UBC Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Urban Forest Inventory & Assessment

Faculty of Forestry

University of British Columbia

UFOR 101

Themes: Biodiversity, Community, Land

Date: May 31, 2019

Urban Forest Inventory & Assessment

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2019

Urban Forest Inventory & Assessment

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URBAN FOREST INVENTORY AND ASSESSMENT

EXECUTIVE SUMMARY

Urban Forest Inventory and Assessment (UFOR 101) started from 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 of biodiversity assets, including urban forest resources, on UBC campus. UFOR 101 was designed and implemented for the first time in 2019. It involved 61 first-year students in the Bachelor of Urban Forestry program (and one visiting student from Japan) and ran from January 2nd to April 3rd, 2019. 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.

At the time of the course, UBC Campus & Community Planning (UBC C&CP) was developing the UBC Urban Forest Management Plan (UFMP). The work conducted by UFOR 101 students provided important information to support this process. 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 the first year, the work focused on a specific area of campus referred to as Phase 1 (see map below). In subsequent years, students will be working in different areas of campus until eventually urban forest inventory and assessment data will have been gathered for the entire UBC campus.

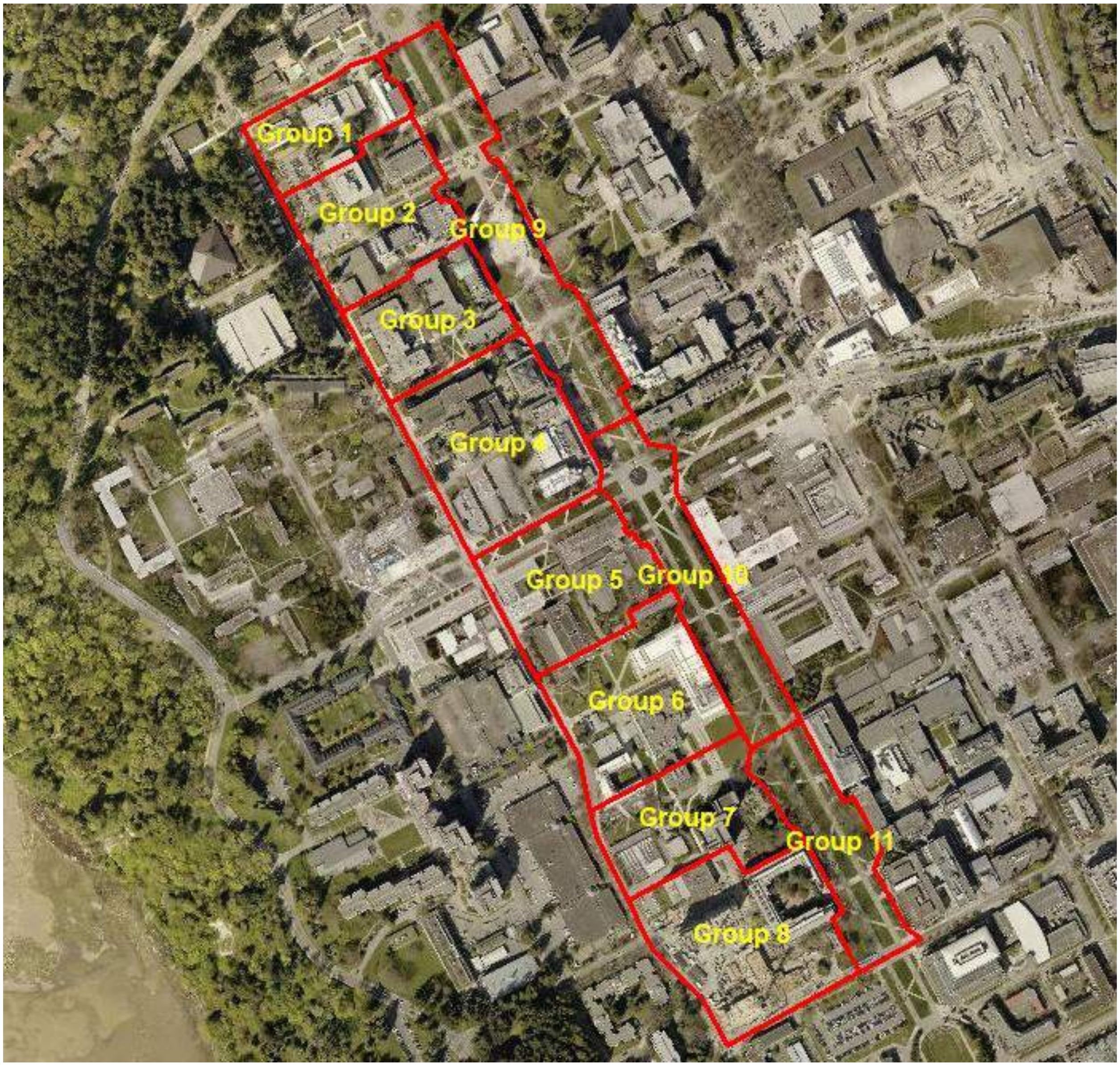
The UFOR 101 course involved four modules, two major group assignments, and final group presentations of all the work. The first assignment comprised an 'urban forest inventory'. For this assignment, students planned and implemented a basic urban tree inventory for a selected area of campus. They worked 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 were used to make recommendations for the UBC UFMP. The eleven reports of the ecosystem services assessment and planning recommendations are attached to this document.

By the end of the course, the students were be able to:

- Describe the importance and multiple uses of urban forest inventories and assessment
- Discuss different approaches adopted for inventories and assessment
- Use different tools to measure the tree and site parameters considered important in inventories and assessments
- Carry out a basic tree inventory
- Undertake assessments of the multiple ecosystem services provided by urban forests
- Apply information from tree inventories and ecosystem service assessments in the urban forest management planning process at the University of British Columbia

The tree inventory data generated by students can be found at:
https://github.com/UBCGeodata/opendata



Map showing eleven student group zones distributed across the Phase 1 area allocated for UFOR 101 in 2019. UBC Campus view retrieved from ArcGIS online basemap for use in ArcMap 10.

Ecosystem Services Assessment of UBC Campus Trees in Zone 1 and Planning Recommendations

Group 1

April 3, 2019

Chelsea Cao, Elaine Hu, Charlotte Mathisen,
Ren Niikura, Michael Sandrin, Alina Ziyun Zeng

University of British Columbia (UBC)

Work Distribution

Member	Section	Possible Pts		Other
Charlotte	**1. Introduction**	10.0		**Layout** **Proofreading of everything**
	describes the purpose of the ecosystem services assessment, background on ecosystem services and typology, and information on the policy context and urban forest planning and management process on campus, drawing on material covered in class and relevant policy documents.			
	2. Site description	5.0		
	provides a description of the selected area of UBC campus assessed by your group. you can include information such as land use type, activities observed in the area, types of facilities observed in the area, different users of the area, specific location (map), and photos of the area to show representative examples. This can be similar to the site description prepared for Assignment 1 (but not copy & paste; try rewording and paraphrasing)			
Alina	**3. Regulating ecosystem services** **3.1.1 Results of i-Tree Eco model** **3.1.2 Methodology of i-Tree Eco model** **3.2.1 Results of i-Tree Canopy model** **3.2.2 Methodology of i-Tree Canopy model** **3.3 Strength and weakness**	15.0		**Layout** **References** **Appendices** **Editing** **Work distribution** **PPT making**
	Describe the methods used to assess and quantify ecosystem services using the i-Tree Canopy and i-Tree Eco models drawing on documentation for both models and material covered in class. discuss the strengths and weaknesses of each method. Present the results of each model			
Elaine	**3. Regulating ecosystem services** **3.4 Similarities and differences** **3.5 Interpretation of each model's results** **3.6 Regulating services and the outputs** **3.6.1 purification of air and carbon sequestration** **3.6.2 soil erosion prevention**	15.0		
	discuss the similarities and differences between the model results. Interpret the results of each model and discuss how your zone provides the different ecosystem services in the output. You may wish to use site photos or maps to illustrate your interpretation.			

Ren	**4. Cultural ecosystem services** **4.1 Defining cultural ecosystem services** **4.2.1 Value Mapping Approach Methodology** **4.3 Visual Representation explanation** **4.4 Strength and weakness of the value mapping approach**	15.0		**Helped editing section 4.2.2** **Value Mapping** **Overall proofreading**
	Describe the methods used to assess and quantify ecosystem services using the cultural ecosystem services value mapping process, drawing on activities and material covered in class. Discuss the strengths and weaknesses of the value mapping approach. Present the results of the mapping exercise, including your final map (in appendices).			
Chelsea	**4. Cultural ecosystem services** **4.2.2 Value Mapping Approach Result**	15.0		
	Interpret the results of the value mapping and discuss how your zone provides the different ecosystem services you identified and mapped. You may wish to use site photos to illustrate your interpretation.			
Michael	**5. Urban forest planning and management recommendations**	15.0		
	integrates the results and interpretation of ecosystem services provision outlined in sections 5 and 6 (regulating ecosystem services and cultural ecosystem services), and uses those results to make urban forest planning and management recommendations for your site. Make sure your recommendations are realistic and take into account the information you provided on the policy context and site description in earlier sections.			

1. Introduction

The University of British Columbia is not just a university but rather a welcoming, diverse, and aesthetically pleasing community where learning, biodiversity, and many more benefits take place. This report will explore these benefits, that are more formally known as ecosystem services, in the assessed area titled Zone 1. A map of Zone 1 is shown in Appendix II, figure 1. Ecosystem services can be described as the benefits that humans receive, either directly or indirectly, from the ecological processes that take place within an ecosystem (Ferrini, Konijnendijk van den Bosch, & Fini, 2017). There are four different categories of ecosystem services: cultural, regulating, provisioning, and supporting. However this report will only look at and explore two: regulating and cultural services.

1.1 Background

Ecosystem services are looked at and measured because of the anthropocentric viewpoint that humans often have, meaning that they value the ecosystem because of the reasons the ecosystem benefits them. This type of viewpoint may not be accurate for all the humans, however many times holds true for the stakeholders that create and implement policies and plans for various ecosystems. This is why ecosystem services act as an important medium for communication between stakeholders, and helps urban foresters translate important issues and non-issues in order to get an ideal outcome. Furthermore, stakeholders and urban foresters use ecosystem services as incentives in planning and managing the urban forest and aim to increase them.

As previously mentioned there are four different categories of ecosystem service, one being cultural. Cultural ecosystem services are non-material and often social benefits. These include the following values: aesthetic, recreation and ecotourism, spiritual and religious, and mental and physical health. Cultural mapping is often used when measuring and valuing the cultural ecosystem services of an area because of the subjectiviness that these type of benefits have. Cultural services regularly get overlooked because of this, yet they are of great significance, and so it is always beneficial to get as much input as possible from the variety of users of an area. More on cultural mapping and the results of it from the assessment of Zone 1 will be discussed in the cultural ecosystem services section of this report.

Next are regulating services which can be described as "services related to maintaining earth's life support system" (Ferrini et al., 2017, p. 51). This includes the regulation of climate, air, water, pollination, erosion, diseases and pests, as well as the purification and treatment of water and moderation of extreme weather events. Many regulating services can be measured through the use of i-tree canopy and i-tree eco, which are the exact methods that were used in the assessment of Zone 1 and will be described in more depth in the regulating ecosystem services section of the report.

Provisioning ecosystem services are essentially the products that an ecosystem provides such as food, raw materials, medicinal resources, and freshwater. While UBC does provide some of these products, this assessment will not be exploring them because these type of ecosystem services are non-applicable in the purpose of this project.

Finally, Supporting ecosystem services are the services "necessary for the production of other ecosystem services" (Ferrini et al., 2017, p. 52). They can be described as the processes that take place within an ecosystem and include nutrient cycling, photosynthesis, and soil formation. An inference can often be made of how efficient these services are when we measure and value regulating services. This is because regulating services are the by-products of supporting services, thus why we won't be measuring them in the assessment of Zone 1.

1.2 Current Policy

The university's current urban forest policy involves many gaps in the protection and management of campuses ecosystem services, as well as no clear plan or direction that the university wishes to implement in the handling and improvement of these services. Current policy documents include the UBC Vancouver Campus Plan: Design Guidelines, the Land Use Plan: Design Guidelines and the UBC Neighborhood Plans, Design Guidelines (Luker, 2019).

1.3 Purpose

This assessment can be seen as a preliminary step, known as tree management and compensation, in a greater project that is being executed by UBC’s SEEDS Sustainability Program and UBC’s Campus and Community Planning (SEEDS Sustainability Program, 2019). This assessment took place in order to update an already existing tree inventory in the key campus areas of UBC’s urban forest. Updating this inventory involves measuring various characteristic such as tree ID, total height, DBH, and crown width, just to name a few. The current condition in which the urban forest is in can be assessed and from there ecosystem services can be examined. Different UBC departments which include Building Operations, Planning and Design, and Sustainability and Engineering may then use this type of examination for there own personal use, in the hopes that they will improve upon the current state of these services. As outlined by Luker (2019), planning analyst of UBC’s Campus and Community Planning, the future policy direction would include a biodiversity component of the new Green Building Action Plan and a Future Biodiversity Strategy.

2. Site Description

Zone 1 is located on the north-west side of campus and is surrounded by West Mall, Crescent Rd, Main Mall, and the Music building. The land in Zone 1 is mainly institutional, however is also used for transportation and recreation.

There are three buildings contained within the zone: the Sing Tao Building, the Frederic Wood Theatre, and the Morris and

Helen Belkin Art Gallery. The Sing Tao Building was built in 1997 and is part of UBC’s Graduate School of Journalism (University of British Columbia [UBC], 2019c). It is located on the corner of Crescent Rd and West Mall, and is surrounded by medium sized trees, such as cherry blossoms, and shrubs.

The Frederic Wood Theatre is centered in the middle of Zone 1 and was constructed in 1963. It is named after the founder of UBC’s players' club, Frederic Wood and hosts a variety productions that are put on by the universities performing arts students (Nothof, 2016). A wood beam facade wraps around the entrance of the building and it is surrounded by a courtyard.

The last building is the Morris and Helen Belkin Art Gallery which is located on the corner of Main mall and Crescent Rd. It officially opened in 1995 and specializes in researching, publishing, educating, and exhibiting contemporary art and its history (UBC, 2019b). The outside of the building is contemporary in its design, which echoes the type of work and research that takes place within the building. This is showcased in its sleek use of lines and colour that make up the windows and walls of the building.

a) b) c)

Fig. 1: a) The Sing Tao building from the view of Crescent Rd (Mathisen, 2019); b) The front entrance of the Frederic Wood Theatre (Mathisen, 2019); c) The front entrance of the Morris and Helen Belkin Art Gallery from the view of Main Mall (UBC, 2019)

The concrete courtyard that is surrounded by trees is nestled between the gallery and the theatre. It is quite spacious which provides the users of the area lots of room to do various activities. The trees are mostly Black Pine, which are very tall and are in close proximity to the buildings. In the centre of the courtyard stands a large Oak tree which is surrounded by benches. Adjacent to the trees is the statue *Asiatic Head* by Otto Fischer-Credo that is positioned under the long covered walkway that cuts through the south-west side of the courtyard. The art piece is actually a replica made by Gerhard Class and it "features a large stylized head with Asian characteristics and has been variously interpreted as both a man and a woman" (UBC, 2019a, p. Otto Fischer-Credo, Asiatic Head). The statue itself and its placement is quite dramatic and reflects the artistic mood of the area.

The area seems aged in comparison to the rest of the campus, and this is evident in the appearance of the buildings and the height of the trees. In addition to the Black Pine trees within the courtyard, there are four more placed within the roundabout by the large pay parking lot. They grow tall and lopsided, giving them a whimsical presence and adding a compelling feature to a somewhat bleak looking area. The large pay parking lot makes up a substantial amount of Zone 1 and can be classified under transportation land use. It is located on the lower left side of the zone and has a high amount of usage from students, faculty, and visitors.

At first glance, Zone 1 appears to be bleak and vacant, however the amount of trees along with their height give the area a sense of wilderness and serenity. In addition to that, while the area is an older part of campus, it still incorporates modern elements which help to portray the artistic aspects that take place within the walls of the buildings. Furthermore, it creates a welcoming space for users to conjugate and be creative.

a) b) c)

Fig. 2: a) Asiatic Head by Otto Fischer-Credo (Mathisen, 2019); b) The Oak tree centered in the courtyard(Mathisen, 2019); c) The entrance to the pay parking lot (Mathisen, 2019)

3. Regulating ecosystem services

Throughout Zone 1, 41 out of 42 trees measured have been analyzed using the i-Tree Eco model for an assessment of the vegetation's estimated canopy cover, structure, value of the ecosystem services that the trees provide, and a few other attributes. Meanwhile, i-Tree Canopy, a model also developed by the U.S. Forest Service, was used to generate a cover assessment within Zone 1. In total, 150 points were classified as either 'tree' or 'non-tree'.

3.1.1 Results of i-Tree Eco model

Stated in the i-Tree Eco report, the most common tree species present in Zone 1 are the Austrian pine (*Pinus nigra*), English holly (*Ilex aquifolium*), and Japanese maple (*Acer palmatum*), which respectfully account for 19.5 percent, 12.2 percent, and 12.2 percent of the trees measured (Appendix I, Fig. 1). In the meantime, only 7 percent of the trees assessed are native to North America, while the majority originate from Europe & Asia (Appendix I, Fig. 2). Trees in Zone 1 are generally very mature in terms of basal and leaf area, and only 9.8 percent of trees have a diameter less than 6" (15.2 cm) (Appendix I, Fig.3). Urban Forest cover is approximately 25.88 thousand square feet, providing 2.375 acres of leaf area. Drawing on recent available weather and pollution data, the pollution removal by trees in Zone 1 was estimated, with ozone being the greatest pollution removed (Appendix I, Fig. 4). A total of 19.01 pounds of air pollution is removed annually, which includes ozone, particulate matter less than 2.5 microns, nitrogen dioxide, carbon monoxide, and sulfur dioxide, all which is roughly equal to an annual value of $1.25 thousand CAD (Appendix I, Fig. 4). About 9.152 pounds of volatile organic compounds are emitted by trees in Zone 1 per year, with 4.193 pounds of it being isoprene and 4.96 pounds being monoterpenes. Northern red oak, in particular, is the major emitter of this urban forest's VOC, which enhances the formation of ozone. With an associated value of $55.8 CAD per year, carbon sequestration of trees in Zone 1 is estimated to be around 1071 pounds annually (Appendix I, Fig. 5). An estimation of 1.428 tons of oxygen is produced by trees in this area every year, which barely makes a difference due to the vast amount of existing oxygen in the atmosphere. Again, Northern red oak is accountable for producing the most oxygen due to its high accumulation of biomass (Appendix I, Table 1). In terms of surface runoff reducing, the trees and shrubs in this area reduce about 1.61 thousand cubic feet a year, contributing to a value equal to $110 CAD (Appendix I, Fig. 6). The structural value associated with the trees is $139 CAD and the functional values have been discussed above (Appendix I, Fig. 7).

3.1.2 Methodology of i-Tree Eco model

i-Tree Eco quantifies urban forest structure and a variety of functional values therein using standardized field data and local hourly air pollution and meteorological data (Nowak & Crane, 2000).

Using measurements of crown dimensions and percentage of crown canopy missing, leaf area of trees is estimated by i-Tree Eco model. Based on "a hybrid of big-leaf and multi-layer canopy deposition models", air pollution removal estimates are "derived from calculated hourly tree-canopy resistances for ozone, sulfur, and nitrogen dioxides" (i-Tree Eco, 2019, p. 21). Values associated with air pollution removal is calculated based on "local incidence of adverse health effects and national median externality costs" (i-Tree Eco, 2019, p. 22). For this assessment in particular, pollution removal value is calculated based on "the prices of $1,348 CAN per ton (carbon monoxide), $95 CAN per ton (ozone), $13 CAN per ton (nitrogen dioxide), $5 CAN per ton (sulfur dioxide), [and] $3,408 CAN per ton (particulate matter less than 2.5 microns)" (i-Tree Eco, 2019, p. 22).

To estimate the gross sequestration and storage of carbon, customized local carbon values are used. Average diameter growth from the associated genus and class is added to the recently measured tree diameter for the gross amount of carbon storage and sequestration in the following year. For this assessment, values of carbon sequestration and storage are calculated based on $104 CAN per ton (i-Tree Eco, 2019).

According to Nowak et al., the amount of oxygen produced by the urban forest is estimated from the amount of carbon sequestered based on atomic weights (2007). At the same time, annual avoided runoff is estimated based on the difference between runoff in the absence and presence of vegetation (i-Tree Eco, 2019). Meanwhile, structural values are directly reflected in the physical well-being of the trees (species, diameter, condition, etc.).

3.2.1 Results of i-Tree Canopy model

Out of 150 points sampled, 62 of them were identified as tree, and the other 88 were non-tree. Two of the urban forest's functions with the most economic value are annual carbon dioxide sequestration in trees ($260.70 CAD) and the annual removal of particulate matter less than 2.5 microns ($275.09 CAD), but they both have high standard errors, making the estimates lack certainty. Annual removal of ozone is estimated to be 17.65 kg and is associated with a value of $95.92 CAD, while about 5.53 kg particulate matters ranging from 2.5 to 10 microns are removed annually. All other functions have relatively small standard errors, and the estimations can be seen in the following chart (i-Tree Eco, 2019).

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	$0.59	±0.06	0.00 t	±0.00
NO2	Nitrogen Dioxide removed annually	$1.51	±0.15	2.65 kg	±0.26
O3	Ozone removed annually	$95.92	±9.33	17.65 kg	±1.72
PM2.5	Particulate Matter less than 2.5 microns removed annually	$275.09	±26.76	1.12 kg	±0.11
SO2	Sulfur Dioxide removed annually	$0.22	±0.02	0.00 t	±0.00
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	$50.24	±4.89	5.53 kg	±0.54
CO2seq	Carbon Dioxide squestered annually in trees	$260.70	±25.36	3.87 t	±0.38
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	$6,547.17	±636.87	97.11 t	±9.45

i-Tree Canopy Annual Tree Benefit Estimates based on these values in g/m²/yr and $/t/yr: CO 0.088 @ $1,932.97 | NO2 0.769 @ $568.01 | O3 5.120 @ $5,435.68 | PM2.5 0.325 @ $245,667.96 | SO2 0.284 @ $228.65 | PM10 1.604 @ $9,086.36 | CO2seq 1,122.000 @ $67.42 | CO2stor is a total biomass amount of 28,177.630 @ $67.42*
Note: Currency is in CAD
Note: Standard errors of removal amounts and benefits were calculated based on standard errors of sampled and classified points.

3.2.2 Methodology of i-Tree Canopy model

i-Tree Canopy allows users to classify cover classes within an area of interest. David J. Nowak, Jeffrey T. Walton, and Eric J. Greenfield, representing USDA Forest Service, developed the concept and prototype of the tool, while the current version was developed by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company) (i-Tree Canopy, 2011).

To run i-Tree Canopy program, a specific boundary of the area in question needs to be defined. In this assessment in particular, tree cover is the only interest. Once the cover classes are named, i-Tree Canopy randomly lays points onto the satellite imagery of the defined zone and the users are then able to classify each point into the class that they fall upon. To maximize the accuracy, as many points as possible should be interpreted.

3.3 Strength and weakness

In general, i-Tree Eco is a great program because once you get your inventory done, all you need to do is tabulate the data and import it into the tool, and a report will be generated for you. There is also further information provided within the report including general recommendations, relative tree effect, potential risks and so forth, making the users more familiar with both the tool and the ecosystem services assessed. Also, graphs and charts are automatically generated by this tool, which helps present the results in a clear and straightforward way. Another strength is that i-Tree Eco helps monetize the services so that they are quantified and given value, which makes the creation of projects and negotiations between stakeholders easier. i-Tree Eco, however, does not come without flaws. The software itself is easy to use, but the font point is too small, so that there is an increased risk of misreading and selecting the wrong option. i-Tree Eco is also limited to the United States, so data for other regions is not yet available. Another thing worth pointing out is that most of the time, to minimize errors in percent canopy cover, field data should be collected during the leaf-on season. However, this inventory violated this rule and therefore the standard error in estimated canopy area would be large, and i-Tree Eco cannot, by itself, recognize such error.

i-Tree Canopy gives a decent overall estimation of the cover classes present in a defined area. In contrast to i-Tree Eco, it takes less time because no field work is needed. This attribute makes i-Tree Canopy a better choice when there is not enough time for an inventory to be conducted. But when higher accuracy is what matters most, i-Tree Eco should be used. One of i-Tree Canopy's downsides is that the accuracy depends a lot on how correctly the user classifies each point. The program lacks high image resolution, and so sometimes it is difficult to interpret cover classes of points with poor image quality. Also, when too few points are classified, the standard error would be high, making the estimates lack certainty. Constantly repeating the same step just to look at more points could be a tiring process.

3.4 Similarities and differences

i-Tree Eco (Eco) and i-Tree Canopy (Canopy) have similar focuses. These focuses include the estimation of economic value and amount of air pollution removal of CO, O_3, 〖NO〗 _2, PM 2.5 and 〖SO〗 _2, also carbon removal and sequestration in both models. Results of both methods are shown in the same unit which is Canadian dollar per year for economic value and tons of gas removed per year for the amount. In addition, the estimated results are quite similar in the general directions of trends. For example, in both results report, two models both pointed out that the largest amount of air pollution removal is taken place by O_3 removal and it provides a significant part of the economic benefits. Also, they both agree with that there is not much amount of CO, 〖NO〗 _2, and 〖SO〗 _2 removed by the trees in zone 1. In addition, the fact that the storage of carbon is much greater than the sequestration of carbon is also emphasized in both results.

Generally, the differences between these two results include the different forms they use to show the result and the accuracy of the estimation. Literally, one of the differences between the results of the two methods is that the pollutants PM10 removal which appears and accounts for a large proportion in overall pollution removal in Canopy, however, Eco does not have that part of estimated for PM10. Meanwhile, the overall amount of air pollution removal for Canopy is slightly higher than Eco, but the total economic value of that is much lower than Eco. Differences in carbon storage and sequestration between these two methods have totally opposite result from air pollution removal. In terms of form they present the result, Canopy only has one overall value and amount of carbon storage and sequestration while Eco have all the data list out for different tree species. In terms of numerical results, Canopy has much higher estimated economic value and amount of carbon in both carbon storage and sequestration than Eco. For carbon sequestration, the overall value of Eco result is approximately $46.7/yr and 0.54t (~1088lb) of carbon, while Canopy has a total value of $260.7/yr and 3.87t of carbon get sequestered. For carbon storage, Eco result in Zone 1 provide a value of $1870/yr and store 16.3t of 〖CO〗_2 , and Canopy shows overall $6547.17/yr of total value provide by Zone 1 and 97.11t carbon storage.

3.5 Interpretation of each model's results

The results of Eco are often presented in the form of graphs, showcasing different aspects of information. Besides the value and amount of pollutants removal and carbon storage/sequestration, Eco also shows the contribution of trees in Zone 1 to the avoidance of runoff and oxygen production. Most of these results are given in the form of detailed value for each important kind. All these detailed and wide range result benefit from plenty of data input from tree inventories. In addition, this report would consider being a more helpful one for stakeholders or researchers because it is evaluated based on local criteria and make it easier to reference for future actions. On the other hand, Canopy has a relatively more general result than Eco, since Canopy estimating the vegetation coverage from randomly assigned points on the map and give the estimated value of pollutants removal and carbon storage and sequestration based on that. In this way, Canopy has more limitations than Eco while the precision of the results depends on the number of points users put, also the sharpness and accuracy of the map will affect the result as well.

However, these two models still have the same focus as well as similar trends in the results and that means the factors lead to these trends is not about tree size or crown size and it is an overall estimate based on the scientific facts. For example, they have the same trends of carbon storage have a larger amount and value than carbon sequestration. Since carbon storage is the amount of carbon bound in the wood while sequestration is about the removal of carbon in the form of CO_2 by photosynthesis of the plants, which in another word the long-term carbon storage. Therefore, carbon sequestration takes more time than just store the carbon, so the total amount of carbon is less than storage and further have a lower value than carbon storage per year. Examples like this one which are the trends that is a general result caused by other factors other than tree species or specific tree size may give a similar answer in both two models.

3.6 Regulating services and the outputs

Benefited by the relatively high tree coverage than other urban areas, Zone 1 on campus provide various regulating services. Regulating services that provided by the trees in Zone 1 include purification of air also carbon storage and sequestration, preventing soil erosion and keep the soil fertile as well.

3.6.1 purification of air and carbon sequestration

One of the most outstanding regulating services is trees improve the local air quality, therefore air pollutant removal is a common content focused by most of data analysis models and these models reports clearly show the value of removing each pollutant. Particulate matter (PM) and ozone are two main air pollutant that affects human health by reducing air concentration (Smith et al., 2011). Luckily, these two types of air pollutants are the two most significant pollutants removed by the trees in Zone 1. Since Zone 1 has two sides of the overall area that are adjacent to the driveway or parking lot which are the areas where air pollutant mainly comes from, trees planted beside these areas can effectively purify the surrounding air. Another important source of air pollution from automobile exhaust is carbon dioxide. However, benefit by regulating services of carbon storage and sequestration provided by local vegetation, part of the amount of carbon dioxide get stored in trees or removed by trees in the long term. Beside air pollutants removal and carbon sequestration, to purify the air plants are also providing oxygen to the region through photosynthesis.

3.6.2 soil erosion prevention

Soil erosion is a key factor of land desertification, vegetation cover plays a vital role in preventing soil erosion (Guerra et al., 2014). The decrease of nutrient content in soil and the imbalance of nutrients will lead to soil erosion (Morgan, 2009). Vegetation is an essential condition for the complete nutrient cycle in the soil by adding organic matters and decomposition into plant-available form then uptake by the plants. According to the analysis results, although the vegetation coverage (41%) is less than half of the total area, this number is still quite high for an urban zone while average urban vegetation coverage is only 27.1% (Nowak & Crane, 2002). In addition, preventing soil erosion is an important condition for maintaining soil fertility and this is another significant regulating services that Zone 1 offers.

4. Cultural ecosystem services Analysis

4.1 Defining cultural ecosystem services

Cultural ecosystem services are defined as the "non-material benefits people obtain from ecosystems", and it is one of the fourth pillars of the ecosystem services approach (Bolund, 1999) . The cultural services provided by the ecosystem can range from aesthetics, cultural significance, spiritual experience, recreational and mental and physical health and on, all in which the amount of benefit cannot easily be quantifiable (Bolund, 1999). Thus, the cultural ecosystem services are highly dependent on an individual's cultural assessment and considered to be highly subjective. This section of the report will focus on the cultural services provided by our designated area; Zone 1, as well as the methods taken in order to quantify the various cultural ecosystem services provided by the zone.

Unlike the other three other ecosystem services, cultural services are an example of non-consumptive and direct use values, meaning the services provided by the environment cannot be easily represented by monetary values or other forms. Quantifying benefits such as aesthetics are extremely difficult, as different individuals will have a different perception of the zone. For example, one may believe that a colorful artwork in the middle of the courtyard gives a unique contrast in color, thus sees the area as aesthetically pleasing. Although, another person may believe that the colorful artwork is too busy for such location, therefore feels that the artwork shouldn't belong there. The two contrasting opinions are the result of the difference in opinion depending on the individuals, and that is the beauty of cultural ecosystem services, as there are no right or wrong answers.

4.2.1 Value Mapping Approach Methodology

One approach towards quantifying the cultural ecosystem services provided by our zone was through a method called the value mapping approach. It is essentially a series of surveys, which transform one's opinion into a numerical value. Zone 1 was divided into 8 distinct sub-zones A to H, where each would have its own unique characteristics. Through visiting each of the sub-zones, the members have individually assessed five basic cultural ecosystem services ranging from diversity and species richness, aesthetics, social cohesion, wilderness, and cultural significance. Then each of the five cultural ecosystem services was graded using the scale 0-5, with 0 being "no feeling" and 5 being "very strong feeling". This process was repeated on all 8 subzones, which as a result produced an "experience dimensions table", with our individual perception towards our zone in a numerical value(Appendix III, Table. 1). Apart from all of the numerical values that have been collected at the site, each members have also carefully observed some key features of the sub-zones, which was later used in the following steps of the value mapping approach.

4.2.2 Value Mapping Approach Result

Zone 1, where the group conducted the mapping approach is situated in the North-West side of the campus, covering parts of West Mall, Crescent Road, Main Mall, and the Music building. In this zone, the buildings include the Sing Tao Building, which is at the left top corner of Zone 1, and it is part of UBC's Graduate School of Journalism. Frederic Wood Theatre is at the center of the zone, which is often used for various performances. Lastly, Morris and Helen Belkin Art Gallery is situated at the right lower corner of the zone. Other observable facilities within the zone include cul-de-sac, parking lot, and a spacious courtyard. It is also important to understand that the buildings in this zone seem to offer some form of artistic, cultural services. Thus, depending on the group members' perception, the assessment will highly differ.

Throughout the process of value mapping, our group has repeated the process of visiting 8 different subzones, and grading each cultural services on the scales of 0 to 5, with 0 being "no feeling", and 5 being "very strong feeling". After all the individuals have conducted their own assessment of each sub-zones, all of the data were collected to be analyzed and visualized. One way to represent the overall assessment of the sub-zone was through creating a table with the sum of each members' assessment of the subzone depending on different cultural zones (Appendix III, Table. 1). Consequently, from the results, it was evident that the sub-zones D and E ranked lowest amongst the 8 sub-zones, while the remaining 6 sub-zones ranked relatively better than sub-zones D and E. The reason for these differences may be due to factors such as proper pavements for walking/biking, existence of the art gallery, which celebrated cultural significance, benches being installed where people can sit, as well as a spacious opening, which could allow more developments. Other positive observations include cultural art forms in the theater as well as grassy areas and large trees, which enhanced a distinct aesthetic. On the other hand, the sub-zones that ranked low had significantly less green space compared to the other areas, which may be a result of the poor location, with no space for green development. A road located adjacent to the sub-zone left a negative impact on our members since safety and noise was a huge issue that arose from the two sub-zones.

Sub-zone A was by far the highest scoring sectors within the zone, situated with the Morris and Hellen Art Gallery. This sub-zone has received relatively a high score on all cultural ecosystem services, except for wilderness (Appendix III, Table. 1). This was due to the relevance to arts hence fitting the aesthetics, social cohesion and cultural significance dimensions. The facility is well developed and maintained, thus the green space was also excelling, as the species composition was higher than other sub-zones. Sub-zone C was Frederic Wood Theatre and its high ratings are sourced from aesthetics, social cohesion, and cultural significance aspect of the cultural ecosystem service (Appendix III, Table. 1). This result was predicted, considering that the area was designed to have an artistic aspect. Sub-zones F was UBC's Graduate School of Journalism, and it contained the Sing Tao Building. This sub-zone had a high rating on social cohesion, diversity, and culture, as the area was intended to be an educational institution with a high level of social cohesion(Appendix III, Table. 1). Sub-zone H was the zone's spacious courtyard, and the cul-de-sac was highly rated due to its aesthetics and wilderness feature, with several old trees with a unique appearance(Appendix III, Table. 1). This area lay between the Frederic Wood Theater and the Morris and Hellen Art Gallery the area was characterized by a concrete floor, which made access from one building to the other easier. Although, our group has found that this area overall did not have enough people utilizing.

The value mapping approach has allowed every individual to express their opinion towards different sub-zones as they wish. It's not rare to see one person assessing the aesthetics of a sub-zone to be a 5, where another person would assess them as 1. Although, one consistency observed was the fact that parking lots and busy street do not possess much cultural ecosystem services. Sub-zones B, D, E, and G were four of the lowest rated zones, which was consistent among all members. The four sub-zones are all either facing the busy street or occupy the parking space, thus had a much lower assessment compared to the other four sub-zones that ranked high.

4.3 Visual Representation explanation

Figure 2 shown in Appendix III is an example of how the value mapping approach can be visualized. The red outline represents the perimeter of the zone, with sub-zones labeled as "Zone 1 A" or such. The different colored stars represent the hot spots for the five different cultural ecosystem services that have been assessed throughout this project. One important fact to know is the fact that there are varieties in the structure of each sub-zones. For example, Zone 1A has a mix of buildings, paved paths, and some vegetation. On the other side, Zone 1C is almost all buildings, with very little buildings, and Zone 1G is almost all parking lot, with little vegetation. Taking those factors into consideration, our group has found some relationships between different cultural ecosystem services. For example, the blue and red stars are often found next to each other, representing that the same area within the sub-zone is providing both ecosystem services. Thus, we have determined that there is a positive relationship between the species richness and aesthetics, meaning our group members have found an area to be aesthetically pleasing if they found high species richness. Vice versa, there was also a negative relationship between wilderness and cultural significance. As seen on the visual, green and orange stars are almost never located in the same area. This is simply due to the fact that our group's felt that there weren't much cultural significance in a wilderness area, rather man-made artistic installments represented more cultural significance.

4.4 Strength and weakness of the value mapping approach

The value mapping approach is an extremely sophisticated approach towards measuring cultural ecosystem services. One of the major strengths of this method is the ability to quantify an individual's non-monetary, non-material benefits, which would be impossible without this approach. Everyone has different perception and opinion towards different topics, therefore the cultural ecosystem services are highly subjective. Although, by forcing ourselves to represent our opinions and feelings in numerical values, it makes the analytical process much easier. As a result, our group was able to quantify all 6 of our opinions of Zone 1 into charts, graphs, or any other visual representations.

Although, there are also weaknesses that arose through our experience conducting the value mapping approach. One of the initial thoughts through the analyzing phase of the value mapping approach was the fact that depending on the sub-zones, our group members had a very different assessment towards the five cultural ecosystem services. For example, one has expressed that the spacious courtyard within sub-zone H with benches and vegetation had a very strong aesthetics, while one member has expressed that it was "too urbanized", thus feeling that it was too much concrete and little vegetation. This is indeed the beauty of the cultural services, as there are no right or wrong answers. Yet the problem with the value mapping approach in our case was the scale. Due to the small-scaled surveying method with only 6 group members participating in this value mapping approach, our data have become somewhat biased. In a highly subjective topic, it is not ideal to have small data sets, as a single member's opinion weighs very heavily towards the overall assessment of the zone. What would make the value mapping approach a much more accurate set of data is through having more data sets; thus having more people do the surveys, assessing the five different cultural ecosystem services. Through achieving that, the biased opinion towards the zone will become a much more unbiased view, creating a much more valuable, accurate representation of Zone 1's cultural ecosystem services.

5. Urban forest planning and management recommendations

Integrating the benefits forests and other plants provide into an urban setting is a difficult task, due to the limited green space available and constant exposure to humanity and interferences that may affect growing conditions. Several approaches can be made or are already used to tackle these issues, with positives and negatives for each.

As discussed earlier, the i-Tree ecosystem analysis is extremely helpful for judging what areas of an urban area or ecosystem should be focused on, and what can or should be done in order to improve the quality of life for those in the surrounding areas. Of course, there are potentials for errors and other misjudgements, but it provides the basis of what needs to be looked into further and give rough estimates about various info. The report for the area we're focusing on, Zone 1 on the UBC campus, provides lots of helpful analyses.

While the site in focus doesn't have a lot of green space compared to other sites on campus, it is still nonetheless valuable with the ecosystem services and aesthetic appeal it provides. In order to make effective planning strategies for the future of a site, a certain aspect of the site must be used as the prime focus, and for strategies and approaches to be based around this (Wassenaer et al., 2000). This helps keep attention to the ecosystem services this site provides, and what can be done to improve them and other aspects as well. Using I-Tree can help determine what areas or services are in need of improving, and which ones are fine as they are currently. Overall, the primary focus of urban planning within this site should be based around canopy coverage, based on the information and analysis currently.

The reason for this focus is that the site is mainly dominated by buildings, asphalt and pavement, with little green space in comparison. While this grey to green space ratio can be seen as unbalanced, attempting to turn the grey space back into green space would cost lots of time and money, and would need serious assessment to make sure that it would be worth it in the long run, so the primary focus should be of the currently available green space instead. According to the analysis of the site, the feeling of wildness is the lowest out of the cultural ecosystem services this site provides, so that should be a priority, among other ecosystem services. While the green space is limited, there are plenty of opportunities to take advantage of, including using the grey space as well. Things like planters, plant pots and other ways of growing plants and small trees either indoors or on pavement can help increase the amount of green, though it does run the risk of such structures getting knocked over or damaged, affecting the plants within. If taken care of properly, ivy and vines running along the sides of blank building walls may be an aesthetic choice, though care must be taken so they won't end up negatively affecting the structural integrity of the building.

