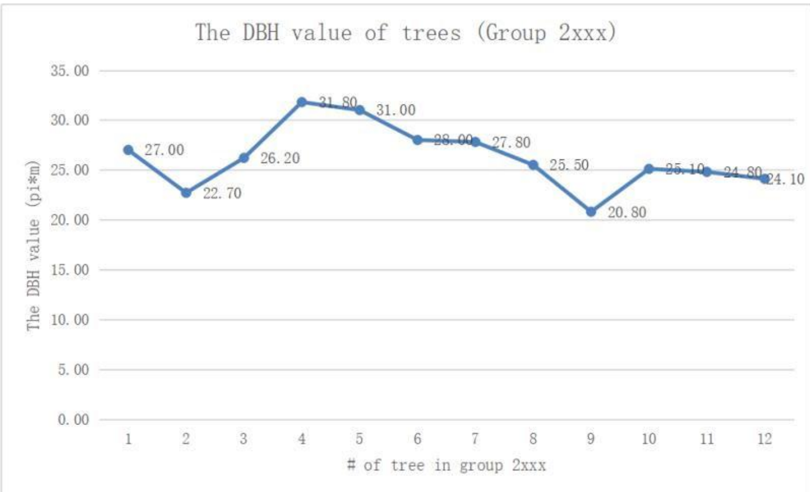
The above chart is showing that the category 3xxx has the highest average value of DBH. This is the portrayal of the average DBH value and 83.58% is occupied by category 3 trees. Although this is the average value, there is clear display of the coverage of category 4xxx trees.

Chart 2



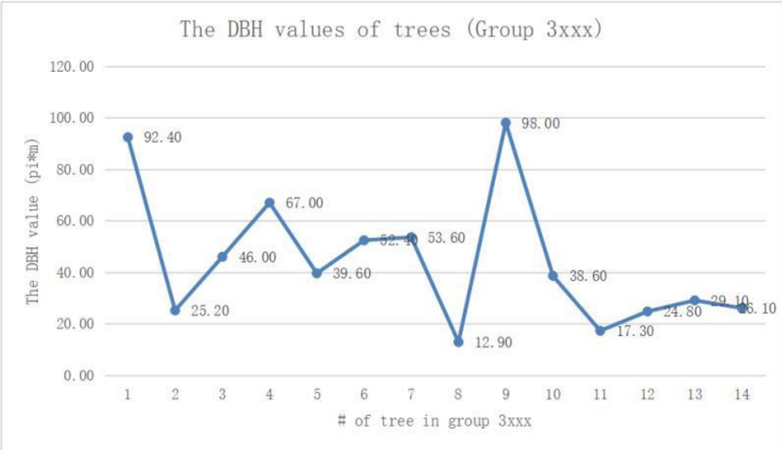
There are three categories of trees. The DBH value of the 4xxx is the most significant one. The second position is occupied by 3xxx category. And the last position is taken by the 2xxx group. All the groups are important but the categorised value is very important. Thus, the graph is clearly showing that the category of 3xxx has the highest most value of DBH. This is very significant.

Chart 3



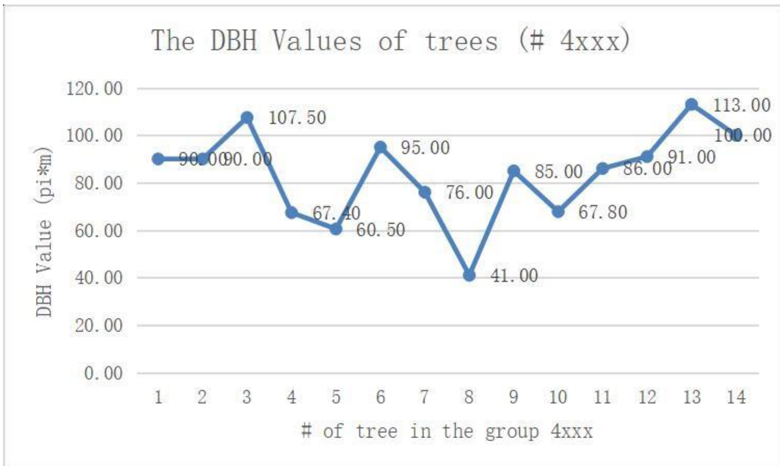
This chart is showing the group 2xxx trees' value. When the DBH value is above 25, there is only 1 tree. And when the value is above 30 pi*m, there are more than 4 trees and the highest level is up to 8 trees. And when the value is less than 25 pi*m, there will be more than 9 trees. So there is a fluctuation in the value and the number of trees vary.

Chart 4



This category of tree has the highest level of fluctuation in the correspondence to the DBH values and the number of trees. The above chart is showing the Group 3xxx trees and there is huge fluctuation with the value. The graph clearly states the scenario. When the value is 98, the number of trees is 9. And for 10 trees, the value becomes 38.60. and when the value is 20 or slightly above, the number of trees are 11 to 14 trees.

Chart 5



This graph is showing a nice balancing. The overall value is clearly getting balanced with the number of trees. There are not many fluctuations. The value is in between 40 pi*m to 110 pi*m and the corresponding number of trees are up to 14 trees, but the variation is not much higher. Only a big variation can be seen in the value of 40 pi*m and there are only 8 trees. After that, the whole scenario is quite balanced. Compared to previous two categories, this is in a stable condition.

3.2 Interpretation of key examples

Cultural importance: Japanese cherry

ID	TAG	DBH	TTH	CBH	LONG	SHORT
2998	N/A	39.3	6.4	0.6	8.7	1.5

In our measurement range, the most culturally distinctive plant is Japanese cherry tree. They are distributed widely all over the world, the most are in temperate regions of the Northern Hemisphere. The cherry tree is an important cultural symbol of Japan, which symbolizes its mass flowering nature as a cloud, and in addition to being a metaphor for the ephemeral nature of life. Japanese cultural tradition is subtly influenced by Buddhism as well. The link between cherry blossoms and the drab unconscious can be traced back to the 18th-century scholar Motoori Norinaga.
The brief blooming of cherry trees, their exquisite beauty and variability, are often associated with death, grace, and an acceptance of fate and karma. As a result, cherry blossoms are highly symbolic and are often used in Japanese art, manga, movies,and also musical performances. In Japan, there is a well-known popular song that was originally played for bamboo flute. Its name is Sakura. The flower is represented in all of Japan's consumer goods as well, such as kimono, stationery and tableware. After the cherry trees bloom, their delicate beauty can only last a week, with their petals falling and covered with a pink carpet on the ground. Usually, their life is not long, only lasting about 16 to 20 years. But some species like black cherry trees have a longer life expectancy, and can live up to 250 years.

Longest branch distance: Northern red oak

ID	TAG	DBH	TTH	CBH	LONG	SHORT
3022	1788	98	20.4	3.2	26.2	14.5

Quercus rubra, are commonly known as the northern red oak; this type of tree has the longest branch distance measured in our group. It is a type of oak tree relating to the red oak group(Quercus section Lobatae). It is a native tree species in North America, and can be found in the eastern and central United States, Southeast and South-central Canada. It has also been introduced to Western Europe in the 1700s, it became one of the most significant invasive species in western and central Europe. Northern red oak prefers soil that is slightly acidic. Northern red oak is recognized to be the state tree of New Jersey in the U.S. and the provincial tree of Prince Edward Island. This tree has been recorded growing up to 43 m, but main grows up to around 28, with a trunk up to 50-100 cm in diameter. In North America's timber production industry, northern red oak is one of the most important oak; high quality red oaks have a high value as lumber and veneer, defective logs can be used as firewood to prevent waste. The acorns produced by the northern red oak provides a food source to wild animals like blue jays, squirrels, and raccoons. In the wild, deer eat the buds and twigs of the tree in the winter. Due to the management of trees at UBC, there will not be many more red oaks in the near future due to the limitation in space and considering the interval between two trees in our measurement area.

Tallest tree: Pacific red cedar

ID	TAG	DBH	TTH	CBH	LONG	SHORT

4433	5688	90	25.8	6.3	7.5	4.3

Thuja plicata is the tallest tree species measured in our area, it is commonly known as Pacific red cedar or Western red cedar. It is a native tree species to the West Coast of Canada and the United States. This type of tree can grow up to 70 m when it reaches maturity. The best environment for pacific red cedar to grow is in moist to wet soils, with abundance of nutrients in the soil. The wild red cedar can get damaged by other animals like deer, and bagworms; the branches may also get damaged due to the ample amount of snow. It is one of the longest life living tree species that can live up to 1000 years. Pacific red cedar can be found among the Pacific Northwest, but this species is naturalized in Britain; it has also been introduced to other countries like Australia, New Zealand, and western Europe. People can always find Douglas-fir and western hemlock near pacific red cedar in most places where it grows, because they survive in the same temperate zone. Natives used to make tools like paddles, arrow shafts with red cedar woods. It is also a favorable type of wood to make outdoor furnitures such as decking and fencing, the wood is naturally durable and light in weight, and has a good resistance to insect damages. Another interesting fact is that the red cedar is British Columbia's official tree, the scientific name plicata is originated from a Greek word meaning "folded in plaits". Pacific red cedar can grow up to 65 to 70 m tall in the future, and up to 7 m in trunk diameter. In the near future, when trees reach maturity, they will start to reproduce by seeds, also vegetatively like the rooting of falling branches.

Works Cited

Brandeis, T., Randolph, K. C., & Strub, M. (2009). Modeling caribbean tree stem diameters from tree height and crown width measurements. Mathematical and Computational Forestry & Natural Resource Sciences, 1(2), 78.

Cris Brack, PhD (UBC) Standard point on tree bole for measurement. Forest Measurement and Modelling. Retrieved 2009-04-18.

Cherry Blossom Tree Facts That You Definitely Never Knew Before
Rebecca Shinners -
https://www.countryliving.com/gardening/g3168/cherry-blossoms-facts/
https://www.for.gov.bc.ca/hfd/library/documents/treebook/westernredcedar.htm

I-Tree Design. (2019). *i-Tree Software Suite.* Retrieved from design.itreetools.org

Morgenroth, J., Oestberg, J., 2017. Measuring and monitoring urban trees and urban forests. Routledge, pp. 35.

UBC. (2018). A Brief History of UBC. Retrieved February 11, 2020, from https://archives.library.ubc.ca/general-history/a-brief-history-of-ubc/

UBC. (2018). The University of British Columbia. Retrieved February 11, 2020, from http://maps.ubc.ca/PROD/index_detail.php?show=y,n,n,y,n,y&bldg2Search=n&locat1=121-1&locat2=#showDetail

Vescera, Z. (2017, November 16). Buchanan Tower doesn't care what you think about it. Retrieved February 11, 2020, from https://www.ubyssey.ca/culture/in-defense-of-buchanan-tower/

Northern Red Oakquercus Rubra
https://www.arborday.org/trees/treeguide/treedetail.cfm?itemID=877

Contribution Description

Group 11

Group Members:

Lulu Li [redacted]: Integration of data tabulation, Interpretation of key examples with Jason for the Summary section.

Tasso Hu [redacted]: Make the list of variables for the Methodology section, responsible for the part of methods used for inventory data collection, final integration and typography of the entire report including the content and group reference.

Jason Li [redacted]: Completing the interpretation of key examples with Lulu for the Summary section.

Yiming Ren [redacted]: Responsible for the Introduction part, including both of purpose of tree inventory and site description.

Shiyi Wang [redacted]: Completing the summary of results, including making graphs and charts.

Yuhan Chen [redacted]: Responsible for the part of methods used to analyse your data in class in the Methodology section.

Ecosystem service assessment report

Xiwen Zhang
Ruoxuan Ma
Xiangyue Chen
Rebecca Cai
Jinru Chai
Viola Zhao

April 8, 2020

Contribution Page

Introduction: Xiangyue Chen

Site Description: Xiwen Zhang

Regulating Ecosystem Services: Viola Zhao

Cultural Ecosystem Services: Jinru Chai

Urban Forest Planning and Management Recommendations: Ruoxuan Ma, Rebecca Cai

Data Tabulation: Xiwen Zhang

I-Tree Eco and Canopy Report: Viola Zhao

Final Editing: Viola Zhao

Introduction

This report is mainly focused on assessing the ecosystem services of urban forestry in zone 1 of The University of British Columbia. All the data were collected by conducting tree inventory, which is a record of the location, characteristics, and assessment of individual trees within a well-defined group (International Society of Arboriculture). Tree inventory is helping with the urban forest planning & management, assessing urban forest condition, assessing ecosystem services provided by urban forests and value the benefits of urban forest (Devisscher & Almas, 2020). Based on the data collected from the tree inventory, this report would provide proper recommendations and suggestions corresponding to the particular ecosystem services of zone 1 in UBC. Moreover, the i-tree canopy, i-tree Eco and cultural services value mapping were applied to this assessment and shown in this report. The results of this report assists the stakeholder with discovering the biodiversity component of the new Green Building Action Plan and future Urban biodiversity planning Requirements for biodiversity compensation for capital projects (Devisscher & Almas, 2020). Due to the complexity of ecological environment development on campus, urban forestry planning requires different processes and is recognized by related policies for each political level. More specifically, the policy landscape directs urban foresters to baselining campus natural assets and consider broader ecological, cultural and social value of these assets.

The following part is site description which illustrates the overview and the specific location description of zone 1. The regulation ecosystem services section is the evaluation of ecosystem services provided by zone 1 by using i-tree canopy and i-tree Eco. The cultural ecosystem services part is the quantification of spiritual enrichment, recreation, social relations and aesthetic values of zone 1. The last part is urban forest planning and management recommendations, this part provides recommendations corresponding to each particular ecosystem service in zone 1.

Site Description

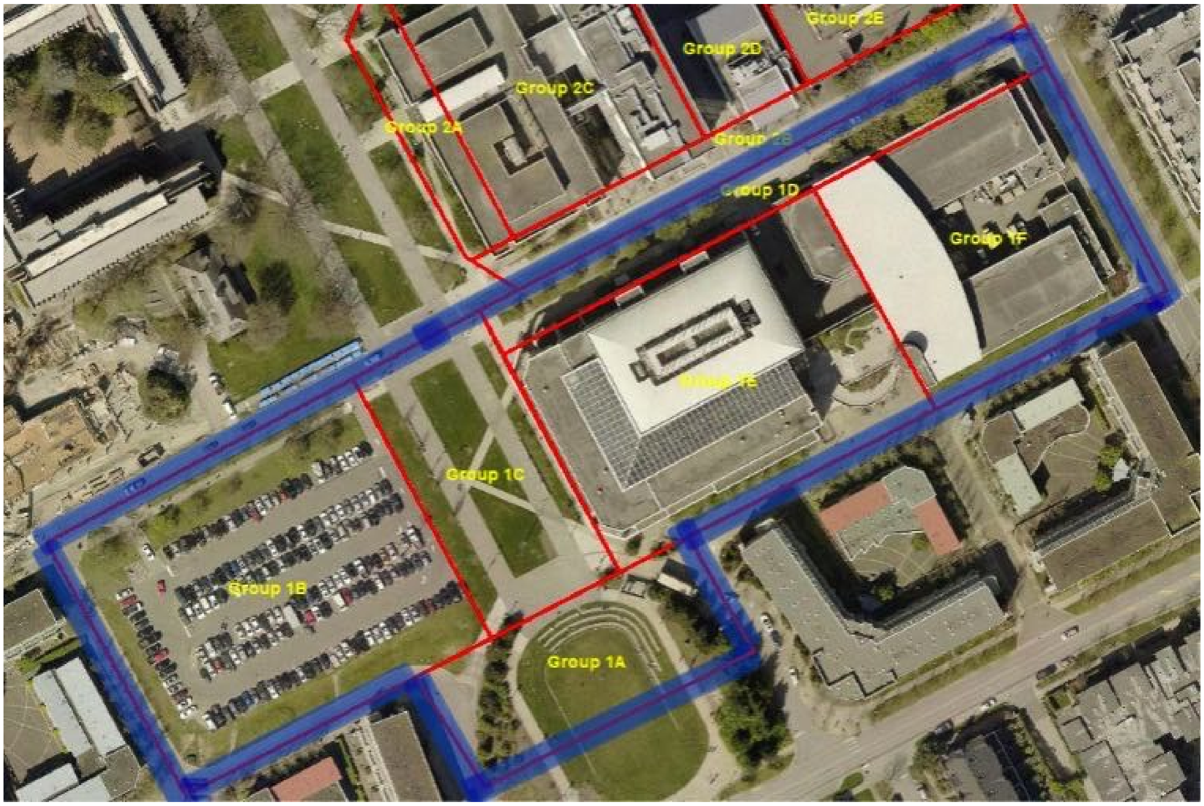


Figure 1: The Satellite Version of Group 1

The Zone 1 fieldwork area is assigned at the southern end of the UBC campus. It is located between the Agronomy Road and Thunderbird Blvd. Figure 1 shows the area selected by the group one, circled by blue, which contains one parking lot (B), two buildings of forest science faculty (E&F), a sidewalk (D), one square of the main mall's lawn (C), and half of the park behind the Sopron Gate (A). Section one covers a large area. It is highly functional. Hence, different sub-zones with distinct land uses. In addition, these correspond to different users and stakeholders.

The rectangular open pay parking lot is situated in the west of Zone 1, which is defined as transportation land use. Some medium-size Robinia Pseudoacacias 'Frisia' were planted by the Agronomy Road, on the side of the entrance. The parking lot is mostly shared by students, university staff and visitors. Furthermore, the management and maintenance of this region are responded to by UBC Parking and Access Services.

On the eastern side of the section, the Forest Science Centre and the Centre for Advanced Wood Processing are located. These two buildings are the center for education, training and technical assistance for forest science faculty. Besides institutional buildings, this region could be considered commercial land use. There is a Tim Hortons inside the Forest Science Centre. In their spare time, people can easily get their coffee and snacks without walking a long distance. Several maple trees with large canopy are arranged along Agronomy Road, next to the Forest

Science buildings. These trees could provide shade for pedestrians from the strong sunlight and heavy rain.

On the lawn of the end of the Main Mall, the Reconciliation Pole was installed in order to encourage everyone who comes across it to learn more about the history of the Indigenous residential schools (Ono, 2017). Some social activities, like protests, about the Indigenous Canadians, would be held under the Reconciliation Pole. On both sides of the Main Mall, some benches are provided for people to sit on for relaxing. In addition to the end of the Main Mall, the small park could also be listed for open space and recreational land. The green space behind the Sopron Gate is in the middle of two groves with diverse tree species, which are small to medium size. The small park is shared by the residences from the communities and students or staff from UBC. It is a great place for children to hang out with their families; people can sit on the grass and have a picnic; students could relax from the busy life when they are taking a seat on the steps.

Regulating ecosystem services

Urban forest is crucial in mitigating urban environment. Trees are very effective at removing pollutions and runoff, reducing urban head island effect, and producing oxygen. These regulating ecosystem services can be quantified by using different applications. In this report, I-Tree Canopy and I-Tree Eco were used to assess the regulating ecosystem services in Zone 1.

I-Tree Canopy Model

I-Tree Canopy helps estimate tree cover and tree benefits in selected areas. This application uses Google Map and random sampling methods. To use I-Tree Canopy, first, we find the project area by zooming in Google map. Then, we define our zone area by contouring it (figure 2). Next, I-Tree Canopy lays random points onto the selected zone, and we are asked to classify either the laid point is a tree or not a tree. The users can decide

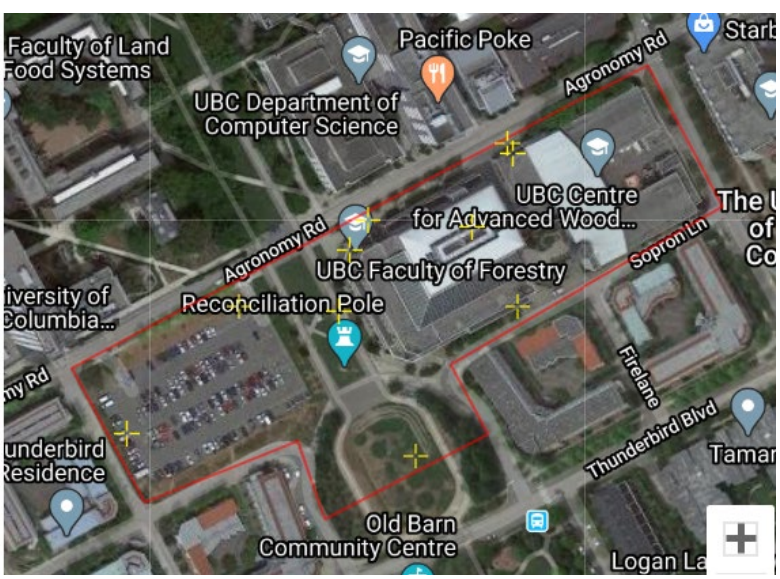


Figure 2. Contoured zone using I-Tree Canopy

how many points to put in the selected zone. I-Tree Canopy will estimate the percent canopy coverage in the project zone based on the point data. The more point defined, the more accurate the estimate will be. In this report, we classified 50 points in our project zone. The strength of I-Tree Canopy is that it does not require field work, requires less tools, and processes data very fast. It is very useful in estimating canopy coverage in a broad area. However, I-Tree Canopy also faces a lot of challenges. First, the accuracy of the highly depend on how accurately the users identify the points laid by I-Tree. When we were doing the tree survey, there were several points that are difficult to tell whether they are trees or not. In addition, Google Earth imagery is poor in resolution in some areas.

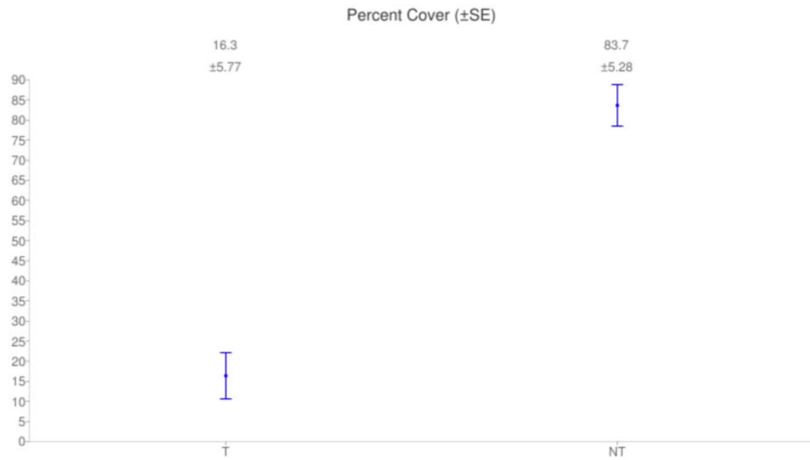
I-Tree Eco Model

I-Tree Eco uses field data collected in the study area to quantify urban forest values and vegetation composition.Specifically, I-Tree Eco take inventory data and generate a report on canopy coverage, species composition, pollution removal, and other regulating ecosystem services. The strength of I-Tree Eco includes: providing more accurate report on canopy cover and species composition, providing more information about environmental effect and structural value in selected area, and giving management recommendations. The weakness about I-Tree Eco is that it requires a lot of field works. The accuracy of I-Tree Eco report highly depends on the field observations by users. They need to corrrectly identify the species and carefully measure the dimensions of each tree, which are time-consuming works.

Results

I-Tree Canopy

According to the results generated using I-Tree Canopy, trees cover approximately 16.3 percent of the prroject area.



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	8	16.3 ±5.77
Non-Tree	All other surfaces	NT	41	83.7 ±5.28

Figure 3. Urban Forest Percentage Cover (I-Tree Canopy)

The report also provided Tree Benefit estimates, specifically, it estimated the amount of pollution removal, carbon storage, and carbon sequestration.

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.35 CAD	±0.00	2.61 kg	±0.00
NO2	Nitrogen Dioxide removed annually	0.60 CAD	±0.00	14.21 kg	±0.00
O3	Ozone removed annually	31.16 CAD	±0.00	141.55 kg	±0.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	64.42 CAD	±0.00	6.88 kg	±0.00
SO2	Sulfur Dioxide removed annually	0.10 CAD	±0.00	8.96 kg	±0.00
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	22.62 CAD	±0.00	47.42 kg	±0.00
CO2seq	Carbon Dioxide squestered annually in trees	2,109.29 CAD	±0.00	28.94 t	±0.00
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	52,972.07 CAD	±0.00	726.72 t	±0.00

Figure 4. Tree Benefits Estimate (I-Tree Canopy)

I-Tree Eco

Zone 1 has 87 trees on site. The most abundant species are Godeln Black Locust. Pacific madrone, and European Beech. Urban forests usually have a high species diversity. 76 percent of the trees are native to North America. Increased diversity helps increase the overall resistence of the urban forest. However, if the species are invasive, it can also decrease the health of urban forests because invasive species compete for resources with native species (Keller et al, 2014).

One of the most direct benefits from trees is the leaf surface area. In zone 1, the urban forest provides 0.51 acres of leaf area, and the canopies cover 17.93 thousand square feet. Douglas-fir has the most abundant leaf surface area in zone 1.

Air pollution is a major problem faced by many cities. One of the most important regulating ecosystem services provided by trees is air pollution removal. Plants absorb pollutants through their stomata (Nowak, 2002) and convert them into acid or other chemicals. According to our I-Tree Eco report, urban trees in zone 1 are estimated to remove 8.79 pounds of air pollution, including ozone, carbon monoxide, nitrogen dioxide, PM2.5, and Sulfur dioxide, annually.

Urban trees can reduce the amount of carbon in the atmosphere by sequestrating carbon, which can help reduce green house gas. Trees and other plants absorb CO2 through photosynthesis and release oxygen through stomata. In zone 1, about 676.5 pounds of carbon is being sequestrated each year, with an associated value of 35 CAD. Trees also store carbon as they grow. Carbon storage can be refered to the amount of carbon that can be realeased when trees decay and die. Urban trees in zone 1 are estimated to store 7 tons of carbon each year. Therefore, keeping trees alive and healthy is very important as trees are the major carbon sinks for the Earth.

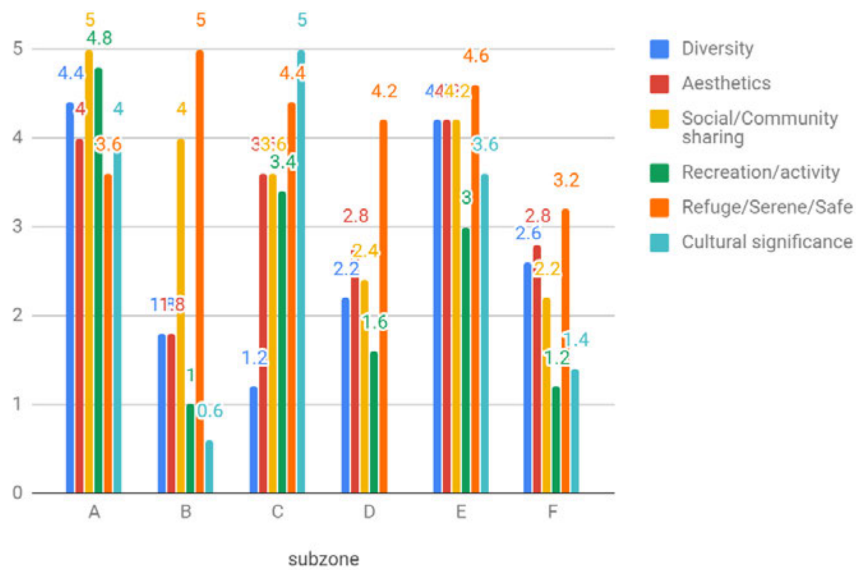
Result Comparison

Both models mentioned tree cover and pollution removal in their reports. However, I-Tree Eco provided a more precise and detailed report. I-Tree Canopy did not specify species. In addition, it overestimated the amount of pollution removal and carbon sequestration and storage. The difference is caused by: 1. I-Tree Canopy uses random sampling while I-Tree Eco uses field data that has the exact number of trees; 2. I-Tree Canopy does not specify the type of species (different species have different pollution removal and carbon sequestration rate).

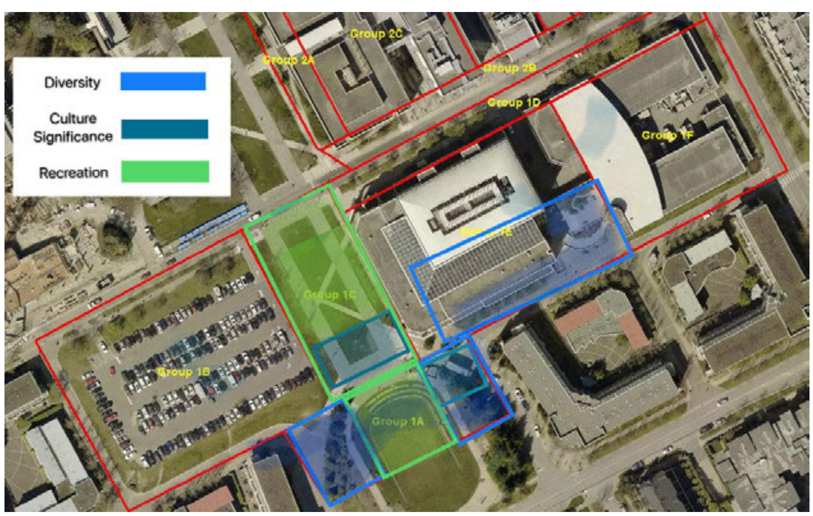
Cultural Ecosystem Services

The cultural ecosystem services are defined as "The nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experience, including, e.g., knowledge systems, social relations, and aesthetic values. "(TEEB). To produce the value mapping, our group has used six dimensions including the diversity, the aesthetics, the social/community sharing, the recreation, the safety, and the cultural significance to help stakeholders have an easy understanding of our zone. Our zone is separated into six different smaller zones and for each subzone, our group members are marked form a scale of 0 to 5 for each dimension. With all the points add up it comes up to the average chart shown below (Figure 1). Continued with the scaling, each group member has discussed their perspective for the reason of their marking and about the weakness and strengths for each subzone base on the cultural ecosystem services. Hence, it summed up the value mapping (Figure 2) for cultural ecosystem services in zone 1.

The value mapping and the average chart is helping stakeholders to have a better understanding of the cultural ecosystem services easier because it is the non-material benefits people can get from the ecosystem. However, the value mapping is mostly based on the 6 of the group members, there could be different views between students and the stakeholders. The strengths of students based on value map under this project are they do have more access and knowledge in zone 1, and base on their own experience they are giving a fair view about the cultural ecosystem services. On the other side, the weakness is obvious, the value map approach only considered the views from group members, but space it is public access, so different age group people and stakeholders could have different opinions about the values of cultural ecosystem services.



（Figure 5. average chart for cultural ecosystem services）

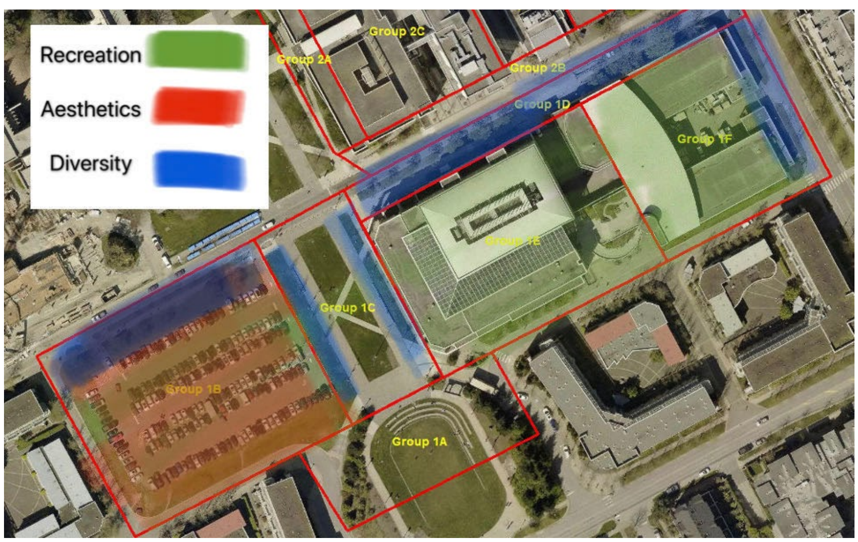


(Figure 6. strengths of cultural ecosystem services)

By the chart shown before (Figure 5), some of the subzones have strengths in both of the six dimensions, but some zone has only one or two strong representatives.

Both of zone A and D have a relatively high score on each category, the score for diversity is the only two subzones having higher than 3, with each having 4.4 and 4.2. The reason for having a lower score in other subzones is because street trees are mainly planted and with the lower diversity in the area will make it more uniformed. firstly, subzone A reached the highest score in diversity is by both sides of species planted beside the pathway. By having more diversity could help this subzone to have more people come and relax while the larger trees can separate the buildings and the green field. As is shown in the figure 3 the subzone A is a small scale of greenfield for people to spend their time and to explore, this place has the highest cultural value for people in the area. Also by having the Sopron gate in subzone A, it is adding more cultural significance in the subzone, some people come to zone 1 for just the Sopron gate and the Reconciliation pole.

Secondly, Subzone B it is a high community sharing area, in which parking lot is provided, it is a convenient place for students and visitors come to UBC, especially surrounded by faculties and the dorms. Although it does not provide much aesthetics or cultural value, subzone B does have a high score for social cohesion and safety in zone 1. Thirdly, subzone C leave a huge green field between the parking lot and forests faculty, it is only planted with medium size street trees on the very edges of both side. But this gives a great value of community sharing for people passing by, also since there is a kindergarten close by, people would like to spend time in subzone C to watch their children play around and enjoy the greenery after school.



(Figure 7. weakness in cultural ecosystem service)

Although most of the subzone is well maintained and with high cultural ecosystem services value, some subzone still has weaknesses that can be improved. subzone F and subzone B does not provide much of the aesthetics value or cultural significance. Street trees are planted with the only serval of trees in single specie. It seems like on every end of zone 1 the street trees were not well maintained and cared for. Trees are distributed with large space in between and trees are not large enough to provide shades during the summer.

In subzone D the cherry trees are planted on half side of the road. It is adding a lot of aesthetics for the sight, but the ground seems to be raised up by the roots of the trees, this could cause more future attention to the sidewalk in order to take care of the safety for passengers.

Urban Forest Planning and Management Recommendations

Urban forestry is mainly designed and planned for managing trees and forest resources in and around urban community ecosystems. Greenspaces provide a massive amount of benefits for society, which contains physically, sociologically, and economically aspects.

To design a useful urban community for people to share their social activities, urban forest planner needs to combine aesthetics and practicability. Tree plantation, selection of tree species is mostly influenced by regulating ecosystem service components. However, aesthetics and feasibility are part of the cultural ecosystem service components. While considering the practicability and aesthetics, planners must first contemplate the ecosystem services components, such as annual precipitation, climate, and flood. After that, the collection of public opinions towards the construction of the green spaces should be done.

For this part of our assignment, it will be illustrating the results indicated in the previous paragraphs related to the topics of urban forest planning and management recommendation. To start with, almost everything in the universe needs management or a well-design management plan for a project, the easiest way to say that is whether a park, a building, a school or an office need a manager. However, this can also be applied in the field of the urban forest.

Based on the data we collected for assignment #2, and according to the analysis we did. The recommendations will focus on two main points; one is how to maximize the benefits that provided by the regulating ecosystem services; the other one is how to batter satisfy the needs of people's daily activities.

In the management strategies of the urban forest, the first scenario we need to consider is how we can convert any negative comments or impact of one urban forest's zone into considerable opportunities. For example, the most important strategy, for now, maybe is the one that proper urban forest management can help to improve air quality. Relating to the regulating ecosystem services for urban forestry, there are five components we are focusing on, which are the canopy coverage; the pollutant removing; the carbon storage; avoiding runoff, and potential pest implication.

To be more specific, considering Canada is the second-largest country in the world and also has a great number of canopy covered in Canada. The urban forester should use these advantages to build more playgrounds, mini-park, or rest areas for local residents to use. However, the greater percentage of canopy cover in one city can help to maximize the utility of removing tones of particulate matter (dust) by the systems of an urban forest. UBC is one of the largest campuses in Canada, planting more trees can even help students, staff, or visitors to have a better quality of air.

The canopy coverage in our group zone has two extreme distinctions. The area around the forestry science building has a considerable size of canopy coverage, which has a positive impact on sunlight exposures. As the majority tree leaves around the building have large surface areas, the amount of sunlight the tree can absorb will be more significant compare to the tree leaves that have small surface areas. It will also be benefited in summer, and large leaves can black the glare and ultraviolet, which people would like to spend more time outside walking around or enjoy summertime.

Shading effect is also one of the best benefits people can get from trees. When planting large trees beside the walkway, playground or even in the urban forest, putting chairs under the large trees should be considered because large trees tend to give more shading effects than small trees. Thus, during the hot summertime, trees shades can reduce surface temperature and also blocks the diffuse radiation which reflected from the sky and it also blocks the heat flow from the building and people can sit on the chair to rest. Looking back to the zone which was assigned to our group, although there are some chairs on the walkway, these chairs are not much welcome than the chair located inside the forestry building. The reason why is because of the chairs located in the walkway is not in a spot that can block the sunlight. If an urban forester considered to re-design the location of those chairs, they can be located beside the trees or under the trees. So, people can gain shading benefits from trees. Another example could be the parking lot, which barely has trees. Thus, there are hardly people around that area. Increasing the number of large leaves tree plantation would be a useful solution. However, the landscape of the parking lot is not suitable for planting trees, an "artificial canopy" could be helpful, and in the summer, some sunshades can be established around the parking lot area.

As the trees are presented as the pollutant removal and storing carbons, the areas with an enormous amount of trees will have more oxygen produced and fewer pollutants. While doing the survey, people are more likely to spend time in the area that has plenty of trees. They state that the air quality is better than the area that has fewer trees. Comparing the parking lot and the middle pathway, the number of people presented in each region has a clear distinction; with the comparison between the automobile exhaust and fresh air, people will choose the latter. Generally speaking, to better obtain the level of oxygen produced and to control the air pollutions better, urban forest planners can spend more time examining the qualities of tree survival. Increasing existing tree coverage and using long-lived trees in an urban forest site will also help reduce pollution emissions from maintenance activities. In particular, as the parking lot does not allow absorption of water and become dumping grounds for careless disposal of trash, the establish of trash bins are necessary. Regular cleaning is essential as well, while some garbage brought by the heavy wind; sediment and fertilizers or pesticides will be carried by the cars, and they will not disappear when nobody cares them. These can be some aspects that affect the air quality.

Regarding avoid runoffs, water retention and water absorption should be deliberated. Different types of soils have different capacity of water absorption and different water retention; by examining the soil type, the various plant should be constructed. With the soil that has weak water retention capacity and inadequate water absorption, more trees should be planted to avoid runoffs, such as Douglas-fir or western redcedars; especially in areas where runoff collects. As runoff soaks into the soil, plant roots help to absorb and filter out pollutants. Planting trees can help tight the soil while considering avoiding runoffs. Another way to prevent runoffs can be by digging a trench, using a shallow, gravel-filled trench to catch and slow runoffs, especially at the base of a slope. The example area in our group zone is the one which contains two slopes area.

British Columbia is one of the largest provinces that the forests are damaged by the pest, such as mountain pine beetles. The pest always has a long-term impact on the tree species, and BC also spends a significant time fighting against the pests. The strategies that help to stop the spread of pests can be harvest the affect trees, the prescribed fire burning the affecting trees, and the preventive treatment, such as pesticide. Nevertheless, on the campus, the prescribed fire is not advisable as there is substantial human traffic, and the burning fire will produce a large amount of carbon dioxide, which will pollute the air. As there is not a very serious situation towards pests' implications, the recommendations can leave until further implementations.

Urban forestry planning and management are not only considering the use of landscape or the plantation of trees, but it is also having a significant focus on the construction of urban areas. Cultural ecosystem services play an essential role while considering the creation of green spaces. The choices of tree plantations or establish leisure facilities are decided while planning and managing. We use six dimensions to exam the needs of development in our assignment 2, which are the species diversity; aesthetics; recreation; cultural significance; community sharing, and serene.

Looking at tree species diversity, our group members found that there is one specific street that does not have much species diversity and it looks very dull in our group one's zone. As the pictures are shown below, the view of the left picture located in UBC is not as good as we can describe than the one on the right side which located in the pacific evergreen realty. From the description of whether the size or the colour of these trees. It is clear that most people will agree with which the view of the picture on the right side is much more charming than the view on UBC's campus. Moreover, a well-designed urban forest management plan should be considered the tree species diversity and the solution for that is maybe planting an evergreen species on that street to increase the beauty during the wintertime.

(Figure 8. UBC) (Figure 9. Pacific Evergreen Realty)

Besides the species diversity, other dimensions in our zones are generally well presented. The cultural significance is keen on the middle sidewalks, and the aesthetic and community sharing are well experienced by the staffs, students, and visitors. A large amount of areas is designed for people to have a walk or a quick relax. Although the majority areas achieved the requirements, there are still some improvement should be made. For instance, the wide-open space results in less feeling of safety; less species diversity results in less sense of aesthetics and will lead to fewer activities in the open areas. The strategies to satisfy people's experience values towards campus can be constructed more streetlamps, which will light the sidewalks while students are walking home after the late classes, and will increase the sense of serene. Various tree species could also be planted to make a better view and catches peoples' attention, and the shelters can be established on the top of the chairs to prevent people from the heavy rains.

Reference:

Almas, Andrew, & Tahia, Devisscher. 2020. "Integrating Data." Presented at University of British Columbia, 2020, Vancouver. Retrieved March 19, 2020. https://canvas.ubc.ca/courses/38878/files/7396238?module_item_id=1711302

Ono, S. J. (2017). Reconciliation Pole Installation Remarks.

10 Ways to Manage Runoff Water. (n.d.). Retrieved from https://www.bioadvanced.com/articles/10-ways-manage-runoff

Kella et al. (2014). Invasive Species in a Globalized World: Ecological, Social, and Legal Perspectives on Policy. DOI:10.7208/chicago/9780226166216.001.0001

Nowak, D. (2002). The Effect of Urban Trees on Air Quality. USDA

Appendix

Figures

Assignment 2: Group 2 Ecosystem Services Assessment Report
Urban Forestry 101

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UFOR 101: Urban Forest Inventory and Assessment

Dr. Tania Devisscher and Dr. Andrew Almas

April 8th, 2020

Contributions

Adra Al-Shakarji was responsible for introduction and site description
Oakley Kang was responsible for cultural ecosystem services and management and recommendations
June Lam was responsible for introduction, site description and overall editing
Kaysha Reeder was responsible for the regulating ecosystem services
Britany Wu was responsible for the regulating ecosystem services
Border Yin was responsible for cultural ecosystem services and management and recommendations

Introduction

The following urban forestry report was completed by six students from the University of British Columbia (UBC) on the Vancouver campus. The purpose of this report is to explore the ecosystem services provided within our prescribed site. Our site encompassed a few buildings, such as the MacLeod Building, the UBC Department of Computer Science, and the Engineering Student Centre. It also contained small patches of roads including Agronomy Road, Main Mall, and East Mall.

To complete the report, we began by understanding our site, followed by setting out a clear methodology, and finally collecting on-the-ground field data and presenting it visually. We were able to provide a numerical value to the regulating and cultural ecosystem services of our site with the data we had previously gathered, along with i-Tree Eco and i-Tree Canopy cultural ecosystem services value mapping softwares. The values we obtained were then used to provide various suggestions regarding the development for this particular site on the UBC campus.

We were able to provide a numerical value to the regulating and cultural ecosystem services of our site with the date we had previously gathered along with i-Tree Eco and i-Tree Canopy cultural ecosystem services value mapping softwares. The values we obtain are then used to provide various suggestions regarding the development for this particular site on the UBC campus.

The recommendations are presented to the students of the class, as well as some stakeholders and the Social Ecological Economic Development Studies (SEEDS) sustainability program. This is all done in efforts to create an archive of the urban forest on campus and to improve it. The objective of UBC's Forestry Visioning Project is "to design a sustainable UBC community that is resilient and adaptive to the effects of climate change." (Du, Sangha, Smith, & Yu, 2017). Furthermore, three main criteria were identified to make a sustainable community successful such as climate resilience, low carbon community, and aesthetic/social values" (Du, Sangha, Smith, & Yu, 2017). Aesthetic/social values are especially important from the feedback provided by passersby that were interviewed.

Through the process of completing this report, students learned to evaluate the ecosystem services benefits using various tools, including one-on-one surveying, and efficient and active teamwork. Students had a chance to interact and explore the values of people regarding a university campus. The chance to apply the knowledge learnt in class has brought a new set of skills and experiences.

Site Description

The site evaluated for this report is on the Vancouver UBC campus, enclosed by the following streets: Agronomy Road, East Mall and Main Mall. The primary buildings on site include: MacLeod Building, UBC Department of Computer Science, and the Engineering Student Centre (see *Figure 1)*. The various buildings on our site, and the popular roads have led to the conclusion that our site's land use is essentially both institutional and transportation since we observed many cars and trucks that were parked along the roads. In the smaller roads and areas behind buildings, where supplies are delivered, and garbage is temporarily stored till removal, there is little to no plants or other form of greenery. The smaller roads are shaded by the towering buildings. Moreover, most of the activities seen consisted of students, staff, or visitors either walking, biking or skateboarding, or driving to and from Agronomy Road, East Mall, and Main Mall. The amount of people peaks on Agronomy Road and Main Mall whenever classes end. In order to more precisely evaluate the ecosystem services that our site provides, it was divided in seven subzones (see *Figure 2*).

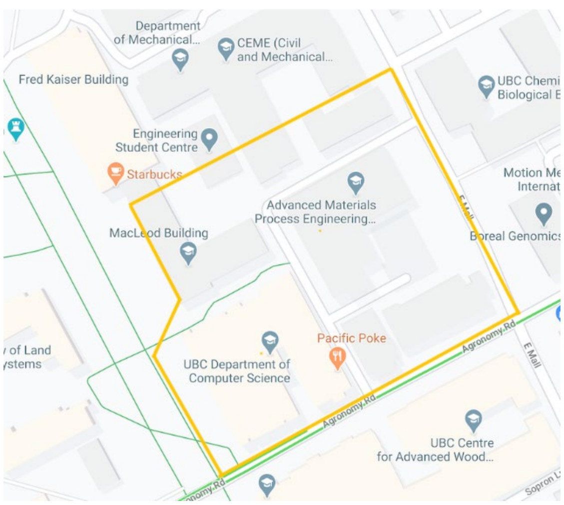

Figure 1. Map of Site 2 boundary from Google Map.

Figure 2. Division of Subzones for Group 2 Site.

Regulating Ecosystem Services

Ecosystem processes control natural phenomena, such as pollination, water purification, erosion, flood control, carbon storage, and climate regulation, while furnishing advantages for the regulating services (Ecosystem Services, 2020).

Methods

i-Tree eco, which uses scientific literature to calculate values (i-Tree Eco User's Manual v6.0, n.d.), was used to analyze the estimated benefit prices the trees in our zone provide.

The first benefit calculated is electricity, and the trees in our zone are estimated to save 0.1 Canadian dollar per kilowatt-hour of electricity (i-Tree Canopy, n.d.). This may be because the electricity saved due to the shade the trees provide during the summer reduces the need for air conditioning, and the trees being windshields during winter reduce the need for heaters. However, since the tree density is low in our area, the effect of saving electricity in this area is limited.

The second benefit provided is carbon storage, which is valued at 104 dollars per ton of biomass (i-Tree Canopy, n.d.). Carbon sequestration occurs due to photosynthesis, which is a process of trees capturing carbon dioxide in the atmosphere and transforming it into biomass (Selin, 2019). Since the trees sequester carbon that would normally enter the atmosphere and cause the temperature to rise, trees play an important role in preventing global warming through climate change mitigation (Carbon Sinks and Sequestration, 2018).

The last benefit estimated by i-Tree eco was avoiding water runoff which is valued at 0.0088 Canadian dollars per gallon (i-Tree Canopy, n.d.). It's a very small number since we don't have a lot of trees in our area. However, this benefit is important since water runoff occurs when rainfall cannot penetrate through paved surfaces and overflows. This, in turn, can lead to flooding, erosion, and habitat loss as it flows to larger bodies of water. Water pollution also occurs since runoff picks up pollutants such as sediment, nitrogen, phosphorus, oil, and metals from the paved surfaces. These effects can be reduced through planting and maintaining trees and other vegetation in a cost-effective way compared to other infrastructures (Trees and Stormwater Runoff, 2017).

The second tool we used was i-Tree canopy to measure the canopy cover in our zone. The canopy cover of our zone is only 12.6%, while the whole campus has a 27% canopy cover and Vancouver City has 18% (i-Tree Canopy, n.d.). The City of Vancouver also has a target of reaching 28% in 2030 (Hanou, Thurau, & Soulliere, 2011). We can see that UBC overall has a good amount of canopy cover, but the distribution of canopy cover is uneven. The lack of canopy cover in our zone can be further seen in the green/grey diagram (*Figure 3*) which shows a visualization of where vegetation is located. Most buildings are surrounded by green spaces, which may maximize the regulating services those buildings gain from trees, for example, temperature regulation and windshields. However, there is not that much green space in the area, additionally, the vegetation in most of the green space is grass and shrubs.

i-Tree canopy also provides the tree benefit estimates where it lists all the gasses the trees in our zone absorbed and the money that would cost to remove it with other technology as seen in *Table 1*. Except for stored CO_2, which is the total amount of CO_2 stored in the trees, all the other gasses are calculated for annual absorption. Out of all the gasses those trees absorbed, the first most absorbed is CO_2stor, second is ozone (O_3), and lastly PM10 (i-Tree Canopy, n.d.). It is worth noticing that even though PM 2.5 isn't the highest gasses absorbed, the regulating service saves the most money, excluding CO2 (i-Tree Canopy, n.d.).

Abbr.	Benefit Description	Value (CAD)	Amount
CO	Carbon Monoxide removed annually	0.35 CAD	5.66 lb
NO2	Nitrogen DIoxide removed annually	0.60 CAD	30.87 lb
O3	Ozone removed annually	31.05 CAD	307.46 lb
PM2.5	Particulate Matter less than 2.5 microns and less than 10 microns removed annually	64.18 CAD	14.94 lb
SO2	Sulfur Dioxide removed annually	0.10 CAD	19.45 lb
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	22.54 CAD	102.99 lb
CO2seq	Carbon Dioxide sequestered annually in trees	2,101.53 CAD	31.43 T
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	52,777.27 CAD	789.22 T

Table 1. Tree benefit estimates.

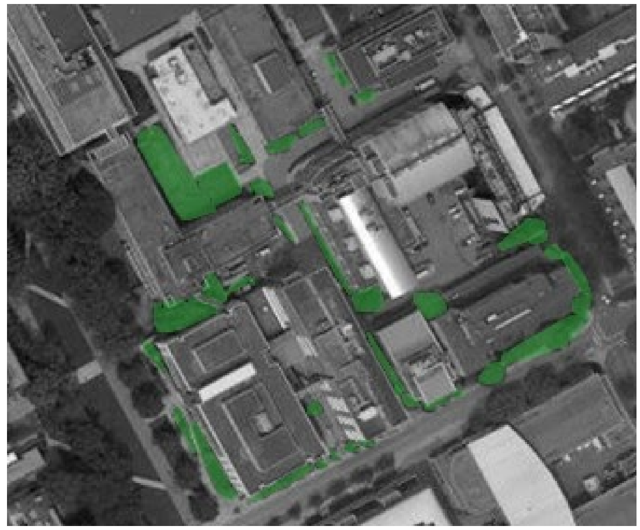

Figure 3. Grey/Green diagram of Group 2 Site.

Cultural Ecosystem Services

Methods

To assess cultural services associated with our zone, we used two methods to retrieve our data: experience value mapping and sentiment mapping. With these two methods, we were able to use our individual perception of the zone as well as surveying others who were also using the space. This allowed us to create field-based interpretations for evaluation and recognizing the intangible benefits obtained in our zone.

Experience value mapping utilized the division of our zone into subzones, displayed in *Figure 1*. Each subzone is ranked in six experience values ranging from species diversity to cultural significance. The full list of values can be seen in the table of Appendix (1).

Sentiment mapping consisted of 30 short surveys of people in three different locations. The participants were asked to rate their attitude towards the location they were standing in and describe some aspects or reasons to support their rating. The surveys occurred in the late afternoon with sunny weather. The ratings and responses of each location can be viewed in Appendices (2) to (4).

Experience Value Mapping and Sentiment Mapping - Strengths and Weaknesses

The methods we used allowed us to assess beyond the dependency of quantitative measures or physical attributes as a primary source (LIndholst, Capersen, & Konijnendijk van den Bosch, 2015). In this way, we were able to consider the human feelings that come from the public spaces in our zone. This would also allow management in future planning processes to make decisions between actors as well as the public's preferences in a way that is more inclusive to citizens (Linholst et al. 2015).

However, in order to reach a more accurate conclusion, we would suggest aiming for more abundant data that would be achieved by expanding the number of people surveyed, making it also more time-consuming. In addition, mapping for cultural service assessment will be frequently faced with inconsistency due to subjective factors such as public knowledge, differing cultures, the individual's mood at the time the survey is taken, the weather on the day of the survey, and individual's willingness to participate. For this report, we found that sunny weather may have influenced more positive responses to our experience valuing and surveys. The locations facing SW at the time of the surveys (late afternoon) ensued a greater number of satisfied responses.

Experience Value Mapping: Data and Interpretations

Analysis of the data gathered by experience mapping displays that there are no especially appealing areas within our zone. The average subzone rating is only (1.71) points out of (5.00) points total. Subzone (2F) has the highest average rating amongst all the subzones. It scores the top ratings across almost all experience values except Cultural significance, and it notably ties for the lowest score in Diversity. Subzone 2E is the second area to share the lowest Diversity ranking with subzone (2F). This is however not surprising for Subzone 2E as it is consistently ranked worst across all experience value categories. The average score of subzone (2F) is nearly triple that of (2E), with the scores of (2.63) and (0.93) respectively.

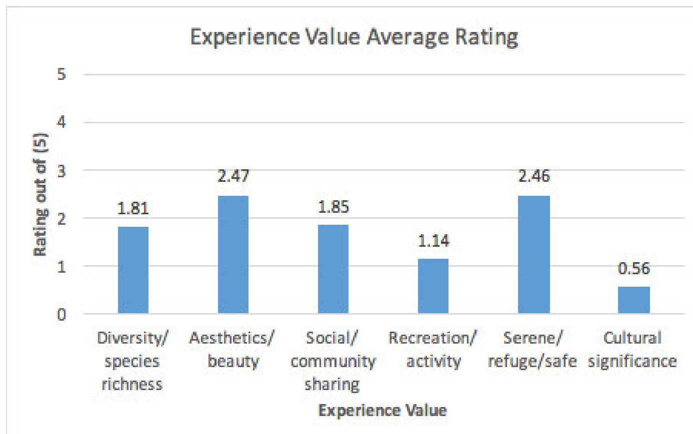

Figure 5. Experience Value Average Rating.

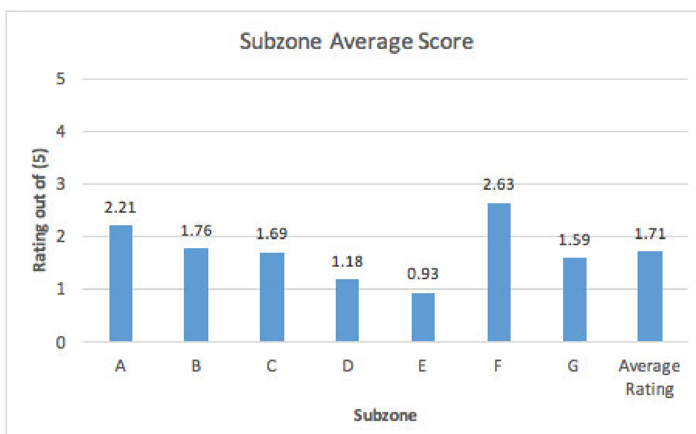

Figure 4. Subzone Average Score.

The high variance in ratings is just as drastic between the experience values of our zone. Averaging each subzone's score for each experience, the best performing value with (2.47) points is Aesthetics/beauty. Close behind is Serenity/refuge with (2.46) points. The lowest scoring value is Cultural significance, only scoring (0.56).

From the subzone analysis, the consensus is that subzone 2F is the most appealing subzone despite its very low Diversity score. This leads us to believe Diversity is not an important factor of good greenspaces in well-developed urban areas. This could be due to visual preferences people may have towards the uniform and consistent aesthetic of monocultures. Minimal species variation could also complement the organized structures of the built environment and contribute to a well-groomed image. Aside from the ecological benefits, species diversity does not appear to be a high priority in creating an appealing space.

This interpretation could also be skewed by the even weight given to each experience value. There are certainly values that hold more importance than others, but our system of data collection does not account for this. Our data would surely become more accurate if value weighting was implemented.

The experience value average scores are not biased by importance, but by personal biases. For every subzone, the lowest-scoring category is Cultural significance. This may be due to unfamiliarity and inability to identify features of cultural import.

Sentiment Mapping: Survey Data and Interpretations

Sentiment mapping survey ratings and their corresponding reasonings can be found in Appendices (2) to (4). below. The first location was located at the Northwest corner of East Mall and Agronomy Rd. Just to the West is the second location along Agronomy Rd. at Engineering Rd. The third and last location is the entrance of ICICS along Main Mall.

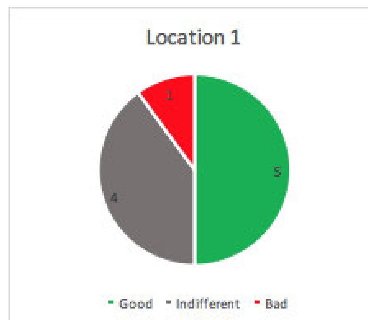

Figure 6. Location 1.

Location (1) is the only site with a negative response. The main reason for this rating is that the site is "boring." The site is a transitory space meant for commuting, there is no space to stop and engage with the site at all. This is also the location that experienced the most people refusing to participate in surveys as most were in a hurry to get to their destination. Some notable details mentioned are trees, greenery, open space, nothing special, boring, poor infrastructure, transportation, and food.

Figure 7. Location 2.

Location (2) is split between good and indifferent ratings. Most comments about safety and cleanliness were mentioned here. Notable details mentioned include trees, aesthetic, cleanliness, safety, gray space, monoculture, same as other places on campus.

Location (3) received only good ratings from participants. Every single person approached for surveys here also agreed to participate. We believe the aspect, time of day, and user context are uncontrolled factors which may have influenced the positive results at this location. Notable details mentioned: trees, greenery, vegetation, views, landscape, open space, animals, culture; people, totem pole, variety in the environment.

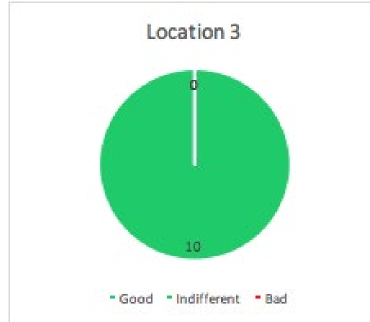

Figure 8. Location 3.

With only one negative response from Location (1), our zone can be generally considered a liked space that creates positive associations, but we must consider factors which may have influenced survey responses. Each location mentioned trees (most frequent), greenery, and vegetation from many participants as a good attribute, as well as frequent mentions of cleanliness, safety, and open space. Some surveys mentioned the sun as an aspect they enjoyed.

Combined Interpretation of Sentiment Map and Experience Value

The results of value mapping and sentiment surveys have been overlaid on the subzone map to help visualize trends. The 3 subzones (2A, 2B, 2F) with the best ecosystem service rankings are colour-coded green, subzone (2C) with median ecosystem services is colour-coded yellow, and the 3 subzones (2D, 2E, 2G) with the least/worst association to ecosystem services are colour-coded red. The three sentiment mapping surveying locations are plotted and colour-coded in the same manner.

Figure 9. Combined Interpretation of Sentiment Map and Experience Value Map.

The survey responses coincided with the experience ratings as there was a general trend of negative responses towards East Mall. The subzones and locations that receive more sunlight in the afternoon tend to score higher in ratings. The impact of sunlight and time of day surveys were conducted may have more impact than previously thought. Furthermore, neighbouring subzones appear to have influence on the experience of a location. With the difficulty of distinguishing boundaries between the subzones, the appearance and sightlines of a subzone affected the response to the adjacent location. For instance, locations 1 & 2 with the visibility of (2D) and (2E) respectively, received worse responses to the survey. Therefore, it may be beneficial to consider the zone even when looking to improve only a particular area, likewise, degradation or improvement of one area will have consequent effects to another.

Urban Forest Planning and Management Recommendations

Some recommendations that can improve our zone are:

1. Increase the green/grey ratio by vegetating unused concrete surface area. Subzone 2E is a valuable candidate for planting more vegetation due to its high concrete surface area and current construction work can make the area more malleable to greenspace additions.

2. Accommodating subzone 2F for more visitors. This site rated the highest in value mapping surveys. Observation of high visitors in this area was made. It may be advantageous to utilize the preexisting popularity to attract additional visitors. The presence of young trees in this area may appeal to a greater number of visitors as they mature and provide more ecosystem services (i.e. shade, aesthetic). The increase in visitors may further stress the subzone. It may be beneficial to monitor the condition of the site in future years.

3. Maintaining and enhancing the sense of safety as it was a notable factor from surveys. Planting thin-stemmed trees with higher canopies to maintain visual sightlines. Selecting mostly deciduous trees for planting will help keep sightlines clear but may cause seasonal cleanliness issues with leaf litter.

4. Incorporating new vertical greening (i.e. vine walls, green roofs, facades). There is a limitation to planting on the ground due to the abundance of tall buildings creating shade that prevents sunlight exposure for plants and the lack of soil available.

5. Species awareness. With the over-domination of *Acer* genus trees, especially *Acer palmatum*, expanding tree species diversity can build resiliency against harm such as pests and diseases. The Arbutus tree in area 2C holds cultural value but its growth and accessibility are restricted by tight walls and surrounding larger trees. Perhaps trees of different genera but of similar growth forms can be planted to retain the uniform aesthetic of a monoculture.

6. Space awareness. Accounting for mature growth form is necessary to plant the appropriately sized vegetation for the corresponding amount of space. This limits the frequency of pruning/trimming. There were some which were cut extremely short which detracted from the appeal of the area. This allows the tree or shrub to grow to its fullest extent with minimal management.

References

Bellis, E., Ikeda, T., Miao, A., & Naveau, A. (2017). *UBC 2017 Stadium Neighbourhood Tree Inventory Report.* Vancouver: University of British Columbia.

Carbon Sinks and Sequestration. (2018, April 2). Retrieved March 24, 2020, from UNECE: https://www.unece.org/forests/outlook/carbonsinks.html

Du, D., Sangha, T., Smith, I., & Yu, H. (2017). *Urban Forestry Visioning Project.* Vancouver: University of British Columbia.

Ecosystem Services. (2020, March 24). Retrieved from National Wildlife Federation: https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services

i-Tre Eco User's Manual v6.0. (n.d.). Retrieved April 6, 2020, from i-Tree: https://www.itreetools.org/tools/i-tree-eco

i-Tree Canopy. (n.d.). Retrieved March 23, 2020, from i-Tree Canopy v6.1: https://canopy.itreetools.org/

LIndholst, A. C., Capersen, O. H., & Konijnendijk van den Bosch, C. C. (2015). Methods for mapping recreational and social values in urban green spaces in the nordic countries and their comparative merits for urban planning. *Journal of Outdoor Recreation and Tourism*, 71-81.

Northeastern Area State and Private Forest. (2016, January 16). Retrieved from U.S. Department of Agriculture: https://www.fs.usda.gov/naspf/publications/urban-watershed-forestry-manual-part-2-conserving-and-planting-trees-development-site-0

Selin, N. E. (2019, January 16). *Carbon Sequestration*. Retrieved April 6, 2020, from Britannica: https://www.britannica.com/technology/carbon-sequestration

Trees and Stormwater Runoff. (2017, September 11). Retrieved April 6, 2020, from Centers for Watershed Protection: https://www.cwp.org/reducing-stormwater-runoff/

(2018). *Urban Forest Strategy: 2018 Update.* Vancouver: City of Vancouver.

Appendix

Appendix (1). Value mapping data. Colour-weighted by column.

Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
A	2.00	3.33	2.50	1.58	2.67	1.17
B	2.08	2.92	2.42	0.75	2.00	0.42
C	2.92	2.67	0.92	0.50	2.33	0.83
D	1.67	1.25	1.00	1.00	2.00	0.17
E	1.25	1.25	0.67	0.50	1.92	0.00
F	1.25	3.38	3.67	2.67	4.00	0.83
G	1.50	2.46	1.75	1.00	2.33	0.50
Average Score	1.81	2.47	1.85	1.14	2.46	0.56
Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)						

Appendix (2). Sentiment mapping survey results from Location (1).

Location 1	June, Adra
Rating	Reason
Indifferent	it's just school; nothing important; aesthetic, cultural values
Indifferent	it's just school; nothing important; aesthetic, cultural values
Good	greenery; open space
Good	greenery; open space; community; landscape; sun; foodtrucks
Good	open space; environment
Good	trees (when in bloom), buildings
Good	no community
Bad	boring; no transportation; starbucks & tims are too busy
Indifferent	doesn't lack anything; not too busy
Indifferent	stop signs

Appendix (3). Sentiment mapping survey results from Location (2).

Location 2	Britany, Kaysha
Rating	Reason
Indifferent	don't really care
Good	many trees; walking paths; accessibility to buildings
Good	spacious; clean
Good	feel safer with trees; looks nicer with trees; clean
Indifferent	lots of concrete; trees are all the same
Indifferent	safe; not pretty as other places on campus
Indifferent	similar to other places on campus; nothing special
Indifferent	similar to other places on campus
Good	clean
Good	trees around; clean

Appendix (4). Sentiment mapping survey results from Location (3).

Location 3	Oakley, Border
Rating	Reason
Good	open space; vegetation
Good	open space; trees; views
Good	views; accessibility
Good	beautiful; variety in environment; nice people
Good	animals; squirrels
Good	trees
Good	greenery; totem pole; sun
Good	greenery; lights at night (past experience)
Good	relaxing
Good	landscape; benches

UBC Ecosystem Services Report

2020-04-08

Group 3

K., Finn | D., JP | O., Lukas | M., Nick | H., Daniel | H., Rowan

I. Introduction

The basis of this project and all of the data collection and fieldwork shown in the following report has taken place on the traditional, ancestral, and unceded Musqueam territory. As a group, we would like to acknowledge and thank the Musqueam people and note that we practiced our tree inventory and data collection in a respectful manner.

The objective of Assignment 2 was to conduct an ecosystem services assessment of a given urban forest site on the University of British Columbia (UBC) campus. Ecosystem services is a concept that seeks to evaluate the direct and indirect socio-ecological benefits the natural environment provides human beings. These benefits are divided into four categories: provisioning, supporting, regulating, and cultural services. In this report, we will be focusing on the regulating and cultural services provided by the urban forest site. Cultural services are classified by the nonmaterial benefits from an ecosystem (e.g. aesthetics, mental health, spiritual, and educational benefits) and regulating services are classified as benefits of regulating functions of an ecosystem (e.g. pollutant removal, climate control, erosion prevention, water regulation, and carbon sequestration). The purpose of an ecosystem services assessment is to quantify and evaluate the benefits of a natural environment to help inform management and policy-making within a given area. (Ferrini et al., 2017)

This report is a continuation of Assignment 1 (Urban Forest Inventory) where i-Tree Canopy, i-Tree Eco, and experience value mapping were used to assess and provide a full review of urban forest ecosystem services. The goal of this report is to provide the stakeholders (UBC Campus + Community Planning and UBC SEEDS [Social Ecological Economic Development Studies] Sustainability Program) with an overview, assessment, and management recommendations concerning the ecosystem services provided by our site. After a full review of the i-Tree Canopy/i-Tree Eco data and our experience value survey data, we created a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis. From the SWOT analysis are derived recommendations involving the maintenance and management of the urban forest within our site.

II. Site Context

A. Site Description

Our group was assigned to the corresponding "Group 3" site within phase 1B of the full UBC campus tree inventory. The site is located on the northwest end of the UBC Point Grey Campus (Figure 1). It is partially bound by Main Mall along the west side of the site and East Mall along the east side of the site, covering a majority of the UBC engineering department (4915’45.0”N 12314’55.6”W). Overall, the buildings located on the site include (Figure 2):

- Fred Kaiser Building
- Civil Engineering and Mechanical Engineering (CEME) Building
- Civil and Mechanical Engineering Structures Lab

- MacLeod Building
- Engineering Student Centre

The site land-use type is fully institutional because it is located within the boundaries of the UBC campus. The buildings offer a vast assortment of facilities including but not limited to, lecture halls, classrooms, labs, fabrication shops, study spaces, student centers and food services. Primary users of the site are engineering students and faculty members accessing the facilities listed above and UBC building operations personnel via utility vehicles accessing the Applied Science Lane, which is the alley running through the site between the CEME building and the Civil and Mechanical Engineering Structures Lab building. Other users include all students and faculty of UBC, visitors, and the general public, who mainly use the site as transportation corridors (Figure 3). Applied Science Lane and East Mall are legal traffic roads, meaning vehicles are present on the site as well.