Other ecosystem services may be focused on as well, such as provisioning, regulating, and supporting. Things like water runoff, potential food production and soil erosion prevention would fall under these categories and are noteworthy to keep in mind while planning. Planting fruit-bearing trees or shrubs could prove beneficial in the long run, similar to other crop-producing plants planted in community gardens in other areas of the campus. One drawback to this is the increased effort in order to have the trees produce fruit, as they require much more energy compared to other trees. Another thing to note is the fruit may not even be edible, as other studies on fruit produced in urban areas have noted products made from such fruit can exceed acceptable safety limits of lead, cadmium and other elements (Kowalski & Conway, 2018). Trees and other plants help prevent soil erosion by keeping it in place, so it doesn't get washed out by rain, or moved by heavy winds, as well as helping complete the nutrient cycle present in soils. The plants already present are doing a great job, though there are some open green spaces with only grass on them, leaving them vulnerable, so additional trees, brushes or shrubs could be planted there to help mitigate erosion. Lastly, water runoff should be kept in mind as well, since the high abundance of grey space makes it difficult for water to enter soil, and instead accumulate on the surface. While things like drains and other ways of displacing water are available, they can be expensive to introduce, while green spaces can provide the same benefits for much cheaper. As said before, planters and plant pots on grey spaces can help mitigate water accumulation and runoff, albeit in a smaller amount. Growing trees with large canopy cover can help prevent water runoff and nutrient contamination, though this requires a lot of space and time (Matteo et al., 2006).

Overall, this site has numerous amounts of ecosystem services and benefits in a small area that can be improved for more efficiency. Determining which services to focus on and base approaches and strategies on can be a tough decision, but the best course of action would to be focusing on the cultural part of the site, due to its low abundance, while keeping the other services in mind in case there can be an overlap between two or more with one solution.

6. Appendices

<u>Appendix I</u>

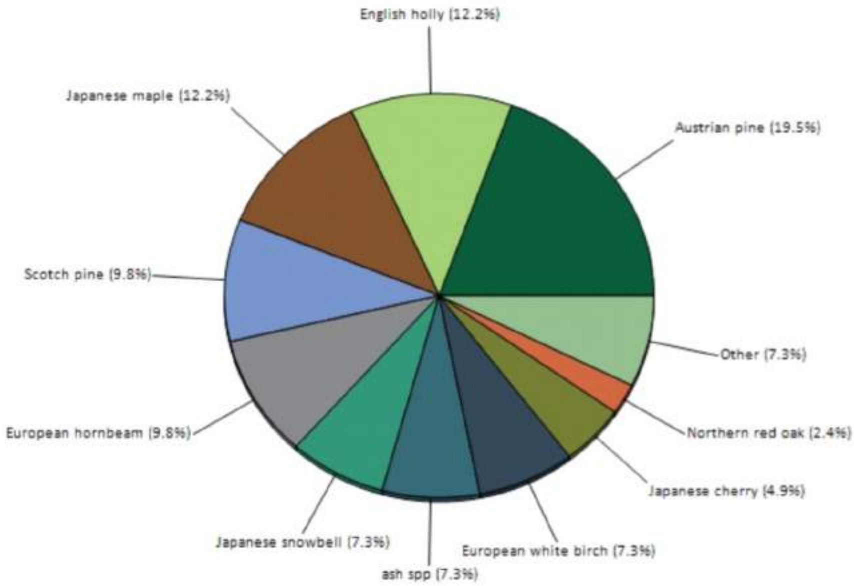


Figure 1. Tree species composition in Zone 1

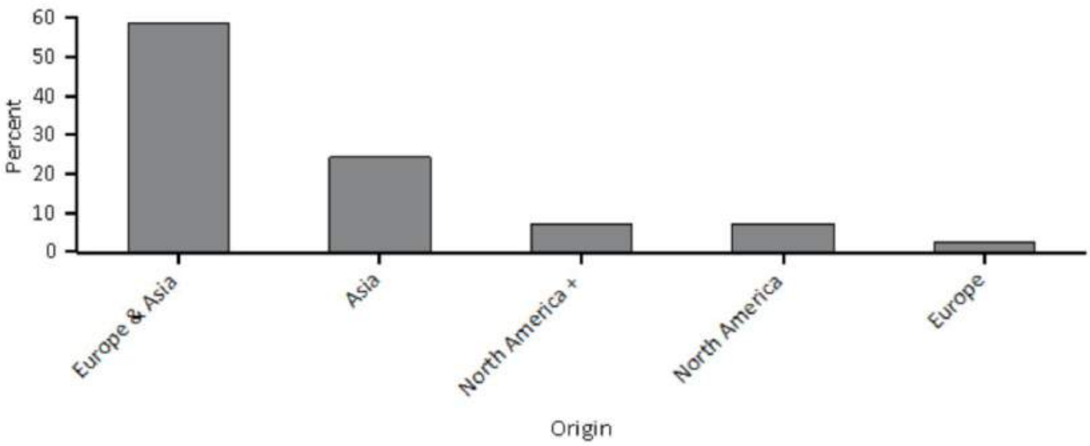


Figure 2. Percent of live tree by area of native origin, Zone 1

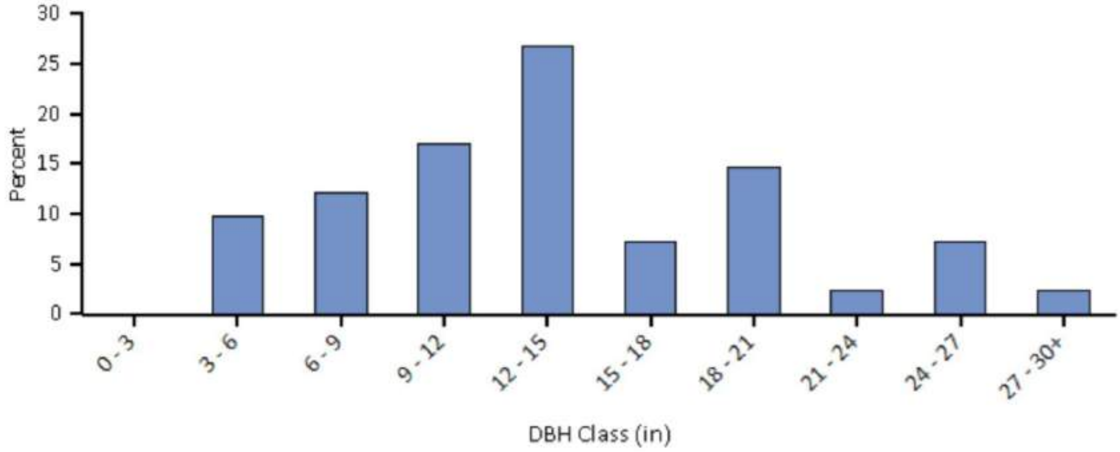


Figure 3. Percent of teen population by diameter class (DBH – stem diameter at 1.37 meters)

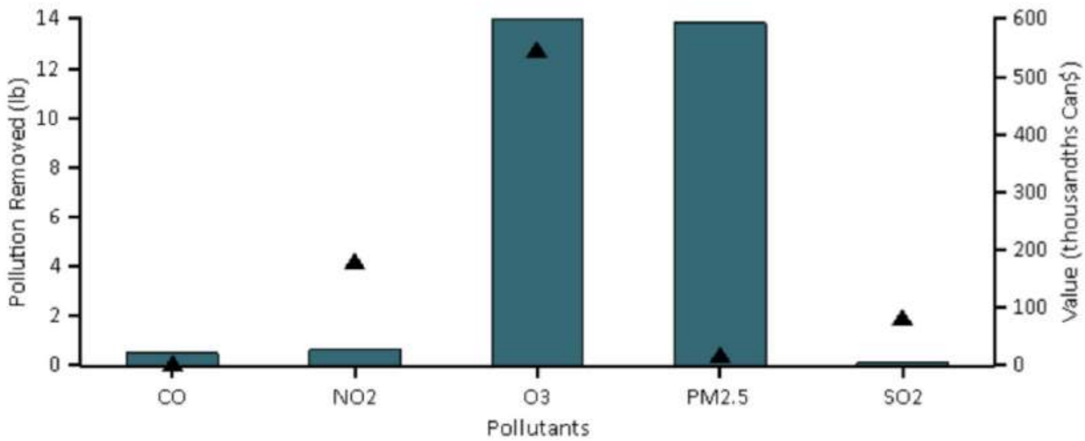


Figure 4. Annual pollution removal (points) and values (bars) by urban trees, Zone 1

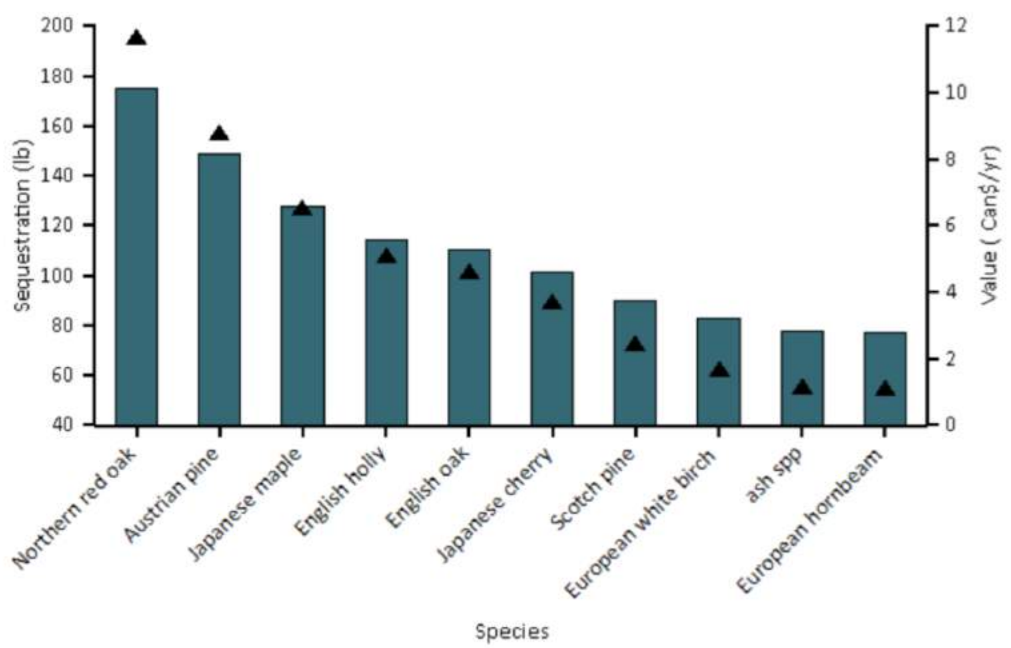


Figure 5. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, Zone 1

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
Northern red oak	519.03	194.64	1	0.02
Austrian pine	417.65	156.62	8	0.02
Japanese maple	337.74	126.65	5	0.01
English holly	286.09	107.29	5	0.00
English oak	269.06	100.90	1	0.01
Japanese cherry	237.05	88.89	2	0.01
Scotch pine	191.54	71.83	4	0.01
European white birch	165.54	62.08	3	0.01
ash spp	145.20	54.45	3	0.01
European hornbeam	143.45	53.79	4	0.01
Common hoptree	76.17	28.57	1	0.00
Japanese snowbell	54.66	20.50	3	0.00
Black tupelo	13.62	5.11	1	0.00

Table 1. the top 20 oxygen production species in Zone 1

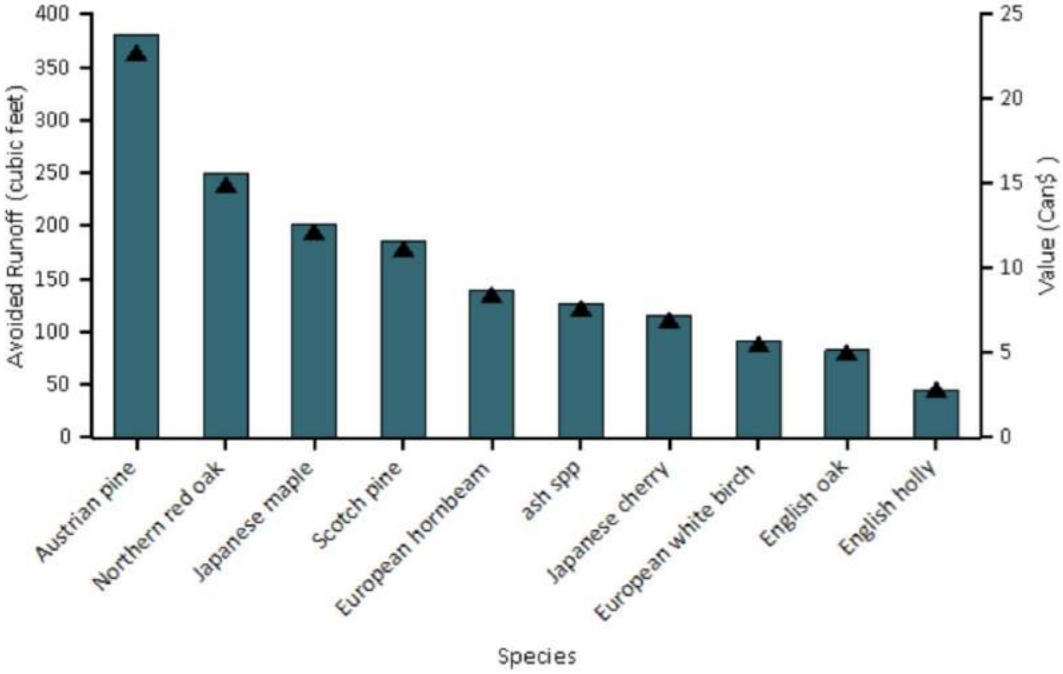


Figure 6. Avoided runoff (points) and value (bars) for species with greatest impact on runoff, Zone 1

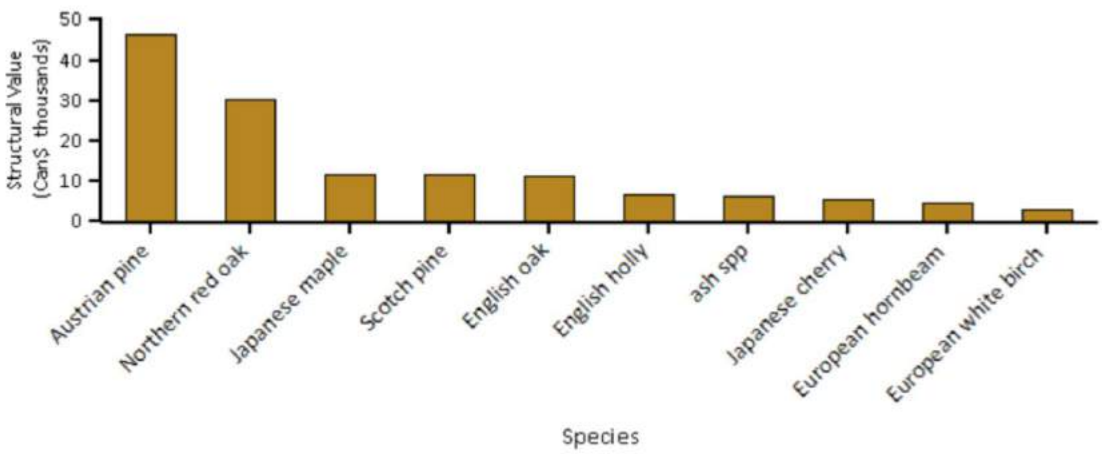


Figure 7. Tree species with the greatest structural value, Zone 1

Appendix II

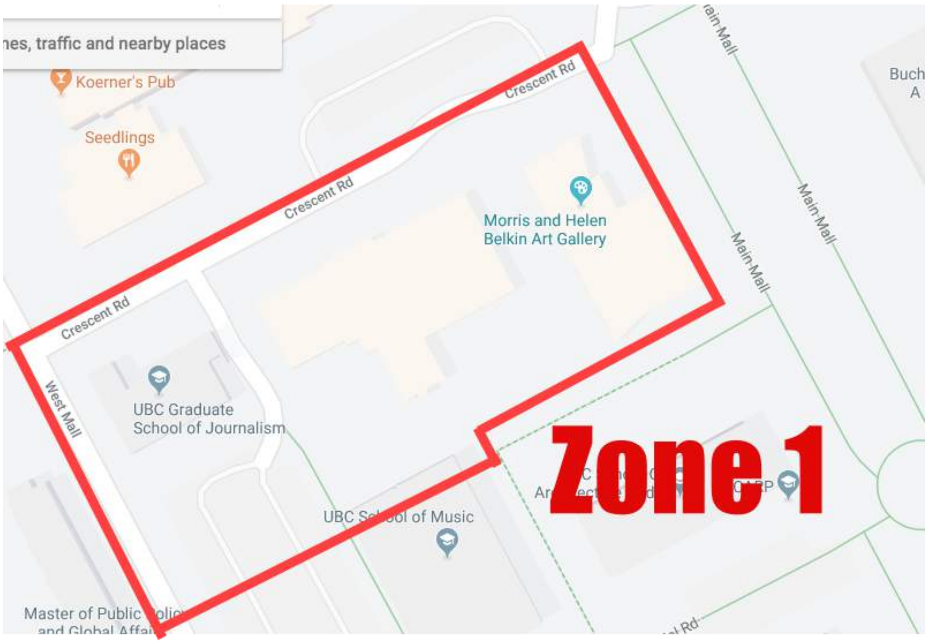


Figure 1. Map of the assessed area titled zone 1

Appendix III

	EXPERIENCE DIMENSIONS				
Subzone ID	**Diversity/ species richness**	**Aesthetics**	**Social cohesion**	**Wilderness/ nature**	**Cultural significance**
SUMMARY					
A	21	18	23	10	23
B	19	17	15	9	10
C	7	13	21	3	21
D	8	12	13	8	11
E	6	11	8	3	4
F	16	10	18	8	16
G	7	9	14	2	2
H	18	21	18	16	19

Table. 1 Sum of the individual scores of value mapping approach

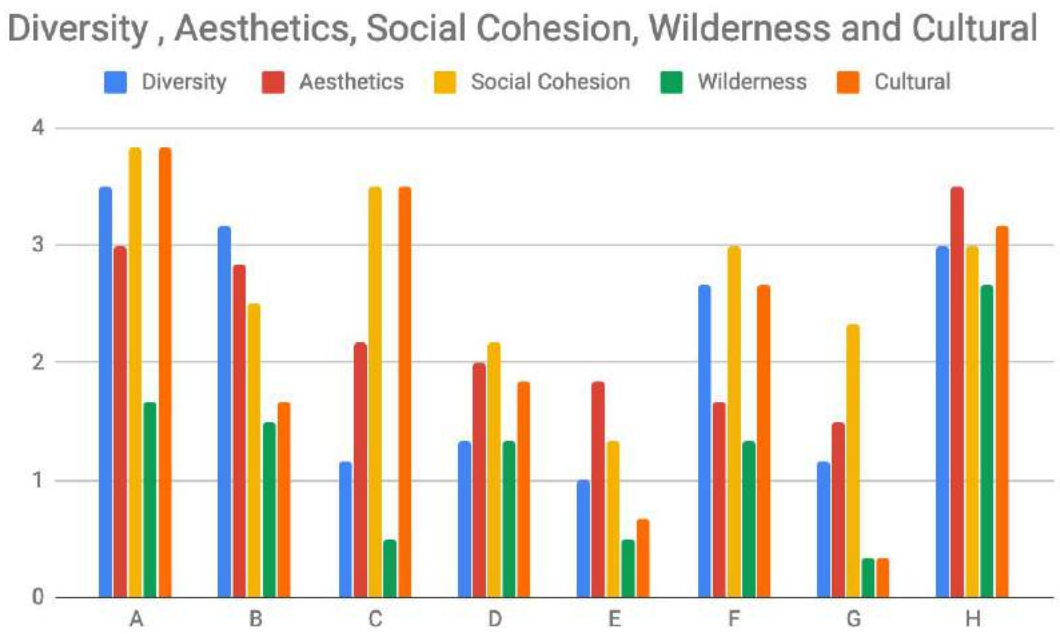


Figure 1. Average scores of different cultural ecosystem services depending on sub-zones

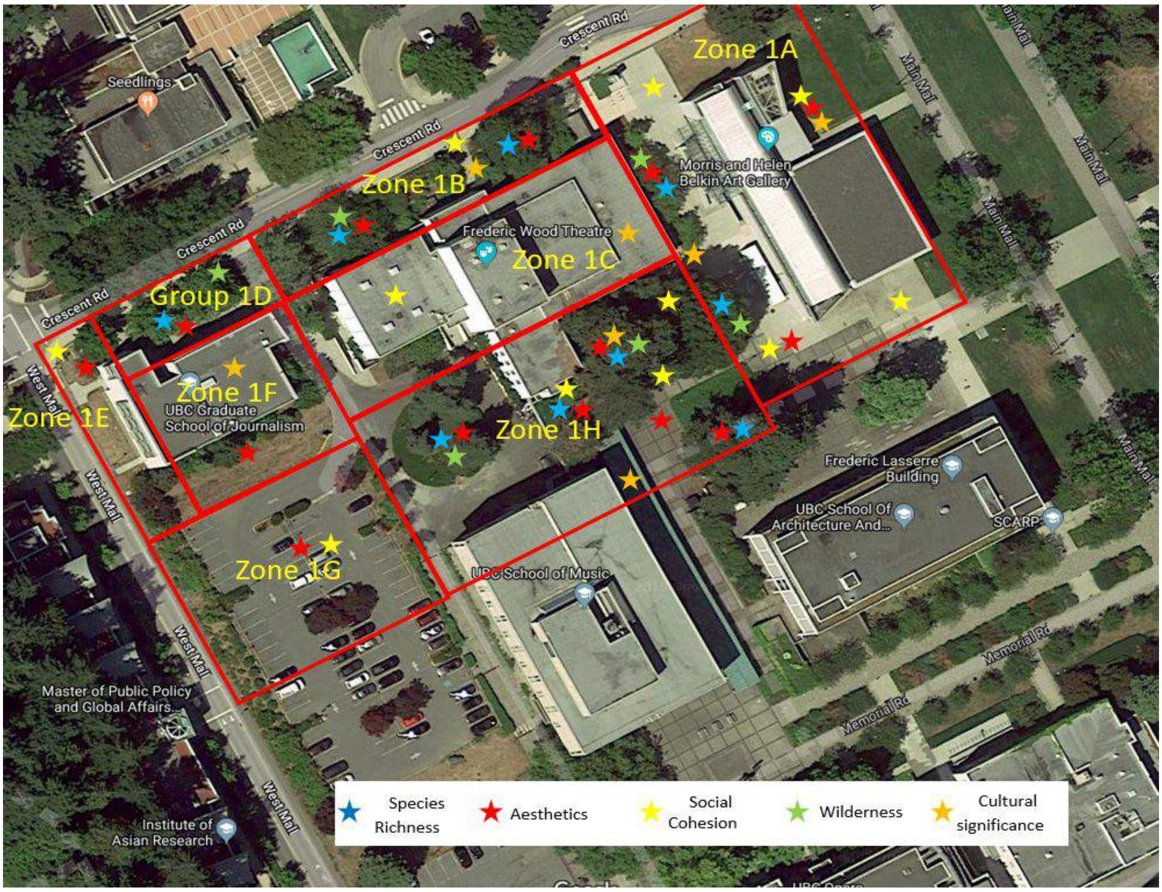


Figure 2. Identified hot spots of various cultural ecosystem services on different sub-zones

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Analysis of UBC Campus Trees in Zone 1 and the Effects and Benefits on the Urban Environment

Group 1

2019

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Ren Niikura, Michael Sandrin, Alina Ziyun Zeng

University of British Columbia (UBC)

Work Distribution

Member	Section		Other
Alina	**Introduction**		**Data tabulation** **Reference list** **Layout & format**
	describes the purpose of the tree inventory, as well as the end users of the inventory data collected on campus.		
Charlotte	**Site Description**		**Proofread everything** **help with style and flow**
	provides a description of the selected area of UBC campus assessed by your group. you can include information such as land use type, activities observed in the area, types of facilities observed in the area, different users of the area, specific location (map), and photos of the area to show representative examples.		
Ren	**Methodology**		**Proofread the last section** **Help with grammar**
	This section describes the methods used for inventory data collection on-the-ground, as well as the methods used to analyze your data in class. A list of variables measured should be included.		
Michael	**Summary of tree inventory data** **Tables (see appendix)**		**Proofread the last section** **Layout**
	You may include tables and graphs showing findings such as species composition in your selected area, including species abundance (stem counts) and dominance (basal area). You may provide summary results showing the structure of the urban forest in your area, for example by plotting the distribution of diameter classes and height classes of the trees you measured.		
Chelsea	**Special trees in selected area**		
	You may also present results to showcase interesting landmark trees, for example, the tallest tree in your area, the tree with the largest crown width, a rare tree, or a tree of cultural importance. You may add some photos to illustrate your findings and provide key examples.		
Elaine	**Interpretation of the findings**	15.0	
	include some interpretation of the findings produced for your area. Some forecasting may also be included to show potential future growth of trees in your area.		

Introduction

Background

Established within the Coastal Western Hemlock biogeoclimatic zone at the left end of its country, the University of British Columbia, an institution initially designed with the image of "a clearing in the forest", has always paid serious attention to its aesthetics (University of British Columbia [UBC], 2009). UBC strives to create a "West Coast feel" character because of where the campus is situated. The university's development patterns have echoed this notion and the campus has gradually formed as a result of its founders' pursuit of lush and easily accessible greeneries (UBC, 2014, p. 8). With three of its sides surrounded by the Pacific Ocean and a dense belt of forest on the other, UBC is proud of its leading role in sustainability and has a reputation of being one of the most visually spectacular learning institutions in the world (Lompart & Ikeda, 2017).

Since the university's expansion in its development of both academic and residential areas, there has been a measurable decline in trees due to the increasing gaps in campus urban forest administration policy. There is a lack in the regulation and enforcement of tree management because there is no unifying master plan. The different guidelines involved causes "management [to fall] under a complex web" (Lompart & Ikeda, 2017, p. 1).

After analyzing existing guidelines and observing urban forestry practices on campus, there is a need to improve the conditions and performance of trees by the means of adequate protection and replacement. With reinforcement as its primary scope, an integrative management plan that reflects campus stakeholders' needs and interests must be formed through the construction of solid recommendations for the future procedure (Lompart & Ikeda, 2017).

Purpose

To compose a plan effective enough to meet all the aforementioned expectations in order for the trees on campus can be appropriately managed. People will benefit from the explicit recognition of resources and the attainable, long term monitoring goals cannot be set unless current conditions are fully understood (Lompart & Ikeda, 2017). A series of complete tree inventories collecting valuable information of campus tree population is crucial in the development of the UBC Urban Forest Management Plan as well as the Future Biodiversity Strategy. A complete tree inventory will also generate a detailed report on the distribution and attributes of the UBC urban forest (Bellis et al. 2017).

Several tree inventories have been conducted since 2017 to provide inputs for UBC's campus trees management plan and equip campus planners with more knowledge about trees' current condition (Bellis et al. 2017). This inventory, in particular, was carried out with the assistance of students registered in the UFOR 101 course upon the Campus + Community Planning request to help with the pre-scoping stage. This inventory is a sample inventory performed in a selected area on campus, bounded by Agronomy Road to the south, Crescent Road to the north, West Mall to the west and Main Mall to the east. It requires an on the ground assessment of trees and aims to collect data regarding common variables that include species, DBH, crown width, tree height, etc., in order to provide campus workers with up to date greenery information.

The primary goal of this inventory is to continue to update information about trees around UBC's academic area by inputting data regarding tree growth into the collector application. The data collected is to be used for analysis, and later to suggest maintenance schedules such as removal and replanting activities. In the following stages, ecosystem services that these trees provide will be evaluated by remote-sensing through the use of i-Tree. That way campus urban forest vision can be formed and the establishment of a management plan can be promoted.

By working outside of the classroom and practicing the use of different tools, students involved in this inventory are able to develop hands-on skills that will be valuable attributes in the workplace. Subsequent interpretation of data collected will also allow for critical thinking and improvement, making students better thinkers when dealing with issues in this field. By becoming more involved in projects on campus, the sense of community engagement is strengthened among the students and the staff because people will learn more about what benefits the trees provide and what can they do to make the trees' performance even better.

End users

Campus + Community Planning; a department that unites various experienced urban planners, engineers, architects, designers, building inspectors, and public consultation professionals, will contribute in shaping an engaging academic environment and sustainable communities at UBC. They will be accountable for "ensuring that any choices made about land, buildings, infrastructure, and transportation support the campus short and long-term goals" (Campus and Community Planning, 2018; University Properties Trust, 2018, para. 3). SEEDS sustainability program, which provides community partners with opportunities be part of "research projects that are tested on campus", would make good use of data from this inventory as well (Social Ecological Economic Development Studies, 2019). Urban Forestry Program Representatives, Building Operations and Arborists, and Planning and Design, will later inform management of decisions and future plans, as well as monitor changes and risks (Lompart & Ikeda, 2017). Students and staff will also become more related to urban forests on campus through the increasing awareness built as a result of transforming theory into practices.

What to expect

In this report, the site where our group conducted tree inventory is described in terms of its landscape and structure. Land use type, activities observed and users are discussed in detail. Thereafter, methods used to carry out on the ground assessment of trees are introduced, as well as the means of interpreting the data collected. The report then highlights species composition of the site, as well as the overall structure of its urban forest, which is then followed by a description of landmark trees. Finally, the report concludes with an overall interpretation of the findings. Challenges and future projections are also covered.

Site Description

The assessed area in this report can be titled as zone 1 and is shown in appendix A as Group 1. Zone 1 is located on the north-west side of campus and is surrounded by West Mall, Crescent Rd, Main Mall, and the Music building. The zones land usage is mainly institutional however is also used for transportation and recreation.

There are three buildings contained within the zone, one being the Sing Tao Building that is located in the left top corner of zone 1. The Sing Tao Building is part of UBC's Graduate School of Journalism and was built in 1997 (UBC, 2019b). It is of a smaller size when compared to the other buildings. There are a significant amount of trees, ferns, and hedges within close proximity to the building that gives it privacy while also acting as a boundary from the road and sidewalk.

The next building is the Frederic Wood Theatre and it is centered in the middle of zone 1. This building was constructed in 1963 and is named after the founder of UBC's players' club, Frederic Wood (Nothof, 2016). The theatre is used by performing arts students who put on a variety of productions that are open to the public. The front of the building incorporates an interesting wood beam facade and is aligned with medium sized trees in which two of them are placed in elevated plots. This design speaks to the buildings use.

The last building is the Morris and Helen Belkin Art Gallery which is located in the right lower quadrant of the zone. It officially opened in 1995 and specializes in researching, publishing, educating, and exhibiting contemporary art and its history (UBC, 2019c). Much like its use, the Belkin Art Gallery has a contemporary design. This is showcased in its sleek use of lines and curves that make up the windows and walls of the building. The gallery's architecture acts as its own art piece and art enthusiasts can appreciate its exterior along with its interior.

a) b) c)

Fig. 1: a) The Sing Tao building from the view of Crescent Rd (Mathisen, 2019); b) The front entrance of the Frederic Wood Theatre (Mathisen, 2019); c) The front entrance of the Morris and Helen Belkin Art Gallery from the view of Main Mall (UBC, 2019)

The courtyard nestled between the gallery and the theatre is largely made up of concrete. It provides students with a large space to gather and socialize, as well as providing a space for theatre-goers to congregate before and after shows. There are few benches throughout the area and some have dedicated plaques. The standout feature, however, is the statue *Asiatic Head* by Otto Fischer-Credo that is positioned under the long covered walkway that cuts through the south-west side of the courtyard. The art piece is actually a replica made by Gerhard Class and it "features a large stylized head with Asian characteristics and has been variously interpreted as both a man and a woman" (UBC, 2019a, p. Otto Fischer-Credo, Asiatic Head). The piece itself along with its placement is quite dramatic and adds character to the area.

The different tree species that are within the courtyard and surround the theatre breaks up the negative space and gives the area a more dynamic vibe. Tree selection and placement almost seem random, yet is done with care as all the trees have a substantial amount of room for water to infiltrate the soil and for their roots to grow.

You can tell the area is aged in comparison to the rest of the campus, and this is evident in the appearance of the buildings, as well as how tall some of the trees are. The trees that act as the centerpiece for the cul-de-sac that is located in the center of the zone especially showcase this attribute. These trees, in particular, give off a mysterious and whimsical presence because they are tall, lopsided, and grow in different directions. They add a compelling feature to a somewhat bleak looking area.

Adjacent to these trees is a large pay parking lot which makes up a substantial amount of zone 1. The parking lot can be classified under transportation land use. It is located on the lower left side of the zone and has a high amount of usage from students, faculty, and visitors.

Zone 1 is an area that at first glance appears to be bleak and vacant, however, the placement and design of the buildings and trees give it an artistic edge. While the area is aged, it still gives off a modern impression and creates a welcoming space for users to conjugate and be creative.

a) b) c)

Fig. 2: a) Asiatic Head by Otto Fischer-Credo (Mathisen, 2019); b) The courtyard (Mathisen, 2019); c) side of the SIng Tao building and entrance to the parking lot (Mathisen, 2019)

Methodology

Efficiency and accuracy become extremely important during qualitative measurements of trees in zone 1. With more than 40 trees within the area, our group developed a systematic strategy which allowed us to accurately measure every indicated tree within at an efficient rate. During our one week of a tree inventory, we used several tools that were provided by the class, which measured specific aspects of a single tree. The specifications of measurements, the methodology, as well as the tools used are listed below. All of the measurements we conducted were in metric units to keep the consistency of data.

Tag, Tag ID, Live/Dead

First step into the tree inventory was to record general information of the tree. We first looked for a circular metal tag which indicates the specific tag ID for every tree at UBC and indicated whether or not it is attached on the tree. If it is attached, we indicated it as a "Y", short for Yes, and "N" for No. Majority of the trees we measured had the tags, therefore we moved on to the next step which was to record the unique tag ID. This information is engraved on to the tag, and it was usually a two to four digit number. If there were no tag present on the tree, we indicated it by writing "none". After that, our group had discussed whether the tree was alive or dead by assessing its overall appearance, leaves, and bark. We indicated a live tree as "L", and a dead tree as "D". We did not require any tools for these three general assessments and it was rather a visual inspection.

Tree ID & Tree Species

Tree ID number and the species are two pieces of information we gathered from the "Collector app", which was an application our team leader possessed. This app indicates the location of the trees that need to be measured, as well as a four-digit tree ID, and the scientific name of the tree species.

Land use

The land use categories were based on the i-Tree Eco categories. We would determine the land use depending on the location of the tree, however since UBC is an institution and all of our trees were within UBC, land use for all trees were indicated as "I", or "Institutional".

Diameter at Breast Height (DBH)

Measuring the diameter of a tree using the "breast height" method was sometimes a challenge, as we stumbled across a group of large trees with shrubs covering the ground, thus it was hard to physically reach the tree. By using a measuring tape which specifically only indicates the diameter of a tree, a member of our team would wrap the measuring tape around the tree at the height of 1.37m, or 4.5 feet above the ground. Once the tape had completely gone around the tree, we would align the tape and read the measurement in cm. During this process, it is extremely important to keep the tape leveled and to have no gaps between the tree and the tape. Another trouble we faced were trees with multiple stems. In this case, we would measure up to the 6 largest stems (we ignored any stems <2 inches in diameter), and calculate the average, which would then be recorded as one tree.

Total Tree Height

Determining the total height of the tree required more complex measurements and calculations. First a member would walk away from the tree, looking parallel to the ground. As soon as the highest point of the tree enters the view of sight, they would stop. The first set of measurement we collected was the distance between this member and the tree. We made sure to keep the measuring tape level in order to avoid any overestimates or underestimates. If the tree is located on a slope, we made sure that the member was standing on the uphill side of the tree. A second set of measurements were collected using a tool called the clinometer. The same member standing away from the tree would look through this tool and line up the central line visible (also known as crosshair) with the highest point of the tree, as well as the lowest point of the tree. There are two values present when looking through the clinometer, and we used the percentage scale located on the right side of the crosshair and used this throughout the entire measurement in order to keep consistency. When looking at the top of the tree we would get a positive value such as 43, and looking at the base of the tree would give us a negative number, usually not too big, such as -10. We would use these two values to calculate the total tree height. The calculation is fairly easy. We would add up the two values, then multiply them by the distance between the tree and the member who took the measurements. For the previous example, (43)+(-10)=33, which means the height of the tree was 33% of the distance between the tree base and the member. If the member was standing 25m away from the tree, it would become 25 * 0.33 = 8.25m.

Live Crown Height

Initial step for measuring live crown height was through visual inspection. Often times, the total tree height does not take into account whether the highest part of the tree is alive. It is not uncommon to see a dead branch being at the highest point of the tree, therefore in this measurement, we determined the highest live crown of a tree. Fortunately, all of our trees had a live top, therefore the live crown height and total tree height was the same for all of our trees. Although, if the live crown was not the same as the total tree height, we would use the same method as measuring the total tree height.

Crown Base Height

The crown base height measures the height from the ground to the lowest crown. Originally, this measurement was performed through the same technique used for measuring the total tree height. Instead of aligning the crosshair with the top of the tree, we aligned it with the lowest crown possible and used the same equation and calculations to determine the height of the lowest crown. Although some of the crowns were very short, therefore there was no need for clinometers. If the crown was reachable, we simply used measuring tape and measured the height of the lowest crown from the ground. There were also other special cases, where the crown was touching the ground. In this case, we indicated the crown base height as “0”, since there were 0cm between the ground and the lowest crown.

Crown Width

Measuring the crown width took two people with the measuring tape, as well as the other members trying to figure out the shortest and longest width of the tree crown. We would then measure the longest crown width, followed by the shortest crown width. For these two measurements, it was important to keep the measuring tape leveled while standing right beneath the crown. After measuring the two sides, we would average them out and indicate them as the crown width.

Crown % Missing

This piece of information was extremely hard to identify, as we could not measure the crown percentage missing with our tools. Rather, we had to gather as a group and discuss roughly how much of the crown was missing. Our estimate ranged depending on the tree, and it was extremely hard to identify the crown percentage missing for trees that were unique in shape and size. Some of the coniferous trees were especially difficult to identify, due to its unpredictable crown size and distribution along the tree.

Crown Light Exposure (CLE)

Crown light exposure refers to whether all five sides of the tree receives a sufficient amount of sunlight. This is another piece of information which had to be discussed among the group members. There were cases where two trees were growing right next to each other, thus one side of each tree was not receiving sufficient sunlight. In these cases, we indicated the crown light exposure as 4, since only 4 sides of the tree were receiving a sufficient amount of light.

Analyzing raw data

Throughout the week of data collection, we were able to record hundreds of measurements from different trees. Numbers by itself won’t convey anything, thus we have created several bar graphs in order to see the relationships between various measurements. This allowed us to deepen our understanding of the trees that are planted at UBC. In addition, we have also used photographs taken during the time of data collection to visually represent how some of the trees we have described look like. Any other key information that conveys information by itself, such as the tree species planted, were used in several analyses, which will be explained in the results and interpretations of the data.

Summary of Tree Inventory Data

The plot we were assigned for data and collection, zone 1, had a large range of trees to analyze and totaled at 42 trees. All of them were alive, but varied in height, diameter at breast height (DBH) and more. The most common tree we analyzed was the *Pinus nigra*, otherwise known as the Black Pine, with 8 specimens analyzed. The least common tree was the *Aralia Elata*, also known as the Chinese Angelica-Tree, with one specimen analyzed.

Using the data collected and presented in Appendix B, we can see what ranges of DBH measurements the trees fall under. A majority of trees have a medium sized base, roughly around 20 to 40 centimeters in diameter, while a smaller number have larger bases, with only one tree, a *Quercus rubra*, or Northern Red Oak, having a base greater than 100 centimeters outgrowing steps that a majority of the trees are still young and growing or haven’t been able to have much secondary growth in terms of width yet, possibly due to growing conditions or another factor affecting growth.

After plotting the data we collected on the total tree height, we can see a pattern on how a large number of trees are at a shorter total tree height compared to the small number of trees at a larger total tree height using Appendix C. The one tree that has a total tree height greater than 30 m is a *Pinus nigra*, also known as a Black Pine. There is a greater number of trees with a relatively short total tree height compared to taller total tree height, with trees within the 2-9 m range equaling the number of trees of all other values combined. This suggests that a large number of trees growing in this site are either young and still growing, or mature and they have had their growth limited by lack of nutrients, space or another limiting factor. Another possibility is the tree had its total height reduced by humans, due to it growing in an urban environment, and being too tall could affect several aboveground structures in a negative way.