B. Urban Forest Description

There are 74 trees on the site. The vast majority of trees on the site were planted in stands or groups. The first group measured was a row of Vine maple (*Acer circinatum*) along the north side of the Fred Kaiser building. These vine maples are next to the stand of Red cedars (*Thuja plicata*), Douglas-firs (*Pseudotsuga menziesii*), and sitka spruce (*Picea sitchensis*). This combination serves as a sort of representation of the composition found in Pacific Spirit Park. The row of vine maples, a plant growing multiple stems, is used to cover the side of the building by having a very broad, covering canopy. Next up on the southern side of the Civil and Mechanical Engineering Structures Lab, beginning on the west with a row of 7 common hornbeams (*Carpinus Betulus*). These trees are planted, similar to the vine maples, along the wall but also have a planted hedge in front of them. Suspected to have a similar, view-blocking, purpose as the row of maples due to their wide, dense, and conical growing canopy. On the other side of the corridor, on the north side of CEME is a small, 3 tree stand, comprised of Serbian spruce (*Picea omorika*), English holly (*Ilex aquifolium*), and Japanese maple (*Acer palmatum*). This group of trees is special due to the physiology of the leaves. In this area, one can find an evergreen needleleaf (spruce), evergreen broadleaf (holly), and a deciduous broadleaf (maple) boasting a nice variety in shapes and colours. East of this group, 5 more Japanese maples are planted, accompanied by 2 Katsura trees (*Cercidiphyllum japonica*), and 1 additional Serbian spruce with dense understory vegetation. Additionally one can find a weymouth pine (*Pinus strobus*) planted alone in the alley on the north side. At the edge of the plot along East Mall, there are 2 sweet gums (*Liquidambar styraciflua*) planted along the roadside of the sidewalk. On the building side of the path, there's Scots pine (*Pinus sylvestris*) and north of it, there are 2 other needleleaf trees that aren't registered on the collector app/inventory list. Continuing down East Mall, planted along the street, are 3 European smoke trees (*Cotinus coggyaria*), more Japanese maples, manna ash (*Fraxinus ornus*), and another weymouth pine. Another group of trees can be found in the courtyard west of the Engineering Student Centre. It entails a very large western hemlock (*Tsuga heterophylla*), Norway maples (*Acer platanoides*), more vine maples, a laurustinus (*Viburnum tinus*), and multiple katsura trees. Also, the passage built by the Engineering Student Center contains additional vine maples and multiple Japanese stewartia (*Stewartia pseudocamellia*). Lastly, there is a single tree that falls into the assigned plot along Main Mall in front of the MacLeod building. It is a large Japanese-cedar or sugi (*Cryptomeria japonica*).

III. Regulating Ecosystem Services

Regulating services on our sample inventory plot were first assessed through i-Tree Canopy. i-Tree Canopy used randomly sampled points on our plot to give an estimation of the regulating services found on our site. After that our group went out into the field and gathered all of the detailed tree data for our sample inventory (tree height, crown width, DBH, etc…), we then inserted the field data of the trees on our site into i-Tree Eco to gain further understanding of the regulating services associated with our plot. i-Tree eco uses measured variables of a tree, mostly relating to the amount of healthy leaf surface area, to calculate important regulating ecosystem services. These measured services indicate the productivity of the site in question in terms of pollutant removal, carbon sequestration, avoided water runoff, etc. i-Tree Canopy is a useful tool when detailed fieldwork and measurements aren't obtainable due to time or budget constraints. Another advantage of i-Tree Canopy is its availability. Anybody with a computer and a web browser can access the i-Tree Canopy software to assess a sample plot's regulating services. i-Tree Canopy uses a random sampling method to determine if a generated point on the plot is a tree or not a tree. Only 50 random points were used in our i-Tree Canopy model, therefore a downside of i-Tree Canopy is that the regulating services shown in figure 8 are highly variable due to its random nature and small sample size. Two separate i-Tree Canopy assessments could likely give different results. i-Tree Canopy also only shows a limited number of measurements focusing mostly on pollutant removal).

If a field-based inventory can be employed, then i-Tree Eco is the preferred method of assessing a site's ecosystem services. Data gathered in the field is more accurate and accounts for more variables than data from a random sampling method, therefore i-Tree Eco is more informative and accurate than i-Tree Canopy. i-Tree Canopy gives the reader an estimate of the pollutants removed by trees and the canopy cover on a site, whereas the i-Tree Eco software uses local pollution and meteorological data in combination with recorded field data to compile an in-depth report on a multitude of tree-related benefits. A strength of i-Tree Eco is that the software provides the reader with data of higher quantity and quality including pollutant removal, canopy cover, as well as structural value, avoided runoff, oxygen production, and carbon storage/sequestration. i-Tree Eco presents all data it calculates in separate graphs with their descriptions and more detailed information.

One weakness of the i-Tree Eco model is that the regulating service graphs the software produces can be misleading to the reader. The model projected that *Acer Circinatum* is the most beneficial in terms of Carbon sequestration and storage, oxygen production, and avoided runoff according to their associated graphs. Figure 9 below is an example of one of the graphs that i-Tree Eco produced in its report. The regulating services graphs (including figure 9) do not clearly display the influence that species abundance has on the graphs. Therefore a downside to the method in which i-Tree Eco assesses a site's regulating services is that it is difficult to say definitively which tree species are maximizing carbon sequestration, avoided runoff and oxygen production because the models on i-Tree Eco do not take into account species abundance. The result is that the graph below can mislead the reader into thinking that *Acer Circinatum* is a species that sequesters a lot of carbon, but this number is due to this species having a high number of individuals present on our site. To get an accurate measurement the user would have to divide the total amount of carbon sequestered by the number of individuals of a given species to show its average sequestration capability. Doing this will show that the species sequestering most carbon per individual on our plot are *Tsuga heterophylla*, *Cryptomeria japonica*, and *Picea sitchensis*.

Carbon storage graphs (figure 10) have a similar problem but show different results than sequestration. Older and therefore larger trees store more carbon since they've had more time to grow and accumulate biomass. Using both these graphs one can see which tree species both remove the most carbon from the atmosphere and also which species store the most. Age is an important factor in these measurements since younger trees haven't sequestered and stored much carbon yet but still have a lot of time to grow.

One of the weaknesses of plot #3 is a large amount of grey-scape in the form of buildings and paved roads. This results in a large amount of impermeable surface and a lot of rainwater runoff. Trees reduce this runoff by intercepting precipitation with their canopy and also absorbing water through their roots. For our site, this is a very important measure to show the risk of flooding. However, i-Tree Canopy does not give an estimate for this service. This poses a problem for producing a useful SWOT analysis and management recommendations (Figure 11).

Structural value is another factor given by i-Tree Eco that refers to the dollar value components that an urban forest possesses. It is measured by the estimated cost of replacing a tree on the plot by another tree of similar size and quality. Structural value is an accurate and informative measure for determining the health and productivity of a site. *Thuja Plicata* has the highest structural value on our site. Two out of the three *Thuja Plicata* on our site were old and tall trees with high DBHs, therefore these two trees had a heavy influence on the total structural value on our site. It is strongly encouraged that these trees are protected from any grey infrastructure development pressures that may arise in UBC's future to protect the structural and compensatory value that these two trees possess (Figure 12).

i-Tree Canopy consistently gave higher measurements than our i-Tree Eco analysis leading us to believe the sampling method likely had a bias towards larger numbers. Additionally, i-Tree Canopy doesn't address any of the problems we identified on our site making it a comparatively weak tool of assessing site #3.

IV. Cultural Ecosystem Services

A. Methods

While conducting the inventory and assessment of our plot we took into consideration the potential cultural ecosystem services present on site. Cultural ecosystem services are considered to be the "the non-material benefits that people obtain from ecosystems through recreation, tourism, intellectual development, spiritual enrichment, reflection and creative and aesthetic experiences" ("Cultural Ecosystem Services," 2020). Specifically, we decided to evaluate the richness/diversity in species, aesthetics/beauty, social/community sharing, recreational activity, serenity/refuge/safety, and cultural significance.

Cultural ecosystem services, and experience value mapping, must be considered while conducting a full inventory of an urban forestry site to quantify and understand how the public uses and values that site. This process is very subjective and relies on personal opinions and feelings, rather than simple numerical measurements that are known to be 'true'. There are no right answers when dealing with experience and value, it depends on the person and the context. Which can all be affected due to their age, ethnicity, gender, occupation, previous experiences, and much more (Johansson et al., 2019). To increase community involvement, and to understand how different people value different greenspace features, value mapping must be conducted. In our case, we focused the value mapping of our site around the six cultural ecosystem services previously mentioned. To do so, all of our group members individually walked the plot, and in each subdivision assigned a number from zero to five (zero being no feeling, and five being a very strong feeling) for each of the cultural ecosystem services. From there, an average number was calculated for each subdivision in each of the six categories. Our group also involved the public by surveying ten people at three different locations within the plot, and for each person, they were asked if this greenspace gave them a good, neutral, or bad feeling, along with a brief explanation as to why.

B. Strengths and Weaknesses

What makes a good approach to value mapping? At its most simple. "Methods implicitly or explicitly provide frameworks for distinctions and judgement about 'good' and 'bad', 'better' or 'worse'" (Lindholst et al., 2015). In other words, value mapping should create differentiation between zones with higher or lower values for specific categories. The mapping of social values should also "assist with procedures such as hotspot identification where important areas that might require special attention from land and resource managers are indicated" (Sherrouse et al., 2011). Our value mapping approaches came with strengths and weaknesses in terms of the accuracy and the depth to which our surveys could reach. The public survey approach was important to better understand how the general public perceives a space, rather than how we do through our urban forestry lense. This potentially removes some bias, as the general public tends to focus mainly on how the space makes them feel in general, rather than niche details such as canopy cover. By receiving the public's opinion it allows us to better understand how the majority of people may react and feel in our location. And gives insight on how to better create/maintain the green space in the future.

On the contrary, public surveying may weaken our results due to more variables coming into play. For example, the day we conducted public surveying, it was one of the sunniest and warmest days for quite some time. Potentially leading to more positive responses, due to the sheer excitement of being outside on a nice day, and not due to the feelings evoked from the local greenery. This, of course, is a strength for our group members' individual rankings, as we all share some previous knowledge about urban forestry allowing us to examine the technical aspects of cultural ecosystem services, such as biodiversity. A weakness of our group members' ranking, on the scale of zero to five, could be that we all had prior group experience in that space before. Meaning, we all have a shared similar experience in those subdivisions from the time of the initial inventory. Leading our results to not be individualistic. Overall, we believe our value mapping approaches succeed in delineating which subzones were hotspots for the six particular cultural ecosystem services in focus. If one were to expand this project or to repeat it in the future, we recommend surveying more people and having more individuals rate each subzone. More data points lead to a more accurate average. Next, we will be discussing our calculated averages and our determined hotspot locations.

C. Results

Our mapping exercise produced a map for each of the six predetermined cultural ecosystem services, with each map marking the subzones with the highest average group rating, the medium average group rating, and the lowest average group rating for that particular cultural value (Figure 13).

Area 'A' ranked highest for the cultural ecosystem services of social/community sharing, and aesthetics and beauty. Area 'F' ranked highest for the cultural ecosystem services of biodiversity/species richness and cultural significance. Area 'D' ranked highest for the cultural ecosystem services of serenity/refuge/safety, recreation/activity, and social/community sharing. Area 'D' is considered to be a hotspot for cultural ecosystem services due to the considerable number of high votes subzone received for various cultural ecosystem services. Area 'B' was ranked, on average by our group members, to be the lowest zone for diversity/species richness, social/community sharing, and recreation and activity. Which is in great contrast when compared to the opinion given by the public which will be presented next.

When the general public was surveyed at three different locations throughout our zone, the results were much different. Participants were simply asked if the surrounding area made them feel good, neutral, or bad, along with a brief description as to why they answered a particular way. Survey location 1 was centred around subdivision 'B', survey location 2 was located in the northeastern portion of subdivision 'F', and lastly, survey location 3 was situated in the greenspace of subdivision 'A' (Figure 14).

Despite survey location 1 being located in the low scoring group average subdivision 'B', every person surveyed in that location ranked the location as 'good'. Making survey location 1 the best scoring location for public opinions. Location 2 also had the majority of the respondents rate the location as 'good', however, four people felt as though the location evoked a 'neutral' feeling. And lastly location 3, the lowest scoring location according to the public, with seven neutral responses, two bad responses, and only one good response. These results will later be discussed in greater detail with further explanation as to why locations scored the way they did with the public.

Another map was created combining all the rankings given by our team members for the various cultural ecosystem services. After the averages were calculated for each of the six categories, any subdivision with an average score of 3 or above was marked with a representative star. Choosing to mark anything ranked above 3 was based on the thinking that a score of 3+ reveals that space brought more than just a neutral feeling. In other words, an average of 3 or more represents a strong feeling of that particular ecosystem service in that zone (Figure 15).

Both subareas 'A' and 'D' appear to be hotspots for several cultural ecosystem services. Each ranking relatively high for aesthetics/beauty, social/community sharing, serenity/refuge/safety, and diversity/species richness. Meaning those areas either hold lots of potential for the categories previously mentioned, or they currently are evoking those feelings. Unfortunately during the time of our surveying, the campus was less busy than usual, therefore we were not able to observe social/community sharing and had to envision its potential in those spaces.

D. Interpretation of Results

Area 'D', when ranked by our group members, was found to be a hotspot for several cultural ecosystem services. Meaning, that this area evokes a strong feeling for numerous services in question. Specifically, this subzone was a hotspot for serenity/refuge/safety, recreation/activity, and social/community sharing. This particular subzone may have scored so high (3.6 average) for the feeling of serenity/refuge/safety due to the wide-open spaces surrounded by buildings. The combination of wide-open green space coupled with buildings along its perimeter gives the space a safe feeling. The buildings also prove a noise barrier from surrounding roads, giving the feeling of refuge or serenity. Subzone 'D' also may have scored high for recreation/activity and social/community sharing due to the potential for recreation in that open space. And with recreation typically comes social/community sharing, as you are often participating in recreation with your community members. Area 'B' was found to be the lowest scoring zone by our group members for several ecosystem services. This could be since the space itself was rather small, only a small paved walkway leading to an alleyway. The area felt compact and overtaken by grey space. Compact spaces do not promote recreation or activity, which seems to come hand-in-hand with social/community sharing.

Although location 1 was located in the low scoring group ranked subzone 'B', the location received by far the most positive public response. This can be attributed to the cedar grove that resided next to the path of which we were surveying. While we were doing our group rankings we knew that area 3 did not extend more than a meter into the cedar grove, thus we chose to leave the cedar grove out while we did our rankings. However, the public had no map to reference and took in the area as a whole, which most likely is the cause for ten 'good' responses. This area was also receiving full sunlight at the time of public surveying, and many responses referenced the nice weather, sun, or cedar grove. These factors led to an overwhelmingly positive public response.

Location 3, which was located in subzone 'A' received the least positive response from this public. This is in direct contrast to how well this zone scored from our group rankings. The public's response often mentioned how this area was simply a path for them, their routine walk from class to class (Figure 7). This area may have also been shaded during the time of public surveying, due to the tall building located in the west. These are the factors we believe caused a hotspot to be rated so poorly. Along with the public not having the insight to look for cultural ecosystem services, and their response simply coming from their personal feelings/memories within the space. Our team members were able to recognize the recent attractive landscaping work, the diversity in species, and space's potential for recreation. All of which the general public is not trained to recognize nor do they consider.

V. SWOT Analysis

A SWOT analysis (figure 16) was conducted to identify and highlight the site's overall strengths, weaknesses, opportunities, and threats. The bolded points are characteristics that we believe should be prioritized as future management considerations.

A. Strengths

The species diversity for our site was adequate. The site contained 76 trees; however, one tree was overlooked during the initial survey, having only registered 75 trees on the collector app. The trees were composed of 19 species, where 3 are found to be dominant (*Acer circinatum*, *Acer palmatum*, *Stewartia pseudocamellia*). The level of diversity was favourable as it avoids potential monoculture consequences. Using Main Mall as an example, being planted with one dominant species can prove problematic in the event of an unprecedented pest or fungal attack.

Based on personal group ratings, nearly all of the site was ranked highly, with an average rating of 4, on Aesthetics Beauty. This is attributed to the site's modern buildings and open spaces.

B. Weaknesses

Upon analysis, it was determined the site was dominantly characterized by small trees. Although 20 trees are relatively larger and having 15.2 cm DBH or greater, about half of the 75 trees fall within the 7.6-15.2 cm range, with a further 18 trees being 7.5 cm or smaller. Because the trees are generally young, this meant that they were subsequently shorter, with about 60% being classed between 3-9 m in height. As such, their canopy hasn't reached its maximum potential and would benefit from more development. Overall, the site was heavily characterized by impermeable surfaces. The inventory survey was conducted during the winter months, meaning most trees didn't have their full canopy available for better estimation. With that said, the canopy cover was estimated to be 10.25% of the total surface area. This is relatively low, making it easy for the greyscape to overpower the greenery. Although the site was found to have an adequate overall species diversity, it was determined that there was an uneven species composition, with some areas having greater diversity over others. Based on personal ratings by our group, the site generally lacked in Recreation Activity and Cultural Significance, earning an average score of 2.3 and 2, respectively.

C. Opportunities

Despite the area containing an abundance of small trees, which was deemed a weakness, it can also be seen as an opportunity. With time, the trees will grow and provide increasingly better ecosystem services, which will come in as increased pollution removal, increased carbon storage sequestration, and better avoided runoff. Avoided runoff as the potential to be a valuable service considering the current low canopy cover, there is little chance for interception. With a more developed canopy, there will be less water that will make it to the impermeable surface, providing some relief to the storm water drains during heavy rainfall events.

The high greyscape suggests that there is an opportunity for implementing more greenspace areas, or at least upgrading existing greenspaces to be better integrated with the current greyscape. These upgrades would potentially increase recreational utility, and make it more inviting to all people, elevating a user's experience values. The area was unfortunately riddled with litter, but by providing a more inviting space, it is hopeful that people will form a civil responsibility for maintaining the area as if it was their own.

There is an opportunity for an elected Urban Forestry student body to act as, in a sense, the first line of inquiry for the Urban Forest at UBC, bringing a student perspective for our Urban Forest that can be passed on and possibly considered by upper level decision-makers.

Based on personal ratings by our group, the site scored an average rating of 3 for Feeling of Refuge, which we believe could be elevated into a strength with some work.

D. Threats

The site wasn't entirely deemed an area of priority as it was largely composed of hidden alleys and pathways. A common theme determined from student surveys was that there was a lack of utility of the spaces, with the majority of the site primarily used as a transportation corridor between classes.

Lastly, the abundance of impermeable surfaces meant that there is a lack of available planting soil, making it difficult to implement more greenspaces.

VI. Urban Forest Planning and Management Recommendations

A. Introduction

Based upon the aforementioned sections and swot analysis, the following recommendations can be made with relative certainty. It is important to note, however, that the recommendations that have been made are based upon various assumptions about data and information that is limited, hard to find, or might not be disclosed altogether to the authors of this report, and therefore, some recommendations may be irrelevant due to existing policy. That being said, all recommendations have been made in good faith and are based upon extensive research and literature published in academia throughout North America and elsewhere.

B. Low Recreational Green Space

Our first issue is that the site showed low recreational green space from poor quality or a lack of grass present in the area. The reasoning behind this is that during surveys of the public, many areas were praised for hiding infrastructure and for the bestowed feeling of refuge but had comments indicating a desire for more grassy green space for recreation and or relaxation. Within the site bounds exists a courtyard located by engineering road and encased by the CEME building, however, it showed major lawn damage akin to that of chafer beetles, largely detracting from recreation and beauty scores and decreasing utility.

Visible and maintained recreational green space areas have been shown through numerous studies to help provide various benefits, including but not limited to improved mood and attitude such as lower frustration and increased brain activity, long-term stress reduction which can lead to better overall health, better productivity through improved mental health and functioning, and improved mindfulness and creativity (Wolf, 2017).

Recommendations to resolve this issue are as follows. Basic lawn maintenance in the courtyard combined with pest management control measures (such as nematode application) can help rejuvenate and alleviate some symptoms of this issue by improving existing infrastructure. Long term solutions include exploring the introduction of more functional green space to the area such as patches of grass.

C. Low Perception of Cleanliness

The second major issue is that the site had a low public perception of urban cleanliness due to large amounts of visible grey architecture and visible litter. While surveying the public, a large contribution of negative comments arose from visible grey infrastructure, bare trees, and litter. Albeit there exists a relatively larger number of trees in the area, many are bare during winter months showing buildings behind them and allowing garbage and other litter present in the planting areas to be shown.

Urban cleanliness is important for various reasons, it improves health and wellness by reducing vectors of disease transmission such as the attraction of rodents to an area and improves location attraction, helps mitigate pollution by removing possible sources of pollution, and it improves safety by removing hazardous materials that could potential be lethal to animals if they were to ingest or interact with the litter or in the case of sharp objects, could cut and lead to infection in humans (Maeena, 2019).

Recommendations to resolve this issue are as follows. Firstly, the underlying issue of urban cleanliness should be dealt with before other steps are taken. This might be through the form of garbage cleanup, the installation of litter bins where possible, and anti littering campaigns across campus. Secondly, more coniferous trees can be planted around buildings to hide the grey infrastructure during winter months. Although this won't improve cleanliness directly, it can help improve the perception of cleanliness(Ferrini et al., 2017).

D. Risky Stand Composition

Our third issue is an uneven and risky stand composition present at the site contradicts the 10-20-30 urban tree population diversity rule which is a set of guidelines to reduce the risk of catastrophic tree loss due to pests. The rule suggests an urban tree population should include no more than 10% of any one species, 20% of any one genus, and 30% of any given family. New discussions, however, in the North American urban foresters community have begun to acknowledge that even the 10-20-30 rule might still not be diverse enough. The reasoning behind this issue is that the current stand composition of nearly 28% of all trees belonging to *Acer circinatum*, 43% of all trees belonging to the genus *Acer*, and 46% of all trees belonging to the family *sapindaceae* clearly breaks the aforementioned rule Ferrini et al., 2017.

To rectify this issue, it's highly recommended that as trees are removed and as new trees are planted, they are from a different family then *sapindaceae* (possible substitutes might include trees belonging to *fagaceae*, *oleaceae*, and *viburnum* which are all present at the site but in much smaller quantities), and that the 10-20-30 diversity rule is acknowledged.

E. High Impermeable Surface Coverage

Our fourth and final issue that we've identified is that the majority of the site area is covered with impermeable surfaces such as asphalt, brick, concrete, stone pavers, and roof tops. Large areas of impermeable surfaces pose various environmental and practical issues including but not limited to the elimination of rainwater infiltration and natural groundwater recharge which often leads to pollutants such as fertilizers, oil and heavy metal products, and litter debris flushing into storm sewers through stormwater runoff, the collection and delayed release of solar heat which raises ambient air temperatures and produces the urban heat island effect; largely increasing energy consumption in buildings, and can decrease soil aeration and volume, leading to smaller growing areas for existing and new trees, making urban forest management more expensive and tedious (City of Vancouver, 2018).

The solution to this issue is to remove excessive impermeable surfaces where possible. This might be achieved by transitioning towards permeable pavement for driveways as they're being replaced and fixed instead of using traditional asphalt, replacing concrete pathways with gravel or wood chips, and building rooftop gardens to help mitigate the heat island effect. Additionally, the size of gardens and properly aerated green-space areas can be increased to help further decrease the heat island effect and help regulate comfortable temperatures in the area (Cappiella, 2006).

VII. CONTRIBUTIONS

In general, all team members equally contributed towards all tasks including report writing, field data collection, report formatting, graph making, and graph interpretations. At the start of this report, each team member was assigned a heading to focus on but was encouraged to contribute towards other sections as well. Our group performed efficiently with no conflict arising. A rough breakdown of how the work was split up is listed here but because of the large overlap of tasks performed by all members, this list should not be taken as exhaustive.

- 16% K., Finn 87777421:
  - Half of Regulating Ecosystem Services
  - Part of the Site's Tree Composition Description
  - Editing
- 16% D., JP 72750003:
  - SWOT Analysis
  - Editing
  - General Contributions to Most Other Sections
- 16% O., Lukas 20982393:
  - Planning and Management Recommendations
  - Editing and Compilation
  - Works Cited
  - Formatting
  - General Contributions Throughout
- 16% M., Nick 49225063:
  - Half of the Regulating Services Section
  - General Editing
- 16% H., Daniel 53154514:
  - Introduction
  - Site Context
  - General Editing
- 16% H., Rowan 91443960:
  - Cultural Ecosystem Services
  - Map Creation and Curation
  - General Editing
  - General Contribution to Other Sections

References

Cappiella, K. (2006). Urban watershed forestry manual : Part 2: Conserving and planting trees at development sites. https://hdl.handle.net/2027/umn.31951d02459279x

City of Vancouver. (2018). *Urban forest strategy* (tech. rep.) [ID: doc:5d86754fe4b030b4e0569c84; M1: Report]. ID: doc:5d86754fe4b030b4e0569c84; M1: Report. https://vancouver.ca/files/cov/urban-forest-strategy.pdf

Cultural ecosystem services. (2020). http://fis.freshwatertools.eu/index.php/infolib/ecoservices/cultural-ess.html

Ferrini, F., van den Bosch, C. C. K., & Fini, A. (2017). *Routledge handbook of urban forestry*. Taylor; Francis. https://doi.org/10.4324/9781315627106

Johansson, M., Pedersen, E., & Weisner, S. (2019). Assessing cultural ecosystem services as individuals' place-based appraisals. *Urban Forestry Urban Greening*, *39*, 79–88. https://doi.org/10.1016/j.ufug.2019.02.011

Lindholst, A. C., Caspersen, O. H., & Konijnendijk van den Bosch, C. C. (2015). Methods for mapping recreational and social values in urban green spaces in the nordic countries and their comparative merits for urban planning. *Journal of Outdoor Recreation and Tourism*, *12*, 71–81. https://doi.org/10.1016/j.jort.2015.11.007

Maeena, T. A. A. (2019). Why cleanliness is important to us. https://gulfnews.com/opinion/op-eds/why-cleanliness-is-important-to-us-1.67068496

Sherrouse, B. C., Clement, J. M., & Semmens, D. J. (2011). A gis application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography*, *31*(2), 748–760. https://doi.org/10.1016/j.apgeog.2010.08.002

Wolf, K. (2017). The health benefits of small parks and green spaces. https://www.nrpa.org/parks-recreation-magazine/2017/april/the-health-benefits-of-small-parks-and-green-spaces/

APPENDIX

Fig. 1. Site Overview

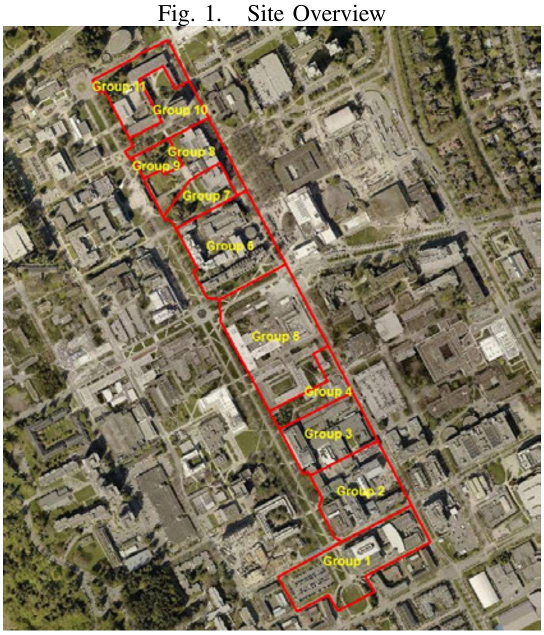

Fig. 2. Group Overview

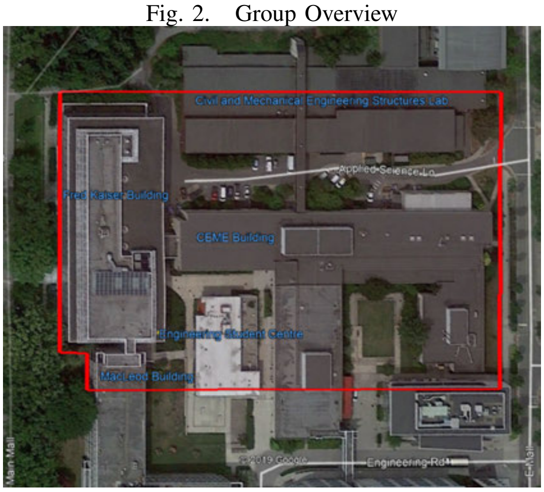

Fig. 3. Site Circulation (Foot Traffic)

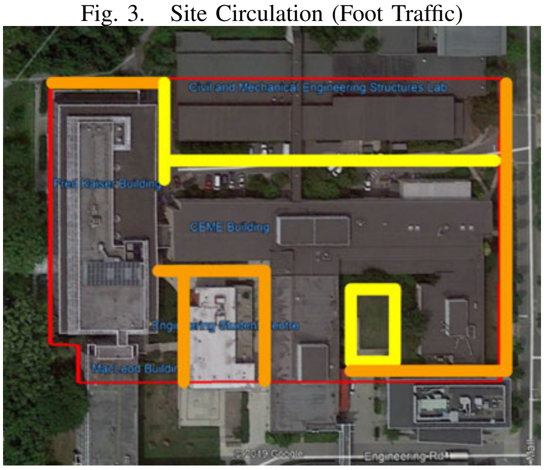

Fig. 4. Grey Green Diagram (Outlines Urban Forest Within Site)

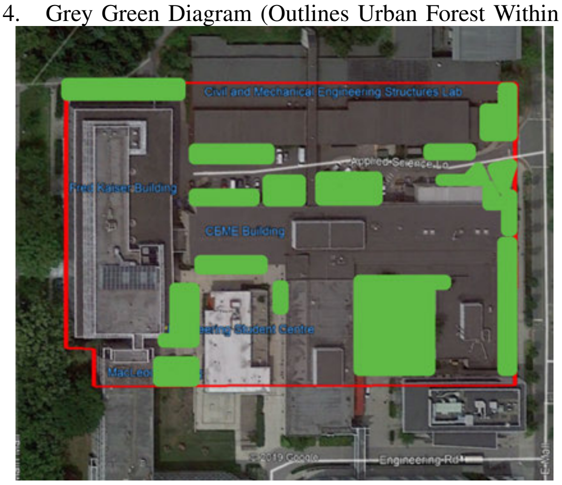

Fig. 5. One of the Larger Trees on our Site

Fig. 6. Another large tree

Fig. 7. Walkway at 3A

Fig. 8. i-Tree Tree Benefit Estimates Table

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	3.92 CAD	±0.00	4.17 lb	±0.00
NO2	Nitrogen Dioxide removed annually	7.58 CAD	±0.00	33.27 lb	±0.00
O3	Ozone removed annually	411.57 CAD	±0.00	203.23 lb	±0.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	1,626.20 CAD	±0.00	15.73 lb	±0.00
SO2	Sulfur Dioxide removed annually	1.02 CAD	±0.00	11.94 lb	±0.00
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	308.62 CAD	±0.00	69.80 lb	±0.00
CO2seq	Carbon Dioxide squestered annually in trees	1,730.45 CAD	±0.00	26.37 T	±0.00
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	43,458.19 CAD	±0.00	662.30 T	±0.00

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and CAD/T/yr: CO 0.791 @ 1,887.93 CAD | NO2 6.314 @ 457.53 CAD | O3 38.570 @ 4,064.73 CAD | PM2.5 2.985 @ 207,510.48 CAD | SO2 2.267 @ 170.95 CAD | PM10 13.247 @ 8,874.67 CAD | CO2seq 10,010.267 @ 65.85 CAD | CO2stor is a total biomass amount of 251,395.359 @ 65.85 CAD*
Note: Currency is in CAD
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

Fig. 9. Estimated annual gross carbon sequestration (points) and values (bars) for urban tree species with the greatest sequestration, i-Tree

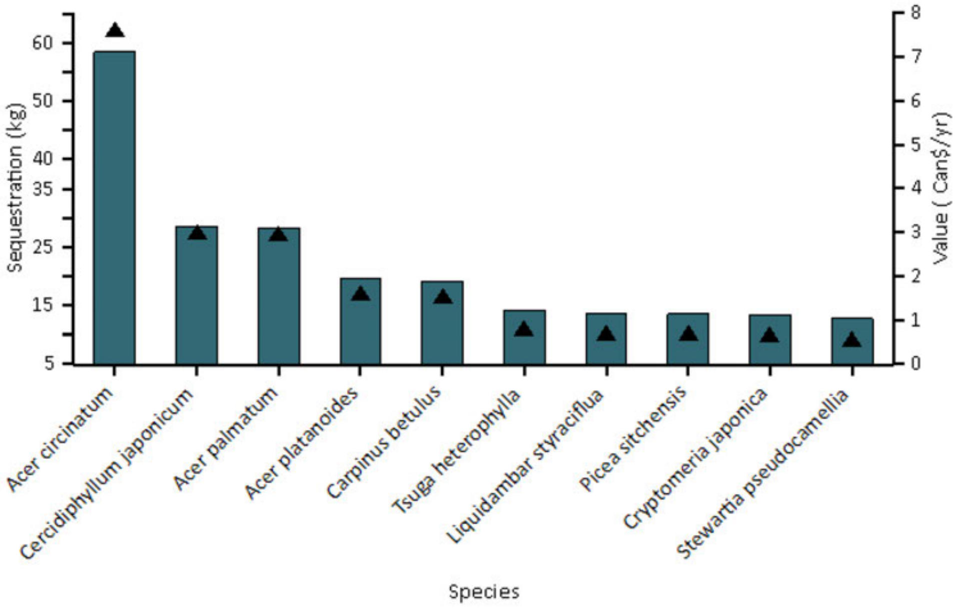

Fig. 10. Estimated Carbon Storage (points) and Values (bars) for Urban Tree Species with the Greatest Storage, i-Tree

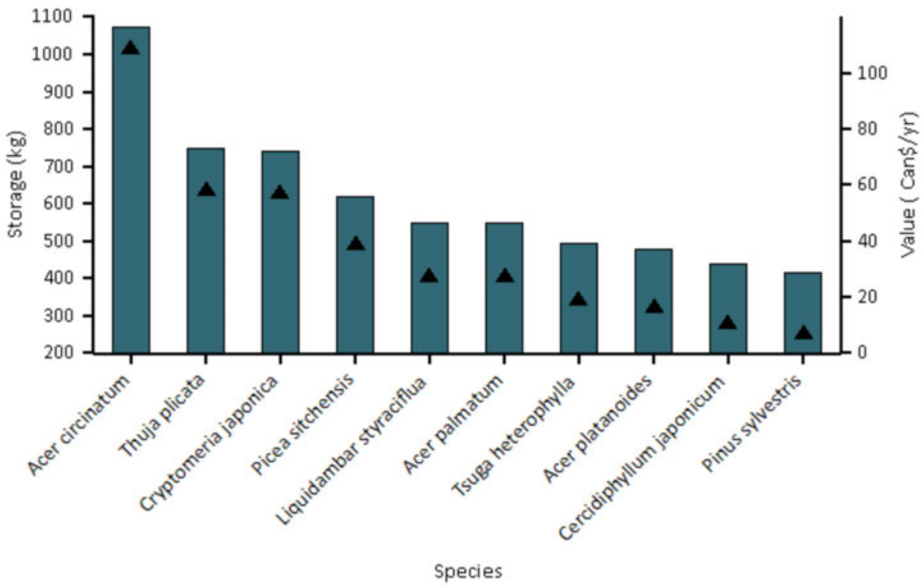

Fig. 11. Avoided Runoff (points) and Values (bars) for Species with Greatest Overall Impact on Runoff, i-Tree

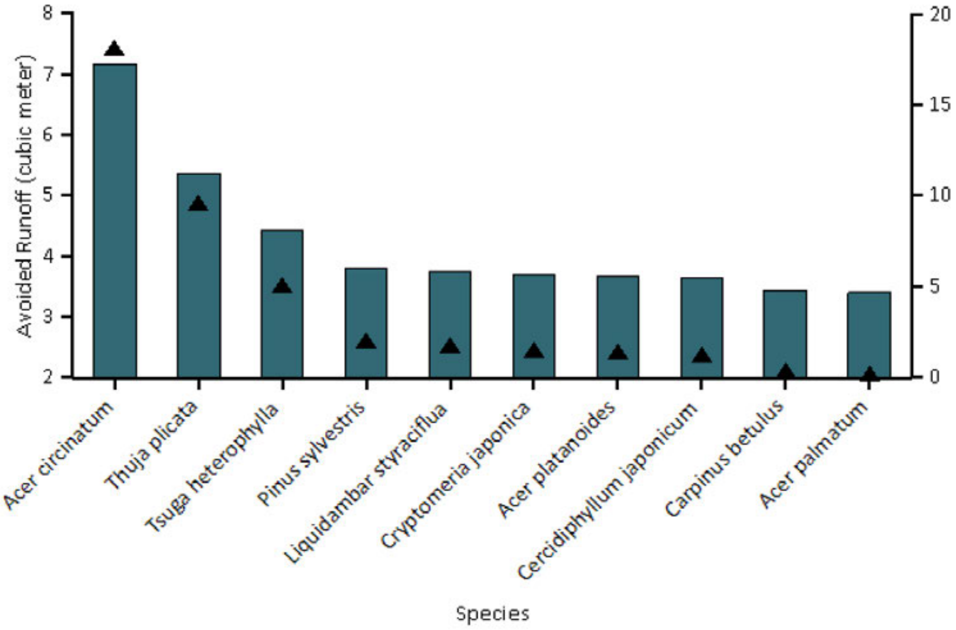

Fig. 12. Tree Species with the Greatest Structural Value, i-Tree

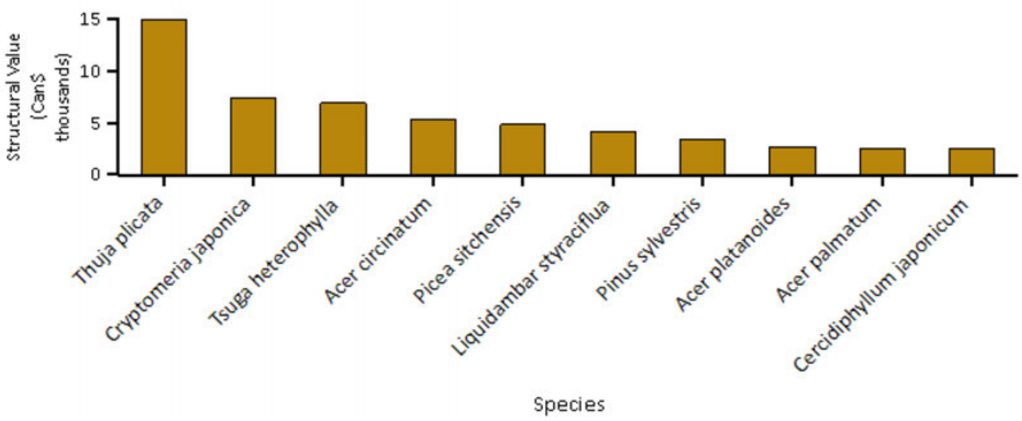

Fig. 13. Cultural Ecosystem Services Maps

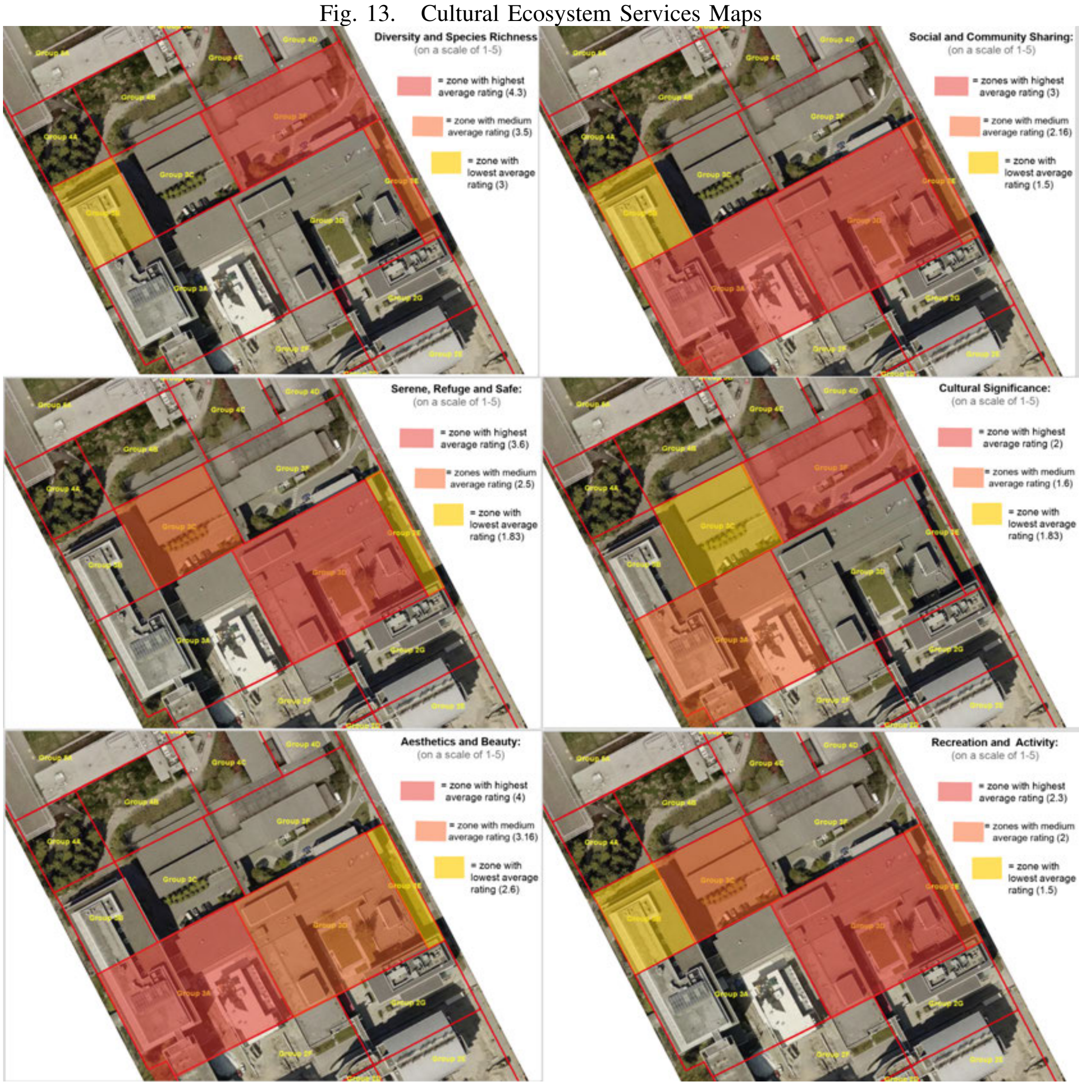

Fig. 14. Public Opinion Charts

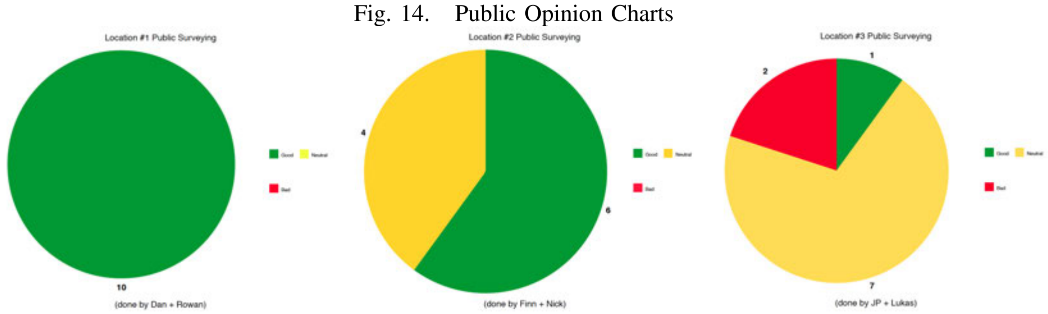

Fig. 15. A Map that Combines all Cultural Ecosystem Services Rankings

Fig. 16. SWOT Analysis Table

Strengths	• Species diversity (19 species, 3 dominant species) • Aesthetics and Beauty (4 score avg)

Weaknesses	• Small trees (~50% 7.6-15.2 cm DBH)
	  ○ Low height (~60% 3-9 m tall)
	  ○ **Canopy cover** (10.25%)
	• **Impermeable surfaces**
	• **Grey infrastructure** overpowers greenery
	• **Uneven species composition**
	• **Recreation and Activity** (2.3 avg)
	• Cultural Significance (2 avg)

Opportunities	• Small trees
	  ○ Pollution removal
	  ○ Carbon storage & sequestration
	  ○ Avoided runoff
	• Increase green space area
	• Increase recreational utility
	• Integrating green and grey scapes areas
	• **Area cleanup to help remove litter**
	• Feeling of refuge (3 avg)
	• UF Student body

Threats	• Not an area of priority ○ Lack of utility by students and staff (used as transportation corridors for between classes) • Lack of available planting soil

Urban Forest Ecosystem Service Assessment

Group 4: Phase 1E3

Due by: April 8, 2020

Contributions

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- Regulating Ecosystem Services:
    - Results & Interpretation

Kirsty Rude
- Cultural Ecosystem Services:
    - Results & Interpretation

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- Cultural Ecosystem Services:
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- Introduction
- Site Description

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- Regulating Ecosystem Services:
    - Methods

Roberta Gonzalez
- Cultural Ecosystem Services:
    - Methods

Zahra Sow
- Planning & Management Recommendations

Introduction

A complete ecosystem service assessment has been conducted in the zone of Group 4, phase 1E3. The purpose of this assessment was to integrate the results from our experience and value mapping surveys with the conventional spatial information of our zone to evaluate the greenspace usage and quality. It allows for an overview of the greenspace "hotpots" in the community and how the urban greenspaces are interpreted by different members of the community.

Ecosystem services "refers to the benefits human populations derive from ecosystems" (Bolund and Hunhammar, 1999). There are four broad categories that ecosystem services can be divided into which include: provisioning, supporting, regulating and cultural. Provisioning ecosystem services are used to describe the material outputs from ecosystems, including food and water, and raw materials (The National Wildlife Federation, n.d.). Supporting ecosystem services are ones that are necessary in producing other ecosystem services, such as nutrient and water cycling (The National Wildlife Federation, n.d.). Regulating services are ones that the ecosystem provides by acting as regulators, including carbon sequestration and storage and local climate and air quality (The National Wildlife Federation, n.d.). Cultural ecosystem services are benefits that people obtain from the ecosystem with no materialistic benefits, such as recreation and tourism (The National Wildlife Federation, n.d.).

UBC's urban forest management is composed of two different departments, Campus and Community Planning (C&CP) and Building Operations Divisions. The Campus and Community Planning department is responsible for the general landscape planning and permits of the UBC campus (Lompart and Ikeda, 2017). Meanwhile, the Building Operations Divisions is responsible for the maintenance of the landscape in UBC campus (Lompart and Ikeda, 2017). As of 2017, the improved implementation and enforcement of the urban forestry management policies and guidelines for UBC include the following:

1. Each department (C&CP and Building Ops.) should have clarified and collaborative goals in urban forest management with effective and efficient communication and processing between departments
2. Creation of regularly maintalues and goals which include specific definitions of what and how is to be achieved
3. Highest ranked staff in planning and permitting of urban forest management and staff involved in direct maintenance of trees should be certified in the International Society of Arboriculture (ISA), with at leasained and updated tree inventory
4. Creation of a significant tree registry
5. Clarification of urban forest vt one ISA certified staff in each department/division (Lompart and Ikeda, 2017).

Site Description

Location

The location of our zone (phase 1E3) is located in the parameters of the outlined area in figure 1, indicated as Group 4. A majority of the zone is situated in an area known as Fairview Grove, which is just off of Main Mall and is situated in between the Fred Kaiser building and the Beaty Biodiversity Museum. A grove is identified in modern landscape architecture as "an independent spatial type in which trees are grouped densely relative to their surroundings and has been used in addressing deficiencies of form, function and experiential quality in contemporary cities" (Gill, 2018). From the grove, the zone extends towards a quiet road - Stores Road - which leads to the Civil and Mechanical Engineering Structures on the left. The site also includes the back alley area of the Beaty Biodiversity Museum and reaches the trees that border the sidewalks of East Mall in front of the Food, Nutrition and Health building and the Earthquake Engineering Research Facility building. Figure 2 is a map of the location of our zone with the buildings indicated for reference.

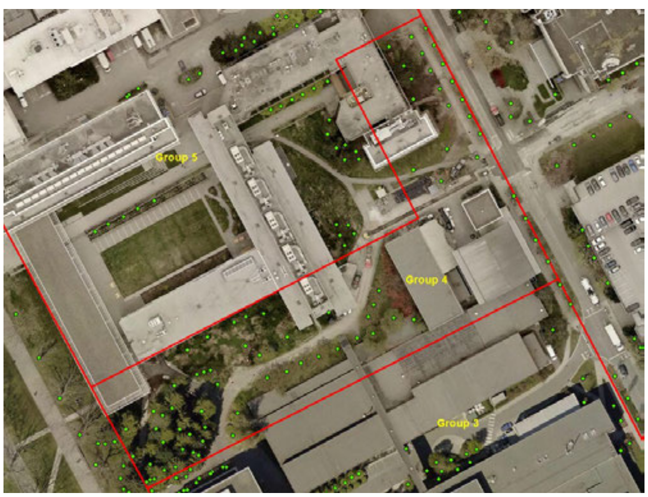

Figure 1: Map of Phase 1E3 (ARCGis, 2020)

Figure 2: Map of Phase 1E3 With Buildings Indicated (Google Maps, 2020)

Land Use & Users

The land use of our zone is for institutional and transportation uses only. The zone is on the University Endowment Lands which sits on the traditional, ancestral and unceded territory of the Musqueam First Nation for the University of British Columbia to operate on. The buildings in our zone include: the Beaty Biodiversity Museum, the Civil and Mechanical Engineering Structures building, the Food, Health and Nutrition building, and lastly the Earthquake Engineering Research Facility building. The end users of this zone are faculty and students who want to take a shortcut towards East Mall from Main Mall or the reverse, or who need access to one of the buildings listed prior. Only permitted staff vehicles are using this route to access the other buildings nearby, such as the Fred Kaiser building, to do maintenance or other duties.

Activities & Facilities

This zone does not allow for many activities to take place as there is limited space due to the close proximities of the buildings that surround the zone. The greenspaces that are prominent, indicated in figure 3 with the blue dots, are not all feasible for activity due to reasons that include, density of the tree canopy, drastic slope in the land, unpleasant views facing a garbage disposal area and an unmaintained space. The only activity that was noticed when observing the site included only walking and casual road-side conversations. There are no sited facilities that are available in the outdoor space of our zone besides a trash and recycling disposal area in the back alley behind the Beaty Biodiversity Museum.

Figure 3: Blue circles Indicating Locations of Greenspace In Phase 1E3 (ARCGis, 2020)

Regulating Ecosystem Services

Methods

i-Tree Canopy and i-Tree Eco are sister programs that were used to calculate and assess the regulating ecosystem services of our zone. To do so, our zone's tree inventory data was inputted and run through assessment tools specific to regulating ecosystem services, such as carbon sequestration, pests susceptibility and air pollution removal. After much time, processing and calculating, the software produces an automated report that includes the analysis of data.

The strength in using i-Tree Canopy and i-Tree Eco is that it is able to output results from a large amount of data, and also can decrease the amount of time spent conducting manual calculations. Thereby, decreasing the time spent on data analysis overall. The accuracy of using such software is also considerably higher than if done manually, which will help in the development of clear, approachable, and realistic future urban forest management plans. For instance, an exact number of days in relation to the carbon emitted in our data. Additionally, i-Tree is able to combine field data that we collected along with local hourly air pollution rates and meteorological data to create a thorough and informative report, thus decreasing human labour in this aspect.

The weakness of these programs lies in the fault of technology. The software is still continuing to develop and is not perfect in its ability to completely replace human labour, as the program is not able to properly distinguish a tree from a non-tree object. Thus, human error is a factor in calculating data, as points must be manually selected. An additional flaw in the i-Tree programs would be that the accuracy of the selection is dependent on the sample size. In other words, the more points there are, the more accurate the estimate produced by the software. If there are not enough points, the chances of error are extremely high, and lead to inaccurate results. Lastly, the program takes much time to develop such a report, though in comparison to manually creating this report, it takes much less time.

Results & interpretations

i-Tree Eco & Air Pollution. The data shown in Figure 7 has been estimated using pollution and weather data from 2010 (the most recent year that information was available). It is estimated that by the end of 2020, the trees in our zone will remove 19.68 lbs of air pollution, and that the pollution removal is greatest for Ozone compounds (O3). The report also states that roughly 4.1 lbs of volatile organic compounds (VOCs) were produced, being mainly produced by Red Cedar's and the Sitka Spruce. Some general strategies to improve pollution reduction that can be applied to our zone include using low maintenance trees, avoiding pollutant-sensitive trees, and sustaining the longest living trees.

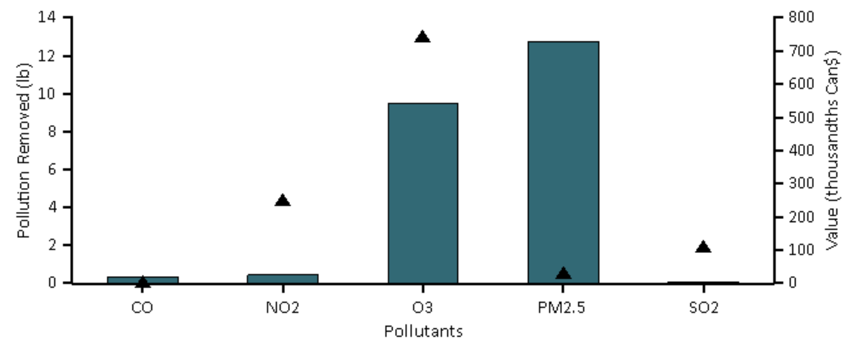

Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Data

i-Tree Eco & Carbon Storage/Sequestration. Trees can trap carbon in the atmosphere via sequestration. The amount sequestered depends on the size and health of the trees. The amount of carbon sequestered by the trees in our zone is about 1550 lbs of carbon per year, the distribution per tree species is shown in Figure 8. Carbon storage plays a role in influencing global climate change, and the trees in this zone are estimated to store around 21.2 tons of carbon. The Alligator wood tree stores 30.5% of the Carbon stored in our zone.

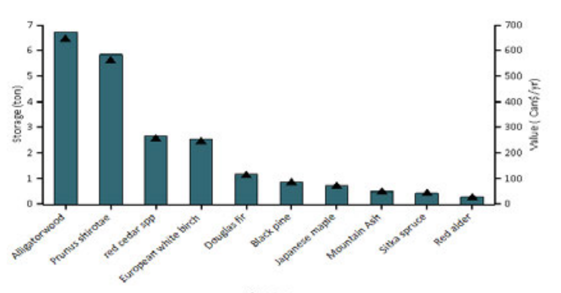

Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Data

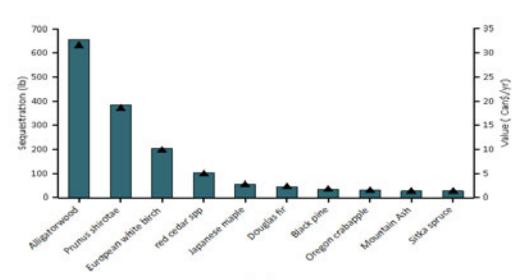

Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Data

Trees also Produce oxygen and reduce surface runoff. The trees in our zone are estimated to produce 2.066 tons of oxygen per year. Avoided runoff is shown below in Figure 10.

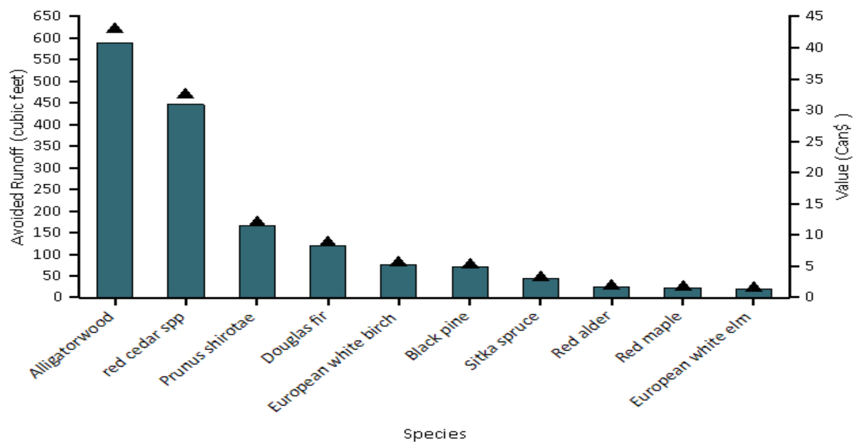

Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Data

i-Tree Canopy. For the i-Tree Canopy project, the report states that out of 100 test points, roughly 27% of our zone is tree cover and 73% is hardcover or shrubs.

Benefit	Value (USD)	±SE	Amount	±SE
Carbon Monoxide Removed Annually	0.51	0.08	12.18oz	2.00
Nitrogen Dioxide Removed Annually	0.98	0.16	6.08lbs	1.00
Ozone removed Annually	53.13	8.72	37.14lbs	6.10
Particulate matter <2.5 Microns removed annually	209.93	34.45	2.87lbs	0.47
Sulfur Dioxide Removed Annually	0.13	0.02	2.18	0.36
Particulate matter >2.5 microns, <10 microns removed annually	39.84	6.54	12.76lbs	2.09
Carbon Dioxide Sequestered in Trees	223.39	36.66	4.82 T	0.79
Carbon Dioxide Stored in Trees	5610.12	920.74	121.05 T	19.87

Figure 11 - Tree Benefit Estimates from i-Tree Canopy.

Result Comparison. The result of how much carbon dioxide is stored in our zone's trees from i-Tree Eco compared with i-Tree Canopy has a very stark difference. i-Tree Canopy estimated 121.05 T of carbon storage, while i-Tree Eco estimated only 21.2 T. However, the i-Tree Eco estimate is likely far more accurate, as i-Tree Canopy only has an estimate of canopy cover to go off of, and that in itself may be inaccurate, while i-Tree Eco has data on the specific species of trees in our zone as well as the exact number of trees. Both i-Tree Canopy and i-Tree Eco show similar relative annual removal for Carbon Monoxide, Nitrogen Dioxide, and Ozone. Ozone was reported as being the highest removed air pollutant by trees in both reports.

Overall, the main contributors to regulating ecosystem services in our zone are the Alligator wood's, Japanese blossom's, and Red cedar's.

Cultural Ecosystem Services

Methods

To assess the cultural ecosystem services provided, the zone of focus was split into 5 subzones: A, B, C, D & F. The location of these subzones can be viewed in appendix A. The assessment of our zone was analyzed in two different aspects, experience and value.

For the experience mapping, the members of our group carried out an evaluation and gave scores to each of the subzones on a scale from 1 to 5 for six different experience dimension values, including: aesthetics, species diversity, social & community sharing, recreation & activity, serenity & safety and finally cultural & historical significance.

With respect to the value mapping, two distinct locations were picked and 10 people were surveyed in each location (location 1 is in subzone A and location 2 is in subzone F). Questions asked in the survey were regarding how the space made them feel: happy, not good or neutral. These locations chosen to survey people were relatively high traffic areas like outside building entrances. However, there are some weaknesses regarding the method used to collect data, especially for experience mapping, as only 5 people were able to participate. This low number is not able to accurately represent what most of the community perceive in relation to the zone. Also, all of this information is based on personal perceptions and opinions, which differ from person to person and this is also the case for the value survey. In relation to the value mapping, results might be influenced by the fact that the day data was collected, it was a sunny day and perceptions may have been skewed toward a positive reaction.

Both mapping methods used the star graphs that have been done for sum in the appendixes, and average in the report. The sum star graphs were made by using the summed up scores we gave in each category for each subzone; one star on the map for each point. For the averaged maps, we summed up all the points again, and then divided amongst the 5 group members for each subzone to determine the average rating per person for each experience dimension value.

Results & Interpretations

Experience Mapping

A representation of the results for the experience mapping done in each subzone is presented in Figure 12. This figure represents the average score per person in regard to each experience dimension category. The categories have been rated out of 5, with the maximum number of stars/points in each subzone being 30, and the maximum for each category in each subzone being 5. All subzones were rated less than 50% satisfactory overall (less than 15 stars/points out of 30) concerning the 6 experience dimension categories.

Figure 12 - Cultural Ecosystem Service Provision: Phase 1E3 (ArcGis, 2020)

Species Diversity. Overall, this zone has an average species diversity satisfaction of 34%. The subzone that was perceived to have the most species diversity was subzone B, with a score of 3. This comparably higher score may be mainly due to the fact that the species populating subzone B were visibly less similar than species in the neighbouring subzones. For instance, the difference between the Alligator wood and Birch trees was more perceptible than the differences between the species populating subzone A, such as the Douglas fir and the Black pine, which are both coniferous and slightly similar in size. However, the rating of subzone B is still arguably low. This may be due to the predominance of monocultures in certain patches of the subzone, which provide a certain sense of uniformity. The subzone perceived to have the least species diversity was subzone D, which has an average score of 0. This result was obtained given the fact that the designated greenspace in this subzone - which is minimal - has been planted with homogenous tree species. The high species diversity experience dimension in subzone B as was achieved by utilizing tree species that were more easily differentiated upon casual viewing of the area. However, the score of the entire zone and more specifically subzone A was hindered by the predominance of small monoculture patches which gave it a more homogenous feel.

Aesthetics. This zone has an average aesthetics rating of 31%, or 2 stars/points per subzone. The subzone perceived to be the most aesthetic was subzone F, with a score of 3. Subzone A closely follows that by one point. When considering what factors could have led subzone F to prevail over the others, the result seemed to be counter-intuitive; especially because according to a study conducted by the *International Journal of Environmental Research and Public Health*, "[subjects] showed greater benefit from exposure to natural settings relative to built settings; as measured by pre-to-post changes in salivary amylase and self-reported stress" (Beil, K., & Hanes, D. 2013). It would be expected for subzone A to have a greater score for the aesthetic experience dimension. The data collected shows the contrary because, first, subzone A has a very dense canopy cover which makes the area appear gloomy even on a bright day; and secondly, there is the possibility that the built and natural environments interact and complement one another, showing a more pleasant aesthetic experience. All other subzones (B, C, & D) have 1 point for aesthetics. This low score for the remaining subzones may be given to the fact that in subzone B, there was some poor maintenance as the stumps and logs of the trees that had been cut down had been left on site, whereas subzones C and D are very bare in terms of greenery (not to mention that the location is mainly composed of alleys and the backs of buildings with disposing sites for trash and residues). It could be said that this zone provides a spectrum of aesthetic experiences: where some are more immersed in nature (such as that of Fairview Grove which provides some sort of escape from the built environment), while others imply a more intermixed experience between built and natural environments, which as shown by the data collected, can be just as (or even more) pleasant than a fully immersive experience.

Social & Community Sharing. Social and community sharing rated quite low, with an average of 1 star in each subzone. The overall rating regarding how well our zone is equipped for social/community sharing is 23%. The highest levels of social/community sharing are in subzones F and D, with 2 stars/points each. One possible explanation for the higher scores on these subzones may be the proximity to important buildings. This is because high traffic areas promote the placement of community sharing supporting infrastructure such as the bike racks found along East Mall as well as benches and communal areas outside of the Civil and Mechanical Engineering building. Furthermore, the fact that these two areas are located on a main road as opposed to alleys that may be avoided by pedestrians due to lack of appeal, may lead to more positive social interactions through a heightened sense of security. Subzones A, B, and C, are all very low rated in social/community sharing: in the case of subzones B and C, this may be due to the dumpster-like look, which may cause users to avoid community sharing activities and engage in less pleasant interactions. Subzone C has been recorded to have 0 social/community sharing points, being the place least enjoyed for these kinds of activities. The reasoning behind the low rating of subzone A is less easily discernible, but the lack of enticing community sharing infrastructure may play a significant role. In this zone, the visual pleasantness may lead to positive human interactions and promote community sharing. Two pieces of infrastructure stand out the most: first the bike racks on the sidewalk of East Mall, and secondly, the information post in subzone A nearby the Beaty Biodiversity museum. However, the low rating of subzone A indicates that the post is not sufficiently engaging to make a significant impact on the experience of people. Perhaps this may be due to its outdated appearance, or the amount of shade, which at times can make it more difficult to appreciate.

Recreation & Activity. Subzones A and F have the highest average score in regard to recreation and activity; this is a score of 1 star/point. What this tells us is that our entire zone has very little opportunity for recreation and/or activity. The main recreational aspect that is significant within the zone is the potential for recreational walks/runs through pedestrian walkways. However, it is important to note that recreation is not necessarily an experience dimension of high priority given that the land cover on the zone is primarily for practical purposes. For reasons stated previously, subzones A and F have attained a higher score. In overview, this is due to the presence of community sharing infrastructure, as well as the aesthetic value of Fairview Grove located in subzone A.

Serenity & Safety. Serenity & safety is rated highest in subzone A, with 3 stars/points. The quality of serenity/safety in this zone overall is 40%, making this one of the most prominent experience dimensions in our zone. One of the main factors that may have led to this relatively higher score is that the area is surrounded on all sides by buildings. This could cause users of this area to have some sense of enclosure which is directly related to the feeling of safety. Furthermore, the presence of Fairview Grove in subzone A probably plays a significant role in the feeling of serenity that is perceived in the area. The thick canopy gives the illusion that the user is actually in a forest, which creates a certain sense of retreat and escape from the built environment, thus, being decisive in the experience dimension of serenity. Therefore, this specific experience dimension relies equally just as much on biotic and anthropogenic features of the landscape.

Cultural & Historical Significance. Only subzone A had scored enough points to have stars on the map for the cultural/historical significance category, all of the other subzones have an average score less than one. This may arguably be the consequence of the presence of the information post located in Fairview Grove, explaining some history behind the location, not to mention the proximity of subzone A to the Beaty Biodiversity Museum, which is a common attraction in the UBC campus among visitors, faculty, and students. The other subzones lack this sense of cultural value. In the case of any of the remaining subzones, cultural value may be assigned to the buildings present in the area. Although subzones B, C, D and F have comparably less cultural value scores than their counterparts, they remain highly important in setting the stage for the types of interactions that will occur in the area, and thus generate some type of cultural importance. For instance, subzones D and F are likely to play a huge part in the experience of students taking classes in the Civil and Mechanical Engineering and the Food, Nutrition and Health UBC building, thus forming part of an academic environment that envelops the daily lives of many students, faculty and other community members.

Value Mapping

Results for the value mapping survey for both locations are presented in Figure 13. Both locations had an equal number of people happy with the space, neutral to the space, or unliking of the space. Overall, 60% of the people surveyed enjoyed our zone and its aspects.

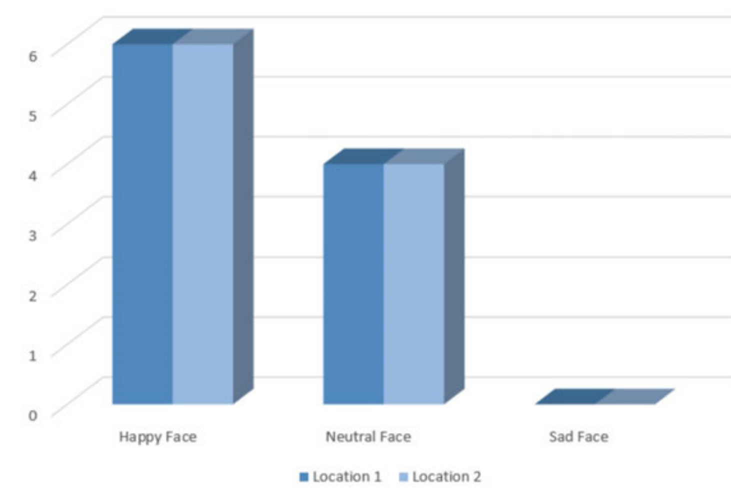

Figure 13 - Value Mapping Survey Results

Location 1. Most of the people surveyed in location 1 who enjoyed the space said it was due to the heavy concentration, variety, and vibrancy of the trees in Fairview Grove. This is evidently interconnected to the experience dimensions of cultural and historical significance, serenity and safety, recreation and activity, aesthetics, and species diversity. Because of this, it can be inferred that subzones that are more 'rounded out' and provide some type of input on all experience dimensions may cause it to become a signature patch that improves the experience of users significantly. Those that were neutral towards the space stated that they were indifferent because the space could incorporate more plant diversity, it was very dark at night, and they said how the buildings and vegetation could be better maintained. This is closely related to the experience dimensions of species diversity as well as the lower social community sharing value. The more homogenous look of having a variety of different species of conifers was evidently not enough to be perceived by the surveyees. Furthermore, the low social community sharing score may have caused the passerbyers to feel indifferent towards what was going on within the zone.

Location 2. Location 2's survey revealed that most of the people who enjoyed the space did so because of the tree lined sidewalk along East Mall. People reported enjoying the aesthetics provided by the trees and their canopy cover. The prevalence of high scores in location 2 for social/community sharing, aesthetics, and recreation have caused this appreciation and positive feedback from the surveyees. Although the species diversity for this location is low, pedestrians seemed to enjoy the presence of trees regardless. This may be due to the fact that the intended purpose of a sidewalk is not for users to remain fixed in the qualities that the trees may or may not have. Those that were neutral towards the space were mostly neutral due to a lack of interest. Those people that were uninterested stated it was either due to the fact that they pass by the area constantly, or that they do not pay much attention to their surroundings. This outcome may be traced back to the core function of the location, where as already stated, gives little importance to appearance and focuses more on function. One person had suggested the addition of more greenery lining the sidewalks to make the area more enjoyable.

Planning & Management Recommendations

Some recommendations that we believe will make the space more inviting to passerby's would include the following points:

During our time spent in the respective zones, we noticed, as well as our surveyees from the value mapping, that certain areas looked overgrown. Therefore, reinforced maintenance is the first management recommendation our group valued important to include for planning and management recommendations. In most subzones, but in particular subzones B and C, many tree logs and stumps were found which created an overall sense of chaos when looking at the aesthetics. We believe spaces occupying those stumps could be repurposed to create spaces in which populations can put into use such as benches, streams or ponds.

We also noticed that a lot of the trees and shrubs in the zones are deciduous, meaning that in the winter time, everything looks bare and unpleasant. Therefore, we recommend planting more coniferous shrubs and trees in all of the zones as they are evergreen which means that the leaves will stay green all year long. This will enhance the overall aesthetics as the presence of constant greenery will ameliorate the setting of the area.

Another recommendation that could change the management of the zone is the augmentation in species diversity. In fact, when looking at the overall species composition of the zone, the combination of trees and shrubs is abundant. The species that were the most dominant were American sweetgum, Pacific red cedar, Douglas fir and Japanese cherry. However, we observed that when walking through subzones, the same few species are only found within one specific area. Therefore, instead of finding a range of species coexisting together, concentrations of individual species were found creating a concentration of species unity and raising a concern in species diversity.

This lack of species diversity within subzones could eventually cause insect infection due to the fact that if one tree is infected, all trees in the same area will be infected as well since they are both from the same species. Evidently, this enforces the idea of increasing variety in species within subzones as it can lead to a decrease in insect susceptibility. In addition species diversity can lead to an increase in other ecosystem services such as aesthetics, recreation and culture. A combination of trees from different species can increase visual appeal for the zone. An improvement in aesthetics will also increase recreation and activity as “there is a positive association between physical activity” (Mytton et al, 2012). In addition, planting new species can add a cultural impact in the zone as some trees in Canada such as Western red cedar have cultural significance.