Looking at Appendix D, you can see the comparison between the live crown height (LCH) versus the crown base height (CBH), and the differences between the two. CBH is the measurement of the distance between the ground surface and the lowest living branch on the tree, while LCH is the measurement of the top of the tree crown to the lowest living branch. Combining the two will give us an estimate on how tall the tree is, but separately we can see how much of the tree height comes from the crown and how much of it comes from the trunk. All of the tree heights have a greater LCH compared to CBH, though some of the tree specimens have similar height measurements for both values. A majority of the specimens measured have a much greater LCH compared to CBH though, suggesting that these trees prioritize canopy growth rather than vertical growth, and don't put much focus on out growing and competing neighboring trees for sunlight. There is an explanation for this behavior. Since these trees are growing in an urban area, they're most likely pruned so each tree won't have to spend as many resources to out-compete one another, and can instead focus on leaf growth, which can be decorative and appealing to the public eye.

Special trees in the selected area

Throughout zone 1, we have identified various species of trees which could be commonly found anywhere else. Within those common tree species, we observed several unique trees ranging in size, shape, and height. By analyzing our data, we have identified some of the interesting measurements and observations for these special trees.

The largest tree

The *Quercus rubra*, within the family of Fagaceae, is commonly known as the northern red oak (Missouri Botanical Garden [MBG], 2019d). In zone 1, this tree had the biggest DBH (116.1714cm) and crown width value(19.47m). The average height of this tree is about 50-70 feet(15-22m) (often larger in nice conditions) and the blooming time is in May. It grows well in dry to medium moisture leveled acidic soil and in full sun (MBG, 2019d). *Quercus rubra* has a well-proportioned canopy, dense branches, and toothed and lobed leaves. Leaves turn brownish-red in the autumn and remain red for a long time (Marshall, n.d.). In the winter, the leaves still have branches (shown in Figure 3), which have a good ornamental effect and are mostly used for landscaping. *Quercus rubra* is a deciduous tree, with an average diameter of 90 cm, and a crown width of up to 15 meters (MBG, 2019d). *Quercus rubra* is a producer in the ecosystem. It produces energy for itself by photosynthesis and can also convert carbon dioxide into oxygen. The tree provides many birds a chance to build their nests, as well as produces acorns, which many kinds of wildlife consume (Marshall, n.d.). Because of its ability to tolerate various conditions, it is grown in many cities and urban areas. It is often used to beautify the environment.

The tallest tree

The tallest tree in zone 1 is the *Pinus nigra*. It is usually known as European black pine, which belongs to the Pine family (MBG, 2019b). This species is native to the mountains of the northeastern Mediterranean region (MBG, 2019b). *Pinus nigra* is a coniferous evergreen tree and has dark-green leaves (needles). *Pinus nigra* performs best in well-drained soil and full sun. It grows to about 80-150 feet (25-45m) tall with a straight trunk that can measure up to 40 to 72 inches in diameter over time (Enescu et al., 2016). There are six *Pinus nigra* trees in our zone, and the average height of these trees is 24m, which is much higher than some of the other species. The bark of *Pinus nigra* is thick and gray-brown in color. It can exist in a variety of soils and has a high tolerance of extreme weather. Because of its ecological flexibility, it is the most widely used tree for reforestation. *Pinus nigra* can be used to control soil erosion and land rehabilitation (Enescu et al., 2016). *Pinus nigra* is naturalized in Canada and widely planted in urban areas to beautify and purify the environment.

The smallest tree

The *Nyssa sylvatica* is the smallest tree in our area. The data we collected shows that this tree has the smallest value in DBH, TTH, LCH and crown width. The common name of *Nyssa sylvatica* is Black gum, and it can be categorized into the Nyssaceae family (MBG, 2019a). The *Nyssa sylvatica* in our site is only 2.835m tall, which is lower than average (30-50 feet). It is easily grown in medium to wet moisture soil with full sun exposure (MBG, 2019a). The *Nyssa sylvatica* has a straight up trunk and rounded crown. The leaves of this species are lustrous and turn purple in the autumn, and eventually become an intense bright scarlet as shown in Figure 5. The *Nyssa sylvatica* blooming time is in May and June, and the flowers are tiny and yellowish green in color. This tree is a major source of wild honey because its flowers are an excellent nectar source for bees. It is suggested to be used as a shade and street tree based on its gorgeous leaves during the autumn.

The tree with an important value

We have only two *Prunus serrulata* trees on our site. *Prunus serrulata* is a group name and the species under this group always have small deciduous trees with short trunks. It is commonly called the Japanese flowering cherry, and reach a height of 25-40 feet (7-12m) (MBG, 2019c). The native range of this species in Japan, China, and Korea. It prefers growing in moist, fertile loam soil with full sun exposure. The flower comes in two colors, white and pink, and can be displayed in different forms of single, semi-double, and double (MBG, 2019a). It may be fragrant or non-fragrant. *Prunus serrulata* is generally small, flowering trees that help to beautify the environment. There are lots of *Prunus serrulata* trees in Canada, especially at the University of British Columbia. The reason why UBC has a variety of *Prunus serrulata* trees is that John w. Neill, who was the university's director from 1949 to 1973, was interested in this species and saw them as a favorable choice for the campus. Since the original trees started to disappear rapidly, he believed we have the responsibility to maintain and expand the diversity of these beautiful trees on the campus (Madden-Krasnick, 2018).

(Grandmont, 2019)

Fig. 3 The biggest Quercus rubra in Zone 1

Fig. 4 The Pinus nigra displaying its straight trunk and gray-brown bark

Fig. 5. The bright scarlet leaves of the Nyssa sylvatica (Grandmont, 2006)

Fig 6. Prunus serrulata in bloom (Rabich, 2016)

Interpretation of the findings

Our findings in this area include the average height (12.26m) and the average DBH (36.3cm) of the trees, and the relationship between the total tree height and crown base height (CBH). We have also found the peak values of the tree data, for example, the trees with the highest and lowest heights and the trees with the largest and smallest DBH. In addition, the number of different types of trees was also covered in our study. The reasons that can be used to explain these findings and data are mainly concluded into three different factors: tree species, the degree of development or tree age, and the location of the trees.

Different tree species

Different tree species often have different sizes and shapes, and their height can be very different depending on the type of tree. For example, *Pinus nigra* is large coniferous evergreen trees have height around 10-40m (Enescu et al., 2016). Eight of the *Pinus nigra* in zone 1 have an average height of 20.74m. Nevertheless, the *Acer Palmatum*, one kind of Japanese maple tree, commonly have a tree height from 4 to 8m (15-25 feet) in urban areas (Gilman, & Watson, 1993). The four of these maple trees in this area have an average height of 7.77m. The average tree height is affected by different trees and tree species. Since the average includes the various heights of all the different species of trees, the average tree height is affected by the composition.

Degree of development

The degree of development of trees can be another factor that affects the tree size in zone 1, which means the age of the trees is important to consider in the data analysis part of the measurement. Most of the trees have different height and crown size during their time of growth, therefore the tree species average size is not enough to explain why a species usually has a large average size but the species sampled from zone 1 are smaller. For example, the eight *Pinus nigra* was divided into two separate locations; one site with three and the other site with five. The site with three *Pinus nigra* are of smaller size, with an average height of 14.11m, and an average DBH of 45cm, while the five trees in the other site have an average height of 24.71 and an average DBH of 57.72cm. Since they are of the same species, the three smaller *Pinus nigra* trees are considered to be younger than the other five. The comparison of the trees in these two areas shows how tree age affects the tree size.

Location of the trees

The location of the trees will also affect their growth rate and size. Different places have different soil texture, sun conditions, and water resources. Since those are all the basic requirements for a plant to grow, tree size will be affected by the variation in requirements (Ordóñez et al., 2005). For example, some trees located near a building that is not tall enough will lose one side of sunshine, such as the trees in our study area which have incomplete sunshine under the five sides of CLE. Lose of sunshine cause trees to have a shorter crown width than others of the same species and age, just like the difference between the two trees of *Fraxinus Sp*. The one with four sides of sunlight has an average crown width of 12.15 and the one that has three sides of sunlight only has a width of 9.58m.

Forecasting show potential future growth of trees

Future growth will be influenced by the conditions and limitations of sunlight, nutrients, water and space for plants to grow. The forecasting of trees in our study site will be separated into two parts: size and age. Trees with a height above 15m and/or a DBH longer than 40cm are assigned into the larger trees part, and others are contained in the smaller trees part.

Large trees

Most of the trees in the larger tree part are usually well organized and located at a wide position with more open space. These open spaces around large trees provide a considerable range for tree growth in the future. This is important because most of these open spaces act as a basis for adequate sun exposure, and many of the trees with 5 sides of sunlight in zone 1 are located in relatively open space. The largest tree in our area is a *Quaercus Rubra*, with DBH of 116.17cm and a height of 24.16m is a good example of open space and opulent sunlight. Trees like this are considered to grow bigger in the future and be in the upper range of average species height. In addition, an open space is a tree’s guarantee ofhelpsg enough nutrients and water for growth and survival.

a) b)

Fig. 7: a) Quaercus Rubra; b) example of tall trees with 5 side sunlight.

Small trees

Unlike the large trees in the open spaces, most of the smaller trees were planted after the buildings were built. Therefore, the sunlight coverage would be less which will hinder branch growth. This can affect the crown development in the future. However, the distances between most of the street trees that are in the same row are well defined with a space of 4-6m. This helpful in getting these smaller trees enough soil, water, and nutrients for growth. Overall, the future growth of small trees with enough space is greater than the trees located in narrow places.

a) b) c)

Fig. 8: a) street trees with reasonable distance in between; b) trees near the building; c) trees located in a narrow place

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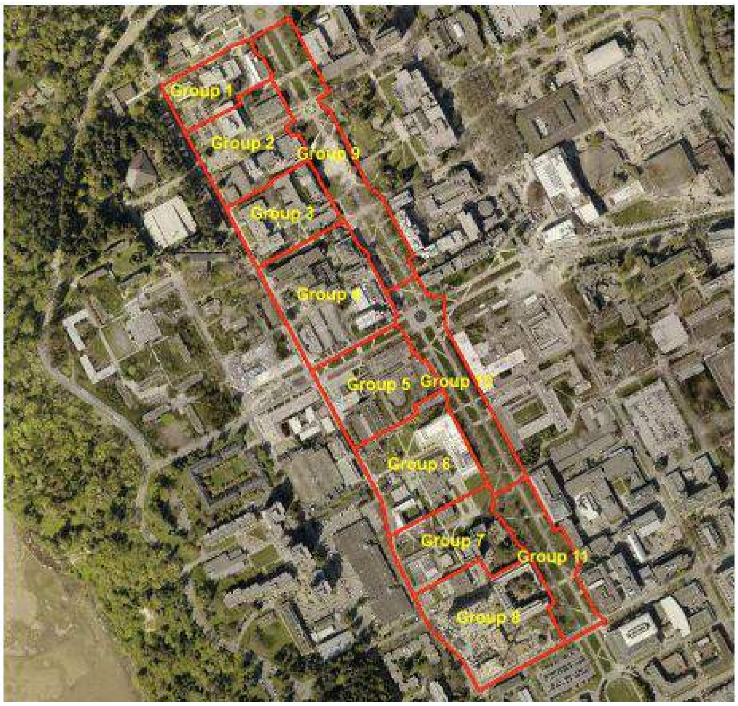
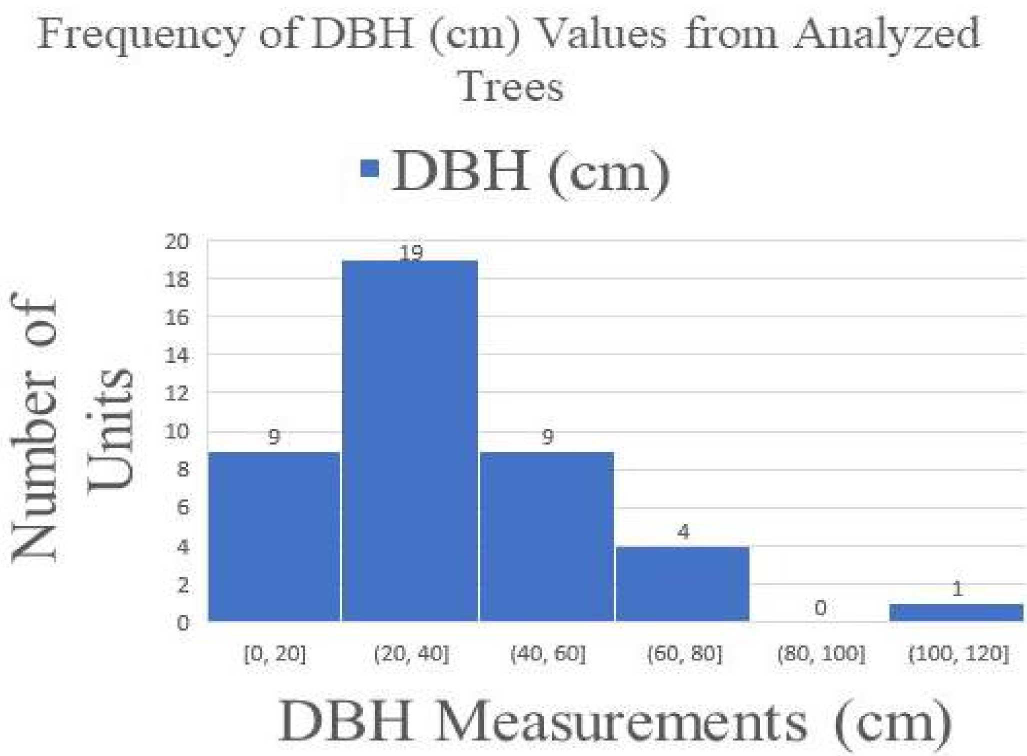
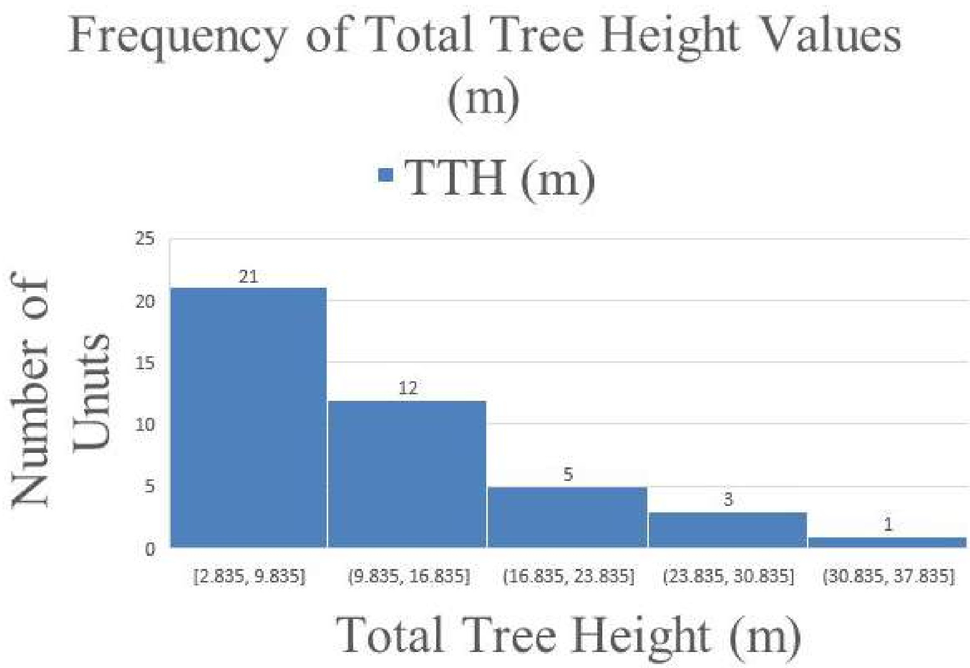
Appendices



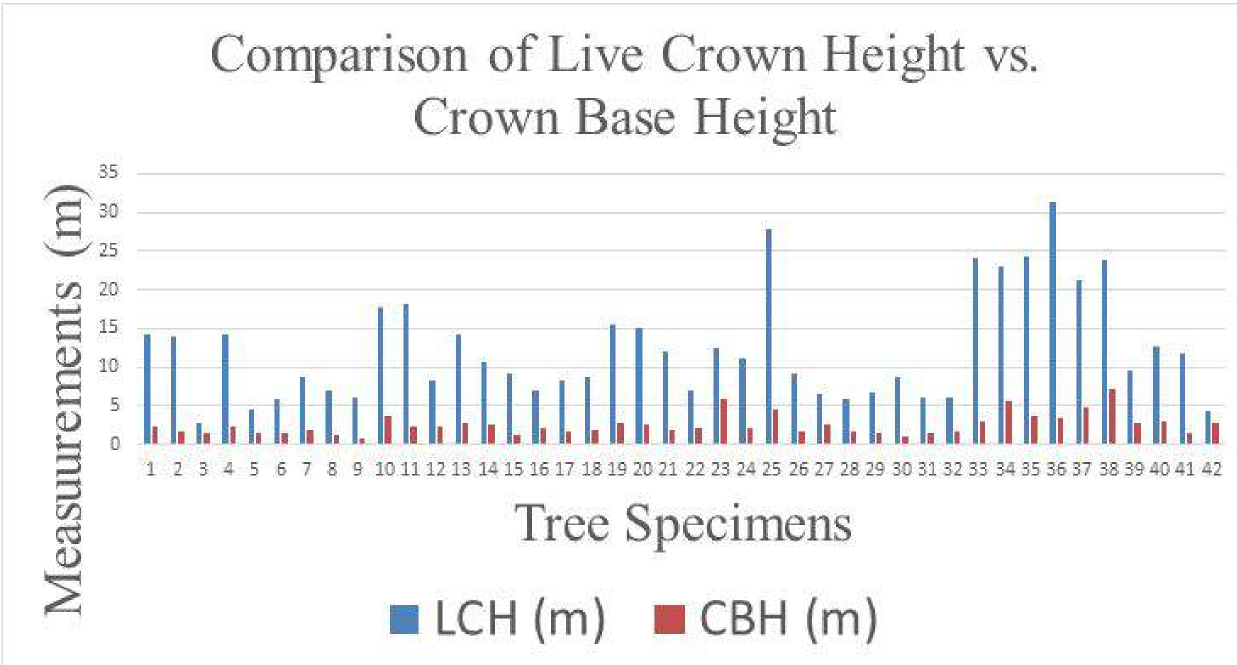
Appendix A (Map of Zones and Zone 1)



Appendix B (DBH measurements of Analyzed Trees)



Appendix C (Tree Height Measurements)



Appendix D (Live Crown Height and Crown Base Height Comparisons)

Memorial Road, UBC . April 1, 2019. Photo taken by Yoshinori Tanaka

UFOR 101 Assignment #2: Ecosystem Service Assessment

Group 2

April 3, 2019

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- Urban forest management recommendations
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- Formatting/editing

Nour Dalati: 86255361

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- Site description
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Raphael Mendoza: 57773533

- Regulating ecosystem services
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- Cultural ecosystem services
    - Connectivity
    - Green Vista
- Urban forest management recommendations
- Liaison between our group and Mr. Egan Davis at UBC Botanical Garden, Ms. Courtnae Cameron at UBC Ceremonies and Events and UBC photographer Mr. Paul Joseph.

2.0 Introduction

Specified by Emma Luker with Campus + Community Planning, an Urban Forest Management Plan is important in order to address gaps in policy around managing our campus' natural assets and a gap in whole-systems approach to consider broader ecological, cultural and social value of these assets (2019). The purpose of the ecosystem services assessment was to add another layer of understanding to our zone. There are four ecosystem services that urban forests provide which are: provisioning services, supporting services, cultural services, and regulating services. This report highlights specifically the cultural and regulating ecosystem services.

Cultural ecosystem services allowed us to show value for things which may come from a person's experience or preference instead of a dollar value. Cultural services include the non-material benefits people obtain from contact with ecosystems which can be aesthetic, spiritual and psychological benefits. Some aspects of cultural ecosystem services that were done include value mapping (Figure 21), where a map of each zone was separated into smaller zones A-H and everyone in the group was asked to give a value from 0-5 based on the experience dimensions: diversity/species richness, aesthetics, social cohesion, wilderness/nature, and cultural significance. These values were then added together and calculated an average to see the areas that were valued the most in each experience dimension.

Regulating ecosystem services are evaluated to show the benefits that can be provided by having trees within our zone. Regulating services are the services that ecosystems provide by regulating the quality of air and soil or providing flood and disease control (TEEB, 2011). This includes things such as air pollution removal, carbon sequestration, carbon storage, water regulation and climate regulation. All of these aspects are important to consider when planning for the future of the zone and areas that can make the overall health of the trees better for longer and make vital plans for replacement. This is important to evaluate in order to see which areas your zone needs to improve upon and where it is strong. When creating an action plan, these evaluations can be very helpful.

This report also serves as additional information for future students, SEEDS, and Campus + Community Planning at UBC. Urban forest planning and management is an integral part of the growth process. In order to evaluate the intrinsic and inherent values, ecosystem services assessments need to be considered. It is our purpose to provide reflection and future forest management recommendations for the campus given the current status of our site.

3.0 Site Description

The site shown in the figure below is situated towards the northwest direction of the Vancouver campus along southwest Marine Drive and Main Mall. The area comprises of approximately 19,669.3 square meters of the land base, in which multiple buildings are located; these include the Auditorium Annex Offices, Old Auditorium, Old Administration Building, Frederic Lasserre Building, and the Music Building. Furthermore, this site houses a wide array of herbaceous plantations, and tree species of which include: Abies grandis, Acer palmatum, Betula pendula, Carpinus betulus 'Fastigiata', Chamaecyparis pisifera squarrosa group, Cupressus nootkatensis, Fraxinus, Liriodendron tulipifera, Pinus nigra, Platanus x hispanica, Prunus sato zakura group, Prunus yedonensis 'Akebono', Pyrus calleryana, Sorbus hupehensis 'Pink Pagoda', Styrax japonica, and Tilia americana. The key users and visitors of the site that are noted include: faculty members and employees of nearby schools (UBC School of Architecture and Landscape Architecture, School of Community and Regional Planning, and School of Music), campus administration, and more greatly, the students.

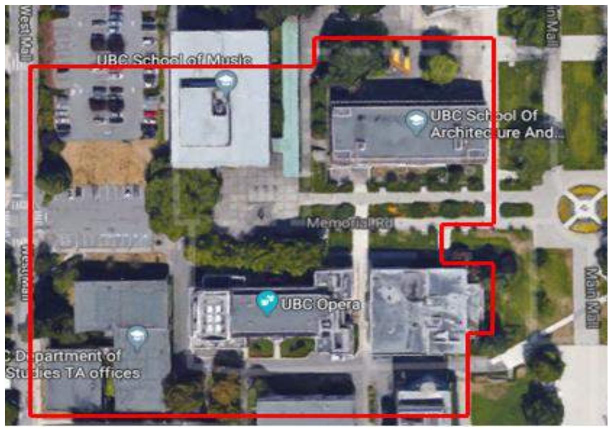

Figure A. Inventory Site, UBC, Vancouver, British Columbia. Photo taken from Google Maps

Located towards the southern direction of the site, by the University Transition Program Building, and in front of the Old Auditorium Building, is the First Tree Plaza (Figure 1.1). The plaza was established in remembrance of heritage trees that were situated along the site's northwest corner. Furthermore, the plaza plays a great role in being a place of quiet refuge and providing one with a sense of isolation that takes their mind away from the daily struggles of life; made possible because of mature Tilia americana trees that surround this specific area. In addition to the above, the fact that there are benches in the plaza gives people an opportunity to sit and relax.

Located conveniently to the east direction of the Music Building, and north direction of the Frederic Lasserre Building is this courtyard (Figure 1.2). The large deciduous tree to the left of the image has the scientific name Liriodendron tulipifera, and the set of seven coniferous trees by the building's front side have the scientific name Pinus nigra. Moreover, there are three trees with the scientific name Styrax japonica along the west side of the Lasserre Building. The main users of this area are students since there are stairs and benches on which people can seat themselves and socialize. Other users include visitors in general since the area acts as a shortcut towards Main Mall, which saves time spent on walking. The fact that this area is open-spaced makes this courtyard very great people for people to get together during lunch and perform activities such as skateboarding.

The sculpture shown is historically significant as it was a prize winner at the first Outdoor Sculpture show held at UBC. The prize-winning piece is located to the northeast direction of the UBC School of Architecture and Landscape Architecture (inside the Lasserre

Building), which is significant since the sculpture illustrates design elements that go hand-in-hand with architecture. The key feature of this sculpture is that it attracts the attention of people (especially students, but also tourists) from Main Mall as a result of being very visible, in which they further get attracted by the courtyard and go make a visit.

A group of three large Platanus x hispanica trees is seen to the northwest of the UBC Opera (Figure 1.3). These trees act as a gateway that separates the inner portion of the campus on the east from the parking lot on the west. The main users of this area are students who pass through in order to get to their next class; there are many classes in the vicinity as indicated by a huge combination of schools, buildings, and departments nearby. The students can also use this space for socialization as there are is a set of stairs for seating and therefore relaxation. A key feature to note is the wide tree canopy cover, which will help to control the urban heat island effect, especially since a large amount of pavement is existent, by providing shade.

The sculpture shown in the image above is found in the centre of the plaza, which is located in the center of the assessed site (Figure 1.4). The sculpture, having been donated by Alfred Blondell, is not only a cultural recognition but an attraction that catches the eyes of many people, whether it be students or visitors. The large ground area of the plaza makes the space ideal for many people to get together and socialize. Furthermore, there are Carpinus betulus 'Fastigiata' trees located in the plaza, at the face of the Old Auditorium, which not only help to boost the aesthetic appeal, but also help evoke feelings of refuge.

This area of the site is divided through the center by Memorial Road which creates a walkway for its users to travel between Main Mall, the plaza, and parking lot (Figure 1.5). Benches are located along the walkway of Memorial Road which allows for people to relax and socialize. Surrounding Memorial Road on each side is an alley of trees given the scientific name Prunus yedonensis. The vegetated line that stretches along the Memorial Road walkway plays a role in the infiltration of stormwater that goes downhill. The main users of this area are students, visitors, as well as tourists who simply pass through and/or come to admire the aesthetics, especially during the spring-time blooms.

4.0 Regulating ecosystem services

Methodology

There were two models used to assess and quantify the regulating ecosystem services in our zone; i-Tree Eco and i-Tree Canopy. In order to use i-Tree Eco, we had to upload our tree inventory data into the program. This allowed us to analyze the benefits and costs our inventory provides along with many other ecosystem services. There is also an option to forecast based on the tree inventory data that we collected. Using i-Tree Eco is reliable since it uses the exact data that we collected on our trees in order to provide an analysis on our site. A drawback to using i-Tree Eco was that some information was not available for some of our regulating ecosystem services (for example pollution removal) because either the amounts were too small or necessary information in order to value them were not available for our location.

To use i-Tree Canopy, you have to select your zone on a google map. Then you have to choose an area in the United States that would be similar to Vancouver (e.g. Washington), and then you proceed to plot random points within your zone. One must determine whether the point is 'tree' or 'non-tree' in order for i-Tree Canopy to calculate tree benefit estimates (for example: CO, NO2, O3, SO2). The more points that you plot on the map, the more accurate your percent cover and tree benefit estimates will be. The drawback to using i-Tree Canopy is that it doesn't calculate the statistics based on the tree inventory data like i-Tree Eco, instead it's estimated using random sampling based on what each point is classified as. There is a chance for human error with this method as well as the opportunity for different results if you perform this assessment multiple times.

Air Quality Regulation

In order to analyze pollution removal for our zone, I chose to compare the results from i-Tree Canopy and i-Tree Eco before deciding to use i-Tree Canopy. This gave a well informed and accurate analysis of the benefits our trees make to the environment as well as the structural values associated. For each model, a comparison was made for carbon monoxide (CO), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), and particulate matter less than 2.5 microns (PM2.5).

The i-Tree Canopy tree benefit report estimates using random sampling and the data below was based on 100 points within our zone. i-Tree Eco provides similar information based on our tree inventory data, but the provided a value of zero for some of the trees either because the information was not available in our area or the reported amounts were too small to consider. Another difference is that i-Tree Eco is able to provide this information for each tree in our inventory. The i-Tree Canopy provides better information for pollution removal, but it isn't 100% reliable either since it's dependent on the person choosing the plot points and the randomness of the plots selected. This is important information to acknowledge when doing a data analysis like this. The results below compare the tree benefits analysis between each model for pollution removal in our zone.

	i-Tree Canopy		**i-Tree Eco**	
	Value (CAD)	**Amount (oz/yr)**	**Value (CAD)**	**Amount (oz/yr)**
CO	$2.47	44.80	$0.03	0.80
NO2	$4.79	357.28	$0.04	93.60
O3	$259.88	2182.56	$0.87	294.70
SO2	$0.64	128.32	$0.01	43.90
PM2.5	$1,026.81	749.6	$0.73	6.80

Figure B: Tree Benefits Analysis between i-Tree Canopy and i-Tree Eco - Pollution Removal (Letticia Smyth, 2019)

Disease and Pest Regulation

The potential pest risk report on susceptibility to pests by stratum according to i-Tree Eco, presented results for 36 pests and diseases. The structural value and leaf area are also estimated based on the number of trees that we have indicated through our tree inventory (i-Tree Eco, 2019). The susceptibility report from i-Tree Eco calculates the damage that a potential outbreak could have based on species diversity in our tree inventory. The number of susceptible trees reflects only the trees within our inventory that could experience mortality due to pests and no other species that may be present in the area (i-Tree Eco, 2019). Since the report shows the total number of trees susceptible to pests and disease and not the species directly affected by each type of pest or disease, we can only speculate the repercussions of this data should any of the trees become susceptible.

Out of all of the trees in our zone, 16 are susceptible to pests including: western spruce budworm, winter moth, sirex wood wasp, southern pine beetle, pine shoot beetle, large aspen tortrix, gypsy moth, fir engraver, emerald ash borer, dogwood anthracnose, balsam woolly adelgid, and Asian long-horned beetle (i-Tree Eco, 2019). The structural value of the trees that are susceptible to pests is $92,637(i-Tree Eco, 2019). The leaf area percentage of trees susceptible to pests is 35.1% (i-Tree Eco, 2019).

Climate Regulation

Climate change is one of the biggest threats our planet is facing. Due to human development, there has been an increase in levels in atmospheric carbon, contributing to climate change. Urban forests are vital components of the ecosystem as they play an important role in mitigating climate change. Trees are vital as they can function not only as a sink through carbon fixation during photosynthesis, but also as a storage for carbon, in the form of biomass (Nowak et al., 2001)

Carbon Sequestration

Urban trees are able to sequester atmospheric carbon in their tissues as they grow, influencing various processes (i.e. building energy use), and altering carbon emissions from their source (Greenfield et al., 2014). Integrating the data of all the 50 trees in i-Tree Eco, the gross carbon sequestration is estimated to be about 1096 pounds of carbon per year. This gross annual amount is associated with a value of Can $57.2 (i-Tree Eco, 2019). The carbon sequestered can be visualized in a different manner as this value is equivalent to about 179 gallons of diesel consumed, about 2,000 pounds of coal burned, or 0.318 homes' electricity use for one year (Environmental Protection Agency, 2019).

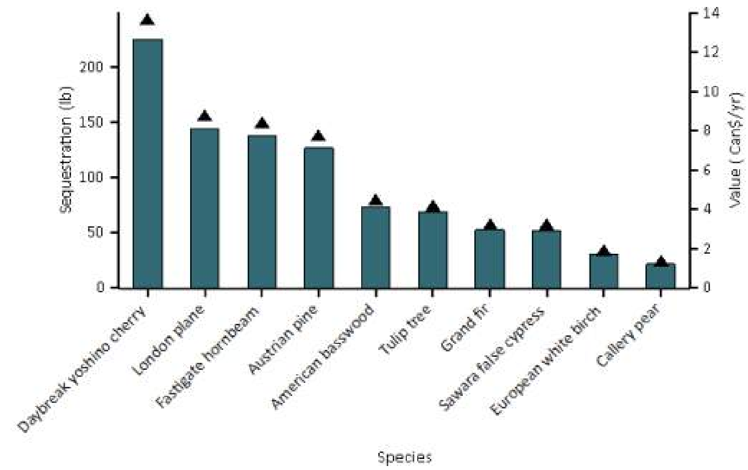

Figure C: Estimated Carbon Sequestered and Values of Urban Tree Species(i-Tee Eco, 2019)

Based on the data generated by i-Tree Eco, the top species that sequesters carbon are Daybreak yoshino cherry, London plane, and Fastigate hornbeam. Daybreak yoshino cherry, being the top tree species, sequestering about 250 pounds of carbon, takes about 28% of the population of the trees, dominating the urban forest of the site with the highest number of trees. The second top tree species with the greatest sequestration is London Plane. Even though there are only 3 London planes in the site, they sequester a high amount of carbon as they are one of the most mature trees in the site (i-Tree Eco, 2019).

Carbon Storage

Another way urban forest can mitigate climate change is through storing carbon within its accumulated tissue. About 19.3 tons of carbon is stored by all 50 trees located in the zone (i-Tree Eco, 2019). This value is equivalent to an annual carbon emission from 6-single family homes, CO2 emissions from about 8.2 million cellphones charged, or annual carbon emissions from 14 automobiles (3). The amount of carbon stored increases as the trees get mature and grow.

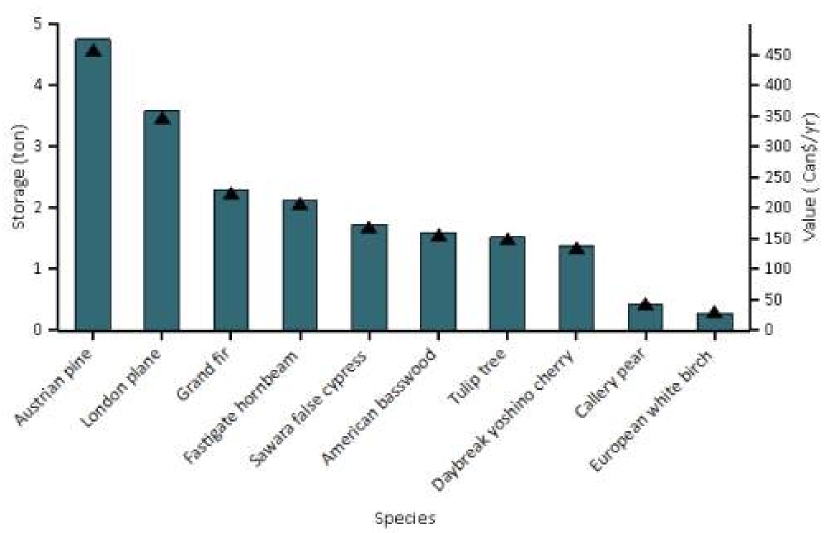

Figure D: Estimated Carbon Storage and Values of Urban Tree Species (i-Tee Eco, 2019)

The analysis of the urban forest of the zone through i-Tree Eco revealed that Austrian pine stores 23.6% of the total carbon stored, being the top greatest species for carbon storage. Austrian pines take about 14% of the population of the trees in the site, with 7 fully mature trees. The single Grand fir in the zone on the other hand, stores about 2.4tons of carbon, which is about 3.5x more than a single Austrian Pine (i-Tree Eco, 2019). The Grand fir in the site, referred to as the "Goliath" is the biggest tree located in the zone.

Both sequestration and storage of carbon increases as the tree develop and grows, however, a significant factor that can affect these regulating services is maintenance. The carbon that is stored, can be released when a tree dies and decomposes. Maintenance of the trees is the key to keep the trees in good condition, further increasing the benefit we get from urban trees and mitigating climate change impacts.

Water Regulation

Another regulating services we benefit from urban trees is through regulation of water as they affect the various aspects of water such as movement, quantity, and quality. Urban trees, vegetation and shrubs have the capacity to control floods, water flow and the variability of water. They reduce surface runoff through infiltration and storage within their roots, intercepting rain (BISE, 2019). In addition to this, they are also capable of treating and purifying, absorbing toxic substances from water (BISE, 2019).

The site is estimated to reduce runoff, by about 2.27 thousand cubic feet per year, in association to the total annual precipitation in 2010 of 46.4 inches (i-Tree Eco, 2019). All three of the London planes located in the zone, has the highest total avoided runoff of about 440 cubic feet (i-Tree Eco, 2019). The surface runoff avoided can be increased through adding more permeable surfaces by increasing number of healthy trees, maintaining vegetation along the zone, and proper management.

5.0 Cultural Ecosystem Services

Sub-Zone 2A: The Reverie Precinct

Aesthetics and Architectural Design:

We cannot analyze the cultural services provided by this area without diving into its history, design, and architecture. The two meters recessed courtyard has a mid-century modern design that follows the surrounding buildings' 1960's design, under the principle of grid forms and straight simple lines. The upward verticality of this grade of tall Pinus nigra contrasts the background of low-rise horizontal buildings (Figure 1) with simple linear façade grids of intersecting perpendicular frames. The same can be said to the red oak and the two tulip trees, as they all share a vertical lofty outline rather than widely spread apart branches which redirects your vision upwards, towards the sky (Figure 1). You can't help but notice that the trees' location and species were carefully integrated into the design and concept and are an integral part of the overall composition of the sunken courtyard. This reveals just how much the landscaping and architecture are interrelated, interdependent, and complementary in their pursuit to establish a specific prevailing theme for this entire site on which they both harmoniously coexist.

<u>Theme and Prevailing Ambience :</u>

The recession of the courtyard establishes a sense of privacy, where one can escape the traffic and noise of main mall, crescent road, and the parking and seek refuge in this platform which is semi-isolated but connected; as it is easily accessible from all directions, and open but enclosed within its surrounding buildings (Figure 2). This creates the perfect ambience for visitors to submerge themselves within the calmness and serenity created by the grade of pines, garden beds, and fence of trees behind the benches. This courtyard contributes great values and benefits for experiences of relaxation and peace of mind.

Sub-Zone 2B: A Structured Wilderness

<u>Aesthetics and Design:</u>

Diverse and multicultural species were chosen to form the grid of cherry blossom trees on both sides of the pedestrian and cyclists; lanes, the bushes and plants of the central rain garden/swale, and the Virginia creepers decorating the walls of the raised garden beds of Japanese snowbell. This area is garnished with various colors at different seasons throughout the year, as the cherries blossom in pink welcoming spring, the rain garden showcases degradations of green and yellow bushes during summer, and the Virginia creepers dress the walls in red during the fall (Figure 3, 4).

<u>Theme and Prevailing Ambience:</u>

The diversity of species and colors and the organized linear grid that the lanes, trees, rain garden, and raised garden beds follow, all together create a structured wilderness that visitors can enjoy all year long. It is constantly changing the ambience by adding and removing natural elements throughout the continuous seasonal cycle. Visitors can meditate towards the direct end view of “Tuning Fork” sculpture and the outline of douglas fir (Pseudotsuga menziesii) in the distant background of the Nitobe Memorial garden from one end (Figure 5), and W. Robert Wyman plaza on the other end.

Sub-Zone 2C: UBC’s Art Piazza

<u>Aesthetics and Design:</u>

This open piazza is designed for fine arts students enrolled in music, art, architecture, and theater. It is centered with a sculpture named “Tuning Fork” (Figure 6). The sculpture’s two upright complementary elements symbolize the deep interconnections between the various arts disciplines. Its vertical linearity also accompanies the trees and contrasts the horizontal buildings in the background. This arts piazza intersects sub-zone 2A through the walkway covered passage, allowing the flow of design and similar grid principles of the 1960’s from one courtyard to the other. The piazza is a meeting hub for the students from different faculties and hosts various social gatherings and interactive events. Even though it is encircled by rows of trees and memorial road, the piazza’s floor is dominated by grey concrete slabs and lacks green cover.

Theme and Prevailing Ambience:

The row of hornbeam trees acts as a green barrier to hide the concrete opera building and offer a natural view surrounding the sculpture. Memorial road from one side offers a variance of colors and London plane (Platanus x hispanica) on the opposite side hide the recessed parking and orients the view towards the outline of the Nitobe Memorial garden in the far end (Figure 5). This offers the piazza a variation of natural views from all directions and creates the perfect ambience for art and nature admiration. The benches offer resting stops and encourage sitting and meditation, however you still feel a bit distant from nature as it surrounds you but is not integrated within the piazza itself.