In the SWOT analysis, the weaknesses included an overall low canopy cover in all subzones besides A, which may be difficult to ameliorate due to much of the site being a concrete walkway which is hard surface cover. Threats that were found include climate change and pests. As previously mentioned above, an increase in species diversity among the subzones can create “ community evenness, and linkage strength and network centrality within a biological network which are all known to correlate with significantly reduced pest populations” (Lundgren et al, 2015). The different pests that are known to be present within most deciduous trees include aphids, ash flower gall mites, ash plant bugs, honeysuckles and many more (North et al, 2014). Besides the weaknesses and threats in this zone, the cultural services although only present in one subzone is relatively strong. In addition, our group found that an increased usage of the area is a reasonable external origin opportunity as it allows for many urban green space arrangements to be created. This would be essential in the overall zone in order to promote ecosystem services such as aesthetics, social/community sharing and finally recreation activity as they seemed to be the least present within the subzones.

References

Beil, K., & Hanes, D. (2013). The influence of urban natural and built environments on physiological and psychological measures of stress— A pilot study. *International Journal of Environmental Research and Public Health, 10,* 1250–1267. doi: 10.3390/ijerph10041250

Bolund, P., & Hunhammar, S. (1999). Ecosystem services in urban areas. *Ecological Economics, 29,* 293–301. Retrieved from https://www.sciencedirect.com/science/article/abs/pii/S0921800999000130

The National Wildlife Federation. (n.d.). *Ecosystem services*. Retrieved April 7, 2020, from https://www.nwf.or Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services

Gill, K. (2018). The grove as an urban tree planting type: The case of Nagele. *Studies in the History of Gardens & Designed Landscapes, 38,* 269-292. doi: 10.1080/14601176.2018.1465273

i-Tree. (n.d.). *Learn about i-Tree*. Retrieved from https://www.itreetools.org/

FMLink. (2016). Servicing those ecosystems: The value of trees. Retrieved from https://fmlink.com/articles/servicing-ecosystems-value-trees/

Lompart, J., & Ikeda, T. (2017). *Urban Forestry Management Plan: Recommendations for the University of British Columbia Vancouver Campus.* Retrieved from https://open.library.ubc.ca/cIRcle/collections/undergraduateresearch/18861/items/1.0356640

Lundgren, J. G., & Fausti, S. W. (2015). Trading biodiversity for pest problems. *Science Advances, 1*. doi: 10.1126/sciadv.1500558

Mytton, O., Townsend, N., Rutter, H., & Foster, C. (2012). Green space and physical activity: An observational study using Health Survey for England data. *Health & Place*, *18*, 1034-1041. doi: 10.1016/j.healthplace.2012.06.003

Agriculture and Forestry. (2015). *Pests of deciduous trees and shrubs*. Retrieved from https://open.alberta.ca/publications/9780773261051#detailed

Appendices

Appendix A – Subzones in Phase 1E3

Appendix B – Locations for Value Mapping Survey

Appendix C – Map of Average Species Diversity

Appendix D – Map of Sum of Aesthetics

Appendix E – Map of Sum of Social & Community Sharing

Appendix F – Map of Sum of Recreation/Activity

Appendix G – Map of Sum of Serenity & Safety

Appendix H – Map of Sum of Cultural/Historical Significance

Appendix I – i-Tree Eco Report I

Susceptibility to Pests by Stratum

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Data, Series: Zone 4, Year: 2020
Generated: 2020-04-06

		Number of Trees		Structural Value (Can$)		Leaf Area (%)		Leaf Area (ac)	
Pest Name	Stratum	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible
Aspen Leafminer	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Asian Longhorned Beetle	Study Area	7	62	20,096	175,206	7.0	93.0	0.1	1.9
Beech Bark Disease	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Butternut Canker	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Balsam Woolly Adelgid	Study Area	1	68	1,060	194,242	1.1	98.9	0.0	2.0
Chestnut Blight	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Dogwood Anthracnose	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Douglas-fir Black Stain Root Disease	Study Area	7	62	18,263	177,039	7.3	92.7	0.1	1.9
Dutch Elm Disease	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Douglas-Fir Beetle	Study Area	7	62	18,263	177,039	7.3	92.7	0.1	1.9
Emerald Ash Borer	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Fir Engraver	Study Area	8	61	19,323	175,979	8.4	91.6	0.2	1.9
Fusiform Rust	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Gypsy Moth	Study Area	9	60	15,471	179,831	6.7	93.3	0.1	1.9
Goldspotted Oak Borer	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Hemlock Woolly Adelgid	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Jeffrey Pine Beetle	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Large Aspen Tortrix	Study Area	5	64	15,099	180,204	6.2	93.8	0.1	1.9
Laurel Wilt	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Mountain Pine Beetle	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Northern Spruce Engraver	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Oak Wilt	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Pine Black Stain Root Disease	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Port-Orford-Cedar Root Disease	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Pine Shoot Beetle	Study Area	7	62	18,263	177,039	7.3	92.7	0.1	1.9
Polyphagous Shot Hole Borer	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Spruce Beetle	Study Area	2	67	3,804	191,499	2.7	97.3	0.1	2.0
Spruce Budworm	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Sudden Oak Death	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Southern Pine Beetle	Study Area	2	67	3,804	191,499	2.7	97.3	0.1	2.0
Sirex Wood Wasp	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Thousand Canker Disease	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1

Page 1

Appendix J – i-Tree Eco Report II

Susceptibility to Pests by Stratum

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Data, Series: Zone 4, Year: 2020
Generated: 2020-04-06

		Number of Trees		Structural Value (Can$)		Leaf Area (%)		Leaf Area (ac)	
Pest Name	Stratum	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible
Winter Moth	Study Area	7	62	4,245	191,057	4.5	95.5	0.1	2.0
Western Pine Beetle	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
White Pine Blister Rust	Study Area	0	69	0	195,302	0.0	100.0	0.0	2.1
Western Spruce Budworm	Study Area	8	61	19,323	175,979	8.4	91.6	0.2	1.9
All Pests	Study Area	22	47	44,908	150,394	20.2	79.8	0.4	1.6

Note: this table tells the potential pest risk rather than actual pest impact

Appendix K – i-Tree Canopy Report

Tree Benefit Estimates

Abbr.	Benefit Description	Value (USD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.51 USD	±0.08	12.18 oz	±2.00
NO2	Nitrogen Dioxide removed annually	0.98 USD	±0.16	6.08 lb	±1.00
O3	Ozone removed annually	53.13 USD	±8.72	37.14 lb	±6.10
PM2.5	Particulate Matter less than 2.5 microns removed annually	209.93 USD	±34.45	2.87 lb	±0.47
SO2	Sulfur Dioxide removed annually	0.13 USD	±0.02	2.18 lb	±0.36
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	39.84 USD	±6.54	12.76 lb	±2.09
CO2seq	Carbon Dioxide squestered annually in trees	223.39 USD	±36.66	4.82 T	±0.79
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	5,610.12 USD	±920.74	121.05 T	±19.87

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and USD/T/yr: CO 0.791 @ 1,333.50 USD | NO2 6.314 @ 323.17 USD | O3 38.570 @ 2,871.04 USD | PM2.5 2.985 @ 146,570.75 USD | SO2 2.267 @ 120.75 USD | PM10 13.247 @ 6,268.44 USD | CO2seq 10,010.267 @ 46.51 USD | CO2stor is a total biomass amount of 251,395.359 @ 46.51 USD*
Note: Currency is in USD
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

About i-Tree Canopy

The concept and prototype of this program were developed by David J. Nowak, Jeffery T. Walton and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company).

Limitations of i-Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate.

A Cooperative Initiative Between:

www.itreetools.org

Ecosystem Service Report

Group 5

April 8 2020

Contribution page

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-Introduction; Site description

Hui Chen
- Regulating Ecosystem Services

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- Regulating Ecosystem Services

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-Cultural Ecosystem Service

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-Cultural Ecosystem Service

Zhiyi Lin
-Urban Forest Planning and Management Recommendations

1. Introduction

Ecosystem services are the direct and indirect contributions of ecosystems to human society, provides benefits to humans by the natural environment and from healthy ecosystems. They support directly or indirectly our survival and quality of life. Assessment of Ecosystem Services is a way to show the importance of ecosystem in the society. From the perspective of regional planners, it is a supporting instrument for planning the use of an area. Using different methods – biophysical, social and economic, can perform ecosystem service assessment. Economic and social assessment reveals the direct benefits to society and therefore can support decision-making on certain land use projects. While biophysical assessment helps to understand the functioning of ecosystem and importance of different species, habitats and types of land cover in supply of the ecosystem services such as we did in some classes ("Assessment of Ecosystems",2018). It provides basis for decision making on solutions for land management and use of nature resources.

With the help of all kinds of assessment such as i-Tree and value mapping, we can integrate experiences with other conventional spatial information, as well as evaluate green space use & quality in order to make contribution. It also allows community participation, and locates green space 'hotspots' so that we can quantify the importance of urban green spaces for different people.

Ecosystems services are mainly based on regulating ecosystem services where we observe the benefits obtained from the regulation ES, cultural ecosystem services which we it's more of a spiritual subject that we feel of a certain place, and these are the two ES we mainly focused on in class. On the other hand, there are provisioning services such as habitats provided and supporting services, which are the things that supports the habitats like worms or fungi.

The success of urban forest management is frequently predicated upon achieving absolute canopy cover targets. Urban forest managers must be able to clearly identify where specific goals or targets have been met and when adaptations are needed with the help of all the assessments. Considerations of urban forest can contain the vegetation resource the community framework, and the resource management approach (Kenney, van Wassenaer & Satel, 2011, pp109-110).

2. Site Description

Our zone is located at the middle of the UBC (figure 1), and it is surrounded by the University Blvd, Main Mall, East Mall and south of the Beaty Biodiversity Museum. The main component of this zone is institutional building and services, while green spaces only take up about 22%. Some representative facilities such as the UBC bookstore, Beaty Biodiversity Museum (figure 2), Biological Sciences Building that leads to the main users of this zone are students, professors and tourists. According to the location of the area and the function of these buildings, it can be assumed that the area has a high institutional involvement.

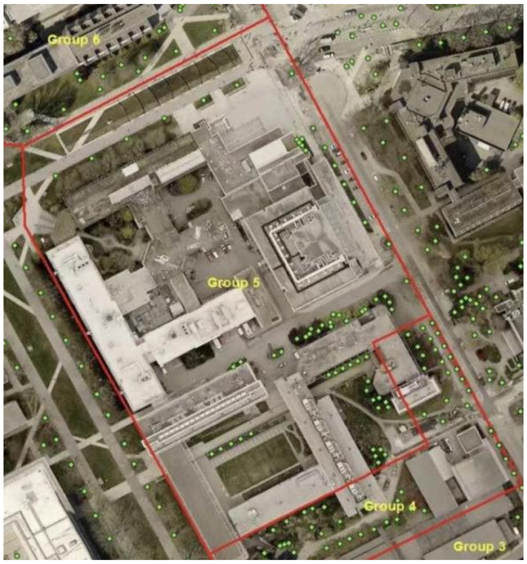


Figure 1 Zone 5 (“google maps”,2020)

Figure 2 Beaty Biodiversity Museum. (“Google Maps”, 2020).

3. Regulating Ecosystem Services

Urban Forest plays a role in constructing an ecological city. Urban Forests will create ecosystems that will provide regulating services to humans. Regulating Ecosystem Services is the benefits obtained from the regulation of ecosystem processes, such as water purification, pollination, avoided runoff, carbon storage & sequestration and so on. In order to analyze the regulating services of our zone, we used i-Tree Canopy and i-Tree Eco two tools.

3.1 Method

3.1.1 i-Tree Canopy

i-Tree Canopy is a tool to estimate tree cover and tree benefits for a given area with a random sampling process that lets ground cover types classified easily ("i-Tree Canopy", n.d.). This tool lays points randomly on Google Earth imagery and the user classifies the cover types of each point falls upon (i-Tree Canopy Technical Notes, 2011).

The first step of using i-Tree Canopy is defining the project area by delimits the boundary of our zone of analysis (Figure 3 & 4). Then, name the cover classes to need to be classified (e.g., tree, non-tree). After that, we classified the cover type of 200 random points within our boundary (Figure 4). At last, we exported the Cover Assessment and Tree Benefits Report (Appendix I).

i-Tree Canopy is an aerial photography-supported method that covers very large areas including trees in private and public land. It also is a 1D structure tool, all operations are based on the aerial top-view. As for the accuracy of the tool, it depends on the amounts of the points. As the number of points increases, the better your cover estimate for the study area and the precision of the percentage estimate will increase as the standard error will decrease (RIDEM Division of Forest Environment, 2014).

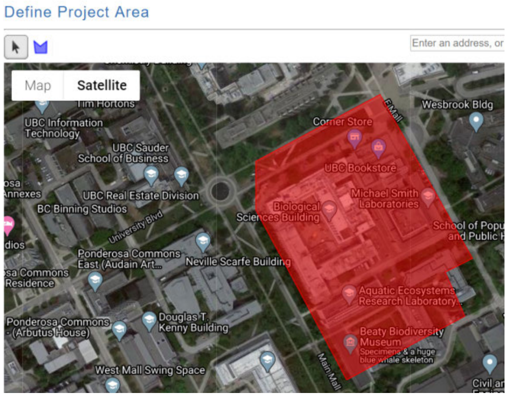


Figure 3 Define Project Area

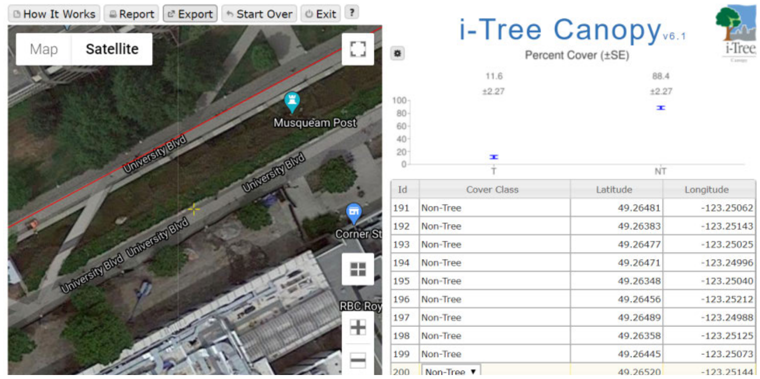


Figure 4 Classify the Cover Type

3.1.2 i-Tree Eco

i-Tree Eco projects involve stages of project design, data collection, data analysis, reporting, and dissemination of findings. i-tree eco model makes use of some data to calculate structural and functional information by using a series of scientific equations or algorithms. These data include tree measurements and field data, which are entered into the Eco application either by web form or by manual data entry. Then they are merged with local pre-processed hourly weather and air pollution concentration data (i-Tree Eco, n.d.).

3.2 Strengths and Weakness

i-Tree Canopy can produce a statistically valid estimate of the land canopy type (Jennings, 2015). It can calculate standard errors of removal amounts and benefits based on sampled and classified points. Therefore, it is a precise and scientific analytical model. Then, there is no spatial restriction for using it, because i-Tree Canopy is an aerial photography-supported method that covers very large areas including trees in private and public land. It can analyze anywhere you study. In addition, it also is an easy-to-use tool with only three steps in the process of operation.

Nonetheless, i-Tree Canopy still has some limitations. As for accuracy, it depends on the ability of the user to correctly classify each point into its corrected class ("i-Tree Canopy", n.d.). If too few points are classified, the standard error will be too high to give any real certainty to the estimate ("i-Tree Canopy", n.d.). So, if you want higher accuracy, the more points should be classified correctly. Additionally, its inventory scale is limited because it is based on aerial photography. We can only use it to look at the overall situation of the large area but can not analyze the specific situation of each tree in this area in detail.

i-Tree Eco methods can be applied to areas of any size and to non-urban areas (E Brown et al., n.d.) Secondly, it has numerous users include thousands of people who do projects ranging from small tree inventories to regional scale assessments and Eco users like government agencies, consultants, non-profits, universities, researchers, volunteers, educators and advocates. Additionally, i-Tree Eco provides extensive forest and individual tree analyses including functional analyses, structural and composition analyses (i-Tree. n.d.). More importantly, i-Tree Eco can be used for complete and sample inventories. As for the complete inventory, it provides flexible and scalable choices that can assess ecosystem services for a single tree or thousands of trees (i-Tree, n.d.).

However, i-Tree Eco still faces some challenges. For example, it costs a lot of time to analyze significant resources of complex and large projects. And more data collection variables are needed to get the most accurate results. Additionally, local data may not be available or complete for all locations, and not representative of actual conditions (Behounek, 2019).

3.3 Results of Model

3.3.1 Results of i-Tree Canopy

After three steps of using i-Tree Canopy, we create a Cover Assessment and Tree Benefits Report (Appendix I). According to the result, it shows that the tree cover of our zone is 11.6(±2.27) percent (Figure 5), which is lower than 18%, the tree canopy cover of Vancouver city (City of Vancouver Urban Forest Strategy, 2014). This suggests that tree cover in this zone is still too low. Therefore, this zone is a potential planting location to increase tree cover.

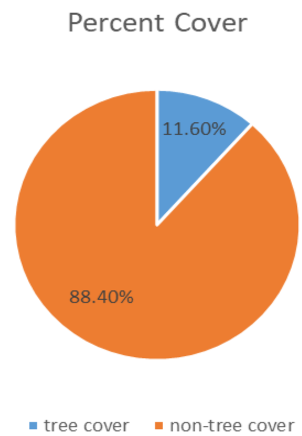


Figure 5 Tree Cover Percent

As for tree benefits estimates, the tree canopy data includes annual benefits based on canopy cover canopy percentages for eight specific categories: carbon monoxide removed annually (CO), nitrogen dioxide removed annually (NO2), Ozone removed annually (O3), particulate matter less than 2.5 microns removed annually (PM2.5), sulfur dioxide removed annually (SO2), Particulate matter greater than 2.5 microns and less than 10 microns remove annually (PM10*), carbon dioxide sequestered annually in trees (CO2seq), and carbon dioxide stored in trees (CO2stor). The air pollutant removal changes NO2, O3, PM2.5 and SO2 concentrations with associated monetary values. The value of the eight categories of benefits showed in Table 1. To sum up, the monetary value that tree canopy in this area brings in absorbing air pollutants is CAD$ 389.18 annually.

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.06 CAD	±0.01	1.01 lb	±0.20
NO2	Nitrogen Dioxide removed annually	0.10 CAD	±0.02	5.53 lb	±1.09
O3	Ozone removed annually	5.44 CAD	±1.07	55.12 lb	±10.81
PM2.5	Particulate Matter less than 2.5 microns removed annually	11.25 CAD	±2.21	2.68 lb	±0.53
SO2	Sulfur Dioxide removed annually	0.02 CAD	±0.00	3.49 lb	±0.68
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	3.95 CAD	±0.77	18.46 lb	±3.62
CO2seq	Carbon Dioxide squestered annually in trees	368.36 CAD	±72.23	5.63 T	±1.10
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	9,251.01 CAD	±1,814.07	141.49 T	±27.74

Table 1 Tree Benefit Estimates

3.3.2 Results of i-Tree Eco

The first regulating ecosystem service we want to stress is carbon storage and sequestration. The i-Tree Eco shows every species' capacities of carbon storage and sequestration. And the amount of carbon annually sequestered is increased with the size and health of the trees (i-tree eco report, 2020). In zone 5, Northern red oaks have big volume, Japanese maples and Black pines are the two common species which both account for about 24.2%. That is the reason why these three species are better at sequestrating and storing carbon in zone 5 (figure 6 & 7). What is more, these three species are planted concentratedly on area B and C (figure 8). Red circles stand for Norther red oaks, blue circles stand for Black pines and purple circles stand for Japanese maples.

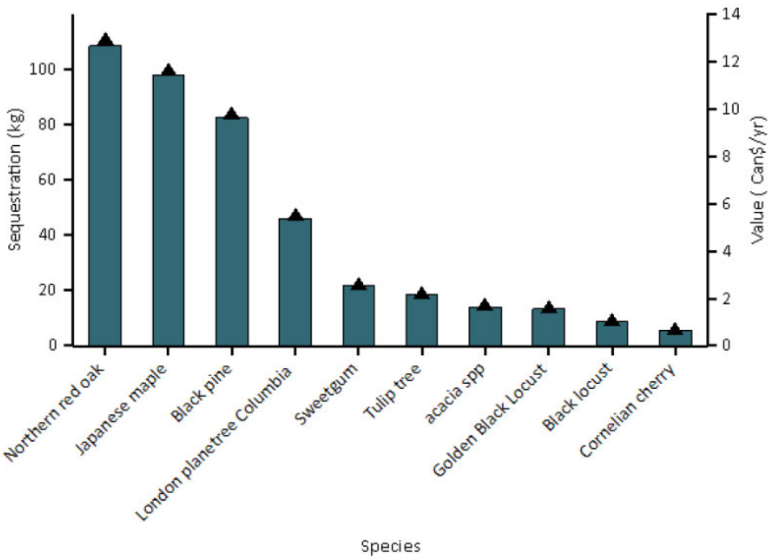


Figure 6 Estimated annual gross carbon sequestration(points) and value(bars) for urban tree species with the greatest sequestration

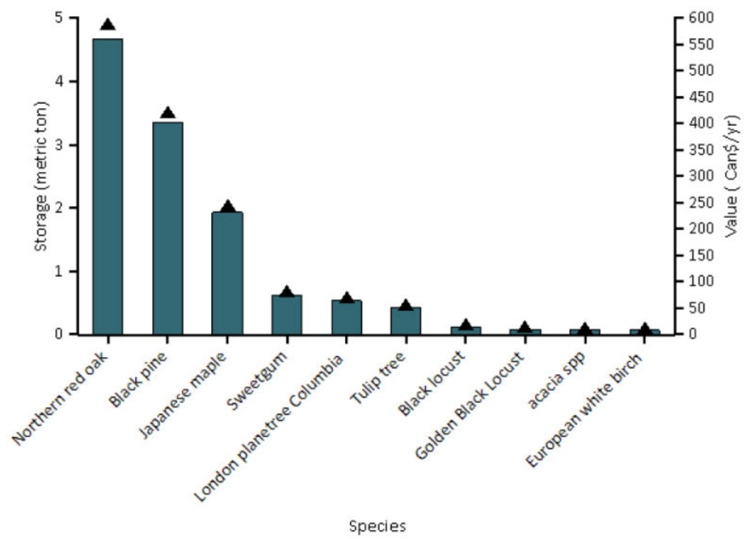


Figure 7 Estimated carbon storage(points) and values(bars) for urban tree species with the greatest storage

The second regulating ecosystem service is avoided runoff. During precipitation events, some portion of the precipitation is intercepted by vegetation while the other portion reaches the ground. Places with surface runoff are easily to contribute pollution to streams, wetlands, rivers, lakes, and oceans (i-tree eco report, 2020). Vancouver is a rainy city, especially in winter. Therefore, the ecosystem service named avoided runoff provided by vegetations is essential to Vancouver. Based on the i-Tree Eco, the top four tree species good at intercepting rain are Northern red oak, London planetree Columbia, Black pine and Japanese maple (figure 9). These trees are planted concentratedly on area B, C and G, additionally brown circle stand for London planetree Columbia (figure 8).

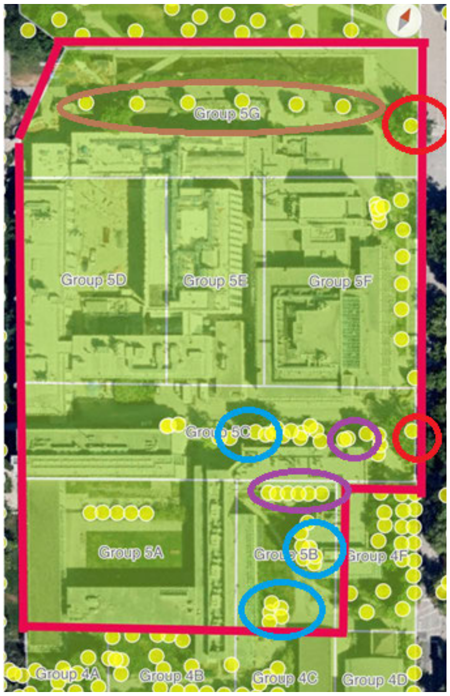


Figure 8 zone map

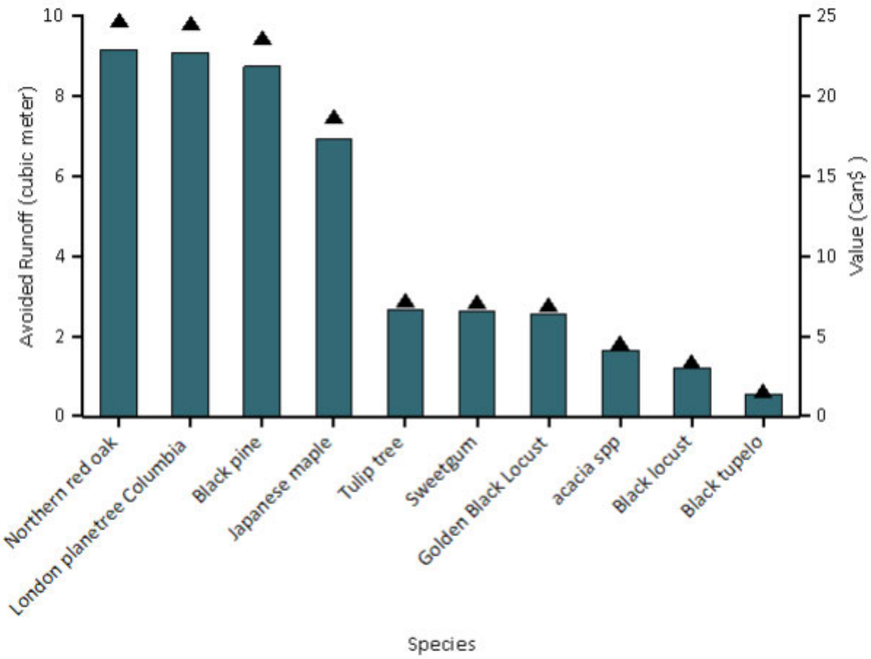


Figure 9 Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff

4. Culture Ecosystem Services

Many studies have explored the range of benefits and services that diverse urban forests provide, including greater ecosystem productivity, higher resilience to environmental perturbations, and increased wildlife habitat. Cultural ecosystem services are also very important, such as mental and physical health, esthetic values and spiritual benefits. We mainly used the cultural ecosystem services value mapping process, including experience value mapping and social value mapping.

4.1 Method

4.1.1 Experience Value Mapping

We divided the zone into seven subzones from A to G (figure 10). Each member in the group valued the six experience dimension of each subzone from 0 to 5, the larger number means the higher value.

The first dimension of experience is the diversity, which is the experience of richness in plants, insects, and animals. Diversity targets have been incorporated into the core objectives of urban forest management plans. Aesthetic value means human preference for open areas with a view. Trees add beauty to their surroundings by adding color to an area, softening harsh lines of buildings and screening unsightly views. When looking at social values, places where have higher experience of organized and entertaining scene and getting together with other people will get a higher score. Recreation refers to any physical or psychological revitalization through the voluntary pursuit of leisure time in urban forests, including, physical and social activities and developed facilities. Refuge is the demarcated and uncluttered place by trees, bushes and fences which can provide a feeling of safety and serene. As for the cultural values, it is necessary to define these terms including society, religion, policy and art, and we focus on the experience of cultivated, man-made surroundings formed by history and culture.

After everyone in the group finished grading each subzone, we collected the data together, summed the individual scores and calculated the average scores. Then, we put the data into Excel and produced some graphs to visualize the results.

4.1.2 Social Value Mapping

In the second part, we used sentiment mapping that is a method of social value mapping. We selected three survey locations in our group zone (figure 10). When we were choosing locations, we tried to avoid the area is not commonly visited by people and selected three locations with high transit which could help us to complete our survey. The first location is at the intersection of the University Blvd and Main Mall, and it is close to the fountain. The second location is at the intersection of the University Blvd and E Mall, and it is in front of the UBC Bookstore. The third location is at the intersection of the E Mall and Biological Sciences Rd. The common of these three locations is high transit and different types of users (e.g. student, professor, visitor and staff), because people of different identities may have different views on the same place. So, these selections can help us diversify our results.

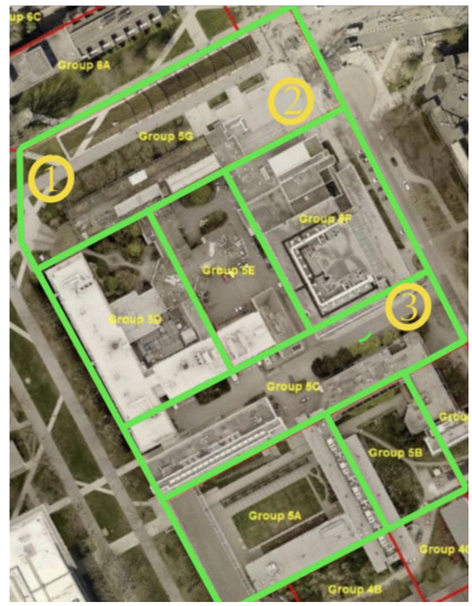


Figure 10 Subzones and location selection

Then we divided into three groups, working in pairs and engaging 10 people in a short survey in each location. During each survey, we would ask each person to look around (360° rotation) and ask her/him the following question: “Based on what you see, how do you feel about this place?”. What’s more, the person can choose to feel good (happy face), indifferent, or not good (unhappy face), and they would also provide reasons for that.

4.2 Strengths and Weakness

We used the value mapping approaches in order to combine experiences with the existing spatial information, assess greenspace use and quality, encourage community participation, locate greenspace ‘hotspots’, and quantify the importance of urban greenspaces for different people.

The mapping of cultural value is linked directly through their use of indicators and parameters within each of the experience dimensions, and this method provides a deeper understanding of space’s recreational potentials and qualities. The key feature of the mapping methods is that they go beyond reliance on quantitative descriptions of physical characteristics or content as the primary information (e.g. the number of sports fields or the area covered by forests). The mapping methods are based on research and agreement between actors in the planning system for evaluating the value of green spaces. The method's adoption depends on the correspondence with public preferences (Lindholst, Caspersen, & Konijnendijk van den Bosch, 2015).

But these approaches provide a rather unbalanced focus on 'amounts' and 'figures' rather than integrating a deeper perspective on the value or 'quality' of urban green spaces (Lindholst, Caspersen, & Konijnendijk van den Bosch, 2015). The surveys we did also have some limitations and inconsistencies based on irresistible factors and subjective factors such as different weather conditions and personal emotions. Besides, the number of people we interviewed was very small, so the result we got is not very accurate. We must expand the number of people surveyed to get more accurate results.

4.3 Results of the Mapping

4.3.1 Results of Experience Value Mapping

We put the data into Excel and produced some graphs to visualize the results (figure 11). The data in this graph is the average score of each group member's feelings about each subzone during the field trip. Each one of these seven subzones has its own unique value of cultural experience.

We calculated not only the average score of six dimensions in each subzone, but also the overall mean of the whole zone in different dimensions. According to the results, we found that the social experience value provided by the whole area is the highest, approximately 3.1 out of 5, while the score of cultural significance is the lowest, which is 1.8 out of 5. This zone is located in the central area of the campus, there are a lot of people every day including students, professors and visitors. And various activities will be held there, such as picnics, events, parties, etc. The experience of organized and entertaining scenes and getting together with other people in this zone is very high. As for the cultural ecosystem services provided by this zone, subzone G is located in the University Blvd and there are Musqueam Post which represents the indigenous people's culture and some artworks, so this subzone has high cultural value. In the other subzone, there are few symbols of cultural and historical signs. Therefore, the total experience of cultural significance is the lowest.

According to the graph, subzone G provided the most cultural ecosystem services. This area is rich in species and gives us the experience of diversity (figure 12). This subzone is located at University Blvd with high transit every day. There are some seats, benches for people to sit down and getting together with others. There are open spaces with corridors and some pillars about indigenous people's culture which increases the experience of anesthetic and culture. The value of aesthetics, social, recreation and cultural significance in subzone G is the highest among these seven subzones. This area is one of the most prosperous areas in UBC and provides more cultural ecosystem services. Subzone E has the lowest value of experience which is located in the narrow area between two buildings, there are no open spaces, benches, and cultural significance, only a tree was planted there (figure 13). And except the staff who recycle the garbage and parking, few people will go through this area. So, in subzone E, all of the value of six dimensions is the lowest and provides the least cultural ecosystem services.

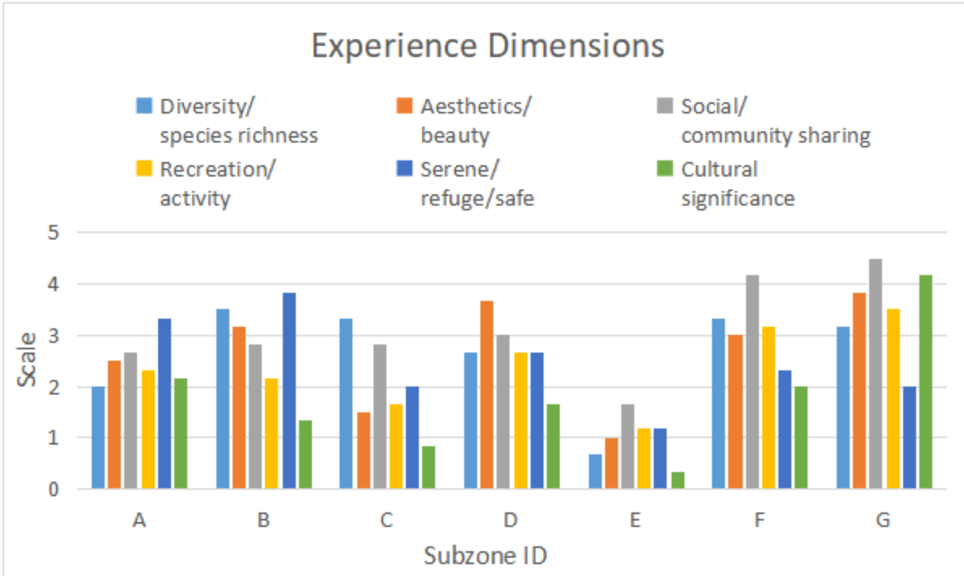


Figure 11 Experiences dimensions

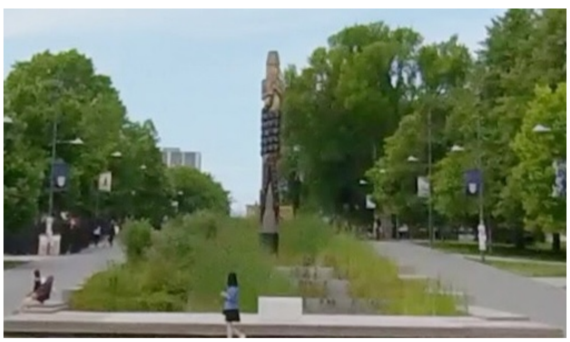


Figure 12 Subzonee G

Figure 13 Subzonee G

4.3.1 Results of Social Value Mapping

According to the results of the survey, Figure 14 shows the interviewers' satisfaction with the greening area within three locations. It is obvious that in these three locations, the first and second location has the highest satisfaction degree, while only half of the people in the third location give a happy face. The first and second locations are in subzone G, and the third location is in subzone C (figure 10). According to the results of Experience Value Mapping, subzone G provided the most cultural ecosystem services, while subzone C provided less. So, it makes sense why did the first and second locations have higher environmental satisfaction.

There are 22 people who feel good about these 3 locations, they feel that this place has high diversity, colorful scenery makes people happy, seasonality, lots of activities (sit and chat), open spaces, clean, green spaces with a view, usually beautiful and clean, lots of sunlight. And there are 8 people felt indifferent about these places, in the location 1 & 2, some people felt there are too many modern buildings and less aesthetic, barren lands and weeds still exist which make a sense of messy. As for location 3, the number of people who feel indifferent is largest. They think this location needs more layers and more space for activities, and there is no leaf in winter which makes people sad.

However, due to the small number of people interviewed in this survey, the evaluation of these three locations is not universal, but representative. People's feelings are also affected by objective conditions (e.g. weather) and subjective conditions (e.g. mood).

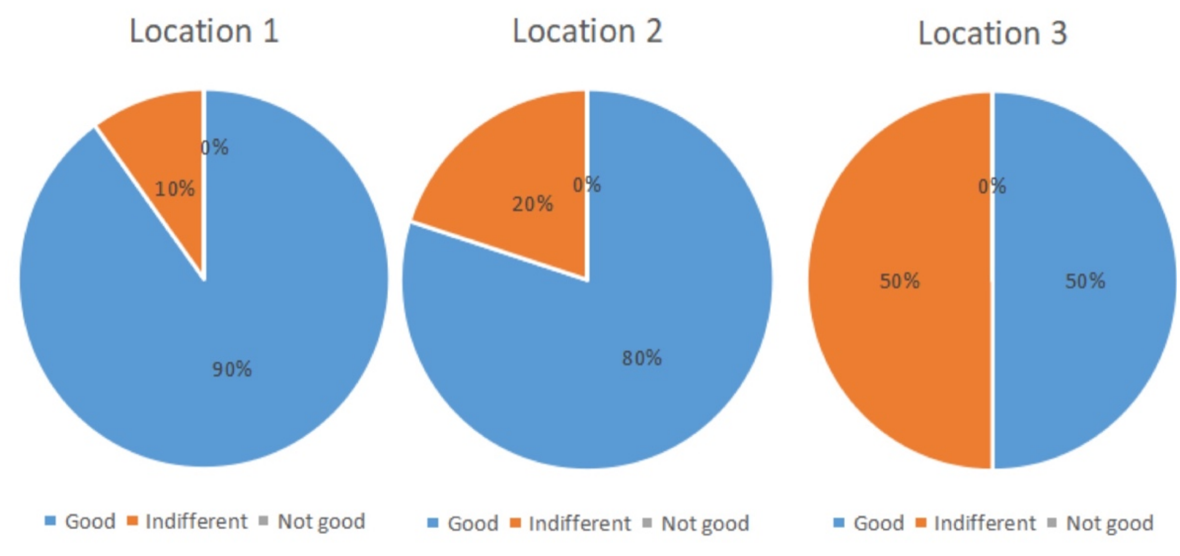


Figure 14 Short survey

5. Urban Forest Planning and Management Recommendations

5.1 Integration of Regulating and Cultural Ecosystem Services

Based on the analysis of regulating and cultural ecosystem services, it can be concluded that this zone provides valuable regulating ecosystem services, including carbon storage and sequestration, runoff reduction and air pollutants absorption, bringing some economic benefits. Also, this zone offers aesthetic, recreational and cultural values, and many other cultural ecosystem services which are hard to measure with money.

One of our findings is that subzones or sites with more green space usually provide more ecosystem services. For example, in subzone B, there are a large area of lawns and 18 trees with 4 different species. It offers more regulating services than some other subzones and gives people a strong sense of diversity, beauty and serene. However, subzone E is area with the lowest regulating and cultural ecosystem services, because there are few trees and other vegetation planted there. We also found that larger and healthier trees can produce more regulating and cultural value. Like the two northern red oak in this zone, they store and sequestrate the largest amount of carbon, and make the greatest impact on runoff, and in the meantime, they are considered as landmarks in the symbolic center of the campus, increasing the recreation and aesthetics of the site.

5.2 Recommendations

5.2.1 Increase Green Space

Through a detailed analysis, we found that green space in this zone is not adequate since institutional buildings and impermeable surface cover a very large area. Therefore, increasing green space is a primary suggestion for the development of this zone.

Trees and other vegetation can be preferentially planted at sites with little green cover, such as subzone D and E (figure 15). The area suitable for planting vegetation in subzone E is a pathway located between two institutional buildings. The space is narrow and limited, so some small tree species and shrubs are the better choices to decorate it. As for subzone D, there is an open space without trees surrounded by buildings. We suggest that this space can be designed to offer students, faculty and staffs a recreational and serene environment with diverse plants, lawns and street furniture, such as benches and tables.

In addition, when selecting species to plant, we should consider many factors, such as whether sites allow trees to prosper and reach their mature growth potential, and whether trees are invasive species. Lists of discouraged trees, shrubs and groundcovers in UBC Vancouver Campus Plan can be used as a reference.

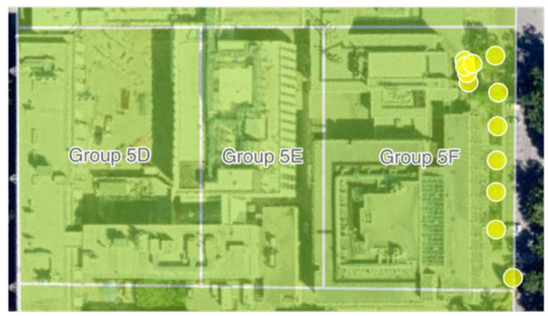


Figure 15 Overview of Subzone D and E

5.2.2 Removal and Maintenance

During the fieldwork, we noticed that five young cornelian-cherries are planted densely in a very narrow space near NCE building. They will compete with each other for space and resources, which has a bad effect on their growth. We suggest that several of them should be removed, so that others can grow well and the landscape of this site can be less messy. Besides, we found there was a lack of maintenance in several sites where the landscapes were quite cluttered, like median strip on University Blvd (figure 16) and green space to the east of Beaty Biodiversity Research Centre Loading Bay (figure 17). Horticulture technicians are supposed to remove weeds, prune trees and shrubs to improve the aesthetic value of these sites and keep the landscape pleasing and prosperous.

Figure 16 A Median Strip on University Blvd

Figure 17 Green Space to the East of Beaty Biodiversity Research Centre Loading Bay

5.2.3 Increase Diversity

According to the tree inventory, it was found that this zone has a relatively high species diversity with 14 species. In the meantime, we discovered that some subzones and sites only have one or two species, showing a dull landscape. For example, in subzone A (figure 18), there are only lawns and a row of Three-Thorn-Acacias which are bald in autumn and winter in a public space surrounded by buildings. Also, in the median strip on university Blvd (figure 16) which has been mentioned above, there are only some weeds and groundcovers scattered haphazardly. Therefore, different species are supposed to be added into these sites to increase diversity. More specifically, we can plant some evergreen ornamental trees, such as black pine in subzone A in order to increase interests in winter; and flowering shrubs, like Rhododendron, can be arranged as supplementary plants in the median strip to improve aesthetic value. Besides, seasonality and layering are two important dimensions of diversity which should be given considerations. Landscapes which change with seasons or have different layers can usually contribute to providing a richer visual experience and better cultural ecosystem services.

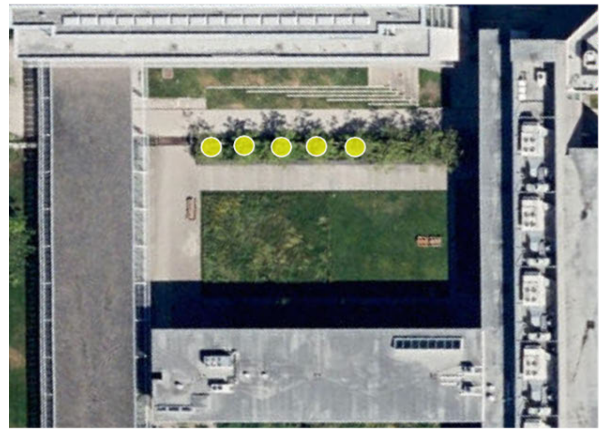


Figure 18 Overview of Subzone A

5.2.4 Adaption to Climate Change

Climate change is a big challenge for urban forest planning and management. It is predicted that by 2050, the summer in Vancouver will get hotter with an increase of 3.9 °C and a doubled number of days above 25 °C (Pacific Climate Impacts Consortium & University of Victoria, 2016). Also, the precipitation in autumn will increase by 12%, while that in summer will decrease by about 19%, which exacerbating differences between the wet and dry seasons (Pacific Climate Impacts Consortium & University of Victoria, 2016). Theses changes can affect urban tree species suitability and urban habitat dynamics (Sukopp and Wurzel 2003). Therefore, in the future planning, technicians and arborists should give priority to the species that has higher resilience and tolerance to drought (Roloff et al. 2009), heat (Yang 2009), and insects and diseases (Poland and McCullough 2006). According design guidebook, European hornbeam (Carpinus betulus), black pine (Pinus nigra), scarlet oak (Quercus coccinea) and Caucasian lime (Tilia euchlora) are appropriate species that can be planed in urban areas with high-volume pedestrians and traffic in Vancouver (Diamond Head, 2017). Besides, increasing diversity is another method to improve the resilience of urban forests, providing urban forests with the capacity to adapt to climate change (Kendal, Dobbs & Lohr, 2014).

References

Behounek, J. [SlideShare]. (2019, June 11). i-Tree 2019 Software Suite. [Video file]. Retrieved from https://www.slideshare.net/jbehounek/itree-intro-for-workshops

Background on "ecosystem services". (n.d.). Retrieved from https://www.doc.govt.nz/about-us/science-publications/conservation-publications/benefits-of-conservation/the-value-of-conservation/background-on-ecosystem-services/

City of Vancouver. (2014). *City of Vancouver Urban Forest Strategy* [Ebook]. Vancouver. Retrieved from https://vancouver.ca/files/cov/Urban-Forest-Strategy-Draft.pdf

Criteria and Indicators for Strategic Urban Forest ... (n.d.). Retrieved from http://fufc.org/soap/kenney_criteria_and_indicators2011.pdf

Diamond Head. (2017). Design Guidebook Maximizing Climate Adaptation Benefits with Trees. Retrieved from http://www.metrovancouver.org/services/regional-planning/PlanningPublications/DesignGuidebookMaximizingClimateAdaptation.pdf

E Brown, M., McGroddy, M., Spence, C., Flake, L., Sarfraz, A., Nowak, D. J., & Milesi, C.(n.d.). Modeling the ecosystem services provided by trees in urban ecosystems: using Biome-BGC to improve i-Tree Eco. Retrieved from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20120009798.pdf

i-Tree Canopy. Retrieved 2 April 2020, from https://canopy.itreetools.org/

i-Tree. (n.d.). i-Tree Eco. Retrieved from https://www.itreetools.org/tools/i-tree-eco

i-Tree. (n.d.). Retrieved from https://tfsweb.tamu.edu/uploadedFiles/TFS_Main/Urban_and_Community_Forestry/Services_for_Local_Government/Inventories_and_Reports/iTree.pdf

Jennings, T. (2015). Utilizing i-Tree to Assess the Urban Forest. Presentation, UNIVERSITY OF TENNESSEE.

Kendal, D., Dobbs, C., & Lohr, V.I. (2014). Global patterns of diversity in the urban forest: Is there evidence to support the 10/20/30 rule? Urban Forestry & Urban Greening, Volume 13, Issue 3, Pages 411-417. Retrieved from https://doi.org/10.1016/j.ufug.2014.04.004.

Lindholst, A. C., Caspersen, O. H., & Konijnendijk van den Bosch, Cecil C. (2015). Methods for mapping recreational and social values in urban green spaces in the nordic countries and their comparative merits for urban planning. Journal of Outdoor Recreation and Tourism, 12, 71-81. doi:10.1016/j.jort.2015.11.007

Poland, TM., & McCullough, DG. (2006). Emerald Ash borer: invasion of the urban forest and the threat to North America's ash resource. J For 104(3):118–124

Pacific Climate Impacts Consortium & University of Victoria. (2016). Climate Impacts Summary. Retrieved from https://vancouver.ca/files/cov/Pacific-climate-impacts-consortium-climate-change.pdf

RIDEM Division of Forest Environment. (2014). [Ebook]. State of Rhode Island. Retrieved from http://www.centralfallsarboretum.org/resources/Canopy%20Assessment%20Report%20-%206.19.14.pdf

Roloff, A., Korn, S., & Gillner S. (2009). The climate-species-matrix to select tree species for urban habitats considering climate change. Urban for Urban Green 8(4):295–308

USDA Forest Service. (2011). i-Tree Canopy Technical Notes [Ebook]. Retrieved from https://canopy.itreetools.org/resources/iTree_Canopy_Methodology.pdf

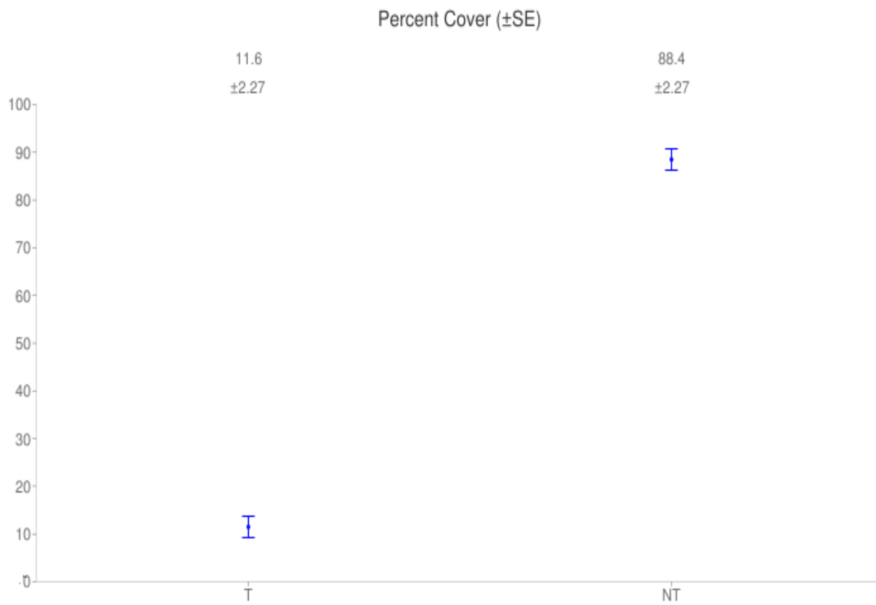
Yang, J. (2009). Assessing the impact of climate change on urban tree species selection: a case study in Philadelphia. J Forest 107(7):364–372

Appendix I

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 4/01/20



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	23	11.6 ±2.27
Non-Tree	All other surfaces	NT	176	88.4 ±2.27

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.06 CAD	±0.01	1.01 lb	±0.20
NO2	Nitrogen Dioxide removed annually	0.10 CAD	±0.02	5.53 lb	±1.09
O3	Ozone removed annually	5.44 CAD	±1.07	55.12 lb	±10.81
PM2.5	Particulate Matter less than 2.5 microns removed annually	11.25 CAD	±2.21	2.68 lb	±0.53
SO2	Sulfur Dioxide removed annually	0.02 CAD	±0.00	3.49 lb	±0.68
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	3.95 CAD	±0.77	18.46 lb	±3.62
CO2seq	Carbon Dioxide squestered annually in trees	368.36 CAD	±72.23	5.63 T	±1.10
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	9,251.01 CAD	±1,814.07	141.49 T	±27.74

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and CAD/T/yr: CO 0.902 @ 120.03 CAD | NO2 4.917 @ 37.90 CAD | O3 48.968 @ 198.16 CAD | PM2.5 2.379 @ 8,430.18 CAD | SO2 3.098 @ 10.51 CAD | PM10 16.403 @ 429.48 CAD | CO2seq 10,010.267 @ 65.62 CAD | CO2stor is a total biomass amount of 251,395.359 @ 65.62 CAD*
Note: Currency is in CAD
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

About i-Tree Canopy

The concept and prototype of this program were developed by David J. Nowak, Jeffery T. Walton and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company).

Limitations of i-Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate.

A Cooperative Initiative Between:

www.itreetools.org

i-Tree
Ecosystem Analysis

test

Urban Forest Effects and Values
二月 2020

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the test urban forest was conducted during 2020. Data from 66 trees located throughout test were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 66
- Tree Cover: 2795 square meters
- Most common species of trees: Black pine, Japanese maple, London planetree Columbia
- Percentage of trees less than 6" (15.2 cm) diameter: 40.9%
- Pollution Removal: 9.824 kilograms/year (Can$1.31/year)
- Carbon Storage: 12.57 metric tons (Can$1.44 thousand)
- Carbon Sequestration: 440.5 kilograms (Can$50.6/year)
- Oxygen Production: 1.175 metric tons/year
- Avoided Runoff: 49.53 cubic meters/year (Can$115/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Structural values: Can$120 thousand

Metric ton: 1000 kilograms
Monetary values Can$ are reported in Canadian Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

Table of Contents

I. Tree Characteristics of the Urban Forest

The urban forest of test has 66 trees with a tree cover of Black pine. The three most common species are Black pine (24.2 percent), Japanese maple (24.2 percent), and London planetree Columbia (9.1 percent).

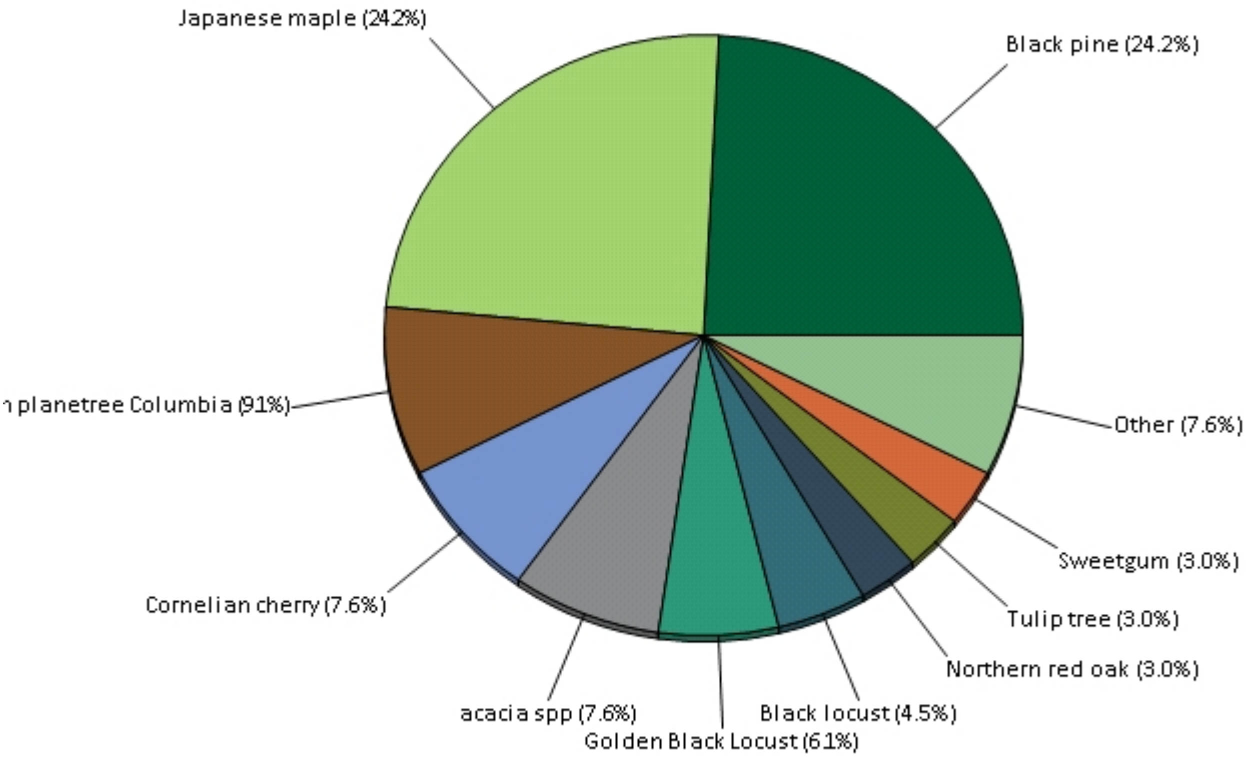


Figure 1. Tree species composition in test

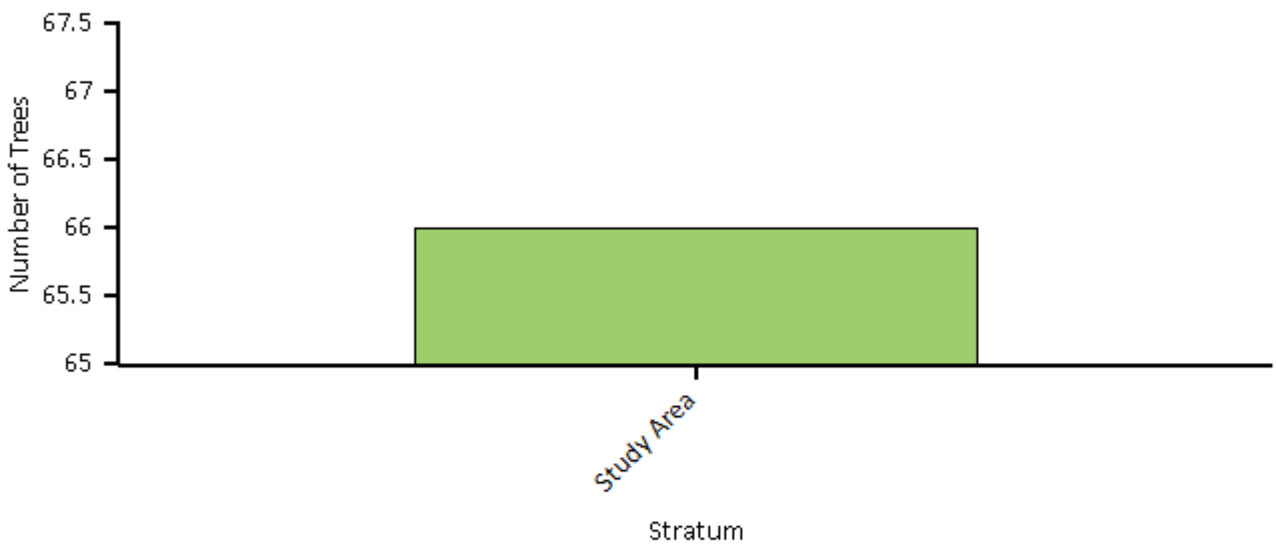


Figure 2. Number of trees in test by stratum

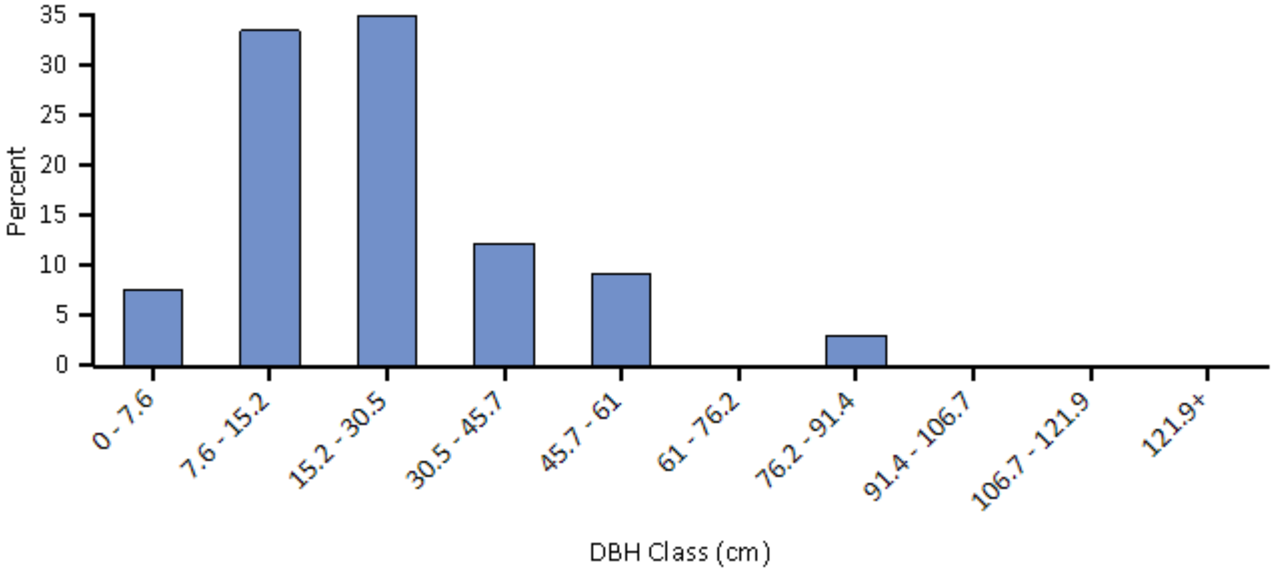


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 1.37 meters)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In test, about 26 percent of the trees are species native to North America. Most trees have an origin from Europe (24 percent of the trees).

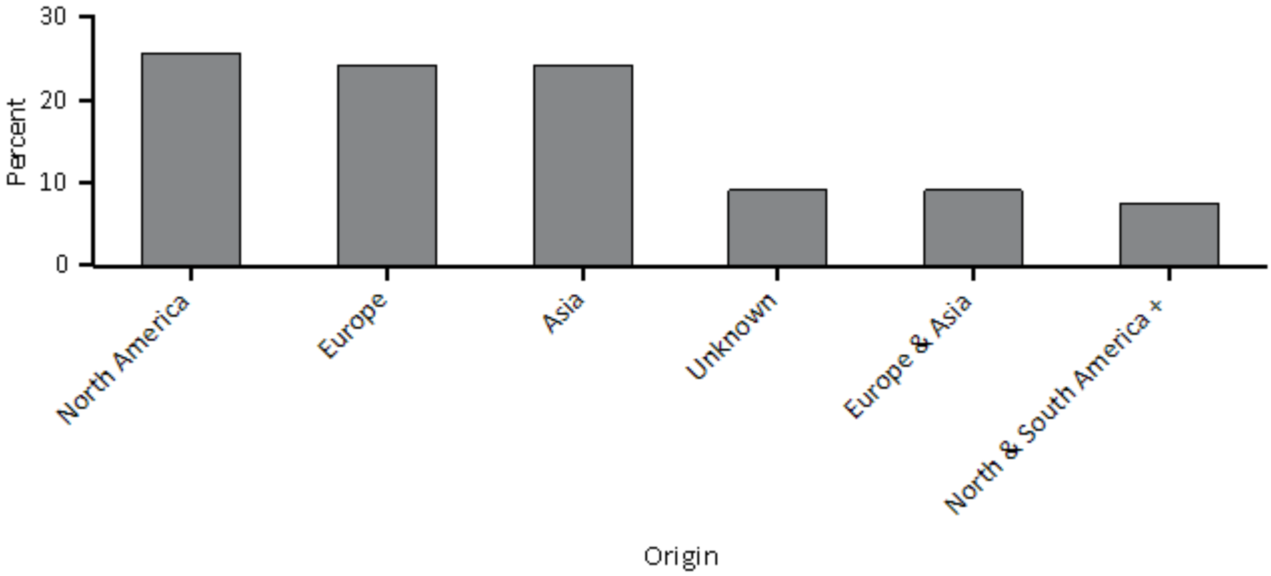


Figure 4. Percent of live tree population by area of native origin, test

The plus sign (+) indicates the tree species is native to another continent other than the ones listed in the grouping.

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas.

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 2795 square meters of test and provide 1.301 hectares of leaf area.

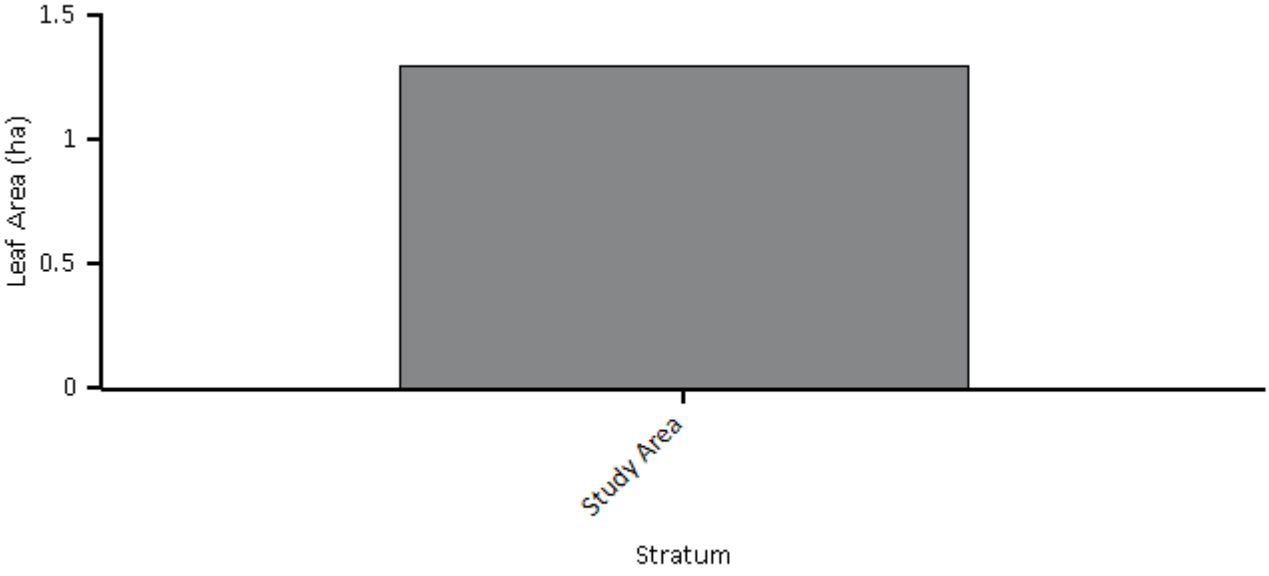


Figure 5. Leaf area by stratum, test

In test, the most dominant species in terms of leaf area are Northern red oak, London planetree Columbia, and Black pine. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in test

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Black pine	24.2	19.0	43.2
Japanese maple	24.2	15.0	39.3
London planetree Columbia	9.1	19.7	28.8
Northern red oak	3.0	19.9	22.9
Golden Black Locust	6.1	5.5	11.6
acacia spp	7.6	3.6	11.2
Tulip tree	3.0	5.7	8.8
Sweetgum	3.0	5.7	8.7
Cornelian cherry	7.6	1.1	8.6
Black locust	4.5	2.6	7.2

Common ground cover classes (including cover types beneath trees and shrubs) in test are not available since they are configured not to be collected.

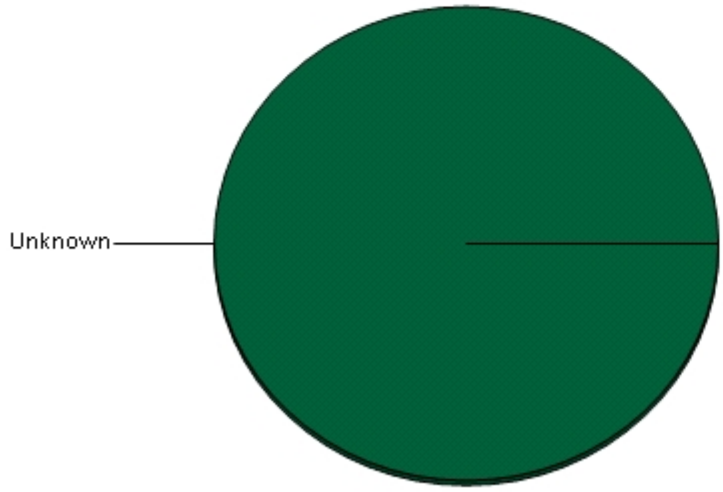


Figure 6. Percent of land by ground cover classes, test

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in test was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 9.824 kilograms of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of Can$1.31 (see Appendix I for more details).

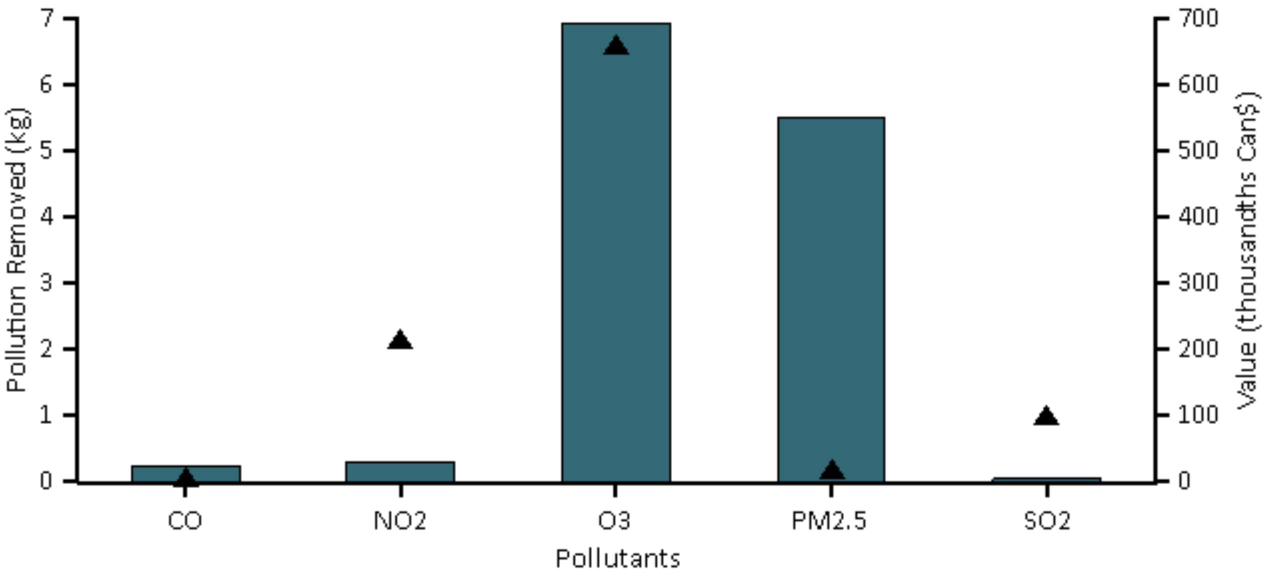


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, test

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 when particulate matter is deposited on leaf surfaces. This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2020, trees in test emitted an estimated 6.045 kilograms of volatile organic compounds (VOCs) (3.655 kilograms of isoprene and 2.39 kilograms of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Sixty- five percent of the urban forest's VOC emissions were from Northern red oak and Black pine. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of test trees is about 440.5 kilograms of carbon per year with an associated value of Can$50.6. See Appendix I for more details on methods.