Sub-Zone 2H: First Tree Plaza

Aesthetics and Design:

The primary reason for this plaza to rank aesthetically the lowest, is perhaps due to its location behind and in between the back alleys of the surrounding buildings. It is accessible from four directions through the back lanes of the buildings. Such prominent trees should have been hosted in an attractive landmark site, open and clearly viewable from all directions. As one of the oldest sites on the current UBC campus, this area deserves more attention and the honorable treatment as a historical site.

Theme and Prevailing Ambience:

The plaza is clearly smothered by close concrete buildings, and no special importance is given to its trees. Although students pass by every day, the majority fail to notice the historical values behind the trees, as they are not highlighted in an eye-catching manner. The garbage bins are located right at the edge of the plaza, and beside their repelling smell, they distract your view away from the trees from all directions (Figure 7). The plates engraved with the age of the trees are small, located below our eyesight, and covered up by soil most of the times (Figure 8). In addition to that, linden attracts a lot of aphids throughout their growing season, and the aphids excrete sticky liquid, which makes the floor and benches underneath sticky and slippery. In fact, the concrete panels of the plaza are a bit stained from it and darker in color. All these factors render the plaza inhospitable and unencouraging for sedentary and socializing activities.

Connectivity

One can access the West Mall by one of two paths from the Main Mall: Memorial Road or the courtyard between the Frederic Lasserre Building and the Belkin Art Gallery. Both paths are connected with the covered walkway hosting the art installation (Figure 9), and eventually merge at UBC's Art Piazza in between the School of Music building and the Old Auditorium of the UBC Opera, which houses another art installation (Figure 6).

At the bottom of the wide staircase west of the Art Piazza, three large London plane trees (Platanus x hispanica) spread their long, twisty limbs to welcome people who are going up the stairs and seeing off those coming down the stairs (Figure 10). The area in front of the stairs is occupied by a parking lot, however, there are young trees growing slowly into large ones along the walk path in front of the University Transition Program Building, which guides pedestrians to the West Mall. This walk path has a garden feature at the corner just before it reaches the West Mall. There are shrubs (Pinus mugo and others) and well manicured flower beds at this corner, and this collection of vegetation buffers the busy feeling of the road (Figure 11). It is a small feature, yet very effective as a green barrier. Together the paper birch (Betula papyrifera) and Japanese maple (Acer palmatum) at this corner, form a tunnel of shade and exhibit beautiful colour with their fine leaves and beautifully contorted trunks. At this point, the pathway meets the shadow of 'the Goliath,' our largest tree, a grand fir (Abies grandis) which stands welcoming right next to the University Transition Program Building (Figure 12). Regardless of its confined location, this tree exhibits a strong life force with scars that tell the history of its survival and limbs that stretch out like arms ready to embrace.

Green Vista

Memorial Road received a major facelift in 2013, transforming it from a regular paved road with parking spaces into a beautiful walk path equipped with benches, a rain garden, and rows of cherry blossom trees. (Figure 3, 13, 14, 15) Remarkably, pedestrians' views are occupied by a green vista to both the east and west of Memorial Road: large trees at either end create thick walls of green in the growing season. In the fall, deciduous and herbaceous foliage in this location present a wide variety of colours, contrasted against the dark green of the coniferous foliage in the background. In the winter, the awe-inspiring silhouette of the deciduous trees with sparkling raindrops instead of foliage entertain viewers' eyes, promising the spring season will come again.

6.0 Urban Forest Planning and Management Recommendations

The garden bed on the east side of the School of Music Building has multiple mature rhododendron. They are all overgrown in their location, branches are brushing against the building wall and the walking path, and the area is filled with garbage. This garden bed can be well revitalized when smaller, shade tolerant species, such as Hosta, Astilbe, Euphobia, Hellebores, Sword ferns, small shrubs such as Choisya, Skimmia, and Pieris fill this site, with a colourful display of flowers and foliage throughout the year.

Regulating Recommendations

Goal:	Climate change adaptation
Objective:	Increase green space coverage and diversity while decreasing hardscape coverage
Strategy 1:	Resilience through biodiversity
Strategy 2:	Temperature reduction through removal of air pollutants
Strategy 3:	Maximize carbon storage and sequestration
Strategy 4:	Reduce VOC emissions from vehicles
Action Plan:	Increase canopy cover by 10% in 5 years, plant 3 giant sequoia trees in 5 years on the north side of the parking lot (west edge of our zone)

After completing the regulating services assessment, some important factors to consider is that most of these ecosystem services come from the large species that are present on our zone. This includes the 7 Pinus nigra, the 3 London plane, the Abies grandis, and the Sawara false cypress. In order to ensure there is no great loss of ecosystem service benefits, it will be important to plan for how to replace them including how many trees, what species, and when to begin planting them. The action plan above was made to take these concerns into consideration.

Cultural Recommendations

Sub-Zone 2A

This courtyard has much more potential to be harnessed. Although the grade of pines grants esthetic and spiritual functions to the courtyard, it is not utilized as much as it should. Inspired by the grade of red maple (Acer rubrum) in front of the Nest building (Figure 16), were students enjoy lying down under the sun, having a picnic, and hosting various events, we hope to convey similar recreational activities in our courtyard. To make it more inviting and hospitable, the prevailing irish ivy (Hedera hibernica) needs to be removed and grass planted to cover up the entire hill. This will provide more green spaces and opportunities to immerse within nature and underneath the pine canopy and attract more visitors to this area (Figure 17). The tulip tree is raised into garden beds, by simply raising the edges and installing wooden benches on top, more inviting spaces for socializing and resting are gained. We also recommend reinstalling the "Cumbria" sculpture (Figure 18), as it further adds vibrance and artistic perspectives to the courtyard.

Sub-Zone 2C

Increasing the green cover within the piazza itself will integrate it more with its surrounding nature, render it further hospitable, offer more permeable surfaces and provide shaded areas. We recommend substituting some of the panels with soil beds and planting more trees to create a direct link between social activities and green spaces (Figure 19).

Sub-Zone 2H

Our primary target for this plaza is restoring the historical and cultural prominence of UBC's first trees. We noticed that our site hosts four different sculptures (Figure 20). Touring around our site, visitors will experience similar and complementary spiritual experiences as they follow along the 1960's ambience and come across the artworks at different locations, which enhances connectivity and linkage among our sub-zones. However, when they reach the tree plaza, they find themselves in an alley and the sensation of art and nature admiration starts to fade away. It is important to sustain the same course of experiences throughout the tree plaza as well. Installing a fifth sculpture in the plaza as a representation of the age and prominence of these trees will liberate them from their concrete surroundings and highlight their values. Art can not only invite more visitors to the plaza, but also honor UBC's oldest remains.

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8.0 Appendix

Figure 1. Courtyard in front of Lasserre building, UBC. March 11,

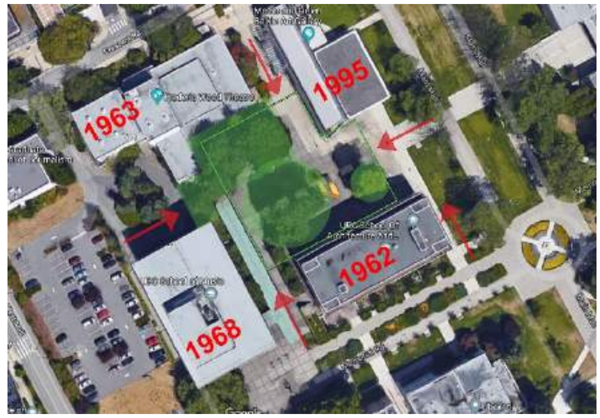


Figure 2. Retrieved from Google Maps, 2019. Edited by Nour Dalati.2019. Photo taken and edited by Nour Dalati.

Figure 3. Memorial road, post-renovation, UBC. Photo retrieved from Wikimedia commons https://commons.m.wikimedia.org/wiki/File:Memorial_Road_UBC.jpg

Figure 4. Memorial road, UBC . April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 5. Memorial Road, UBC. March 13, 2019. Photo taken and edited by Nour Dalati.

Figure 6. The "Tuning Fork" by Gerhard Class, 1968, in front of the Music Building, UBC. UBC Archives photo #1.1/15764. Retrieved from https://www.library.ubc.ca/archives/sculptures/sculptures1.html

Figure 7. First Tree Plaza, UBC. March 11, 2019. Photo taken by Nour Dalati.

Figure 8. First Tree Plaza, UBC. March 11, 2019. Photo taken by Nour Dalati.

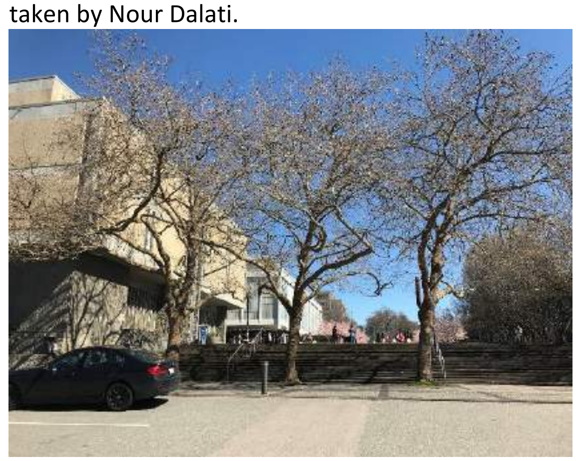


Figure 9. 'Asiatic Head' by Otto Fischer-Credo, 1958/replica by Gerhard Class, 1977, at the north end of the walkway, UBC. April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 10. London plane, staircase and parking lot, UBC. April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 11. Small green barrier at Memorial Rd. and West Mall, UBC. April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 12. "Grand Fir" West mall, UBC. March 13, 2019. Photo taken by Yoshinori Tanaka.

Figure 13. Memorial Road, pre-renovation. Photo retrieved from https://pricetags.ca/tag/ubc/page/4/

Figure 14. Memorial Road, post-renovation. Photo retrieved from Wikimedia Commons https://commons.m.wikimedia.org/wiki/File:Memorial_Road_UBC.jpg

Figure 15. Memorial Road, post-renovation, the rain garden. Photo retrieved from UBC Campus + Community Planning https://planning.ubc.ca/vancouver/news-events/newsletter/2013-10-18/turning-rainfall-resource

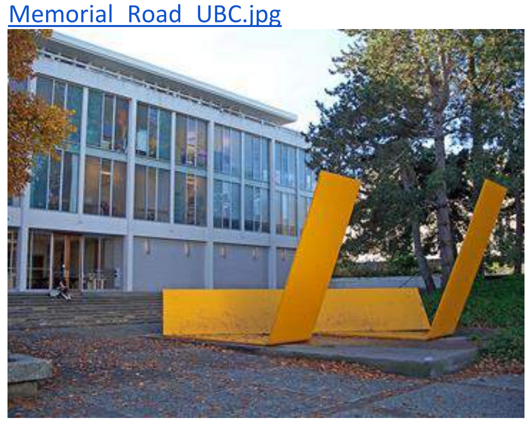


Figure 18. “Cumbria”, In front of Lasserre Building, UBC. Retrieved from http://thetalon.ca/wp-content/uploads/2014/10/1737504296_d5a55cd5f3_z.jpg

Figure 16: Maple Grade in front of Nest, UBC. March 29, 2019. Taken and edited by Nour Dalati.

Figure 17: Pine Grade in front of Lasserre building, UBC. March 11, 2019. Taken and edited by Nour Dalati.

Figure 19. The Arts Plaza, UBC. April 1, 2019. Photo taken by Yoshinori Tanaka, edited by Nour Dalati.

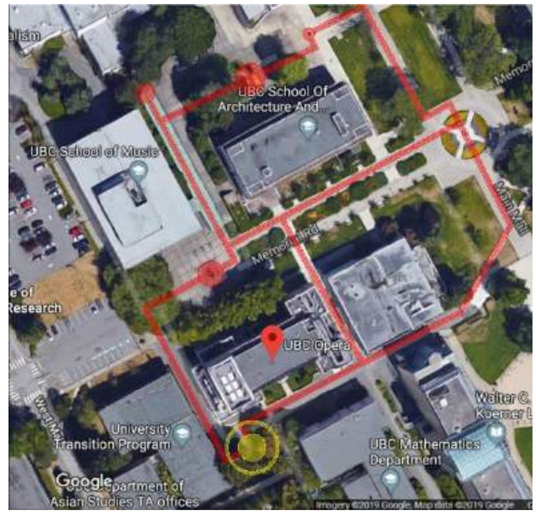


Figure 20. Retrieved from Google Maps, 2019. Edited by Nour Dalati.

Value Mapping

Stars indicates highest average value point among our group members, relative to other elements.

Diversity

Aesthetics

Social Cohesion

Cultural Significance

Not strong in any values (average point <2.0)

Figure 21. Retrieved from Google Maps, 2019. Edited by Yoshinori Tanaka

Figure 1.1. First Tree Plaza, UBC, Vancouver, British Columbia. February 6, 2019. Photo taken by Raphael Mendoza

Figure 1.2. Courtyard next to the Frederic Lasserre Building, UBC, Vancouver, British Columbia. April 2, 2019. Photo taken by Dilraj Thind

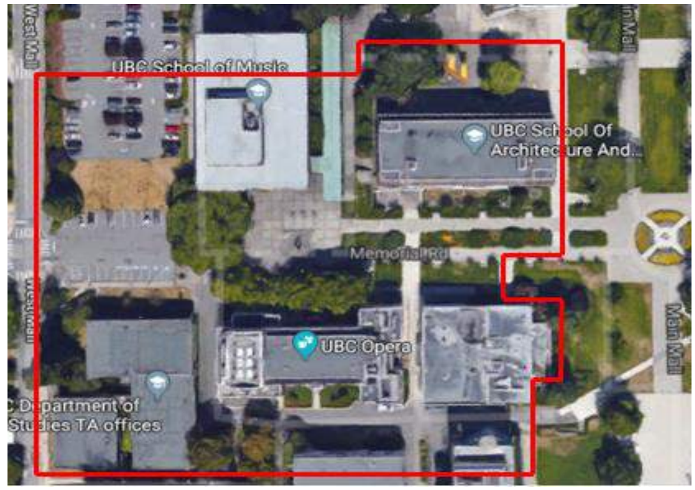
Figure 1.3. Courtyard next to the Frederic Lasserre Building, UBC, Vancouver, British Columbia. April 2, 2019. Photo taken by Dilraj Thind

Figure 1.4. A set of mature trees near the front of UBC Opera, UBC, Vancouver, British Columbia. April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 1.5. The “Tuning Fork” Sculpture in front of the Music Building, UBC, Vancouver, British Columbia. April 1, 2019. Photo taken by Yoshinori Tanaka.

Figure 1.6. Memorial Road, UBC, Vancouver, British Columbia. April 1, 2019. Photo taken by Yoshinori Tanaka.

Photo taken by Yoshinori Tanaka



Inventory Site, UBC, Vancouver, British Columbia.
Photo taken from Google Maps

Assignment 1:
Urban Forest Inventory and Assessment
UBC Winter Term 2

Group 2 | UFOR 101 | February 10, 2019

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1.0 Group Contribution Description

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- Group leader
- Excel file tabulation and management
- Data analysis
- Summary of tree inventory data
- Formatting and grammatical review

Nour Dalati - 86255361

- Introduction
- Methodology
- Data analysis
- Summary of tree inventory data

Dilraj Thind - 77843482

- Site description

Raphael Mendoza - 57773533

- Site description
- Photography

Matteus Yep - 20967659

- Introduction
- Methodology

Yoshinori Tanaka - 88029608

- Points of interest within Summary of tree inventory data
- Photography

2.0 Introduction

The tree inventories created by UFOR 101 students, will act as a database of the trees located on the UBC campus. The tree inventories serve various purposes vital for the maintenance and growth of the urban forest of UBC. Developing an urban forest management plan for UBC Vancouver campus, requires an understanding of the current urban forest coverage, existing trees' locations, species, and health, to better asses, maintain, and enhance the current urban forest. The fundamental basics of such study is found in the data collected in the tree inventories. Whether through maintenance schedules for pruning, assessing the health and determining needs for removal and tree replacement, or pest and disease control, tree inventories act as an asset to the management of all trees on campus. The tree inventories also serve as a platform to enhance current management policies, implement stronger strategies, and encourage more sustainable practices that allow urban forest management to meet UBC's sustainability goals. The inventories are the building blocks for visualizing the ecosystem services provided by the urban forest and assessing the potential services it is capable of providing in the future.

The end users of the inventory come from a wide spectrum of disciplines. Authorities such as municipalities can benefit from the tree inventories by comparing the urban forest of UBC to other surrounding cities, and assessing budgets, hazard prevention, and possible future policies and plans. Researchers and academics like NGOs, professors, and students, can use the data from the inventories to study and conduct advanced research into various disciplines such as quantifying and qualifying ecosystem services and socio-economic dynamics. Citizens also benefit from such inventories as they become more involved in the management of the urban forest of the shared UBC community and aware of the various services valuable to their health and well being.

Through our tree inventory and report, we aim to contribute to the establishment of such a prominent database that will act as the premises for our second assignment, and hopefully for future sustainable development projects in the UBC community.

3.0 Site Description

The selected site is located on the northwest portion of the Vancouver campus along SW Marine drive and Main Mall. It encompasses about 19669.3 square meters of land where various buildings are located. The main land use of the selected site is for institutional and park purposes, mainly for students and university employees. The main buildings within the scope of the site includes the Frederic Lassere Building, Music Building, Auditorium Annex Offices, Old Auditorium and old Administration building. The main users of the site are students, employees and faculty members of UBC School of Architecture and Landscape Architecture, School of Music, School of Community and Regional Planning, and Campus Administration. In addition to this, the site is covered by herbaceous plantations and an array of tree species including Platanus hispanica, Pinus nigra, Tilia americana, Prunus yedonensis 'Akebono' and Carpinus betulus 'Fastigiata'.

Figure 1. Memorial Road, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

The site is divided in the middle by Memorial Road, creating a walkway through the Plaza and parking area. Memorial road is surrounded by an alley of Akebono Cherry trees, sitting area, and vegetation swales located in the middle of Memorial Road for stormwater runoff infiltration as it is a downhill slope. The swales act as infiltration basins, as well as visual and aesthetics purposes. The formally planted Prunus yedonensis 'Akebono or Akebono Cherry trees creates movement leading to the Plaza. In addition, benches and a seating area are located along the walkway of Memorial Road.

Figure 2. The "Tuning Fork" Sculpture in front of the Music Building UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

The Plaza, the center of the site, provides an open space where not only students can sit down, interact with each other, and a space of refuge, but also a great place for campus visitors to see. The plaza also provides an entry to the site where all the street meets as well as the parking lot. The "Tuning Fork" sculpture is located in the middle of the plaza. The sculpture, donated by Alfred Blondell, provides a cultural tribute to the artist and UBC School of Music. Along the borders of the plaza are formally planted deciduous Caprinus betulus 'Fastigiate', also known as European Hornbeams, overlooking the windows of the Old Auditorium (University of British Columbia, 2019).

South of the site, in front of the Old Auditorium, adjacent to the University Transition Program Building, is the First Tree Plaza. The plaza was made in remembrance and commemoration of the heritage trees that were located along the northwest corner of the site. The plaza has provided a space for relaxation with the benches located in the plaza, and a sort of isolation or place of refuge as the plaza is surrounded by mature Tilia americana trees.

Figure 3. Courtyard next to the Frederic Lasserre Building, UBC, Vancouver, British Columbia. February 6, 2019. Photo taken by Raphael Mendoza

This courtyard is conveniently located to the north of the Lasserre Building, and east of the Music Building. The area is a great place for individuals to socialize as there are benches in the vicinity, as well as stairs on which people can seat. The open space has been witnessed to be an ideal spot for students gathering during lunch or performing pastime activities such as skateboarding. A lot of visitors are also seen to pass through the area since it allows for easier access to Main Mall - a shortcut that saves walking time. The courtyard also is a motivating factor for students who are studying art or design in either the school of architecture or music, or the art gallery; all three buildings are located closely across each other. The large surface area and square footage of the courtyard allow for an inspiring view when looking outside the windows, while the trees can filter out excessive sunshine to help keep the building cool and lower air conditioning costs in the summer months. The large tree seen in the image has the scientific name Liriodendron tulipifera. Towards the right (not shown in image) were a set of seven trees given the scientific name Pinus nigra. Along the west side of the Lasserre Building (also not shown in image) were three trees with the name Styrax japonica.

Figure 4. A set of mature trees near the front of UBC Opera, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

Towards the northwest direction of the UBC Opera is a set of three large trees given the scientific name Platanus x hispanica. The role that these trees play is that they act as a gateway leading towards the interior portion of the campus; isolating the parking lot on the west side from the inside part of the campus on the east. The stairs are a place of choice for people to socialize during the times of sunshine in the warmer months, in which the wide tree canopy cover plays a key role in providing a cooling effect via shade. In greater terms, the trees are also very beneficial in controlling the urban heat island effect. This is because the shade, again, provided by the large canopy would prevent the concrete from heating up which is witnessed around much of the surrounding. This area is known for its higher level of traffic also because of students walking to their next class; which could include a wide range of buildings since there are many schools and departments in the vicinity.

The walkway shown above is a structure that can lead individuals from the set of mature trees by the UBC Opera (shown in figure 4) to the courtyard that is north of the Lasserre Building and to the east of the Music Building (shown in figure 3). A walk through this walkway feels like a haven that evokes feelings of peace and tranquility; this is since it is very quiet, roofed, and free from a large crowd. Furthermore, the plants and shrubs immediately along one side of the walkway are also significant as they take the individual's attention away from everyday struggles and causes them to de-stress and improve focus once again. In addition to this area being a great place for students to de-stress and restore focus, the walkway has also been a very popular place for art students to rehearse acting or practice photography/filming. Nonetheless, tourists have also been witnessed walking through this space. Something to note is that individuals might also pass through this walkway as it can provide shade from intense sunlight and shelter from rain, since it is, again, roofed.

4.0 Methodology

Our group conducted a traditional ground-based field survey, where we measured and assessed all 50 trees located on our plot and from which we created our tree inventory. With the guidance of the Collector App, we established the borders of our zone. We began our work from the south corner behind the UBC Opera Building and covered our plot in an organized manner from one street to another until we reached the final destination behind the Lasserre Building. The first step was to match the tree on site with the same tree on the Collector App. We checked the tree tag on site and recorded the tree IDs found on the app. We determined the land use according to the i-Tree Eco categories and being located around UBC faculty buildings, all of our trees are categorized as institutional. We identified the species and genus from the Collector App. Using different measuring tools, we were able to measure various dimensions of the trees, such as the stem diameter at breast height (DBH) using the diameter tape, total tree height (TTH), living crown height (LCH) and crown base height (CBH) using the clinometer, and the crown width using the tape measure talley.

The DBH was measured at 1.37 m above the ground, and raised the measurement point enough to avoid swelling stems or branches in trees with irregularities. We came across two trees having more than one stem and applied the necessary adjustments to ensure proper measurement. The DBH of each of the multiple stems was measured and the average DBH was calculated.

The right side of the clinometer was used to estimate the percentage height. We measured the distance from the clinometer to the tree, recorded the percentage of the top and base of the tree, and calculated the total tree height by adding the two numbers then multiplying their sum by the distance. The crown base height was calculated using the percentage side of the clinometer as well, to record the percentage of the distance from the ground to the base of the live crown, and the distance from the base to the top of the live crown. We calculated the CBH by multiplying the sum of both percentages by the distance from the clinometer to the tree.

The percentage of crown missing was estimated based on observing the tree crown from at least two directions and visualizing the space missing between branches. Pictures from class lectures were used as a reference in making these estimates. The trees were observed in broad daylight where we assessed each side and the top for any areas where the trees would not be receiving sunlight. Some examples for sunlight blockage were from adjacent buildings or taller surrounding trees. The trees were then given a number from 0 to 5, indicating the crown light exposure (CLE).

To measure the crown width, we used the tape-measure talley to estimate the width of the crown on the longest side and then a perpendicular measurement. The crown width is calculated by the average of both sides, being their sum divided by two.

5.0 Summary of Tree Inventory Data

The summary of our tree inventory data starts with the abundance of species composition. We have a quarter of our trees that are individual species, so we have highlighted in Figure 5 all of the species with 3 or more trees and in Figure 6, the pie chart comprises of the single tree species that are present in our zone.

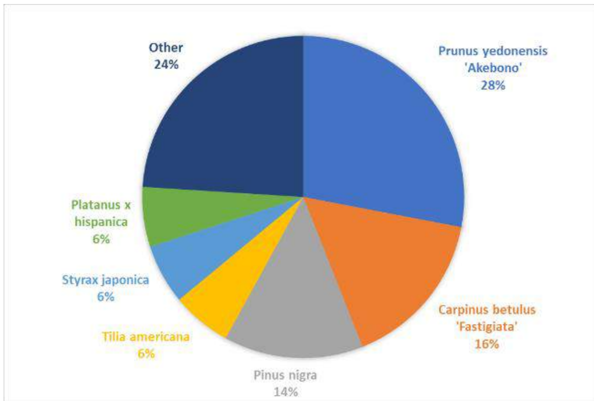

Figure 5. Composition of Species: Abundance. Species consisting of >2 trees in our zone.

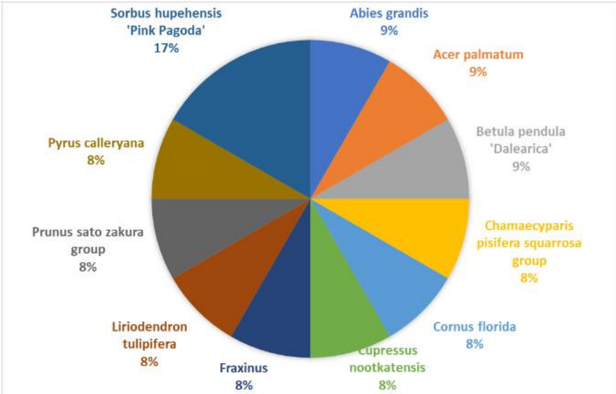

Figure 6: Composition of Species: Abundance. Trees that are included in the 'other' category.

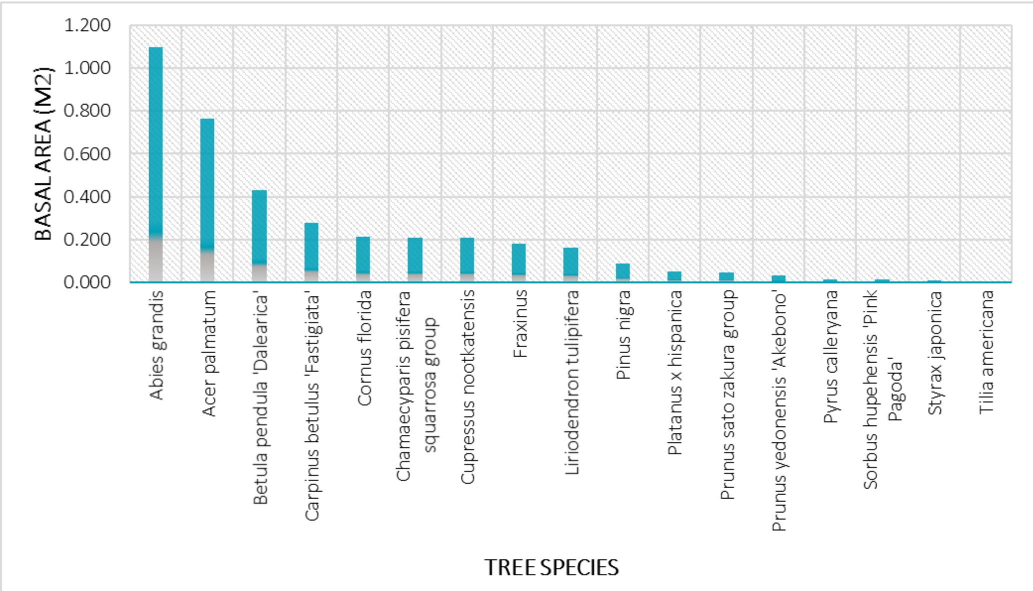

Figure 7: Composition of species that dominate our zone.

The figure above highlights that over 50% of our urban forest consists of three main species: Pinus nigra, Carpinus betulus 'Fastigiate', and Prunus yedonensis 'Akebona'. There was also a 20% dominance by the individual trees in our zone. This made for an interesting composition in our zone since there were multiple areas that had all the same species and then some areas that were comprised of individual trees of varying species.

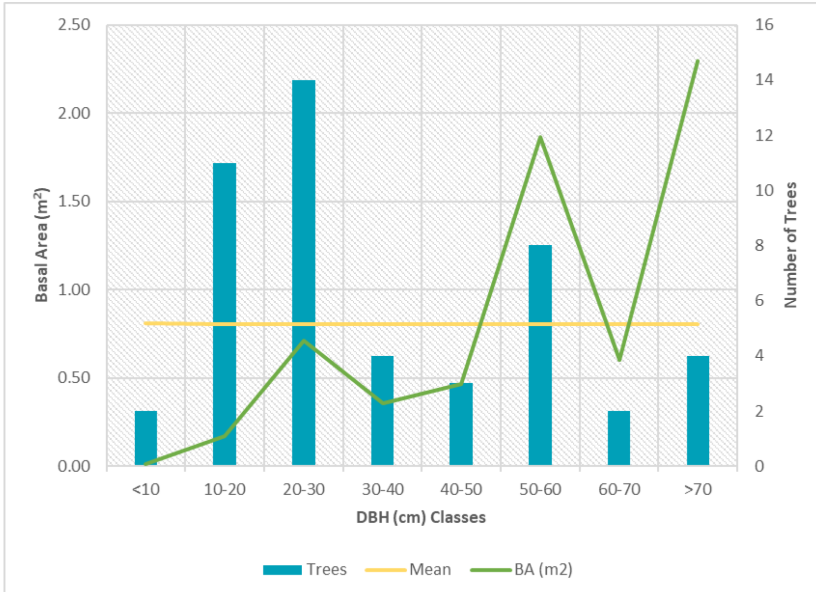

Figure 8. Urban Forest Structure. This graph shows the basal area coverage for the trees in each DBH class.

Figure 8 shows that the basal area was greater with the trees in the top DBH classes even though they only consisted of 8% of our total inventory. There is a large sample of trees that are in the 10-30 cm DBH classes which make up half of our total number of trees but have a basal area coverage less than the mean BA of .81 cm.

Figure 9. Urban Forest Structure: Total Tree Height.

Figure 9 represents to total tree height categorized by 6 different tree height classes. The tree heights in our zone range from 3.38 m to 28.51 m. The majority of our trees were within the 5-10 m tree height class which consisted of mostly Prunus yedonensis 'Akebono'. The least number of trees were within the >25 m class and were both Pinus nigra.

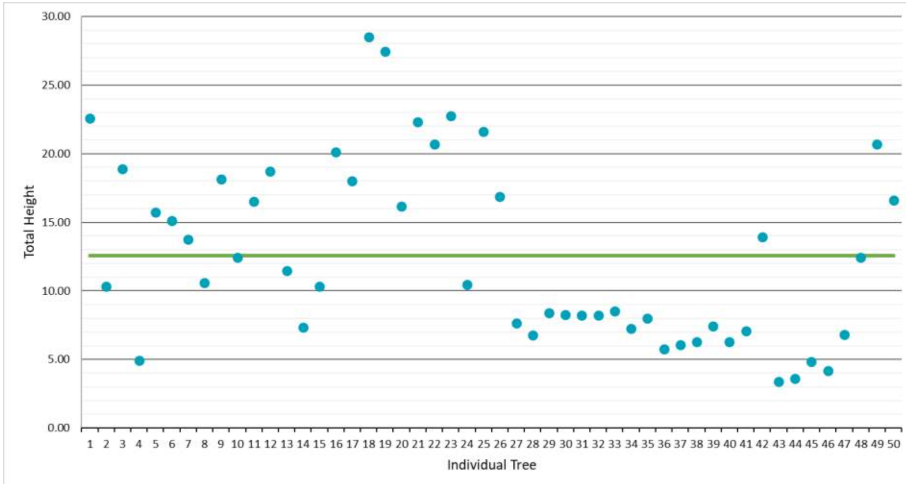

Figure 10. Urban Forest Structure: Individual Tree Height and Mean

In figure 10, the scatter graph represents the height of each tree within our zone organized by species (alphabetically). The green line demonstrates the mean height which is 12.56 m. This can either mean that most of our trees are young plantings or smaller species selections.

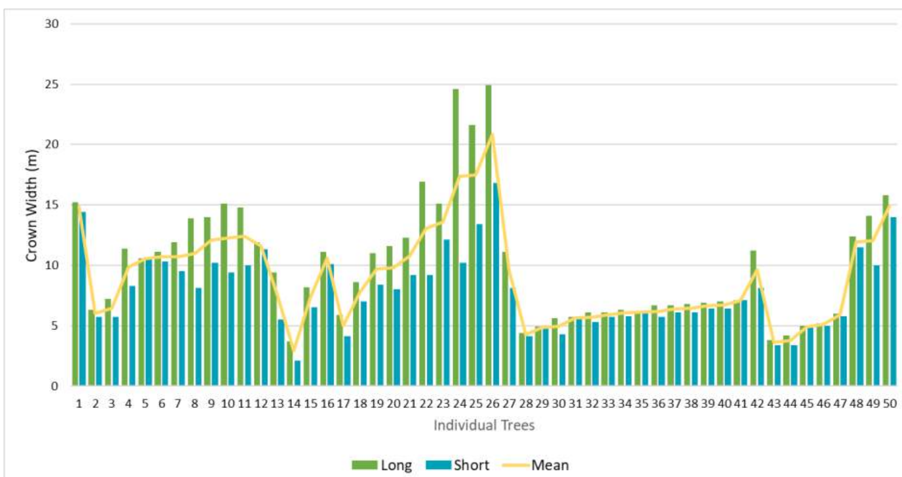

Figure 11. Urban Forest Structure: Crown Width.

The individual trees have been sorted in this graph by species to highlight the similar size of crown width within the same species as well as the variability from one species to the next.

5.1 Points of Interest

Group 2 had a great opportunity to perform the tree inventory on a site with remarkable points of interest. The elements described here are good examples of the cultural benefit which an urban forest provides us.

Firstly, in the courtyard behind the Geography Building, one can find a rock with a plaque commemorating UBC's First Tree Plaza: "The first in a row of Class Trees running south behind the Geography Building, this Large Leaf Linden, Tilia platyphyllos, was the University's first Class Tree. Initially planted at UBC's Fairview Slopes Campus by the Graduating Class of 1919, it was later moved to its current location when the UBC Campus was relocated to Point Grey in 1923." Since 1919, the graduation tree planting ceremony has been one of UBC's traditions, and some 8,000 trees have been planted (University of British Columbia, 2019). In the UBC Report from May 3rd, 2007, this Tree Plaza is highlighted in an interview with Professor E.P.Oberlander: "In the 60s and 70s this area was the place to think, meet and visit with fellow students and to enjoy the natural beauty of the campus." (Waugh, 2007) According to the article, this plaza was once taken over by dumpsters, and it was no longer utilized as a 'plaza.' The President's Advisory Committee on Campus Enhancement alongside with UBC Campus and Community Planning worked together to revitalize this area into a garden with benches and the commemorative plaque. (Waugh, 2007) The trees standing now are likely not the original trees planted in 1919; they look much younger. We found it significant that the graduation tree planting ceremony started exactly 100 years ago, and the site we surveyed includes the original location of the ceremony. This Tree Plaza has become, for sure, the place for thinking and visiting for the students of today.

Figure 12. The First Tree Plaza behind the Geography Building, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

Figure 13. The First Tree Plaza Commemoration Plaque behind the Geography Building, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

Secondly, there is an impressive stand of seven Pinus nigra in the courtyard surrounded by Morris and Helen Belkin Art Gallery, the School of Architecture Building and the School of Music Building. It is hard not to notice these large pine trees with their impressive form and height: some of them are close to 30m tall, and they are planted to form a group in the graded ground, which has an enhancing effect on the size of these trees as a whole. According to Egan Davis, Principal Instructor Horticultural Training Program at UBC, the planting design displayed here was a common trend in 1970's (Personal communication, 2019).

This landscape architecture was designed successfully with foresight of the future of these trees in this courtyard, which suites very well to its given space without posing any possibility of failure in the near future. Additionally, one of these Pinus has a heavy lean which shows the acrobatic 'bonsai' quality in a large scale. All of them are in good health and they seem to be contributing to the quietness of the courtyard.

Figure 14. Pinus nigra grove beside the Architecture Building, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

Figure 15. Pinus nigra grove beside the Architecture Building, UBC, Vancouver, British Columbia. February 4, 2019. Photo taken by Yoshinori Tanaka.

Lastly, an Abies grandis on West Mall, south of the intersection at Memorial Road stands out. David Tracey, the author of Vancouver Tree Book refers to this tree as 'Goliath' in his book. (Tracey, 2016) Indeed, it is a remarkable specimen. Despite the challenges to its growth and well-being, it stands gracefully with a grand height and form, full of foliage and strong life force. This Goliath marks near 21m in height, and it has a large trunk of near 120cm DBH. It is precious to see a tree this large in the urban setting; the contrast between the human infrastructure and the tree is visually impactful. Near the top of this tree, part of its trunk is exposed due to loss of branches, which adds great character to the tree. Compartmentalization, which is a defense mechanism against pathogens entry into the tree tissue (cambium, phloem and xylem), has successfully protected the part that survived. This trunk is visually scarred, however other parts of the same trunk are fully alive and functioning because of this defense mechanism. With trees, scars often add aesthetic beauty and the record their history. We admire their wisdom and resilience.

Figure 5. Abies grandis on West Mall at Memorial Road, UBC, Vancouver, British Columbia. February 8, 2019. Photo taken by Yoshinori Tanaka.

6.0 References

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University of British Columbia. (2019) *Graduation at UBC - Tree Planting Ceremony*. Retrieved from https://graduation.ubc.ca/event/about/tree-planting-ceremony/

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Waugh B. (2007) *Revitalized social space links campus to its grad roots.* UBC Reports (Vol.53 No.5 May 3, 2007). Retrieved from UBC News https://news.ubc.ca/2007/05/03/archive-ubcreports-2007-07may03-gradroots/

University of British Columbia

Ecosystem Services Assessment

Zone 3

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Dave Choi	Introduction Site description
Eric Wei	Cultural Services Site Observation Traffic Map

Introduction

The objective of *Assignment 2: Ecosystem Services Assessment* is to draw upon *Assignment 1: Inventory analysis,* and assess the provision of ecosystem services at Zone 3 on the UBC Vancouver campus. The intent of this report is to provide stakeholders such as UBC Campus + Community Planning and UBC SEEDS an overview, assessment and informed suggestions regarding the ecosystem services provided by Zone 3. A previous inventory was conducted by UBC in 1998 which surveyed over 11,000 trees. Seventy-one trees were inventoried in our assigned area. Being a main thoroughfare for student traffic, and being historically relevant, the ecosystem services provided by Zone 3 are essential at making this space on campus an effective institutional environment, a proper assessment of these ecosystem services is essential for preserving this environment. Currently, students, professors, tourists and alumni enjoy and actively use this space on campus. In the future, UBC Vancouver Campus + Community Planning will use the gathered information to guide management opportunities and plans (UBC SEEDS, 2018, p.6). Future management choices include tree maintenance, risk assessment, the removal of trees in poor health, and the plantation of new trees in areas which require more species diversity or more overall tree abundance.

Site Description - *See figures 1,2,3*

Zone 3 is a two hectare area located on the north west end of UBC Vancouver campus. This land is fully institutional because it is situated within the university campus. It is important to consider the fact that "UBC lies on the traditional, ancestral and unceded territory of the musqueam people" (UBC, 2017). Main mall and West mall, the two arterial roads in Zone 3 are connected by Agricultural Road that serves as a collector road. Agricultural Road is subject to heavy pedestrian traffic. Many students from Ponderosa and Place Vanier use Agricultural Road to get to the main arterial road for classes. The close proximity of the Math Building, Geography Building, and the Sauder School of Business drive a large population of users to utilize Agricultural Road. It is also common to see UBC utility vehicles pass through Zone 3 along with the pedestrians. This has caused issues with soil compaction along Agricultural Road *(See figure 4)*. Additionally, Zone 3 has many antiquated grey infrastructural with rich historical value.

Zone 3 is home to 16 tree species, with the most abundant species being: "Sawara Cypress" (Chamaecyparis Pisifera), the "Katsura" (Cercidiphyllum Japonicum), the "Autumn Brilliance" (Amelanchier grandiflora) and the "Japanese Crepe Myrtle" (Lagerstroemia fauriei).
Across the seventy trees inventoried, there was diversity of native and non native tree species which reflects the diverse socio demographic nature of UBC. This biodiversity is helpful to maintain a healthy ecosystem and to improve ecosystem services in the area. Additionally, there are six basswood trees and three oak trees planted for the legacy and honor of the past graduates of UBC. In Zone 3, the integration of open green space layout along with the infrastructure provides a rich urban forest impression of the campus.

Ecosystem Services Analysis

Regulating Services

I-Tree ECO Report Analysis

iTree Eco Methods of Model

Data retrieved from field work including tree species identification, DBH, total tree height, live crown height, crown base height, percent crown missing, and crown light exposure, was formatted in an Excel spreadsheet and then submitted to the iTree Eco software program. Through the standardized field data, the program was able to quantify the structure of the urban forest and its associated services including:

- "Urban forest structure (species composition, tree health, leaf area)
- amount of pollution removed hourly by the urban forest, and its associated percept 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." (iTree Ecosystem Analysis, 2019).

I. Tree Characteristics of Urban Forest

Biodiversity is an essential factor to measure urban forests health and resiliency. In this section, results in species abundance and DBH classes measured by I-Tree Eco will be analyzed to asses Zone Three's ecosystem conditions and resulting in regulating ecosystem services. For this section, i-Tree ECO created visualizations of Group Three's tree inventory data to highlight Diameter at breast height (DBH) classes, species composition, and species origin.

In Zone Three there is a total of 70 trees making up the urban forest composition in the zone. The urban forest in Zone Three is comprised of 70 total trees and 16 tree species. The most common tree species in the zone include Sawara False Cypress, making up 28.6% of the total tree population, and Apple Serviceberry and Katsura Tree that make-up 12.9% of the tree population each (*See figure 5*). According to I-tree ECO, these 17 species originate from all around the world, with 54% from Asia, 17% from North America, and only 4% from British Columbia, while the remaining 18% of tree species are of unknown origin (*See figure 6*). Diameter at breast height (DBH) in zone three varies widely. 34% of the 70 trees have a DBH under 6 inches (15.2 cm) which indicates that these trees are either quite young or the species in this class are traditionally small. 29% of these trees have a DBH in a range of 6-17 inches (15.24-43.18cm) and the majority, 37% of trees have a DBH larger than 18 inches (45.72 cm) (*See figure 7*). This results in 46 of the trees being in larger DBH class which indicates that these trees must be of an older, larger composition and structure. These results of species type, origin, and DBH indicate that there is some substantial biodiversity in Zone Threes urban forest, but there is slight domination in Sawara False Cypress, species from Asia, and larger DBH class. This indicates that tree selection is swayed towards larger trees, and since Sawara False Cypress originates from Japan, there is a slight preference of regional aesthetic in the area. The DBH class dominance could also indicate that the majority of trees in the zone were planted many years ago, giving time to DBH to become larger.

Tree diversity in regards to species type, species origin, and DBH ensures a resilient ecosystem that can enhance regulating services. Regulating services that can be improved through substainatal species diversity include moderation of extreme events and disease and pest regulation (Bank, 2010). Biodiversity can also increase cultural services such as aesthetic appeal through adding a "wildness" aspect in the diverse area.

II. Urban Forest Cover and Leaf Area

Vegetation cover in urban areas can be a good indicator of urban forest ecosystem services in urban areas. I-Tree ECO assesses leaf area and tree canopy cover by USING measurements of percent crown missing and crown dimensions input by users(i-Tree ECO, 2019, pg. 21). According to i-tree ECO, Zone Three has 37.41 thousand square feet of tree cover, which equals to approximately 32% canopy cover in the zone (i-Tree ECO, 2019, pg. 7)

Leaf area is a factor that contributes to overall ecosystem health due to the nutrients in leaves as well as their insulating properties and their ability to manage infiltration of rainwater into the soil (Taugourdeau et al, 2014). In Zone Three it is estimated that there are 3.836 acres of leaf area (i-Tree ECO, 2019, pg. 7). The dominant tree species contributing to leaf area are American Basswood, Sawara False Cypress, and English Oak *(See figure 8)*. It is worth noting that although some of these species may have low representation in tree population, they significantly contribute to leaf area in Zone Three. English Oak and American Basswood only make up 11.5% of the total species population of Zone Three, but these two species contribute to 45.3% of the total leaf area in the zone *(See figure 8).*

III. Air Pollution Removal by Urban Trees

Urban forests "reduce air temperature, directly removing pollutants from the air, and reduce energy consumption in buildings, which consequently reduce air pollutant emissions from the power sources" (iTree Eco, 2019). When not removed, air pollution leads to poor human health, damage to materials and equipment and ecosystem processes, and reduced visibility. For this measurement, iTree Eco collects data for ozone, sulfur, dioxide, nitrogen dioxide, carbon monoxide, and particulate matter that is less than 2.5 microns due to relevance towards human health. iTree Eco's estimates were determined by hourly tree-canopy resistance towards the pollutants stated above based on data collected from large leaf and multi-layer leaf canopy complexions well as leaf phenology and area. In terms of particulate matter that is 2.5 microns in size or smaller, there is possibility for this pollutant to either be released back into the atmosphere or removed during precipitation events. In the uncommon event where this resuspension occurs, an increase in atmospheric pollutant concentration will result.

Air pollution value is calculated by Vancouver's health effect incidence and median externality costs on the effects of the listed pollutants based on the U.S. Environmental Protection Agency's Environmental Benefits Mapping and Analysis Program. The program's damage function approach "is based on the local change in pollution concentration and population" (iTree Eco, 2019). This analysis uses the pollution removal vale of $1,348CAN per ton of carbon monoxide, $95CAN per ton of ozone, $13 per ton of nitrogen dioxide, $5CAN per ton of sulfur dioxide, and $3,413 per ton of particulate matter that is less than 2.5 microns.

The report also mentions that trees 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). Upon further research, it is concluded that tree plantings will still improve air quality regardless of this factor, but species that emit a low amount of volatile organic compounds should be considered (USDA Forest Service, 2002).

Data is depicted on a three axis bar graph with pollution removed (pounds), pollutants (elements), and value (thousandths of a CAN$) on respective axes *(See figure 9)*. Zone 3 removed the most ozone of the 5 pollutants accounted for at nearly 20 pounds worth $0.9CAN. Particulate matter removes one of the lowest amounts at around two pounds worth, but is valued the most at the closest to $1. Results include that the more available field data and pollution and weather data, the greater amounts of ozone trees can remove. Our zone removes a combined amount of 29.08 pounds of ozone, carbon monoxide, nitrogen dioxide, particulate matter (>2.5 microns in size), and sulfur dioxide per year, and is valued at $1.93 a year. The 29.08 pounds per year is equivalent to roughly 1.5 gallons worth of carbon emissions released. Trees in this site also emit around 7.4 pounds of VOC which contribute to ozone formation. iTree Eco's documentation gives recommendation to improve air quality. *(See figure 10)*

IV. Carbon Storage and Sequestration

Carbon Sequestration

Carbon sequestration has to do with tree's ability to convert inorganic, atmospheric carbon to organic form. Trees alleviate climate change especially in urban environments by sequestering atmospheric carbon and storing it in their tissue to build biomass. This calculation looks at the carbon dioxide released from buildings and emitted from fossil-fuel based power sources and the amount of carbon that gets sequestered which increases with tree size and health. Estimated carbon sequestration was calculated using tree's average diameter growth with the addition of the tree condition and then added to the existing tree diameter to measure carbon sequestration through carbon storage; the "tree dry-weight biomass was converted to stored carbon by multiplying by 0.5." (iTree Eco, Appendix, p. 22).

Another three axis bar graph represents carbon sequestration in pounds, by species, and the annual value. Sawara false cypress sequesters about 410 pounds of carbon worth about $22 while Apple serviceberry sequesters the least at about 25 pounds and valued at around $1. Overall, the zone sequesters 1,335 pounds of carbon annually, valued at $69.6 CAN *(See figure 11)*. The amount sequestered is equivalent to the emission of five cars that each hold twelve gallons of gas.

Carbon Storage

Through carbon sequestration, trees build biomass and store carbon and release it back into the atmosphere when they die; it is an indicator of carbon released during decomposition. Carbon storage takes into account the amount of carbon found in woody vegetation above and below ground. Carbon storage was calculated using the dry-weight biomass which was then converted to stored carbon by multiplying by 5. Tree maintenance also has an effect for it allows continual carbon storage but can also contribute to carbon emissions. iTree Eco suggests that using wood of dead trees for wood products or to heat buildings will help reduce carbon emissions from the natural decomposition of from fossil fuel or wood based power plants.

Results found that Sawara false cypress store and sequesters the most carbon of the site; storing approximately approximately 51.3% of the total carbon at 13.7 tons stored and 33.1% of all sequestered carbon valued at about $1,350/yr. Total results include 25.1 tons of carbon storage worth $2.61 thousand. Using the Red Oak trees that are along UBC's Main Mall, that weigh roughly 2.16 tons, Zone 3 of 70 trees stores about 12.5 Red Oaks worth of carbon (*See figure 12*). iTree Eco is specifically useful in this case due to the contribution of each species in terms of carbon storage. Unfortunately, it does not include the species abundance in relation to other species and there is no clarity in regards to whether it is the species itself that stores more carbon or if it is due to the higher species abundance.

Value for Carbon Storage and Sequestration is based on Vancouver carbon values calculated at $104CAN per ton.

V. Oxygen Production

Oxygen production is related to amount of carbon sequestered by trees which is connected based on atomic weights: "net O2 release (kg/yr) = net C sequestration (kg/yr)" (iTree Eco, 2019). For the purpose of this inventory report, oxygen production was determined from gross carbon sequestration and does not accounts for decomposition.

iTree Eco's documentation is seen through a table with the top 20 oxygen production species in Zone 3 see . It includes, oxygen (pounds), gross carbon sequestration (pound/yr), number of trees, and leaf area (square feet) (*See figure 13)*. However, it does not specify if it is the average leaf area of the tree or not. A positive aspect is that it shows leaf area relation and the abundance of tree species as well as shows the oxygen produced as well as carbon sequestration per year. This data displays that oxygen production is relatively insignificant due to stable oxygen already present in the atmosphere and its production through aquatic systems; the atmosphere is a large reserve of oxygen. iTree Eco proposes that "[i]f all fossil fuel reserves, all trees, and all organic matter in soils were burned, atmospheric oxygen would only drop a few percent (Broecker 1970)." This scenario provided emphasizes the insignificance of oxygen production in the Zone.

Sawara false cypress produces 1,177 pounds of oxygen, the most in the zone where the zone produces a total of 1.78 tons of oxygen/year. Upon further research, results included that the average human inhales about 2.18 tons of oxygen a year; therefore, our zone produces roughly half of what one human would need to breathe in a single year.

VI. Avoided Runoff

Avoided runoff is a benefit of trees and shrubs in urban areas. It is directly related to surface runoff which is the amount of precipitation that does not get intercepted or absorbed by vegetation or soils and other permeable surfaces. The presence of vegetation and root systems "promote infiltration and storage in the soil" (iTree Eco, 2019). Vegetation such as trees and shrubs intercept pollution from runoff that can end up in wetlands, lakes, oceans, and streams; however, iTree Eco only takes into account the precipitation that is intercepted by leaves, not including branches or bark. iTree Eco's analysis came from the calculation of Vancouver's annual precipitation and took the difference in annual avoided run off with and without vegetation present.

Avoided runoff value is determined by estimated local values of Vancouver. In the case that local values are not available, the national average is taken and converted to local currency with exchange rates applied. The value of avoided runoff is calculated with the price of $0.07CAN per cubic feet.

Zone 3 captures about 2.46 thousand cubic feet of avoided runoff a year at a value of $160 CAN. This is is equivalent to 69,659.44 liters worth of avoided runoff. The documentation for avoided runoff in Zone 3 is portrayed on a three axis bar graph with avoided runoff, species, and value (CAN$) on their respective axis. Tilia americana (American basswood) captures the most runoff in the zone at about 850 cubic feet of avoided runoff worth around $55 (*See figure 14*). On the other hand, holly species capture the least amount at less than 50 cubic feet worth around $1. Weaknesses of this include the misrepresentation of the quantity of species in the graph and how species abundance affects avoided runoff. Common names are also used rather than scientific and the holly species is not specified.

VII. Trees and Building Energy Use

Trees have the ability to reduce building energy consumption in summer months by shading building, providing evaporative cooling, and blocking wind (iTree Eco, 2019, Pg. 15). Trees can affect energy consumption depending on location and distance of trees in regards to built infrastructure (iTree Eco, 2019, Pg. 15). Energy use savings can be estimated by measuring tree distance and direction to space conditioned infrastructure (iTree Eco, 2019, Pg. 15). For the purpose of Zone Three's report, this data was not collected. Collection of this data in the future could give the UBC community information about annual energy savings in warm and cool seasons.

VIII. Structural and Functional Values

Structural and functional values of urban forests estimate monetary values from benefits that trees provide in urban areas. Structural value is based on individual tree composition such as species type, age, and canopy cover, as well as carbon storage capacity in trees and their roots (i-Tree Eco, 2019, pg. 16). Structural value is assessed in i-Tree Eco by estimating the monetary value of trees by the American Council of Tree and Landscape Appraisers (i-Tree Eco, 2019, pg. 22). The American Council of Tree and Landscape Appraisers estimates value based tree species, condition, location, and diameter to produce structural value data used in i-Tree Eco (Nowak et al 2002) According to i-tree Eco, the major species that contribute to structural value include Sawara False Cypress, American Basswood, English Oak, and Incense Cedar, which amounts to approximately CAD $258 thousand structural value.

Functional values are based on the services trees perform and include carbon sequestration, avoided rainwater runoff, and pollution removal (Lavorel, 2013). i-tree Eco estimates that carbon sequestration in Zone Three values to CAD $70, avoided rainwater runoff is CAD $162, and pollution removal accounts to CAD $1.93 which equals to $233.93 functional value annually *(See figure 15)*.

According to i-tree Eco analysis, the sum of structural and functional value in Zone Three equals CAD $260,843 *(See figure 15)*.

IX. Potential Pest Impacts

Various insects and diseases can infest urban trees and can potentially kill trees. These potential pest impacts can reduce the health and structural value of urban forests (MacLean, 2016).
i-Tree Eco estimates potential pest risk by evaluating pest range maps from the Forest Health Technology Enterprise Team (FHTET) (i-Tree ECO, 2019, pg. 23). Pests tend to have different tree hosts depending on location. In Zone Three, the most likely species to potentially damage tree species include Gypsy Moth, Winter Moth, Oak Wilt and Sudden Oak Death (fungus species), and the beetle species Polyphagous shot hole borer (i-Tree ECO, 2019, Pg, 17). According to the Zone Three i-Tree Eco report, these potential pests can cause a structural value reduction of CAD $154 thousand. This considerable value reduction demonstrates the significance of proper continuous management in urban forests, despite prominent establishment initiatives.

I-Tree Canopy

i-Tree Canopy estimates tree cover and tree given functional services for a classified area through a random sampling process. This data is acquired through the classification of ground cover types by using Google Maps aerial photography (i-Tree Canopy, n.d.). According to i-tree Canopies assessment for Zone Three, the zone contains a canopy cover of 29.3 percent with a standard error of +/- 5.26 percent. Total non-tree cover, which includes any built infrastructure or structure without green composition comprises 70.7 percent of the total area of Zone Three, which has a standard error of +/- 5.26 percent.
i-Tree Canopy also measured estimated tree benefits in Zone Three. According to the i-Tree Canopy report, Zone Three removes 13 ounces of CO, 7 pounds of NO2, and 47 pounds of O3 annually *(See figure 16)*. Additionally, Zone Three trees remove approximately 15 pounds of Particulate Matter (PM10) and 2.6 pounds of Sulfur Dioxide annually. Sequestered and stored Carbon Dioxide is also measured by i-Tree Canopy, with an estimated value of approximately 5 tons of CO2 sequestered by trees, and approximately 129 tons of CO2 stored in trees on site *(See figure 16).*

i-Tree Canopy obtains data from user input by a series of data points that identify vegetative spots using Google Maps aerial photography. This method can produce results that measure relative tree cover in a confined area. This method can be helpful for an estimated canopy cover, but there is a possibility of standard errors in this method, as illustrated by Zone Three's suggested 29.3 percent canopy cover with a standard error of +/- 5.26. This method is also prone to human input errors while establishing points on the aerial view map. Estimated tree benefits also have a possibility of standard error, which an average +/- 4.97 standard error for tree benefit amounts of CO, NO2, O3, CO2, ect. Although these estimates may not be entirely accurate, data from i-Tree Canopy is beneficial to visualize relative amounts of canopy cover and tree benefits. i-Tree Canopy can be an effective tool to approximately estimate ecosystem services through vegetative cover analysis. Such ecosystem services that can be estimated include moderation of extreme weather events, pollination, and pest mitigation, and can possibly inform stakeholders on climate, water, and erosion regulating services through estimated vegetative coverage (Lavorel, S. (2013) & (Bank, W. (2010).

i-Tree Canopy versus i-Tree Eco Results Comparison

During this inventory and ecosystem services assessment, both iTree Eco and iTree Canopy contributed qualitative and quantitative results for regulating services. While the two produced some overlapping summaries, the two programs differed in various ways. Using Zone 3's field data, iTree Eco produced a sum of all values for respective services (such as air pollutant removal) where as iTree

Canopy provided the individual measurements and values of respective pollutants; therefor, iTree Canopy is more specific with numbers and Eco gives an overview of values.

In terms of methodologies used in the respective software, iTree Eco uses standardized field data and local hourly air pollution and meteorological data to quantify urban forest structure and its numerous effects. iTree Canopy's accuracy relies on the ability of the user to classify points into accurate classes being tree or non-tree. The number of points in the system also influences results; the more points, the more accuracy.

The Eco program was especially useful for giving an overview of the enter forest including methodologies, calculations, results, and summaries. Canopy focused specifically on canopy coverage within the zone and the benefits such as pollutants removed and carbon that is sequestered and stored through the canopy coverage of the urban forest. In terms of result values, numbers varied between the two programs. A cumulative value of the overlapping air pollutants removed came out to be around 60.46 pounds in iTree Canopy whereas iTree Eco revealed 29 pounds. Similarly, monetary values differed substantially where Canopy produced a much larger number and also had different currencies. When such results are reviewed, standard error is important note. Another comparison between results is the inclusion of particulate matter that is greater than 2.5 microns in the iTree Canopy report as opposed to iTree Eco measuring particulate matter of 2.5 microns or less.

Cultural Services

Zone 3 assessment of ecosystem services used several methods of analysis including a value mapping process, analysis of the areas traffic-pedestrian flows and observations of various social interactions. Those analyses led to the creation of three different metric related figures presented in the following section. The first figure represents the value mapping process which produced 5 value maps individually addressing specific subcategories. The second figure is a visual representation of the pedestrian traffic flows through out Zone 3. The third and final figure is a hot spot analysis representing the various specific areas of social cohesion and cultural significance within Zone 3.

Value Map:

In order to create the five value maps, each member of group 3 was given the opportunity to assess Zone 3 based off of five subcategories; Diversity and Species Richness, Cultural Significance, Aesthetic, Social Cohesion and Wilderness/Nature. Zone 3 was then divided into smaller subzones. Each member of the group individually assessed each subzone by each subcategories using a scale from zero to five. The values indicating low to high values respectively. The average values were then taken for each subzone within each category to create the visual map.

Evaluating each of the subcategories through value maps has its strengths and weaknesses. The evaluation was goal oriented and quantitatively based. Its assessment was conducted by students with a significant familiarity with Zone 3; however, it is important to note that it was not performed by full time users of Zone 3. Additionally, not all subcategories are easily converted from qualitative feel to quantitative values. Depicting qualitative observations through quantitative values may have resulted in inaccurately depicted data.

The maps indicate the average values given to each subcategory through the opacity of the green shading within each subzone. A darker shade of green is associated with a higher value, and a lighter shade or no shading indicates a weak to a non-existent value.

Aesthetic: *See figure 17*

The figure created for aesthetics reveals that the project area has a fairly consistent aesthetic throughout Zone 3. Although this may seem positive and the presence of an existing aesthetic is a good foundation, the average values for Zone 3 range between 2.5 to 3. This sets a good foundation for the project area to further improve its aesthetic, which will contribute to the overall value of Zone 3.

Diversity and Species Richness: *See figure 18*

The overall diversity and species richness of Zone 3 greatly varies subzone to subzone. The two mathematics buildings have the greatest surrounding species diversity and richness at an average of approximately 3.25. The geography building and surrounding subzones are in the middle with an approximate average value of a 2.25. The lowest evaluated subzone is at the Koerner library with an average value below 1. It should be a priority to not only increase the areas values but to have greater diversity within all of the Zone 3's subzones.

Social Cohesion*: See figure 19*

Zone 3's overall social cohesion is low with nearly all values remaining below a 2.5, with the exception of two subzones. The current social cohesion within Zone 3 is provided by the several worn down benches located around the math and geography buildings and the urban gardens in the courtyard of the geography building. There is significant room for improvement around the remaining subzones to provide opportunities for cohesion.

Wilderness/ Nature: *See figure 20*

The multiple subzones' abilities to mimic a feeling of the natural environment held fairly consistent throughout the project area. The values all ranged on the lower end of the rating scale and leave great opportunities for improvement. The far side of the geography building had the greatest feeling of immersion in nature due to the stand of tall, relatively mature false cypress. The false cypress donate themselves specifically to providing a wilderness associated feeling year round, as coniferous trees maintain their canopy throughout the winter season.

Cultural significance*: See figure 21*

Cultural significance is consistently low throughout Zone 3. Only one subzone has as a significant contribution to cultural significance, located in the courtyard of the geography building. This concentration of cultural significance is provided by the several graduation trees, as well as informational and commemorative plaques located around the courtyard (*see figures 22,23 and 24*). It is important to note that the graduation trees are monocultural. With one tree already dead, it is important to consider the conservation of these trees as well as future species diversification in order to mitigate imminent risk towards this aspect of cultural services.

Traffic Flow Map: *See figure 25*

The pedestrian traffic flow map was created by three members of the group observing the different traffic patterns of Zone 3 at various locations and times. After observing the area over an elapsed time of approximately 3 hours between the 3 individuals, the observations were then categorized per each main path, sidewalk or street. These flow patterns were then assessed on the basis of volume to create the final map.

The traffic map's creation is a qualitative approach at attempting to understand Zone 3's uses and traffic flows. Although the observation times were varied, not all variations of potential environmental factors were observed. This could cause potential variations in traffic flow, however the overall variation in times of day as well as scheduled days were considered during the observation process.

The traffic map illustrates the highest volume of traffic throughout Zone 3 traveling along the sidewalk of west mall, down agricultural road, in between the math annex and the math department, and finally traveling down the left cross path in the courtyard. More moderate levels of traffic flow through the furthest side of the geography building and in between the geography building and the mathematics department. The lowest levels of traffic travel in and out of the buildings.

The various traffic flows throughout Zone 3 reveal important implications about Zone 3's use. The heavy volume of traffic flows throughout Zone 3's main paths with reduced volumes entering and exiting the buildings suggest that Zone 3 is primarily used as a thoroughfare. This is important to acknowledge, as many of Zone 3's cultural services should be focused on benefiting the pedestrians passing through the area, additionally to the users of Zone 3's buildings. The traffic map reveals the areas of heaviest pedestrian occupation and should be used to model future placement of many cultural services. Currently the sites highest valued cultural services exists in the less trafficked areas. Considering these locations and the Zone 3's current traffic patterns will considerably increase the area's effectiveness towards cultural services.

Hot Spot Map: *See figure 26*

The hot spot map was created using the same method as the pedestrian traffic flow map. During the observation process, observers noted locations of social cohesion where users would rest and interact amongst each other. These locations were marked as hotspots along with areas around Zone 3 that were noted to provide cultural significance to its users.

The hotspot approach used is an objective approach that analyzes the physical environment provisioning of cultural services. It is a effective way to view how Zone 3 provides cultural services based on its physical surrounding but may miss areas of social cohesion that exist sporadically, unrelated to the obvious physical environment.

The hotspot approach used is an objective approach that analyzes the physical environment provisioning of cultural services. It is a effective way to view how Zone 3 provides cultural services based on its physical surrounding but may miss areas of social cohesion that exist sporadically, unrelated to the obvious physical environment.

The hotspot map displays two different categories of hotspots.. The purple hot spots, indicating social cohesion, are comprised of a combination of provided seating, and a table located outside the geography building. The yellow hotspot indicate areas of cultural significance that Zone 3 has to offer. This map highlights a stand of graduation trees as well as locations that feature various commemorative or informational plaques.

The hotspot map, like the values map, indicates a significant concentration of the locations for both social cohesion and cultural significance. In order to improve the effectiveness of these cultural services a greater distribution of these services would be beneficial.

Management Opportunities

Compiling evidence from *Assignment 1; Inventory Analysis* and evidence from *Assignment 2; Ecosystem Services Assessment,* group 3 informed strategic management options.

Methodology

When developing a methodology to inform management options for *Zone 3* we first looked at the management cycle; Where are we know? Where do we want to go? How do we get there? Have we arrived? Due to the nature of this assignment, we decided to focus mainly on the first three steps of the management cycle. Saying this, upon suggesting improvements for Zone 3, it is important to set logical and quantitative goals in order to evaluate future progress.

Swot Analysis

To begin; Where are we know? Our group conducted a SWOT analysis for Zone 3. When conducting a SWOT analysis, the site was assessed for its *Strengths*, *Weaknesses*, *Opportunities*, and *Threats*. By compiling the information from three separate SWOT analysis; (tree inventory, regulating ecosystem services, and cultural ecosystem services), the group developed an overall SWOT analysis for our site; See Appendix Figure 26

Overall SWOT Analysis; See figure 27

Goal Planning

Once the SWOT analysis had been conducted our group discussed in what ways we could improve the site (keeping in mind the opportunities and threats which have been identified). First, we decided four goals; broad topics for how our site could improve. Next, 4 feasible objectives corresponding to each goal were decided. When choosing objectives, feasibility and use of existing opportunities were the most important factors.

Goal #1: Increased Permeable Ground - See appendix figures 28 and 29

Objective: Replace all impervious pathways with permeable brick pavers.

Taking into account the existing pathway network, we noticed high non-permeability, and the high risk of water pooling/flooding at our site, the first goal our group established was increased permeable ground. To achieve this, an objective of replacing all impervious pathways with permeable brick papers was set. If achieved this would create a more reliable stormwater management system, add aesthetic value and add approximately 19280 sq ft of permeable ground to the site.

Goal #2: Increased Cultural Awareness - See appendix figures 30 and 31

Objective: Redesign graduation tree plaques

Considering the lack of awareness surrounding the geography class trees at site 3, our group decided the second goal should be cultural awareness. The existing class trees at site 3 are greatly overlooked due to lack of proper representation. Rather than a plaque depicting the purpose and story behind these trees, deteriorating rocks with engraved class years tell the story of the trees. To improve this, our group made an objective to redesign the graduation tree plaques. By redesigning the class-tree plaques in order to better explain their purpose, and adding flowers surrounding class trees, there will be a greater value surrounding cultural awareness at site 3, greater aesthetic value, and greater appreciation towards UBC alumni.

Goal #3: Increased Climate Change Mitigation - See appendix figures 32,33,34,35

Objective: Add carbon storing elements to site 3.

After discovering the relatively low carbon sequestration per year and relatively low particulate removal, our group set a goal to improve climate change mitigation at site 3. To achieve this goal, our realistic objective was to use empty space such as building roofs and walls more efficiently. Our vision for this objective is to create a green wall on the back of the Koerner library and a green roof on top of the geography building. Through these mechanisms, over 30000 sq ft of carbon-storing elements will be added to site 3, there will be better roof-top water absorption, added aesthetic value, and increased particulate removals.

Goal #4: Increased Social Cohesion - See appendix figures 36 and 37

Objective: Create an urban green space for students to congregate

Noticing the heavy traffic and inefficient use of space at site 3, our group saw the potential for an improvement in social cohesion. After setting a goal for increased social cohesion, considering the opportunity section of the site analysis, we set an objective to redesign the large unused courtyard in the center of site 3. We envision a social hotspot, this would include a set of picnic tables and chess boards, added deck space, and 1427 ft of added rain gardens. Picnic tables, chess boards, and added deck space will provide students with 1681 sq ft of redesigned study, recreation, and leisure space. Rain gardens will improve aesthetics, stormwater regulation and the connectivity of green infrastructure (such as integration with existing rain gardens on site). Another main point in this objective was to ensure all areas remain permeable, as water pooling was an issue previously in this area.

Appendix

Figure 1: Front of Geography building

Figure 2: Courtyard in centre of Zone

Figure 3: Math Annex building

Figure 4: Soil compaction Zone 3

I. Tree Characteristics of the Urban Forest

The urban forest of UFOR_Group_3_Analysis has 70 trees with a tree cover of Sawara false cypress. The three most common species are Sawara false cypress (28.6 percent), Apple serviceberry (12.9 percent), and Katsura tree (12.9 percent).

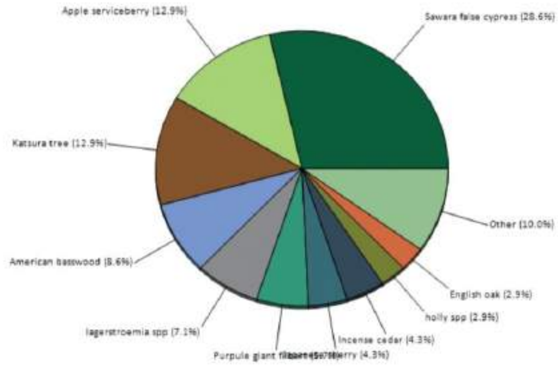


Figure 1. Tree species composition in UFOR_Group_3_Analysis

Figure 5: Species Population Graph

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 UFOR_Group_3_Analysis, about 17 percent of the trees are species native to North America. Most trees have an origin from Asia (54 percent of the trees).

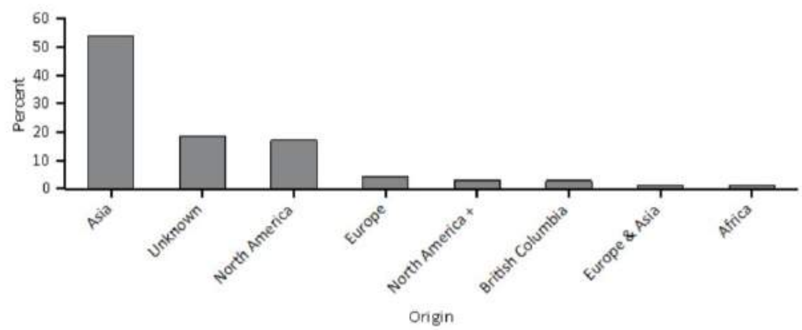


Figure 6: Species Origin Graph

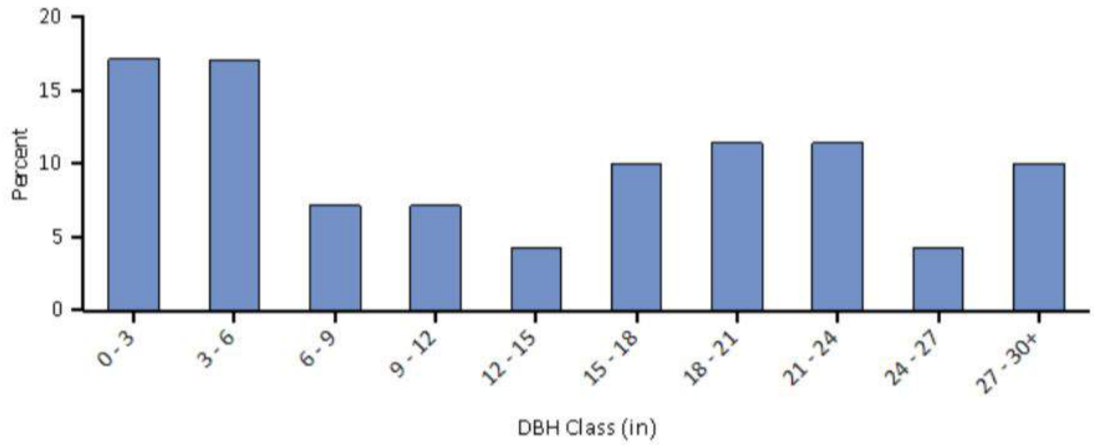


Figure 7: Species DBH Graph

In UFOR_Group_3_Analysis, the most dominant species in terms of leaf area are American basswood, Sawara false cypress, 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 UFOR_Group_3_Analysis

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Sawara false cypress	28.6	28.5	57.1
American basswood	8.6	34.2	42.8
Katsura tree	12.9	7.5	20.4
English oak	2.9	11.1	14.0
Apple serviceberry	12.9	0.5	13.3
Incense cedar	4.3	3.7	8.0
lagerstroemia spp	7.1	0.3	7.4
Purpule giant filbert	5.7	1.5	7.2
Japanese cherry	4.3	2.3	6.6
Pacific madrone	2.9	2.9	5.8

Figure 8: Species leaf area Graph

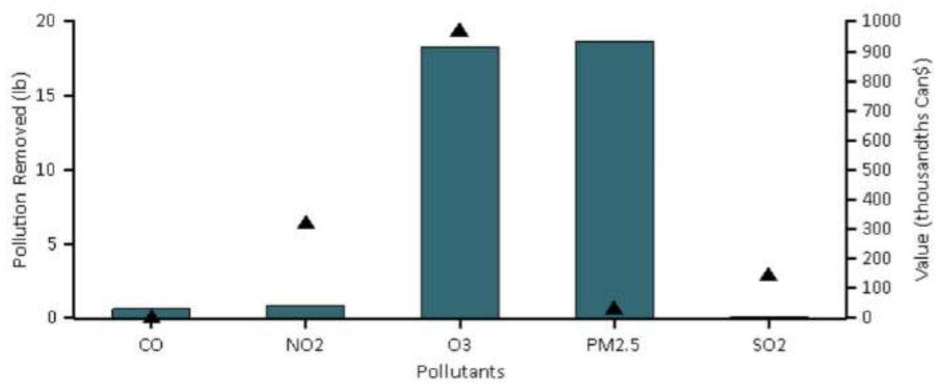


Figure 9: Air pollution removal by trees

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

Figure 10: Urban forest management strategies to help improve air quality

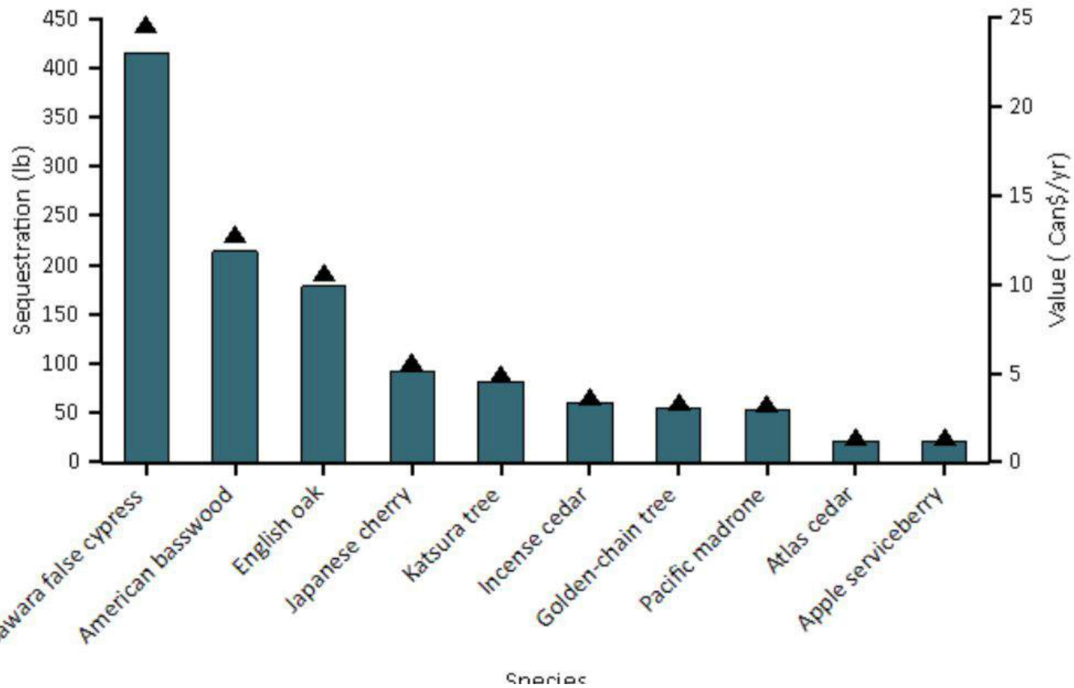


Figure 11: Annual gross carbon sequestration and value

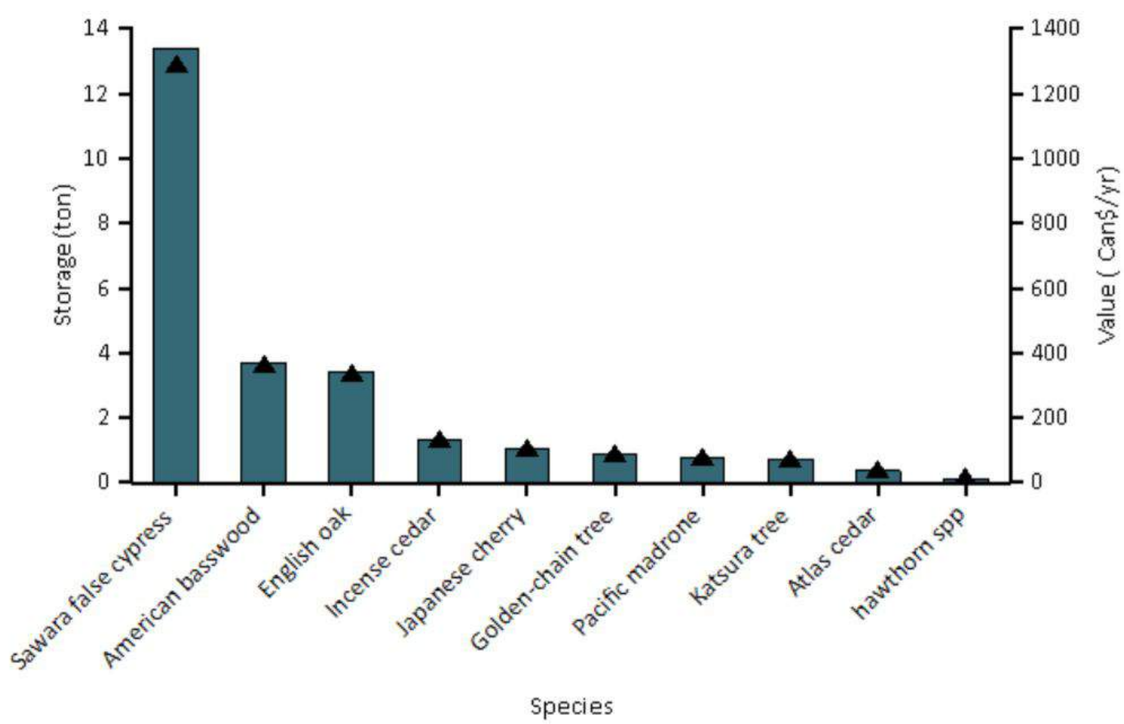


Figure 12: Estimated Carbon Storage and Values

Table 2. The top 20 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
Sawara false cypress	1,177.82	441.68	20	0.05
American basswood	607.22	227.71	6	0.06
English oak	506.51	189.94	2	0.02
Japanese cherry	263.96	98.99	3	0.00
Katsura tree	233.83	87.69	9	0.01
Incense cedar	171.51	64.32	3	0.01
Golden-chain tree	157.74	59.15	1	0.00
Pacific madrone	150.91	56.59	2	0.00
Atlas cedar	62.02	23.26	1	0.01
Apple serviceberry	61.88	23.20	9	0.00
Purpule giant filbert	37.39	14.02	4	0.00
holly spp	37.07	13.90	2	0.00
hawthorn spp	32.12	12.04	1	0.00
Common pear	29.48	11.05	1	0.00
lagerstroemia spp	23.29	8.74	5	0.00
Japanese maple	6.81	2.55	1	0.00

Figure 13: Top 20 oxygen production species

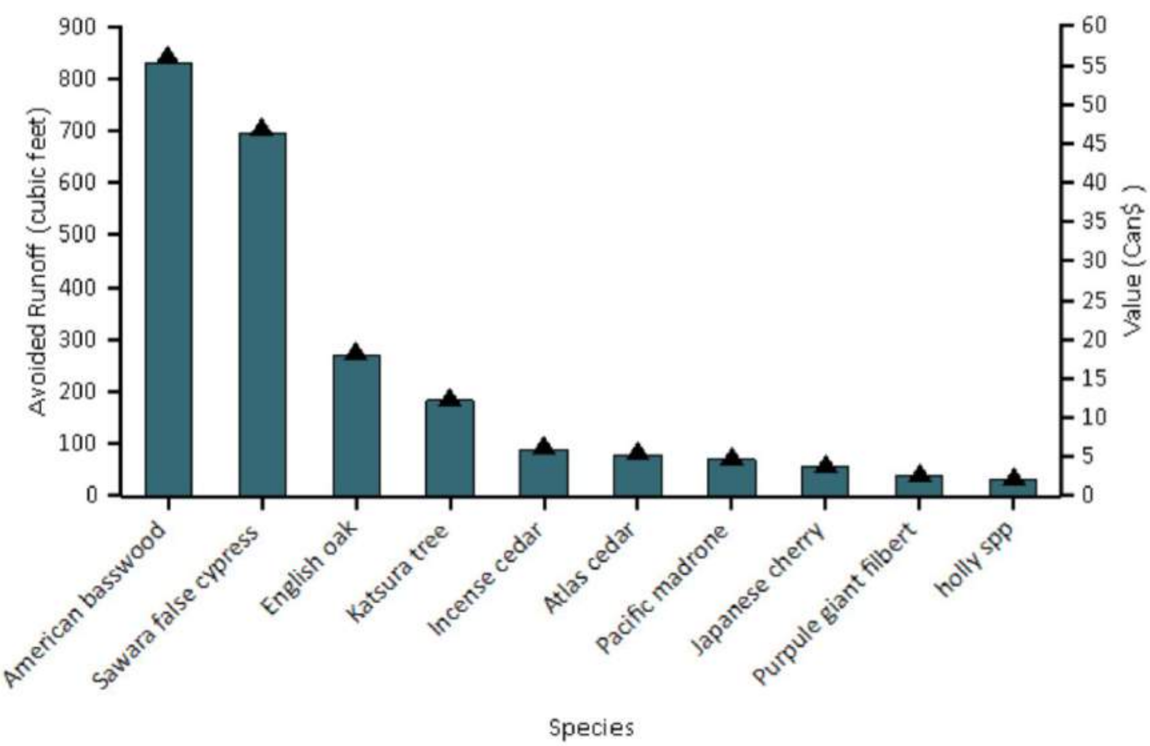


Figure 14: Avoided Runoff and Value

Urban trees in UFOR_Group_3_Analysis have the following structural values:

- Structural value: Can$258 thousand
- Carbon storage: Can$2.61 thousand

Urban trees in UFOR_Group_3_Analysis have the following annual functional values:

- Carbon sequestration: Can$69.6
- Avoided runoff: Can$162
- Pollution removal: Can$1.93
- Energy costs and carbon emission values: Can$0

(Note: negative value indicates increased energy cost and carbon emission value)

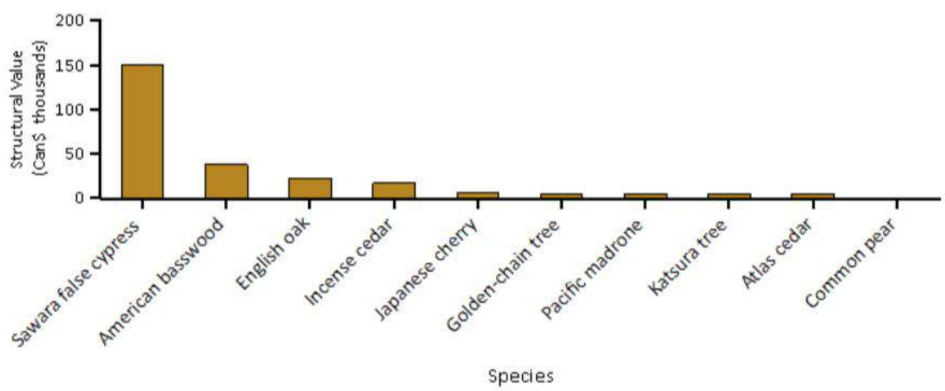


Figure 15: Structural Values

Tree Benefit Estimates

Abbr.	Benefit Description	Value (USD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.54 USD	±0.10	12.97 oz	±2.32
NO2	Nitrogen Dioxide removed annually	1.38 USD	±0.25	7.06 lb	±1.27
O3	Ozone removed annually	87.84 USD	±15.74	47.02 lb	±8.43
PM2.5	Particulate Matter less than 2.5 microns removed annually	251.94 USD	±45.15	2.98 lb	±0.53
SO2	Sulfur Dioxide removed annually	0.20 USD	±0.04	2.60 lb	±0.47
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	46.01 USD	±8.25	14.73 lb	±2.64
CO2seq	Carbon Dioxide squestered annually in trees	238.76 USD	±42.79	5.15 T	±0.92
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	5,996.10 USD	±1,074.64	129.37 T	±23.19

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and USD/T/yr: CO 0.787 @ 1,333.50 USD | NO2 6.863 @ 391.85 USD | O3 45.682 @ 3,749.93 USD | PM2.5 2.899 @ 169,479.81 USD | SO2 2.529 @ 157.74 USD | PM10* 14.312 @ 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.