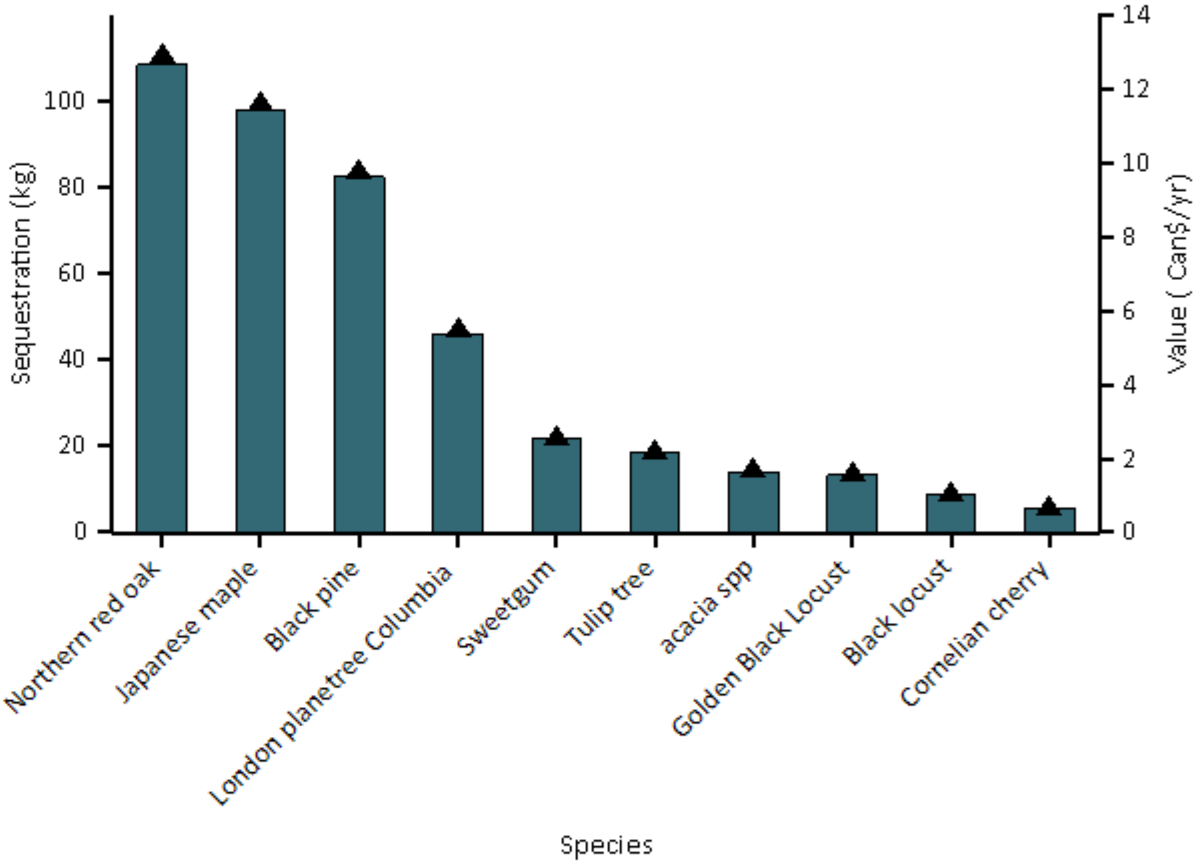


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, test

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in test are estimated to store 12.6 metric tons of carbon (Can$1.44 thousand). Of the species sampled, Northern red oak stores and sequesters the most carbon (approximately 38.9% of the total carbon stored and

25.1% of all sequestered carbon.)

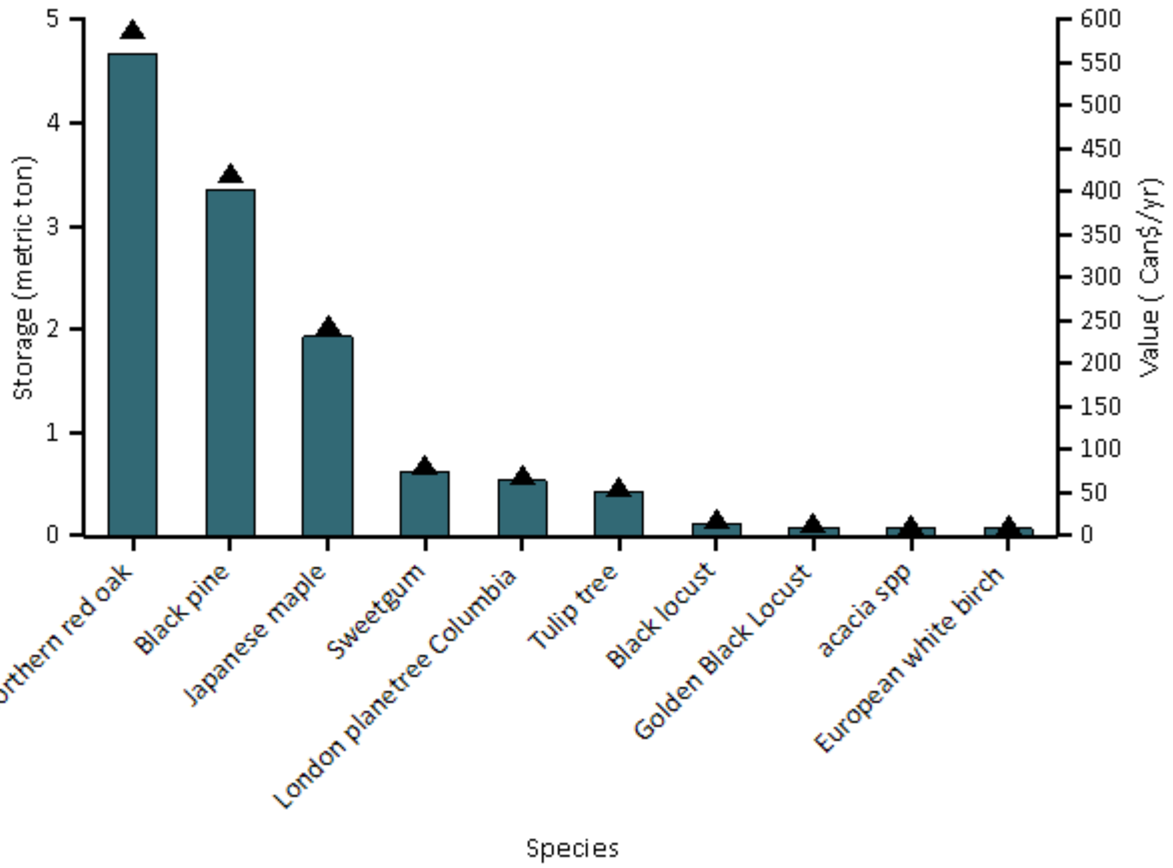


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, test

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in test are estimated to produce 1.175 metric tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (kilogram)*	*Gross Carbon Sequestration (kilogram/yr)*	*Number of Trees*	*Leaf Area (square meter)*
Northern red oak	294.69	110.51	2	0.00
Japanese maple	265.64	99.62	16	0.00
Black pine	223.80	83.93	16	0.00
London planetree Columbia	125.01	46.88	6	0.00
Sweetgum	58.59	21.97	2	0.00
Tulip tree	49.85	18.69	2	0.00
acacia spp	38.30	14.36	5	0.00
Golden Black Locust	36.47	13.68	4	0.00
Black locust	23.99	9.00	3	0.00
Cornelian cherry	15.14	5.68	5	0.00
Black tupelo	13.80	5.17	1	0.00
European white birch	12.05	4.52	1	0.00
Flowering dogwood	9.26	3.47	2	0.00
catalpa spp	8.03	3.01	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of test help to reduce runoff by an estimated 49.5 cubic meters a year with an associated value of Can$120 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In test, the total annual precipitation in 2010 was 117.8 centimeters.

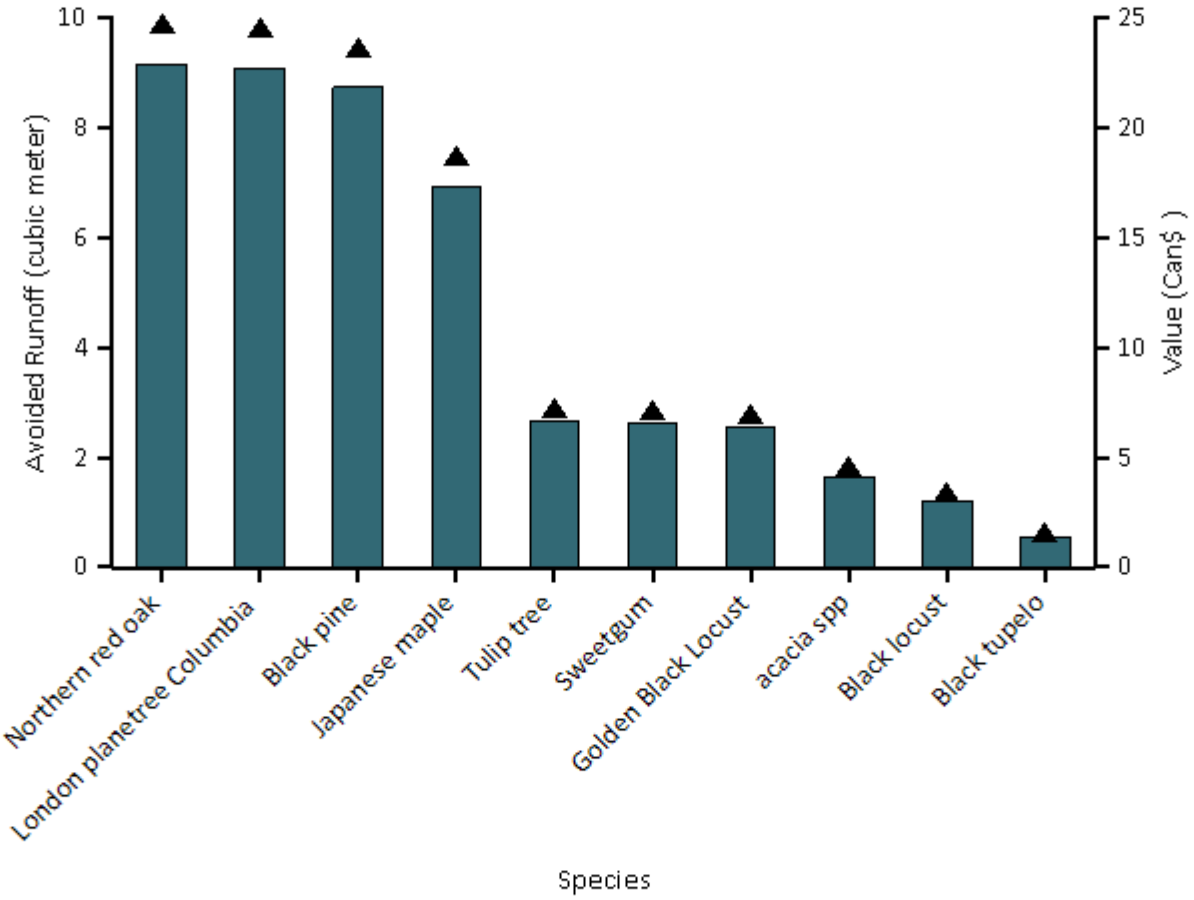


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, test

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, test

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (kilograms)	0	0	0

[a]MBTU - one million British Thermal Units
[b]MWH - megawatt-hour

Table 4. Annual savings [a](Can$) in residential energy expenditure during heating and cooling seasons, test

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of Can$95.9883333333333 per MWH and Can$17.8878017585382 per MBTU (see Appendix I for more details)
[c]MBTU - one million British Thermal Units
[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

<u>Urban trees in test have the following structural values:</u>

- Structural value: Can$120 thousand
- Carbon storage: Can$1.44 thousand

<u>Urban trees in test have the following annual functional values:</u>

- Carbon sequestration: Can$50.6
- Avoided runoff: Can$115
- Pollution removal: Can$1.31
- Energy costs and carbon emission values: Can$0

(Note: negative value indicates increased energy cost and carbon emission value)

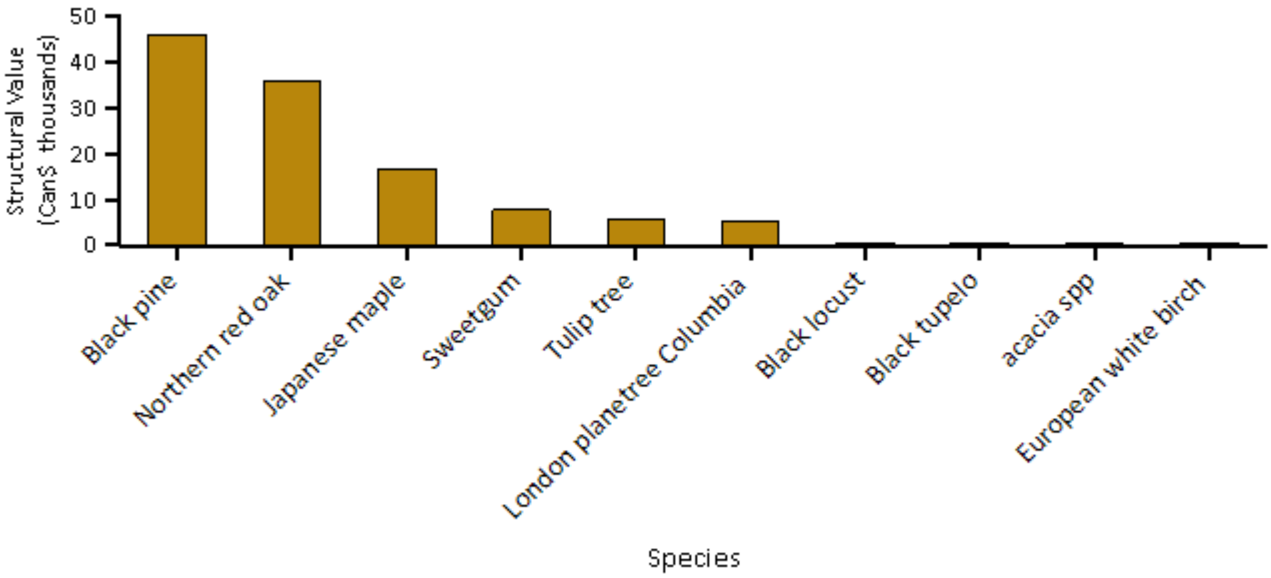


Figure 11. Tree species with the greatest structural value, test

[1] Structural value in Canada is calculated using the same procedure as the U.S. (Nowak et al 2002a). Base costs and species values are derived from the International Society of Arboriculture Ontario Chapter and applied to all Canadian provinces and territories.

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact.

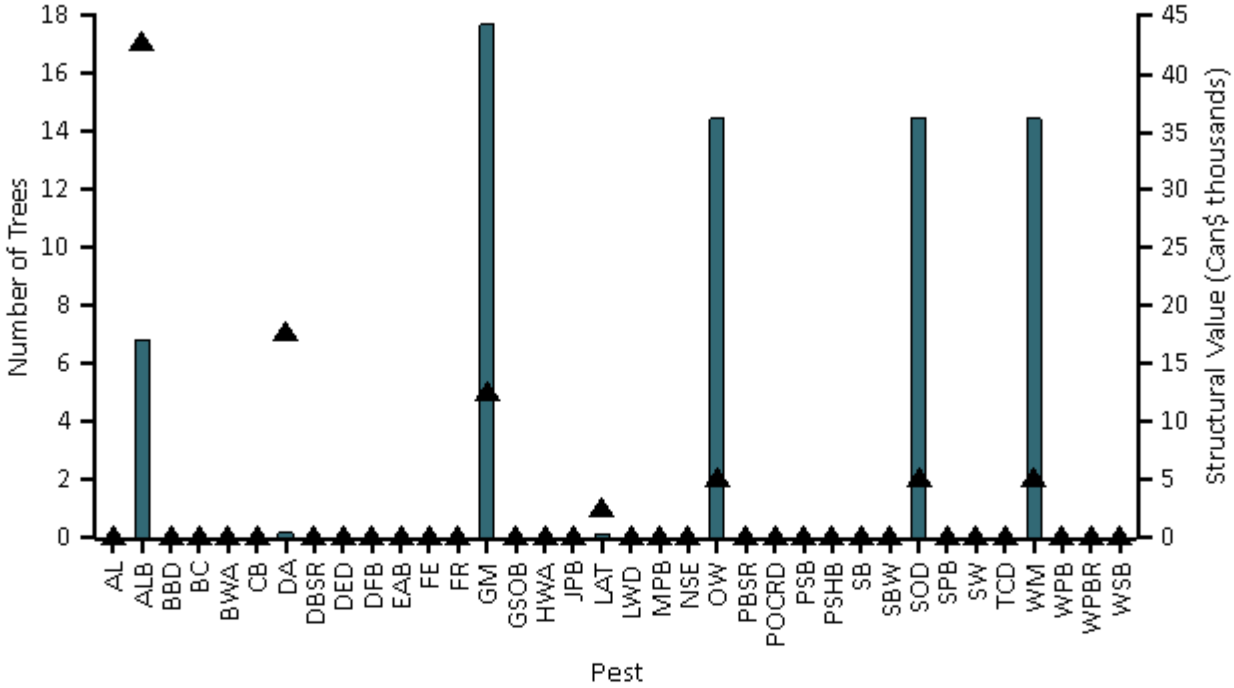


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) by potential pests, test

Aspen leafminer (AL) (Kruse et al 2007) is an insect that causes damage primarily to trembling or small tooth aspen by larval feeding of leaf tissue. AL has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Asian longhorned beetle (ALB) (Animal and Plant Health Inspection Service 2010) is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 25.8 percent of the test urban forest, which represents a potential loss of Can$17.1 thousand in structural value.

Beech bark disease (BBD) (Houston and O'Brien 1983) is an insect-disease complex that primarily impacts American beech. This disease threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Butternut canker (BC) (Ostry et al 1996) is caused by a fungus that infects butternut trees. The disease has since caused significant declines in butternut populations in the United States. Potential loss of trees from BC is 0.0 percent (Can$0 in structural value).

Balsam woolly adelgid (BWA) (Ragenovich and Mitchell 2006) is an insect that has caused significant damage to the true firs of North America. test could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 10.6 percent of the population, which represents a potential loss of Can$467 in structural value.

Douglas-fir black stain root disease (DBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks Douglas-firs. test could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, test could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Douglas-fir beetle (DFB) (Schmitz and Gibson 1996) is a bark beetle that infests Douglas-fir trees throughout the western United States, British Columbia, and Mexico. Potential loss of trees from DFB is 0.0 percent (Can$0 in structural value).

Emerald ash borer (EAB) (Michigan State University 2010) has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

One common pest of white fir, grand fir, and red fir trees is the fir engraver (FE) (Ferrell 1986). FE poses a threat to 0.0 percent of the test urban forest, which represents a potential loss of Can$0 in structural value.

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The gypsy moth (GM) (Northeastern Area State and Private Forestry 2005) is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 7.6 percent of the population, which represents a potential loss of Can$44.2 thousand in structural value.

Infestations of the goldspotted oak borer (GSOB) (Society of American Foresters 2011) have been a growing problem in southern California. Potential loss of trees from GSOB is 0.0 percent (Can$0 in structural value).

As one of the most damaging pests to eastern hemlock and Carolina hemlock, hemlock woolly adelgid (HWA) (U.S. Forest Service 2005) has played a large role in hemlock mortality in the United States. HWA has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The Jeffrey pine beetle (JPB) (Smith et al 2009) is native to North America and is distributed across California, Nevada, and Oregon where its only host, Jeffrey pine, also occurs. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Quaking aspen is a principal host for the defoliator, large aspen tortrix (LAT) (Ciesla and Kruse 2009). LAT poses a threat to 1.5 percent of the test urban forest, which represents a potential loss of Can$410 in structural value.

Laurel wilt (LWD) (U.S. Forest Service 2011) is a fungal disease that is introduced to host trees by the redbay ambrosia beetle. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Mountain pine beetle (MPB) (Gibson et al 2009) is a bark beetle that primarily attacks pine species in the western

United States. MPB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The northern spruce engraver (NSE) (Burnside et al 2011) has had a significant impact on the boreal and sub-boreal forests of North America where the pest's distribution overlaps with the range of its major hosts. Potential loss of trees from NSE is 0.0 percent (Can$0 in structural value).

Oak wilt (OW) (Rexrode and Brown 1983), which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 3.0 percent of the test urban forest, which represents a potential loss of Can$36.1 thousand in structural value.

Pine black stain root disease (PBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks hard pines, including lodgepole pine, Jeffrey pine, and ponderosa pine. test could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Port-Orford-cedar root disease (POCRD) (Liebhold 2010) is a root disease that is caused by a fungus. POCRD threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

The pine shoot beetle (PSB) (Ciesla 2001) is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. PSB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Polyphagous shot hole borer (PSHB) (University of California 2014) is a boring beetle that was first detected in California. test could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Spruce beetle (SB) (Holsten et al 1999) is a bark beetle that causes significant mortality to spruce species within its range. Potential loss of trees from SB is 0.0 percent (Can$0 in structural value).

Spruce budworm (SBW) (Kucera and Orr 1981) is an insect that causes severe damage to balsam fir. SBW poses a threat to 0.0 percent of the test urban forest, which represents a potential loss of Can$0 in structural value.

Sudden oak death (SOD) (Kliejunas 2005) is a disease that is caused by a fungus. Potential loss of trees from SOD is 3.0 percent (Can$36.1 thousand in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

The sirex woodwasp (SW) (Haugen and Hoebeke 2005) is a wood borer that primarily attacks pine species. SW poses a threat to 0.0 percent of the test urban forest, which represents a potential loss of Can$0 in structural value.

Thousand canker disease (TCD) (Cranshaw and Tisserat 2009; Seybold et al 2010) is an insect-disease complex that kills several species of walnuts, including black walnut. Potential loss of trees from TCD is 0.0 percent (Can$0 in structural value).

Winter moth (WM) (Childs 2011) is a pest with a wide range of host species. WM causes the highest levels of injury to its hosts when it is in its caterpillar stage. test could possibly lose 3.0 percent of its trees to this pest (Can$36.1 thousand in structural value).

The western pine beetle (WPB) (DeMars and Roettgering 1982) is a bark beetle and aggressive attacker of ponderosa and Coulter pines. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Since its introduction to the United States in 1900, white pine blister rust (Eastern U.S.) (WPBR) (Nicholls and Anderson 1977) has had a detrimental effect on white pines, particularly in the Lake States. WPBR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Western spruce budworm (WSB) (Fellin and Dewey 1986) is an insect that causes defoliation in western conifers. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Appendix I. i-Tree Eco Model and Field Measurements

i-Tree Eco is designed to use standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects (Nowak and Crane 2000), including:

- Urban forest structure (e.g., species composition, tree health, leaf area, etc.).
- Amount of pollution removed hourly by the urban forest, and its associated percent air quality improvement throughout a year.
- Total carbon stored and net carbon annually sequestered by the urban forest.
- Effects of trees on building energy use and consequent effects on carbon dioxide emissions from power sources.
- Structural value of the forest, as well as the value for air pollution removal and carbon storage and sequestration.
- Potential impact of infestations by pests, such as Asian longhorned beetle, emerald ash borer, gypsy moth, and Dutch elm disease.

Typically, all field data are collected during the leaf-on season to properly assess tree canopies. Typical data collection (actual data collection may vary depending upon the user) includes land use, ground and tree cover, individual tree attributes of species, stem diameter, height, crown width, crown canopy missing and dieback, and distance and direction to residential buildings (Nowak et al 2005; Nowak et al 2008).

During data collection, trees are identified to the most specific taxonomic classification possible. Trees that are not classified to the species level may be classified by genus (e.g., ash) or species groups (e.g., hardwood). In this report, tree species, genera, or species groups are collectively referred to as tree species.

<u>Tree Characteristics:</u>

Leaf area of trees was assessed using measurements of crown dimensions and percentage of crown canopy missing. In the event that these data variables were not collected, they are estimated by the model.

An analysis of invasive species is not available for studies outside of the United States. For the U.S., invasive species are identified using an invasive species list for the state in which the urban forest is located. These lists are not exhaustive and they cover invasive species of varying degrees of invasiveness and distribution. In instances where a state did not have an invasive species list, a list was created based on the lists of the adjacent states. Tree species that are identified as invasive by the state invasive species list are cross-referenced with native range data. This helps eliminate species that are on the state invasive species list, but are native to the study area.

<u>Air Pollution Removal:</u>

Pollution removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns. Particulate matter less than 10 microns (PM10) is another significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, and sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). As the removal of carbon monoxide and particulate matter by vegetation is not directly related to transpiration, removal rates (deposition velocities) for these pollutants were based on average measured values from the literature (Bidwell and Fraser 1972; Lovett 1994) that were adjusted depending on leaf phenology and leaf area. Particulate removal incorporated a 50 percent resuspension rate of particles back to the atmosphere (Zinke 1967). Recent updates (2011) to air quality modeling are based on improved leaf area index simulations, weather and pollution processing and interpolation, and updated pollutant monetary values (Hirabayashi et al 2011; Hirabayashi et al 2012; Hirabayashi 2011).

Trees remove PM2.5 when particulate matter is deposited on leaf surfaces (Nowak et al 2013). This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors. Generally, PM2.5 removal is positive with positive benefits. However, there are some cases when net removal is negative or resuspended particles lead to increased pollution concentrations and negative values. During some months (e.g., with no rain), trees resuspend more particles than they remove. Resuspension can also lead to increased overall PM2.5 concentrations if the boundary layer conditions are lower during net resuspension periods than during net removal periods. Since the pollution removal value is based on the change in pollution concentration, it is possible to have situations when trees remove PM2.5 but increase concentrations and thus have negative values during periods of positive overall removal. These events are not common, but can happen.

For reports in the United States, default air pollution removal value is calculated based on local incidence of adverse health effects and national median externality costs. The number of adverse health effects and associated economic value is calculated for ozone, sulfur dioxide, nitrogen dioxide, and particulate matter less than 2.5 microns using data from the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program (BenMAP) (Nowak et al 2014). The model uses a damage-function approach that is based on the local change in pollution concentration and population. National median externality costs were used to calculate the value of carbon monoxide removal (Murray et al 1994).

For international reports, user-defined local pollution values are used. For international reports that do not have local values, estimates are based on either European median externality values (van Essen et al 2011) or BenMAP regression equations (Nowak et al 2014) that incorporate user-defined population estimates. Values are then converted to local currency with user-defined exchange rates.

For this analysis, pollution removal value is calculated based on the prices of Can$1,486 per metric ton (carbon monoxide), Can$106 per metric ton (ozone), Can$15 per metric ton (nitrogen dioxide), Can$5 per metric ton (sulfur dioxide), Can$3,798 per metric ton (particulate matter less than 2.5 microns).

Carbon Storage and Sequestration:

Carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. To calculate current carbon storage, biomass for each tree was calculated using equations from the literature and measured tree data. Open-grown, maintained trees tend to have less biomass than predicted by forest-derived biomass equations (Nowak 1994). To adjust for this difference, biomass results for open-grown urban trees were multiplied by 0.8. No adjustment was made for trees found in natural stand conditions. Tree dry-weight biomass was converted to stored carbon by multiplying by 0.5.

Carbon sequestration is the removal of carbon dioxide from the air by plants. To estimate the gross amount of carbon sequestered annually, average diameter growth from the appropriate genera and diameter class and tree condition was added to the existing tree diameter (year x) to estimate tree diameter and carbon storage in year x +1.

Carbon storage and carbon sequestration values are based on estimated or customized local carbon values. For international reports that do not have local values, estimates are based on the carbon value for the United States (U.S. Environmental Protection Agency 2015, Interagency Working Group on Social Cost of Carbon 2015) and converted to local currency with user-defined exchange rates.

For this analysis, carbon storage and carbon sequestration values are calculated based on Can$115 per metric ton.

Oxygen Production:

The amount of oxygen produced is estimated from carbon sequestration based on atomic weights: net O2 release (kg/yr) = net C sequestration (kg/yr) × 32/12. To estimate the net carbon sequestration rate, the amount of carbon sequestered as a result of tree growth is reduced by the amount lost resulting from tree mortality. Thus, net carbon sequestration and net annual oxygen production of the urban forest account for decomposition (Nowak et al 2007). For complete inventory projects, oxygen production is estimated from gross carbon sequestration and does not account for decomposition.

Avoided Runoff:

Annual avoided surface runoff is calculated based on rainfall interception by vegetation, specifically the difference between annual runoff with and without vegetation. Although tree leaves, branches, and bark may intercept precipitation and thus mitigate surface runoff, only the precipitation intercepted by leaves is accounted for in this analysis.

The value of avoided runoff is based on estimated or user-defined local values. For international reports that do not have local values, the national average value for the United States is utilized and converted to local currency with user-defined exchange rates. The U.S. value of avoided runoff is based on the U.S. Forest Service's Community Tree Guide Series (McPherson et al 1999; 2000; 2001; 2002; 2003; 2004; 2006a; 2006b; 2006c; 2007; 2010; Peper et al 2009; 2010; Vargas et al 2007a; 2007b; 2008).

For this analysis, avoided runoff value is calculated based on the price of Can$2.32 per m^3.

Building Energy Use:

If appropriate field data were collected, seasonal effects of trees on residential building energy use were calculated based on procedures described in the literature (McPherson and Simpson 1999) using distance and direction of trees from residential structures, tree height and tree condition data. To calculate the monetary value of energy savings, local or custom prices per MWH or MBTU are utilized.

For this analysis, energy saving value is calculated based on the prices of Can$95.99 per MWH and Can$17.89 per MBTU.

Structural Values:

Structural value is the value of a tree based on the physical resource itself (e.g., the cost of having to replace a tree with a similar tree). Structural values were based on valuation procedures of the Council of Tree and Landscape Appraisers, which uses tree species, diameter, condition, and location information (Nowak et al 2002a; 2002b). Structural value may not be included for international projects if there is insufficient local data to complete the valuation procedures.

Potential Pest Impacts:

The complete potential pest risk analysis is not available for studies outside of the United States. The number of trees at risk to the pests analyzed is reported, though the list of pests is based on known insects and disease in the United States.

For the U.S., potential pest risk is based on pest range maps and the known pest host species that are likely to experience mortality. Pest range maps for 2012 from the Forest Health Technology Enterprise Team (FHTET) (Forest Health Technology Enterprise Team 2014) were used to determine the proximity of each pest to the county in which the urban forest is located. For the county, it was established whether the insect/disease occurs within the county, is within 400 kilometers of the county edge, is between 400 and 1210 kilometers away, or is greater than 1210 kilometers away. FHTET did not have pest range maps for Dutch elm disease and chestnut blight. The range of these pests was based on known occurrence and the host range, respectively (Eastern Forest Environmental Threat Assessment Center; Worrall 2007).

Relative Tree Effects:

The relative value of tree benefits reported in Appendix II is calculated to show what carbon storage and sequestration, and air pollutant removal equate to in amounts of municipal carbon emissions, passenger automobile emissions, and house emissions.

Municipal carbon emissions are based on 2010 U.S. per capita carbon emissions (Carbon Dioxide Information Analysis Center 2010). Per capita emissions were multiplied by city population to estimate total city carbon emissions.

Light duty vehicle emission rates (g/mi) for CO, NOx, VOCs, PM10, SO2 for 2010 (Bureau of Transportation Statistics 2010; Heirigs et al 2004), PM2.5 for 2011-2015 (California Air Resources Board 2013), and CO2 for 2011 (U.S. Environmental Protection Agency 2010) were multiplied by average miles driven per vehicle in 2011 (Federal Highway Administration 2013) to determine average emissions per vehicle.

Household emissions are based on average electricity kWh usage, natural gas Btu usage, fuel oil Btu usage, kerosene Btu usage, LPG Btu usage, and wood Btu usage per household in 2009 (Energy Information Administration 2013; Energy Information Administration 2014)

- CO2, SO2, and NOx power plant emission per KWh are from Leonardo Academy 2011. CO emission per kWh assumes 1/3 of one percent of C emissions is CO based on Energy Information Administration 1994. PM10 emission per kWh from Layton 2004.
- CO2, NOx, SO2, and CO emission per Btu for natural gas, propane and butane (average used to represent LPG), Fuel #4 and #6 (average used to represent fuel oil and kerosene) from Leonardo Academy 2011.
- CO2 emissions per Btu of wood from Energy Information Administration 2014.
- CO, NOx and SOx emission per Btu based on total emissions and wood burning (tons) from (British Columbia Ministry 2005; Georgia Forestry Commission 2009).

Appendix II. Relative Tree Effects

The urban forest in test provides benefits that include carbon storage and sequestration, and air pollutant removal. To estimate the relative value of these benefits, tree benefits were compared to estimates of average municipal carbon emissions, average passenger automobile emissions, and average household emissions. See Appendix I for methodology.

Carbon storage is equivalent to:

- Amount of carbon emitted in test in 0 days
- Annual carbon (C) emissions from 10 automobiles
- Annual C emissions from 4 single-family houses

Carbon monoxide removal is equivalent to:

- Annual carbon monoxide emissions from 0 automobiles
- Annual carbon monoxide emissions from 0 single-family houses

Nitrogen dioxide removal is equivalent to:

- Annual nitrogen dioxide emissions from 0 automobiles
- Annual nitrogen dioxide emissions from 0 single-family houses

Sulfur dioxide removal is equivalent to:

- Annual sulfur dioxide emissions from 12 automobiles
- Annual sulfur dioxide emissions from 0 single-family houses

Annual carbon sequestration is equivalent to:

- Amount of carbon emitted in test in 0.0 days
- Annual C emissions from 0 automobiles
- Annual C emissions from 0 single-family houses

Appendix III. Comparison of Urban Forests

A common question asked is, "How does this city compare to other cities?" Although comparison among cities should be made with caution as there are many attributes of a city that affect urban forest structure and functions, summary data are provided from other cities analyzed using the i-Tree Eco model.

I. City totals for trees

City	*% Tree Cover*	*Number of Trees*	*Carbon Storage (metric tons)*	*Carbon Sequestration (metric tons/yr)*	*Pollution Removal (metric tons/yr)*
Toronto, ON, Canada	26.6	10,220,000	1,108,000	46,700	1,905
Atlanta, GA	36.7	9,415,000	1,220,000	42,100	1,509
Los Angeles, CA	11.1	5,993,000	1,151,000	69,800	1,792
New York, NY	20.9	5,212,000	1,225,000	38,400	1,521
London, ON, Canada	24.7	4,376,000	360,000	12,500	370
Chicago, IL	17.2	3,585,000	649,000	22,800	806
Phoenix, AZ	9.0	3,166,000	286,000	29,800	511
Baltimore, MD	21.0	2,479,000	517,000	16,700	390
Philadelphia, PA	15.7	2,113,000	481,000	14,600	522
Washington, DC	28.6	1,928,000	477,000	14,700	379
Oakville, ON , Canada	29.1	1,908,000	133,000	6,000	172
Albuquerque, NM	14.3	1,846,000	301,000	9,600	225
Boston, MA	22.3	1,183,000	290,000	9,500	257
Syracuse, NY	26.9	1,088,000	166,000	5,300	99
Woodbridge, NJ	29.5	986,000	145,000	5,000	191
Minneapolis, MN	26.4	979,000	227,000	8,100	277
San Francisco, CA	11.9	668,000	176,000	4,600	128
Morgantown, WV	35.5	658,000	84,000	2,600	65
Moorestown, NJ	28.0	583,000	106,000	3,400	107
Hartford, CT	25.9	568,000	130,000	3,900	52
Jersey City, NJ	11.5	136,000	19,000	800	37
Casper, WY	8.9	123,000	34,000	1,100	34
Freehold, NJ	34.4	48,000	18,000	500	20

II. Totals per hectare of land area

City	*Number of Trees/ha*	*Carbon Storage (metric tons/ha)*	*Carbon Sequestration (metric tons/ha/yr)*	*Pollution Removal (kg/ha/yr)*
Toronto, ON, Canada	160.4	17.4	0.73	29.9
Atlanta, GA	275.8	35.7	1.23	44.2
Los Angeles, CA	48.4	9.4	0.36	14.7
New York, NY	65.2	15.3	0.48	19.0
London, ON, Canada	185.5	15.3	0.53	15.7
Chicago, IL	59.9	10.9	0.38	13.5
Phoenix, AZ	31.8	2.9	0.30	5.1
Baltimore, MD	118.5	25.0	0.80	18.6
Philadelphia, PA	61.9	14.1	0.43	15.3
Washington, DC	121.1	29.8	0.92	23.8
Oakville, ON , Canada	192.9	13.4	0.61	12.4
Albuquerque, NM	53.9	8.8	0.28	6.6
Boston, MA	82.9	20.3	0.67	18.0
Syracuse, NY	167.4	23.1	0.77	15.2
Woodbridge, NJ	164.4	24.2	0.84	31.9
Minneapolis, MN	64.8	15.0	0.53	18.3
San Francisco, CA	55.7	14.7	0.39	10.7
Morgantown, WV	294.5	37.7	1.17	29.2
Moorestown, NJ	153.4	27.9	0.90	28.1
Hartford, CT	124.6	28.5	0.86	11.5
Jersey City, NJ	35.5	5.0	0.21	9.6
Casper, WY	22.5	6.2	0.20	6.2
Freehold, NJ	94.6	35.9	0.98	39.6

Appendix IV. General Recommendations for Air Quality Improvement

Urban vegetation can directly and indirectly affect local and regional air quality by altering the urban atmosphere environment. Four main ways that urban trees affect air quality are (Nowak 1995):

- Temperature reduction and other microclimate effects
- Removal of air pollutants
- Emission of volatile organic compounds (VOC) and tree maintenance emissions
- Energy effects on buildings

The cumulative and interactive effects of trees on climate, pollution removal, and VOC and power plant emissions determine the impact of trees on air pollution. Cumulative studies involving urban tree impacts on ozone have revealed that increased urban canopy cover, particularly with low VOC emitting species, leads to reduced ozone concentrations in cities (Nowak 2000). Local urban management decisions also can help improve air quality.

Urban forest management strategies to help improve air quality include (Nowak 2000):

Strategy	*Result*
Increase the number of healthy trees	Increase pollution removal
Sustain existing tree cover	Maintain pollution removal levels
Maximize use of low VOC-emitting trees	Reduces ozone and carbon monoxide formation
Sustain large, healthy trees	Large trees have greatest per-tree effects
Use long-lived trees	Reduce long-term pollutant emissions from planting and removal
Use low maintenance trees	Reduce pollutants emissions from maintenance activities
Reduce fossil fuel use in maintaining vegetation	Reduce pollutant emissions
Plant trees in energy conserving locations	Reduce pollutant emissions from power plants
Plant trees to shade parked cars	Reduce vehicular VOC emissions
Supply ample water to vegetation	Enhance pollution removal and temperature reduction
Plant trees in polluted or heavily populated areas	Maximizes tree air quality benefits
Avoid pollutant-sensitive species	Improve tree health
Utilize evergreen trees for particulate matter	Year-round removal of particles

Appendix V. Invasive Species of the Urban Forest

Invasive species data is only available for the United States. This analysis cannot be completed for international studies because of a lack of necessary data.

Appendix VI. Potential Risk of Pests

Pest range data is only available for the United States. This analysis cannot be completed for international studies because of a lack of necessary data.

References

Abdollahi, K.K.; Ning, Z.H.; Appeaning, A., eds. 2000. Global climate change and the urban forest. Baton Rouge, LA: GCRCC and Franklin Press. 77 p.

Animal and Plant Health Inspection Service. 2010. Plant Health – Asian longhorned beetle. Washington, DC: U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

Baldocchi, D. 1988. A multi-layer model for estimating sulfur dioxide deposition to a deciduous oak forest canopy. Atmospheric Environment. 22: 869-884.

Baldocchi, D.D.; Hicks, B.B.; Camara, P. 1987. A canopy stomatal resistance model for gaseous deposition to vegetated surfaces. Atmospheric Environment. 21: 91-101.

Bidwell, R.G.S.; Fraser, D.E. 1972. Carbon monoxide uptake and metabolism by leaves. Canadian Journal of Botany. 50: 1435-1439.

British Columbia Ministry of Water, Land, and Air Protection. 2005. Residential wood burning emissions in British Columbia. British Columbia.

Broecker, W.S. 1970. Man's oxygen reserve. Science 168(3939): 1537-1538.

Bureau of Transportation Statistics. 2010. Estimated National Average Vehicle Emissions Rates per Vehicle by Vehicle Type using Gasoline and Diesel. Washington, DC: Burea of Transportation Statistics, U.S. Department of Transportation. Table 4-43.

Burnside, R.E.; Holsten, E. H.; Fettig, C.J.; Kruse, J. J.; Schultz, M.E.; Hayes, C.J.; Graves, A.D.; Seybold, S.J. 2011. Northern Spruce Engraver. Forest Insect & Disease Leaflet 180. Washington, DC: U. S. Department of Agriculture, Forest Service. 12 p.

California Air Resources Board. 2013. Methods to Find the Cost-Effectiveness of Funding Air Quality Projects. Table 3 Average Auto Emission Factors. CA: California Environmental Protection Agency, Air Resources Board.

Carbon Dioxide Information Analysis Center. 2010. CO2 Emissions (metric tons per capita). Washington, DC: The World Bank.

Cardelino, C.A.; Chameides, W.L. 1990. Natural hydrocarbons, urbanization, and urban ozone. Journal of Geophysical Research. 95(D9): 13,971-13,979.

Childs, R. 2011. Winter Moth Identification and Management. Amherst, MA: University of Massachusetts Amherst, Landscape, Nursery & Urban Forestry Program.

Ciesla, W. M. 2001. Tomicus piniperda. North American Forest Commission. Exotic Forest Pest Information System for North America (EXFOR).

Ciesla, W. M.; Kruse, J. J. 2009. Large Aspen Tortrix. Forest Insect & Disease Leaflet 139. Washington, DC: U. S. Department of Agriculture, Forest Service. 8 p.

Clarke, S. R.; Nowak, J.T. 2009. Southern Pine Beetle. Forest Insect & Disease Leaflet 49. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

Cranshaw, W.; Tisserat, N. 2009. Walnut twig beetle and the thousand cankers disease of black walnut. Pest Alert.

Ft. Collins, CO: Colorado State University.

Seybold, S.; Haugen, D.; Graves, A. 2010. Thousand Cankers Disease. Pest Alert. NA-PR-02-10. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

DeMars, C. J., Jr.; Roettgering, B. H. 1982. Western Pine Beetle. Forest Insect & Disease Leaflet 1. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

Diller, J. D. 1965. Chestnut Blight. Forest Pest Leaflet 94. Washington, DC: U. S. Department of Agriculture, Forest Service. 7 p.

Eastern Forest Environmental Threat Assessment Center. Dutch Elm Disease. http://threatsummary.forestthreats.org/threats/threatSummaryViewer.cfm?threatID=43

Energy Information Administration. 1994. Energy Use and Carbon Emissions: Non-OECD Countries. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Energy Information Administration. 2013. CE2.1 Fuel consumption totals and averages, U.S. homes. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Energy Information Administration. 2014. CE5.2 Household wood consumption. Washington, DC: Energy Information Administration, U.S. Department of Energy.

Federal Highway Administration. 2013. Highway Statistics 2011.Washington, DC: Federal Highway Administration, U.S. Department of Transportation. Table VM-1.

Fellin, D. G.; Dewey, J. E. 1986. Western Spruce Budworm. Forest Insect & Disease Leaflet 53. Washington, DC: U.S. Department of Agriculture, Forest Service. 10 p.

Ferrell, G. T. 1986. Fir Engraver. Forest Insect & Disease Leaflet 13. Washington, DC: U. S. Department of Agriculture, Forest Service. 8 p.

Georgia Forestry Commission. 2009. Biomass Energy Conversion for Electricity and Pellets Worksheet. Dry Branch, GA: Georgia Forestry Commission.

Gibson, K.; Kegley, S.; Bentz, B. 2009. Mountain Pine Beetle. Forest Insect & Disease Leaflet 2. Washington, DC: U. S. Department of Agriculture, Forest Service. 12 p.

Haugen, D. A.; Hoebeke, R. E. 2005. Sirex woodwasp - Sirex noctilio F. (Hymenoptera: Siricidae). Pest Alert. NA-PR-07-05. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Area State and Private Forestry.

Heirigs, P.L.; Delaney, S.S.; Dulla, R.G. 2004. Evaluation of MOBILE Models: MOBILE6.1 (PM), MOBILE6.2 (Toxics), and MOBILE6/CNG. Sacramento, CA: National Cooperative Highway Research Program, Transportation Research Board.

Hessburg, P. F.; Goheen, D. J.; Bega, R.V. 1995. Black Stain Root Disease of Conifers. Forest Insect & Disease Leaflet 145. Washington, DC: U.S. Department of Agriculture, Forest Service.

Hessburg, P. F.; Goheen, D. J.; Bega, R.V. 1995. Black Stain Root Disease of Conifers. Forest Insect & Disease Leaflet 145. Washington, DC: U.S. Department of Agriculture, Forest Service.

Hirabayashi, S. 2011. Urban Forest Effects-Dry Deposition (UFORE-D) Model Enhancements, http://www.itreetools.org/eco/resources/UFORE-D enhancements.pdf

Hirabayashi, S. 2012. i-Tree Eco Precipitation Interception Model Descriptions, http://www.itreetools.org/eco/resources/iTree_Eco_Precipitation_Interception_Model_Descriptions_V1_2.pdf

Hirabayashi, S.; Kroll, C.; Nowak, D. 2011. Component-based development and sensitivity analyses of an air pollutant dry deposition model. Environmental Modeling and Software. 26(6): 804-816.

Hirabayashi, S.; Kroll, C.; Nowak, D. 2012. i-Tree Eco Dry Deposition Model Descriptions V 1.0

Holsten, E.H.; Thier, R.W.; Munson, A.S.; Gibson, K.E. 1999. The Spruce Beetle. Forest Insect & Disease Leaflet 127. Washington, DC: U.S. Department of Agriculture, Forest Service. 12 p.

Houston, D. R.; O'Brien, J. T. 1983. Beech Bark Disease. Forest Insect & Disease Leaflet 75. Washington, DC: U. S. Department of Agriculture, Forest Service. 8 p.

Interagency Working Group on Social Cost of Carbon, United States Government. 2015. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. http://www.whitehouse.gov/sites/default/files/omb/inforeg/scc-tsd-final-july-2015.pdf

Kliejunas, J. 2005. Phytophthora ramorum. North American Forest Commission. Exotic Forest Pest Information System for North America (EXFOR).

Kruse, J.; Ambourn, A.; Zogas, K. 2007. Aspen Leaf Miner. Forest Health Protection leaflet. R10-PR-14. Juneau, AK: U. S. Department of Agriculture, Forest Service, Alaska Region.

Kucera, D. R.; Orr, P. W. 1981. Spruce Budworm in the Eastern United States. Forest Pest Leaflet 160. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

Layton, M. 2004. 2005 Electricity Environmental Performance Report: Electricity Generation and Air Emissions. CA: California Energy Commission.

Leonardo Academy. 2011. Leonardo Academy's Guide to Calculating Emissions Including Emission Factors and Energy Prices. Madison, WI: Leonardo Academy Inc.

Liebhold, A. 2010 draft. Personal communication on the geographic distribution of forest pest species.

Lovett, G.M. 1994. Atmospheric deposition of nutrients and pollutants in North America: an ecological perspective. Ecological Applications. 4: 629-650.

McPherson, E.G.; Maco, S.E.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; VanDerZanden, A.M.; Bell, N. 2002. Western Washington and Oregon Community Tree Guide: Benefits, Costs, and Strategic Planting. International Society of Arboriculture, Pacific Northwest, Silverton, OR.

McPherson, E.G.; Simpson, J.R. 1999. Carbon dioxide reduction through urban forestry: guidelines for professional and volunteer tree planters. Gen. Tech. Rep. PSW-171. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 237 p.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Crowell, A.M.N.; Xiao, Q. 2010. Northern California coast community tree guide: benefits, costs, and strategic planting. PSW-GTR-228. Gen. Tech. Rep. PSW-GTR-228. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Vargas, K.E.; Maco, S.E.; Xiao, Q. 2006a. Coastal Plain Community Tree Guide: Benefits, Costs, and Strategic Planting PSW-GTR-201. USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Vargas, K.E.; Xiao, Q. 2007. Northeast community tree guide: benefits, costs, and strategic planting.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Gardner, S.L.; Cozad, S.K.; Xiao, Q. 2006b. Midwest Community Tree Guide: Benefits, Costs and Strategic Planting PSW-GTR-199. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Gardner, S.L.; Vargas, K.E.; Xiao, Q. 2006c. Piedmont Community Tree Guide: Benefits, Costs, and Strategic Planting PSW-GTR 200. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Maco, S.E.; Xiao Q.; Mulrean, E. 2004. Desert Southwest Community Tree Guide: Benefits, Costs and Strategic Planting. Phoenix, AZ: Arizona Community Tree Council, Inc. 81 :81.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Scott, K.I.; Xiao, Q. 2000. Tree Guidelines for Coastal Southern California Communities. Local Government Commission, Sacramento, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q. 1999. Tree Guidelines for San Joaquin Valley Communities. Local Government Commission, Sacramento, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; Maco, S.E.; Hoefer, P.J. 2003. Northern Mountain and Prairie Community Tree Guide: Benefits, Costs and Strategic Planting. Center for Urban Forest Research, USDA Forest Service, Pacific Southwest Research Station, Albany, CA.

McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; Pittenger, D.R.; Hodel, D.R. 2001. Tree Guidelines for Inland Empire Communities. Local Government Commission, Sacramento, CA.

Michigan State University. 2010. Emerald ash borer. East Lansing, MI: Michigan State University [and others].

Mielke, M. E.; Daughtrey, M. L. How to Identify and Control Dogwood Anthracnose. NA-GR-18. Broomall, PA: U. S. Department of Agriculture, Forest Service, Northeastern Area and Private Forestry.

Murray, F.J.; Marsh L.; Bradford, P.A. 1994. New York State Energy Plan, vol. II: issue reports. Albany, NY: New York State Energy Office.

Nicholls, T. H.; Anderson, R. L. 1977. How to Identify White Pine Blister Rust and Remove Cankers. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry

Northeastern Area State and Private Forestry. 1998. How to identify and manage Dutch Elm Disease. NA-PR-07-98. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

Northeastern Area State and Private Forestry. 2005. Gypsy moth digest. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry.

Nowak, D.J. 1994. Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 83-94.

Nowak, D.J. 1995. Trees pollute? A "TREE" explains it all. In: Proceedings of the 7th National Urban Forestry Conference. Washington, DC: American Forests: 28-30.

Nowak, D.J. 2000. The interactions between urban forests and global climate change. In: Abdollahi, K.K.; Ning, Z.H.; Appeaning, A., eds. Global Climate Change and the Urban Forest. Baton Rouge, LA: GCRCC and Franklin Press: 31-44.

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193:119-129.

Nowak, D.J., Hirabayashi, S., Bodine, A., Hoehn, R. 2013. Modeled PM2.5 removal by trees in ten U.S. cities and associated health effects. Environmental Pollution. 178: 395-402.

Nowak, D.J.; Civerolo, K.L.; Rao, S.T.; Sistla, S.; Luley, C.J.; Crane, D.E. 2000. A modeling study of the impact of urban trees on ozone. Atmospheric Environment. 34: 1601-1613.

Nowak, D.J.; Crane, D.E. 2000. The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions. In: Hansen, M.; Burk, T., eds. Integrated tools for natural resources inventories in the 21st century. Proceedings of IUFRO conference. Gen. Tech. Rep. NC-212. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 714-720.

Nowak, D.J.; Crane, D.E.; Dwyer, J.F. 2002a. Compensatory value of urban trees in the United States. Journal of Arboriculture. 28(4): 194 - 199.

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Hoehn, R.E. 2005. The urban forest effects (UFORE) model: field data collection manual. V1b. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station, 34 p. http://www.fs.fed.us/ne/syracuse/Tools/downloads/UFORE_Manual.pdf

Nowak, D.J.; Crane, D.E.; Stevens, J.C.; Ibarra, M. 2002b. Brooklyn's urban forest. Gen. Tech. Rep. NE-290. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 107 p.

Nowak, D.J.; Dwyer, J.F. 2000. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, John, ed. Handbook of urban and community forestry in the northeast. New York, NY: Kluwer Academics/Plenum: 11-22.

Nowak, D.J.; Hoehn, R.; Crane, D. 2007. Oxygen production by urban trees in the United States. Arboriculture & Urban Forestry. 33(3):220-226.

Nowak, D.J.; Hoehn, R.E.; Crane, D.E.; Stevens, J.C.; Walton, J.T; Bond, J. 2008. A ground-based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry. 34(6): 347-358.

Nowak, D.J.; Stevens, J.C.; Sisinni, S.M.; Luley, C.J. 2002c. Effects of urban tree management and species selection on atmospheric carbon dioxide. Journal of Arboriculture. 28(3): 113-122.

Ostry, M.E.; Mielke, M.E.; Anderson, R.L. 1996. How to Identify Butternut Canker and Manage Butternut Trees. U. S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Albers, S.N.; Xiao, Q. 2010. Central Florida community tree guide: benefits, costs, and strategic planting. Gen. Tech. Rep. PSW-GTR-230. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Vargas, K.E.; Xiao Q. 2009. Lower Midwest community tree guide: benefits, costs, and strategic planting. PSW-GTR-219. Gen. Tech. Rep. PSW-GTR-219. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Phelps, W.R.; Czabator, F.L. 1978. Fusiform Rust of Southern Pines. Forest Insect & Disease Leaflet 26. Washington, DC: U. S. Department of Agriculture, Forest Service. 7 p.

Rexrode, C. O.; Brown, H. D. 1983. Oak Wilt. Forest Insect & Disease Leaflet 29. Washington, DC: U.S. Department of Agriculture, Forest Service. 6 p.

Schmitz, R. F.; Gibson, K. E. 1996. Douglas-fir Beetle. Forest Insect & Disease Leaflet 5. R1-96-87. Washington,DC: U. S. Department of Agriculture, Forest Service. 8 p.

Smith, S. L.; Borys, R. R.; Shea, P. J. 2009. Jeffrey Pine Beetle. Forest Insect & Disease Leaflet 11. Washington, DC: U. S. Department of Agriculture, Forest Service. 8 p.

Society of American Foresters. 2011. Gold Spotted Oak Borer Hitches Ride in Firewood, Kills California Oaks. Forestry Source 16(10): 20.

U.S. Environmental Protection Agency. 2010. Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards. Washington, DC: U.S. Environmental Protection Agency. EPA-420-R-10-012a

U.S. Environmental Protection Agency. 2015. The social cost of carbon. http://www.epa.gov/climatechange/EPAactivities/economics/scc.html

U.S. Forest Service. 2005. Hemlock Woolly Adelgid. Pest Alert. NA-PR-09-05. Newtown Square, PA: U. S. Department of Agriculture, Forest Service, Northern Area State and Private Forestry.

U.S. Forest Service. 2011. Laurel Wilt. Atlanta, GA: U. S. Department of Agriculture, Forest Service, Forest Health Protection, Southern Region.

University of California. 2014. Polphagous Shot Hole Borer. Sacramento, CA: University of California, Division of Agriculture and Natural Resources.

van Essen, H.; Schroten, A.; Otten, M.; Sutter, D.; Schreyer, C.; Zandonella, R.; Maibach, M.; Doll, C. 2011. External Costs of Transport in Europe. Netherlands: CE Delft. 161 p.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2007a. Interior West Tree Guide.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2007b. Temperate Interior West Community Tree Guide: Benefits, Costs, and Strategic Planting.

Vargas, K.E.; McPherson, E.G.; Simpson, J.R.; Peper, P.J.; Gardner, S.L.; Xiao, Q. 2008. Tropical community tree guide: benefits, costs, and strategic planting. PSW-GTR-216. Gen. Tech. Rep. PSW-GTR-216. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

Worrall, J.J. 2007. Chestnut Blight. Forest and Shade Tree Pathology.
http://www.forestpathology.org/dis_chestnut.html

Zinke, P.J. 1967. Forest interception studies in the United States. In: Sopper, W.E.; Lull, H.W., eds. Forest Hydrology. Oxford, UK: Pergamon Press: 137-161.

Urban Forest Inventory and Assessment

Group 6

April 8, 2020

Name	Contribution
Molly Kim	Introduction, Site description, Urban forest and management recommendation, cultural services and regulating services
Keith Chau	Introduction, cultural services, urban forest and management recommendation

Introduction

Ecosystems are communities formed by the interaction between living (plants, animals, microbes) and non-living organisms (air, water, mineral soil). Human beings are both part of ecosystems and benefit from ecosystems in many ways (Biodiversity International, 2020).
The main purpose of this ecosystem service assessment is to identify the benefits the local urban forests provide to our campus, while mapping user experience within the area. Our local urban forest consists of trees, shrubs, and gardens. Though there are 4 ecosystem services in this report, we will focus mainly on regulating and cultural services (Ferrini F, 2007). Regulating ecosystem services benefits are provided by urban forests to balance our environment. While cultural services help identify the connections and experences people have wiith nature (Ferrini F, 2007).
The management of the urban forest is called urban forestry which often is complex and uncertain. Partering with SEED (Sustainable Ecolgical Economic Development Studies) and UBC Campus & Community Planning, we take on the task of doing a partial tree inventory of the UBC campus to seek future growth opportunities.

Site Description

This site is located at UBC, Greypoint, specifically, the corner of the intersection of Main Mall and University Boulevard. The trees are located around and in-between buildings. For this site the land use type is institutional (Chemistry and HEBB buildings). This area is usually assessed by students and staff that enter and exit the buildings. This area is not suitable for any activities and due to that this place is very quiet. There are benches under large canopy covered tall trees so students can attain shade after their class. Moreover, there are bike parking areas, including a bike lock-up cage located within the center of the outdoor area within the Chemistry building.

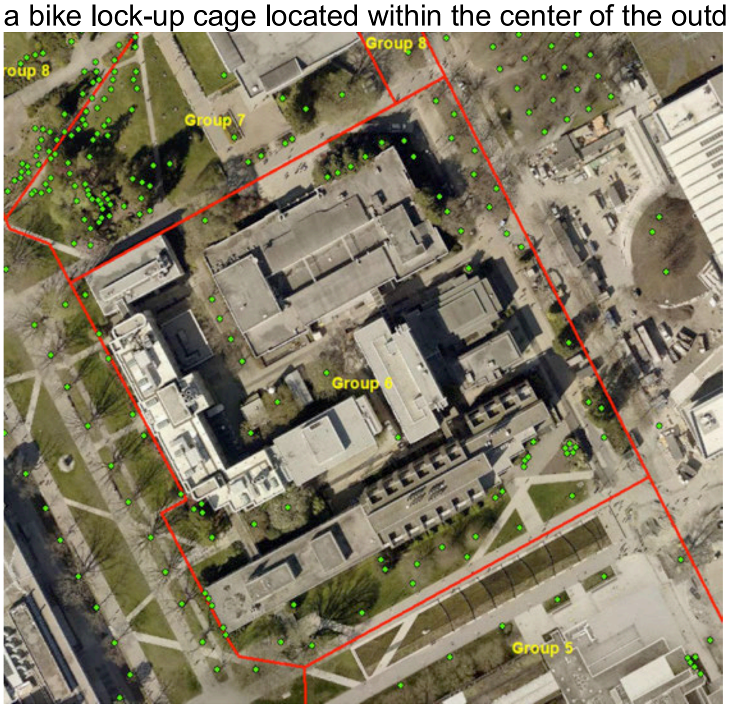


Figure 1. Map of our location and green dots are the tree location.

Regulating Ecosystem Services

i-Tree Canopy method is designed to allow users to easily and accurately estimate tree and other cover classes within their city or any area they like. The strength of this method is that it

can easily be done and the results can be shown right after inputing the tree, non tree data. Yet, some of the weaknesses of this method is that the accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. If too few points are classified, the standard error will be too high to have any real certainty of the estimate. Moreover, another weakness of this process is that the Google imagery may be difficult to interpret in all areas due to relatively poor image resolution, environmental factors, or poor image quality.
i-Tree eco method is a model that uses tree measurements and other data to estmate ecosystem services and structural characteristics of urban or rural forest. The strengths of this method is that it does most of the work for us. After entering the species from our site, it gives all the information that is relavant to our project. However, this method also has some weaknesses as well. First weakness is that without the actual data for each tree, the Eco model will use various appraoches to fill in the missing variables. There are some of the tree species that haven’t been found in one of our graphs, which tells me that it is filled in randomly. Therefore, if all the datas are not clear or not “perfect” i-Tree eco will also not be precise.

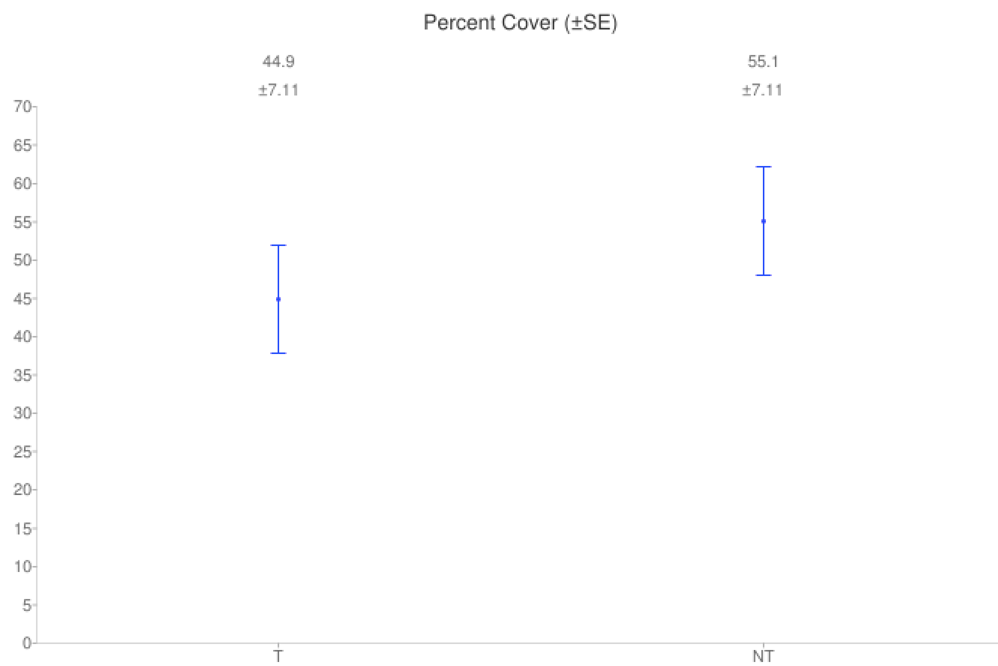


Figure 2. i-Tree canopy result

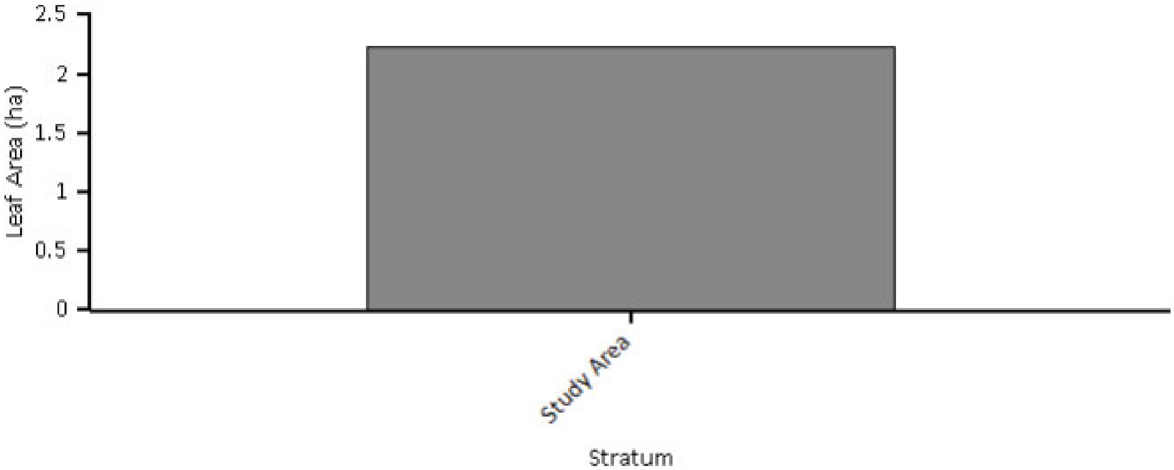


Figure 3. Leaf area by stratum

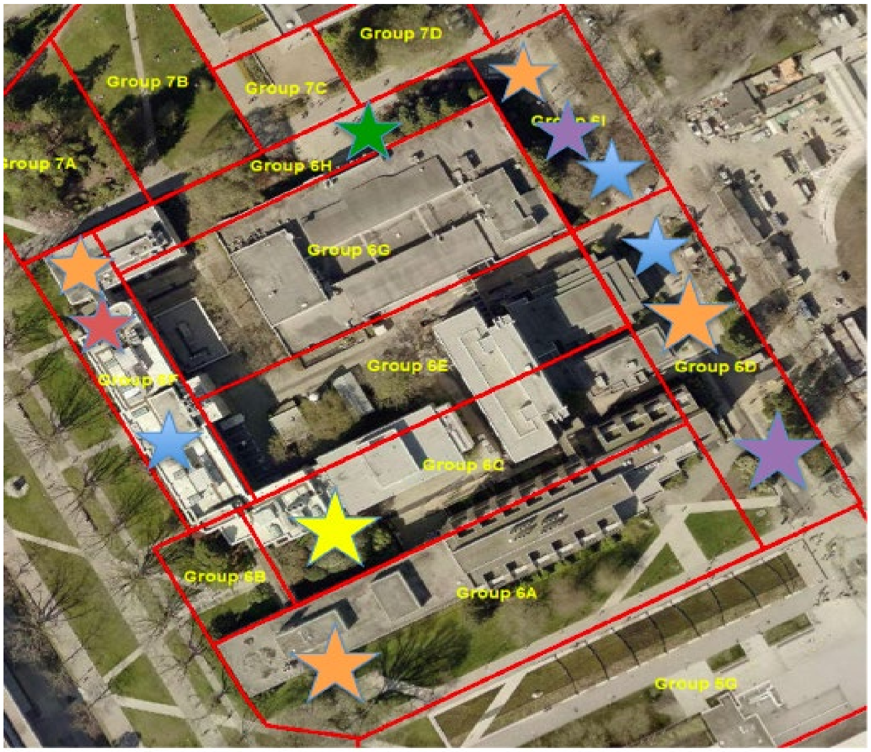
These two are different models derived from one i-tree canopy and i-tree eco. The difference between these two models is that i-tree canopy used tree vs non tree to determine the canopy cover, but in i-tree eco leaf area of trees was assessed using measurements of percentage of crown canopy missing and crown dimensions. The similarities between the two models is that leaf area and the canopy cover is quiet similar. In Figure 2 the percent cover of tree species is about 45% and the leaf area is about 2.23 hectares. If we say the total leaf area cover is 5 hectares then, 2.23 hectares take over around 55%.

Through these models it was easier to tell what our zone provides with the different ecosystem services. The canopy covers provide climate regulations such as wind speed. Higher number of canopy cover means wind speed will decrease and will have less damage to the community. 45% is not a small amount of canopy cover, which our zone provides good climate regulation. However, there are still worse cases to this. Winds can be pretty strong and they can definitely damage the trees meaning that it might fall over. This can cause great damage to the site and if there are more trees that means more risk of damage can be done to the site.

Cultural Ecosystem Services

To assess the cultural services we used the method called “value mapping”. The purpose of value mapping is to integrate experiences with other conventional spatial information, allow community participation, and locate greenspace ‘hotspots’. By surveying people who use the building (both students and professors), we were able to map out the cultural services that this area provides.

The strength of this method is that it involves taking the perspective of people who use the site and to identify the values people have in our local urban forest. One of the difficulties that our group encountered was the time constraint and amount of people surveyed. Our area also contains a Weeping Willow Tree, in which an older folk told us about. The story that the older gentlmen told is a great example of the various connections people can have towards our urban forests.



	Social/ community sharing
	Serene/ refuge/ safe
	Aesthetics/ beauty
	Diversity/ species richness
	Recreation activity
	Cultural significance

Figure 4. The highest scales of experience dimensions for each subzone ID

Data was collected from value mapping techniques, responses varied from person to person, a vareity of results came. Large areas where people could congregate, benches for everyone to sit on. A large amount of traffic and sound in some of the areas. Very serene and peaceful for everyone to enjoy. Trails running throughout locations and home of a famous willo tree. Locations of refuge scattered around our locations, coverage for rain and shade throughout.

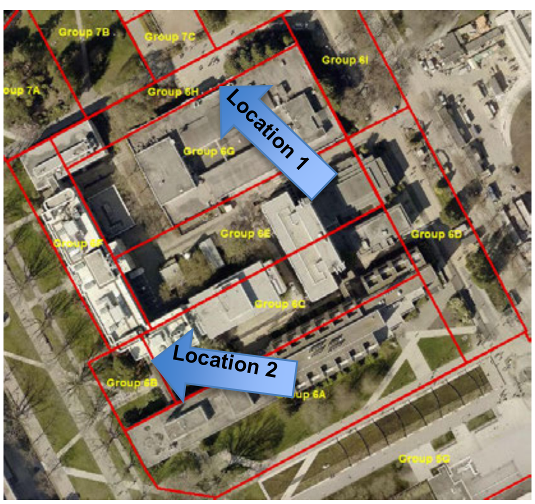


Figure 5. Two locations for survey

We did a survey at the location 1 and 2 and the location was decided by the most number of people walking by. In each location we surveyed 10 people and asked them “based on what you see, how do you feel about this place?” In location 1, out of 10 we had 8 people that felt good about the place and rest of the two were medium. The main reasons that people chose happy is because it makes them feel at home, peace, and feeling lucky to be at that place. People who said medium was because they had allergies, but it does not make them unhappy about the place. In location 2, out of 10 we had 9 people who felt happy about this place and the main reason was because it is balanced between nature and architecture, sunny place, and species are easily visible. One person who chose medium said that they feel bland because of the colour of the building which is grey.

Figure 6. This place shows the blandness of the building colour, grey. It sets up a sad and not close to relaxing mood.

Urban Forest Planning and Management Recommendations

With the information provided by i-Tree canopy and i-Tree Eco on the regulting services and cultural ecosystem services, we have come up with possible growing opportunities.

One of the recommendations that we have is to increase biodiversity by adding more green infrastructure to the building. While loooking at the map, our group noticed that the roofs of the buildings are very open and can be a place to improve on. Our group suggests the additon of green roofs, gardens, or solar panels for energy if the structure permits. Our suggestions for green roos is in relation to the UBC Green Building Action Plant to increase possible habitats for birds, pollinators, and to sustainably collect rainwater (UBC Green action plan, 2019).