Figure 16: Tree Benefit Estimates

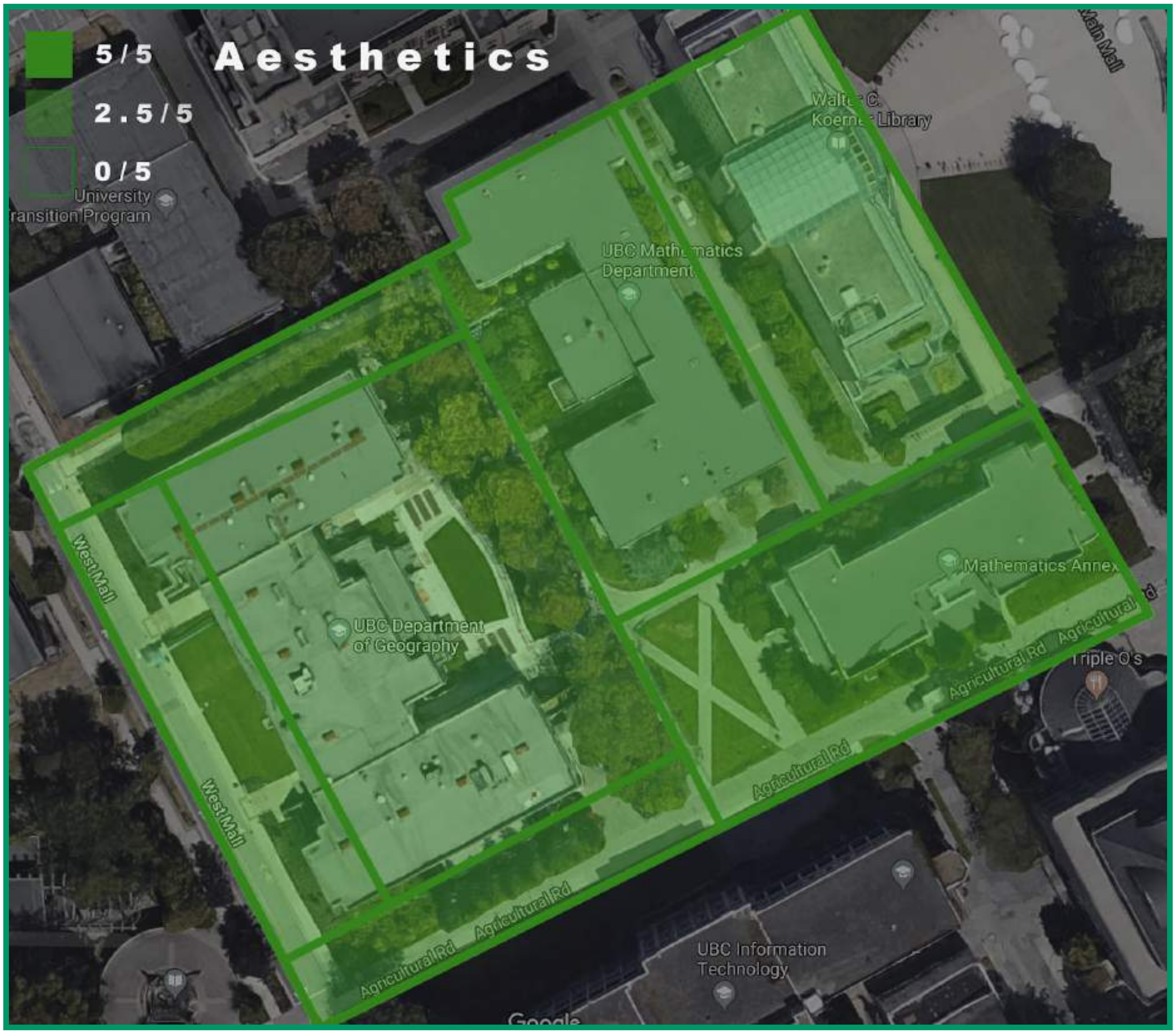


Figure 17: *Aesthetic Value Map*

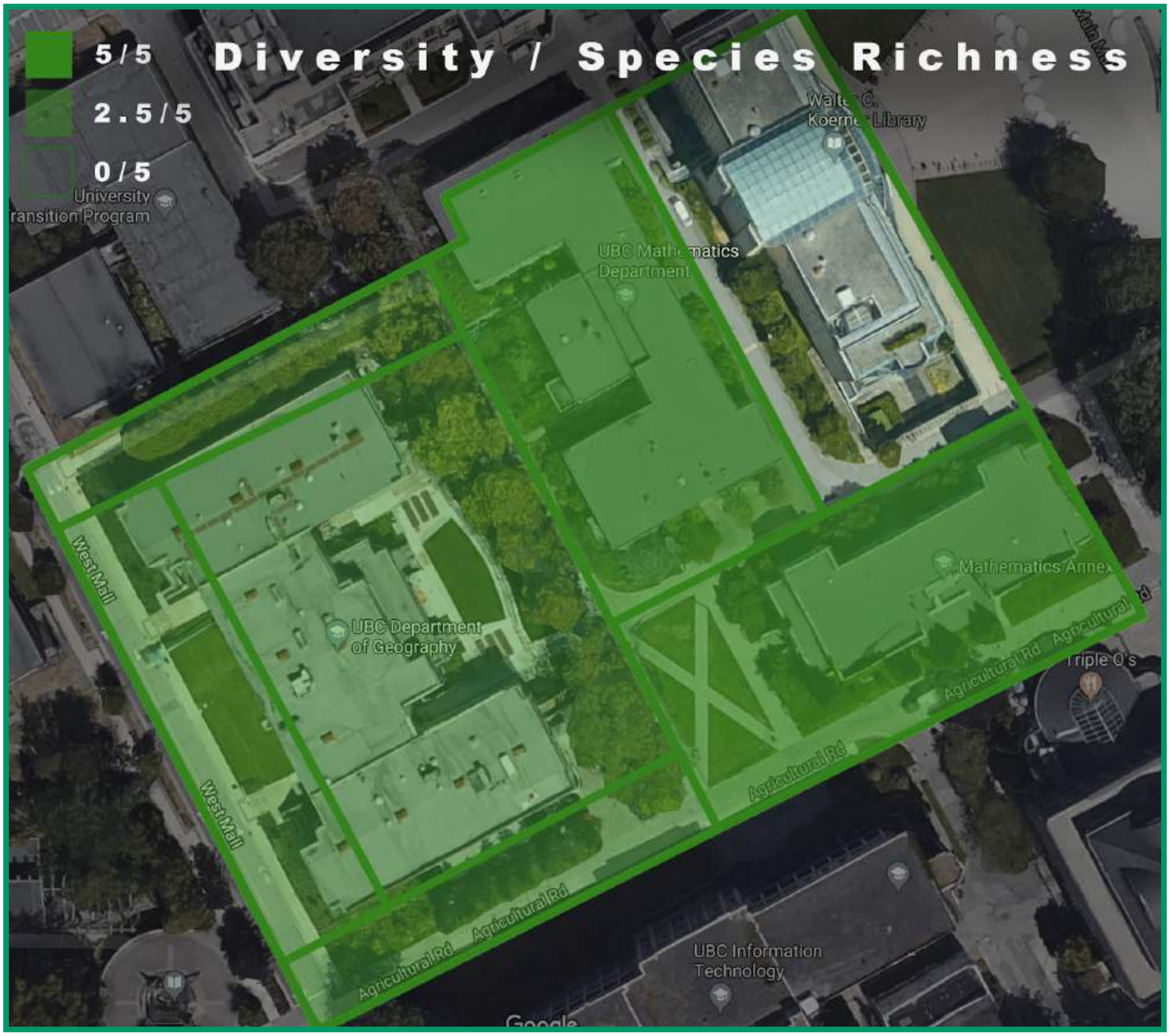


Figure 18: Diversity and Species Richness Map

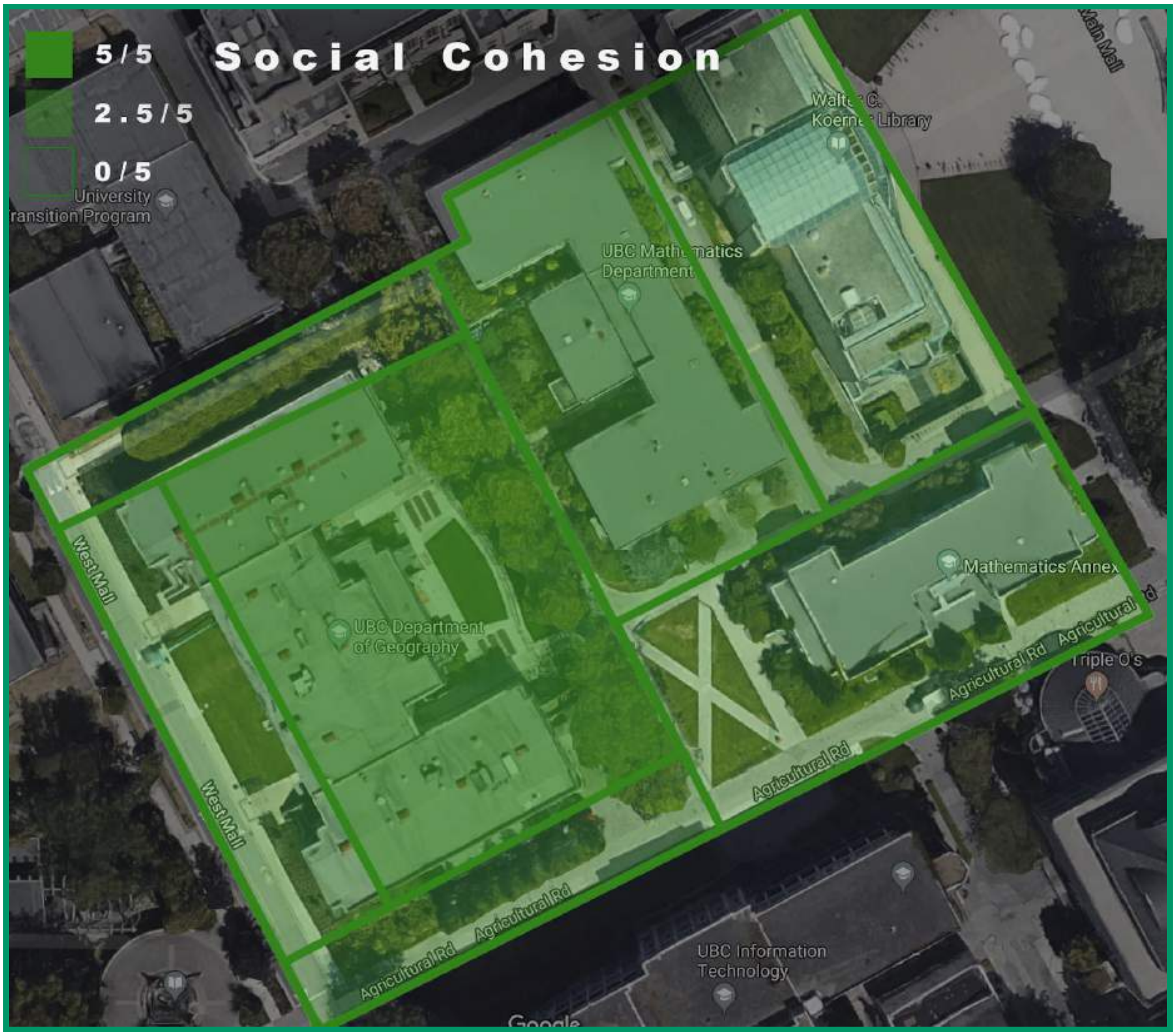


Figure 19: Social Cohesion

Figure 20: Wilderness / Nature

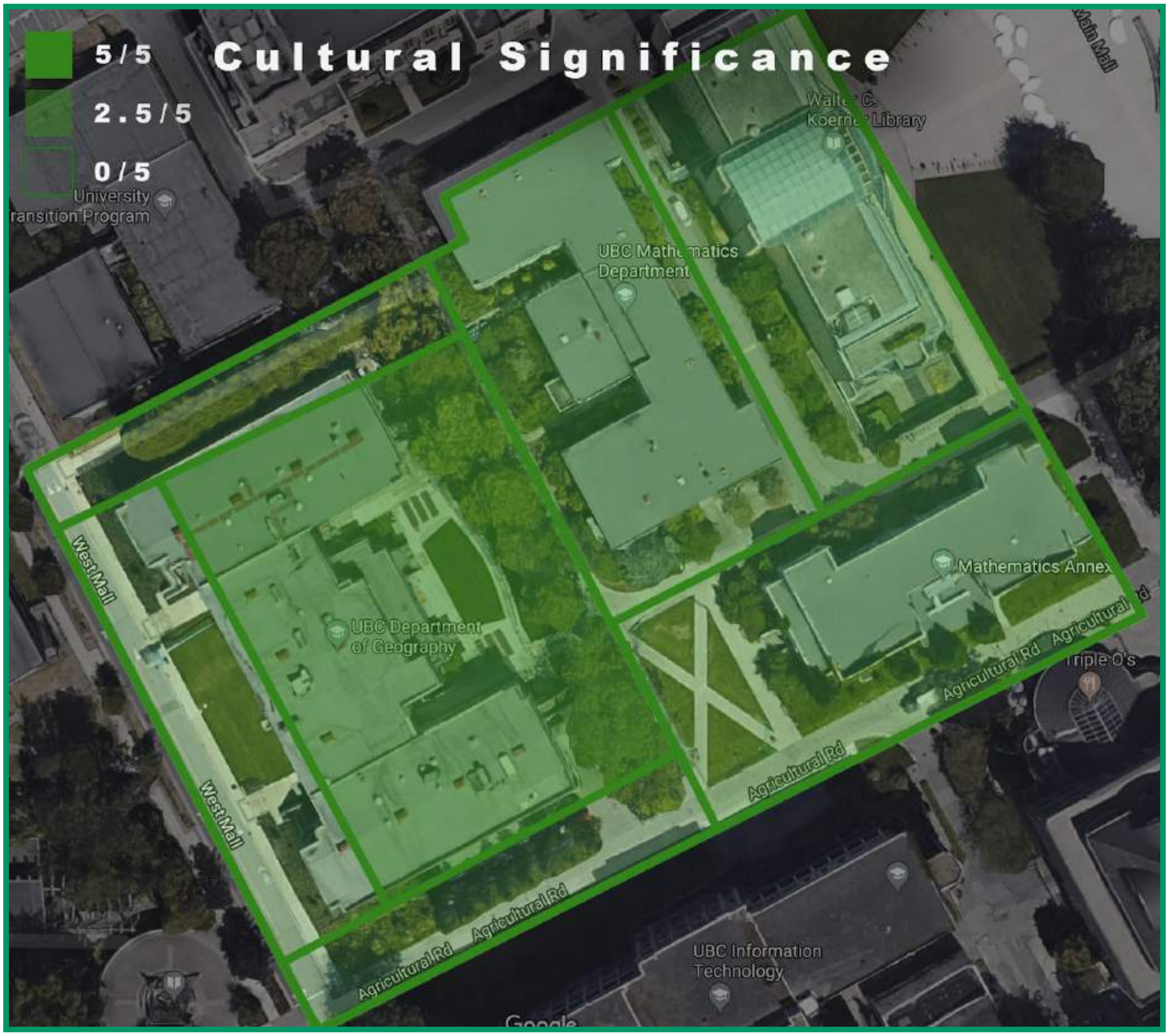


Figure 21: Cultural Significance

Figure 22: Stand of Graduation trees

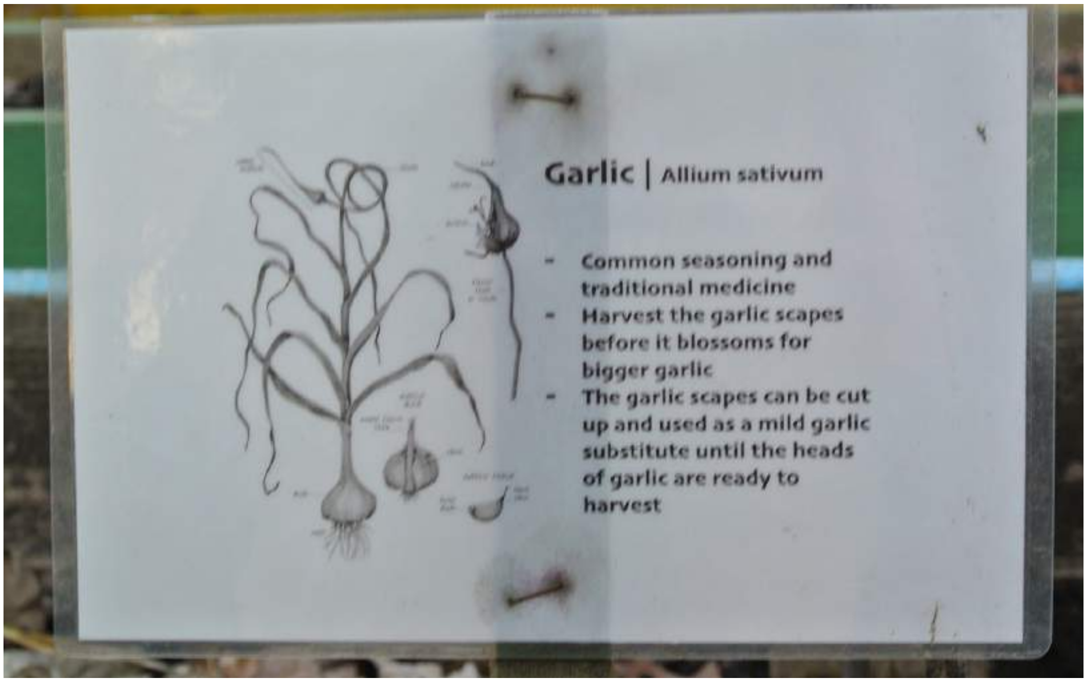
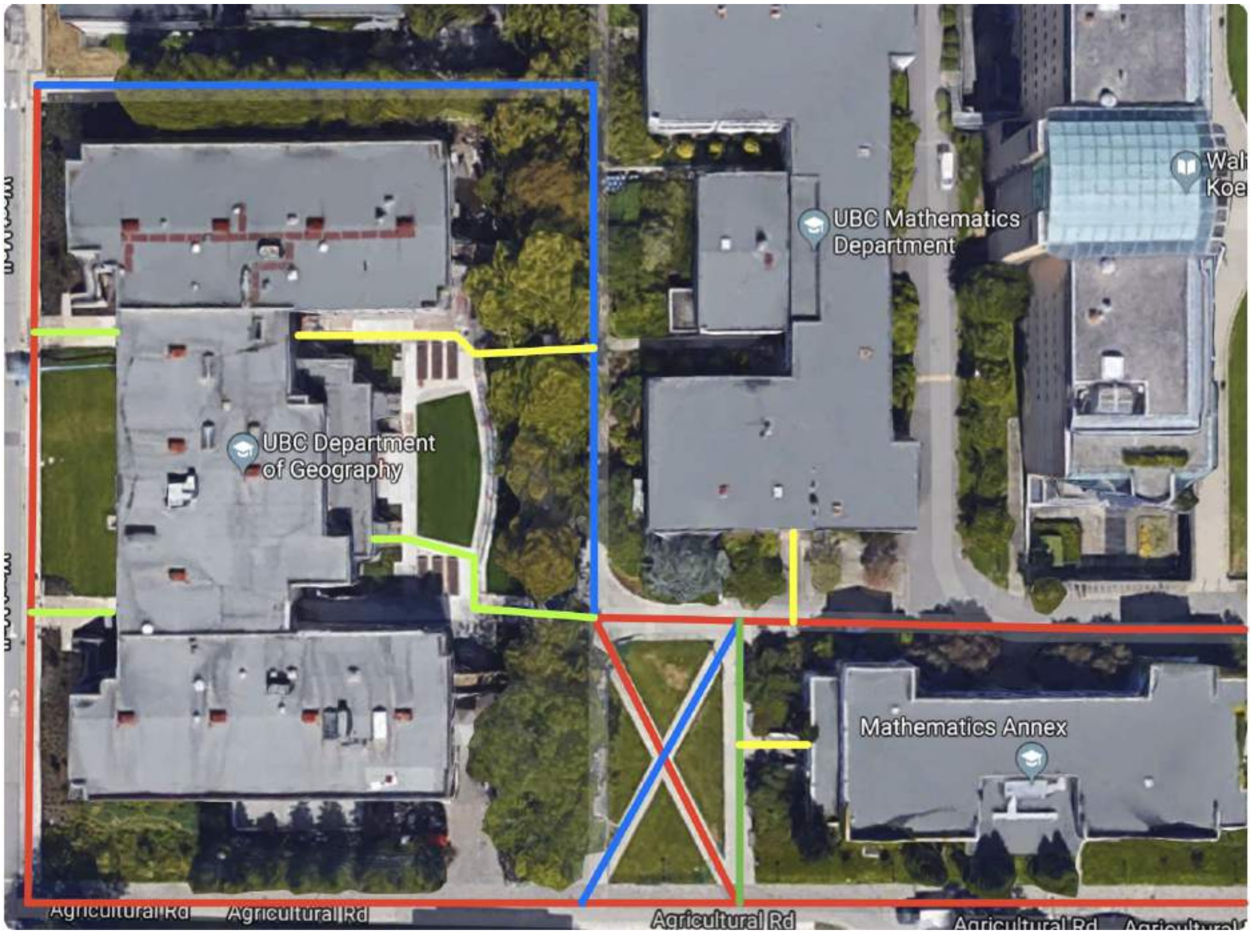


Figure 23: Community garden information sign

Figure 24: Graduation class benches



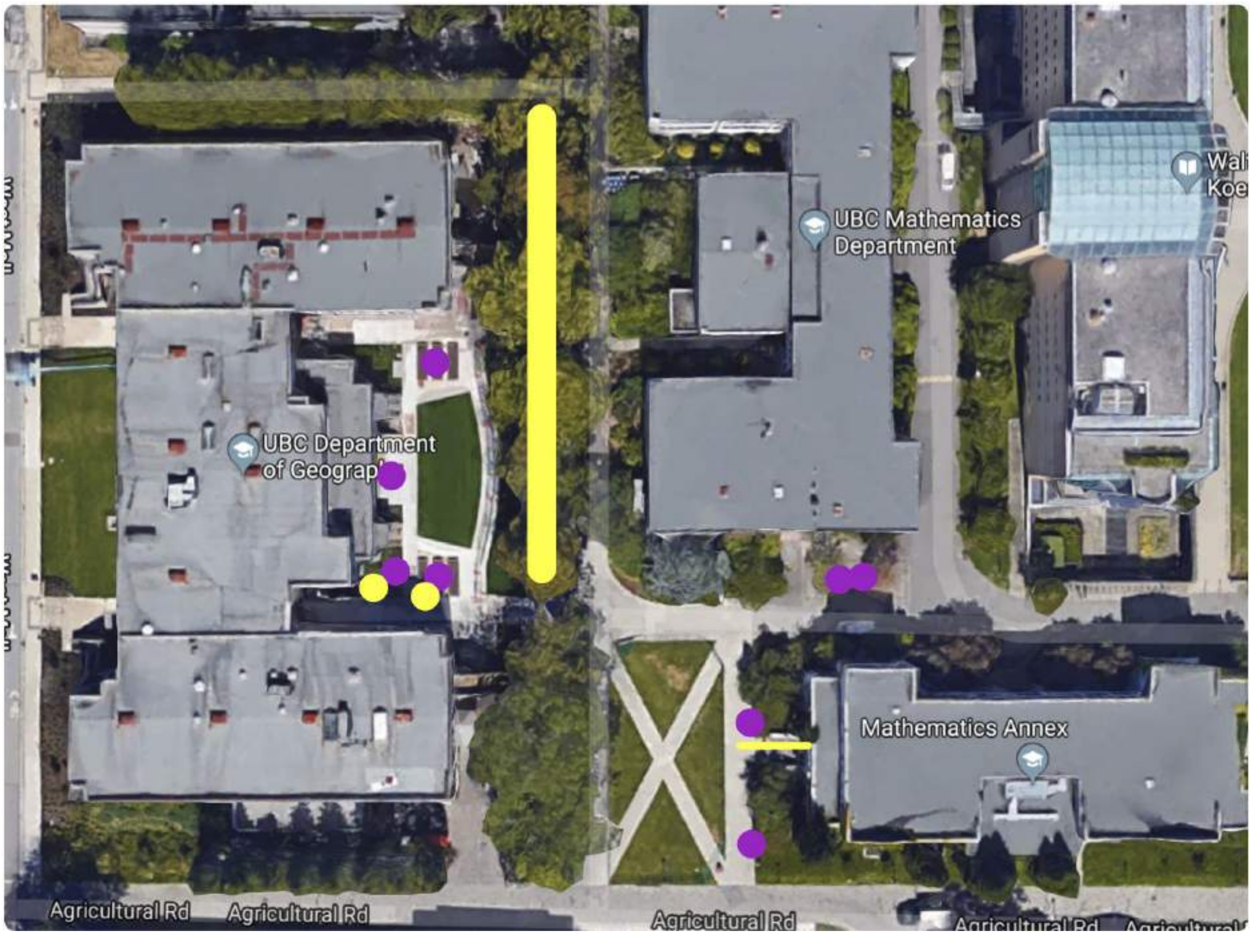
— = High volume of traffic

— = Moderate volume of traffic

— = Lower volume of traffic

— = Minimal volume of traffic

Figure 25: Traffic Map



— = Areas for Social Cohesion

— = Elements of Cultural Significance

Figure 26: Hotspot Map

Strengths - High traffic area - A broad range of DBH classes - Diverse age range - Relatively high canopy cover	*Weaknesses* - Low permeable ground - Many species, however, lack of representation from some species - Dominance by few tree species - Lack of social activity / social cohesion - Low awareness of cultural significance -Low yearly carbon sequestration and particulate removal
Opportunities - Large unused courtyard - Roof-area on multiple buildings - Existing pathway network - Existing graduation trees	*Threats* - Pest outbreak - Flooding - Tree death

Figure 27: Swot analysis for Zone 3

Figure 28/29: Before and After; Increased Permeable ground

Figure 30/31: Before and After; Increased cultural Awareness

Figure 32: Before: Geography building roof

Figure 33: After: Geography building roof

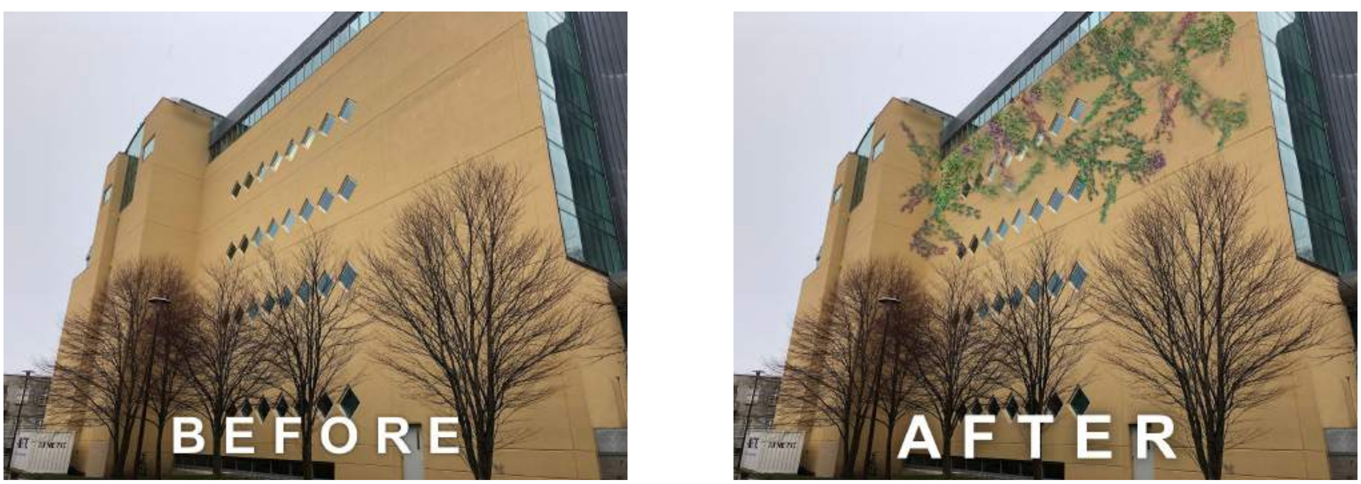


Figure 34/35: Before and After: Carbon storing elements (Green Wall)

Figure 36/37: Before and After: Redesigned social space

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2019

University of British Columbia
Urban Forest Inventory

Feb 10th 2019

Group 3

Contributions:

Group Member:	Contributions:
Sam Clement 58384082	Report: - Cover Page - Data Calculations - Introduction - Site Description - Figure Creation - References Pages Fieldwork: - Crown light exposure - Crown percentage missing - Crown width - DBH - Species identification - Tree ID
Eric Wei 19443001	Report: - Facilitation/ determination of summary section and metrics - Appendix - Data Entry - Data Calculations - Figure Creation - Summary: - *Native vs. Exotic Species* Field Work: - Total Tree Height - Crown Base Height - Live Crown Height - Recording Tree Tag ID
Chanel Yee (Group Leader) 57531873	Report: - Data entry - Methodology section - References page - Revision Fieldwork: - Crown light exposure - Crown percentage missing - Crown width - DBH

	- Species identification - Tree ID

Liam Gannon
31459944
	Report:
	- Facilitation/ determination of summary section and metrics
	- Data Entry
	- References page
	- Data Calculation
	- Revision
	- Summary Section:
	    - *The Difference in Total Tree Height (TTH) from Live Crown Height (LCH) vs. Species and Average Crown Missing Percent per Species*
	    - *Relative Basal Area in percent per Species*
	Field Work:
	- Total Tree Height
	- Crown Base Height
	- Live Crown Height
	- DBH
	- Species ID
	- Tree ID

Dave Choi 86747680	Report: - Facilitation/ determination of summary section and metrics - Figure Creation - Data Entry - Data calculations - Data review & corrections - Summary Section - *Average Crown Base Height and Crown Width per Species* Fieldwork: - Tree ID - Species ID - DBH - Land use - Tree Tag

Kristi Ellerbroek
58306267
	Report:
	- Figure Creation
	- Data calculations
	- Summary Section
	    - *Crown Light Exposure*
	    - *Coniferous vs. Deciduous Species*
	Fieldwork:
	- Tree ID
	- Species ID
	- DBH
	- Land use
	- Tree Tag

Figure 1: Inventory site for group 3. Locations of the three most abundant tree species are included; see legend in top left corner.

Introduction

The purpose of this project is to update the University of British Columbia Vancouver Campus' tree inventory by performing inventories divided into several sections around the UBC Vancouver academic core. Using predefined tree identification numbers and locations found on the collector app for ArcGIS, metrics are added to the existing database, including location, species, size, structure and health. This information will provide important insights into the structure, diversity, and condition of the urban forest on campus. In the future, UBC Vancouver Campus + Community planning will use the gathered information to guide management opportunities and plans (UBC SEEDS, 2018, p.6). Future management choices include tree maintenance, risk assessment, the removal of trees in poor health, and the plantation of new trees in areas which require more species diversity or more overall tree abundance.

Site Description

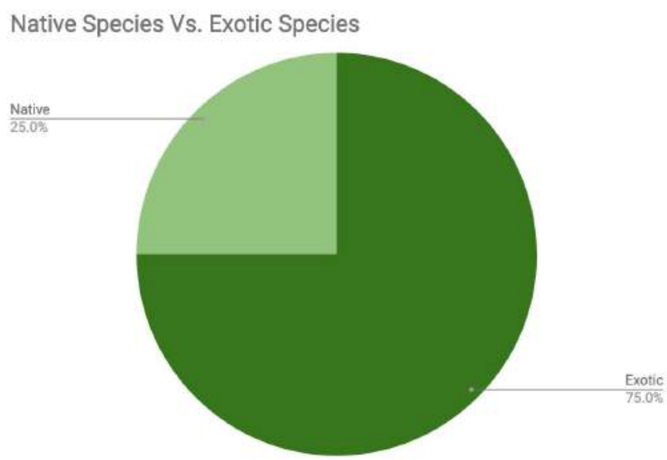
The defined project site for is a two-hectare area on the north-west end of the UBC Vancouver campus. The land use of the site is one hundred percent institutional; however, it is important to note, "UBC lies on the traditional, ancestral and unceded territory of the Musqueam people"(UBC, 2017).

The project area has two main roadways, West Mall, which runs on the west boundary of the defined area, as well as Agricultural Road, a non-public vehicle pathway which runs on the south boundary of the defined site. Agricultural road is heavily trafficked by students as it connects UBC's main mall to West Mall. The road also acts as main route in the network of pathways in the site, leading students to buildings such as the Geography Building, Math building and Integrated Sciences Building.

Due to the frequently trafficked pathways through the center of the site, the main users of this area are students traveling to class. Although a large percentage of site use includes transit, in warmer seasons the area may be popular amongst students as an outdoor study space. Due to the proximity of the Math Building, Geography Building and the Sauder School of Business, the population of students is greatly diverse in terms of represented faculty.

This project area is home to 16 different tree species, the most abundant species include: "Sawara Cypress" (Chamaecyparis Pisifera), the "Katsura" (Cercidiphyllum Japonicum), the "Autumn Brilliance" (Amelanchier grandiflora) and the "Japanese Crepe Myrtle" (Lagerstroemia fauriei). In total, 71 trees were mensurated on our site (*Table 1)*, along with these trees a great variety of shrubs and flowers were found. The defined site provides a great mix of native and non-native trees (*see graph 1 on appendix)* which suits the diverse sociological environment of UBC, an element which is greatly important in any urban forest.

Graph 1: Native Tree Species Vs. Exotic Tree Species.



Along with great diversity, the natural elements of this site provide the community with a variety of ecosystem services. This site provides valuable cultural services to the university through six basswood trees and three oak trees which are dedicated to several previously graduated classes.

In terms of the significance of the predefined site amongst the whole UBC Vancouver campus, this site offers an open-layout greenspace which allows for many natural benefits otherwise unavailable to students amongst the often "grey" university campus. The site may seem negligible amongst the large Vancouver campus; however, as seen in the figures and graphs below, it plays an important role in the greater urban forest.

Table 1: Species found in project area, 71 trees total, 16 species.