Moreover, our group noticed that the corridor between the building could also use an upgrade. Although the corridor is mainly used to transport chemical and lab material into the building, we believe this area can be improved. The grey corridor may be an opportunity to increase the feeling of refuge by adding natural colours such as flowers and trees. Another simple way to upgrade this grey corridor may be to offer it as a blank canvas for an art project; letting people interact with the building may bring more cultural value and can increase activities that can happen near this area.

Our suggestions for Urban planning and management recommendations are mostly aimed at the idea of increasing biodiversity. Each organism in the ecosystem no matter how big or small has a role in the ecosystem. By increasing the biodiversity of our local urban forests, supporing and regulating services can be distributed more evenly to each organisms; the ore biodviersity in an ecosystem the healthier it can be.

Introducing more colours to the area can increase the feeling of serenity or refuge of the site. Our site as a whole is categorized as an institutional building. However, as previously mentioned, due to the historical background, it is difficult to make any new additions to the structure. Therefore, our main recommendations for the are are based around increasing biodiversity to help destress students through the comfort of nature.

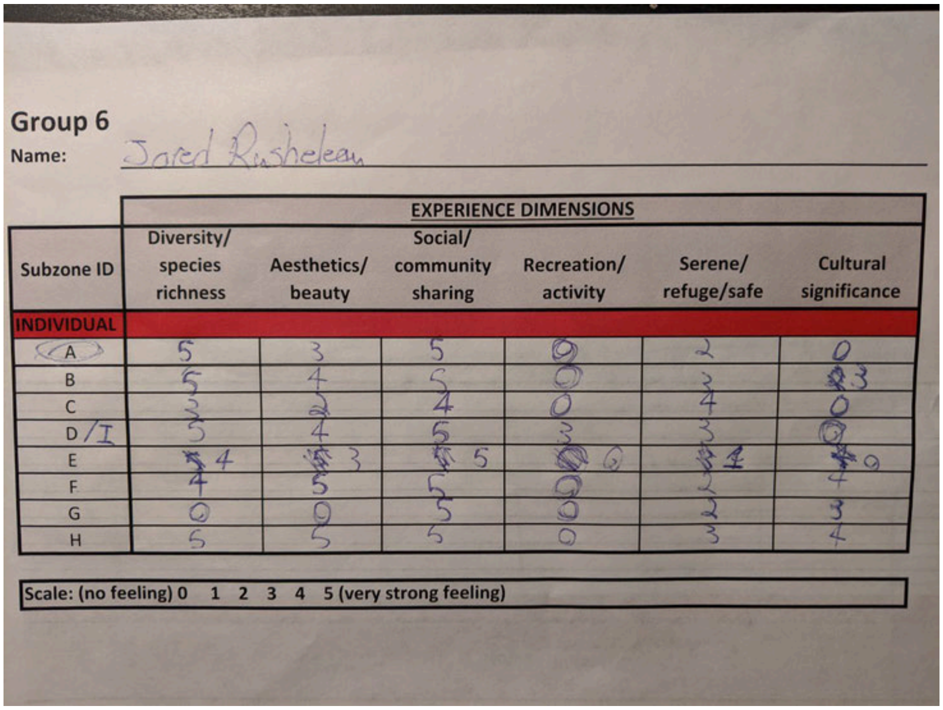
References

Biodiversity International. (2020). What are ecosystem services? Retrieved from https://wle.cgiar.org/content/what-are-ecosystem-services

Ferrini, Francesco (2017), et al. Routledge Handbook of Urban Forestry. Routledge, London;New York;, doi:10.4324/9781315627106.

UBC Green Action Plan (2019). UBC Green Building Action Plan. Retrieved from https://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_Green_Building_Action_ActionAppendices.pdf

Appendices

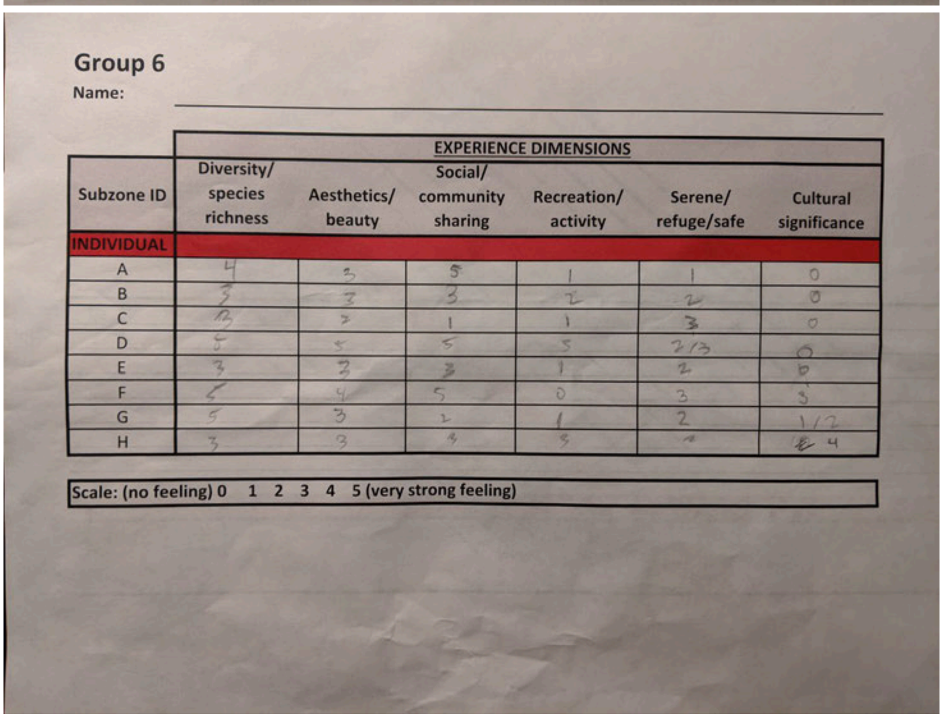


Group 6

Name: Jared Rushelean

	EXPERIENCE DIMENSIONS					
Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
INDIVIDUAL						
A	5	3	5	0	2	0
B	5	4	5	0	3	3
C	3	2	4	0	4	0
D / I	5	4	5	3	3	0
E	4	3	5	0	4	0
F	4	5	5	0	2	4
G	0	0	5	0	2	3
H	5	5	5	0	3	4

Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)



Group 6

Name:

	EXPERIENCE DIMENSIONS					
Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
INDIVIDUAL						
A	4	3	5	1	1	0
B	3	3	3	2	2	0
C	3	2	1	1	3	0
D	5	5	5	5	2/3	0
E	3	3	3	1	2	0
F	5	4	5	0	3	3
G	5	3	2	1	2	1/2
H	3	3	4	5	[illegible]	4

Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)

Group 6

Name: Keith Chau

Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
	EXPERIENCE DIMENSIONS					
INDIVIDUAL						
A	4	3	5	1	1	0
B	3	3	3	2	2	0
C	3	2	1	1	3	0
D	5	5	5	5	2/3	0
E	3	3	3	1	2	0
F	[illegible]	4	5	0	3	3
G	5	3	2	1	2	1/2
H	3	3	4	3	[illegible]	~~2~~ 4

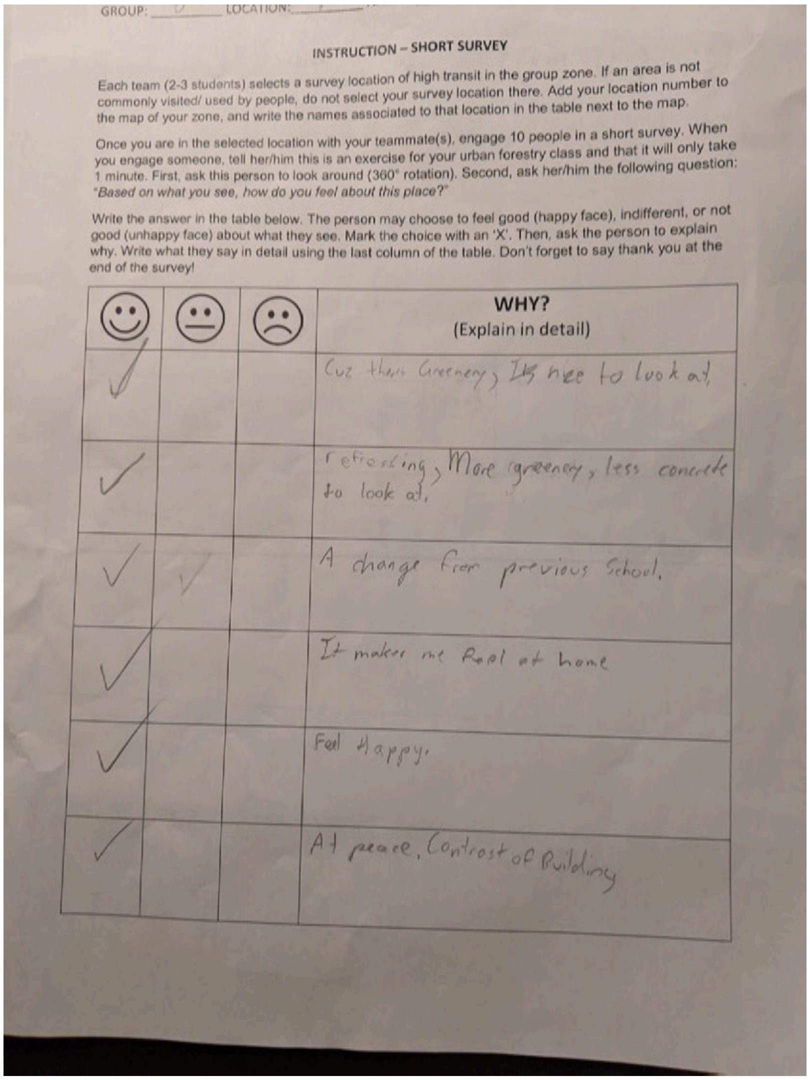
Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)

Group 6

Name: Marcus Nikolovski

Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
	EXPERIENCE DIMENSIONS					
INDIVIDUAL						
A	4	3	5	4	2	0
B	4	4	5	3	2	4
C	3	3	4	4	4	1
D/1	5	4	5	4	3	0
E	4	4	4	4	4	2
F	5	5	5	3	3	4
G	2	1	3	2	4	4
H	5	4	5	3	2	4

Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)



GROUP: ________ LOCATION: ________

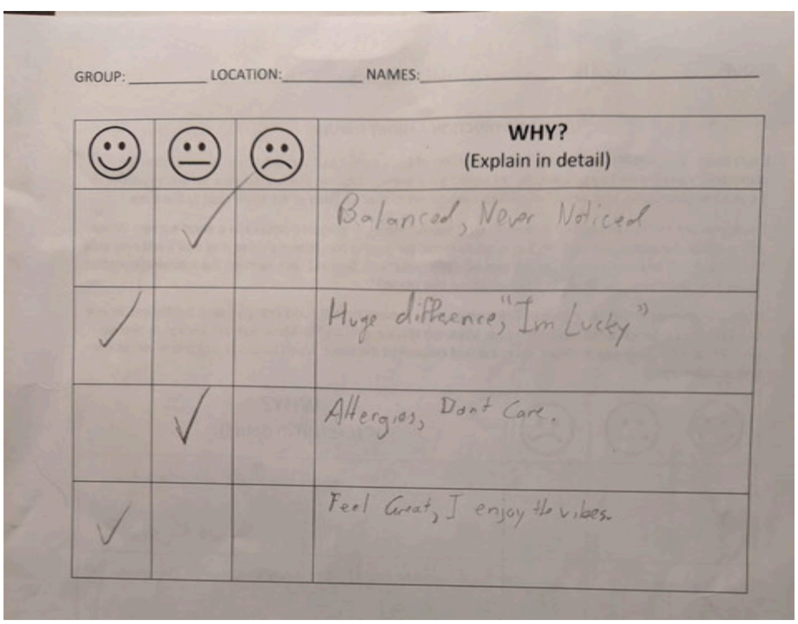
INSTRUCTION – SHORT SURVEY

Each team (2-3 students) selects a survey location of high transit in the group zone. If an area is not commonly visited/ used by people, do not select your survey location there. Add your location number to the map of your zone, and write the names associated to that location in the table next to the map.

Once you are in the selected location with your teammate(s), engage 10 people in a short survey. When you engage someone, tell her/him this is an exercise for your urban forestry class and that it will only take 1 minute. First, ask this person to look around (360° rotation). Second, ask her/him the following question: *"Based on what you see, how do you feel about this place?"*

Write the answer in the table below. The person may choose to feel good (happy face), indifferent, or not good (unhappy face) about what they see. Mark the choice with an 'X'. Then, ask the person to explain why. Write what they say in detail using the last column of the table. Don't forget to say thank you at the end of the survey!

☺	😐	☹	WHY? (Explain in detail)
✓			Cuz there Greenery, ~~It's~~ nice to look at.
✓			refreshing, More greenery, less concrete to look at.
✓	✓		A change from previous School.
✓			It makes me feel at home
✓			Feel Happy.
✓			At peace, Contrast of Building



GROUP: ________ LOCATION: ________ NAMES: ________________

☺	😐	☹	WHY? (Explain in detail)
	✓		Balanced, Never Noticed
✓			Huge difference, "Im Lucky"
	✓		Allergies, Dont Care.
✓			Feel Great, I enjoy the vibes.

GROUP: 6 LOCATION: 2 NAMES: Jared Rusheleau

INSTRUCTION – SHORT SURVEY

Each team (2-3 students) selects a survey location of high transit in the group zone. If an area is not commonly visited/ used by people, do not select your survey location there. Add your location number to the map of your zone, and write the names associated to that location in the table next to the map.

Once you are in the selected location with your teammate(s), engage 10 people in a short survey. When you engage someone, tell her/him this is an exercise for your urban forestry class and that it will only take 1 minute. First, ask this person to look around (360° rotation). Second, ask her/him the following question: "*Based on what you see, how do you feel about this place?*"

Write the answer in the table below. The person may choose to feel good (happy face), indifferent, or not good (unhappy face) about what they see. Mark the choice with an 'X'. Then, ask the person to explain why. Write what they say in detail using the last column of the table. Don't forget to say thank you at the end of the survey!

☺	😐	☹	**WHY?** (Explain in detail)
✓			Sunny, nature balance
✓			balance between nature and architecture
✓			Sunny day, birds/trees
✓			Good contrast between ~~[illegible]~~ concrete and trees
✓			Sunny, trees
✓			Mainly sun is out, lots of green!

GROUP: ________ LOCATION: ________ NAMES: ________________

☺	😐	☹	**WHY?** (Explain in detail)
✓			Sunny, not rainy!
	✓		bland, sort of grey.
✓			More sunny than Korea, people are out.
✓			Nice day, beautiful campus!

Ecosystem Services Assessment
Group 7

Submission date: 2020/4/08

Jiatong Gao
Yiqin Shen
Jiayi Chu
Max An
Fletcher Chan
Xiaolong Li
Thomas Huen

Contribution

Introduction	**Fletcher Chan & Jia Tong Gao**
Site Description	**Jia Tong Gao**
Regulating Services: i-Tree Canopy	**Jiayi Chu**
Regulating Services: i-Tree Eco	**Yiqin Shen**
Similarities and Differences in Results	**Jiayi Chu**
CES: Experience Dimensions & interpretation	**Thomas Huen**
CES: Short Surveys & interpretation & forecast	**Max An**
Recommendations	**Xiaolong Li**

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Introduction

The goal of an ecosystem services assessment is to attribute values to the natural environment around us. The Ecosystem services assessment we conducted focuses strictly on Phase 1C2. The environment around us in UBC provides a vast range of benefits and experiences to those who attend our university, these include many things such as the aesthetic values derived from visiting the university or the fresh air that is cycled through the unceded territory of the Musqueam people. These experiences can be separated into four different factors known as the "Ecosystem services". The four ecosystem services are as such; Provisioning services(Products obtained from ecosystems), Regulating services(Benefits obtained from the regulation of ecosystem processes, Cultural services(Non material benefits obtained from ecosystems and Supporting services(Services necessary for the production of all other ecosystem services.

The data we have collected and derived for our ecosystem services assessment are from multiple sources. The inventory data obtained from fieldwork 1, which included important attributes of trees such as DBH, TTH, abundance of species, and many more are used as inputs for iTree Eco and iTree Canopy to estimate ecosystem services values. An experience dimension scoring is carried out in 5 subzones, along with in-person surveys amongst the 3 most popular subzones. The surveys provided qualitative, relatively bias-free opinions about the subzones, which can be very helpful in aiding recommendations for planning and setting future goals.

The purpose of this ecosystem service assessment was not only to identify and label ecosystem services on phase 1C2 but also find out how urban forestry has shaped the student body and those who visit UBC by altering the green environment around us. This ecosystem service assessment was also conducted so that we could identify the experiences people have when visiting or passing certain areas of this university and for us that was Phase 1C2. Because UBC is an ever growing institute that inspires education one of the other purposes of this ecosystem service assessment is to use the feedback provided to us and use it to not only improve the area but plan for the future as well. All of these details and comments we researched and assessed can help with future urban forest planning and use the feedback of those who utilise phase 1C2 everyday as a stepping stone to future urban forest projects and plans. With clear information and detail of UBC's urban forest community this makes initiating and implementing a management plan much easier.

The end users of this small scale project would not only be UBC itself since all of this data helps planning for the future and organization much easier, it also benefits anyone that attends this world class university. Students and professors alike get to enjoy the spiritual and aesthetic benefits of our urban forest. Since this assessment is about taking in people's impression of the urban forestry around UBC, their feedback is not only crucial but fundamental in the way that future students and other people who come to UBC can have their image of this world renowned university positively altered if we utilize the feedback we got from this assessment as even a small detail but can change people's perspective of the school entirely. Although it may seem like a small scale project planned by a forestry class to give forestry students field work experience in their respective careers, it actually plays a significant impact in the wellbeing for many of those who attend the University of British Columbia.

Site Description

The area we assessed is located in the east of Main Mall, the north of Chemistry Building and the south of Ladner Clock Tower. The longitude and latitude coordinates are about 49.15 ° N, 123.15 ° W.

The plot can be divided into two areas by land use: east and including the lawn in the middle is classified as institutional, and west of that is classified as Park (figure 1). The eastern area features the IKB Learning Centre with a wide, paved road to serve more foot traffic. The western area is dense and diverse in tree species, featuring most of the greenery of the site with a small botanical garden, and gravel footpaths that navigate from IKB to either Main Mall or Agricultural road.

Figure 1. Rough aerial sketch of land use and features

The site serves the user in several ways with its facilities, such as providing footpaths for students/pedestrians/tourists leading and leaving the IKB Learning Centre (figure 2, 3), an open resting area on the lawn that can provide space for other recreational activities (figure 4), and a small botanic garden with benches for users to rest and relax (figure 5).

Figure 2. Front of the IKB Learning Centre

Figure 3. Side of the IKB Learning Centre

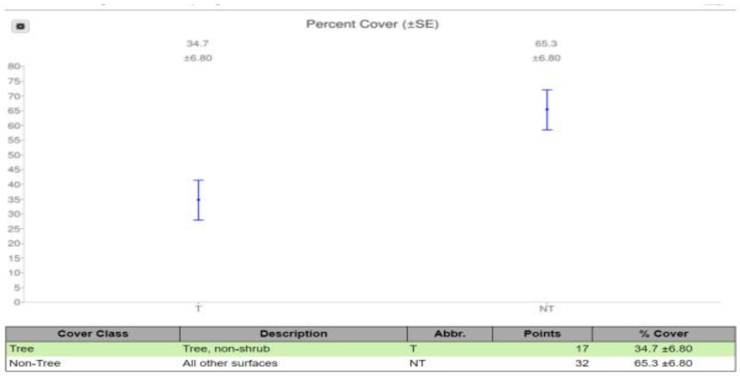
Figure 4. Lawn for multiple recreational activities

Figure 5. Small botanical garden and benches

Regulating Ecosystem Services: i-Tree Canopy

Results

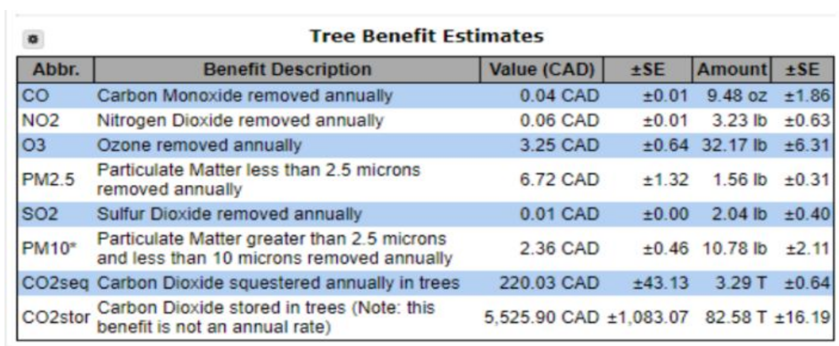
The report of i-tree canopy mainly includes two parts: in the first part, it estimates the tree coverage of that zone based on the vegetation cover properties of the 50 points randomly marked before, which is about 34.7%. (Figure 6)



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	17	34.7 ±6.80
Non-Tree	All other surfaces	NT	32	65.3 ±6.80

Figure 6. Tree coverage

In the second part, it estimates the annual removal of some air pollution elements, such as CO, NO2, O3, PM2.5 etc. And also annual CO2 sequestration and total CO2 storage by trees in our zone and convert these amounts into values in Canadian dollars. (Figure 7). The result sheet illustrates that among the first few air pollution items the annual removal amount of O3 is the largest, which is 32.17 lb, but only worth 5.25 CAD. And the highest value is the annual removal of PM2.5, which is 6.27 CAD, while it's amount is only 1.56 lb. Besides, the amount of annual CO2 sequestration is 3.29 tons, which is worth 220.03 CAD and the value of total CO2 storage is even higher, which is 5525.9 CAD.



Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.04 CAD	±0.01	9.48 oz	±1.86
NO2	Nitrogen Dioxide removed annually	0.06 CAD	±0.01	3.23 lb	±0.63
O3	Ozone removed annually	3.25 CAD	±0.64	32.17 lb	±6.31
PM2.5	Particulate Matter less than 2.5 microns removed annually	6.72 CAD	±1.32	1.56 lb	±0.31
SO2	Sulfur Dioxide removed annually	0.01 CAD	±0.00	2.04 lb	±0.40
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	2.36 CAD	±0.46	10.78 lb	±2.11
CO2seq	Carbon Dioxide squestered annually in trees	220.03 CAD	±43.13	3.29 T	±0.64
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	5,525.90 CAD	±1,083.07	82.58 T	±16.19

Figure 7. I-Tree Canopy regulating values estimate

Therefore, we can find that the Regulating Ecosystem Services that this zone can provide are air quality regulation, carbon sequestration and carbon storage.

Interpretation

As for why the report came out the conclusion of the above regulating ecosystem services is because the branches and leaves of trees can filter the dust, absorb and purify the toxic gases in the air, so trees have the function of purifying the air. In addition, trees can absorb CO2 and release oxygen by photosynthesis, thus sequestering and storing carbon, and also help to purify the air. The report of I-Tree Canopy is to estimate the tree coverage of this zone, and then calculate the value of various regulating ecosystem services by using certain calculation methods.

Regarding how this model calculates the ecosystem services values of trees for the removal and absorption of various air pollution elements, we found that on I-Tree Canopy, it has an initial "Removal rate (lbs / acer / yr) "of each element. As long as it gets a value related to vegetation coverage after randomly picking points and multiplying the "Removal rate" and that value, we can finally get the amount of elements' removal or absorption by the plants in the final report. Similarly, when calculating the value of each element, it also has an initial "Monetary value (CAD / T / yr)", as long as the unit of each element's amount converted into tons, and then multiplied by Monetary value , we get the values in the final report. (Figure 8)

Tree Benefits

	Abbreviation	Benefit Description	Removal Rate (lbs/acre/yr)	Monetary Value (CAD/T/yr)
1	CO	Carbon Monoxide removed annually	0.902	120.65 CAD
2	NO2	Nitrogen Dioxide removed annually	4.917	38.09 CAD
3	O3	Ozone removed annually	48.968	199.18 CAD
4	PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	16.403	431.69 CAD
5	PM2.5	Particulate Matter less than 2.5 microns removed annually	2.379	8,473.58 CAD
6	SO2	Sulfur Dioxide removed annually	3.098	10.56 CAD
7	CO2seq	Carbon Dioxide squestered annually in trees	10,010.267	65.95 CAD
8	CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	251,395.359	65.95 CAD

Page 1 of 1 View 1 - 8 of 8

Figure 8. Removal Rate & Monetary Value

Strengths and Weaknesses

The advantage of i-Tree Canopy model is that it is very convenient, and the results are very concise.

However, its results are usually not very precise, here are some reasons:

1. We do not need to input accurate data ;

2. Relatively low image resolution, it just estimates the vegetation coverage based on our top-down identification of the ground cover of an existing blurry map;

3. The accuracy of the evaluation depends on the user's ability to correctly classify each point. If there are too few classification points, the error will be higher, and the accuracy of the final value estimation will be reduced.

Regulating Ecosystem Services: i-Tree Eco

Results

According to the estimation and analysis of i-tree Eco, the regulating ecosystem services provided by the region can be divided into four aspects, pollution removal, carbon storage and sequestration, oxygen production and runoff avoided, which I will analyze in turn.

Air Pollution Removal

Air pollution is a major global problem, which affects human health and well-being, ecosystem health and air visibility. Trees eliminate air pollution by intercepting particles on the surface of plants and absorbing gaseous pollutants through the stomata of leaves. As shown in figure 9, the air pollution elements that are measured are ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO2). Also, in this area, pollution removal was greatest for ozone.

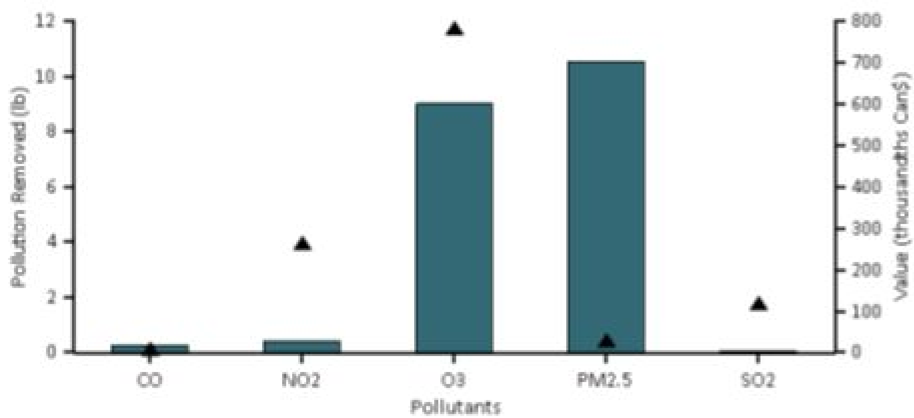


Figure 9. Annual pollution removal (points) and value (bars) by trees in the zone

It is estimated that trees remove 17.69 pounds of air pollution per year with an associated value of Can$1.36. But it is worth mentioning that besides pollution removal, trees in the zone emitted an estimated 4.071 pounds of volatile organic compounds (VOCs). But the volatile organic compounds (VOCs) produced by vegetation and nitrogen oxides (NOx) emitted by humans will react to produce new ozone. Therefore, planting trees with low VOC emissions may help to reduce the urban ozone content to a greater extent.

Carbon Storage and Sequestration

Carbon dioxide is a kind of greenhouse gas, the increase of the concentration of carbon dioxide in the atmosphere will aggravate global warming. However, trees play an important role in removing carbon (in the form of carbon dioxide) from the atmosphere through the process of photosynthesis, and this procedure is called carbon sequestration. The gross sequestration of trees in our zone is about 855.9 pounds of carbon per year with an associated value of Can$44.6.

Also, as a tree grows, it stores more carbon by holding it in its accumulated tissue, and this is carbon storage, which refers to the amount of carbon bound up in woody material above and below ground. Trees in our zone are estimated to store 21.3 tons of carbon (Can$2.22 thousand).

Therefore, trees in urban areas currently store carbon, which can be emitted back to the atmosphere after tree death, and sequester carbon as they grow, that is why they influence local climate, carbon cycles, energy use and climate change (Nowak, Greenfield, Hoehn & Lapoint, 2013).

Oxygen Production

The production of oxygen is one of many environmental benefits produced by trees, while urban trees can produce a lot of oxygen. Trees in our zone are estimated to produce 1.141 tons of oxygen per year. But considering that the oxygen content in the global atmosphere is basically unchanged, and about 21% of the atmospheric volume is oxygen, the production of oxygen is not a significant ecological benefit. As Miller (1979) once stated, we have many serious ecological problems, but asphyxia due to lack of oxygen is not one of them.

Avoided Runoff

Urban development leads to the change of surface coverage, destroys the hydrological cycle of the city, and increases the amount of urban rainwater runoff and the risk of local floods. However, urban trees and shrubs play an important role in reducing surface runoff. They have the ability to intercept precipitation, evaporation and transpiration, store and infiltrate rainwater through roots. The trees and shrubs of our zone help to reduce runoff by an estimated 1.52 thousand cubic feet a year with an associated value of Can$100.

Strengths and Weaknesses

Unlike i-Tree Canopy, i-Tree Eco uses a bottom-up approach. Its assessment of urban forest structure, its related ecosystem services and related values are based on field vegetation data sampled, collected and inventoried by us. Therefore, based on the artificial field trip and the estimation of many ecosystem services and their values provided by i-Tree Eco, users can well estimate the basic forest information needed for management (for example, species composition, tree health, risk), and monitor the changes of forest composition and value. However, this method also has some disadvantages, because users have to collect accurate field data, which leads to the existence of data collection cost, as well as the consumption of manpower and time, and this cost is different according to the project scale and scope, if we want to measure the trees in the whole city, it will definitely consume more time and money.

Similarities and Differences in Results

Through comparing the results of both reports, we found that there are some similarities and differences between the results of the two reports.

Similarities

- 1. Both of them express the Regulating Ecosystem Services values in CAD;
- 2. Both of them estimate the values of air pollution removal and CO2 sequestration by trees.

Differences

- 1. The results of I-Tree Eco are more accurate;
- 2. I-Tree Eco analyzes more aspects in regulating services than I-Tree Canopy;
- 3. The value calculated by I-Tree Canopy is generally higher than those by I-Tree Eco.

Therefore, if people just want to roughly understand the regulating ecosystem service of an area, then they can use I-Tree Canopy which is easy to operate and has clear results report; but if it is a professional forestry researcher, who want to carry out detailed regulating ecosystem service of an area for analysis, I-Tree Eco is recommended, and before using I-Tree Eco, people need to measure the inventories of the study area first.

Cultural Ecosystem Services

Experience Dimensions:

During the field activity, our group did a self-evaluation regarding how we feel about the 5 subzone in our zone in different dimensions, such as diversity, aesthetics, social sharing, recreation, serene and cultural significance. Between a scale of 1 to 5, we are evaluating the zone individually.

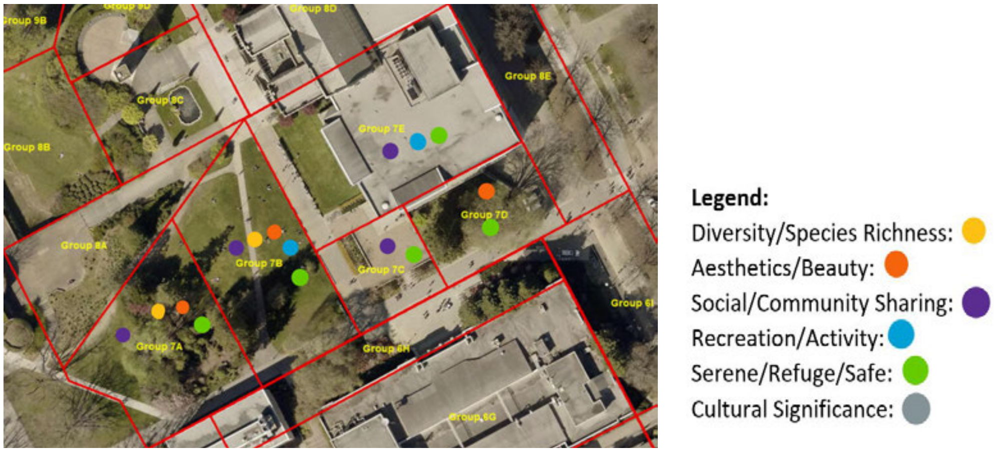


Figure 10. Cultural Ecosystem Services hotspots

The result is as shown above (figure 10) and we made a visualized map in order to show the experience dimensions clearer. Every colored dot represents an average score of 2.5 or higher in the summary table, which represents a relatively higher score of experience dimensions. As shown in the map, Zone 7A and 7B have high average scores in 4 out of 5 experience dimensions, except cultural significance. This is because of the mini-garden in the area along with the high levels of ecological services. This statement coincides with our short survey which correspondents say they feel happy regarding the biodiversity that is visible in the area.

Educational services can also be noticed in our field activity. Under most trees in our zone, there are tags including the scientific name and habitat of the species. These tags contribute to educational cultural services since people will notice the tag and learn about the species as they walk by.

Interpretation:

From our experience dimensions summary, sub zone 7A was first with a score of 22, followed by 7B and 7D scoring 15, E scoring 12, and 7C at last scoring 11. As recalled, sub zone A has a diverse greenery due to the botanical garden which is the primary reason it is ranked first. Sub zone 7C is the opposite, having a monoculture of Japanese Maple, which is why it ranks the lowest. Based on the result of the rankings, there is a common trend that the greater amount of trees equals the greater amount of people ranking the sub zone more beautiful. However, there is one exception with sub zones 7C and E. Sub zone 7E is ranked higher than 7C although sub zone 7E has 2 trees compared to sub zone 7C's 6 trees. However, sub zone E had a flat area of grass compared to 7C being all concrete. The grey concrete flooring presents a dull and less appealing scenery.

Short Survey:

During a field activity, our group selected 3 designated sub zones which we thought were the most visited and used among all the other sub zones. We then splitted up in pairs to survey 10 random people passing in the subzone. We asked the participant for a 360 degree turnaround evaluation and their initial feelings and thoughts about the area itself and its surroundings. The people we surveyed varied from students resting and eating lunch or students passing by, tourists, etc.

Location: 7A

From the short survey on location 7A, 100% (10/10) of the respondents felt happy. Their reasons were because the diversity of tree species and sizes was very appealing, found the place peaceful, sense of safety, likes to swing on the hanging on the tree, relaxing, elegant, and enjoys walking along the path going through.

Location: 7B

From the short survey on location 7B, 70% (7/10) of the respondents felt happy. Their reasons were because it was a relaxing place to rest, an abundance of greenery, dense tree canopy, benches to sit, ‘natural’ feeling (does not stand out but rather blends in naturally with surroundings), bucolic and nostalgic feeling, diverse amount of tree species, subtle, and calming to look at. 20% (2/10) of the respondents felt indifferent. Their reasons were due to the season. The respondent prefered summer time more because of the temperature, sunlight, presence of green on trees and bushes. 10% (1/10) of the respondents felt unhappy. The respondent’s reason was the dull and monotonous grey colours and felt that there are not enough flowers.

Location: 7E

From the short survey on location 7E, 50% (5/10) of the respondents felt happy. Their reasons were because there were benches connected to tables for studying while enjoying the view, the contrast between concrete structures and greenery was appealing, variety of heights and volume of trees, clock tower ringing every hour, changes in depth and slopes of the ground, mix of traditional and modern buildings, can see see the surrounding view that are far away (~150 metres). However, 50% (5/10) of the respondents felt indifferent. Their reasons were because the clock tower is unappealing due to the boring grey colour, not enough flowers planted, enjoys the view but a bit noisy due to main road, not ideal place to study on a rainy day due to the absence of a roof, grass is mushy on a rainy day, not enough trees planted, no leaves on trees, and too sunny for studying.

Interpretation:

It is no surprise that subzones 7A and 7B with a score of 10/10 and 7/10 respectively would be of greater significance as compared to subzone 7E’s 5/10 on respondent’s happiness on the area. These results coincide and can relate to our self survey result; 7A and 7B with a score of 22 and 15 respectively would be of greater significance as compared to subzone 7E’s 12 on aesthetics and beauty. Based on the comments and reasoning from the respondents, the resting area in 7A, along with the various species and density of greenery was a huge determinant on their first impressions and reactions. ⅝ of respondents who were indifferent and unhappy were not happy due to the weather while ⅜ of respondents who were indifferent and unhappy were not happy due to the lack of greenery and flowers. However, both reasons behind their feelings towards the area are influenced by the season. If we were to conduct the same survey during the months of June, July, and August, we might have received more happy results. During the summer the temperature is the hottest and a greenery density increases due to sunlight. Depending on the season, the presence of greenery could alter the aesthetic value of the sub zone.

Forecasting

First of all, there are many multi-stem trees in our zone, especially near the mini-garden area. Some of the stems have a large tilting angle towards the ground. Those trees are expected to continue growing for many years and we expect the angle will continue to increase. We believe those stems may have a hazard of falling and hurting the pedestrians after years of growing. As a suggestion, proper support for multi-stem trees is needed in the future to ensure safety.

Secondly, there are old and newly planted trees around the IKB learning center. We forecast these trees may continue to grow and the branches and leaves may block the window of the library, and thus will block sunlight from coming into the building. As a suggestion, regular pruning for branches of those trees around the library is needed to allow sunlight coming into the building.

Recommendation

Firstly, the staff need to improve implementation and enforcement of urban forest management, using I-Tree Eco and I-Tree Canopy neatly. As we mentioned, comparing the results of both reports, there are some similarities and differences. Therefore, using two analyses in a proper situation is significant. For example, I-Tree Canopy, which is easy to operate, on the other side, I-Tree Eco is more accurate. In the meanwhile, the staff need to maintain and improve distribution and cohesivity of the site urban forest. Increasing tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. How to fix the invasive plants issues is one of the most important challenges. At the same time, incorporate aesthetics management into urban forest management as a part of site landscape designing. Aesthetics management is equally valuable in landscape designing. Next, empower the site community in urban forest management on campus and facilitate community involvement in its governance. Public engagement as a non-negligible part in designing of urban forest, it can not only provide a lot of valuable inspiration to designers, but also can improve the atmosphere of humanism. In addition, take into consideration potential future challenges and opportunities into urban forest management and create achievable, guiding long-term goals for the site's urban forest. Such as the effects of climate change and future development projects on campus. Here are the patches of recommendations:

- Roles each department plays in urban forest management should be clarified (communication and processing between departments made more efficient and effective), for example, designing and operations of public works, development review services, transportation and so on.

- Schedule of a regularly updated and maintained tree inventory.
- Creation of a significant tree registry.
- Clarify urban forest values and goals, including specific definitions of what is trying to be achieved and how it will be achieved.
- The last point is the distribution of greenways. Aesthetics and practically are two key elements.
- To combat the dull concrete flooring in subzone 7E, artists from the Art Department can paint the floor to make the place more vibrant and lively.

Works Cited

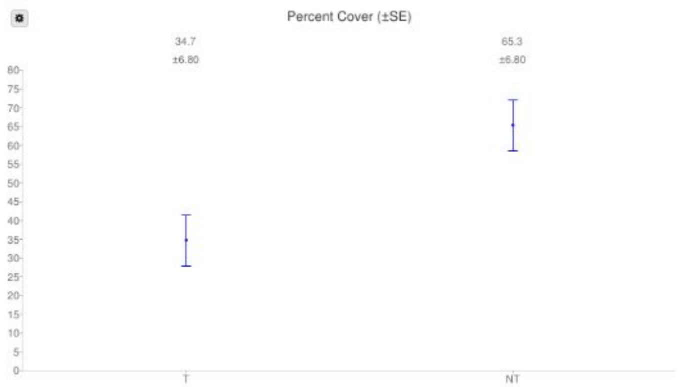
Miller, G.T. (1979). Living in the Environment. Wadsworth Publ. Co., Belmont, CA. p. 91.

Nowak, D. J., Greenfield, E. J., Hoehn, R. E., & Lapoint, E. (2013). Carbon storage and sequestration by trees in urban and community areas of the United States. Environmental Pollution, 178, 229-236. doi:10.1016/j.envpol.2013.03.019

Appendices

I: Report of i-Tree Canopy

i-Tree Canopy v6.1
Cover Assessment and Tree Benefits Report
Estimated using random sampling statistics on 3/23/20



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	17	34.7 ±6.80
Non-Tree	All other surfaces	NT	32	65.3 ±6.80

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.04 CAD	±0.01	9.48 oz	±1.86
NO2	Nitrogen Dioxide removed annually	0.06 CAD	±0.01	3.23 lb	±0.63
O3	Ozone removed annually	3.25 CAD	±0.64	32.17 lb	±6.31
PM2.5	Particulate Matter less than 2.5 microns removed annually	6.72 CAD	±1.32	1.56 lb	±0.31
SO2	Sulfur Dioxide removed annually	0.01 CAD	±0.00	2.04 lb	±0.40
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	2.36 CAD	±0.46	10.78 lb	±2.11
CO2seq	Carbon Dioxide squestered annually in trees	220.03 CAD	±43.13	3.29 T	±0.64
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	5,525.90 CAD	±1,083.07	82.58 T	±16.19

II: The report of i-tree Eco has been submitted together with the assignment in the form of file "i-Tree Eco Report_Group7".

Group 7

	EXPERIENCE DIMENSIONS					
Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance
SUMMARY						
A	24	22	15	12	17	8
B	16	15	19	17	21	9
C	8	11	17	12	17	6
D	14	15	12	12	15	9
E	6	12	21	19	16	12
F						
G						
H						
AVERAGE						
A	4	3.67	2.5	2	2.83	1.33
B	2.67	2.5	3.17	2.83	3.5	1.5
C	1.33	1.83	2.83	2	2.83	1
D	2.33	2.5	2	2	2.5	1.5
E	1	2	3.5	3.17	2.67	2
F						
G						
H						
Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)						

III: Experience dimensions assessment table.

Ecosystem Services Report

Irving K. Barber Learning Center

&

Residential School History and Dialogue Centre

Martin, A., Rueter, A., Phuong, K., Tsawada-Tse, E., Yan, H., & Du, Y.

Date of Submission: 2020-04-08

Group 8

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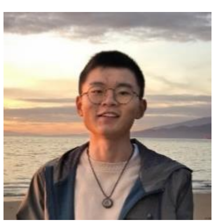

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Cover photo by Anya Rueter

Introduction

"A vision of net positive ecological and human health in pursuit of an exceptional built environment that supports the academic mission of teaching, learning, and research"

- UBC Green Building Action Plan, 2018, p. 7

The urban forest of the University of British Columbia's (UBC) Vancouver campus has contributed to the vibrant, picturesque landscape of the campus. In the summer of 2017, UBC Vancouver campus began the process of establishing a tree inventory, including an assessment of ecosystem services (Lompart & Thomas, 2017). The inventory will allow stakeholders to properly plan, manage, and monitor the urban forest, as well as allocate a sufficient budget for these measures (Lilly, 2010). The measure of ecosystem services throughout UBC Vancouver campus' urban forest will allow for the proper allocation of resources for the planning and management of the urban forest. There are four types of ecosystem services: (i) regulating; (ii) cultural; (iii) provisioning; and (iv) supporting. This ecosystem services report focuses on the regulating and cultural ecosystem services of an area described as "Site C3".

This ecosystem services report includes four sections: (i) Site Description, (ii) Regulating Ecosystem Services, (iii) Cultural Ecosystem Services, and (iv) Urban Forest Planning and Management Recommendations. The "Site Description" section provides a general description of Site C3. The "Regulating Ecosystem Services" section analyzes and discusses the regulating ecosystem services of Site C3. The "Cultural Ecosystem Services" section analyzes and discusses the cultural ecosystem services of Site C3. The "Urban Forest Planning and Management Recommendations" section analyzes data from the inventory and ecosystem services value mapping to recommend future planning and management opportunities for Site C3.

This ecosystem services report serves to provide the Social Ecological Economic Development Studies (SEEDS) sustainability program with information pertaining to the current state of ecosystem services on the site. This report will also likely be used by UBC's Building Operations and Planning and Design departments, as this report includes specific information in relation to the suggested management practices of the site's arborists, horticulturists, and pest management crews. Researchers may use the inventory data and reports to assess changes to the urban forest, as well as noting current benefits that the urban forest provides (Ferrini et al., 2017). Similarly, the use of the report to highlight examples of current ecosystem services could be used by course instructors in lectures. As this publication will be publicly available, the use of the report by students in future writing about the UBC Vancouver Campus is also likely.

The authors hope the information made available through this report, both current data and recommendations, are used in the future decisions of urban forest planning and management. As such, the inclusion of data and analysis within this report may be used as justification within UBC's policies and planning material, such as future publication of the *Green Building Action Plan.*

Site Description

Preface: This section defines the site boundaries and describes the infrastructure on Site C3. This section also includes information on the users and ecosystem services provided.

Acknowledgment

We acknowledge that the UBC Vancouver campus, on which Site C3 is located, is situated on the traditional, ancestral and unceded territory of the Musqueam people (University of British Columbia, 2018a, p. 12).

Site Boundaries

This ecosystem services report focuses on a study site included in Phase 1 of the UBC Vancouver campus urban forest tree inventory as part of the larger Urban Forest Management Plan (Naveau et al., 2017). The study site described is labelled on the UFOR101_TreeSurvey map file system as “Phase 1C3” (Burton, 2020) and will hereafter be referred to as “Site C3”. The total area surveyed in the ecosystem services report is 1.5 hectares in size (Burton, 2020).

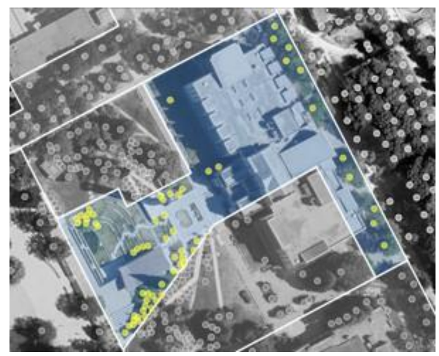


Fig. 1: Site C3 Boundaries (Burton, 2020)

Site C3 encompasses much of the land surrounding UBC’s Irving K. Barber Learning Centre (IKBLC) and the Residential School History and Dialogue Centre (RSHDC). The site is defined by the following road boundaries: Memorial Road to the north, East Mall to the east, Agricultural Road to the south, and Main Mall to the west (Burton, 2020). Areas within this boundary but not included in this inventory consist of the northwest quadrant between Learner’s Walk, the Ladner Clock Tower, Memorial Road, and Main Mall, as well as the heavily vegetated region in the southern section of the plot bounded by the side walk connecting Learner’s walk to Main Mall, and the sidewalk along East Mall (Burton, 2020). All street trees within the boundaries along East Mall are included in this inventory. Figure 1 provides a visual reference of the boundaries, indicated by a white border line along the perimeter of the colored area, and a visual reference of the site, colored blue. Areas in black and white are considered outside the scope of this inventory and are not included in this report.

Site Users and Services

The IKBLC provides many services to UBC students, faculty, and staff including lecture halls, study spaces, the Music, Art & Architecture Library, a small cafe, and the Rare Books and Special Collections archive (University of British Columbia, n.d.).

Points of Interest

Site C3 contains the Library Garden and Learner’s Walk, located in front of the IKBLC, which serve as a study space and recreation area, with an abundance of greenery creating a peaceful and calming atmosphere. Connecting Agricultural Road to Memorial Road is Learner’s Walk, a wide pathway to the west of the IKBLC. This hardscape features benches and tables that serve as a place for studying and socialization. Located next to the RSHDC and to the west of the IKBLC is a softscape with a cascading grass slope which forms a bowl shape. This grass area is considered a good place of refuge because of the quiet and calming atmosphere frequently utilized by users; because of its importance to our plot, we will regularly be referring to this section of Site C3, referred to as “grass area”.

Regulating Ecosystem Services

Preface

Regulating ecosystem services are benefits provided by nature's regulating properties, such as pollution removal and carbon sequestration. This section begins with an introduction of i-Tree ECO and i-Tree Canopy and a description of the methods and limitations. This section will then critically analyze several regulating services, noting points that may indicate potential aspects of improvement for Site C3.

i-Tree Eco

i-Tree Eco is a software application designed by the United States Forest Service used for urban and rural forestry analysis and ecosystem services valuations (i-Tree, 2020a). i-Tree's analysis data quantifies ecosystem services values and produces management reports that urban foresters and policy makers can use to determine appropriate management plans, including information on pest susceptibility (i-Tree, 2020b). The i-Tree software system is publicly available and is used by a diverse number of users, including municipal, provincial, and federal governments, commercial arborists, consulting urban foresters, researchers, and private property owners (i-Tree, 2020b).

i-Tree Canopy

i-Tree Canopy is a web browser application designed by the United States Forest Service to estimate the tree canopy cover of an urban forest plot, as well as to infer regulatory service benefits based on the canopy value obtained (i-Tree, n.d.). This tool/software is utilized by first identifying and defining the project area on a Google Map image, then manually assigning randomly chosen points as "Tree" or "Non-Tree" (i-Tree, n.d.). Finally, these points are processed to produce an accurate estimation of the canopy cover within the area. Based on the canopy cover data, i-Tree Canopy produces estimations of pollution removal values, such as carbon monoxide and ozone removal (i-Tree, n.d.).

Methodology for i-Tree Eco

The data used in i-Tree Eco was collected during the inventory phase of the *Inventory Report* (2020). The values from the *Inventory Report* (2020) were imputed into the following i-Tree Eco data categories: tree species; land use; diameter at breast height (DBH); height of DBH measurement; total tree height; live crown height; crown base height; tree crown width (long); tree crown width (short); crown percent missing; and crown light exposure. Using this inventory data, climate data, and average monetary values, i-Tree Eco determines the regulating ecosystem services and their related monetary values.

Methodology for i-Tree Canopy

Canopy cover for this report was estimated using the i-Tree Canopy software program. The first step in using the software program is to identify and define the project area using Google Earth (i-Tree, n.d.). i-Tree Canopy then selects randomly generated points from within the project area, which the user identifies as "Tree" or "Non-Tree" (i-Tree, n.d.). The more points generated by the user, the greater the accuracy of the program's estimation of canopy cover. The project area is then processed by the i-Tree Canopy software to produce an accurate estimation of the canopy cover percentage, providing quantified values for pollution removal and other regulatory ecosystem services (i-Tree, n.d.).

In this report i-Tree Canopy was used to determine the canopy cover only. Estimated quantities and monetary value of regulating ecosystem services were determined using the i-Tree Eco software application.

Limitations of i-Tree Eco and i-Tree Canopy

i-Tree ECO requires detailed data and a base knowledge of urban forestry, which may make it difficult for the layperson to use the program. It also likely makes it difficult for the layperson to understand the results published in the i-Tree Eco reports. Users may not be able to see a direct image of the investigated site, which i-Tree Canopy provides.

i-Tree Canopy is subject to several limitations. The accuracy of the estimated canopy cover and related data depends on the user's accuracy in determining points as “Tree” or “Non-Tree” (i-Tree, n.d.). The quantitative values of benefits obtained are estimates based solely on the canopy cover data; external variables, such as tree species and size, are not accounted for in estimations (i-Tree, n.d.).

Results and Analysis

Pollution Regulation

In analysis of the i-Tree Eco data and Appendix A, we discover that the trees on Site C3 remove 9 pounds of ozone annually (i-Tree, 2020c). Site C3 also removes a small amount of PM2.5, nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO) (i-Tree, 2020c). Despite an insignificant amount of PM2.5 removal, there is a high monetary value from its removal (i-Tree, 2020c). The removal of PM2.5 is an important aspect of pollution removal as PM2.5 can cause significant cardio and pulmonary diseases (Pietrangelo and Holland, 2017). Thus, the pollution removal of PM2.5 can help users improve their physical health and should be considered an important benefit of the ecosystem services of the site.

The increase in atmospheric carbon content is one of the most significant drivers of climate change (Guzman, 2013). Because of this, the carbon sequestration and storage of trees is important in helping regulate the effects of climate change. The total carbon sequestration and storage on Site C3 is 1046 pounds of carbon per year, a monetary value of $54.50 CAD (i-Tree, 2020c). Currently, the trees on Site C3 store a total of 26.9 tons of carbon, a monetary value of $2 810 CAD (Appendices B & C) (i-Tree, 2020c). Among the species evaluated, *Quercus robur* accounted for 84.8% of the carbon sequestration and storage and therefore is one of the most important species on Site C3 (i-Tree, 2020c).

Canopy Cover

In the i-Tree Canopy analysis, the canopy cover for Site C3 is 24%, with 12 points marked to be “Tree, non-shrub” (*i-Tree Canopy, version 6.1,* 2020*)*. The quantitative size of the tree cover was found using i-Tree Eco, determined to be 22.76 thousand square feet providing 1.692 acres of leaf area (i-Tree, 2020c). The shade from tree canopy in an important factor on the westside of the IKBLC, which allows sciophilous plants to grow.

The canopy cover also helps regulate the temperature of the understory landscape. Because the canopy cover for the site is 24%, it will help in regulating the heat island affect through the evaporation of water, cooling the area around it (Ferrini et al., 2017). Because there *Quercus robur* is in close proximity to the IKBLC, the canopies of the trees will help reduce the amount of sunlight penetrating into the building, which will help regulate the exterior and interior temperatures of the building.

Biodiversity

According to our analysis in *Inventory Report* (Martin et al., 2020), Site C3 consists of 16 species among 13 genera. *Acer circinatum* accounted for 30 of the 73 trees identified on the ArcGIS application (Martin et al., 2020). The implications of a monoculture include increased susceptibility to forest pests, which will be discussed in the "Urban Forest Planning and Management Recommendations" section.

Deciduous trees have been found to far outnumber evergreen coniferous trees; 71% of the inventoried trees were deciduous, 29% of the inventoried trees were evergreen conifers (Martin et al., 2020). This can negatively affect multiple regulating ecosystem services, such as wind buffering, pollution removal, and avoided runoff because the canopy cover of Site C3 decreases as deciduous trees shed leaves. The absence of leaves was a common critique of users and will be discussed further in the "Cultural Ecosystem Services" section.

Stormwater Runoff

The urban forest can be utilized to limit runoff of stormwater after long periods of intense rainfall. The capacity of the urban forest to limit stormwater runoff depends on multiple factors, such as canopy cover, tree size, and tree distribution. In Site C3, the urban forest reduces runoff by 1 100 cubic feet per year or 31.14 cubic meters per year (i-Tree, 2020c). The monetary value of this runoff reduction is $72 CAD (i-Tree, 2020c). The i-Tree Eco report showed that the *Quercus robur* on East Mall provides most of the runoff reduction capacity, as shown on Appendix D, which illustrates the runoff reduction capacity of the urban forest by tree species (i-Tree, 2020c). The runoff reduction capacity is highest along East Mall, as a result of the mature *Quercus robur* (i-Tree, 2020c); this implies that the removal of any or all *Quercus robur* will significantly decrease the runoff reduction capacity of Site C3. To maximize the potential for regulating runoff, the number of species that can effectively absorb runoff would need to be increased; this may require waiting for current trees to mature to increase their capacity for reducing runoff, as juvenile trees with smaller DBH do not contribute highly to the regulation of stormwater runoff.

Soil erosion from areas with gradient will be regulated by the root structure of the trees on Site C3. Additionally, the canopy cover reduces the impact of rainwater on the soil (Ferrini et al., 2017). The root structure and canopy cover act to regulate the soil erosion and leaching of nutrients from the site (Brady & Weil, 2010).

Cultural Ecosystem Services

Preface: Cultural services are "the non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences" (Ferrini et al., 2017, p. 52). This section includes a description of our methodology, the benefits and limitations of value mapping, and the results and analysis of our findings. Identifying cultural ecosystem services on Site C3 is crucial in determining the availability and diversity of sociological benefits, thus guiding urban forest planning and management strategies to address areas with low cultural ecosystem services value.

Cultural Ecosystem Services Value Mapping

Ecosystem services value mapping determines the views of the public users on the current state of the urban forest. Ecosystem services value mapping include the ability to engage stakeholders, an important process when emphasizing evidence-based decision making. On Site C3, we collected opinions from we the authors and conducted a field survey which allowed for candid, random, and natural responses from site users. Candid responses are typically formulated from first impressions and observations which highlight the urban forest aspects and functions users enjoy and utilize.

Methodology of Cultural Ecosystem Services Value Mapping

In quantifying the cultural services of Site C3, we developed six experience dimensions of different cultural services that might be provided in each subzone. These six experience dimensions are: (i) diversity/species richness; (ii) aesthetics/beauty; (iii) social/community sharing; (iv) recreation/activity; (v) serene/refuge/safety; and (vi) cultural significance.

Site C3 was then divided into five subzones labeled Subzones A – E, as seen in figure 2. We the authors conducted a group walkthrough of the five subzones, rating the feelings produced by each experience dimension on a scale of 1 (no feeling) to 5 (very strong feeling). This produced quantitative data with which the cultural services of each subzone could be compared. The data was compiled to show the average level of feeling of each experience dimension in each subzone as indicated by the entire group.

Fig. 2: Site C3 Subzones A - E (Burton, 2020)

To evaluate users' appreciation of the site, we conducted a survey in which users were asked how they felt about the landscaping and greenery of Site C3. We surveyed users in three heavily trafficked locations of Site C3, focusing on locations which we felt would provide beneficial feedback. These locations were: (i) the grass area in front of IKB; (ii) the path connecting Main Mall and Learner's Walk; and (iii) outside the back entrance of IKB along East Mall.

In total, 30 responses were recorded from users of varying age demographics and from different roles in the UBC community (i.e. students, instructors, alumni). We asked respondents to classify their feelings of the area around them into one of three categories: (i) happy/good; (ii) indifferent; or (iii) not happy/not good. Respondents were then asked to provide comments about the location; these comments were recorded for future reference. The feelings and comments from respondents were then compiled to identify trends for each location and the overall site.

While conducting surveys it is important that surveyors keep methods consistent to avoid accidental bias. By questioning each respondent in a like fashion, surveyors can collect responses which can be easily compared.

Limitations of Cultural Ecosystem Services Value Mapping
This report is written by students from the Department of Urban Forestry; as such, the authors are knowledgeable on criteria for determining the experience dimension values. As a result of this selection bias, the authors recognize to certain aspects of the urban forest. Randomized feedback from public users allow for the collection of other perspectives, which helped the authors note aspects that users find interesting about Site C3.

Value mapping only captures the quantitative data on a limited scale of one to five.

From observation, respondents who were members of groups were influenced by others' feedback, generally agreement amongst the group was frequently noted.

Weather and season are a limitation of our cultural ecosystem services value mapping. On the day that the value mapping was conducted, it was a sunny, warm, spring afternoon following a dark winter. Because of this, users were maximizing the benefits of the site's landscape. If surveys had been conducted on a cold, rainy day, it is predicted that respondents would have a more negative view of the landscape and may not have been outside using the services. The surveys were also conducted in early March when deciduous trees remain leafless; respondents who were indifferently or not happy/not good cited the leafless trees and lack of greenery as the reasoning for their responses. To avoid these limitations in future surveys, surveyors should consider surveying over a long period of time. This will also highlight the benefits of the site based on seasons, which will be useful in determining proper planning and management recommendations.

Results and Analysis
Authors' Value Mapping
Appendix E illustrates the authors' average ranking of the six experience classes. Results demonstrated that subzone A, the plot east to the RSHDC, ranked 4.3 out of five in species richness. Species richness is the "number of species present in a sample, ecological community… or any defined spatial unit" (Veech, 2018, p. 287). The authors' prior knowledge of tree species distribution mapping during the writing of *Inventory Report* (Martin et al., 2020) contributed to their responses. Examples of tree species in this subzone include *Sequoiadendron giganteum, Acer circinatum, Cupressus nootkatensis* and *Thuja plicata,* compared to other subzones with limited diversity, such as subzone E which has a monoculture of *Quercus robur* (Martin et al., 2020).

Site C3 has low cultural significance at an overall average of 2.93. However, there are three notable subjects that showcase cultural significance. The *Sequoiadendron giganteum* located next to the RSHDC is part of an UBC art project titled "Millennial Time Machine" by artist Rodney Graham (Morantz, 2017). The sequoia symbolizes the "long legacy that UBC has in front of it, and its past" (Morantz, 2017). Subzone C's stone bench in front of the water fountain was constructed in memory of the University of

British Columbia's first president, Frank F. Wesbrook (Doyle & Hart, 2014). The *Sequoiadendron giganteumin* located next to IKBLC was planted as a commemorative tree for UBC's centennial year, as seen on the stone plaque beside the tree (Appendix F). The IKBLC is one of UBC's most culturally and historically significant buildings as it was one of the first buildings to be constructed on the Vancouver campus (University of British Columbia, n.d.). The trees and features surrounding the IKBLC hold some importance; however, these symbols remain unknown to users unless they take a campus tour or seek out information significant sites around the campus.

The authors' value mapping from Subzone B indicated that the grass plot next to the RSHDC had the highest rating of cultural services in four out of six experience dimensions. The grass softscape makes the area ideal for recreation, socializing, refuge, and is aesthetically pleasing, especially on sunny days (a visual of this landscape can be found in Appendix G).

Subzone E, IKBLC facing East Mall, ranked the lowest in five out of six experience dimensions. The permeable path and mature *Quercus robur* surrounded by bare soil did not satisfy species richness and recreation use, nor did the landscape provide adequate space for recreation.

Cultural services related to academics remain low on Site C3. The authors of this report found aesthetics and refuge to be the strengths of this site.

Public Users' Value Mapping

Appendix H shows a map of Site C3 with an overlay of citizen value mapping results. Emoticons represent participants' overall feelings toward a space based on the three predetermined answers. Respondents generally provided positive or little feedback on the urban forest composition of Site C3. All participants surveyed in Subzone B enjoyed the space and had positive comments. Testimony from participants include "since it's a nice day, I enjoy being here. The grass and landscape have been designed very well, it's a nice green space compared to the buildings around the area" and "the area is calm, and I enjoy the openness, it's a simple design. It's a nice place to come alone or with a friend, just to de-stress" (excerpt from field notes, 2020).

On Site E (East Mall), most participants wished to see improvements made to the space. Testimony from these respondents included commentary that the space could be improved by adding more vegetation. Overall, the community members were appreciative of the urban forest surrounding IKBLC and the RSHDC.

Appendix I is a table illustrating the frequency of keywords used by respondents in describing the urban forest. Common themes of grass, diversity, design, and relaxation represent the main attributes community members want and like about the urban forest surrounding IKBLC and RSHDC. "Grass" was a keyword noted in eight of the 30 responses of public users. Respondents associated grass to landscape design and a foundation for recreation, social activities and interactions. On East mall, two members wished to see an increase of evergreen trees to add colour during winter months. The species richness concentration near RSHDC diagonal intersection was references positively by three respondents.

Urban Forest Planning and Management Recommendations

Increasing Community Involvement

Increasing community involvement will promote engagement in Site C3 and aid in determining the expectations of users. Community involvement will also highlight dissatisfaction and current weaknesses of Site C3.

Our principal recommendation is to increase community involvement as we believe that participation and public perception are critical to the further development of cultural ecosystem services at this site. Our cultural ecosystem services value mapping has already gathered preliminary data on the opinions of users. However, this value mapping captures the views and opinions of the public on a specific point in time. To better understand the cultural ecosystem services of this plot, prolonged research is required. An alternative method to ground based ecosystem services mapping could be the use of online surveys, which would allow more users to provide feedback. However, this could potentially limit responses to those who are able to contribute through an online platform. To alleviate this limitation, we suggest the addition of suggestion boxes on Site C3 and scheduled meetings with users; these methods would allow for the collection of information or data from a diverse respondent pool and under different settings. This will help determine the management concerns that are most pressing, helping to aid in the appropriate allocation of resources.

It should be noted that urban forest planning and management should not be limited to community input, as certain urban forest planning and management strategies are only apparent to those with expertise in urban forestry, urban planning, horticulture, or arboriculture.

Adapting to Climate Change Impact

It is the responsibility of urban foresters and municipal arborists to account for climate change impacts when planning future development of the urban forest. Certain native tree species may not be able to survive changes in temperature or precipitation (Langor et al., 2014). Studies suggest that the mean temperature of Metro Vancouver will increase 3.7 degrees Celsius by 2050 (Metro Vancouver, 2016). The i-Tree Eco report shows that most regulatory ecosystem services such as carbon storage, avoidance of runoff, and pollutant absorption are currently provided by *Quercus robur* (i-Tree Eco, 2020c). The ideal growing condition of *Quercus robur* is between seven degrees Celsius to 21 degrees Celsius (Plants for a Future, n.d.). If temperatures consistently exceed this range, as they likely will as a result of climate change, there is a potential for the decrease of regulatory ecosystem services on this site. It is important that urban forest planning and management solution account for the impact that climate change poses on our urban forest.

Management opportunities to address this issue might incudes planting tree species that are habituated to the predicted future climate, as this will help stabilize the urban forest as climate change impacts intensify.

Increasing Greenery of Site C3

We propose an increase in evergreen vegetation on the site. This would serve to improve the year-round aesthetic value of the site, thus increasing the cultural ecosystem services of the site. Evergreen tree species already planted on the site include *Pseudotsuga menziesii* and *Thuja plicata*; however, *Thuja plicata* is not recommended due to its comparatively substantial irrigation requirements. An additional option to use a variety of coloured mulches which will help increase the overall colour scheme of the site. This potentially alleviates public concerns about the colour scheme of the site brought to our attention in the cultural ecosystem services value mapping. However, future research on public views in response to these management solutions will help guide future planning and management strategies to align with public opinion.

Management Strategies for Frequently Trafficked Areas
Soil compaction has been identified as a future area of concern by the authors of this report. Soil compaction can cause a reduction in gas exchange, water infiltration, water storage capacity, and soil porosity, thus being detrimental to plant growth (Brady & Weil, 2010).

Public users were noted to walk over the soil on East Mall to access the IKBLC. This will result in the compaction of the soil. This might also be a safety concern as the soil will become slippery when saturated. By increasing vegetation in this area, we hope to discourage users from traversing across the soil.

Areas of high traffic on the site and areas with improper drainage will be most at risk of soil compaction (Brady & Weil, 2010). A particular area of concern is the grass area as this area sees a high amount of traffic. Soil management strategies for this area may include regular monitoring and the addition of fertilizer to the site to ensure sufficient nutrient availability for plant growth.

Erosion Prevention
Due to the significant gradient of the slope surrounding the ramp approaching the RSHDC, water runoff is a concern. Water runoff in this section of Site C3 will lead to erosion and decrease nutrient availability for plants (Lilly, 2010). The erosion could result in soil washing onto the concrete, which may impact the aesthetic value of the plot. By planting tree species with large root structures, the soil could be stabilized to prevent erosion. Using trees with high water absorption rates would reduce the amount of stormwater runoff as well.

Pest Susceptibility
i-Tree Eco identified 36 pests for “Greater Vancouver A”, the greater location in which Site C3 is categorized (Appendix J: Susceptibility to Pests by Stratum). Based on the inventory data and species composition of Site C3, only 17 of the 36 pests have the potential to directly impact trees in this site. Of the 17 pests with susceptible trees in the site, 12 of the pests target less than four individual trees. This pest management section will focus on pests affecting greater than four individual trees, based on the large gap in parameter values between ‘3 susceptible trees’ and ’12 susceptible trees’ (ex. Winter Moth).

Appendix K shows the five most impactful pests to site C3. Asian longhorned beetle, which has the greatest number of susceptible trees in our plot, has a comparatively lower potential risk when compared to Gypsy Moth, Oak Wilt, or Polyphagous Shot Hole Borer. This significant difference in potential impact and loss is because *Quercus robur* is susceptible to gypsy moth, oak wilt, and polyphagous shot hole borer, but not Asian longhorned beetle (Sinclair & Lyon, 2005; Canadian Food

Inspection Agency, 2016). Based on their age and volume, *Quercus robur* contributes significantly to the ecosystem services of Site C3. Therefore, pest damage resulting in the mortality spiral of *Quercus robur* will be detrimental to the value of Site C3's ecosystem services.

The three species of *Acer* on Site C3 are susceptible to Asian longhorned beetle (Canadian Food Inspection Agency, 2016). Because the *Acer* are juvenile, the total potential structural value loss and potential leaf area loss remain small; thus, the concern for the loss of *Acer* is only due to the significant number of individual trees that would be lost to the pest.

We suggest developing an integrated pest management plan that focuses on preventative measures and monitoring. Proper pruning cuts during the correct pruning season will help reduce the susceptibility (Lilly, 2010). It will be important to develop a monitoring plan to identify pests when they enter the plot, a role that can be undertaken by UBC's soft landscape division. Because of the risk of high structural value loss, there should be low tolerability for these pests before the action threshold is reached and treatments and controls are utilized.

Because our inventory determined that *Acer circinatum* made up 42% of species composition, we suggest that *Acer circinatum* no longer be planted until the composition of Site C3's urban forest is stabilized based on the 30-20-10 model. This could be achieved by planting tree genera with lower composition percentages, such as *Malus fusca* or *Picea sitchensis*.

Addressing Accessibility Concerns

We propose the construction of two new ramps to address the accessibility concerns brought to our attention by a respondent in the RSHDC Diagonal Intersection location during the cultural ecosystem services value mapping. Currently, the west entrance to the IKBLC is not wheelchair accessible. Site users with limited mobility who are entering the IKBLC must do so from the entrance on East Mall. The construction of a ramp to allow access through the main entrance to IKB would aid in increasing the cultural ecosystem service value of the site. The construction of a ramp to the lower area of the grass plot area would allow for access to the pond and large green space at the bottom of the plot. Because of the gradient of the grass plot section, the lower section is the only place with enough flat ground for activities.

However, the construction of a ramp to the lower section of the grass area is a major undertaking. A temporary solution to the accessibility concerns is to extend the open hours of the RSHDC, which has an elevator that accesses the lower section of the grass plot. Currently, the RSHDC is only open from 10 a.m. to 3 p.m. during the week (Residential School History and Dialogue Centre, n.d.). Extending the hours of the center would allow people with limited mobility to access the grass plot. Though this would not allow 24/7 access to the grass plot, it would extend the usability of this area during daytime hours.

We also suggest the construction of additional benches in accessible areas of the green plot so that those unable to access the benches along the slop of the grass plot can still use the area socially.

Increasing Social Value

There is a large concrete area next to the RSHDC noted to have low cultural value by the authors (this area is highlighted in blue on figure 3). To address this issue and improve the social value of this venue, we suggest adding planters and cement ping pong tables, similar to those constructed outside of the Orchard Commons Student Residence. Because of the potential difficulty in watering the flowers in the planters during dry periods, the use of planters with self-contained water reservoirs would a good choice for this site. Adding this area to the list of venues on the *Outdoor Event Bookings* page (UBC Campus and Community Planning, 2020) will additionally increase the visibility of this area as a social venue. To increase the safety of this area, we suggest an increase in lighting, as there are no lights along this stretch and there's limited visibility at night.