Species	Common Name	Count		Species	Common Name	Count
Acer Palmatum	Japanese Maple	1		Crataegus	Hawthorn	1
Amelanchier grandiflora	Autumn Brilliance	5		Ilex pernyi	Perny Holly	2
Arbutus Menziesii	Pacific Madrone	2		Laburnum x watereri vossii	Bean Tree	1
Calocedrus Decurrens	Incense Cedar	3		Lagerstroemia fauriei	Japanese Crepe myrtle	5
Cedrus atlantica "Glauca"	Atlas Cedar	1		Prunus sato zakura group	Japanese Cherry	3
Cercidiphyllum Japonicum	Katsura	9		Pyrus calleryana	Callery Pear	5
Chamaecyparis Pisifera	Sawara Cypress	20		Quercus robur	Common Oak	3
Corylus Maxima purpurea	Purple Leaved Filbert	4		Tilia americana	Basswood	6

Methodology:

For the purpose of this paper and the UBC Inventory report, team members were assigned to collect data in terms of tree ID and species in correspondence with Collector for ArcGIS. Students were also tasked with locating tree tags if applicable, recording land use, measuring diameter at breast height, total tree height, live crown height, crown base height, crown width, crown missing, and crown light exposure in the defined area. Measurements were taken in the field and calculations were to be completed after relevant data was collected.

Methods Used for Inventory Data Collection On-the-Ground

The methodology used for field work execution involved the basic procedure of data collection with the inclusion of the team's own method. Team members were divided into smaller groups of one to two, each assigned with different tasks in terms of what measurements to be taken. Where some tasks turned out be quicker, the leading group created the path for the remaining groups to follow in correspondence with their order of trees.

Diameter at Breast Height (DBH)

The first group that set out located trees and recorded the tree ID number and species from the Collector for ArcGIS app, checked for a tree tag and recorded it if applicable. The group then identified if the tree was living or dead, classified the land use, and recorded diameter at breast height using the diameter tape measure. This group would then outline and create the path for the rest of the group members to follow in terms of the order of trees to measure. For this purpose, the team created their own style of keeping track of trees, aside from the information given on the app. Each tree was given a number ranging from 1-71, marking each tree with its assigned number as the group created the path.

Total Tree Height, Live Crown Height, Crown Base Height

The next group that set out was in charge of recording data for total tree height, live crown height, and crown base height with the use of the clinometer. Total tree height was measured along the main stem of the tree from the base to the top, regardless of the live crown height for this specific measurement. These measurements were taken by measuring the distance from the base of the tree to the person standing with the clinometer. The percent seen on the right side through the clinometer is then recorded.

The procedure explained above applied to the measurement of live crown height and crown base height with a few adjustments. Live crown height and crown base height measurements were taken from the same distance away from the tree base as the total tree height measurements. Percentages were recording using the clinometer from the base of the tree to the top of the live crown along the main stem. Crown base height measures the height from the base of the tree to the height of the live crown which is determined by the lowest level of live foliage on the last branch. For trees that had a large crown base height, the same procedure used to measure total tree height was repeated with the clinometer. For trees that had a relatively low crown base height, an eslon tape measure was used.

The calculations for the measurements listed above were all done in the same manner. The equation goes as followed: the absolute value of the sum of the two percentages taken from the base and the top of the tree, the top of the live crown, the base of the crown and finally multiplying that by the distance in meters.

During the data synthesis process, team members noticed some discrepancies and inaccuracies in some of the recorded values in regards to total tree height, live crown height, and crown base height. Certain numbers did not align with realistic values, therefore a comparison between Google Maps Street View and the site was conducted where members compared the recorded height of the tree to the height of the closest building. Upon realizing that some trees did not have realistic heights, members returned to the cite to remeasure with more accuracy.

Crown Width

Crown width measured the width of the crown in two directions, long and short with the use of an eslon tape. Calculations were made by taking the average of the two measurements to result in an overall crown width of each tree in terms of meters.

Percent Crown Missing and Crown Light Exposure

These two measurements were performed without the use of tools or technology. Percent crown missing was determined by two team members standing about 90 degrees apart with the tree as the focal point and estimating the percent of the crown that was missing. Each prediction was made by looking at the specific tree's crown potential and the percent of the crown volume that was not occupied by branches or leaves due to pruning, die back, etc. This percent was estimated and recorded.

In regards to crown light exposure, each tree had a potential of having five sides getting exposed to sunlight. This was determined by taking note of the presence of buildings and other trees or objects that could interfere with the amount of sunlight a tree received.

Methods Used to Analyze Data/Figures:

The following figures (including a variety of tables and graphs) were prepared in a manner to best display variations in data as well as the significance and relationship between multiple measurements. Standard deviation portrays the possible room for error in data collection in the field as well as calculation discrepancies.

Relative Basal Area in Percent per Species

Basal area, the area of the cross section at diameter at breast height of a tree stem (Natural Resources Canada, 2019), reports on the percent of area that each species occupies and correlates with individual tree size, biomass, leaf surface area, and canopy cover (Nitoslawski, 2016). This calculation assesses tree composition which aids in understanding species dominance in the given cite. Variables include tree species and basal area, taken from the formula: Relative Abundance=basal area of species i/total basal area (McPherson & Rowntree, 1989; as cited in Nitoslawski, 2016).

Species Abundance

The species abundance table (*see table 1 in appendix)* provides a general overview of the trees collected. This counts the trees and gives that basic diversity breakdown in terms of species. Table 1 can inform future decisions for diversification through its numerical count of tree species dominance. Variables include tree species name and the number of each species.

Native vs. Exotic Species

Research was conducted to determine which of the following trees that were inventoried are native to the Coastal Western Hemlock Zone and those that are foreign to the region. This comparison, as portrayed through a pie graph *(see graph 1 of appendix)*, provides implication of the effects that these trees will have on local fauna; the more abundant native trees are beneficial for the local wildlife species. This data determines the urban forest's resilience for the more exotic and diverse species present, the less likely a species specific disease will clear the entire site. Variables include the amount of tree species broken into native versus exotic categories.

Coniferous vs. Deciduous Species

The purpose of graph 2 of the is appendix is to depict the seasonal implications towards specific species and the urban forest's ecosystem services. For example, this graph gives insight as to which tree species will have an active canopy during winter that will be able to provide ecosystem services such as carbon sequestration year-round. The variables include tree species that are either coniferous or deciduous.

Crown Light Exposure

The crown light exposure pie graph *(see graph 3 of appendix)* portrays which trees (not species specific) have exposure to sunlight, ranging from one to five sides of possible exposure. This information provides detail as to which trees are receiving optimal sunlight exposure for production purpose such as photosynthesis and tree growth. This displays the reciprocal effects between sunlight and the presence of trees in close proximity to each other and buildings. Trees were separated in terms of how many sides were exposed to light: one to two sides, three sides, and four to five sides.

The Difference in Total Tree Height (TTH) from Live Crown Height (LCH) vs. Species and Average Crown Missing Percent per Species

Calculations were made to determine which species are thriving better in their current environment and which are experiencing health decline, as seen through the difference of these two measurements. The difference in Total Tree Height and Live Crown Height *(see graph 4 of appendix)* reports on the amount of dead top a tree has and gives the overall live/dead status of the tree. Variables include tree species and the associated difference in each average tree height and live crown height.

In the same area of methodology but on different figures *(see graph 4 and graph 5 of appendix)*, the average crown missing percentage per species is included in comparison to the difference in TTH from LCH per species. The two in comparison with each other can report on the average decline in canopy percentage in each species.

Average Crown Base Height and Crown Width per Species

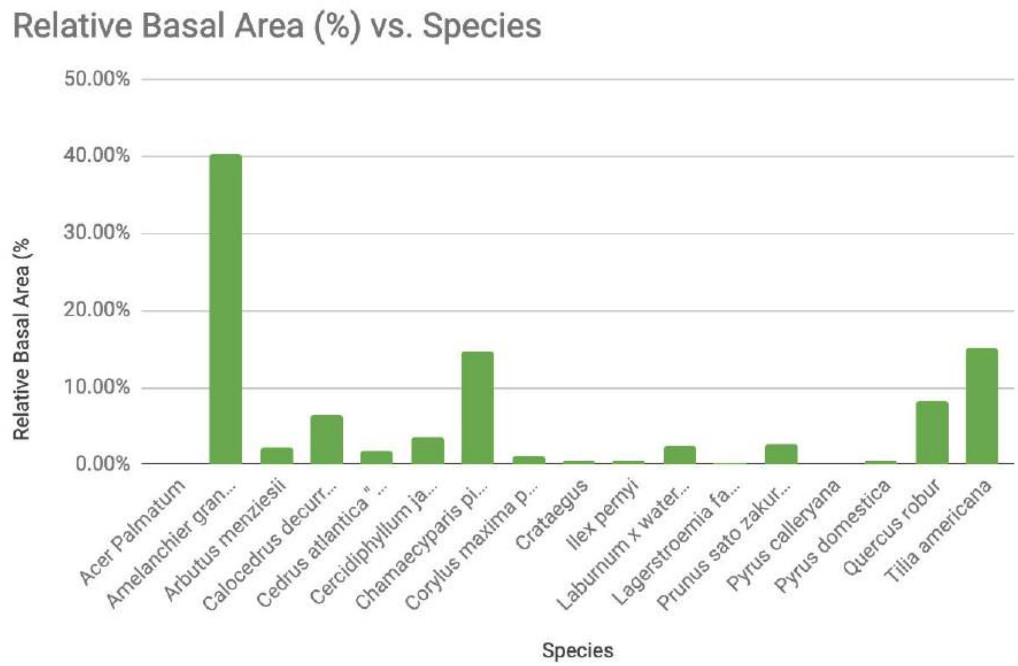
These two measurements in comparison with each other depict the height between the base and crown as well as the width of the crown per species *(see graph 6)*
. This information displays how much space a tree is taking up in terms of horizontal width and its proximity to buildings and areas of institutional use. This data allows the university to consider the spatial limits of trees that the university wants to allow as well as possible pruning opportunities. Variables include the average crown base height per species and the average crown width per species.

Summary of Tree Inventory data:

The site inventory measured all 71 tree's within the defined project area. The following section analyzes the different metrics and graphs compiled from the measurements in order to gain a better understanding of the site's urban forests composition. This analysis will be useful to help inform future decision making, and strategies. The data compiled in this report can also be used to create further comparisons and draw different conclusions about the site's composition, beyond what is contained in this report.

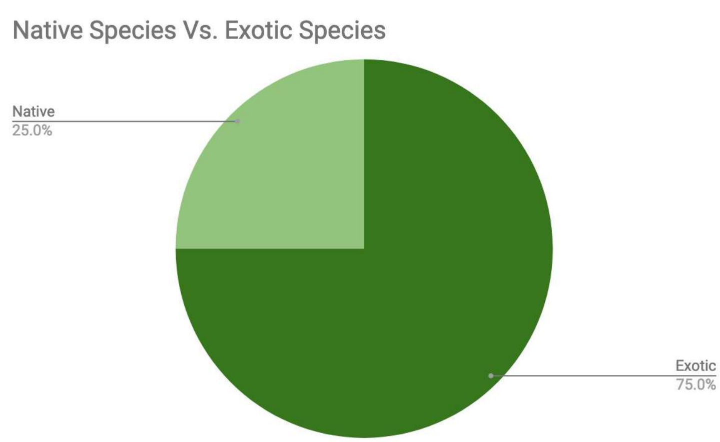
Relative Basal Area in percent per Species

After determining the relative dominance in terms of basal area, approximately 70% of the site's overall basal area was occupied by three species: *Amelanchier grandiflora* (40.18%), *Tilia americana* (15.18%), and *Chamaecyparis Pisifera* (14.18%) *(see graph 8 on appendix for the full breakdown)*. According to Nitoslawski (2016), relative dominance is an important figure in understanding the urban forests' overall diversity (p. 73). Having three tree species comprise 70% of the forests' basal area shows space for improvement on the site's species diversity. The concern of diversity is amplified by the fact that *Amelanchier grandiflora* takes up nearly half of the site's total basal area. If this species were to be infected by a disease or pest, it could be at risk to significantly decrease the area's overall provisioning of ecosystem services. The risk is due to the basal area's nonlinear correlation to canopy availability, leaf size and overall tree biomass (Bartelink H.H., 1997). The sites' relative basal area metrics are a strong indicator of the need to further improve species diversity within the defined area.



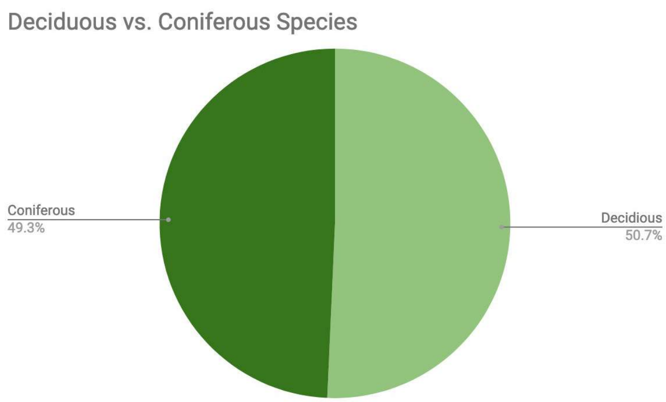
Native vs. Exotic Species

Having a blend of native and exotic species is prefered over having a single-species dominated canopy. Single-species dominated canopies are at risk for mass mortality resulting in a substantial loss of ecosystem services. Native species have been shown to house a greater spectrum of insects and mites than more recently naturalized, also known as exotic, species (Nitoslawski, 2016). In addition, native tree species have been shown to encourage native bird diversity and are less likely to become invasive (Nitoslawski, 2016). Referring to the native vs. exotic species pie chart in graph 1 of the appendix, there are 75% more exotic species than native species. After analyzing this data and seeing the impacts that native trees have on local ecosystems, it can be concluded that more native trees should be planted on this plot to promote the diversity of birds.



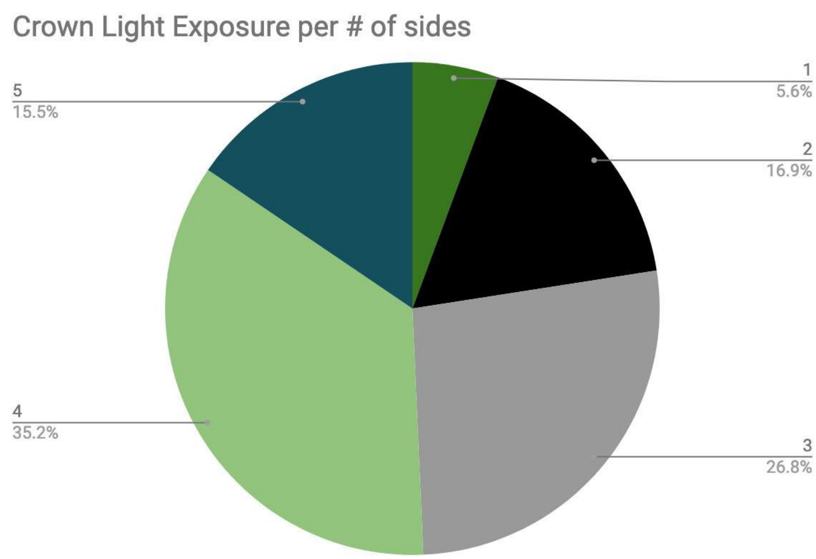
Coniferous vs. Deciduous Species

In terms of tree class composition, the defined project area was relatively equal in terms of coniferous and deciduous trees. In the site, 49.3% of trees were coniferous and 50.7% of trees were deciduous. This metric could be compared to analyze specific tree class needs regarding optimal maintenance and landscape planning based on tree class characteristics, health requirements, and leaf litter maintenance. Additionally, canopy cover of coniferous versus deciduous could be used to determine how much canopy cover is lost in winter, or relative pruning needs for the two species classes.



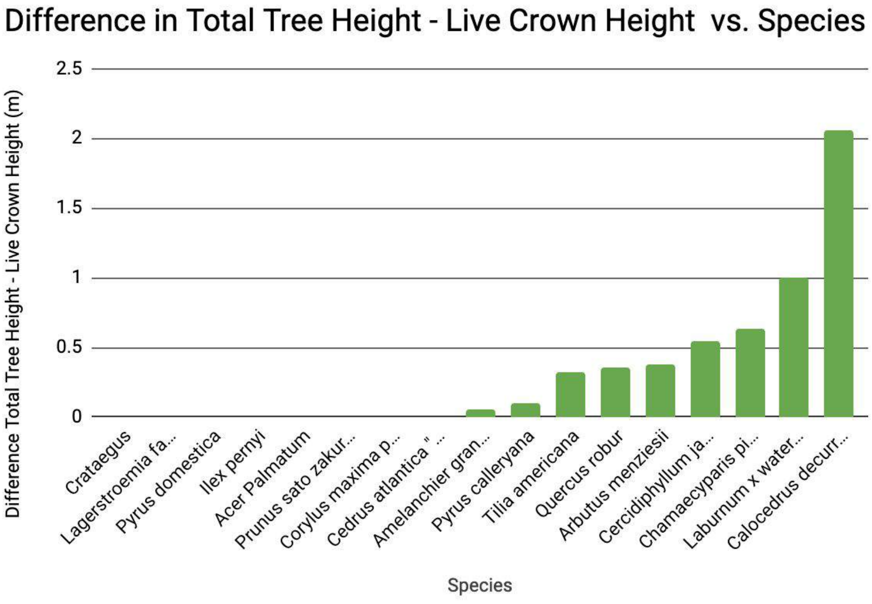
Crown Light Exposure

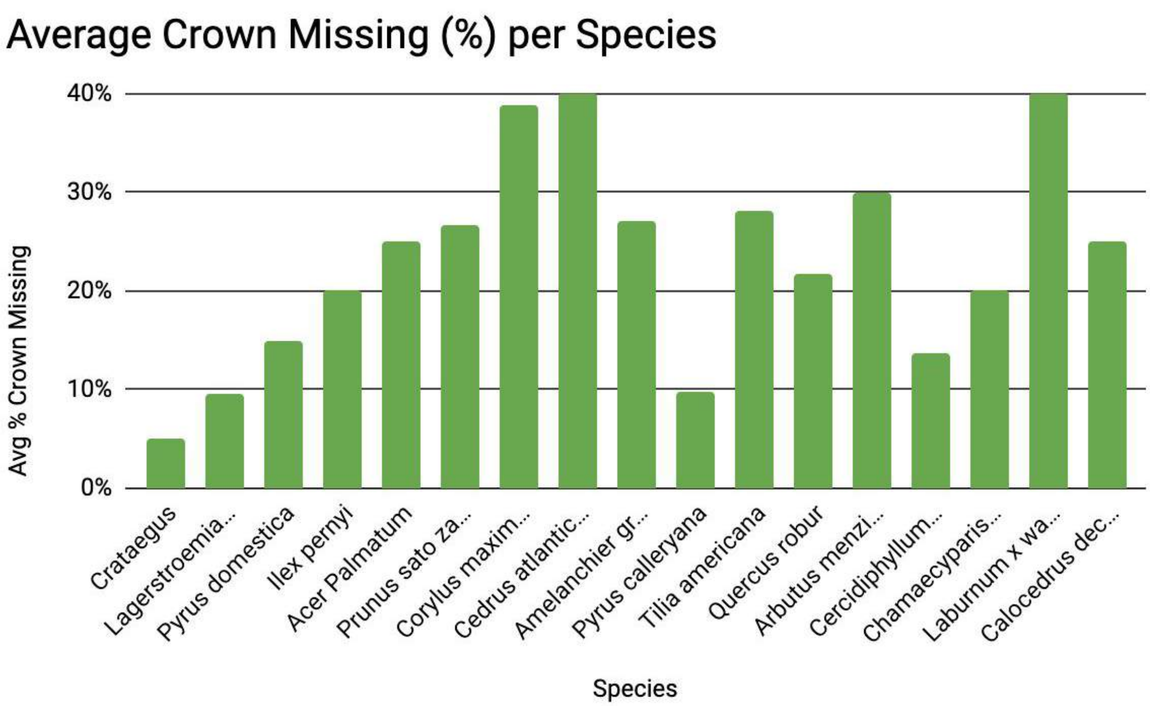
Crown light exposure classification is a method used to measure the amount of light received by a trees crown (Bechtold, 1970). In the defined project area, crown light exposure was used to measure the amount of sunlight available for trees regarding obstructions from the built and natural environment around the area. 15.5 % of 71 trees measured had crown light exposure on five sides; this indicates that 15.5% of trees had optimal crown light exposure with very minimal obstruction. The bulk of the site's trees (62%) had a moderate crown light exposure of four (35.2%) or three sides (26.8%). This dominant group is pretty befitting considering the obstruction from the necessary infrastructure in the surrounding area, with relatively decent crown light exposure. As indicated from the graph, 16.9% of the assessed trees had a crown light exposure of two sides, and 5.4% had a crown light exposure of one side. This indicates that these trees had relatively poor exposure, within a range of two to one sides of the crown exposed to light. This data could be used to assess obstructions from other trees and the built environment, to consider tree health and overall possible growing conditions for present trees in the site.



The Difference in Total Tree Height (TTH) from Live Crown Height (LCH) vs. Species and Average Crown Missing Percent per Species

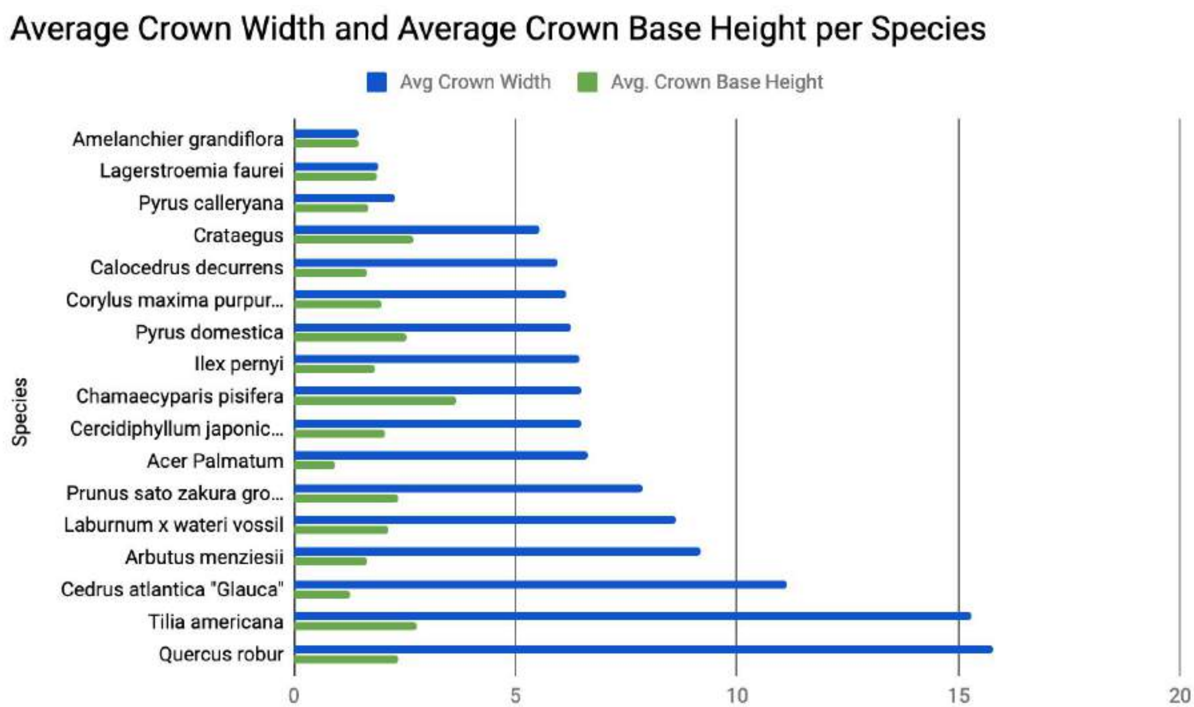
The difference in total tree height from the live crown height was taken in order to determine the average dead top of each tree species. The average crown percent missing per species is an assisting determinant in the overall health of the tree. These two metrics compared per species helps determine how healthy trees are in their current environments. The species with the greatest average dead top is *Calocedrus Decurrens* at just over 2m, the second is *Laburnum x watereri vossii* at 1m, and the third is *Chamaecyparis Pisifera* at .6m. In terms of percent crown missing the tree species with the greatest average canopy decline are *Laburnum x watereri vossii* and *Cedrus atlantica "Glauca,* both missing 40% of their canopy. The species suffering from the second most canopy decline is *Corylus Maxima purpurea,* missing 38.75% of its canopy. The comparison of these two metrics displays that *Laburnum x watereri vossii* is on average one of the tree species suffering from the greatest visual decline in the defined project area. Another species also suffering from greatest average overall visual decline is *Calocedrus Decurrens,* with an average dead top double the amount of any other species and with the 7th greatest percent of tree canopy missing at 25%. Using these two metrics as a comparison can inform future planting strategies and determine which species (or species with similar needs and characteristics) will be best fit for the project area.





Average Crown Base Height and Crown Width per Species

These two measurements give insight into the specific species' tree forms. The crown base height and crown width per species gives us a comprehensive pruning schedule of a specific tree species. The trees' average crown width provides sufficient information about space requirements. Depending on the location, trees with relatively larger crown width may require frequent pruning. With this knowledge, stakeholders can determine an ideal tree species to a certain location based on the average characteristics and space requirements of a tree species. In our project site, the three tree species with the largest average crown height species in order were: Quercus robur, Tilia americana, and Cedrus atlantica "Glauca".



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Appendix

Graph 1 Native Species vs. Exotic Species

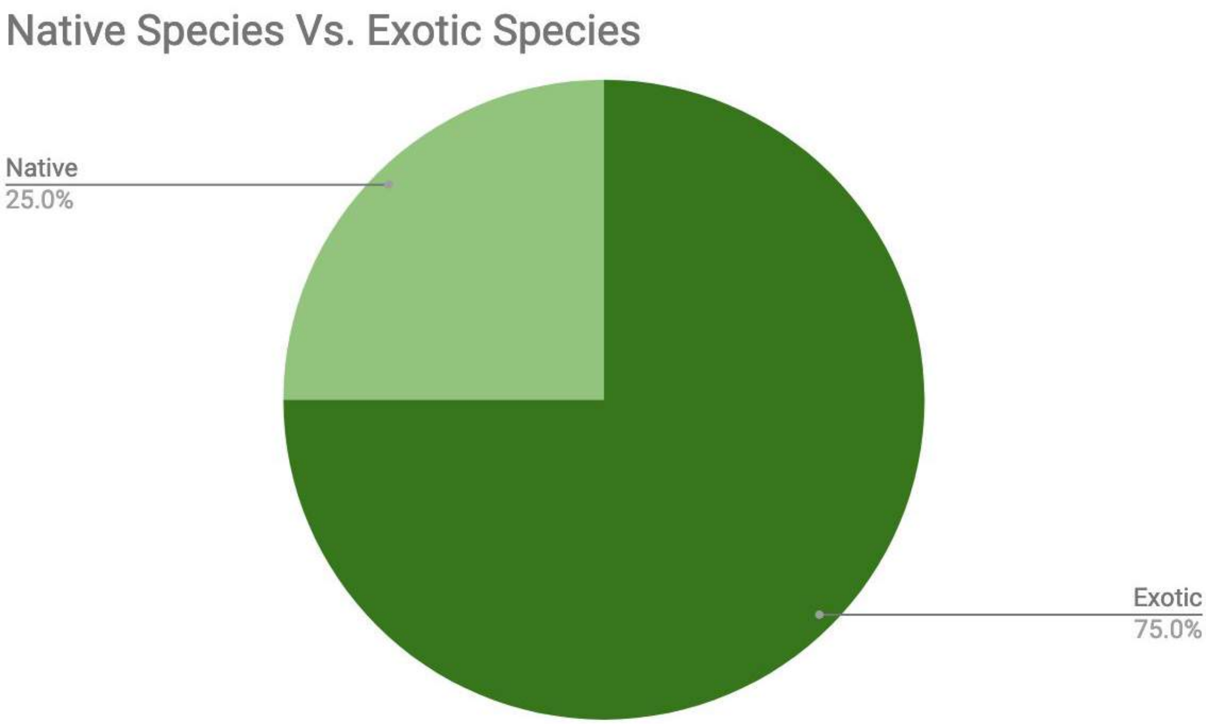
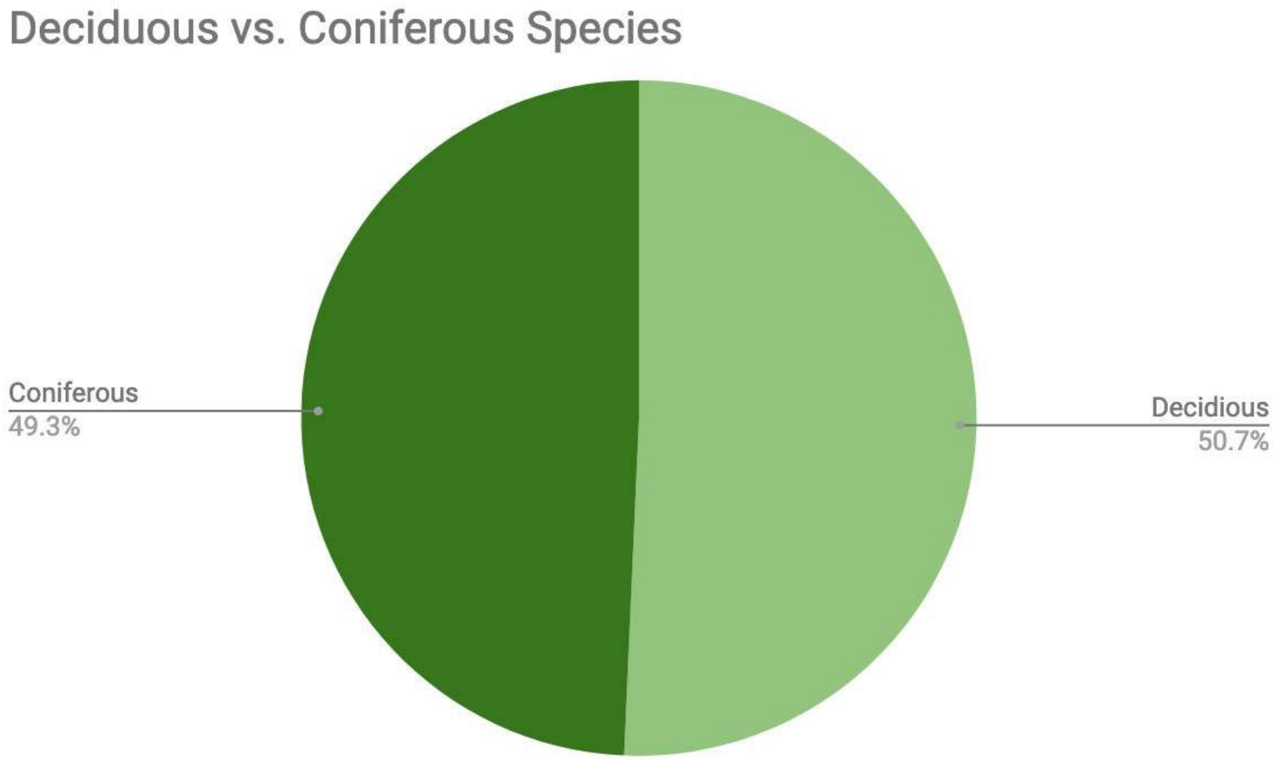


Table 1 Species Abundance

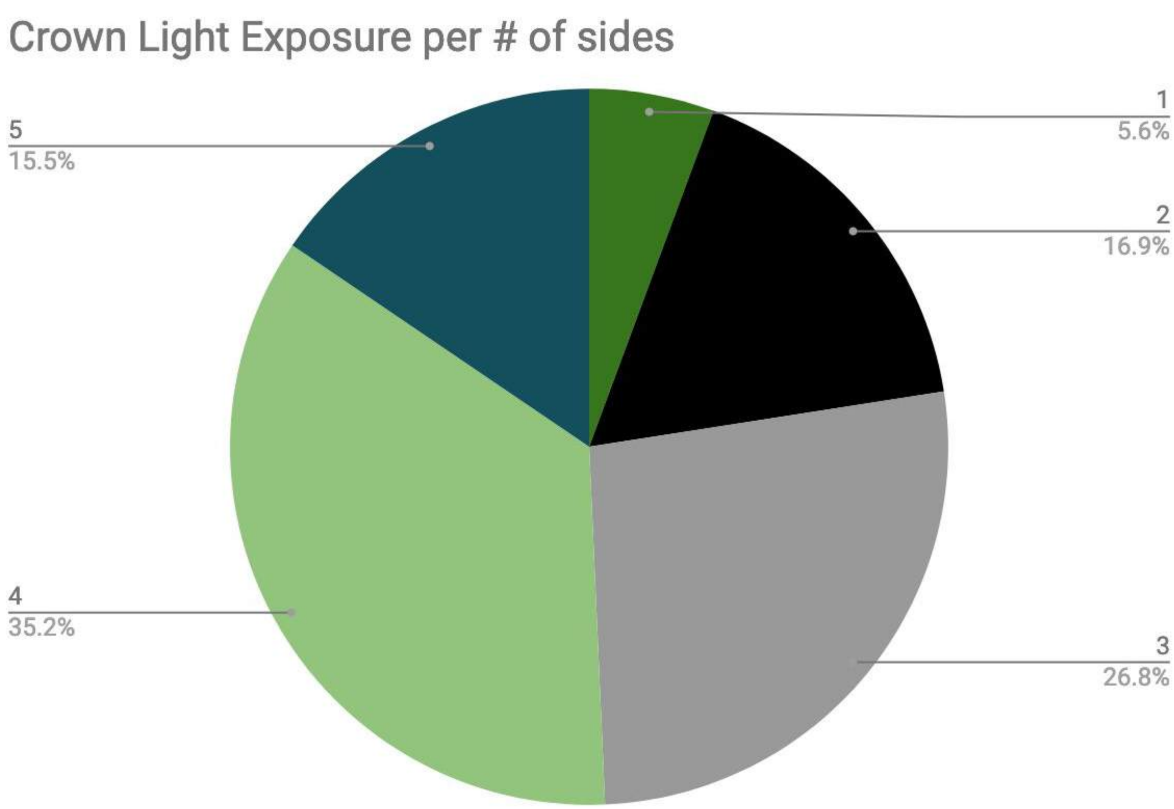
Species found in project area, 71 trees total, 16 species.

Species	Common Name	Count		Species	Common Name	Count
Acer Palmatum	Japanese Maple	1		Crataegus	Hawthorn	1
Amelanchier grandiflora	Autumn Brilliance	5		Ilex pernyi	Perny Holly	2
Arbutus Menziesii	Pacific Madrone	2		Laburnum x watereri vossii	Bean Tree	1
Calocedrus Decurrens	Incense Cedar	3		Lagerstroemia fauriei	Japanese Crepe myrtle	5
Cedrus atlantica "Glauca"	Atlas Cedar	1		Prunus sato zakura group	Japanese Cherry	3
Cercidiphyllum Japonicum	Katsura	9		Pyrus calleryana	Callery Pear	5
Chamaecyparis Pisifera	Sawara Cypress	20		Quercus robur	Common Oak	3
Corylus Maxima purpurea	Purple Leaved Filbert	4		Tilia americana	Basswood	6

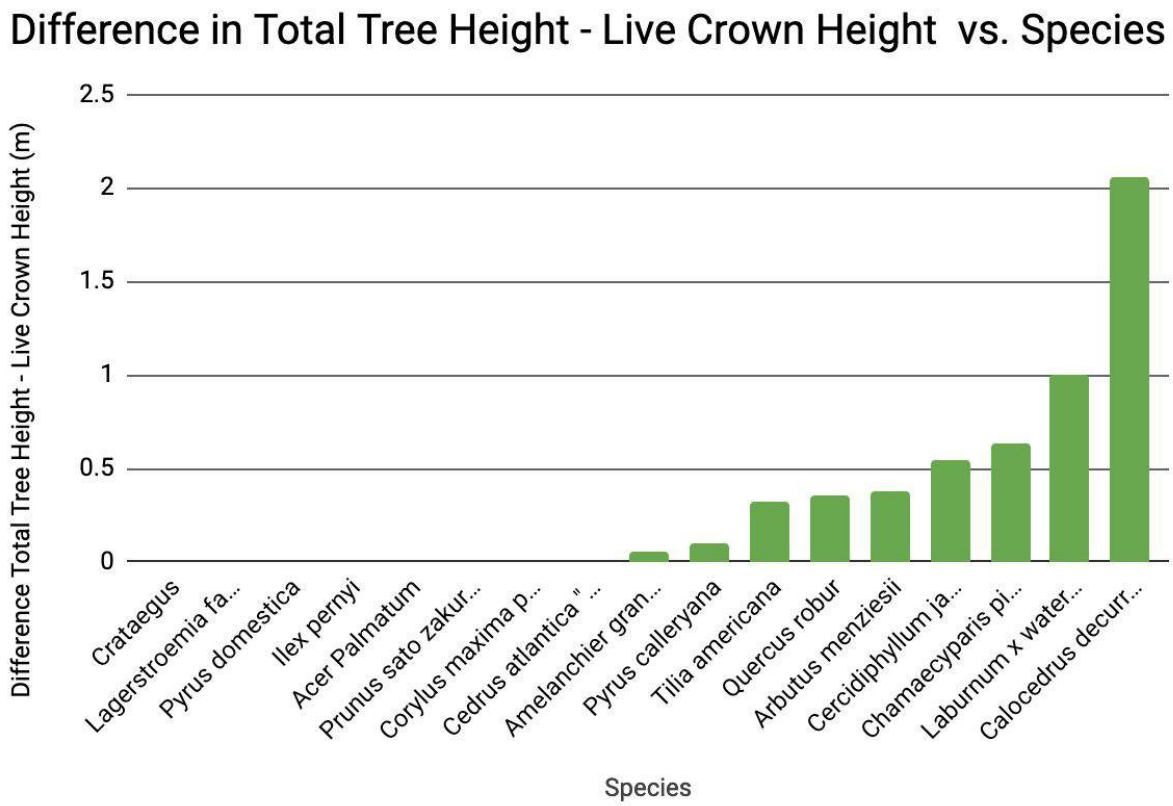
Graph 2 Coniferous vs. Deciduous



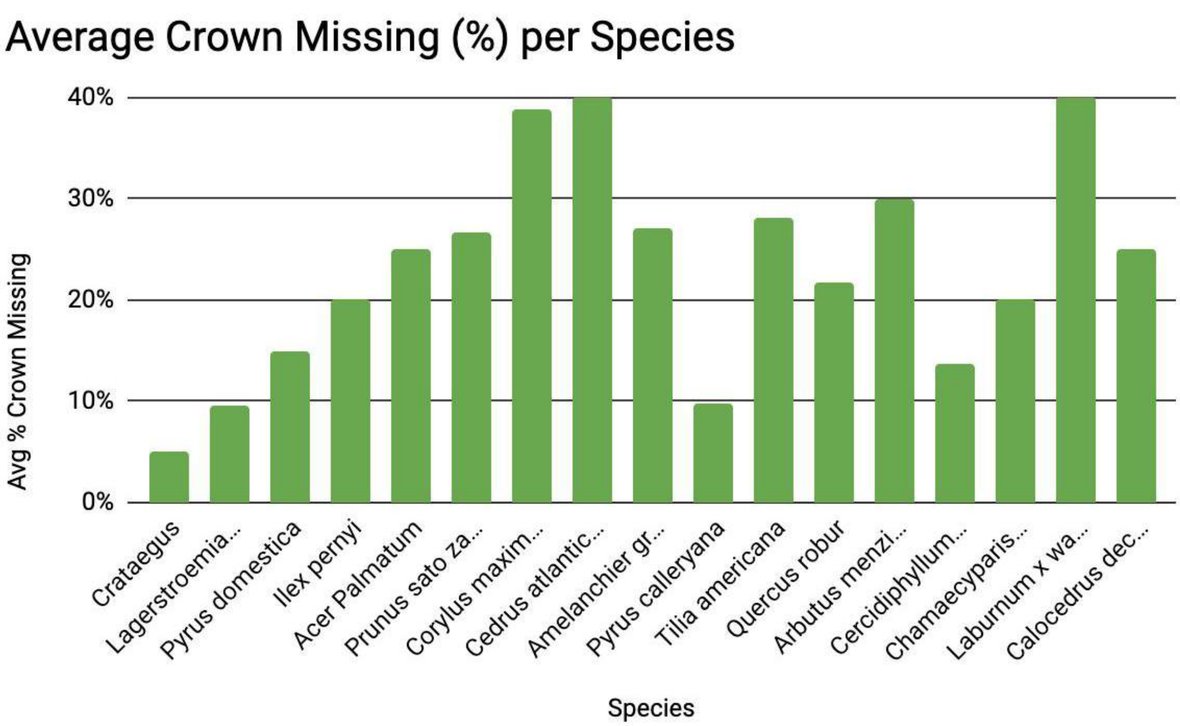
Graph 3 Crown Light Exposure



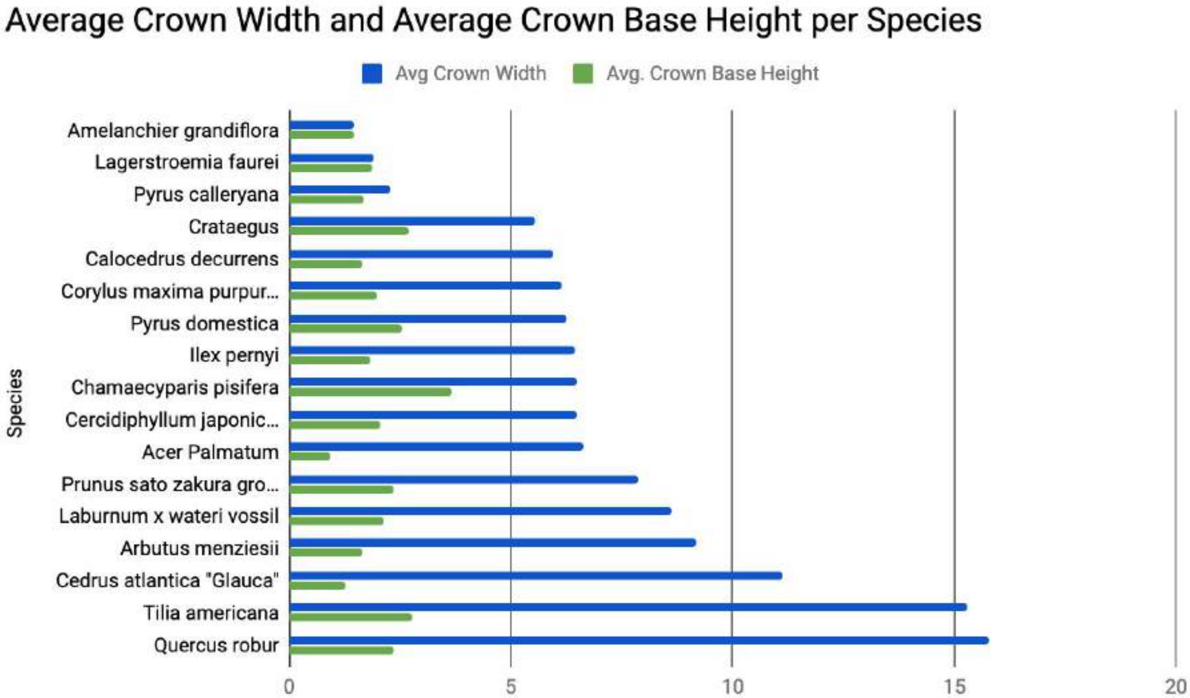
Graph 4 Difference in Total Tree height and Live Crown Height