Fig. 3: Area of Low Cultural Significance (Google Maps, 2020)

Conclusion

This report covered ecosystem services of Site C3 surrounding the IKBLC and RSHDC, including the grass area of the Library Garden and a significant portion of Learners' Walk. Site C3 has several regulating ecosystem services, including carbon sequestration, regulation of storm water runoff, and pollution regulation. *Quercus robur* contributes the most significantly to the regulating ecosystem services, a result of their large basal area and maturity (i-Tree Eco, 2020b). Site C3's cultural value was noted to be significantly benefited by the grass area, which contributes highly to a sense of community and serenity.

With the contribution of users' opinions, the authors of this report have documented several urban forest planning and management recommendations; the principal recommendation being the continued involvement of community members in the planning process. As UBC Vancouver campus moves into a future of unknowns, largely as a result of climate change, the continued monitoring of the urban forest is crucial. Likewise, the consideration of users should stand at the forefront of future policy and planning decisions, for in the words of Margaret J. Wheatley (2010), "there is no power for change greater than a community discovering what it cares about" (p. 64).

References

Brady, N. C., & Weil, R. R. (2010). *Elements of the Nature and Properties of Soils* (3rd ed.). Upper Saddle River, NJ: Pearson Ag.

Burton, J. (2020). *UFOR101_TreeSurvey* [map file system]. Retrieved from Collector for ArcGIS.

Campus and Community Planning. (2020). *Outdoor Event Bookings.* University of British Columbia. Retrieved from https://planning.ubc.ca/outdoorevents

Canadian Food Inspection Agency. (2016). *Asian Longhorned Beetle Preferred Host Trees.* Government of Canada. Retrieved from https://www.inspection.gc.ca/plant-health/plant-pests-invasive-species/insects/asian-longhorned-beetle/host-trees/eng/1337878437101/1337878521504

Doyle, M., Hart, R., Kam, M., Liem, A., & Viziru, A. (2014, July). *The Presidents of UBC*. Retrieved from https://www.ubc.ca/stories/2014-summer/the-presidents-of-ubc.html

Duddy, A. M. (2019). Using Diversity Guidelines to Enhance Small Stand Sustainability: A Case Study. *Arborist News*, *28*, 30 – 37. Retrieved from https://www.isa-arbor.com/Publications/Arborist-News

Ferrini, F., Konijnendijk van den Bosch, C. C., & Fini, A. (2017). Routledge Handbook of Urban Forestry. Abingdon, OX: Routledge Handbooks.

Guzman, A. T. (2014). *Overheated: The Human Cost of Climate Change.* Oxford Scholarship. doi:10.1093/acprof:osobl/9780199933877.001.0001

i-Tree Eco. (2020a). Susceptibility to Pests by Stratum. *Group 8 i-Tree Project*.

i-Tree Eco. (2020b). *Metadata Report for Group 8 i-Tree Project*.

i-Tree. (2020a). *About* [web page]. Retrieved from https://www.itreetools.org/about i-Tree. (2020b). *i-Tree Eco* [web page]. Retrieved from https://www.itreetools.org/tools/i-tree-eco

i-Tree. (2020c). *i-Tree Ecosystem Analysis: Group 8 i-Tree Project.*

i-Tree. (n.d.) *i-Tree Canopy Factsheet.* Retrieved from www.itreetools.org/resources/content/canopy_factsheet

Langor, D. W., Cameron, E. K., MacQuarrie, C. J. K., McBeath, A., McClay, A., Peter, B., … & Pohl, G. R. (2014). Non-native species in Canada's boreal zone: diversity, impacts, and risk. *Environmental Reviews, 22*, 372 - 420. doi: 10.1139/er-2013-0083

Martin, A., Rueter, A., Phoung, K., Sawada-Tse, E., Yan, H., & Du, Y. (2020). *Inventory Report.* Unpublished report.

Metro Vancouver. (2016). *Climate Projections for Metro Vancouver.* Vancouver, BC: Metro Vancouver. Retrieved from http://www.metrovancouver.org/services/air-quality/AirQualityPublications/ClimateProjectionsForMetroVancouver.pdf

Morantz, E. (2017, October 18). Hidden in Plain Sight: A place of learning. *UBC Life Blog*. Retrieved from https://students.ubc.ca/

Nahuelhaul, L., Ochoa, F. B., Rojas, F., Diaz, G. I., & Carmona, A. (2016). Mapping social values of ecosystem services: What is behind the map? *Ecology and Society,* 21. doi: 10.5751/ES-08676-210324

Naveau, A., Miao, A., Bellis, E., & Ikeda, T. (2017). *UBC 2017 Stadium Neighborhood Tree Inventory Project.* Vancouver, BC. Retrieved from https://sustain.ubc.ca/sites/default/files/seedslibrary/UBC%202017%20Stadium%20Neighbourhood%20Tree%20Inventory%20Project_0.pdf

Office of Housing and Construction Standards. (2014). *Building Access Handbook*. Province of British Columbia. Retrieved from https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/2014_building_access_handbook.pdf

Pietrangelo, A., & Holland, K. (2017). *The Top 10 Deadliest Diseases*. Healthline. Retrieved from https://www.healthline.com/health/top-10-deadliest-diseases

Plants for a Future. (n.d.). *Quercus robur – L.* Retrieved from https://pfaf.org/user/Plant.aspx?LatinName=Quercus+robur

Residential School History and Dialogue Centre. (n.d.) *About*. University of British Columbia. Retrieved from https://irshdc.ubc.ca/

Sinclair, W. A., & Lyon, H. H. (2005). *Diseases of Trees and Shrubs* (2nd ed.). Ithaca, NY: Cornell University Press.

Study. Arborist News, Volume 28, Number 2, 30 – 37.

University of British Columbia. (2018a). *Indigenous Peoples: Language Guidelines.* Vancouver, BC. Retrieved from https://assets.brand.ubc.ca/downloads/ubc_indigenous_peoples_language_guide.pdf

University of British Columbia. (2018b). *UBC Green Building Action Plan: Pathway to a New Positive Campus.* Vancouver, BC. Retrieved from https://planning.ubc.ca/sites/default/files/2019-11/PLAN_UBC_Green_Building_Action_Plan_Full.pdf

University of British Columbia. (n.d.). Building History and Highlights. Retrieved from https://ikblc.ubc.ca/spaces/building-history-and-highlights/

Wheatley, M. J. (2010). *Turning to One Another* (2nd ed.). San Francisco, CA: Berrett-Koehler Publishers.

Appendices

Appendix A

Annual Pollution Removal and Value

This graph displays the annual pollution removal of five pollutants (shown by triangular points) and the value of the pollution removal (shown by bars). Ozone is removed the most, PM2.5 is the second most. This graph comes from the *Group 8 i-Tree Eco Report* (*i-Tree, 2020c*)

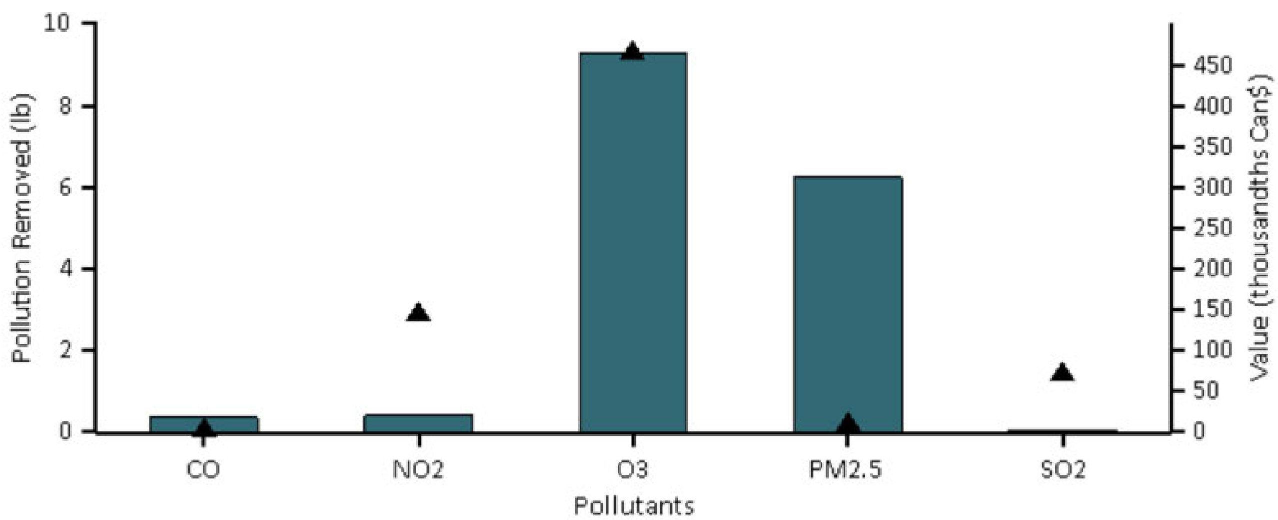
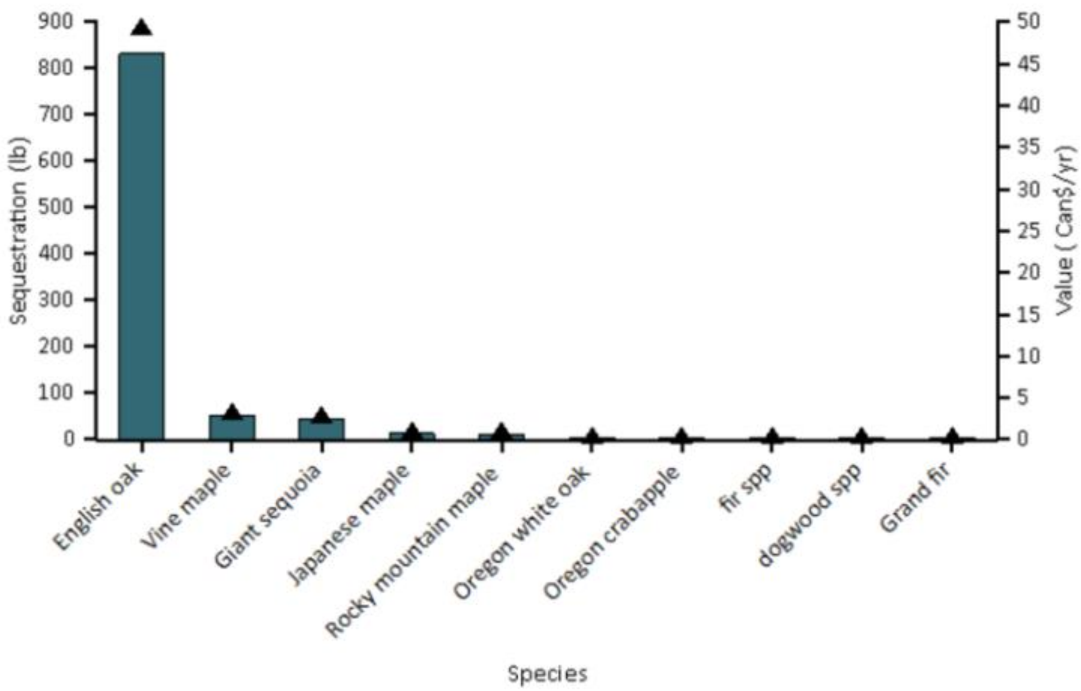


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Group 8 i-Tree Project

Appendix B

Carbon Sequestration and Value

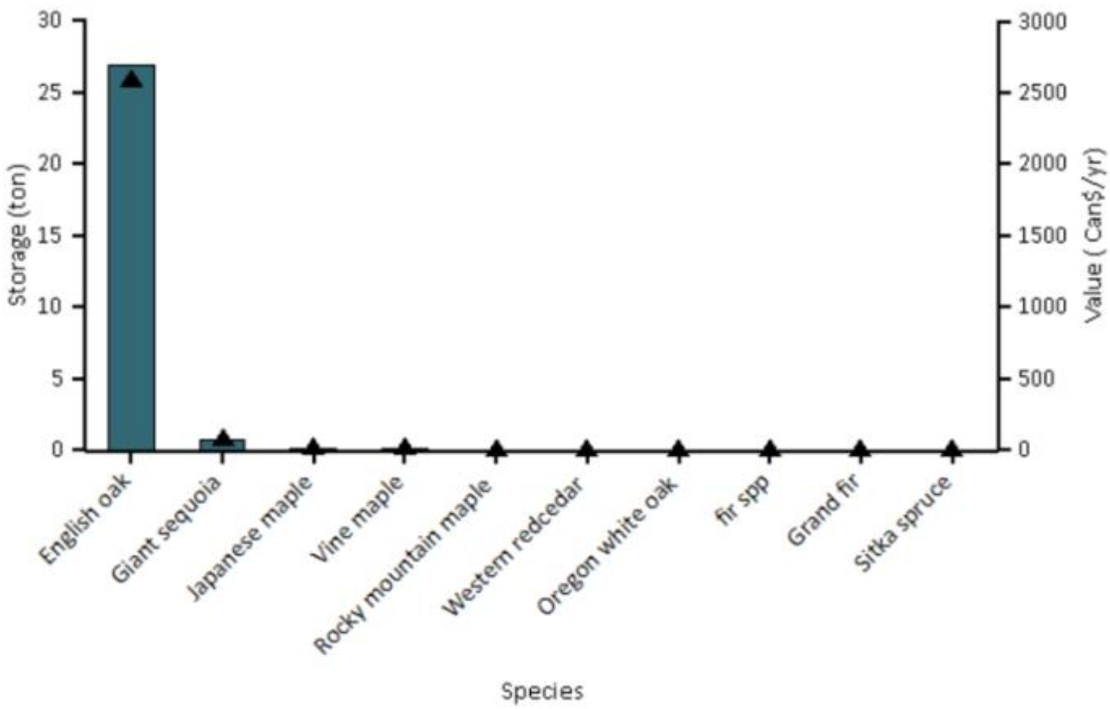
This graph displays the annual carbon sequestration (shown by triangular points) and the value of the carbon sequestration per year (CAD) (shown by bars), divided by tree species. English oak (*Quercus robur*) is the highest contributor to carbon sequestration and has the largest value. This graph comes from the *Group 8 i-Tree Eco Report* (*i-Tree, 2020c*)



Appendix C

Carbon Storage and Value

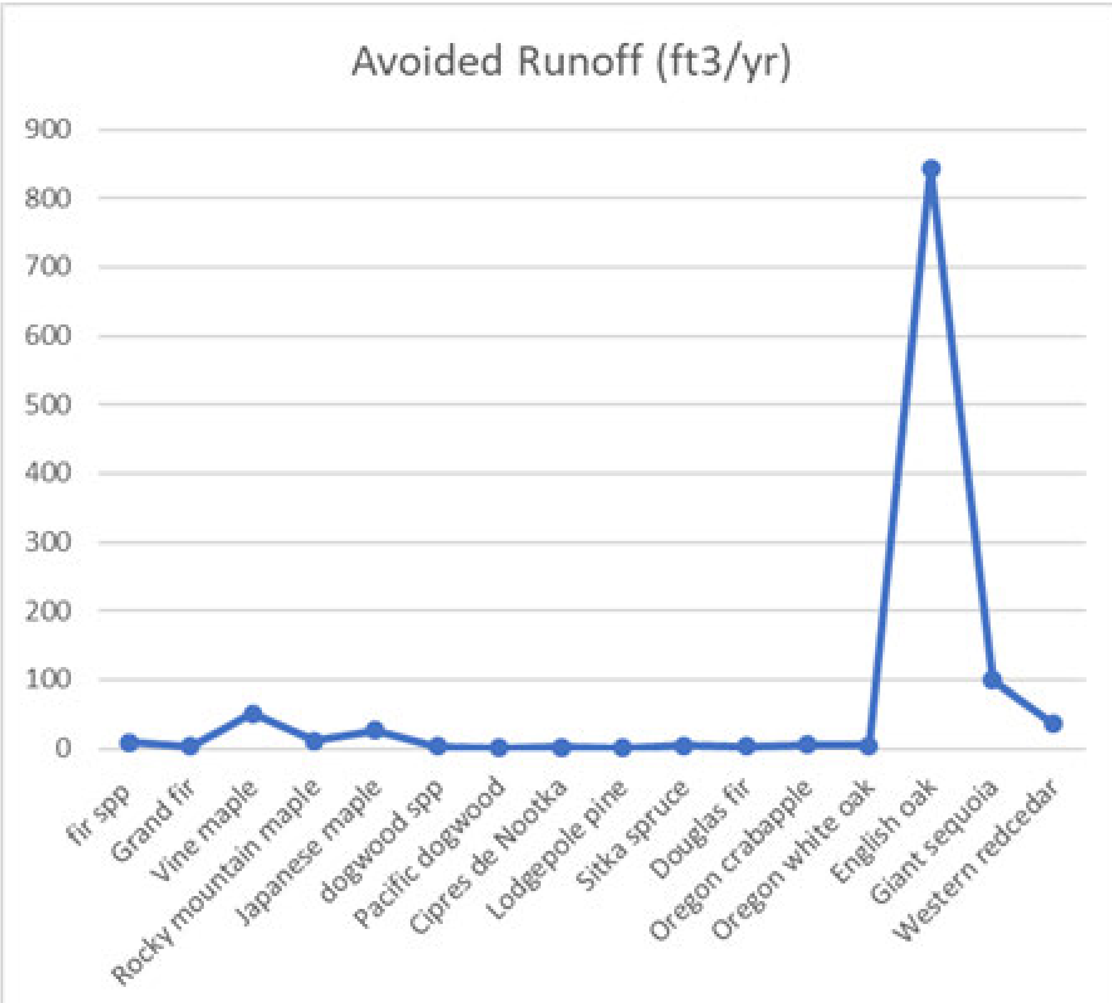
This graph displays the carbon storage (tons) (shown by triangular points) and the value of the carbon storage per year (CAD) (shown by bars), divided by tree species. English oak (*Quercus* robur) stores the most significant amount of carbon, resulting in the largest monetary value of storage. This graph comes from the *Group 8 i-Tree Eco Report* (*i-Tree, 2020c*).



Appendix D

Avoided Runoff by Tree Species

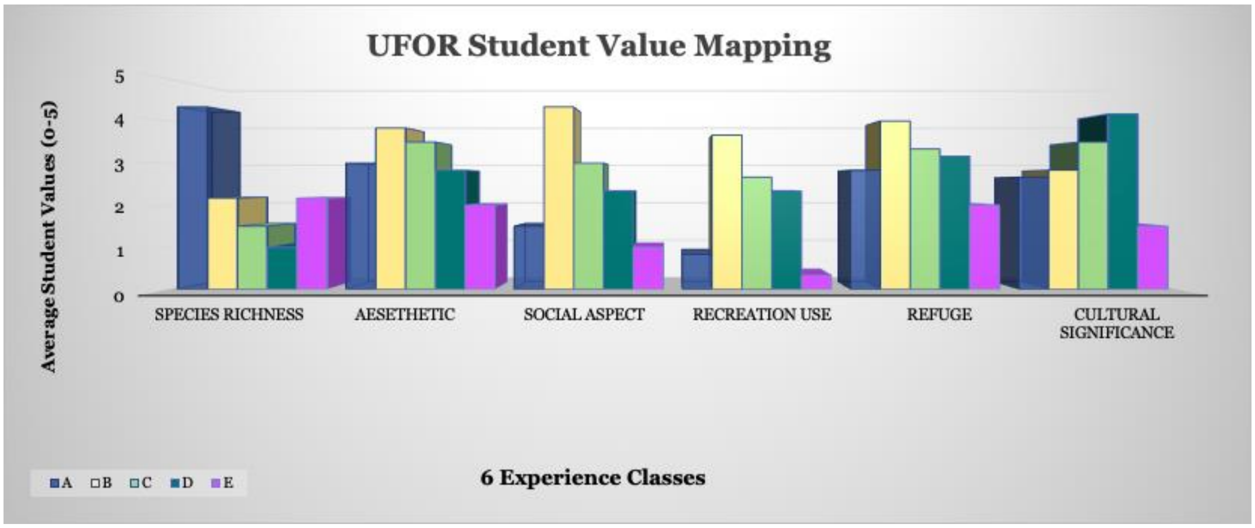
This graph shows the avoided runoff in cubic feet per year, divided by tree species. As seen on the graph, English oak (*Quercus robur*) has the highest avoided runoff per cubic feet per year. This graph is made using data from the *Group 8 i-Tree Eco Report* (*i-Tree, 2020c*).



Appendix E

Authors' Value Mapping

This graph shows the results of the authors' (students') value mapping from the walkthrough of the subzones. It displays the average value assigned to each of the six dimensions in the subzones. A map of the subzones can be seen on *Figure 2* in the report.



Appendix F

Giant Sequoia Plaque

This is a photo of the stone plaque detailing the Centennial Sequoia to the northwest of the IKBLC. This *Sequoiadendron giganteum* was planted in 2015 to celebrate the centennial year of UBC.

Appendix G

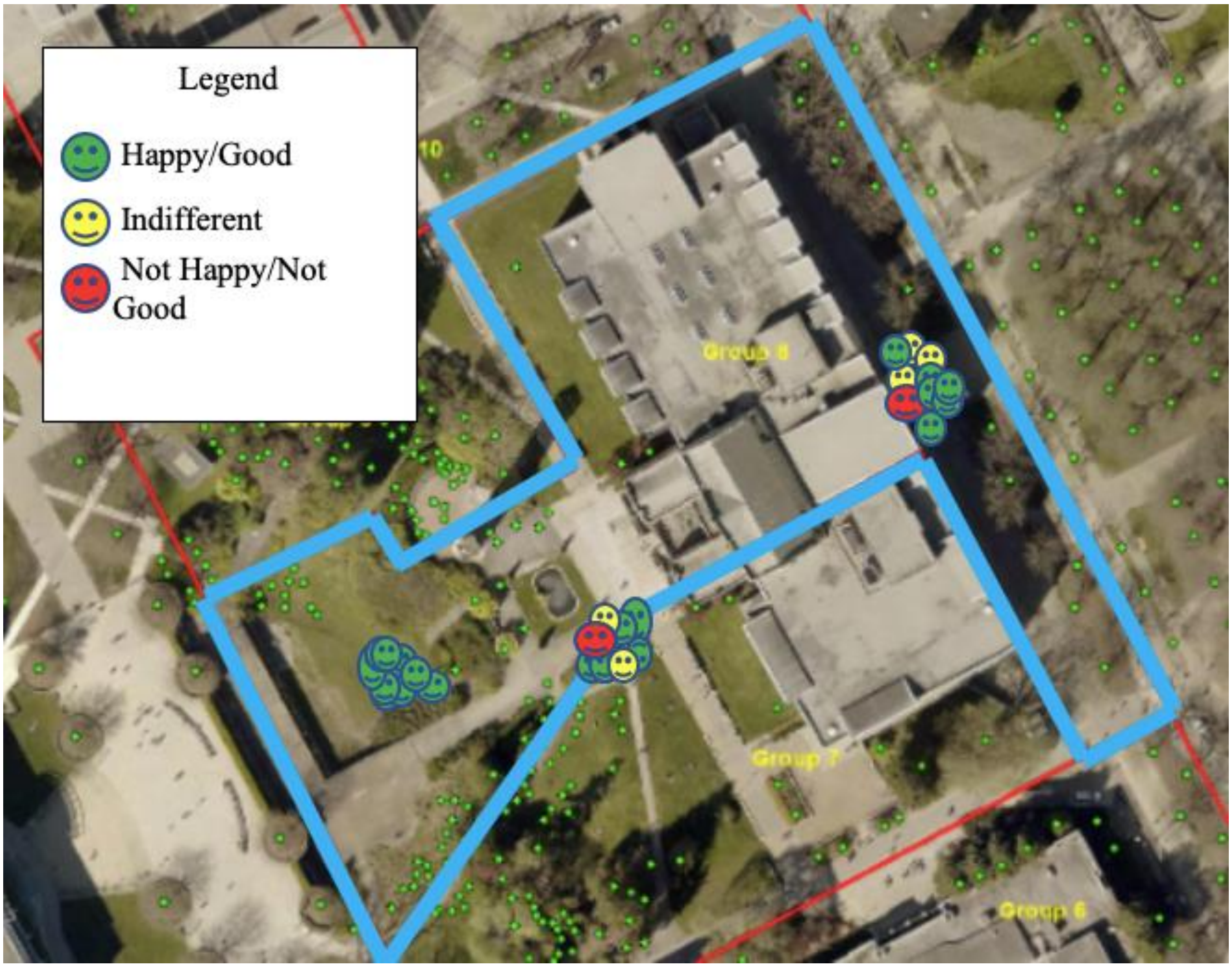
Grass Area Landscape Visual

This is a photo of the grass area adjacent to the RSHDC and west of the IKBLC. The area is frequented by users as a recreational site.

Appendix H

Site C3 with an Overlay of Citizen Value Mapping Results

This map of Site C3 (boundaries indicated in blue) shows the results of our citizen value mapping, as described through the use of emoticons (see "Legend" on map) and is described in the "Cultural Ecosystem Services" section. This map is taken from the ArcGIS software (Burton, 2020).



Appendix I

Frequency of Keywords in Cultural Ecosystem Services Value Mapping

This chart shows the frequency of key words in the commentary provided by respondents.

Location	Keywords	Frequency
IKBLC on East Mall	Grass	0
	Diversity	2
	Design	0
	Relax	1
Grass plot	Grass	2
	Diversity	0
	Design	2
	Relax	2
RSHDC diagonal intersection	Grass	6
	Diversity	3
	Design	2
	Relax	1

Appendix J

Pest Susceptibility by Stratum

This chart shows the susceptibility of trees on Site C3 to certain pests found in “Greater Vancouver A” (i-Tree Eco, 2020a)

Susceptibility to Pests by Stratum

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020-03-17

		Number of Trees		Structural Value (Can$)		Leaf Area (%)		Leaf Area (ac)	
Pest Name	Stratum	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible
Aspen Leafminer	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Asian Longhorned Beetle	Study Area	36	41	2,412	158,455	8.0	92.0	0.1	1.6
Beech Bark Disease	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Butternut Canker	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Balsam Woolly Adelgid	Study Area	3	74	152	160,716	1.0	99.0	0.0	1.7
Chestnut Blight	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Dogwood Anthracnose	Study Area	3	74	176	160,691	0.3	99.7	0.0	1.7
Douglas-fir Black Stain Root Disease	Study Area	1	76	57	160,810	0.3	99.7	0.0	1.7
Dutch Elm Disease	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Douglas-Fir Beetle	Study Area	1	76	57	160,810	0.3	99.7	0.0	1.7
Emerald Ash Borer	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Fir Engraver	Study Area	2	75	108	160,760	0.5	99.5	0.0	1.7
Fusiform Rust	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Gypsy Moth	Study Area	19	58	146,128	14,740	77.6	22.4	1.3	0.4
Goldspotted Oak Borer	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Hemlock Woolly Adelgid	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Jeffrey Pine Beetle	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Large Aspen Tortrix	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Laurel Wilt	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Mountain Pine Beetle	Study Area	1	76	51	160,816	0.0	100.0	0.0	1.7
Northern Spruce Engraver	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Oak Wilt	Study Area	14	63	145,916	14,952	77.1	22.9	1.3	0.4
Pine Black Stain Root Disease	Study Area	1	76	51	160,816	0.0	100.0	0.0	1.7
Port-Orford-Cedar Root Disease	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Pine Shoot Beetle	Study Area	2	75	108	160,759	0.3	99.7	0.0	1.7
Polyphagous Shot Hole Borer	Study Area	13	64	145,842	15,025	76.8	23.2	1.3	0.4
Spruce Beetle	Study Area	2	75	119	160,748	0.4	99.6	0.0	1.7
Spruce Budworm	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Sudden Oak Death	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Southern Pine Beetle	Study Area	3	74	171	160,697	0.4	99.6	0.0	1.7
Sirex Wood Wasp	Study Area	1	76	51	160,816	0.0	100.0	0.0	1.7
Thousand Canker Disease	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7

Page 1

Susceptibility to Pests by Stratum

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020-03-17

		Number of Trees		Structural Value (Can$)		Leaf Area (%)		Leaf Area (ac)	
Pest Name	Stratum	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible	Susceptible	Not Susceptible
Winter Moth	Study Area	12	65	611	160,257	2.2	97.8	0.0	1.7
Western Pine Beetle	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
White Pine Blister Rust	Study Area	0	77	0	160,867	0.0	100.0	0.0	1.7
Western Spruce Budworm	Study Area	2	75	108	160,760	0.5	99.5	0.0	1.7
All Pests	Study Area	65	12	149,096	11,772	87.6	12.4	1.5	0.2

Note: this table tells the potential pest risk rather than actual pest impact

Page 2

Appendix K

Five Most Impactful Pests to Site C3

This chart details the five most impactful pests to Site C3, noting number of susceptible trees and the result of an impact on the urban forest. This chart was made using data from (i-Tree Eco, 2020a)

Pest Name	**Number of Susceptible Trees**	**Potential Structural Value Loss (Can$)**	**Potential Leaf Area Loss (%)**
Asian Longhorned Beetle	36	2 412	8.0
Gypsy Moth	19	146 128	77.6
Oak Wilt	14	145 916	77.1
Polyphagous Shot Hole Borer	13	145 842	76.8
Winter Moth	12	611	2.2

Appendix L

Authors' Value Mapping Numbers

This spreadsheet shows the individual markings of each author for individual subzones based on six experience dimensions. The totals for each cell were then averaged amongst the group, and the overall ecosystem services were averaged from the 5 subzones (A-E).

Student:		Diversity	Aesthetics	Social Aspect	Recreation	Refuge	Cultural Significance
Totals	A	4.33333	3	1.5	0.8333333	2.8333	2.666666667
	B	2.16667	3.833333	4.333333333	3.6666667	4	2.833333333
	C	1.5	3.5	3	2.6666667	3.3333	3.5
	D	1	2.833333	2.333333333	2.3333333	3.1667	4.166666667
	E	2.16667	2	1	0.3333333	2	1.5
Lily	A	4	5	2	1	4	3
	B	2	4	4	3	3	1
	C	3	5	3	3	5	2
	D	1	2	2	2	4	3
	E	2	1	1	0	3	1
Han	A	5	2	1	1	2	3
	B	3	3	3	5	5	4
	C	1	5	1	1	2	4
	D	0	4	1	3	1	5
	E	3	3	1	0	2	3
Karman	A	4	2	3	1	5	4
	B	2	5	5	4	5	3
	C	1	4	3	4	5	5
	D	0	3	2	3	4	5
	E	2	3	0	0	3	3
Eakin	A	4	3	1	1	3	1
	B	1	4	5	5	5	3
	C	2	4	4	5	4	4
	D	3	4	4	4	4	4
	E	2	1	2	2	1	0
Alex	A	4	2	2	1	3	2
	B	2	3	4	2	3	3
	C	1	1	3	2	4	2
	D	1	3	2	1	5	4
	E	2	2	1	0	2	1
Anya	A	5	4	0	0	0	3
	B	3	4	5	3	3	3
	C	1	2	4	1	0	4
	D	1	1	3	1	1	4
	E	2	2	1	0	1	1

	Diversity	Aesthetics	Social Aspect	Recreation	Refuge	Cultural Significance
Averages of A to E	2.23	3.03	2.43	1.97	3.07	2.93

Appendix M

i-Tree Canopy Data

This shows the data by individual points used by i-Tree Canopy to produce the estimated canopy cover of 24% (*i-Tree Canopy, version 6.1,* 2020).

Id,Cover Class,Description,Latitude,Longitude

1,Non-Tree,All other surfaces,49.267201506381,-123.25171277301

2,Non-Tree,All other surfaces,49.267917935592,-123.25344356887

3,Tree,"Tree, non-shrub",49.266928590214,-123.2536887116

4,Non-Tree,All other surfaces,49.267052746567,-123.25264493508

5,Non-Tree,All other surfaces,49.267121417392,-123.25287941114

6,Non-Tree,All other surfaces,49.267429808041,-123.25306282144

7,Non-Tree,All other surfaces,49.267236661885,-123.25315454565

8,Non-Tree,All other surfaces,49.267416322722,-123.25272308035

9,Non-Tree,All other surfaces,49.267326433183,-123.2529465301

10,Non-Tree,All other surfaces,49.267322345272,-123.25317343272

11,Non-Tree,All other surfaces,49.267843264518,-123.25339496063

12,Tree,"Tree, non-shrub",49.267936136847,-123.25245638405

13,Non-Tree,All other surfaces,49.266955941944,-123.25379293943

14,Non-Tree,All other surfaces,49.267463015619,-123.25325070382

15,Non-Tree,All other surfaces,49.267721779387,-123.25232156005

16,Non-Tree,All other surfaces,49.267379646068,-123.25219805878

17,Non-Tree,All other surfaces,49.267392424306,-123.25307907393

18,Tree,"Tree, non-shrub",49.267836174067,-123.25231382497

19,Non-Tree,All other surfaces,49.267049741355,-123.25416096256

20,Non-Tree,All other surfaces,49.267388842559,-123.25250179873

21,Non-Tree,All other surfaces,49.267222152725,-123.25173401431

22,Non-Tree,All other surfaces,49.267995427813,-123.25280006135

23,Non-Tree,All other surfaces,49.267548081111,-123.25258345491

24,Non-Tree,All other surfaces,49.267009003132,-123.25359862632

25,Tree,"Tree, non-shrub",49.267269789689,-123.25186012217

26,Non-Tree,All other surfaces,49.26715673988,-123.25268575667

27,Non-Tree,All other surfaces,49.268111090705,-123.25311602067

28,Tree,"Tree, non-shrub",49.267396948954,-123.2520417355

29,Non-Tree,All other surfaces,49.267324676324,-123.25388453009

30,Non-Tree,All other surfaces,49.267412280073,-123.25233137117

31,Non-Tree,All other surfaces,49.267470085163,-123.25269118574

32,Non-Tree,All other surfaces,49.267227844863,-123.25268297781

33,Non-Tree,All other surfaces,49.267231901036,-123.25210761036

34,Tree,"Tree, non-shrub",49.267245277687,-123.25175146785

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36,Non-Tree,All other surfaces,49.267943793731,-123.25322465846

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38,Non-Tree,All other surfaces,49.267716297661,-123.2524877578

39,Tree,"Tree, non-shrub",49.268236782545,-123.25263724463

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41,Tree,"Tree, non-shrub",49.26692939807,-123.25354304731

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54,Tree,"Tree, non-shrub",49.266949878956,-123.25357778318

55,Tree,"Tree, non-shrub",49.267277823957,-123.25443677645

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57,Tree,"Tree, non-shrub",49.267204657224,-123.25352722102

58,Non-Tree,All other surfaces,49.267980725305,-123.25304828135

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60,Non-Tree,All other surfaces,49.267148855184,-123.25212084571

61,,,49.267140262675,-123.25232087973

Appendix N

Benefits Summary of Trees by Species

This shows the benefits of trees by species (*i-Tree Canopy, version 6.1,* 2020).

Benefits Summary of Trees by Species

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020-03-17

i-Tree Eco

Species	Trees	Carbon Storage		Gross Carbon Sequestration		Avoided Runoff		Pollution Removal		Structural Value
	Number	(ton)	(Can$)	(ton/yr)	(Can$/yr)	(ft^3/yr)	(Can$/yr)	(ton/yr)	(Can$/yr)	(Can$)
fir spp	2	0.01	0.87	0.00	0.21	8.21	0.54	0.00	0.01	101.14
Grand fir	1	0.01	0.79	0.00	0.16	2.66	0.18	0.00	0.00	50.57
Vine maple	30	0.10	10.56	0.03	2.98	50.62	3.33	0.00	0.04	1,543.98
Rocky mountain maple	4	0.02	2.56	0.01	0.71	11.44	0.75	0.00	0.01	205.86
Japanese maple	2	0.11	11.66	0.01	0.73	26.13	1.72	0.00	0.02	662.60
dogwood spp	2	0.00	0.32	0.00	0.17	2.79	0.18	0.00	0.00	117.45
Pacific dogwood	1	0.00	0.02	0.00	0.03	0.27	0.02	0.00	0.00	58.72
Cipres de Nootka	1	0.00	0.12	0.00	0.02	1.65	0.11	0.00	0.00	55.51
Lodgepole pine	1	0.00	0.13	0.00	0.05	0.50	0.03	0.00	0.00	51.22
Sitka spruce	2	0.00	0.47	0.00	0.14	4.43	0.29	0.00	0.00	119.49
Douglas fir	1	0.00	0.18	0.00	0.01	3.34	0.22	0.00	0.00	57.09
Oregon crabapple	5	0.00	0.33	0.00	0.22	4.82	0.32	0.00	0.00	212.06
Oregon white oak	1	0.01	1.34	0.00	0.28	3.87	0.25	0.00	0.00	73.33
English oak	13	25.85	2,694.18	0.44	46.20	843.15	55.50	0.01	0.63	145,842.38
Giant sequoia	2	0.77	79.99	0.02	2.48	98.91	6.51	0.00	0.07	11,202.22
Western redcedar	9	0.02	2.25	0.00	0.08	35.62	2.35	0.00	0.03	513.84
Total	**77**	**26.92**	**2,805.78**	**0.52**	**54.49**	**1,098.43**	**72.31**	**0.01**	**0.82**	**160,867.47**

Page 1

Benefits Summary of Trees by Species

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020-03-17

i-Tree Eco

Carbon storage and gross carbon sequestration value is calculated based on the price of Can$104.21 per ton.
Due to limits of available models, i-Tree Eco will limit carbon storage to a maximum of 7,500 kg (16,534.7 lbs) and not estimate additional storage for any tree beyond a diameter of 254 cm (100 in). Whichever limit results in lower carbon storage is used.
Avoided runoff value is calculated by the price Can$0.066/$ft^3$. The user-designated weather station reported 46.4 inches of total annual precipitation. Eco will always use the hourly measurements that have the greatest total rainfall or user-submitted rainfall if provided.
Pollution removal value is calculated based on the prices of Can$1,347.90 per ton (CO), Can$100.10 per ton (O3), Can$14.08 per ton (NO2), Can$4.98 per ton (SO2), Can$3,600.32 per ton (PM2.5).
Structural value is the estimated local cost of having to replace a tree with a similar tree.
A value of zero may indicate that ancillary data (pollution, weather, energy, etc.) is not available for this location or that the reported amounts are too small to be shown.

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Appendix O

Summary of *i-Tree Ecosystem Analysis: Group 8 i-Tree Project*

This shows the summary of *i-Tree Ecosystem Analysis: Group 8 i-Tree Project* (*i-Tree Canopy, version 6.1, 2020*).

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Group 8 i-Tree Project urban forest was conducted during 2020. Data from 77 trees located throughout Group 8 i-Tree Project were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 77
- Tree Cover: 22.76 thousand square feet
- Most common species of trees: Vine maple, English oak, Western redcedar
- Percentage of trees less than 6" (15.2 cm) diameter: 77.9%
- Pollution Removal: 13.8 pounds/year (Can$0.82/year)
- Carbon Storage: 26.92 tons (Can$2.81 thousand)
- Carbon Sequestration: 1046 pounds (Can$54.5/year)
- Oxygen Production: 1.394 tons/year
- Avoided Runoff: 1.098 thousand cubic feet/year (Can$72.3/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Structural values: Can$161 thousand

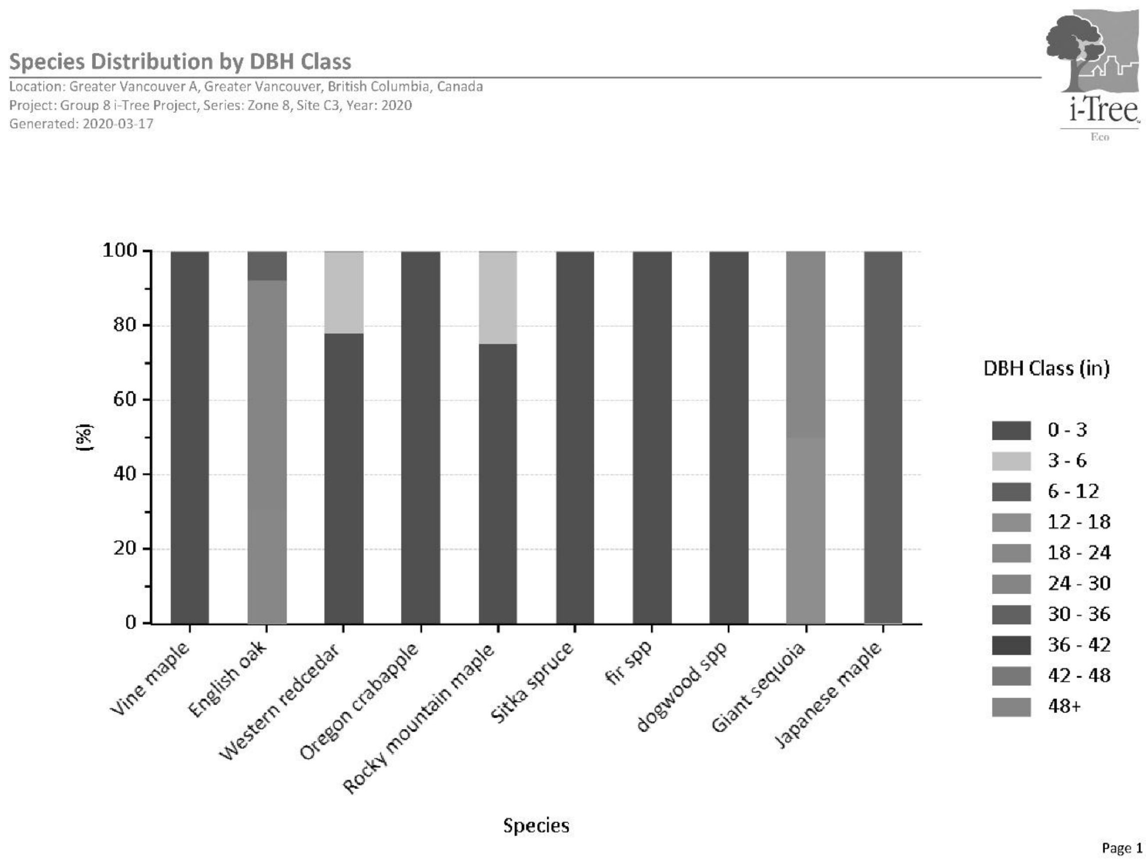
Ton: short ton (U.S.) (2,000 lbs)
Monetary values Can$ are reported in Canadian Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

Appendix P

Species Distribution by DBH Class

This shows the distribution of DBH classes by species (*i-Tree Canopy, version 6.1,* 2020).



Appendix Q

Project Metadata

This section shows the summary of project metadata from *i-Tree Ecosystem Analysis: Group 8 i-Tree Project* (*i-Tree Canopy, version 6.1,* 2020).

Metadata Report For:

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020-03-17

i-Tree Eco v6.0.19
Project created: 2020-03-16
Project location: C:\Users\alexj\Documents\UBC\UFOR\Assignment 2\Uploaded to Google Drive \Group8_iTree.ieco
Model HAS been run

Project Type: Complete Inventory

- Project: Group 8 i-Tree Project
- Series: Zone 8, Site C3
- Year: 2020
- 77 trees

Project Info:

- Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
    - Leaf on day (day of year, 1 - 365, when frost ends): 122
    - Leaf off day (day of year, 1 - 365, when frost begins): 285
    - Frost-free days: 163
    - Longitude: -123.06504389
    - Latitude: 49.3668227726
    - Elevation: 2,398.3 (ft)
- Area: Not configured (Strata check box must be checked in Data Collection Options and proper area entered in Project & Strata Area form)
- Population: 16,133
- Study area is treated as Urban: Yes
- Units: Metric

Pollution Details:

- Year: 2010

CO	O3	NO2	SO2	PM2.5	Location	Station ID
				Yes	British Columbia, Canada	100121
Yes	Yes	Yes	Yes		British Columbia, Canada	100132

Weather Station Details:

- Year: 2010
- USAF: 718920
- WBAN: 99999
- Name: VANCOUVER INTL

* see avoided runoff report for annual precipitation total used for analysis

Benefit Prices:

- Electricity Can$ (CAD)/kWh: 0.10 (Eco default value: 0.10 for 2012)
- Fuels Can$ (CAD)/Therm: 1.79 (Eco default value: 1.79 for 2012)
- Carbon Can$ (CAD)/ton: 104.21 (Eco default value: 104.21 for 2016)

Page 1

Metadata Report For:

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group 8 i-Tree Project, Series: Zone 8, Site C3, Year: 2020
Generated: 2020 03 17

- Avoided Runoff Can$ (CAD)/gallon: 0.0088 (Eco default value: 0.0088 for 2004)

Models:

- Forecast v6.0.19
- UFORE-D v1.1.0

Processing History:

Date/Time	File Name	Retrieved
March 16, 2020 11:24 PM	002_02_014_00364_Group8_iTree.eco2020_3_16_84279.zip	No

Report Availability

- Formatted Reports
    - Written Report
    - Composition and Structure
        - Structure Summary
            - By Species
            - By Stratum and Species
        - Population Summary
            - By Species
            - By Stratum
            - By Stratum per Unit Area (Unavailable: "Strata/Area" not checked)
            - Public and Private by Stratum (Unavailable: "Public/private" not checked)
            - Street Trees by Stratum (Unavailable: "Street tree/non-street tree" not checked)
        - Species Distribution
            - By DBH Class (chart)
            - By DBH Class (vertical table)
            - By DBH Class (horizontal table)
            - By DBH Class and Stratum (vertical table)
            - By DBH Class and Stratum (horizontal table)
        - Importance Values
            - By Species
        - Diversity Indices (Unavailable for this project type or location)
            - By Stratum (Unavailable for this project type or location)
        - Species Range
            - Native Status by Stratum
        - Condition
            - By Species
            - By Stratum and Species
        - Crown Health
            - By Species
            - By Stratum and Species
        - Leaf Area
            - By Stratum
            - By Stratum per Unit Area (Unavailable: "Strata/Area" not checked)
        - Leaf Area and Biomass
            - Of Shrubs by Stratum (Unavailable for this project type or location)
            - Of Trees and Shrubs by Stratum

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Ecosystem Services Assessment

Zone 9

Tanner Wick - [redacted]
Marquita Zollmann - [redacted]
Alex Ferreira - [redacted]
Sophia Brunoro - [redacted]
Mitchell Wong - [redacted]
Sophie Damian - [redacted]

Contributions

Tanner - Title Page/Regulating Ecosystem Services

Marquita - Introduction/some formatting

Alex - Urban Forest Planning and Management recommendations/some formatting and editing

Sophia - Cultural ecosystem services and Value mapping, editing

Sophie - Cultural ecosystem services and value mapping.

Mitchell - Site Description, editing

Introduction

This assignment built upon data collected during the tree inventory to provide shareholders for this area with information on the ecosystem services provided as well as future management recommendations. By surveying students on campus as well as using tools such as iTree, we were able to examine the benefits of the ecosystem services in more depth than in the previous report. This gave us a better idea of the role this plot of urban forestry provided on the UBC campus. Combining this information with the data collected to help with tree monitoring, we were able to determine management strategies that would best benefit our plot. The tree inventory and assessment we had previously done on all 55 trees in the area is crucial to the ongoing monitoring of the site. By repeating the tree monitoring in future years it can be compared to the data compiled in this project to inform on how well management strategies are working and any change within the trees of our plot.

Going into more detail on ecosystem services was important because not only were we able to assess the area for potential areas of improvement, but we were able to receive feedback from the UBC community of the importance of having greenspaces on campus. Although this plot was relatively small in comparison to some of the others, it was evident from our surveys that it had a positive impact on students and faculty. Furthermore, this second assessment of our area allowed our team to really reflect on the impact greenspaces have on each of us personally, and we hope others will use the data collected to ensure the community will continue to benefit from these areas.

Figure 1: Clock tower and surrounding plaza before renovation in 2016.

Site description

Zone 9 is located next to the Ladner Clock Tower on the North side of the UBC campus. It is in between the Irving K. Library and the Koerner Library. The official title of zone 9 is the Library garden, however, it can also be considered as UBC's central park due to the area being in a high traffic part of UBC and many people walk through, or past, the Library garden daily. Zone 9 is only the Northern portion of the

Library garden and the overall percent tree cover is 54%. This zone does not cover as much land as the other zones around campus, however, it consists of many trees within close proximity of each other. Since the trees are very close to each other, the foliage of the trees overlap a lot. This zone also consists of approximately 35% understory/shrub layer. This layer has portions that are in open areas and are uniform; as well as underneath the trees partially covered by shade. In 2016, the gardens in this zone have gone through recent landscape redesign (Shanel, 2015). This redesign has made the space feel more natural with many trees and shrubs compared to the rest of the campus (Shanel, 2015). To pay homage to the unseeded territory of the Musqueam People, the zone has also been redesigned to remember their legacy and history (Shanel, 2015).

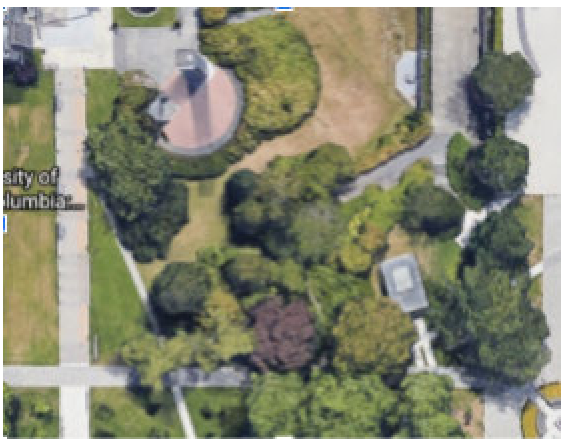


Figure 2: Aerial photograph of zone 9.

The land use type of zone 9 is an Institutional park zone. Students and others can use this space for relaxation under the tree canopy. However, this zone can also be classified under the “other” category due to the fact that it has other purposes that students, faculty, and the community may use the space for. One reason why the zone's land use type is also considered to be “other” is because of the modern art piece in the Northwest corner. The art piece is in a glass box under a cement slab. The art piece is an old-fashioned carriage with an old-fashioned camera inside of it. The art piece is designed by Rodney Graham and it uses the camera to focus on a tree within zone 8 and it creates an amazing image of the tree. When looking through the camera, the tree appears to be growing upside down. Despite the space being in the middle of the UBC campus, the zone consists of a lot of wildlife, such as: squirrels, birds, and insects. The most common residents of this space would be squirrels and birds because there are a lot of trees that they can use for habitat and food sources. Within this zone, there is also a small pond that acts as another mini-ecosystem. In the pond, there are a variety of different bacterias and microorganisms. With all of the trees and the pond being very close together, this zone is a perfect place for wildlife to live and find nutrients. When we were at the zone, we did not see a lot of squirrels but we saw a few birds flying around, however, when less people were on campus and as the sun set, more wildlife was present at the zone.

At zone 9, there are two main gravel paths. One path borders the south end of the plot and allows students and other citizens to quickly walk to their destination or take a shortcut. The other path splits into multiple mini-pathways diagonally through the zone between the trees. Besides the gravel pathways, there are also many cement walkways on the North, East, and West sides of the zone. The zone is in a very high traffic area of the campus so these walkways/pathways are used constantly everyday. Students are the main users of this area because it is a great area to relax and walk around in between class times. Many students, faculty members, local community members, and tourists use this area for study sessions or to just sit and have lunch. It is also a great area for photographers to take many nature photos, as we have seen a couple of times while at the zone. Though our zone 9 is very small, there are many wonderful trees and history allowing it to stand out from the rest of the gardens in UBC.

<ins>Cultural Ecosystem Services</ins>

The data collected from the value mapping indicated that people overall had extremely positive reactions regarding our zone. The overall consensus about the area was that it was very peaceful and a nice break from the hecticness of classes. Out of the multiple people who we interviewed, only a handful of them were neutral about the area and no one had a negative response. The data collected from our own personal response was relatively consistent with each member in the group.

Figure 3: Rodney Graham Millennium Sculpture Pavilion on Northwest corner of Zone 9.

In terms of Richness of Species the space was decently compact and full of different organisms arraying from tiny microbes in the small pond to towering cedar trees and a variety of things in between. On the scale from 1-5, the richness of species averaged about three or four. Overall, the amount of different species of trees varied between one to four trees per each species and a total of 19 species. The Thuja plicata and Acer circinatum were very abundant, having 13 and 9 trees in the area. There was a large amount of biodiversity in trees, however, there was a lesser amount of animals. With there being only a handful of mammals such as squirrels and raccoons and some species of birds. Ultimately, the zone was rich in a diverse array of different organisms contributing to the richness of species.

The social aspect of this zone is to obtain the experience of an organized and entertaining place for people to come together with other people for the enjoyment of social interactions and nature. The zone's noise levels were quite calm, due to the sounds of birds chirping and the peaceful sounds of wind rustling branches as it provided a gentle breeze for those passing by the zone. The values were different in this zone in a social aspect as it was more individual. This place did not provide a field for playing sports or a playground, it simply had one bench in the middle and a winding path making it feel as it was a place to wonder but not stay for too long.

When speaking in terms of aesthetics, the space could use some improvement cleaning up and trimming some shrubs and fallen tree litter. One man also suggested that the placement of certain rocks could have been placed more purposefully, rather than “unorganized and had no direction in placement”. Answers were also dependent on where the person was from originally.

For example, one woman from the greater Ontario area said that the space was very nice because

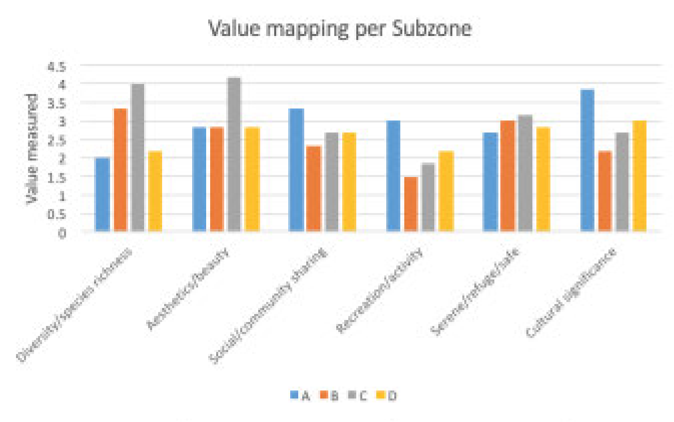


Figure 4: Multi-bar graph showing value mapping throughout zone 9.

it was completely different and uncommon to have urban design within a university campus, where she was from. Compared to that of a girl who was from British Columbia and lived there her entire life, suggesting that we add more flower- like plants to add colour and contrast the dull green and brown of the trees. Of course, both of these opinions are completely subjective depending on personal preferences and what they are normally exposed to. The rating given to the aesthetics of the zone ranged anywhere between a 2-4 depending on the person. Nonetheless, as people expressed, when asked what they thought of the space, the overall opinion was that they enjoyed it and thought it was peaceful.

The zone was very serene and peaceful considering its location is in between two major hubs on campus. Based directly between Buchannan and IKB library, one would expect this area to be buzzing with people, however this was not the case. Many of those walking through the path were just taking it because they enjoyed the area, rather than it being a shortcut or quick route to get from point A to point B. From the information collected by those passing by, people often said that the path was so quiet and nice, being the main reason why they enjoyed taking it. Once again people stated that the space was relaxing and a calming break from the hustle of everyday life of classes. The overall rating for the area was on average a four or five, as the general consensus was that the area was very peaceful. Due to the shade of the trees allowing some light in, those walking through had the ability to be out of harsh direct sunlight and enjoy the nature surrounding them.

The main cultural values that can be determined are the social and spiritual aspects which people associate with nature. Our zone has a trail cutting through the middle which students, faculty, and staff can use to cut through during their busy days. In the middle of the path is a bench allowing some to take a break from their day and just sit and enjoy nature. This also contributes to social benefits because it enables people to come together and take pleasure in the scenery around them. While the data was being collected, we also witnessed people walking in groups, indicating that this

Figure 5: Clock Tower and surrounding area at night.

space is often correlated with social interactions. In our zone there was an old landmark on UBC's Vancouver campus. This artifact is called the Ladner Clock Tower, it was completed in 1968. The history behind the tower is that it was a gift from Leon J. Ladner, Ladner wanted the "clock tower to serve the purpose as an inspiration to UBC students: *When that clock tower is completed and the clock rings out the passing of each hour, I hope it will remind the young students that not only does time go fast, but that the hours at our university are very precious and the use of those hours will seriously affect the success, the happiness and the future of their lives."* (Wodarczak, 2013) Overall the clocktower has huge cultural significance for UBC as a whole, because it brings students together.

The zone did not score very high in terms of refuge for those in our group. The data ranged from zero to three. The main source of refuge comes from the trees. They allowed for protection from direct sunlight due to the semi-thick canopy. Although it provides shade, the trees do not allow for a huge protection of rainfall, which is very common here in Vancouver. There was also a single lamp allowing for some light when it gets dark at night. There was also one bench located in the middle of the path, allowing for a few people to take a seat and enjoy the scenery. Other than that, however, the main source of refuge would be the break that people can have from reality when they enter through the wooded area.

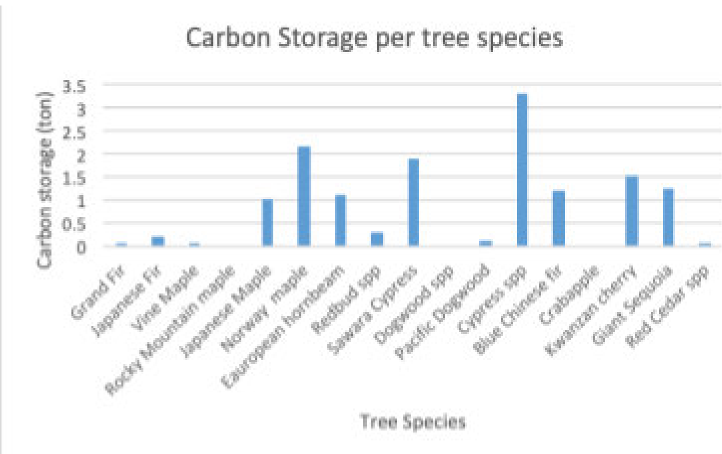


Figure 6: Bar graph showing carbon storage per tree species in zone 9.

Regulating Ecosystem Services

Regulating ecosystem services are the benefits gained from the natural management practices within an ecosystem. This can be anything from water purification to climate regulation to pollination, along with many more. The main services that zone 9 focuses on are carbon storage, carbon sequestration, stormwater runoff, erosion, and climate regulation. I-Tree Eco is where we input our data from Assignment 1 to have it create our regulating services values, along with all of our graphs and tables. I-Tree Eco also showed the structural value, which is based off of the same measurements as regulating services. Our group also looked into how tree size and structure affected regulating services. Tree size means more biomass which greatly affects carbon storage and stormwater regulation, while the rest of the regulating services are affected to a lesser degree. The structure or type of the tree affects storm water runoff, climate regulation, and to a lesser extent carbon sequestration and carbon storage. A large/mature tree has the same effect in regulation services as approximately 100-200 juvenile trees of the same type. This discrepancy is due to the fact that regulating services become more pronounced and build up over the lifespan of the tree.

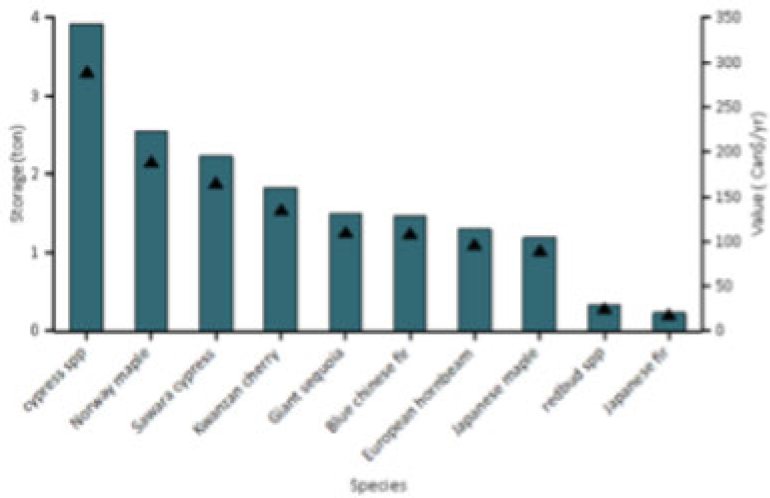


Figure 7: Carbon storage per tree species with monetary value.

Out of the main regulating services within zone 9, carbon storage was overall the highest in monetary value sitting at $1,469.02 which equaled 14.1 tons of carbon for the total zone. This value was the overall combination of our trees acting as a carbon sink. A carbon sink is an area where carbon is stored from the atmosphere within the earth reducing the overall amount affecting climate change. Carbon sinks are very useful areas for larger businesses or in this case universities as it can be seen as emission reduction for their carbon footprint. The tree species with the highest amount of stored carbon was the cypress spp. at 3.3 tons between 5 trees while the "Kwanzan Cherry" had the most stored carbon of any individual tree at 1.53 tons. The "Kwanzan Cherry" is in quotations because that is not the actual species, but rather, it was an unidentified tree in the app that we couldn't figure out and i-Tree Eco does not accept no name trees. Therefore, we randomly chose "Kwanzan Cherry" even though that is NOT its actual species. We apologize for any confusion this causes. The larger a tree is or the more biomass it has the more carbon that tree can store. This biomass includes the aboveground part of the tree which is what most people think of when the size of the tree is taken into account, but the root systems of trees also greatly impact the amount of carbon a tree can store.

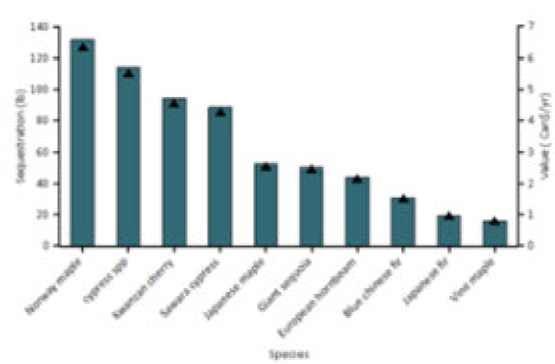


Figure 8: Bar graph showing carbon sequestration per tree species and monetary value in Can$.

Carbon sequestration is closely linked to carbon storage as carbon sequestration is the act of the tree "sequestering" or taking in atmospheric carbon and keeping it within the tree as a carbon sink. Carbon sequestration is the second most profitable yearly value at $34.65, which equaled 0.33 tons a year. When carbon sequestration is added up annually, it becomes carbon storage. Carbon storage is also defined as the total amount of carbon sequestered in the tree's lifetime. The Norway Maple is the tree that sequesters the most carbon within zone 9 ($6.58/0.6 Tons) which is different from its placement on the carbon storage graph. Carbon sequestration is affected by tree size but it is also affected by the type of tree. Norway maples, which are second in carbon storage, are the leaders in carbon sequestration because of their species being better at taking in atmospheric carbon than cypress spp.

Stormwater runoff is all of the excess water that runs along the surface of the soil instead of percolating to the underground water reserves. Stormwater runoff is the most profitable annual regulating ecosystem within zone 9 at $88.47 or 1,343.93 ft³ per year. Stormwater runoff affects the rate of erosion within a zone because the surface water gradually wears away at the surface soil taking away the topmost layer each time, causing erosion to occur. Trees have many ways of slowing stormwater which therefore hinders erosion. The larger a tree's leaves or canopy is, the area of stormwater hitting the ground is lessened. When water runs through the canopy it slows the speed of its descent allowing the water more time to percolate into the soil. This means that less water builds up on the surface allowing for a gradual flow, slowing or halting stormwater runoff. The trees themselves also take up water into their roots draining the soil of its water saturation. When this is paired with the slowing of the rainfall, it becomes a much bigger impact of slowing the stormwater and speeding up the soil infiltration rate greatly decreasing erosion.

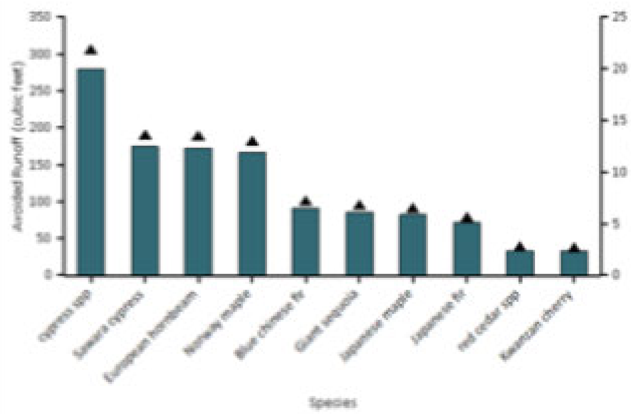


Figure 9: Bar graph showing avoided water runoff within zone 9 per tree species.

Climate regulation is the act of trees affecting our climate through various ways, like pollution removal or evapotranspiration. The trees take up a total of $1.04 per year of pollutants from the atmosphere. Zone 9 was best at taking up particulate matter and ozone. There were also negligible amounts of carbon monoxide, nitrogen dioxide and sulfur dioxide taken up. The climate was also regulated through temperature changes

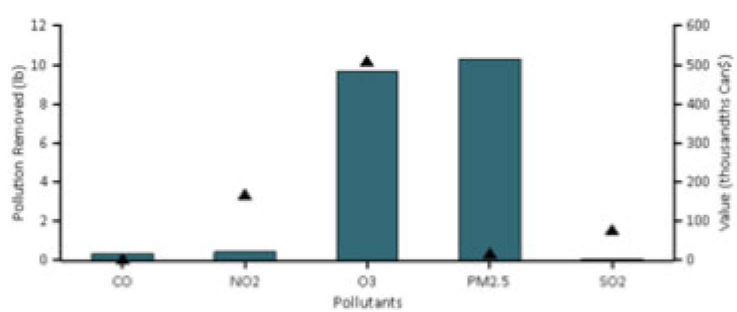


Figure 10: Various pollutants removed by trees in zone 9.

around the trees. Trees provide lots of shade which does little to alter the temperature but within the shade of a tree it is always cooler. This is because of evapotranspiration, which takes heat into the trees and releases evaporated water into the atmosphere. This exchange acts as a cooling mechanism which causes the low temperature around the trees. In groups of trees this can actually change the temperature of the area which makes it a climate regulating process.

The overall structural value of the zone is closely related to the regulating services amounts but is defined by the tree species, trunk area, health of the tree, and the location of the tree. The correlation occurs because the better suited a tree species is to regulating services, the better structural value it will have. This correlation also occurs with tree size. The total structural value of the zone is $141,893.73 with cypress spp. having the highest value per species at $40,312.41 and the giant sequoia having the largest value at $17,699.43 for an individual tree. The chart below has the total values of all regulating services for zone 9 per tree species tallied together into a total at the bottom.

Species	Trees	Carbon Storage		Gross Carbon Sequestration		Avoided Runoff		Pollution Removal		Structural Value
	Number	(ton)	(Can$)	(ton/yr)	(Can$/yr)	(ft³/yr)	(Can$/yr)	(ton/yr)	(Can$/yr)	(Can$)
Grand fir	3	0.02	2.22	0.00	0.46	13.63	0.90	0.00	0.01	151.71
Japanese fir	2	0.19	20.02	0.01	0.96	77.34	5.09	0.00	0.06	1,851.51
Vine maple	7	0.02	2.08	0.01	0.80	13.61	0.90	0.00	0.01	360.26
Rocky mountain maple	1	0.00	0.37	0.00	0.14	0.58	0.04	0.00	0.00	51.47
Japanese maple	3	1.00	104.41	0.03	2.61	89.05	5.86	0.00	0.07	7,105.86
Norway maple	3	2.14	223.46	0.06	6.58	180.94	11.91	0.00	0.14	15,083.46
European hornbeam	1	1.09	113.95	0.02	2.20	187.52	12.34	0.00	0.15	6,667.59
redbud spp	1	0.28	28.71	0.01	0.77	9.41	0.62	0.00	0.01	1,993.46
Sawara cypress	4	1.87	195.05	0.04	4.43	189.40	12.47	0.00	0.15	27,565.31
dogwood spp	1	0.00	0.11	0.00	0.07	0.49	0.03	0.00	0.00	58.72
Pacific dogwood	1	0.11	11.81	0.00	0.46	11.61	0.76	0.00	0.01	779.85
cypress spp	5	3.30	343.77	0.05	5.71	304.12	20.02	0.00	0.24	40,312.41
Blue chinese fir	1	1.22	127.53	0.01	1.55	99.11	6.52	0.00	0.08	13,495.41
crabapple	2	0.00	0.05	0.00	0.07	1.71	0.11	0.00	0.00	84.82
Kwanzan cherry	1	1.53	159.94	0.05	4.71	35.74	2.35	0.00	0.03	7,623.97
Giant sequoia	1	1.25	130.40	0.02	2.52	93.13	6.13	0.00	0.07	17,699.43
red cedar spp	12	0.05	5.13	0.01	0.60	36.55	2.41	0.00	0.03	1,008.49
Total	**49**	**14.10**	**1,469.02**	**0.33**	**34.65**	**1,343.93**	**88.47**	**0.01**	**1.04**	**141,893.73**

Figure 11: Table produced by i-Tree Eco showing various metrics about the urban forest in zone 9.

<u>Urban Forest Planning and Management recommendations</u>

According to the data that was produced from our field surveys and value mapping, there are surely areas of our zone that could use improvement. As stated in the cultural ecosystem services portion of this report, many passersby thoroughly enjoyed the areas of the zone and showed appreciation for the urban forest as they perceived it. In terms of future planning and management, a high percentage of our zone could be improved with the help of a landscape architect, and further, more detailed input from the UBC community. But with the information that we received throughout our field surveys, our group compiled the data and brainstormed where our zone could be improved and managed better. Through careful analyzation of public feedback, we would recommend to increase the frequency that gardeners maintain our zone; enhanced care and maintenance could potentially attract more guests to enjoy the space and benefit from it.

Moreover, increasing the variety of flora planted throughout our zone could potentially increase the overall enjoyment of the space. This could include more plants that bloom at different times throughout the spring, summer, and fall which could add more variety in colour throughout the year. Although this could increase expenditure for the grounds crew that works throughout UBC, it would greatly benefit the students and faculty that enjoy the space. As mentioned earlier, to increase the visual appeal of our zone, more regular visits from UBC gardeners would have the potential to attract more guests and increase the overall enjoyment of the space.

Figure 12: Example of bench that we propose to be implemented in zone 9.

Another observation that our group identified is that the short trails that weave throughout our plot are mainly used as walking paths to cut through our plot rather than for enjoying the space. Our group suggests adding more benches and places that could be used for enjoying the space as it is but also for a place of refuge.

Figure 13: Examples of proposed colourful shrubs and vegetation that could be added to zone 9 to increase the visual appeal.

Lastly, adding teared community gardens would likely increase the interaction with our zone. Our group recommends building wooden garden boxes on the south side of the main stand of trees and positioned on the high side of the grass hill. This location has the potential to supply plants with ample amounts of sunlight and also offers a place that is highly accessible. By implementing garden boxes, it would add to the provisioning ecosystem services that are non-existent throughout our plot. The addition of these community gardens could have the ability to make great impacts to our zone as it would increase the overall biodiversity present, as well as, create more human interaction with the space which tends to be beneficial to our human health. A variety of studies have shown the positive impacts that community gardens can have when implemented into a space, they include: increased food security, increased physical activity through maintenance of gardens, improve dietary habits through education, and many more examples. (DeMuro, 2013). The addition of these gardens is one of our groups most valued planning recommendations within our zone as we can imagine how these changes could have great positive impacts on the UBC community.

Appendix

Added photos of zone 9

Figure 14: Photograph taken in zone 9 looking northwest.

Figure 15: Photograph taken in zone 9 looking northeast.

Figure 16: Pond on the north corner of zone 9.

References

DeMuro, K. (2013, July 11). The many benefits of community gardens. Retrieved April 1, 2020, from https://greenleafcommunities.org/the-many-benefits-of-community-gardens/

Shanel, D. (2015,). Library garden to be redesigned. The Ubyssey Retrieved from https://www.ubyssey.ca/news/library-garden/

Wodarczak, E. (2013,). The clock tower and the anarchists. Retrieved from https://trekmagazine.alumni.ubc.ca/2013/dec-2013/features/the-clock-tower-and-the-anarchists/

Image References

https://trekmagazine.alumni.ubc.ca/trek-43-may-18-prez-life-ladner-clock-tower/

https://trekmagazine.alumni.ubc.ca/2013/dec-2013/features/the-clock-tower-and-the-anarchists/

https://orientation.grad.ubc.ca/clock-tower-2/

https://you.ubc.ca/instagram/youbcpic-look-way-ladner-clock-tower-iconic-campus-landmark-known-many-graduating-classes-students-ubc/

https://www.tripadvisor.com/LocationPhotoDirectLink-g154943-d591266-i270209105-University_of_British_Columbia-Vancouver_British_Columbia.html

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.tripadvisor.com%2FAttraction_Review-g154943-d19744164-Reviews-Ladner_Clock_Tower-Vancouver_British_Columbia.html&psig=AOvVaw1aof3RNfSLrC3nZz_2oAap&ust=1585242869984000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJil04WQtugCFQAAAAAdAAAAABAD

https://open.library.ubc.ca/collections/arphotos/items/1.0025058

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.mapleridgenews.com%2Fnews%2Fubc-6-sexual-assaults-likely-have-same-suspect-rcmp-says%2F&psig=AOvVaw1aof3RNfSLrC3nZz_2oAap&ust=1585242869984000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCJil04WQtugCFQAAAAAdAAAAABAH

https://en.wikipedia.org/wiki/Abies_grandis

https://www.gardenia.net/plant/acer-palmatum-garnet-japanese-maple

http://blogs.ubc.ca/conifersubc/?page_id=23

https://www.pinterest.ca/pin/15762667431117898/

https://www.google.com/url?sa=i&url=https%3A%2F%2Fwww.eventbrite.com%2Fd%2Fcanada--vancouver%2Fmtu-ubc%2F%3Fpage%3D6&psig=AOvVaw388hPStRWWsvERqVEXrHzR&ust=1585243357009000&source=images&cd=vfe&ved=0CAIQjRxqFwoTCOCI2--RtugCFQAAAAAdAAAAABAK

Ecosystem Service Assessment Report

Group number: 10

Date: 07. 04. 2020

Group Members:

Xingcan Cao

Angela Jiang

Qian Li

Erin Liang

Qiao Wang

Yizhen Zhang

Contributions

Part	Name
Introduction and site description	Qiao Wang
Regulating Ecosystem Services	Xingcan Cao
Regulating Ecosystem Services	Erin Liang
Cultural Ecosystem Services	Yizhen Zhang
Cultural Ecosystem Services	Angela Jiang
Urban forest planning and management	Qian Li

Introduction

This report presents the ecosystem services assessment provided by the urban forest in our Zone 10. We applied the most relevant and recent Millennium Ecosystem Assessment framework to the urban realm to demonstrate how ecosystem services are delivered, what drives them, how they are received by beneficiaries, and the role of social preferences in the provision of ecosystem services (Fini, Konijnendjk, &Ferrini, 2017)

With a well-developed geographic information system application, we can calculate and map the social values of ecosystems services as perceived by diverse groups of ecosystem stakeholders (Sherrouse, Clement, &Semmens, 2011). To be more specific, analysis and explanations of cultural and regulating ecosystem service provision in Zone 10 and recommendations for the UBC urban forest management plan will be shown in detail. Through i-Tree Eco, the assessed regulating ecosystem services involve air pollution removal and carbon storage and sequestration et al., but the cultural service assessment is more limited to the comparisons.

Ecosystem services have a significant impact on human beings, assessments of ecosystem services aim to evaluate the effect of policy decisions and identify benefits as well as trade-offs within environmental management (Schmidt, Sachse, &Walz, 2016). In addition, ecosystem services assessment may contribute greatly to environmental planning and management as well (von Haaren & Albert, 2011). The biophysical tree inventory we participate in might help with urban forest planning which aims to enhance, protect and manage our campus natural assets and consider the broader ecological, cultural and social value of these natural assets.

Besides, the current UBC plans and policies like Campus Land Use Planning and UBC Public Realm Planning outline where, how much, and what type of buildings, and outdoor spaces the university will provide ("Policies and Plans", n.d.). Especially the UBC Public Realm Planning, which involves the Public Realm Plan, naming trees and benches, campus tree management et cl, providing strategies for design, development, and management of UBC's public spaces ("Policies and Plans", n.d.). In addition, there are also some future directions related to urban forest planning like the biodiversity component of the new Green Building Action Plan.

Site description

Our Zone 10 is irregularly shaped and located in the north-western part of the campus, consisting of institutional buildings like Buchanan Block C, D and E Buildings and the Buchanan tower, together with roadways, and a small-sized garden.

Figure 1

Figure 2

The main purpose of the area is to serve as institutional land use, as a place to provide classrooms and room for other learning activities. In addition, this site is also well-facilitated (see Figure 1&2) and with high green area coverage. Through the estimation and calculation of i-Tree Canopy tool, the proportion of green areas is about 48%. The small urban park between Buchanan Block D Building and Buchanan Block E Building not only has the beautiful landscape design but also provides the benches, stone-paved road and other facilities.

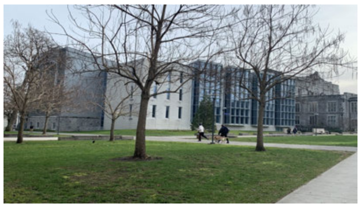


Figure 3

The Memorial Road in our site is a road with a large flow of people, because it is the main path for students who take classes in Buchanan Buildings, and it is also connected the IKB library, IKB Learning Centre and Main Mall, which also directly leads to the fact that the users of our site are mainly students, together with professors, faculties, tourists, neighbours and so on. However, on weekends, the on-site users could be totally different. When students are enjoying free weekends without classes many nearby residents do jogging, walk their dogs on the site (see Figure 3).

Regulating ecosystem services

Methods

We used two model to assess the Regulating Ecosystem Services in our plot. One is the i-Tree Canopy model which is estimate tree cover and benefits with a random sampling process in the selected area. At the beginning of using i-Tree Canopy model, we selected our zone in the map (Figure 4).

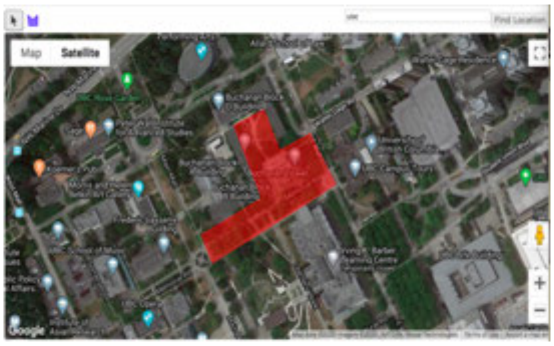


Figure 4

Then we chose 200 points randomly in the selected area, and defined the points are with trees or non-trees. The more points, the results will more accurate. In the i-Tree canopy report, it simply shows the estimation of tree benefit to the environment and the quality of regulating services provided in our zone, such as the amount of pollutants are removed by the trees in our plot.

Another model we used is i-Tree Eco model. Instead of analysing the tree cover and benefits by choosing points in selected area, i-Tree Eco is a software application that using data collected from single tree or complete tree inventory. To start the i-Tree Eco, we need to get the following datas---- species, DBH, Land Use, Total tree height, Crown size and Crown light exposure, from tree inventory. Then open i-Tree Eco and create a new project, enter our project information, such as project name, series name and series year, in Project Definition. Proceed to the location lab, selected the closest weather station and the closest location to our plot, that shown on Map the application provided, is Richmond. Next, we needed to select the data field on Data Collection Option tab. We selected species, DBH, land use, total tree height, crown size, and crown light exposure, which is the same as the data field we prepared at the beginning. Then, import the inventory data. According to the column to Eco fields, make sure the data and columns match the data to Eco data categories. Aftering finishing the data import process, set up the Benefit prices as current USD/CAD exchange rate. At last, submit data and explore the results. Due to the large database of i-Tree Eco, there are more detail and rich contents in report. It not only includes the analyses of regulating services, but also some structure and composition analyses and some management suggestions.

Both of these two models are having huge database to analysis the data by their specific methods. However, there are some limitation for both models. For i-Tree Canopy, the accuracy of the analysis very depends on the users if they able to define each point into correct tree or non-tree classes. Due to the satellite view, some points are not clear enough for user to define. Otherwise, the random selection of points might causes the result too much tree points or too much non-tree points. For i-Tree Eco model, the accuracy of the analysis not only depends on the complete inventory from user, but also the database of i-Tree also needs to be more accurate. Therefore, it is necessary to keep update the database frequently.

Results

The following part shows the results of two models. In the i-Tree canopy report, the percentage canopy cover of our site is about 48%. We selected a total of 200 random samplings. The standard error of the estimate floated was 3.53%. From i-Tree ecosystem analysis, the pollution removal is about 10.46 kilograms/year (Can$1.3/year). It mainly includes five air pollutants (Chart 1

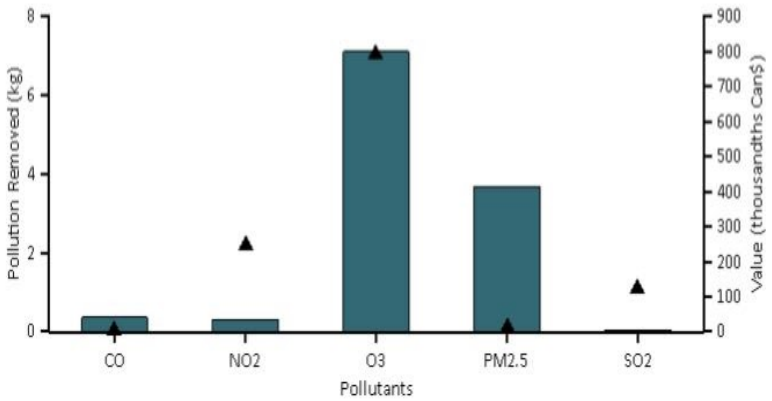


Chart 1

) ozone, carbon monoxide, nitrogen dioxide, particulate matter less than 2.5 microns, and sulfur dioxide. Among them, trees have the largest absorption of ozone and the highest total value. Carbon Storage and Carbon Sequestration are 240.9 metric tons and 1.216 metric tons respectively. The value can reach Can $ 27.7 thousand and Can $ 140 / year. Southern catalpa

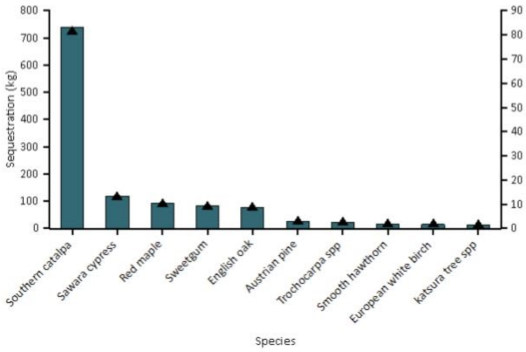


Chart 2

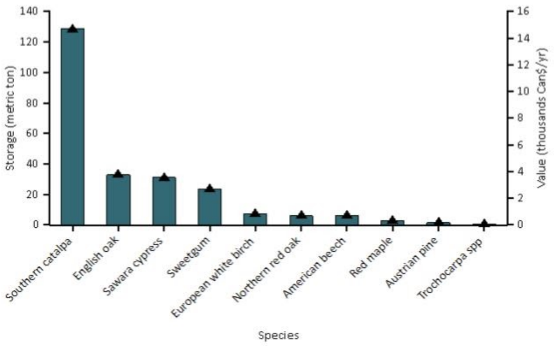


Chart 3

that is the most dominant species can store total about 130 metric tons carbon and sequester total 750 metric tons carbon (Chart 2 and 3). In addition, the vegetation in this area can produce 3.242 metric tons of oxygen per year. Another important benefit of urban forest is it reduces surface runoff. The trees and shrubs can reduce runoff by 55.68 cubic meters/year in site 10 that create total value of Can$129 per year. It is worth noting that Sweetgum has made the greatest contribution in this regard (Chart 4). The structural value of trees can reach Can $ 1.51 million in this area. From Chart 5, it is evident that Southern catalpas has a structural value of more than Can $0.7 million. Lastly, Chart 6 analyzes the potential impact of 36 pests. Among them, Gypsy moths(GM) have the most damage, threaten 12 trees and may cause losses exceeding Can $ 450 thousand.

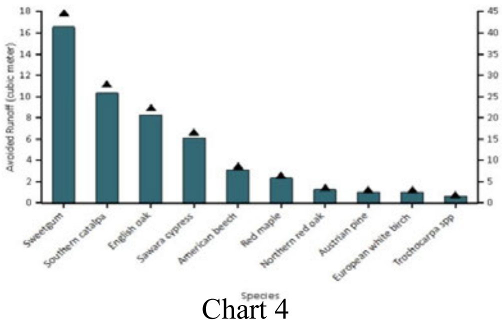


Chart 4

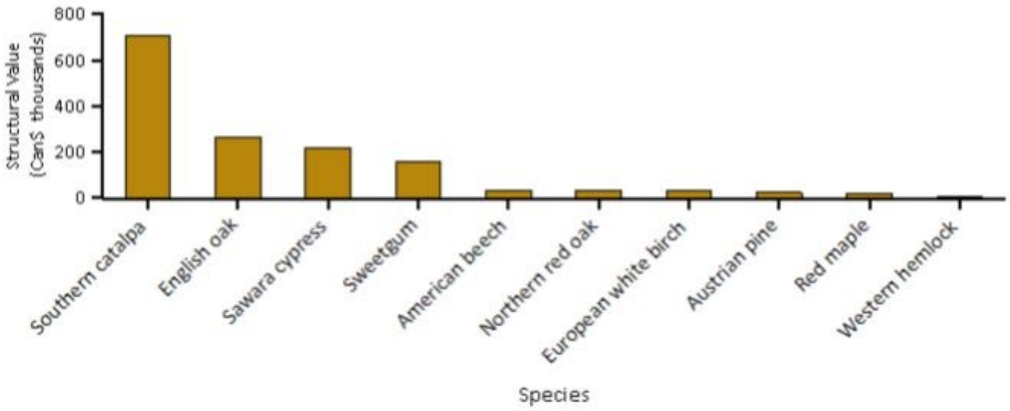


Chart 5

This section discusses the similarities and differences between the two model results. Both reports mention tree cover and tree benefit estimates. In the i-Tree canopy model, random sampling statistics was used to estimate the result and it was established that each sampled result was different. We have conducted two times samplings, with 90 points selected for the first time and 200 points selected for the second time. For cover assessment, the two results are basically similar and more accurate. The first percentage tree cover is 48.5 and the second is 48. Since there are less points selected for the first time, the standard error for the first time is larger. Therefore, we used the second time results. But for the tree benefits estimates, the two results are very different, and there is a big difference between the results in the i-Tree eco model. The results of the model tree benefits estimate are unstable and inaccurate. Therefore, we consider the results of the i-Tree eco model are more reliable. Two models show the results for cover assessment in different forms. i-Tree canopy estimated the forest coverage of the area while i-Tree eco showed the tree cover area and leaf area and introduced the percent leaf area of several most dominant species. It is not difficult to see that the data of both models indicate that the vegetation coverage in this area is high, which makes a huge contribution to the nearby ecosystem.

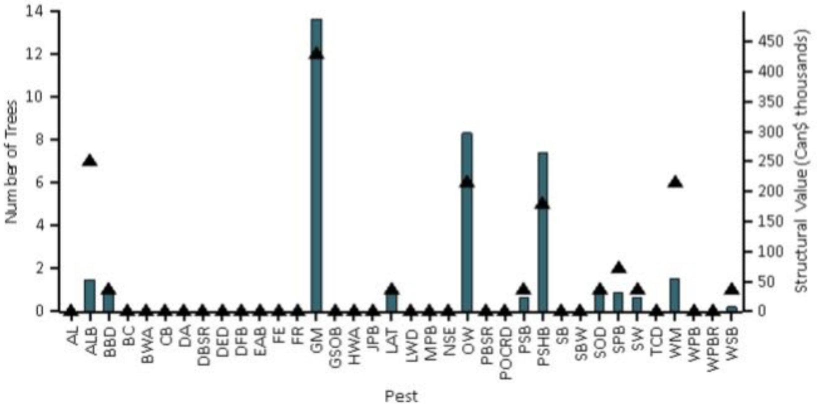


Chart 6

Canopy cover plays an important role in temperature regulation. In summer, Trees release heat into the atmosphere faster than concrete and asphalt surfaces. Thus, they can weaken the urban heat islands effect. The shadows of trees play an important role in cooling the surrounding environment (Hartin, 2019). In winter, the canopy cover can block the wind. According to studies by Arbor Day Foundation, trees can reduce 35 mile-per-hour winds to just 10 mph (The Davey Tree Expert,2014). Canopy cover of our block is relatively high making the surrounding climate more comfortable. Air pollutants directly damage human health and ecosystems as well as reducing visibility. Vegetation can directly remove air pollutants (Nowak and Dwyer 2000). From Chart 1, it seems that annual pollution removal and value by urban trees are inconsistent. This is because the default air pollution removal value varies depending on the local incidence of adverse health effects and national median externality costs (Nowak et al 2014). Carbon Sequestration can help reduce global warming. Trees can absorb carbon dioxide during photosynthesis and sequestrate carbon in new growth every year (Abdollahi et al 2000). This process helps to maintain the carbon dioxide content in the air in a balanced range thereby regulating the climate. Carbon storage is relative with fossil fuel formation and have a high value. Comparing annual carbon storage and carbon sequestration, we can find that the carbon storage is far less than carbon sequestration of our block's urban forest. However, the value of carbon storage is far greater than carbon sequestration when we analysis value of both. Therefore, we consider the value of carbon storage to be extremely high. It is well known that the photosynthesis of plants produces oxygen and the plants in our area produce a lot of oxygen every year. However, this benefit of trees is minimal because there is a lot of stable oxygen in the atmosphere and the ecosystem in the ocean also produces a lot of oxygen (Broecker 1970). Surface runoff can lead to many damages. For example, pollution of streams, wetlands, rivers, lakes, and oceans. Nonetheless, vegetation can effectively reduce surface runoff. The branches intercept the rain while the roots of plants promote rainwater infiltration (Hirabayashi, 2012). From i-Tree eco report, we establish the data that avoided runoff value is calculated based on the price of Can$2.32 per m^3. This value indicates avoided runoff is significant. Sweetgums have the max contribution on avoided runoff. They are medium to large trees with width crown. These characteristics are more conducive to preventing rainwater runoff. With the increase in amount and size of healthy, the structural value of urban forest will increase (Nowak et al, 2002a). The structural value of urban forests is huge. The amount of money to buy a sapling is not costly. However, the value that the trees create is infinite. The gypsy moth (GM), Oak wilt (OW) and Polyphagous shot hole borer (PSHB) are the three main objects of insect control used in analyzing potential pest impacts. The health of urban forests is related to structural value and ecosystem service value.

Cultural ecosystem services

Methods

During our cultural ecosystem services valuing, we conducted four references to determine the cultural ecosystem services in our zone using the value mapping process.

i-Tree is a set of methods for evaluating urban and rural forestry and for determining benefits. It was designed and implemented by the U.S. Forest Service to measure and evaluate trees ecosystem services including pollution reduction, carbon sequestration, carbon emission avoidance, stormwater runoff and more. Tree canopy and benefits can easily be measured using aerial photographs in the i-Tree Canopy application. We also used the i-Tree Eco application that is a flagship device that measures the structure, threats and benefits and importance of forest populations.

The other way of data collecting is that the six members of our group observed and estimated the cultural ecosystem services on our own. We were provided with recording sheets and a grading scale from one to five, and five is the highest mark. We were divided into smaller groups in order to get fewer distractions and capture measurements accurately. We took half an hour to walk around in our subzones and did our personal evaluations.

The last reference we have is from the users on campus. We took about an hour and did a survey with students, staff, and other users walked pass our zone. It was a one-minute short survey, happily, everyone was willing to help us with our inventory. We received a lot of feedbacks for our zone, that helped us with further improvement

These are four ways we worked on in order to collect the cultural ecosystem services in our zone. i-Tree is definitely an easy and reliable source to gather the information we need from a online database. The other two methods are personal experiences. Group members' assessments and surveys present us results from a different perspective.

Results

Experience value mapping

Chart 1 shows the results of the experience value mapping in our zone areas. In terms of 6 experience dimensions, five subzones were scored based on the 6 members' observation and assessment. Sum of data in Subzone A, B, C, D, E are shown as the below and the average scored data of value dimensions are also given in below bar chart.

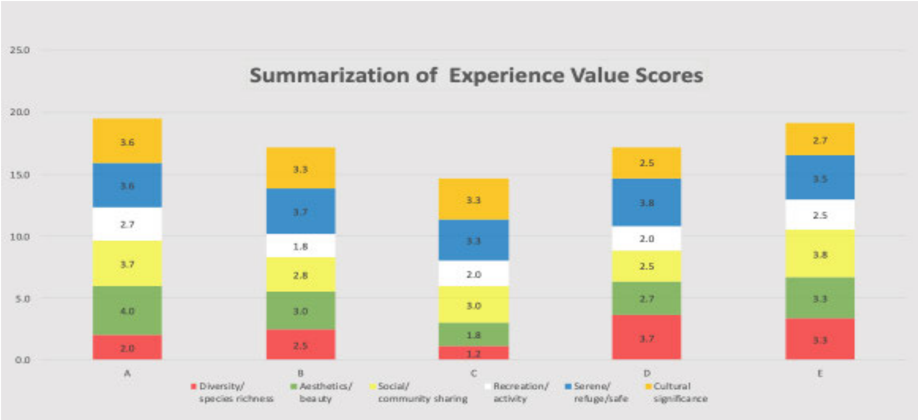


Chart 7

It can be seen that subzone A and subzone B got the highest average scores in respect of 6 dimensions among our zone areas, and the sum of these data are respectively 19.5 and 19.2. Subzone B and subzone D got the same average ranking, and the sum of data is equally 17.2. And subzone C is the zone area with the lowest average ranking of six values. When we do the evaluation in terms of individual dimensions, it seems our area covers basically all experience values, and these values vary in terms of different subzones. The specific data given on the bar illustrates that serene values are a salient dimension in our zone area, basically above the average of 3, and there is less recreation value observed and evaluated in our zone, with only around 2 scored on average.

To more directly observe the results of our experience value mapping and get the exact distribution of these values in each subzone, we mark different dimensions with different colors on our group zone map.

Map 1

As Map 1 shows that subzone A and subzone E are most densely-marked with stars among our zones, and it also satisfies the conclusion from bar graphic we observed. Subzone A is more likely to show aesthetic and social values because this subzone is located on the memorial road, which featured on the broad boulevard, green trees and large numbers of pedestrians (Figure 5).And there are also many concrete benches placed on this road for seating areas, representing the experience of social scene (Figure 6). Cultural significance is also a salient dimension in subzone A, even though not many of them are marked in this map. Experience of cultural and historical values are generally formed through cultivated and man-made surroundings (Grahn and Stigsdotter, 2010). Some orange stars marked represent some old artifacts with historical meaning or art status. For instance, we notice that a stele erected on the end of Memorial Road is to commemorate the generous actions of student bodies (Figure 8). This is also the reason why it got a high ranking of cultural significance value without many marked stars.


Figure 5


Figure 6


Figure 8

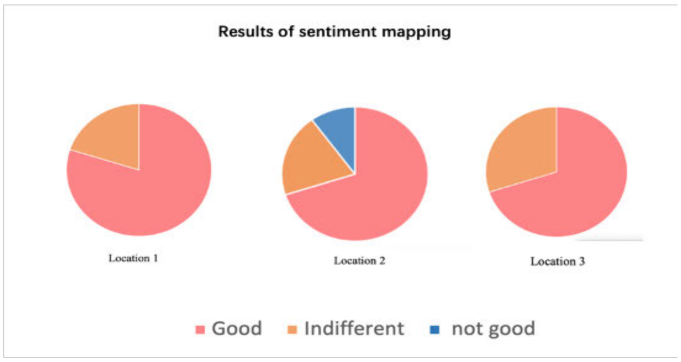
Subzone B has more serene and refuge values marked in this map, and it related to the sense of safe generated by the lush bushes and leafy trees in front of the Buchanan Block B Building. Subzone C covers quite a large area among all subzone, but fewer varieties of experience values are revealed in this area due to few factors that appeared in this area. The main function of this subzone is for staffs' official and linkage between the memorial Road and teaching buildings inside. The main characteristics of this area is concrete and stone for pathway and building with less green spaces. This also explains why there are few dimensions marked in this map. However, it's noticeable that this area has great cultural significance, and it can be explained by the Buchanan Tower with a long history. Subzone D is primarily a narrow pathway connecting the E Mall and the group of Buchanan buildings area. It has more richness and serene values, relating to diversified and tall woods placed on is subzone. And there are more esthetic and social values marked on the subzone E. This area consists of green lawns, a small stream, concrete pathway, seating areas, covering multiple factors in relation to different experience dimensions. it can be observed that lush bushes are planted in the front of buildings and also combine some benches and water factors, providing for rest and short talk for students (Figure 9). Large grassy fields in front of the Buchanan Block E Building also add the experience of beauty.


Figure 9

Taken together, there are a variety of experience dimensions involved in our zone areas, with salience of serene and aesthetic values . The representation of six values are different among five subzones. Specifically, subzone A and subzone E have the highest scores of six experience value dimensions due to coverage of multiple factors, and subzone C is featured on cultural significance.

Sentiment mapping

As map 2 shows, we select 3 locations to do our sentiment mapping survey. And these locations we selected are either as the linkage of different subzones or featured on large volumes of pedestrians. And the results of this survey are shown in the below (see Chart 2).



Map 2

Chart 8

The survey results show that most people feel good of 3 locations and location 1 seems to more likely to get good feedback among our survey areas. We assume more preference of location 1 may be related to the multiple factors around this area covering the beauty, serene and social values. And we also collect some keywords from their explanations through the word cloud tool (Figure 10). It can be seen that trees and quiet are common keywords given by surveyed people. This result to some extent reflects that serene value is a salient dimension in our zone area. But it should be noted that the result of this sentiment mapping may be affected by external conditions. For instance, bad weather would influence people's mood, thus affecting their feedback. and due to the lack of understanding of our major, some of them just give the reason driven by their completely subjective feelings, like because they always pass by this area, and less related to 6 value dimensions.

Figure 10

The strengths and weaknesses of the value mapping approach

The advantage of the value mapping approach is that our report will include results from different resources. Our report comprises accurate data from the online database, but also includes personal views and opinions. Accurate data makes our reports more convincing, and personal opinions can help us enhance our zone. The weakness of the value mapping approach is that it only covers six group members' ecosystem services assessments and a minority of zone users' perspectives. There is no guarantee that everyone's ideas will be the same or not inconsistent with the data on the Internet.

Urban forest planning and management recommendations

The tree canopy cover currently displayed in our zone is about forty-eight percent with sixty trees and fourteen species, which is better than many places in Vancouver. However, the species distribution and canopy cover are uneven. An even distribution of an urban forest is not only offering more ideal benefits but also provides a different visual effect. According to our value mapping, our zone presents favourable results in six experience values of a good quality urban forest, especially good in the experience value of serene. Whereas, the experience value of species richness and aesthetics are poor in some areas. Trees in our zone are basically located in Zone A, B, C and D. As we can see from the Figure 11, the distribution of trees in area A, B, C and D are more even than the distribution of trees in area E because we can see obviously that the tree canopy in area E is less than fifty percent. Apart from that, the most common tree in our zone is Indian-Bean (also called Southern catalpa), which accounts for fifty-three percent of the total. However, the other thirteen species in our zone only account for less than ten percent respectively. Therefore, in our future planning about our zone should increase the experience value of species richness, aesthetics and improve the distribution of the tree canopy cover and tree species.

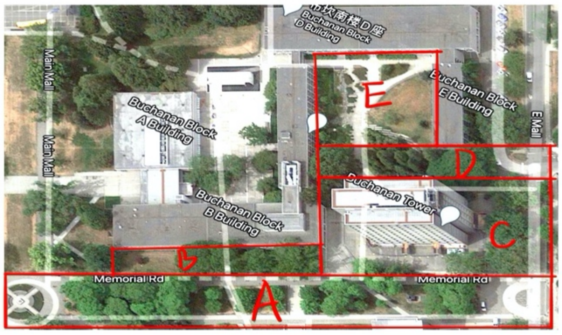


Figure 11

Trees in our zone also provide multiple regulating ecosystem services, such as carbon sequestration and storage, air pollution removal, oxygen production and avoid runoffs. And all of these regulating services creates social and economic values by the structure and functions of our zone. Based on the analysis chart from i-Tree Eco, the performance of Indian-Bean, Sweetgum and Sawara cypress are better than the performance of the other species in carbon sequestrations and storage, oxygen production and the reduction of surface runoff. Indian-Bean and Sweetgum also contribute to air pollution removal and majorly for ozone O3 and PM2.5. Since the estimation for structural and functional value of an urban forest depends on the tree species, size and the health condition of the trees. In our future planning, our goal is to maximize the benefits we can gain from our zone.

Although the trees in our zone can create favourable social and economic values, there still have some potential pests that can threaten the health condition of the trees. According to the i-Tree Eco model, the gypsy moth, oak wilt and polyphagous shot hole borer are the most threatening potential pests. And these pests can cause widespread defoliation and death, which could affect almost fifty percent of the trees of our zone. Besides, the potential pests can lead to a potential loss of more than one million CAD structural value, which accounts for sixty-seven percent of the total structural value. Hence, the management and prevention of potential pests are essential to maintain and improve the health condition of the trees in our zone.

Briefly, the aim of our recommendations is to contribute to achieve a sustainable benefit goal and maximize benefits to a limited extent. The analysis and assessment of the trees in our zone can directly influence the development and management of our zone. Therefore, we propose three recommendations for our zone to reach our goal by focusing on the current data and analysis we have. Firstly, the distribution of tree species and canopy cover needs to be improved to a more even distribution, which can contribute to the aesthetics experience and also come with other benefits. Then, enhancing air quality is important for a campus with a large flow of people. Furthermore, improving the health condition and safety of the trees and maintaining a good health level of the trees in the long term.


Figure 12

Since the most common species of our zone is Indian-Bean (Southern catalpa) which basically concentrated in area A (see Figure 11) and the number of Indian-Bean account for fifty-three percent, then our purpose is to adjust the proportion of each species to a similar level but maintain current design to the greatest extent. All the adjustments are for increasing the structural and functional values; thus, we only focus on improving the proportion of trees that can offer high values. According to the integration of the report from the i-Tree Eco model, the main source of the structural and functional value of our zone is provided by Indian-Bean, Sawara cypress, Sweetgum and English oak. And Indian-Bean, Sweetgum and English oak are mainly distributed in area A, B and C, accounting for 53.3%, 6.7% and 8.3% of the total number of trees, respectively. Meanwhile, Indian-Bean and English Oak are street trees, and the unity or similarity of the tree species plays a good role in the aesthetics experience. Therefore, we do not recommend any adjustment to the quantity of Indian-Bean and English oak. In our recommendation, we are planning to make the proportion of sweetgum to increase to 10%. Combining Figure 11 and Figure 12 we can observe that there is almost one-third of the open space in area B without any vegetation, so we can plant more Sweetgum in this space. In addition, we also mentioned that the canopy cover of area E is less than fifty percent, since there only have three trees on a large-scale lawn (see figure 13). Accordingly, we could plant more trees here to improve the canopy cover of area E by the species we already have like American beech and Austrian pine which also performance good at multiple regulating services. Besides, you can also plant new species to increase the species richness experience of our zone and the species selection should focus on how many benefits and value the species can provide.

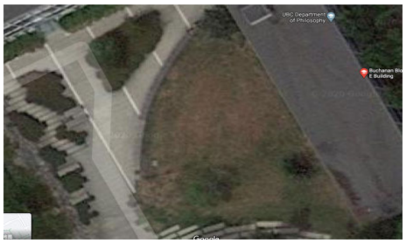


Figure 13

For the enhancement of air quality, improving the density of canopy cover also can increase the carbon sequestrations and storage and the production of oxygen, which is a good way to offer good air quality. However, the removal of air pollution is also significant for increasing air quality. As we mentioned above that good air quality is important for the campus, which is because of “the air pollutants result in many short-term and long-term health effects (Jyothi et al. 2016. p. 6)." There have thousands of people who come and go by every day, and most of them are students and UBC staffs. Hence, we recommend to plant more trees with big leaf area or evergreen trees to maximize air pollution removal. Based on the i-Tree Eco model, trees in our group performance good in the removal of O3 and PM2.5. However, the result of air pollution removal is inconspicuous to see during the beginning and end of a year (see Appendix). Therefore, planting more evergreen trees can maintain the removal of air pollutants for a whole year.

Despite we improve all aspects that we mentioned above of our zone, we probably cannot reach the final ends -- a sustainable benefit goal. Therefore, improving the health condition and safety of the trees and maintaining a good health level of the trees in the long term is extremely essential. As we discussed there might have three threatening pests that can result in sixty-seven percent loss of the total structural value. For avoiding the potential loss, a proper and effective management plan for our zone is needed. UBC has already come up with several management plan to the integrated pest management (IPM). The IPM program is a way to control the pest effectively by using the chemical material without any negative impacts on environment (UBC Safety and Risk Service). But the chemical control could result in multiple issues that negative for our ecological environment, such as the pest may evolve a resistance to those chemical material, which leads to the pest outbreak again (hui et al. 2016. p. 19). Accordingly, we recommend a more natural and harmless way to control and prevent the outbreak of pests and monitor the health condition of trees by arborists and other associated experts. For instance, we could control the pest by biological control, which is a way to artificially release the natural enemies of the pests. Besides, the other common natural method is to improve the density of trees and the species diversity. All these pests control method need to implement and management by people who with expertise.

In conclusion, our zone has been providing multiple regulating services with sixty trees and performing good in experience value mapping but still existing some disadvantages need to be improved or adjusted, such as the distribution of tree species and the canopy cover and the potential threats of potential pests. Overall, the good quality of an urban forest can create both social and economic values, but sometimes the function of some trees cannot exert. Consequently, tree inventory and assessment are needed to work as a tool to enhance all the aspects of our trees. The result of the inventory data and the analysis of ecosystem assessment can decide where shall we go and how to get the destination. The goal of our future planning for zone 10 is to achieve sustainable benefit in the long term, which we could by make the trees exert their functions and values to the greatest extent by several strategies and actions. And all the recommendations we propose are base on the current achievements we have. Thus, a precise inventory and assessment also decide the overall quality of an urban forest in the past, now and future.

Reference

Abdollahi, K.K.; Ning, Z.H.; Appeaning, A., eds. 2000. Global climate change and the urban forest. Baton Rouge, LA: GCRCC and Franklin Press (pp. 77).

Broecker, W.S. 1970. Man's oxygen reserve. Science 168(3939): 1537-1538.

Hartin, J. (2019). Why planting shade trees helps reduce the temperature of urban heat islands.Retrieved From Https://www.ocregister.com/2019/06/11/why-planting-shade-trees-helps-reduce-the-temperature-of-urban-heat-islands/

Ferrini, F., Bosch, Cecil C. Konijnendijk van den, Fini, A., & Taylor & Francis eBooks A-Z. (2017). *Routledge handbook of urban forestry*. London;New York;: Routledge. doi:10.4324/9781315627106

Grahn, P., & Stigsdotter, U. K. (2010). The relation between perceived sensory dimensions of urban green space and stress restoration. *Landscape and urban planning*, *94*(3-4), 264-275.

Hirabayashi, S. 2012. i-Tree Eco Precipitation Interception Model Descriptions, http://www.itreetools.org/eco/resources/iTree_Eco_Precipitation_Interception_Model_Descriptions_V1_2.pdf

i-Tree Eco Model. 2020. *Itreetools.Org*. https://www.itreetools.org/tools/i-tree-eco

Nowak, D.J., Hirabayashi, S., Bodine, A., Greenfield, E. 2014. Tree and forest effects on air quality and human health in the United States. Environmental Pollution. 193:119-129.

Nowak, D.J.; Crane, D.E.; Dwyer, J.F. 2002a. Compensatory value of urban trees in the United States. Journal of Arboriculture. 28(4): 194 - 199.

Nowak, D.J.; Dwyer, J.F. 2000. Understanding the benefits and costs of urban forest ecosystems. In: Kuser, John, ed. Handbook of urban and community forestry in the northeast. New York, NY: Kluwer Academics/Plenum: 11-22.

Omprakash R. &Jyothi S., et al. (2016). Assessment of Air Quality Impacts on Human Health and Vegetation at an Industrial Area. DOI: 10.1061/(ASCE)HZ.2153-5515

Policies and Plans. Retrieved 5 April 2020, from https://planning.ubc.ca/planning-development/policies-and-plans

Schmidt, K., Sachse, R., & Walz, A. (2016). Current role of social benefits in ecosystem service assessments. *Landscape and Urban Planning*, 149, 49-64. doi:10.1016/j.landurbplan.2016.01.005

Sherrouse, B. C., Clement, J. M., & Semmens, D. J. (2011). A GIS application for assessing, mapping, and quantifying the social values of ecosystem services. *Applied Geography*, 31(2), 748-760. doi:10.1016/j.apgeog.2010.08.002

The Davey Tree Expert. (2014). You won't believe what your tree is doing for you. Retrieved from https://blog.davey.com/2014/07/you-wont-believe-what-your-tree-is-doing-for-you/

UBC Safety and Risk Services. Retrieved from https://srs.ubc.ca/environment/pollution-prevention/integrated-pest-management-2/

Von Haaren, C., & Albert, C. (2011). Integrating ecosystem services and environmental planning: limitations and synergies. *International Journal of Biodiversity Science, Ecosystem Services & Management*, 7(3), 150–167.

Zhang B., Zhang H. (2016). *Chapter 2: Pest Control and Ecological Regulation*. Research on Optimization of Ecology Teaching Content and Course System Construction (pp. 18-21). Retrieved from https://books.google.ca/books?id=Fel6DwAAQBAJ&pg=PT73&lpg=PT73&dq=%E6%80%8E%E4%B9%88%E9%98%B2%E6%B2%BB%E5%92%8C%E7%AE%A1%E7%90%86%E6%9E%97%E5%9C%B0%E5%AE%B3%E8%99%AB&source=bl&ots=d7ltuRyJAA&sig=ACfU3U2V4BG4HlaW98LLPninyl2C9WNGDA&hl=zh-CN&sa=X&ved=2ahUKEwiS-8GbktnoAhWJtZ4KHQ70AYYQ6AEwAHoECAsQLQ#v=twopage&q&f=false

Chart 1. Annual pollution removal(points) and value(bars) by urban trees, Group10. 2020. Group10 i-Tree ecosystem analysis.

Chart 2. Estimated annual gross carbon sequestration(points)and value(bars)for urban tree species with the greatest sequestration, group10. 2020. Group10 i-Tree ecosystem analysis.

Chart 3. Estimated carbon storage(points)and values(bars)for urban tree species with the greatest storage, group10. 2020. Group10 i-Tree ecosystem analysis.

Chart 4. Avoided runoff(points) and value(bars)for species with greatest overall impact on runoff, group10. 2020. Group10 i-Tree ecosystem analysis.

Chart 5. Tree species with the greatest structural value, group10. 2020. Group10 i-Tree ecosystem analysis.

Chart 6. Number of trees at risk(points) and associated compensatory value(bars) by potential pests, group10. 2020. Group10 i-Tree ecosystem analysis.

Figure 4. The Area of Zone 10. Google Map. Retrieved from https://www.google.com/maps/search/buchannan/@49.2648877,-123.2548815,16z/data=!3m1!4b1

Figure 11. The Area of Value Mapping. Google Map. Retrieved from https://www.google.com/maps/search/buchannan/@49.2648877,-123.2548815,16z/data=!3m1!4b1

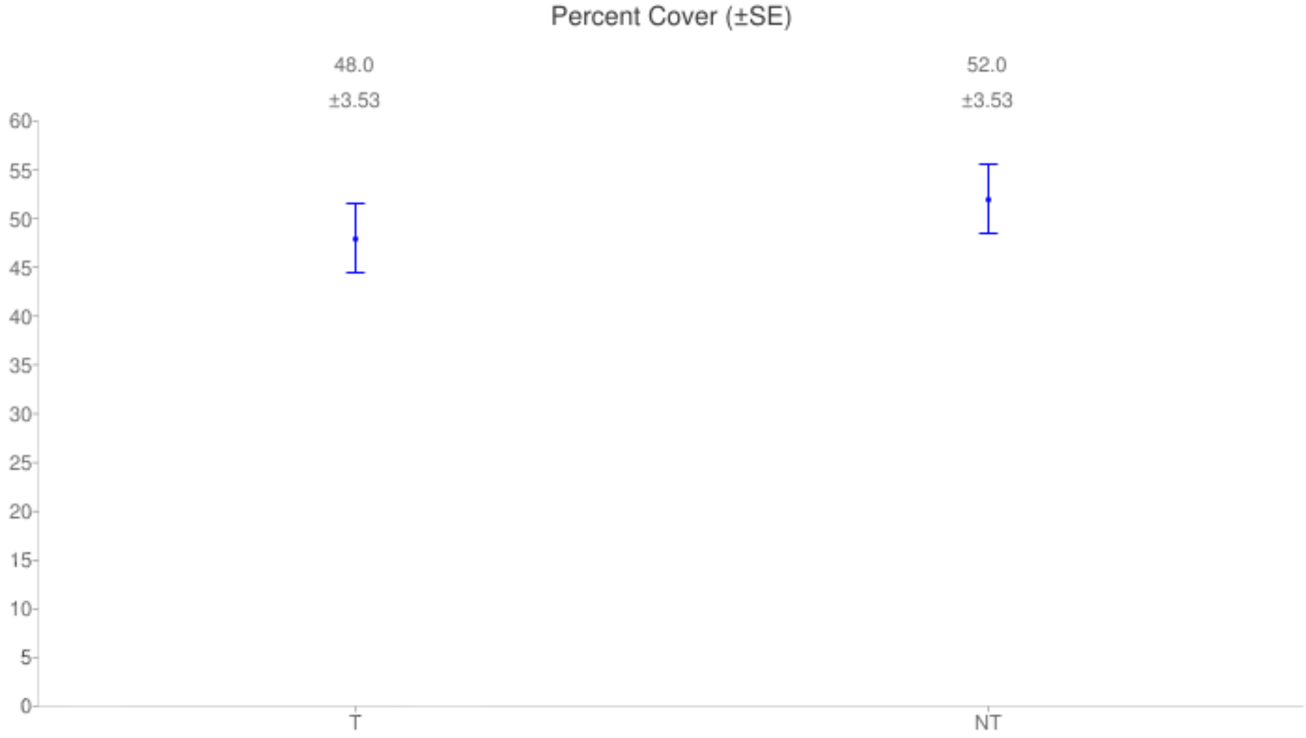
Figure 13. The Area E of Zone 10. Google Map. Retrieved from https://www.google.com/maps/search/buchannan/@49.2648877,-123.2548815,16z/data=!3m1!4b1

Appendix A

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 4/07/20



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	96	48.0 ±3.53
Non-Tree	All other surfaces	NT	104	52.0 ±3.53

Summary

Understanding an urban forest's structure, function and value can promote management decisions that will improve human health and environmental quality. An assessment of the vegetation structure, function, and value of the Group10 urban forest was conducted during 2020. Data from 60 trees located throughout Group10 were analyzed using the i-Tree Eco model developed by the U.S. Forest Service, Northern Research Station.

- Number of trees: 60
- Tree Cover: 4553 square meters
- Most common species of trees: Southern catalpa, English oak, Sawara cypress
- Percentage of trees less than 6" (15.2 cm) diameter: 0.0%
- Pollution Removal: 10.46 kilograms/year (Can$1.3/year)
- Carbon Storage: 240.9 metric tons (Can$27.7 thousand)
- Carbon Sequestration: 1.216 metric tons (Can$140/year)
- Oxygen Production: 3.242 metric tons/year
- Avoided Runoff: 55.68 cubic meters/year (Can$129/year)
- Building energy savings: N/A – data not collected
- Avoided carbon emissions: N/A – data not collected
- Structural values: Can$1.51 million

Metric ton: 1000 kilograms
Monetary values Can$ are reported in Canadian Dollars throughout the report except where noted.
Ecosystem service estimates are reported for trees.

For an overview of i-Tree Eco methodology, see Appendix I. Data collection quality is determined by the local data collectors, over which i-Tree has no control.

I. Tree Characteristics of the Urban Forest

The urban forest of Group10 has 60 trees with a tree cover of Southern catalpa. The three most common species are Southern catalpa (53.3 percent), English oak (8.3 percent), and Sawara cypress (8.3 percent).

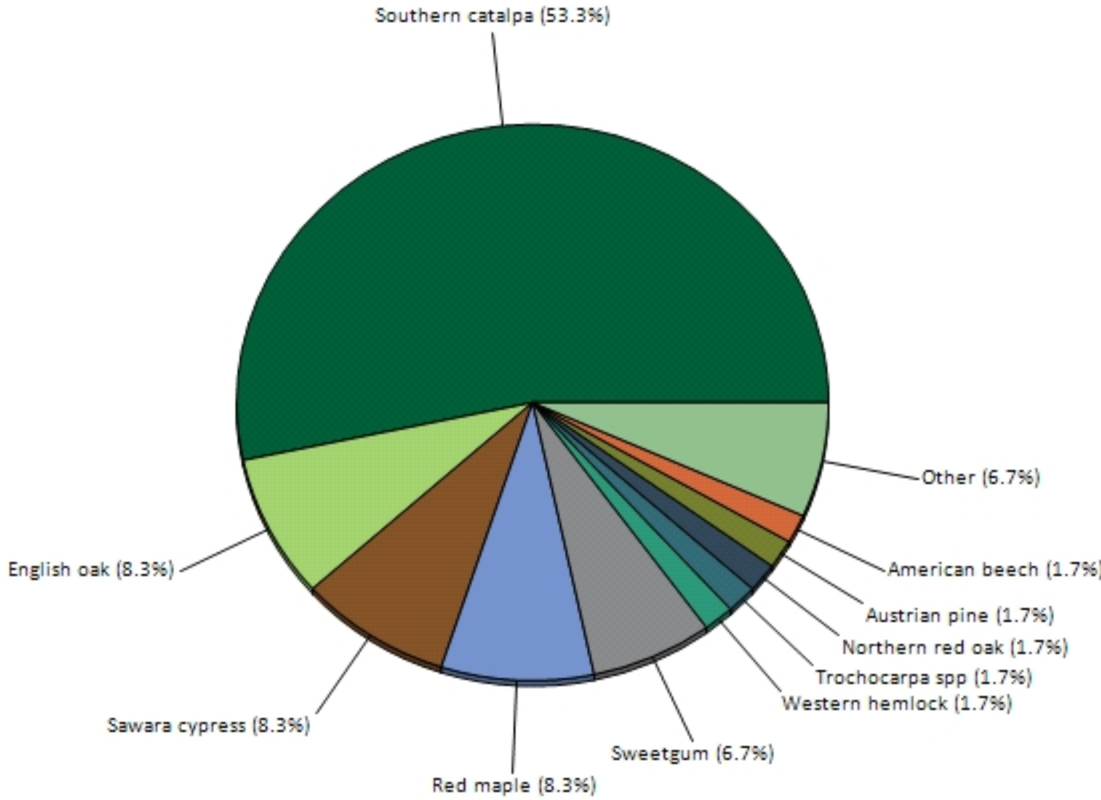


Figure 1. Tree species composition in Group10

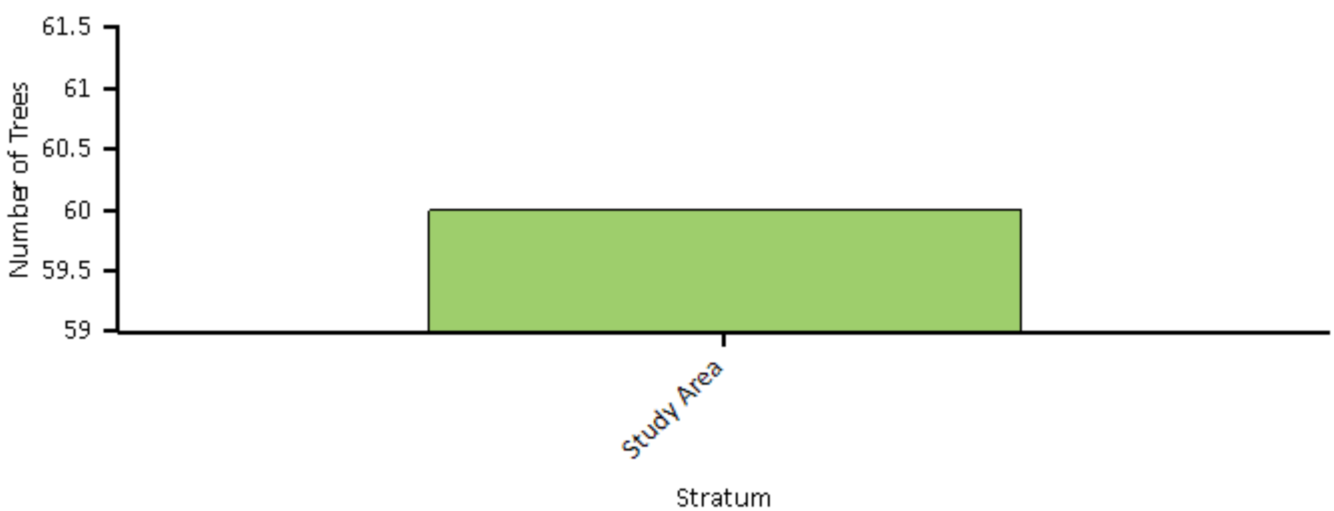


Figure 2. Number of trees in Group10 by stratum

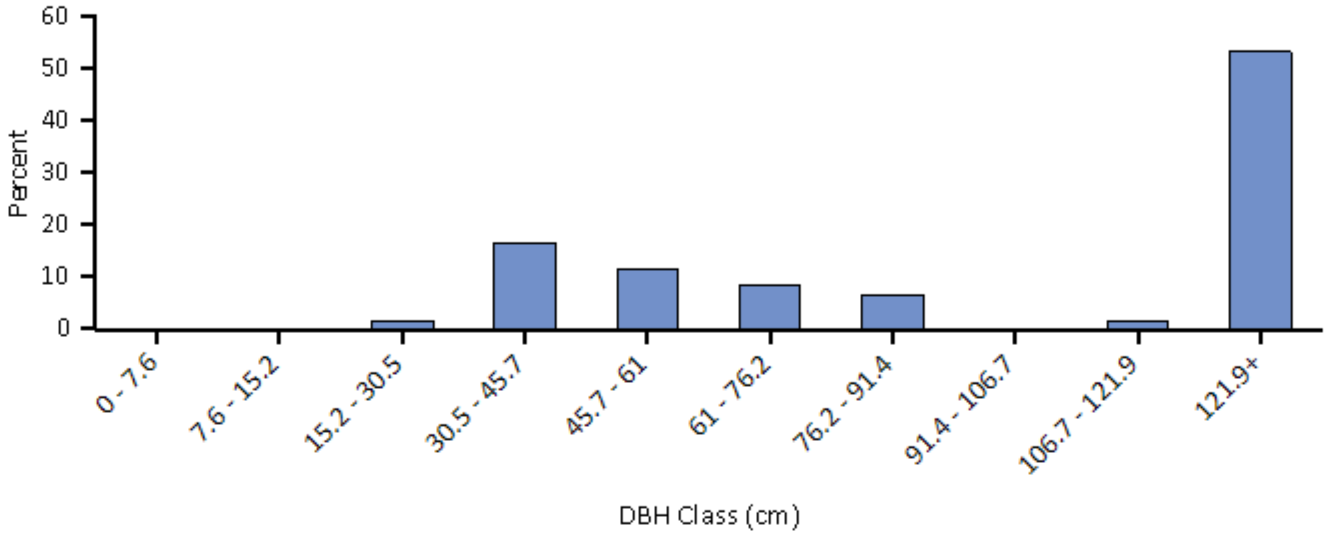


Figure 3. Percent of tree population by diameter class (DBH - stem diameter at 1.37 meters)

Urban forests are composed of a mix of native and exotic tree species. Thus, urban forests often have a tree diversity that is higher than surrounding native landscapes. Increased tree diversity can minimize the overall impact or destruction by a species-specific insect or disease, but it can also pose a risk to native plants if some of the exotic species are invasive plants that can potentially out-compete and displace native species. In Group10, about 73 percent of the trees are species native to North America. Most trees have an origin from Europe (10 percent of the trees).

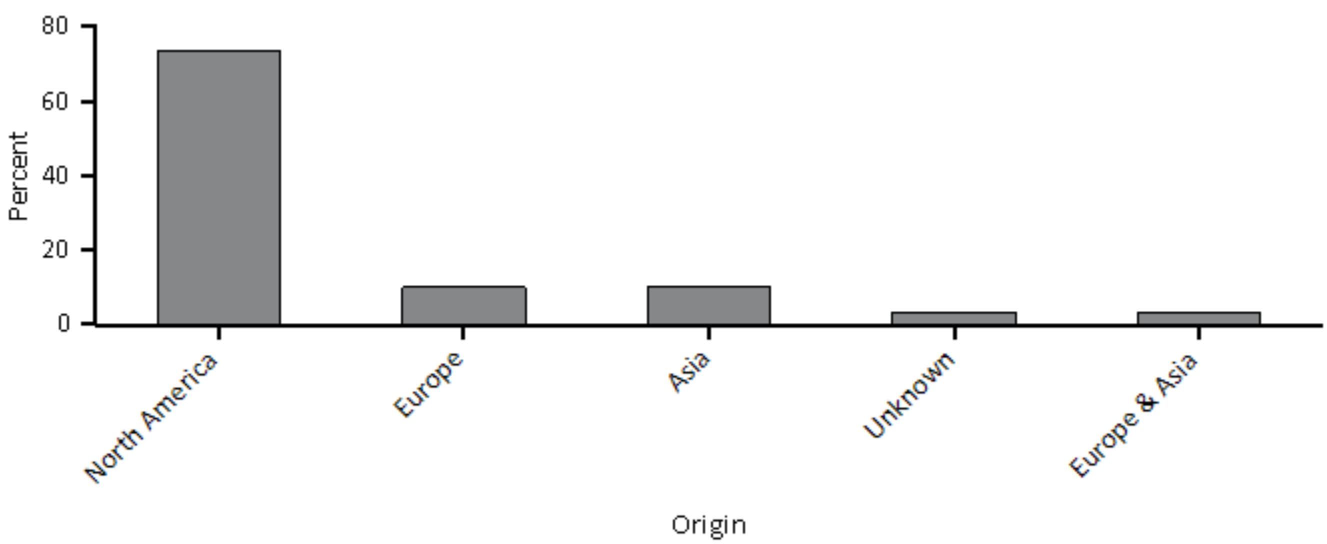


Figure 4. Percent of live tree population by area of native origin, Group10

Invasive plant species are often characterized by their vigor, ability to adapt, reproductive capacity, and general lack of natural enemies. These abilities enable them to displace native plants and make them a threat to natural areas.

II. Urban Forest Cover and Leaf Area

Many tree benefits equate directly to the amount of healthy leaf surface area of the plant. Trees cover about 4553 square meters of Group10 and provide 0.8222 hectares of leaf area.

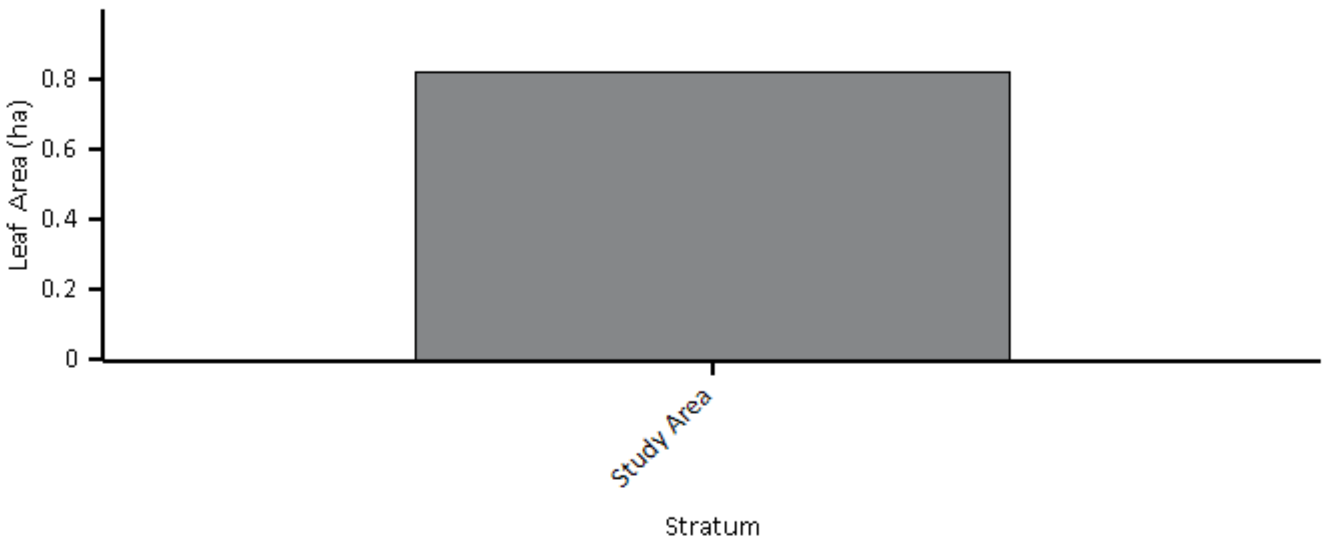


Figure 5. Leaf area by stratum, Group10

In Group10, the most dominant species in terms of leaf area are Sweetgum, Southern catalpa, and English oak. The 10 species with the greatest importance values are listed in Table 1. Importance values (IV) are calculated as the sum of percent population and percent leaf area. High importance values do not mean that these trees should necessarily be encouraged in the future; rather these species currently dominate the urban forest structure.

Table 1. Most important species in Group10

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Southern catalpa	53.3	19.9	73.3
Sweetgum	6.7	32.0	38.6
English oak	8.3	16.0	24.3
Sawara cypress	8.3	11.8	20.2
Red maple	8.3	4.5	12.9
American beech	1.7	6.0	7.7
Northern red oak	1.7	2.4	4.1
Austrian pine	1.7	2.0	3.7
European white birch	1.7	2.0	3.7
Trochocarpa spp	1.7	1.2	2.9

Common ground cover classes (including cover types beneath trees and shrubs) in Group10 are not available since they are configured not to be collected.

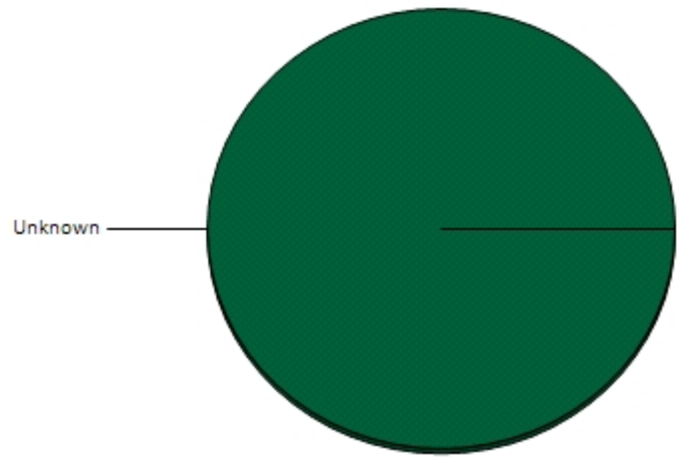


Figure 6. Percent of land by ground cover classes, Group10

III. Air Pollution Removal by Urban Trees

Poor air quality is a common problem in many urban areas. It can lead to decreased human health, damage to landscape materials and ecosystem processes, and reduced visibility. The urban forest can help improve air quality by reducing air temperature, directly removing pollutants from the air, and reducing energy consumption in buildings, which consequently reduces air pollutant emissions from the power sources. Trees also emit volatile organic compounds that can contribute to ozone formation. However, integrative studies have revealed that an increase in tree cover leads to reduced ozone formation (Nowak and Dwyer 2000).

Pollution removal[1] by trees in Group10 was estimated using field data and recent available pollution and weather data available. Pollution removal was greatest for ozone (Figure 7). It is estimated that trees remove 10.46 kilograms of air pollution (ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5)[2], and sulfur dioxide (SO2)) per year with an associated value of Can$1.3 (see Appendix I for more details).

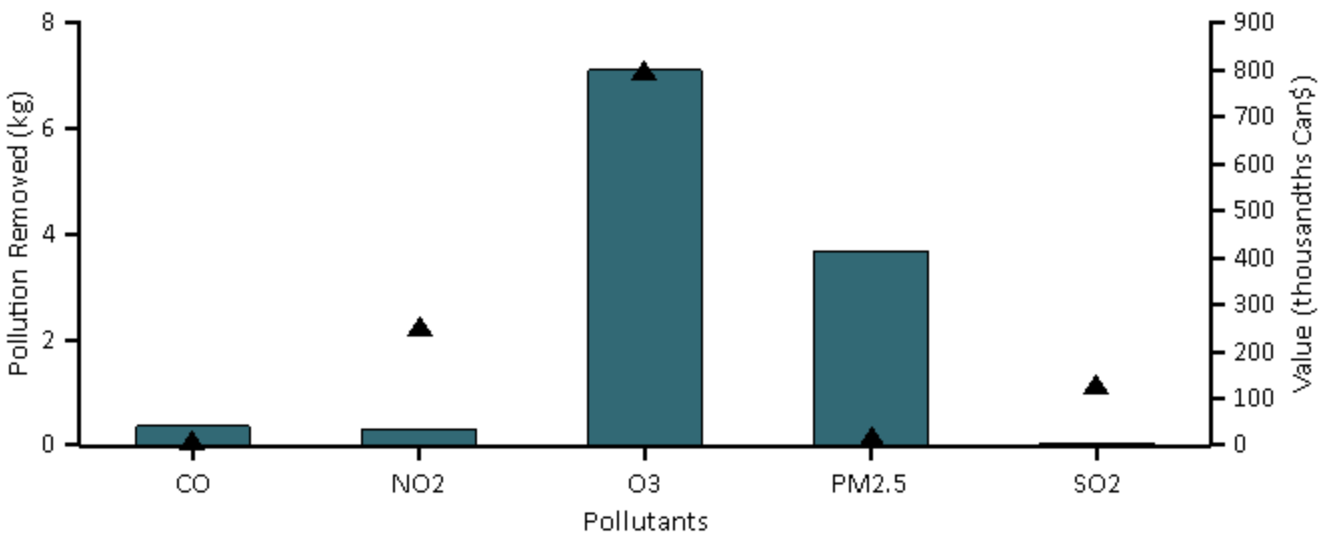


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, Group10

[1] Particulate matter less than 10 microns is a significant air pollutant. Given that i-Tree Eco analyzes particulate matter less than 2.5 microns (PM2.5) which is a subset of PM10, PM10 has not been included in this analysis. PM2.5 is generally more relevant in discussions concerning air pollution effects on human health.

[2] Trees remove PM2.5 when particulate matter is deposited on leaf surfaces. This deposited PM2.5 can be resuspended to the atmosphere or removed during rain events and dissolved or transferred to the soil. This combination of events can lead to positive or negative pollution removal and value depending on various atmospheric factors (see Appendix I for more details).

In 2020, trees in Group10 emitted an estimated 5.497 kilograms of volatile organic compounds (VOCs) (4.693 kilograms of isoprene and 0.8043 kilograms of monoterpenes). Emissions vary among species based on species characteristics (e.g. some genera such as oaks are high isoprene emitters) and amount of leaf biomass. Eighty- seven percent of the urban forest's VOC emissions were from Sweetgum and English oak. These VOCs are precursor chemicals to ozone formation.[3]

General recommendations for improving air quality with trees are given in Appendix VIII.

[3] Some economic studies have estimated VOC emission costs. These costs are not included here as there is a tendency to add positive dollar estimates of ozone removal effects with negative dollar values of VOC emission effects to determine whether tree effects are positive or negative in relation to ozone. This combining of dollar values to determine tree effects should not be done, rather estimates of VOC effects on ozone formation (e.g., via photochemical models) should be conducted and directly contrasted with ozone removal by trees (i.e., ozone effects should be directly compared, not dollar estimates). In addition, air temperature reductions by trees have been shown to significantly reduce ozone concentrations (Cardelino and Chameides 1990; Nowak et al 2000), but are not considered in this analysis. Photochemical modeling that integrates tree effects on air temperature, pollution removal, VOC emissions, and emissions from power plants can be used to determine the overall effect of trees on ozone concentrations.

IV. Carbon Storage and Sequestration

Climate change is an issue of global concern. Urban trees can help mitigate climate change by sequestering atmospheric carbon (from carbon dioxide) in tissue and by altering energy use in buildings, and consequently altering carbon dioxide emissions from fossil-fuel based power sources (Abdollahi et al 2000).

Trees reduce the amount of carbon in the atmosphere by sequestering carbon in new growth every year. The amount of carbon annually sequestered is increased with the size and health of the trees. The gross sequestration of Group10 trees is about 1.216 metric tons of carbon per year with an associated value of Can$140. See Appendix I for more details on methods.

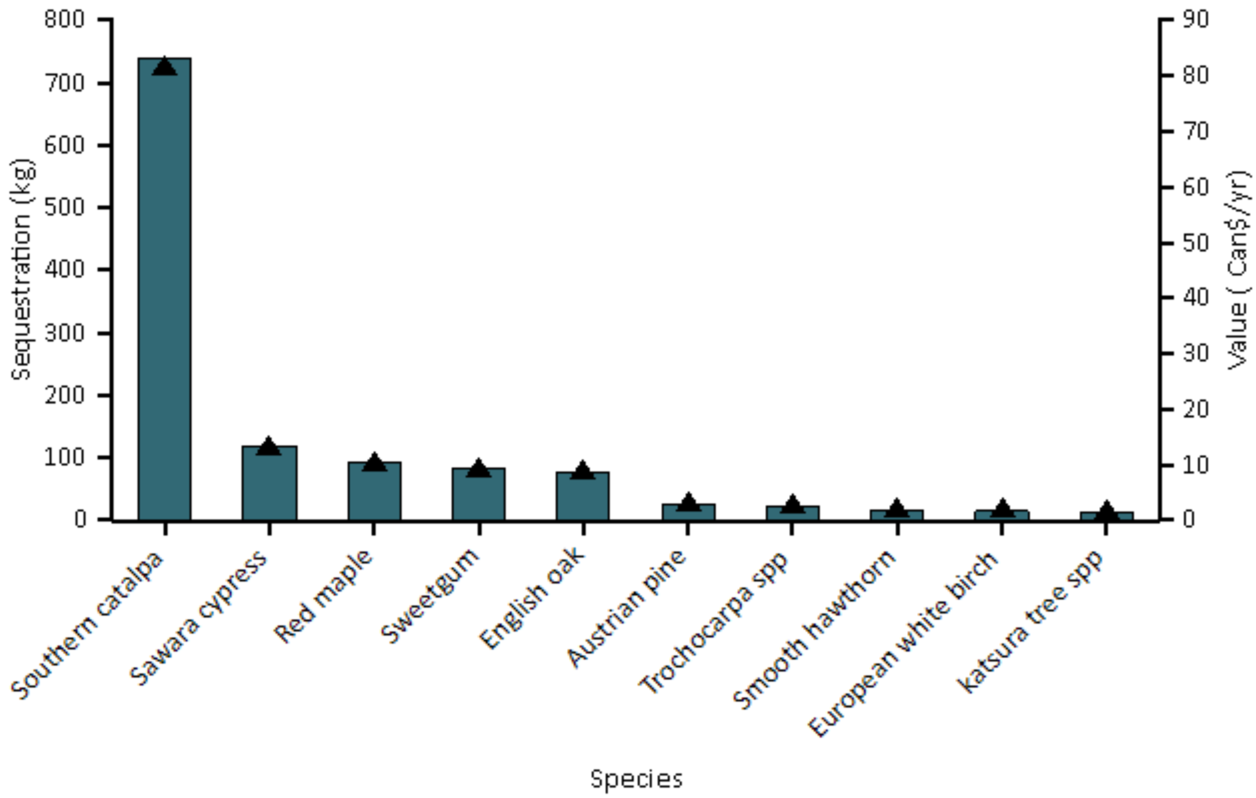


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Group10

Carbon storage is another way trees can influence global climate change. As a tree grows, it stores more carbon by holding it in its accumulated tissue. As a tree dies and decays, it releases much of the stored carbon back into the atmosphere. Thus, carbon storage is an indication of the amount of carbon that can be released if trees are allowed to die and decompose. Maintaining healthy trees will keep the carbon stored in trees, but tree maintenance can contribute to carbon emissions (Nowak et al 2002c). When a tree dies, using the wood in long-term wood products, to heat buildings, or to produce energy will help reduce carbon emissions from wood decomposition or from fossil-fuel or wood-based power plants.

Trees in Group10 are estimated to store 241 metric tons of carbon (Can$27.7 thousand). Of the species sampled, Southern catalpa stores and sequesters the most carbon (approximately 53.3% of the total carbon stored and 59.5% of all sequestered carbon.)

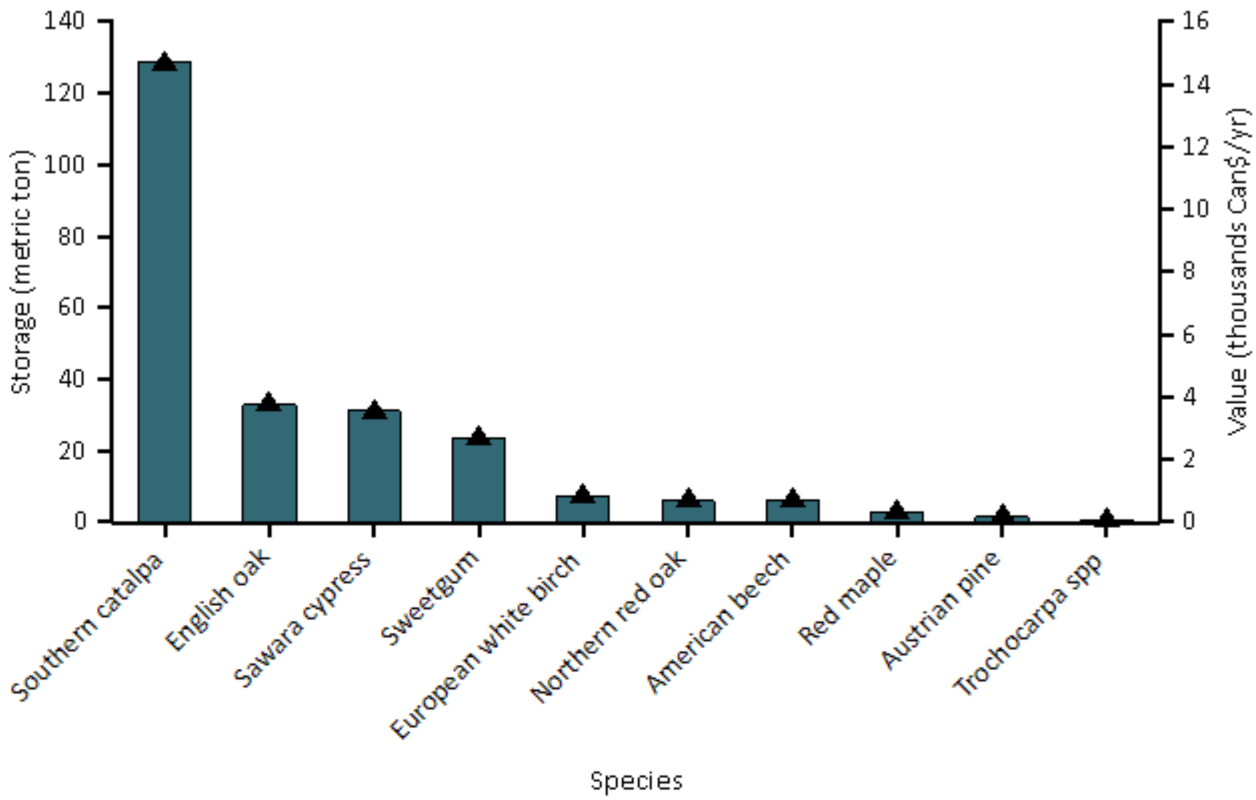


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, Group10

V. Oxygen Production

Oxygen production is one of the most commonly cited benefits of urban trees. The annual oxygen production of a tree is directly related to the amount of carbon sequestered by the tree, which is tied to the accumulation of tree biomass.

Trees in Group10 are estimated to produce 3.242 metric tons of oxygen per year.[4] However, this tree benefit is relatively insignificant because of the large and relatively stable amount of oxygen in the atmosphere and extensive production by aquatic systems. Our atmosphere has an enormous reserve of oxygen. If all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970).

Table 2. The top 20 oxygen production species.

Species	*Oxygen (kilogram)*	*Gross Carbon Sequestration (kilogram/yr)*	*Number of Trees*	*Leaf Area (square meter)*
Southern catalpa	1,928.31	723.12	32	0.00
Sawara cypress	310.82	116.56	5	0.00
Red maple	242.83	91.06	5	0.00
Sweetgum	217.44	81.54	4	0.00
English oak	201.13	75.42	5	0.00
Austrian pine	68.88	25.83	1	0.00
Trochocarpa spp	60.70	22.76	1	0.00
Smooth hawthorn	43.70	16.39	1	0.00
European white birch	40.00	15.00	1	0.00
katsura tree spp	37.30	13.99	1	0.00
Northern red oak	32.00	12.00	1	0.00
American beech	32.00	12.00	1	0.00
Japanese maple	13.87	5.20	1	0.00
Western hemlock	13.32	4.99	1	0.00

VI. Avoided Runoff

Surface runoff can be a cause for concern in many urban areas as it can contribute pollution to streams, wetlands, rivers, lakes, and oceans. During precipitation events, some portion of the precipitation is intercepted by vegetation (trees and shrubs) while the other portion reaches the ground. The portion of the precipitation that reaches the ground and does not infiltrate into the soil becomes surface runoff (Hirabayashi 2012). In urban areas, the large extent of impervious surfaces increases the amount of surface runoff.

Urban trees and shrubs, however, are beneficial in reducing surface runoff. Trees and shrubs intercept precipitation, while their root systems promote infiltration and storage in the soil. The trees and shrubs of Group10 help to reduce runoff by an estimated 55.7 cubic meters a year with an associated value of Can$130 (see Appendix I for more details). Avoided runoff is estimated based on local weather from the user-designated weather station. In Group10, the total annual precipitation in 2010 was 117.8 centimeters.

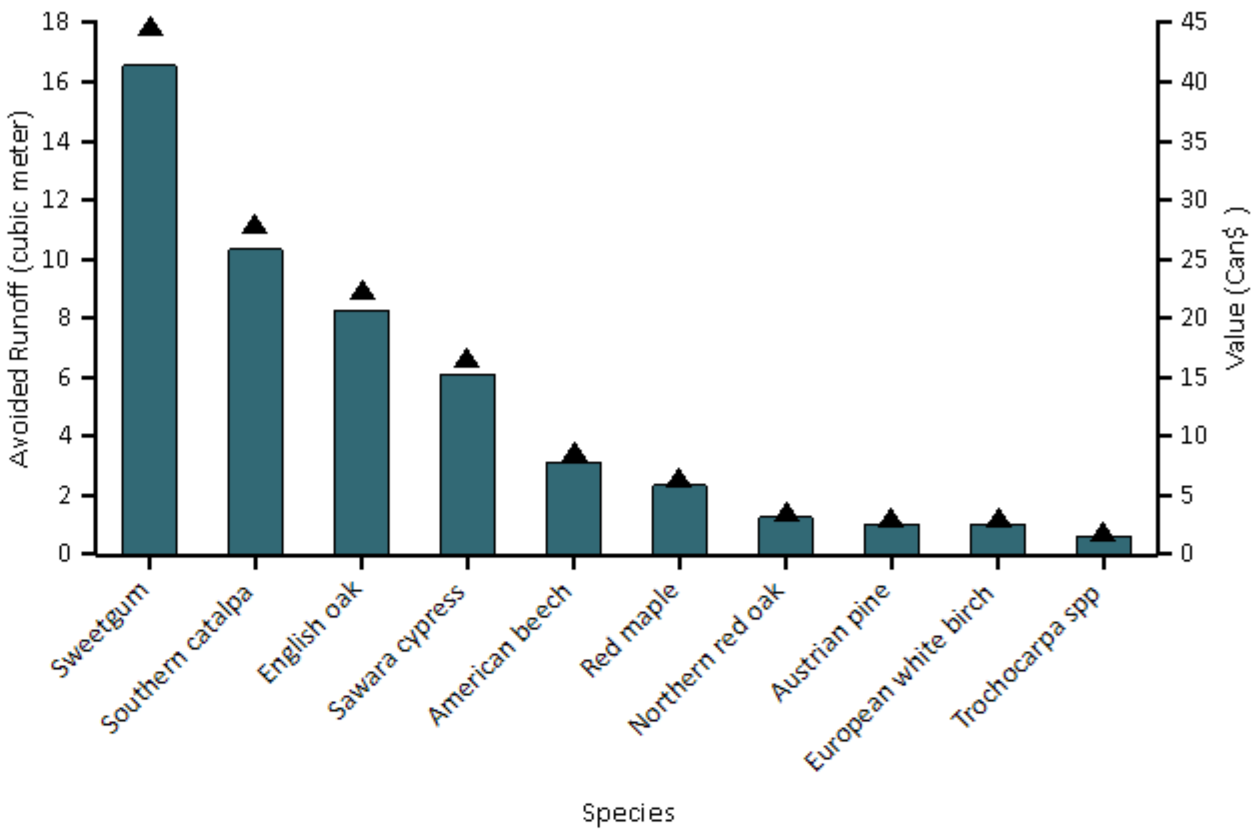


Figure 10. Avoided runoff (points) and value (bars) for species with greatest overall impact on runoff, Group10

VII. Trees and Building Energy Use

Trees affect energy consumption by shading buildings, providing evaporative cooling, and blocking winter winds. Trees tend to reduce building energy consumption in the summer months and can either increase or decrease building energy use in the winter months, depending on the location of trees around the building. Estimates of tree effects on energy use are based on field measurements of tree distance and direction to space conditioned residential buildings (McPherson and Simpson 1999).

Because energy-related data were not collected, energy savings and carbon avoided cannot be calculated.

Table 3. Annual energy savings due to trees near residential buildings, Group10

	Heating	*Cooling*	*Total*
MBTU[a]	0	N/A	0
MWH[b]	0	0	0
Carbon Avoided (kilograms)	0	0	0

[a]MBTU - one million British Thermal Units
[b]MWH - megawatt-hour

Table 4. Annual savings [a](Can$) in residential energy expenditure during heating and cooling seasons, Group10

	Heating	*Cooling*	*Total*
MBTU[b]	0	N/A	0
MWH[c]	0	0	0
Carbon Avoided	0	0	0

[b]Based on the prices of Can$95.9883333333333 per MWH and Can$17.8878017585382 per MBTU (see Appendix I for more details)
[c]MBTU - one million British Thermal Units
[c]MWH - megawatt-hour

[5] Trees modify climate, produce shade, and reduce wind speeds. Increased energy use or costs are likely due to these tree-building interactions creating a cooling effect during the winter season. For example, a tree (particularly evergreen species) located on the southern side of a residential building may produce a shading effect that causes increases in heating requirements.

VIII. Structural and Functional Values

Urban forests have a structural value based on the trees themselves (e.g., the cost of having to replace a tree with a similar tree); they also have functional values (either positive or negative) based on the functions the trees perform.

The structural value of an urban forest tends to increase with a rise in the number and size of healthy trees (Nowak et al 2002a). Annual functional values also tend to increase with increased number and size of healthy trees. Through proper management, urban forest values can be increased; however, the values and benefits also can decrease as the amount of healthy tree cover declines.

Urban trees in Group10 have the following structural values:

- Structural value: Can$1.51 million
- Carbon storage: Can$27.7 thousand

Urban trees in Group10 have the following annual functional values:

- Carbon sequestration: Can$140
- Avoided runoff: Can$129
- Pollution removal: Can$1.3
- Energy costs and carbon emission values: Can$0

(Note: negative value indicates increased energy cost and carbon emission value)

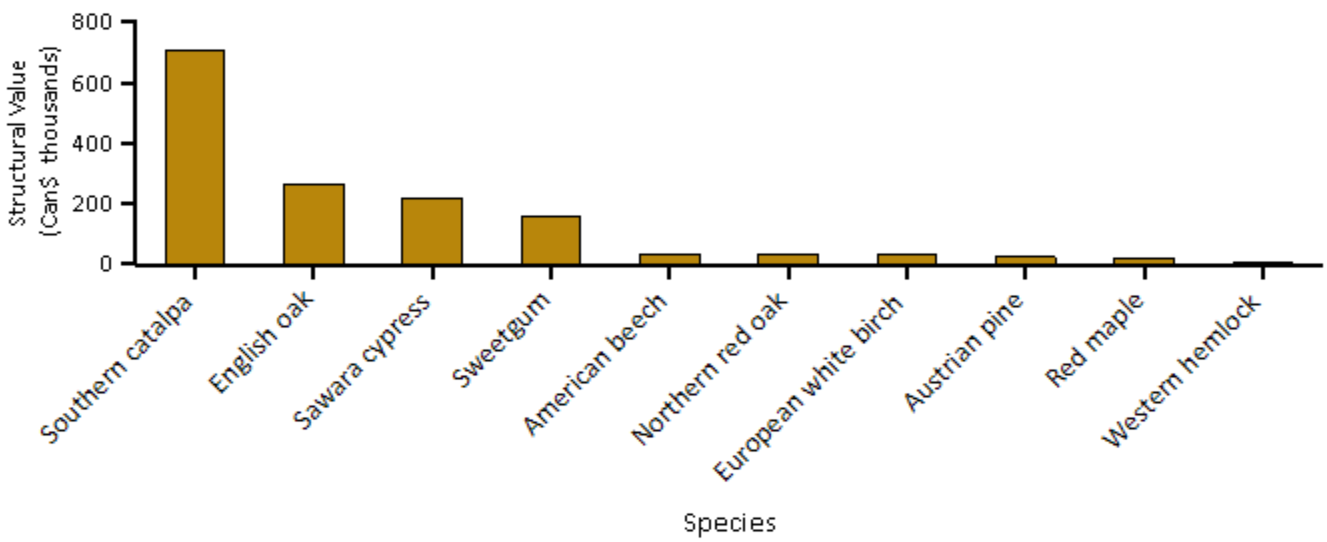


Figure 11. Tree species with the greatest structural value, Group10

[1] Structural value in Canada is calculated using the same procedure as the U.S. (Nowak et al 2002a). Base costs and species values are derived from the International Society of Arboriculture Ontario Chapter and applied to all Canadian provinces and territories.

IX. Potential Pest Impacts

Various insects and diseases can infest urban forests, potentially killing trees and reducing the health, structural value and sustainability of the urban forest. As pests tend to have differing tree hosts, the potential damage or risk of each pest will differ among cities.Thirty-six pests were analyzed for their potential impact.

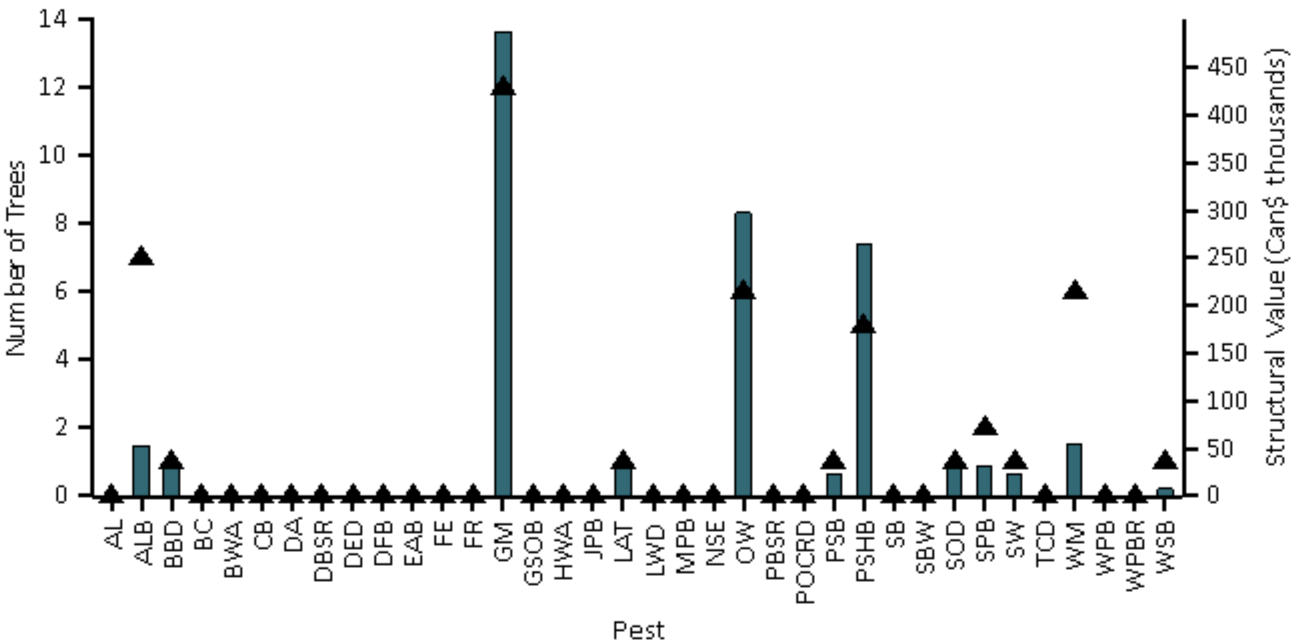


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) by potential pests, Group10

Aspen leafminer (AL) (Kruse et al 2007) is an insect that causes damage primarily to trembling or small tooth aspen by larval feeding of leaf tissue. AL has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Asian longhorned beetle (ALB) (Animal and Plant Health Inspection Service 2010) is an insect that bores into and kills a wide range of hardwood species. ALB poses a threat to 11.7 percent of the Group10 urban forest, which represents a potential loss of Can$53.2 thousand in structural value.

Beech bark disease (BBD) (Houston and O'Brien 1983) is an insect-disease complex that primarily impacts American beech. This disease threatens 1.7 percent of the population, which represents a potential loss of Can$36 thousand in structural value.

Butternut canker (BC) (Ostry et al 1996) is caused by a fungus that infects butternut trees. The disease has since caused significant declines in butternut populations in the United States. Potential loss of trees from BC is 0.0 percent (Can$0 in structural value).

Balsam woolly adelgid (BWA) (Ragenovich and Mitchell 2006) is an insect that has caused significant damage to the true firs of North America. Group10 could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

The most common hosts of the fungus that cause chestnut blight (CB) (Diller 1965) are American and European chestnut. CB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Dogwood anthracnose (DA) (Mielke and Daughtrey) is a disease that affects dogwood species, specifically flowering and Pacific dogwood. This disease threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Douglas-fir black stain root disease (DBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks Douglas-firs. Group10 could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

American elm, one of the most important street trees in the twentieth century, has been devastated by the Dutch elm disease (DED) (Northeastern Area State and Private Forestry 1998). Since first reported in the 1930s, it has killed over 50 percent of the native elm population in the United States. Although some elm species have shown varying degrees of resistance, Group10 could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Douglas-fir beetle (DFB) (Schmitz and Gibson 1996) is a bark beetle that infests Douglas-fir trees throughout the western United States, British Columbia, and Mexico. Potential loss of trees from DFB is 0.0 percent (Can$0 in structural value).

Emerald ash borer (EAB) (Michigan State University 2010) has killed thousands of ash trees in parts of the United States. EAB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

One common pest of white fir, grand fir, and red fir trees is the fir engraver (FE) (Ferrell 1986). FE poses a threat to 0.0 percent of the Group10 urban forest, which represents a potential loss of Can$0 in structural value.

Fusiform rust (FR) (Phelps and Czabator 1978) is a fungal disease that is distributed in the southern United States. It is particularly damaging to slash pine and loblolly pine. FR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The gypsy moth (GM) (Northeastern Area State and Private Forestry 2005) is a defoliator that feeds on many species causing widespread defoliation and tree death if outbreak conditions last several years. This pest threatens 20.0 percent of the population, which represents a potential loss of Can$488 thousand in structural value.

Infestations of the goldspotted oak borer (GSOB) (Society of American Foresters 2011) have been a growing problem in southern California. Potential loss of trees from GSOB is 0.0 percent (Can$0 in structural value).

As one of the most damaging pests to eastern hemlock and Carolina hemlock, hemlock woolly adelgid (HWA) (U.S. Forest Service 2005) has played a large role in hemlock mortality in the United States. HWA has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The Jeffrey pine beetle (JPB) (Smith et al 2009) is native to North America and is distributed across California, Nevada, and Oregon where its only host, Jeffrey pine, also occurs. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Quaking aspen is a principal host for the defoliator, large aspen tortrix (LAT) (Ciesla and Kruse 2009). LAT poses a threat to 1.7 percent of the Group10 urban forest, which represents a potential loss of Can$31.5 thousand in structural value.

Laurel wilt (LWD) (U.S. Forest Service 2011) is a fungal disease that is introduced to host trees by the redbay ambrosia beetle. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

Mountain pine beetle (MPB) (Gibson et al 2009) is a bark beetle that primarily attacks pine species in the western United States. MPB has the potential to affect 0.0 percent of the population (Can$0 in structural value).

The northern spruce engraver (NSE) (Burnside et al 2011) has had a significant impact on the boreal and sub-boreal forests of North America where the pest's distribution overlaps with the range of its major hosts. Potential loss of trees from NSE is 0.0 percent (Can$0 in structural value).

Oak wilt (OW) (Rexrode and Brown 1983), which is caused by a fungus, is a prominent disease among oak trees. OW poses a threat to 10.0 percent of the Group10 urban forest, which represents a potential loss of Can$297 thousand in structural value.

Pine black stain root disease (PBSR) (Hessburg et al 1995) is a variety of the black stain fungus that attacks hard pines, including lodgepole pine, Jeffrey pine, and ponderosa pine. Group10 could possibly lose 0.0 percent of its trees to this pest (Can$0 in structural value).

Port-Orford-cedar root disease (POCRD) (Liebhold 2010) is a root disease that is caused by a fungus. POCRD threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

The pine shoot beetle (PSB) (Ciesla 2001) is a wood borer that attacks various pine species, though Scotch pine is the preferred host in North America. PSB has the potential to affect 1.7 percent of the population (Can$23.6 thousand in structural value).

Polyphagous shot hole borer (PSHB) (University of California 2014) is a boring beetle that was first detected in California. Group10 could possibly lose 8.3 percent of its trees to this pest (Can$264 thousand in structural value).

Spruce beetle (SB) (Holsten et al 1999) is a bark beetle that causes significant mortality to spruce species within its range. Potential loss of trees from SB is 0.0 percent (Can$0 in structural value).

Spruce budworm (SBW) (Kucera and Orr 1981) is an insect that causes severe damage to balsam fir. SBW poses a threat to 0.0 percent of the Group10 urban forest, which represents a potential loss of Can$0 in structural value.

Sudden oak death (SOD) (Kliejunas 2005) is a disease that is caused by a fungus. Potential loss of trees from SOD is 1.7 percent (Can$33.5 thousand in structural value).

Although the southern pine beetle (SPB) (Clarke and Nowak 2009) will attack most pine species, its preferred hosts are loblolly, Virginia, pond, spruce, shortleaf, and sand pines. This pest threatens 3.3 percent of the population, which represents a potential loss of Can$30.9 thousand in structural value.

The sirex woodwasp (SW) (Haugen and Hoebeke 2005) is a wood borer that primarily attacks pine species. SW poses a threat to 1.7 percent of the Group10 urban forest, which represents a potential loss of Can$23.6 thousand in structural value.

Thousand canker disease (TCD) (Cranshaw and Tisserat 2009; Seybold et al 2010) is an insect-disease complex that kills several species of walnuts, including black walnut. Potential loss of trees from TCD is 0.0 percent (Can$0 in structural value).

Winter moth (WM) (Childs 2011) is a pest with a wide range of host species. WM causes the highest levels of injury to its hosts when it is in its caterpillar stage. Group10 could possibly lose 10.0 percent of its trees to this pest

(Can$53.6 thousand in structural value).

The western pine beetle (WPB) (DeMars and Roettgering 1982) is a bark beetle and aggressive attacker of ponderosa and Coulter pines. This pest threatens 0.0 percent of the population, which represents a potential loss of Can$0 in structural value.

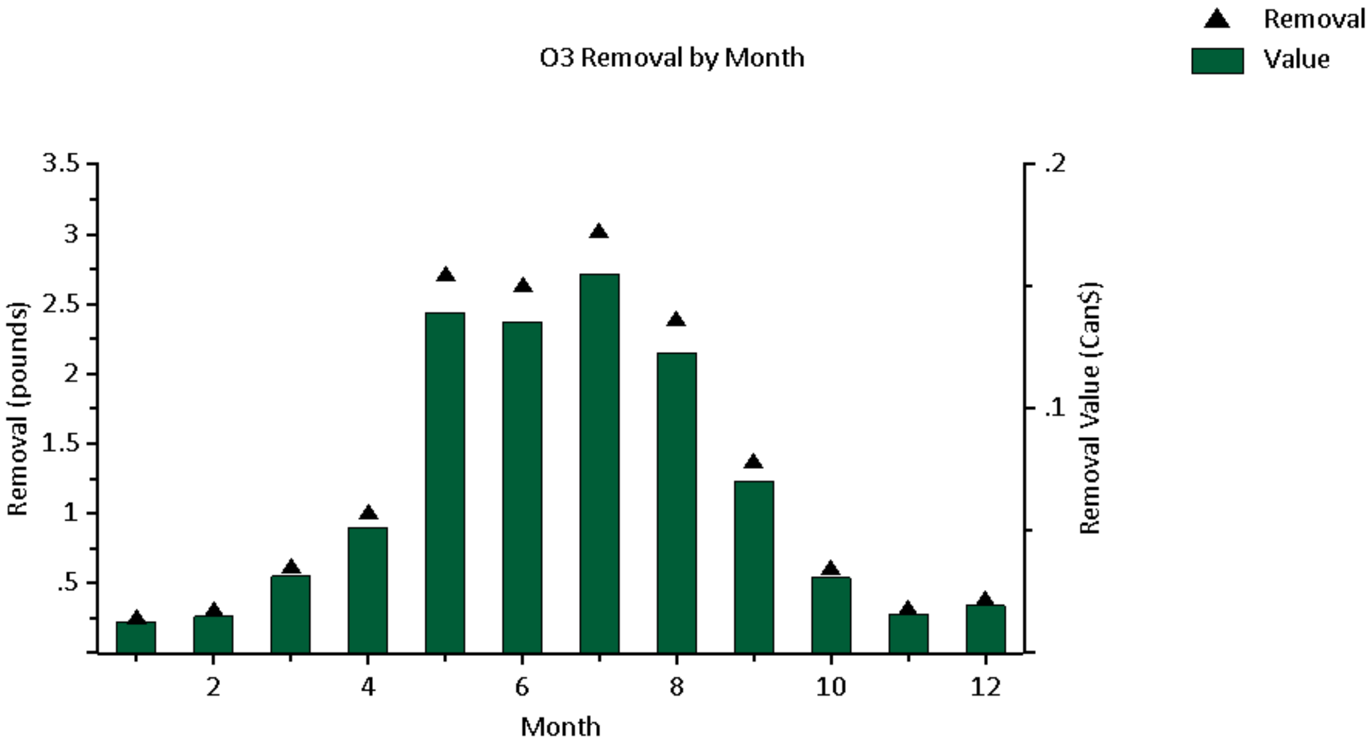
Since its introduction to the United States in 1900, white pine blister rust (Eastern U.S.) (WPBR) (Nicholls and Anderson 1977) has had a detrimental effect on white pines, particularly in the Lake States. WPBR has the potential to affect 0.0 percent of the population (Can$0 in structural value).

Western spruce budworm (WSB) (Fellin and Dewey 1986) is an insect that causes defoliation in western conifers. This pest threatens 1.7 percent of the population, which represents a potential loss of Can$7.35 thousand in structural value.

Appendix C

Pollution Removal by Trees and Shrubs - Monthly Removal

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group10, Series: Zone 10, Year: 2020
Generated: 2020/3/22



O3 value is calculated based on the price of Can$0.05 per pound.

Ecosystem services report

Prepared by:

Group 11

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University of British Columbia

April 8, 2020

For UFOR 101, UBC Winter term 2, 2020

Table of Contents

1 Introduction

1.1 Purpose

This Group 11 assessment is going to determine certain contributions for the ecosystem as the result to understand the structure of an urban forest, function, and value can promote management decisions that will improve human health and environmental quality. In this task of making a tree inventory of a section of the University of British Columbia campus. From the course and personal point of view, mastering the basic measurement methods and understanding the measurement process is extremely important throughout the learning. When after clearly understanding the current situation., it is significant to the management of tree distribution and future assessment and their development. How to observe the tree concentration can give the keys that can assure that the biological distribution of these biological forms have to be maintained in the areas where they are standing. The idea of a tree inventory is mostly to understand and to construct the form on why there are significant concentrations or distributions of trees inside the UBC campus. In order to understand the structure of an urban forest, function and value can promote management decisions that will improve the human health and environmental quality.

Figure 1.1 Tree inventory zone map

1.2 Site description

Tree Inventory Zone in the UBC Campus is from Buchanan Building Blocks A to E including Buchanan Tower Those are located in the most northern part of the campus between Crescent and Memorial Rd. This complex of buildings is one of the most important complexes inside the campus because many cultural activities among other types of meetings inside the campus are made. Thus, in the history of the entire campus, it is one of the buildings that were constructed during the period of considerable structure expansion after World War Two. The Buchanan Buildings provide a study place for students, professors, and any other individuals. The reflection pool is a landmark and it surrounds a stunning white concrete pavilion. A quarter land area is a flat road and public utilities including the parking lots, street lights, tables, chairs, and trash cans. The rest of the land is made up of greens, such as grassland and trees. Therefore, the zone offers enough space and comforts in the terms of its biological diversity, which is advantageous for the environment and also following many of the politics of the Canadian government regarding ecological balance and sustainability of the environment. This zone is also where people interact and exchange and many amenities like the vegetation helps to increase the value of the buildings, but also their intrinsic value where they are located.

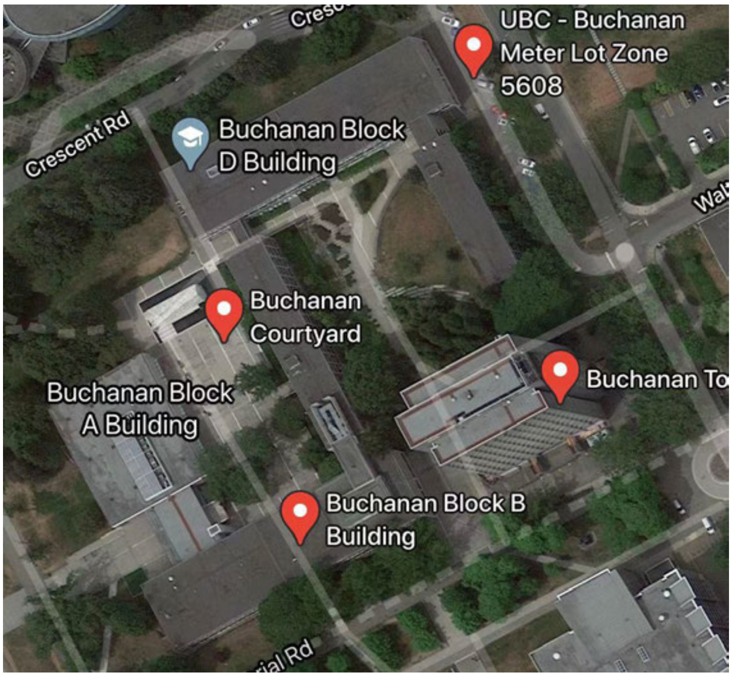

Figure 1.2 Main areas of the site

2 Regulating ecosystem services

2.1 Description of models

The i-Tree Canopy and the i-Tree Eco tools provide vital data to understand the urban forests' structure, function, and value. The data is useful in promoting management decisions aimed to improve human health and environmental quality. This part describes the i-Tree Canopy and i-Tree Eco tools.

The i-Tree canopy model can be bottom-up or top-down depending on which method one intends to use. In our group assessments both bottom-up and top-down i-Tree Canopy assessments were carried out because we provide the types of information required in the report (i-Tree, 2020).

The bottom-up approach involves field-based assessments that examine the physical structure of the forest, such as the number of trees, the species composition. It is used for advocacy and strategic forest management (i-Tree, 2020). Assessors use the approach in connecting the structure, values, and functions of the forest visa vice risks, costs, and needs it presents insofar as environmental conservation and sustainability are concerned. The top-down approach assesses the canopy cover of urban forests using satellite images or aerial images. It determines the distribution and amount of tree cover in a metropolitan area, the cover types, and the potential for future tree planting opportunities based on available space.

The i-Tree Eco model uses data and tree measurements to estimate the nature and types of ecosystem services and physical and structural features of both urban and rural forests ("i-Tree Eco | Ecosystems Knowledge Network," 2020). The model is a complete package in that it has sampling data protocols, flexible data options, automated processing, and reports. It uses the Eco application or a web in which data is entered digitally or manually. The data are usually merged with local information on hourly weather and concentration of air pollution (i-Tree Eco, 2020). Using scientific equations and algorithms, the model calculates the functional and structural information about a given urban centre.

2.2 Weaknesses and strengths

When we use i-Tree Canopy and i-Tree Eco, we can clearly feel their pros and cons. Technology has brought convenience to people, which of course includes the combination of environment and technology. When we use these tools, we avoid a lot of time and energy consumption of manual measurement. Meanwhile, there is some data that we cannot measure and can only use satellites for exploration. Especially when measuring with us during the rainy and snowy seasons in Vancouver, the software provides us with more direct and efficient data. For example, i-Tree Canopy provides the location of trees which shows by spot and the tree species. The data presented to us by i-Tree eco is more accurate, such as economic value and carbon dioxide storage. But at the same time, they also have drawbacks. The user of the assessment tools is still us. We can't be sure that the inventors really know how to use the tools that he has. If the inventors have misunderstanding the result would be completely different. And it actually consumes a lot of time when you set up the tools. And the cost of technology tools will be more expensive, software editing will become more complicated.

2.3 Similarities and differences

Both models provide data and information about urban forest structure. The i-Tree Canopy model provides information such as the number of trees, their locations, the composition of species, the health of trees, risks, and tree sizes (i-Tree, 2020). The i-Tree Eco mainly focuses on ecosystem services. From the i-Tree canopy and i-Tree Eco we know there are 28 trees in total (Figure 1), tree cover is 1.515 thousand square feet (Figure 2). The most common species of trees: Western redcedar, Raywood ash, European mountain ash (Figure 3 & Table 1). On the other hand, i-Tree Eco provides the results like pollution removal, carbon storage, carbon sequestration, oxygen production (i-Tree Ecosystem Analysis, p. 2). All the services mentioned above have brought certain economic value.

2.4 Outputs

2.4.1 Air pollution removal by urban trees

Pollutant removal is calculated for ozone, sulfur dioxide, nitrogen dioxide, carbon monoxide and particulate matter less than 2.5 microns(i-Tree, p. 21). The removal amount is based on the big-leaf and multi-layer canopy. It is estimated that trees remove 22.84 ounces of air pollution (Figure 4). The total removal value is calculated based on the prices of Can$1,348 per ton (carbon monoxide), Can$103 per ton (ozone), Can $15 per ton (nitrogen dioxide), Can $5 per ton (sulfur dioxide), Can$ 3,722 per ton (particulate matter less than 2.5 microns)(i-Tree, p. 22). Through the comparison of value, we found our area has a significant role in carbon monoxide removal and PM 2.5 removal. That most depends on the tree size and species also their health condition.

2.4.2 Carbon storage and sequestration

Storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation. Sequestration is the removal of carbon dioxide from the air by plants(i-Tree, 2020). With global warming and the advancement of the industrial age, the storage of carbon dioxide has become particularly important, despite being on campus, we also have carbon dioxide from traffic and people exhaling. For our zone the total value is Can$ 104 per ton. The gross of sequestration is about 969.7 pounds of carbon/year (Figure 5) and the store of carbon is 67.5 tons (Figure 6). Although global warming is slowing, the situation is not optimistic. This shows the importance of our reforestation, and this is a long-term plan. Because if we stop the idea of rebuilding the forest, the consequences will be unimaginable.

2.4.3 Oxygen production

While the forest absorbs carbon dioxide, it also releases oxygen, but compared with the production of oxygen, people are more concerned about the carbon dioxide emissions it can reduce because oxygen is already present in the air in large amounts. Our area produces 1.293 tons of oxygen/year (Table 2).

2.5 Model Analysis

Climate change is one of the most important issues that humans must consider right now, trees and green spaces help to cool the urban climate sufficiently. Urban trees help improve global warming by sequestering atmospheric carbon in their tissues. According to the data generated by itree, the gross sequestration in our study area is about 969.7 pounds of carbon per year. The amount of carbon annually sequestered would increase as the trees grow larger in size, also is associated with the health of the trees.

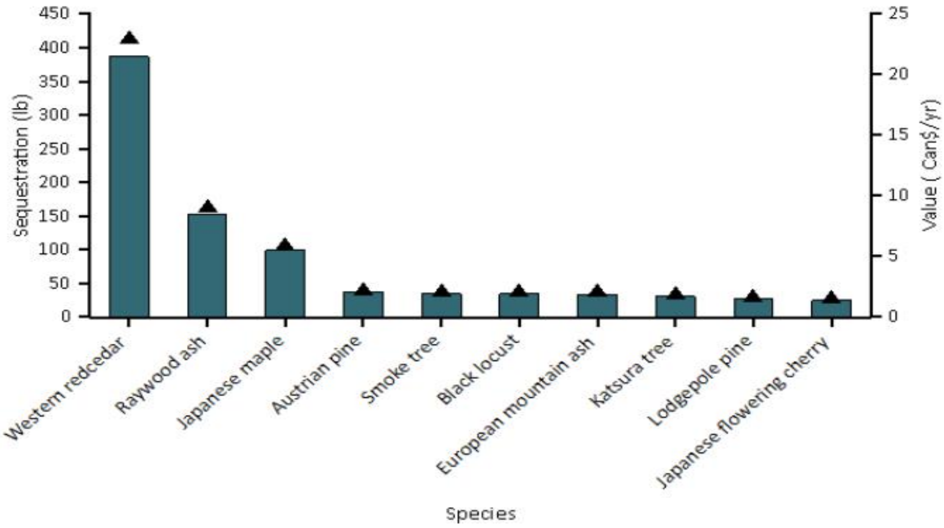

Figure 2.5.1 Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, i-Tree group 11 UBC

Surface runoff can be a serious concern in urban areas, as it can lead to pollution to streams, oceans, and lakes. It is the movement of water on the surface of land/soil to the oceans, it consists of precipitation that cannot evaporate, nor penetrate through the surface to become groundwater. The trees and shrubs in our study area help to reduce surface runoff by approximately 123 cubic feet a year, the annual precipitation in 2010 was 46.4 inches.

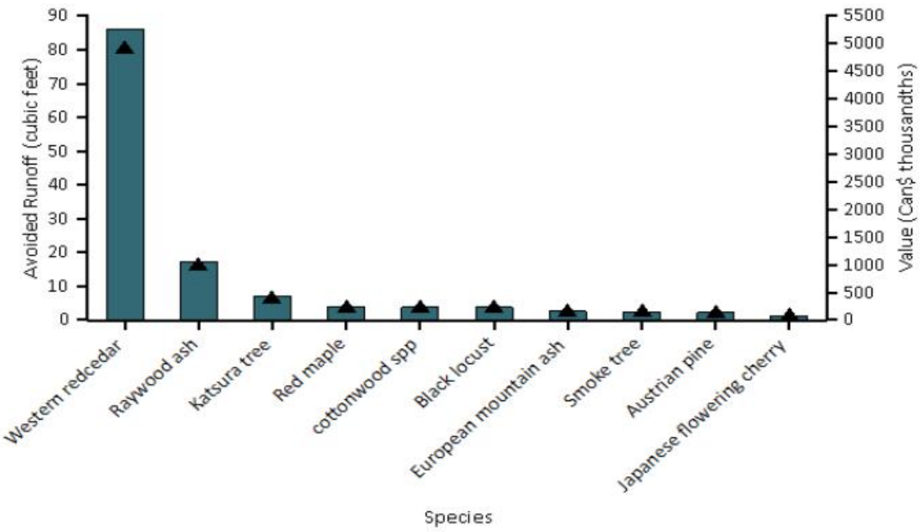

Figure 2.5.2. Avoided runoff and value for species with greatest overall impact on runoff,i-Tree group11 UBC

Carbon storage is another way trees help to improve global climate change, trees store more carbon as it grows. If a tree dies and decays, it releases the same amount of carbon stored back into the atmosphere. Because most evergreen trees have a relatively long lifetime, maintaining healthy trees will help keep the amount of carbon stored in trees. As a tree dies, using the wood to produce heat or energy reduces carbon emissions from wood decomposition. Trees in our study area store approximately upto 67.5 tons of carbon. Western red cedar stores and sequesters the most carbon within the area.

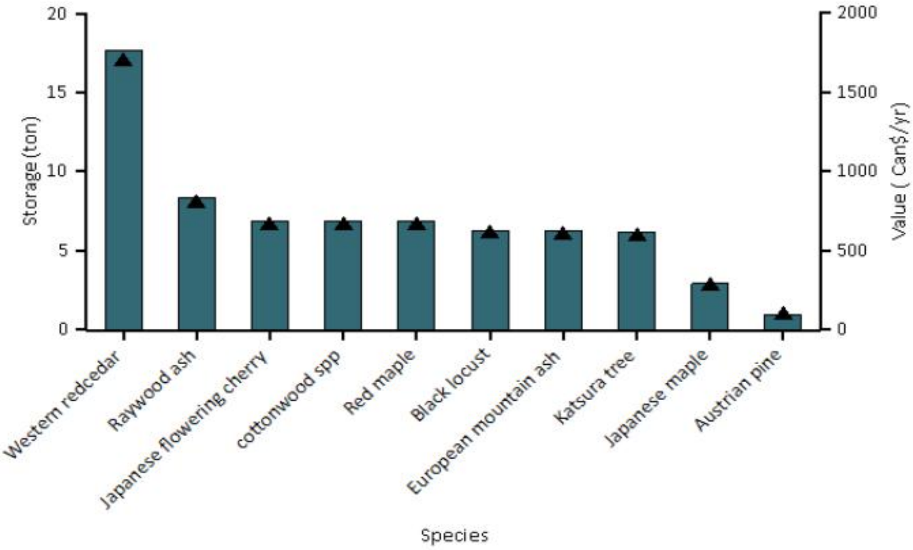

Figure 2.5.3. Estimated carbon storage and values for urban tree species with the greatest storage, i-Tree group 11 UBC

There are potential impacts to urban forests that may be caused by insects, and diseases. It may lead to killing the trees and reducing the structural value and sustainability of the urban forest. According to the diagram, Asian longhorned beetle(ALB) poses a threat to 14.3 percent of urban forest in our study area. which can cause a potential loss of Cad.$134 thousand in structural value. Emerald ash borer(EAB) also has the potential to affect the same amount as ALB in our zone with less population required. IT may cause a potential loss of Cad.$68 thousand in structural value.

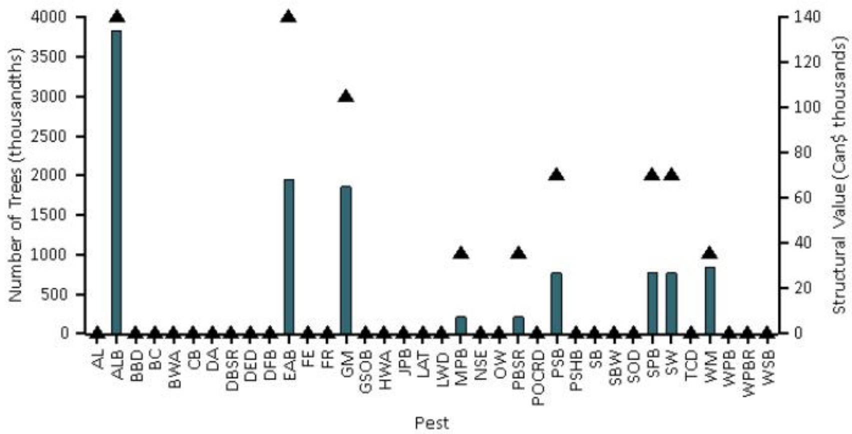

Figure 2.5.4 Number of trees at risk and associated compensatory value by potential pests, i-Tree group 11 UBC

3 Cultural ecosystem services

3.1 Methodology

There are two types of methods used to assess and quantify ecosystem services, which are experience dimension sheets, and another one is the in-street interview.

First of all, each member individually assessed five sub-zones, A, B, C, D, E by applying six experience dimensions onto group range, which are diversity, aesthetics, community sharing, recreation, serene, cultural significance. The highest and lowest scores in diversity are sub-zone C and B respectively, where sub-zone C has a little wood and sub-zone B is mostly open space. The sub-zone A and B tied for first place on aesthetic, it's a perfect combination of nature and square. The sub-zone E is the least beautiful and safe place which has an old parking lot. Sub-zone A provides a safe and comfortable area for community sharing and recreation. Instead, sub-zone C is a quiet and low transit road. Even though there is a safety station, it is still quite unsafe especially during cloudy days. This makes it have a low score in social, activity, serene and cultural significance. It is worth mentioning that there is a row of memorial trees in sub-zone E, which makes it valuable in cultural significance. Ranking of sub-zones from highest to lowest are A, D, E, B, C.

Secondly, six group members separated into three small groups, each small group needed to interview ten people within the selected sub-zone which is high transit. Engage them to answer how they feel about the surroundings and explain why. Based on collected data from 3 selected sub-zones, A, B, and E, there are 23 smiley faces, 6 neutral faces, and only 1 sad face. The best comments are it's a nice place in good weather and a lot of green plants surround them. For instance, "I enjoy nature, especially today is a sunny day;" "My puppy and I love to go for a walk here, you can feel nature but also on the campus;" "Perfect balance of nature and human beings." According to a few neutral faces, people reflect that buildings and roads are too old and need to be repaired. "The facility building is kind of old;" "Not modern enough;" "The path is kind of dangerous during the night, might need improvement." The only sad face reflects that "Feel awful on a raining day due to the side path too dark after the sun goes down."

Group 11

Rank:	yellow: 1st	blue: 2nd	orange: 3rd	green: 4th	white: 5th		
	EXPERIENCE DIMENSIONS						
Subzone ID	Diversity/ species richness	Aesthetics/ beauty	Social/ community sharing	Recreation/ activity	Serene/ refuge/safe	Cultural significance	Subtotal Score
SUMMARY							
A	15	20	24	25	25	20	129
B	11	20	21	20	24	18	114
C	22	19	11	13	21	16	102
D	17	19	21	20	23	19	119
E	18	18	20	19	21	21	117
F							
G							
H							
AVERAGE							
A	3	4	4.8	5	5	4	
B	2.2	4	4.2	4	4.8	4.6	
C	4.4	3.8	2.2	2.6	4.2	3.2	
D	3.4	3.8	4.2	4	4.6	3.8	
E	3.6	3.6	4	3.8	4.2	4.2	

Figure 3.1 Summary and Average score chart of Experience dimension

According to the results of both methods, we can see the rank of the sub-zone by summarizing all the marks given by each member. Furthermore, we can also know where the highest and lowest-ranked sub-zone are within high transit. And the participants gave us more objective opinions and suggestions. We can improve based on these ideas, and do our best to integrate experiences with other traditional spatial information, and also quantify the value of urban green spaces for different people.

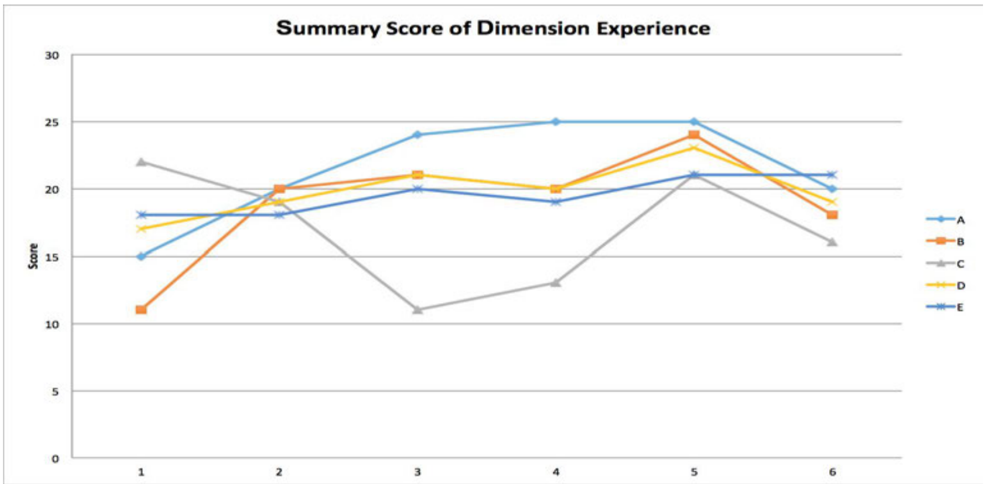

Figure 3.2 Line graph of Dimension experience

3.2 Weaknesses and strengths

There are some strengths and weaknesses of the value mapping approach. Value map is a tool for measuring and visualizing value. The strength is that people can clearly see the advantages and disadvantages of an item that needs to be evaluated. For instance, from figure 6. 2 the trend of sub-zone D and E is relatively flat; the trend of sub-zone A and B is likely a growing upward arc-shape line; the trend of sub-zone C is a downward curve. So that people can see the problem directly and improve it. Such as zone 11, some buildings have several plants nearby, which results in a low score of tree species diversity. Therefore, students can be called on to plant more trees in these areas where there is lack of plants. But there are also some drawbacks to this approach. Value is difficult to measure by certain standards, so the accuracy of the data assessed through surveys may not be very high. The data of value evaluation is kind of subjective. By investigating different groups of people, different values may be obtained. In the same place, everyone's intuitive feelings and the grade they are given might be thoroughly different. The only way to make the data more convincing is to collect scores from more people. As a result, once the data does not reach a certain amount, it is inaccurate.

Figure 3.3 Final value mapping map

3.3 Results and interpretation

The area that group eleven members investigated was UBC zone 11, where can be found the embodiment of cultural ecosystem services. Cultural ecosystem services are the intangible benefits that people get from the ecosystem through entertainment, "tourism, intellectual development, spiritual enrichment, reflection, creation, and aesthetic experiences"(Freshwater Information System). When people evaluated the cultural system services of UBC zone 11, many of the higher scores were due to rich human activities. There were some people sitting on the bench and reading books, some of them lay on the lawn and enjoyed the sunshine, and some were walking and playing sports on urban green spaces. During the in-class survey, one of the members was an art student. He said that he likes the green space and cherry blossoms in zone 11, and he often paints these scenes on campus to relax.

There are also some cultural ecosystem service examples in life from several aspects below. Agricultural landscapes offer many recreational opportunities and are considered to have mental health benefits. For agricultural tourism, this is a fast-growing market, which allows urban residents to connect with nature. Generally, attractive farms are those whose products have a good environment, sustainability and close connection with nature. Satoyama Initiative and Globally Important Agricultural Heritage Sites recognize the high cultural value of agricultural landscapes to the society. For example, forest is the source of many technological developments, one of which is to help collect urban rainwater. Many religions are also related to agriculture. For an instance, people in Bali mainly eat rice, so the goddess of rice Dewi SRI is revered there. During the period of harvest, their village will be decorated with many colorful flags, and there are some straw dolls that represent Dewi Sri will be placed as a gift in the granary. All the activities and buildings that can display culture are the criteria for our evaluation of cultural system services and are what we identified and mapped.

4 Urban forest planning and management recommendations

4.1 Data integration

This section outlines recommendations for actions to be taken by Tree Inventory Zone in the UBC Campus in conjunction with regulating ecosystem services and cultural ecosystem services. Major regulating ecosystem services for our Tree Inventory Zone (Buchanan Building Blocks A to E) include air pollution removal, carbon storage & sequestration, and oxygen production. Two potential threats to urban forests of this region include pests and surface runoff. On the other hand, we summarize the cultural ecosystem services after recording all the data based on experience dimension sheets. By comparing the scores of these sub-zones, we find that sub-zones with high experience values are the comfortable and well-designed communities, while sub-zones with low experience values are a lack of diversity and safety.

4.2 Planning and management recommendations

In order to propose corresponding suggestions for urban forestry management according to the realistic situation of Buchanan Building Blocks A to E, we drew inspiration and obtained clear and intuitive data from the i-Tree Canopy and the i-Tree Eco tools. Also, we combined both concerns of i-tree ecosystem analysis from i-Tree Eco model results and the comments from sentiment mapping surveys (i-Tree, 2020). Our recommendations focus on the implementation and implementation of policies and procedures, including enhancing local biodiversity, respecting cultural significance, providing passive recreational opportunities for people and minimizing ongoing interventions. We identified six basic recommendations:

1. Add more green plants in the buildings.
2. As for the outside, it may be better to use flowering trees instead of only green leaves.
3. Paving the footpath besides Buchanan Building A.
4. A better combination of planting trees (layers).
5. Install some more street lights to improve the situation that students cannot see the road clearly in the evening.
6. Improve some of the side paths, slippery and muddy during raining days.

4.3 Conclusion

The UBC campus has a wide variety of trees, but poor health due to development pressures and external factors (such as traffic fumes) completes the threat of tree loss. This means that maintaining a detailed tree inventory is critical to supporting and implementing urban forest programs on campus. In summary, these recommendations are a few steps that our tree inventory zone can take to improve urban forest management and governance within its scope (Buchanan Building Blocks A to E). By adopting the regular green space construction based on the collected data and keeping the approach flexible, this site can become one of the most popular sites in UBC.

Appendix

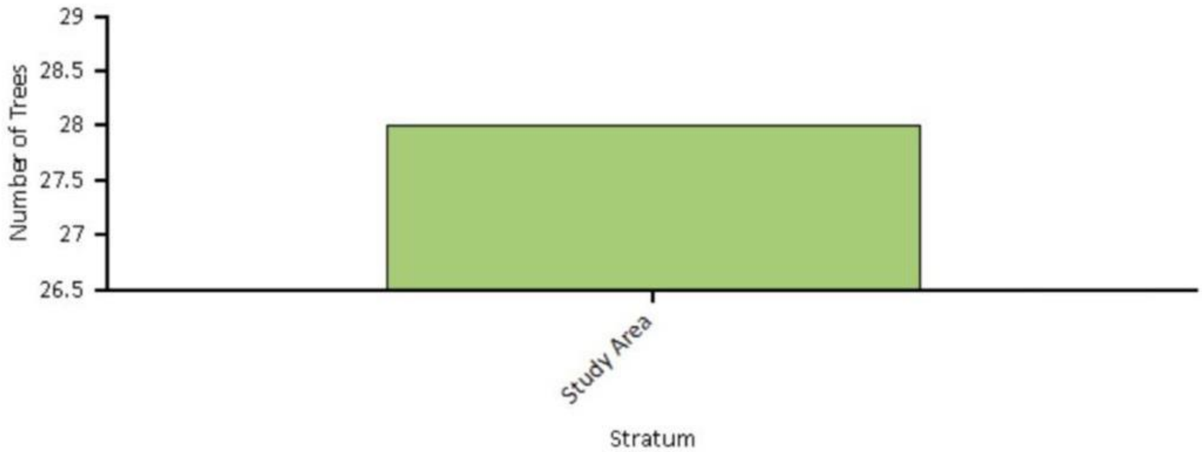

Figure 1. Number of trees in i-Tree group 11 UBC by stratum

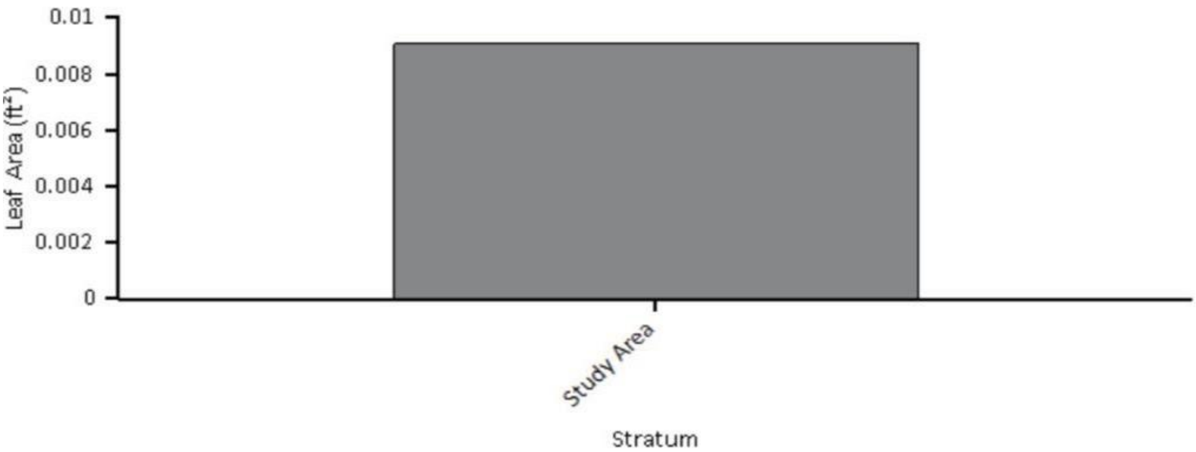

Figure 2. Leaf area (Tree Canopy)

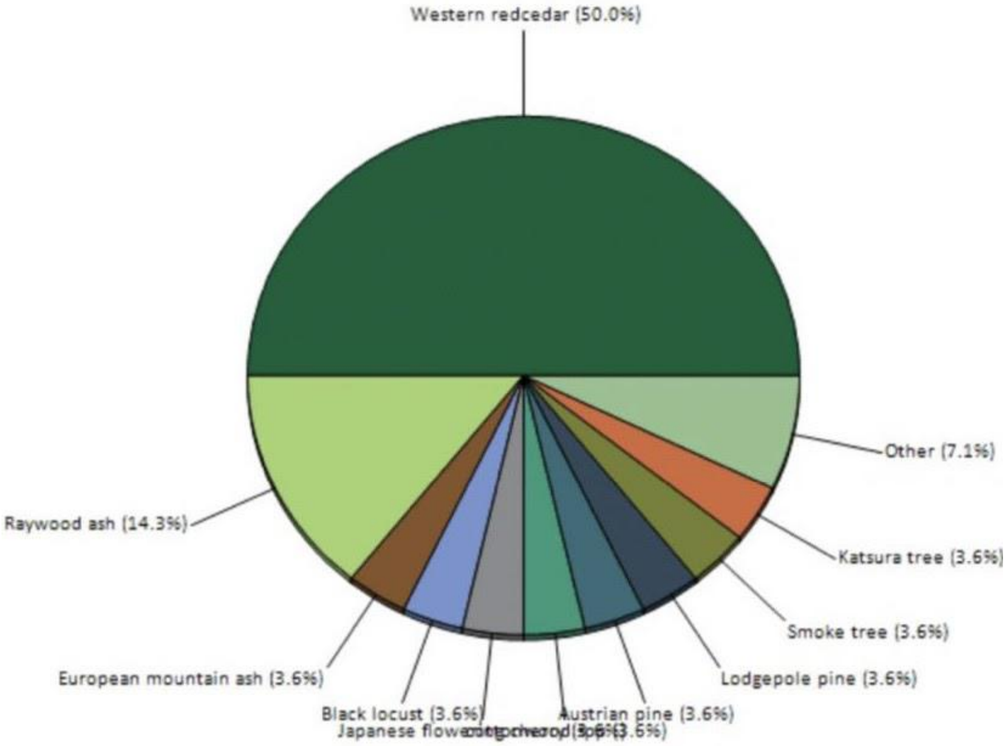

Figure 3. Tree species composition in i-Tree group 11 UBC

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Western redcedar	50.0	65.2	115.2
Raywood ash	14.3	13.0	27.3
Katsura tree	3.6	5.2	8.7
Red maple	3.6	2.9	6.5
cottonwood spp	3.6	2.9	6.5
Black locust	3.6	2.9	6.4
European mountain ash	3.6	1.9	5.5
Smoke tree	3.6	1.8	5.4
Austrian pine	3.6	1.7	5.2
Japanese flowering cherry	3.6	1.0	4.5

Table 4. Most important species in i-Tree group 11 UBC

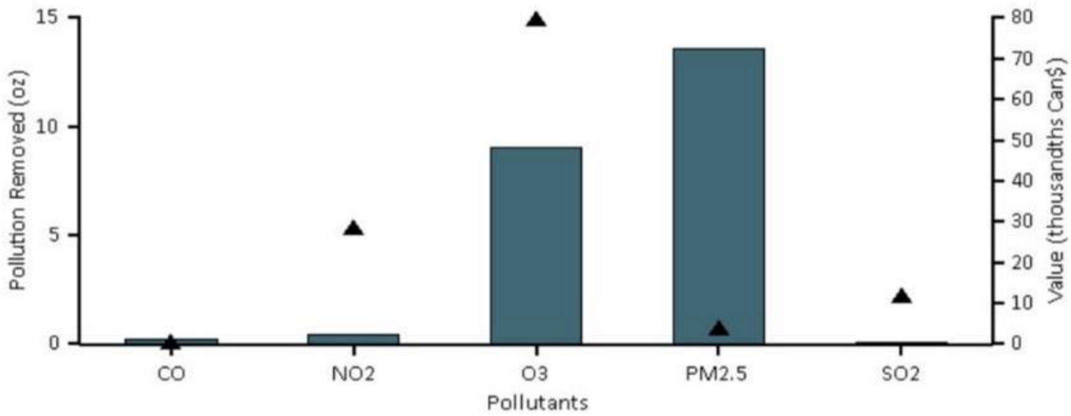

Figure 5. Annual pollution removal (points) and value (bars) by urban trees, i-Tree group 11 UBC

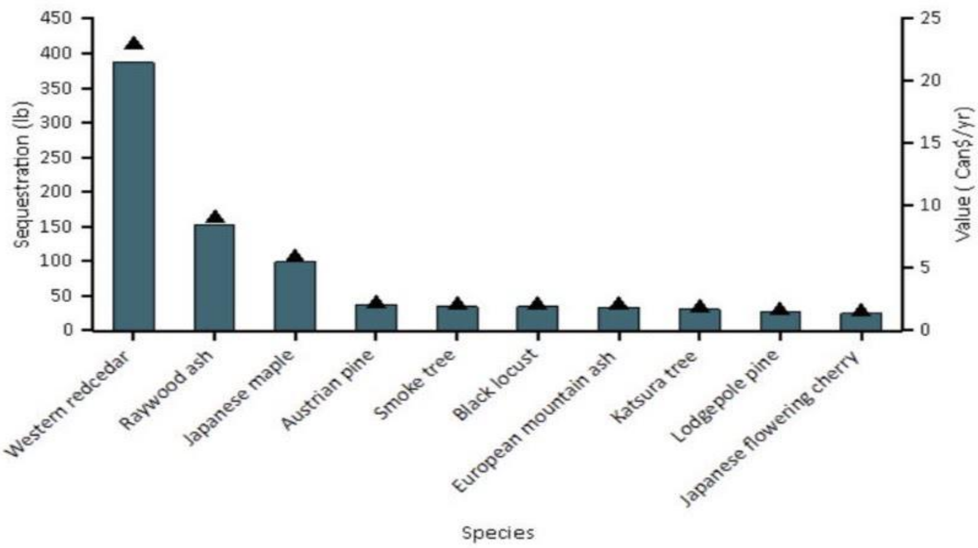

Figure 6. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, i-Tree group 11 UBC

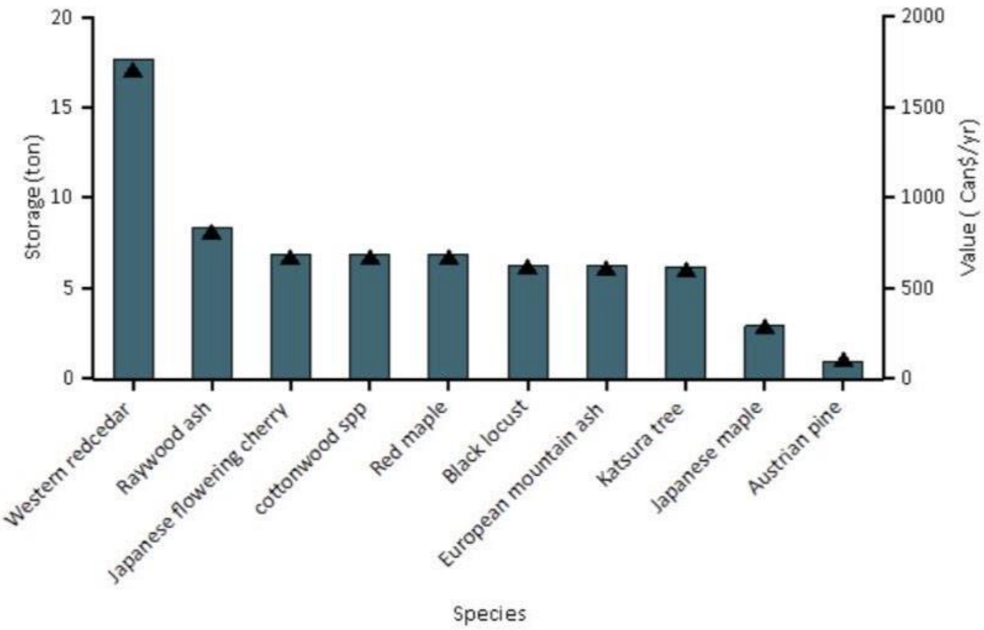

Figure 7. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, i-Tree group 11 UBC

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
Western redcedar	1,099.41	412.28	14	0.01
Raywood ash	432.11	162.04	4	0.00
Japanese maple	281.29	105.48	1	0.00
Austrian pine	104.27	39.10	1	0.00
Smoke tree	99.23	37.21	1	0.00
Black locust	97.41	36.53	1	0.00
European mountain ash	96.58	36.22	1	0.00
Katsura tree	87.06	32.65	1	0.00
Lodgepole pine	76.99	28.87	1	0.00
Japanese flowering cherry	70.55	26.46	1	0.00
cottonwood spp	70.55	26.46	1	0.00
Red maple	70.55	26.46	1	0.00

Figure 8. The top 20 oxygen production species

Works Cited

Ciesla, W. M. 2001. Tomicus piniperda. North American Forest Commission. Exotic Forest Pest Information System for North America (EXFOR).

FRESHWATER MULTIPLE STRESSOR TOOLBOX. (n.d.). Retrieved from http://fis.freshwatertools.eu/index.php/infolib/ecoservices/cultural-ess.html

Haugen, D. A.; Hoebeke, R. E. 2005. Sirex woodwasp - Sirex noctilio F. (Hymenoptera: Siricidae). Pest Alert. NA- PR-07-05. Newtown Square, PA: Department of Agriculture, Forest Service, Northern Area State and Private Forestry.

House, T. (2017, November 15). The Elements of a Value Map. Retrieved from https://medium.com/the-abcs-of-creating-a-value-proposition-canvas/the-elements-of-a-value-map-7af0d00a682e

i-Tree Eco (2020). Use of Direct Measures by i-Tree Eco (v6.0): Overview of the derived variables and ecosystem services that are estimated by the i-Tree Eco model and how they use the direct measures collected in the field.. (2020). [Ebook]. Retrieved from http://file:///C:/Users/Prismos%20Server/Downloads/Ecov6_data_variables_ES_relationships.pdf

i-Tree Eco | Ecosystems Knowledge Network. (2020). Retrieved 6 April 2020, from https://ecosystemsknowledge.net/i-tree-eco

i-Tree. (2020). Learn about i-Tree. Retrieved 6 April 2020, from https://www.itreetools.org/

Kruse, J.; Ambourn, A.; Zogas, K. 2007. Aspen Leaf Miner. Forest Health Protection leaflet. R10-PR-14. Juneau, AK: U. S. Department of Agriculture, Forest Service, Alaska Region.

Kucera, D. R.; Orr, P. W. 1981. Spruce Budworm in the Eastern United States. Forest Pest Leaflet 160. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

McPherson, E.G.; Maco, S.E.; Simpson, J.R.; Peper, P.J.; Xiao, Q.; VanDerZanden, A.M.; Bell, N. 2002. Western Washington and Oregon Community Tree Guide: Benefits, Costs, and Strategic Planting. International Society of Arboriculture, Pacific Northwest, Silverton, OR.

Nicholls, T. H.; Anderson, R. L. 1977. How to Identify White Pine Blister Rust and Remove Cankers. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry

Nowak, D.J. 1994. Atmospheric carbon dioxide reduction by Chicago's urban forest. In: McPherson, E.G.; Nowak, D.J.; Rowntree, R.A., eds. Chicago's urban forest ecosystem: results of the Chicago Urban Forest Climate Project. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 83-94.

Nowak, D.J. 1995. Trees pollute? A "TREE" explains it all. In: Proceedings of the 7th National Urban Forestry Conference. Washington, DC: American Forests: 28-30.

Peper, P.J.; McPherson, E.G.; Simpson, J.R.; Albers, S.N.; Xiao, Q. 2010. Central Florida community tree guide: benefits, costs, and strategic planting. Gen. Tech. Rep. PSW-GTR-230. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA.

U.S. Environmental Protection Agency. 2015. The social cost of carbon. http://www.epa.gov/climatechange/ EPAactivities/economics/scc.html

Wu, J., Wang, Y., Qiu, S., & Peng, J. (2019). Using the modified i-Tree Eco model to quantify air pollution removal by urban vegetation. Science of the total environment, 688, 673-683.

Contribution Description

Group 11

Group Members:

Lulu Li [redacted]: Completing both of Weaknesses & strengths and Results & interpretation parts for the Culture ecosystem services section; Integrating the graphs by i-Tree with Jason Li.

Tasso Hu [redacted]: Completing the whole Urban forest planning and management recommendations section; Final integration and typography of the entire report including the content, appendix and group reference.

Jason Li [redacted]: Completing the Model Analysis part for the Regulating ecosystem services section; Integrating the graphs by i-Tree with Lulu Li.

Yiming Ren [redacted]: Completing several parts for the Regulating ecosystem services section, including Description of models, Weaknesses and strengths, Similarities and differences, and outputs.

Shiyi Wang [redacted]: Completing the Introduction and Site description section.

Yuhan Chen [redacted]: Completing the Methodology part for the Regulating ecosystem services section; Integrating the value mapping map.