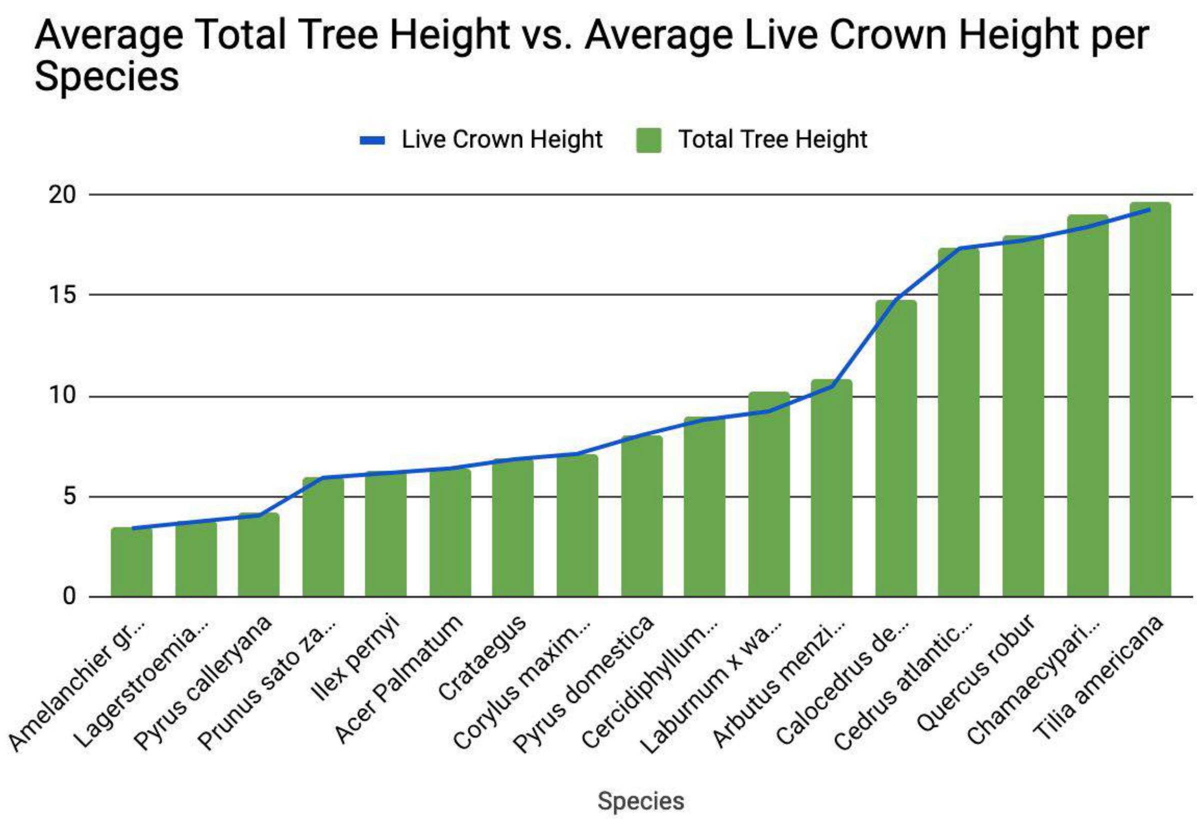
Graph 5 Average Crown Missing (%) per Species



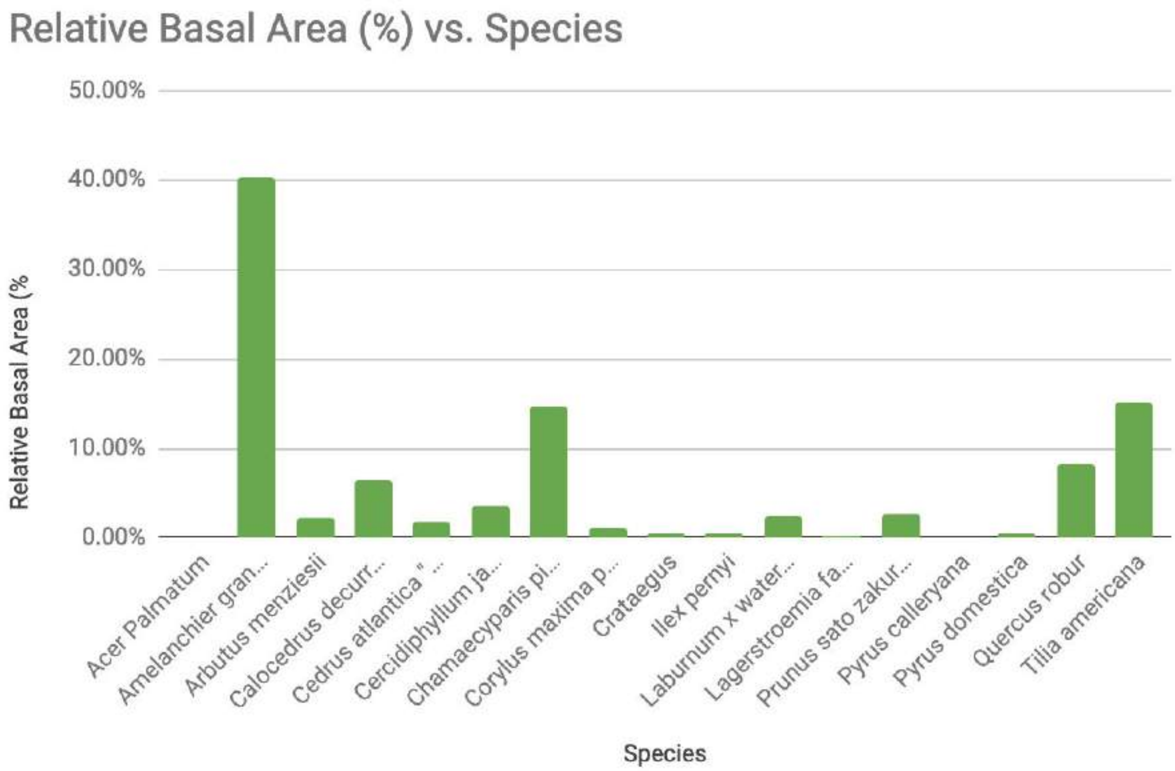
Graph 6 Average Crown Width and Average Crown Base Height per Species



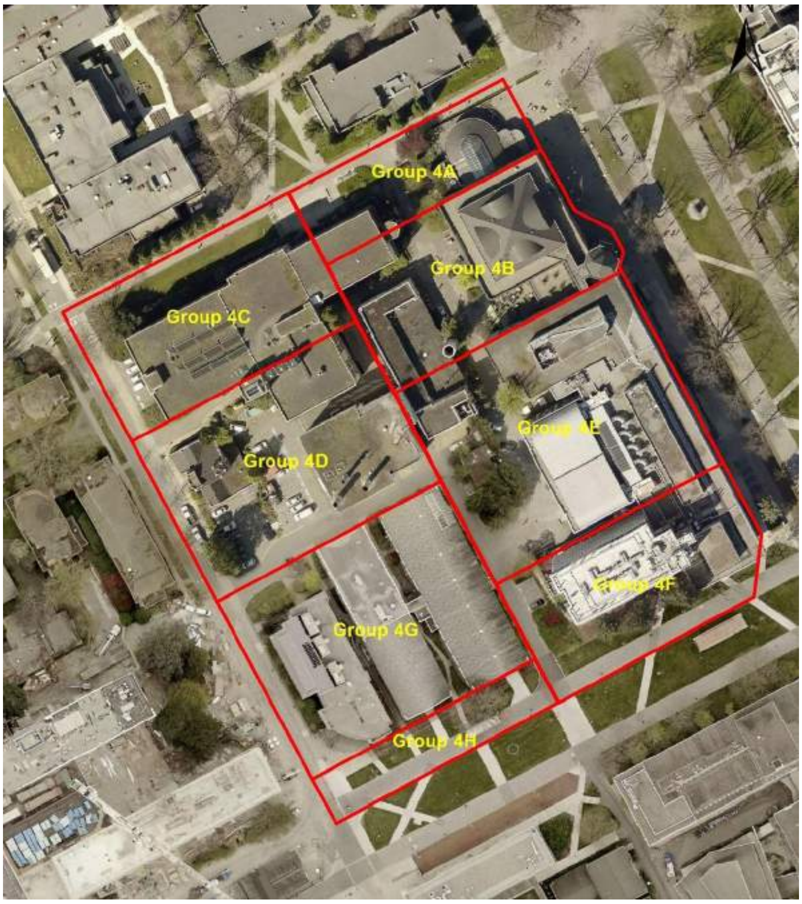
Graph 7 Average Crown Total Tree Height vs. Average Live Crown Height per Species



Graph 8 Relative Basal Area (%) vs. Species



GROUP 4 Ecosystem Services Report



Course: UFOR 101 201
Instructor: Dr Tahia Devisscher, Dr Lorien Nesbitt
Members: Kay Lin, Satyam Soni, Tim Su, Yiyang Wang,Grace Zhang, Yi Zhang
Date: April 2nd 2019

CONTRIBUTION DESCRIPTION

Kay Lin: Responsible for the method and the interpretation of regulating services. Finished the i-tree Eco and i-tree Canopy assessment. Formatting for the report.

Satyam Soni: Introduction and site description. References. Part of Urban Forest Planning and Management.

Tim Su: Urban Forest Planning and Management Recommendations. Creating experience dimension value graphs.

Yiyang Wang: Write cultural ecosystem services interpretation and outcomes;
Create hotspot and value coloring maps/ draw visualization of site recommendation (via Procreate software).

Grace Zhang: Describe the methods used to assess and quantify ecosystem services using the cultural ecosystem services value mapping process, drawing on activities and material covered in class. Discuss the strengths and weaknesses of the value mapping approach. Screenshot and editing pictures for regulating services, formatting for the report and appendix.

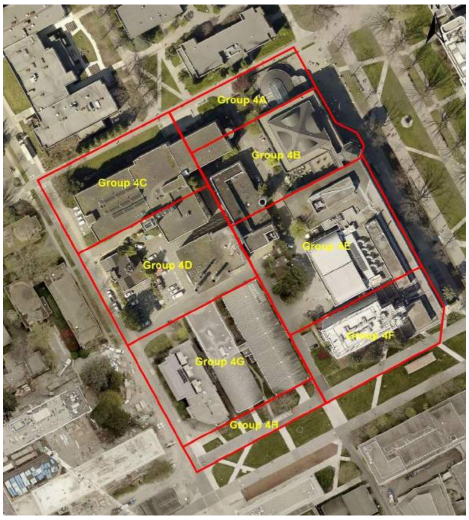
Yi Zhang: Responsible for the result and the interpretation of regulating services.

I. Introduction

The following report focuses on the next aspects of our site analysis: ecosystem service assessment. Ecosystem services are the different type of benefits provided by the ecosystem. It can be an ecosystem influenced by humans like an urban forest or an environment with limited human intervention. There are four different types of ecosystem services: provisioning services, regulatory services, cultural services and supporting services. Provisioning services include materials provided by the environment like food, timber, medicines etc. Regulatory services are the services which help manage and control other processes like stormwater management and microclimatic control in urban areas. Activities like tourism, social cohesion etc. are examples of cultural services provided by the ecosystem while supporting services includes services such as animal habitat and soil nutrient recycling. This report particularly focuses on regulating and cultural services of our site. We have used various inventory tools like i-Tree and i-Tree Eco to analyze these aspects of our site . This was done by using various metrics such as carbon sequestration, oxygen production, etc. We also found some areas in our site which have potential for improvement in terms of aesthetic appeal as well as better management.

Site Description

Our analysis included a thorough analysis of all the trees in a complete block of UBC campus. The block included the area cornered by Jack Bell and Leonardo S. Clink building on West Mall along with Triple O's restaurant and Henry Angus building on the Main Mall.



For analysis, our block was divided into eight smaller zones 4A - 4H. All these zones were separately analysed on each aspect while carrying out inventory so as to better understand the ecosystem services provided by the site.

The land in our site is primarily dominated by educational buildings, food outlets, coffee shops, a library as well as parking spots. A majority of the users of this site include UBC students, staff, workers followed by visitors or tourists. Our site includes various educational buildings along with parking spaces, cafes as well as eateries.

Interestingly, our site also includes a Powerhouse in Zone B which supplies potable water around UBC (Source: Energy and Water Services, UBC). Moreover we also found places within the site which includes run-down buildings and areas with limited human activities. These areas showed signs of improper management because of presence of trash spread around and therefore had scope for improvement.

II. Regulating Ecosystem Services

1. Method

During the process, two assessment models were used to measure the ecosystem service values and potential risks in our zone. One is i-tree Eco Model and one is i-tree Canopy.

To use i-Tree Eco Model, we preconditioned the inventory data of trees that have been measured in our site to fit the requirement of i-tree Eco Model. Using i-tree Eco Model to process our inventory data and send it to the i-tree eco and waited for the final report. Base on the hand write report that they sent back, we selected the information we need to continue the assessment.

To use i-Tree Canopy, we open i-Tree Canopy website and then defined our zone area on the map.100 points were selected and divided into trees and no-tree, all judgements are based on the group member who conducted the assessment. After that, we got the estimating report of ecosystem services values that base on the points we selected and divided.

1.1 Strength and Weakness

The strength of i-Tree Eco model is that it can generate more accurate report and it is more accord with the actual condition of our site because the model is run based on the inventory data which measured all trees in our zone. Furthermore, the handwrite report include many useful information such as avoid water run-off and pest risk. However, to increase the accuracy of the report, it needs actual inventory data to run the model and it also took time to get the feedback ecosystem services report, which is highly time consuming. The accuracy of report depends on how accurate our inventory data is. Our inventory data missed a part of trees that can not be measured in our zone, hence our ecosystem services report is less accurate.

The i-Tree Canopy is easy to conduct and we can get the result as soon as we finished the process. The accuracy of the report data is based on the number of points that are selected. Beside that, the judgement of whether a point belongs to tree or not is decided by group member, which is subjective and it will influence the accuracy of the data by the member's knowledge about the site. We chose 100 points for the assessment which is much less than standard amount of points that are needed to conduct the assessment which is 500, therefore, the data we received from i-tree Canopy are estimated values.

2. Result

2.1 Canopy cover:

The tree canopy cover is 17.2% and the non-tree cover is 82.2%. Table 1 shows the tree benefit estimates.

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	1.12 CAD	±0.25	1.27 lb	±0.28
NO2	Nitrogen Dioxide removed annually	2.02 CAD	±0.45	7.00 lb	±1.55
O3	Ozone removed annually	92.83 CAD	±20.49	54.09 lb	±11.94
PM2.5	Particulate Matter less than 2.5 microns removed annually	194.34 CAD	±42.90	2.76 lb	±0.61
SO2	Sulfur Dioxide removed annually	0.30 CAD	±0.07	3.44 lb	±0.76
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	63.57 CAD	±14.03	15.35 lb	±3.39
CO2seq	Carbon Dioxide squestered annually in trees	345.09 CAD	±76.17	5.62 T	±1.24
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	8,666.41 CAD	±1,912.95	141.02 T	±31.13

Table 1

2.2 i-Tree Eco Report:

Urban Forest Cover and Leaf Area: Trees cover about 33.83 thousand square feet of zone 4 and provide 3.998 acres of leaf area. In zone 4, the most dominant species in terms of leaf area are sycamore spp, Sawara false cypress, and European white elm. The 10 species with the greatest importance values are listed in the table below.

Species Name	Percent Population	Percent Leaf Area	IV
sycamore spp	6.6	14.0	20.6
Sawara false cypress	4.9	13.4	18.4
European white elm	3.3	12.6	15.8
holly spp	11.5	2.7	14.2
English holly	3.3	10.5	13.8
maple spp	9.8	2.4	12.2
European beech	9.8	2.2	12.0
Austrian pine	3.3	8.3	11.6
Japanese maple	6.6	4.3	10.8
plum spp	6.6	4.1	10.7

Table 2

2.3 Air Pollution Removal by Urban Trees

Pollution removal was greatest for ozone (Figure 1). It is estimated that trees remove 27.96 pounds 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$1.91.

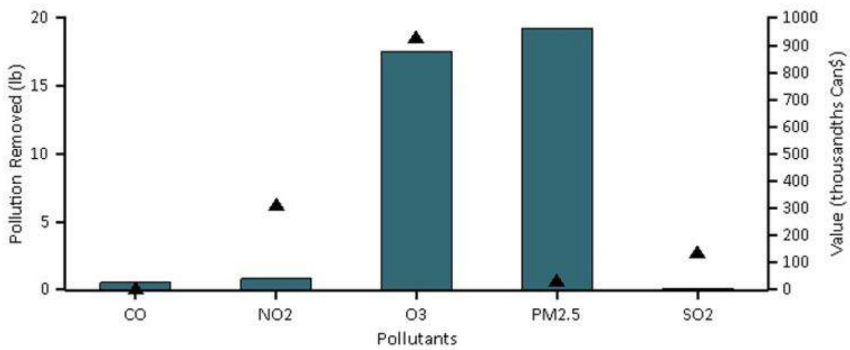


Figure 1

In 2019, trees in zone 4 emitted an estimated 7.293 pounds of volatile organic compounds (VOCs) (3.336 pounds of isoprene and 3.957 pounds 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. Forty- two percent of VOC emissions of the urban forest were from Austrian pine and sycamore spp. These VOCs are precursor chemicals to ozone formation.

2.4 Carbon Storage and Sequestration

The gross sequestration of zone 4 trees is about 1382 pounds of carbon per year with an associated value of Can$72.(figure 2)

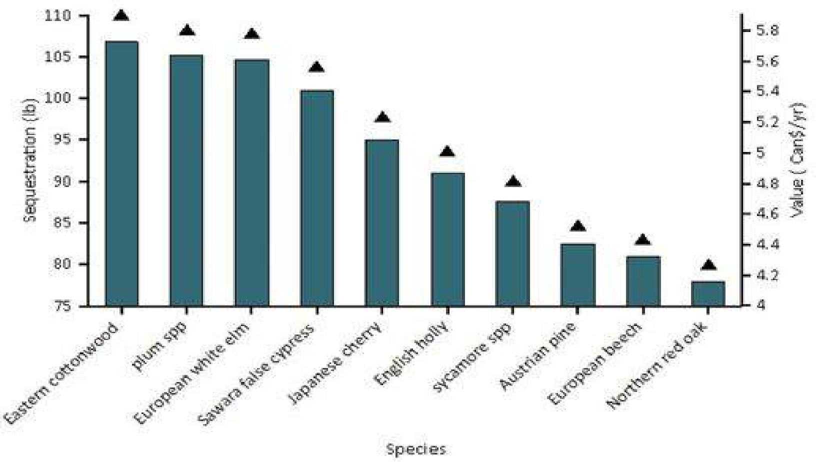


Figure 2

Trees in zone 4 are estimated to store 22.5 tons of carbon (Can$2.35 thousand). Of the species sampled, Sawara false cypress stores the most carbon (approximately 12.4% of the total carbon stored) and Eastern cottonwood sequesters the most (approximately 7.95% of all sequestered carbon.)(figure 3)

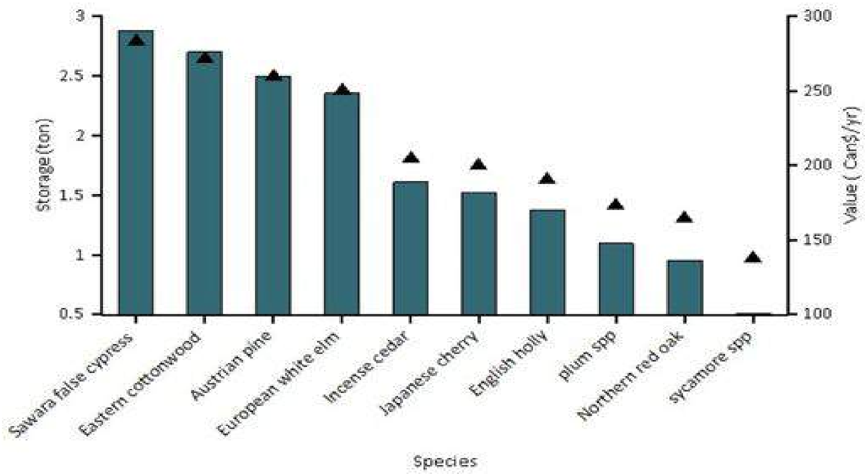


Figure 3

2.5 Oxygen Production

Trees in zone 4 are estimated to produce 1.843 tons of oxygen per year. (See in appendix A)

2.6 The similarities and differences

Both two tools show the canopy cover, but it is expressed by percentage in I-tree canopy and is expressed by exact size in i-Tree Eco. In terms of absorption of pollutants, i-Tree Canopy shows the removal amount and value of seven kinds of polluting gases, but I-tree eco report shows only five types of polluting gas absorption and value without PM10 and CO2. It shows the amount and value of carbon sequestration and storage per year. It also shows the value of top 10 tree species in the form of a histogram. In terms of the amount, the absorption amount of CO is consistent in the results of the two tools. The absorption amount of NO2, O3, and SO2 are all higher in i-Tree Canopy, and the absorption amount of PM2.5 is higher in I-tree eco. In terms of the value, the value of O3 and PM2.5 is all higher in I-tree eco. The value of CO, NO2, and SO2 is consistent in the results of the two tools.

In addition to pollutant removal, carbon sequestration, and storage, as well as canopy coverage, the i-tree eco report also presents other regulating ecosystem services, including oxygen production, runoff avoidance, and energy-saving function. So it is more specific. The data of i-tree eco report come from our field survey, so they are more accurate and reliable.

3. Interpretation

The result of i-tree canopy shows the service of carbon sequestration, climate regulation, and air purification. Canopy coverage determines the ability of trees to absorb carbon and regulate temperature. The low canopy coverage in the result indicates that the trees in the zone do not have an excellent ability to absorb carbon, so the ability to curb climate change will be weak. Moreover, it does not provide enough area to regulate temperature. However, trees in this area absorb a variety of pollutants, and the amount of ozone is the highest, demonstrating their good ability to purify the air. In the i-tree eco report, in terms of pollutant absorption, the sycamore spp has the highest percentage of leaf area with an excellent ability to absorb pollutants. However, this species emits a large amount of volatile matter, which can cause the formation of ozone and thus offset some of the environmental benefits. In the map of our zone (Figure 5), the location of this tree species is in the orange circle, indicating that the trees in this area have a strong function of pollutant absorption. The absorption of various pollutants also reflects the ability of trees in this area to clean the air. Next ecosystem service is carbon storage and sequestration which helps to mitigate climate change. The Sawara false cypress stores the most amount of carbon. In the map of our zone, the location of this tree species is in the red circle, indicating that the trees in this area have a strong function of carbon storage. Eastern cottonwood has the highest amount of carbon sequestration and produces the largest amount of oxygen. In the map of our zone, the location of this tree species is in the purple circle, indicating that the trees in this area have strong functions of carbon sequestration and oxygen production to improve the air quality.

The trees in our site help reduce approximately 2.36 thousand cubic feet of water run-off a year, which worth about Can$160. The sycamore species, Sawara false cypress and European white elm are the top three species that help avoid most of water runoff in the zone. It is important to take these three species into consideration when we are planning to improve the regulating ecosystem services of this area.

The report shows that Asian longhorned beetle (ALB) has the biggest threat to trees in our zone. About 18% of trees of the site can be threatened by ALB, which has a potential loss of Can$12.2 thousand in structural value. Southern pine beetle has the highest potential loss which worth Can$28.1 thousand in structural value. It attacks most of pine species in our zone, such as loblolly, Virginia, pond, spruce, shortleaf, and sand pines. Therefore, it needs to pay more attention on the pest impact and compensatory value of the trees we selected to plant in our site.

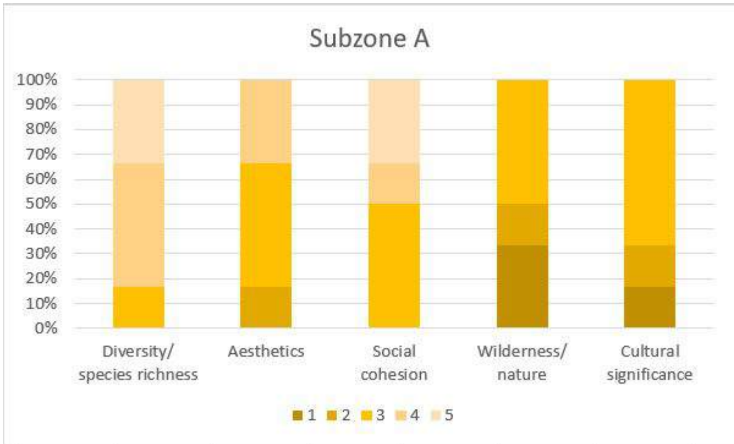
II. Cultural Ecosystem Services

When assessing the cultural ecosystem services, we started with an experience value survey. The survey is an evaluation sheet that contains five ecosystem services, and everyone in the group has an opportunity to present their thoughts toward our zone. The three cultural services that we measured are specifically social cohesion, cultural significance, and aesthetics.

Group 4

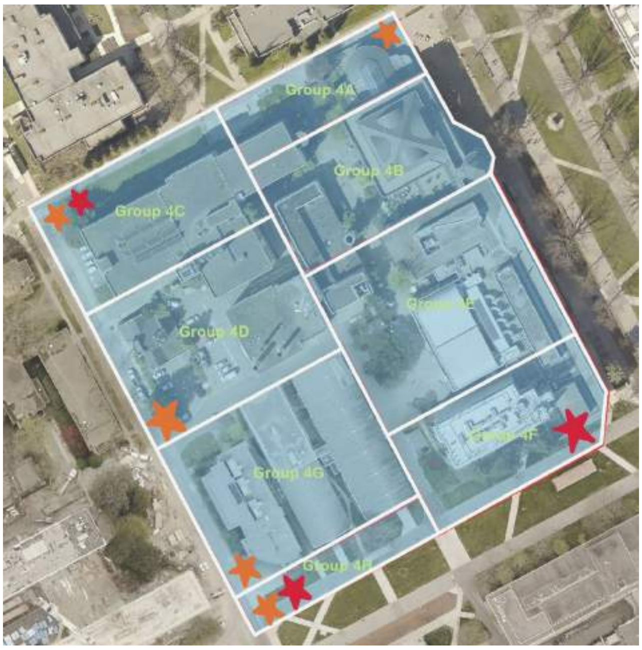
	EXPERIENCE DIMENSIONS				
Subzone ID	Diversity/ species richness	Aesthetics	Social cohesion	Wilderness / nature	Cultural significance
SUMMARY					
A	19	13	17	7	9
B	12	6	10	9	5
C	15	13	13	12	11
D	15	11	13	5	8
E	16	9	9	9	4
F	12	13	10	5	7
G	10	12	13	6	8
H	14	14	17	6	4
AVERAGE					
A	3.2	2.2	2.8	1.2	1.5
B	2.0	1.0	1.7	1.5	0.8
C	2.5	2.2	2.2	2.0	1.8
D	2.5	1.8	2.2	0.8	1.3
E	2.7	1.5	1.5	1.5	0.7
F	2.0	2.2	1.7	0.8	1.2
G	1.7	2.0	2.2	1.0	1.3
H	2.3	2.3	2.8	1.0	0.7
Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)					

The picture above shows the summary and average score for the entire group. While we are making the assumptions, we considered some aspects that helped us to interpret values. Within social cohesion, the associations that we looked at were communication, the sharing of resources, and the community buildings. Moreover, for aesthetics values, we paid attention to the available spaces that students and staffs could occupy. Also, the attractiveness of recreational value was also recognized. As for the cultural services, the cultural significance was not visible, most of the infrastructures were new.



Based on the summary of the survey, we came up with one chart for each subzone. As shown in the graph, the chart is very straight forward, and all the values are presented. Finally, we colored the map of our zone according to the values and marked down the hotspots by stars in the subzones (as shown in picture 1 and 2 below). Different colors of the stars represent different service dimensions, and the size of the stars are various relative to their scores (proportions).

The strength of the value mapping approach is that the graphs are made according to the result of the survey which involves various opinions. Each individual might have different perceptions of recreational and aesthetic values based on their different backgrounds. It is a benefit to generate a summary value map that incorporates diverse objectives. Although we can consider diversity as a strength, it can also become a weakness when the scale of the survey is significant. For example, when we were examining the aesthetics value for our subzone G, only two people out of six scored above two. Preferences can predominantly affect the result for the value mapping.



Picture 1: hotspots in among subzones (red stars: aesthetics; orange stars:social cohesion

The hotspots are made to reflect the most significant value the subzones have. It is apparent that most of our zones have provided decent cultural ecosystem services, especially in aesthetics and social cohesion dimensions. The place where users tend to get social cohesion are mostly at the corner of two busy roads, or where crowds meet. For example, in A and H subzone, it is at the corner of two roads; in subzone D, it is at the downslope of the parking lot exit. However, of the three perspectives we covered in the survey, the cultural significance dimension is the most, not obvious. It got relatively low scores because there are less or no construction or landscape design showing culture elements, such as sculptures, totem column, etc.

Also, it should be pointed out that there are not stars in both B and E subzones, because the values of these three aspects are all below average as we assessed. The key reason is that ecosystem services users receive depend on the land use type the zone covers. Among the eight subzones, B and E are the only ones that have utility land use. The other subzones are mostly used as institutional or transportation (Group4_InventoryReport, 2019). There are a couple of powerhouses operated by UBC utility department at the back of Sauder Business Building in B and E areas. Additionally, there is a garbage disposal area at the border of A and B area, which belongs to the Triple O's and Tim Horton's cafe. All of these functions have made it hard for B and E subzones to provide users with a high quality of cultural ecosystem services.

Picture 2: value color mapping based on the average score

Moreover, we made color maps reflecting the distribution of one category of value around our zone. The darker color demonstrates the higher average score of one specific value. Overall, the distribution of cultural ecosystem services is unequal within our zone. When we look into the single service. When comparing aesthetics and social cohesion, we found out that subzone A and H rank high in both aesthetics and social cohesion. Because they are at at the vital geographical spot where there is a large volume of people, especially during peak hours. Additionally, there are popular campus cafes located close to or in the subzones (see picture 3). That is why not only constructions are visually appealing but the potential of social activities is high. Looking into the cultural significance color map, we noticed that even the highest mark is lower than the average score of the previous two aspects. But A and G have a relatively high score because we consider the UBC information technology located in these two zones have high historic value, which creates the cultural and aesthetic atmosphere for the users, including students and staff.

Picture: Triple-O’s cafe located at the corner of subzone A (Yelp, 2019)

III. Urban Forest Planning and Management Recommendations:

(Powerhouse in zone B)

After observations throughout our inventory, there are planning and management recommendations the group wishes to address. The first recommendation is to increase canopy cover over targeted areas. Displayed in the color mappings previously along with physical observations, subzones B and E lack aesthetic value due to poor canopy cover and poor management. By planting more trees and increasing green spaces, both regulating and cultural ecosystem services can be enhanced. More canopy cover increases carbon sequestration, this is especially important when there are multiple powerhouses located in the two zones which affects the air quality. While increase in green space will increase its aesthetic value, and create a more presentable environment.

(Tree in zone B)

(Tree in zone E)

Furthermore, there are specific trees in subzones B and E that requires management, which leads to the another recommendation which is better management and maintenance around targeted areas. Large trees should not be planted near building (shown in the two photos above) as this limits the health and growth of the trees itself. Because of limited growth space, theses trees were observed to grow away from the building, resulting in tilt of the trees. This could be very dangerous as the trees may collapse if no action is taken.

(Visualization picture drawn by Yiyang Wang)

Subzone C is rated relatively high in aesthetics value, the zone had high canopy cover and high species diversity, however, there is always room for improvement for each of the subzones, if there were benches put along the sidewalks for people to socialize and appreciate the green spaces, it will significantly increase the social cohesion value. This can be complemented by adding deciduous trees like Red Oaks which have a high aesthetic appeal because of their wide canopy. Moreover, the trees also allow sunlight to pass through during winter (as it loses its foliage) while keeping it shady during hot summer months.

Adding on, Subzone A has a high value of social cohesion, but there could be more canopy cover along the pavement walkways to further increase its aesthetic value. Once these recommendations are implemented, these zones would be perfect illustrations.

(Visualization picture drawn by Yiyang Wang)

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Energy and Water Services, UBC (n.d.). Water. Retrieved April 2, 2019, from http://energy.ubc.ca/ubcs-utility-infrastructure/water/

Group4_InventoryReport, (2019). UFOR 101 assignment 1.

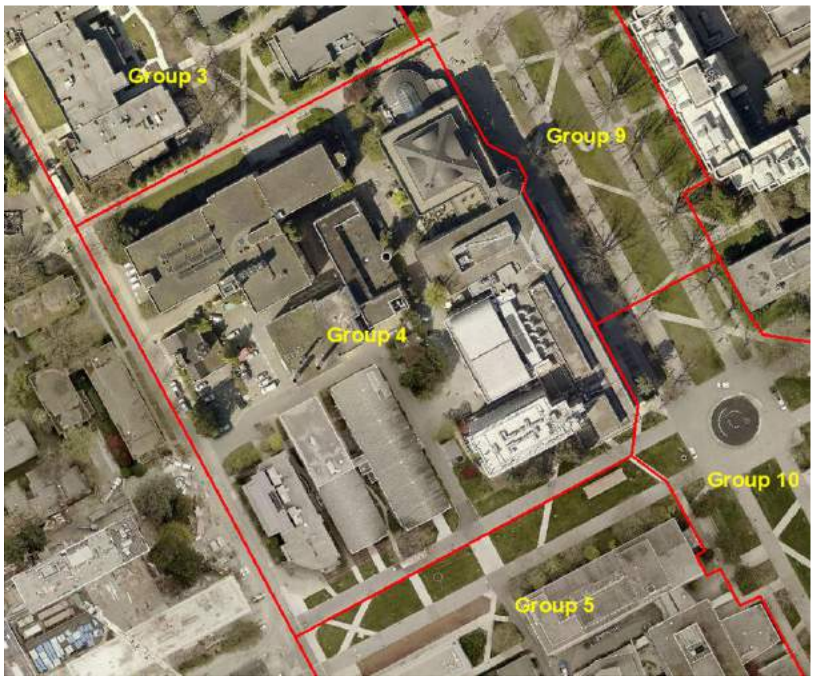
Photograph of UBC Triple O's, (2019). Yelp. Retrieved from: https://www.yelp.ca/biz/triple-os-vancouver-7

Appendix A

Table 2. The top 20 oxygen production species.

Species	*Oxygen (pound)*	*Gross Carbon Sequestration (pound/yr)*	*Number of Trees*	*Leaf Area (square feet)*
Eastern cottonwood	293.03	109.89	1	0.00
plum spp	288.37	108.14	4	0.01
European white elm	287.15	107.68	2	0.02
Sawara false cypress	276.51	103.69	3	0.02
Japanese cherry	260.18	97.57	1	0.00
English holly	249.06	93.40	2	0.02
sycamore spp	239.62	89.86	4	0.02
Austrian pine	225.42	84.53	2	0.01
European beech	221.01	82.88	6	0.00
Northern red oak	212.81	79.81	1	0.01
maple spp	180.73	67.77	6	0.00
serviceberry spp	152.30	57.11	1	0.00
Incense cedar	139.53	52.33	2	0.00
holly spp	131.87	49.45	7	0.00
White ash	115.35	43.26	2	0.01
Japanese maple	114.13	42.80	4	0.01
Eastern hemlock	76.12	28.55	3	0.00
katsura tree spp	67.11	25.17	3	0.00
Cherry plum	39.72	14.89	1	0.00
hazelnut spp	38.24	14.34	1	0.00

GROUP 4 INVENTORY REPORT



Course: UFOR 101 201
Instructor: Dr Tahia Devisscher, Dr Lorien Nesbitt
Members: Grace Zhang, Kay Lin, Satyam Soni, Tim Su, Yiyang Wang, Yi Zhang
Date: February 10th 2019

CONTRIBUTION DESCRIPTION

Kay Lin: Responsible for the content of methodology of total tree height and crown base height and participated in the summary and analysis; responsible for the measurement of total tree height and crown base height during the field work; participated in data tabulation.

Satyam Soni: Responsible for measuring DBH, crown light exposure, percent crown missing, and writing the introduction, site description and pictures, along with complete final editing and revision of the document.

Tim Su: Responsible for the content of methodology of DBH and Crown width. Responsible for Measuring DBH, crown width, total tree height, and crown base height.

Yiyang Wang: Responsible for the making the graph(summary table, land use graph) and writing relative content in the summary of the inventory data; Responsible for recording the data, evaluating CLE, and percent crown missing during the measurement process; Also tabulating part of the data into excel sheet.

Grace Zhang: Responsible for the content of methodology of percent crown missing, crown light exposure, data collection, and revision of the summary. Participated with the measurement of total tree height, crown base height and crown width during fieldwork.

Yi Zhang: Responsible for logging data into the excel with Yiyang Wang; Responsible for making the graphs of composition and abundance, DBH classes and Total height classes, as well as the analysis of the graphs. Downloading the app to guide group members and Participating with the measurement of total tree height, crown base height and DBH, etc during fieldwork.

Introduction

The plot for Group 4 had a diverse variety of tree types. Some were huge while others were tiny and while some were wide others were relatively narrow. We also found a few trees missing from the app and added their coordinates in the plot data. The following sections contain a detailed description of our analysis of the plot. The purpose of our study is to study the condition and size of the canopy cover on campus. This involves a detailed analysis of individual trees by assessing them on specific metrics like canopy height, width, etc. This will help the Urban Foresters and arborists on campus manage the UBC canopy cover more effectively by providing them with detailed information of trees on campus. Moreover, the data from the report will further help us in our ecosystem service assessment later this semester.

Site Description

Our analysis included a thorough analysis of all the trees in a complete block of UBC campus.The block included the area cornered by Jack Bell and Leonardo S. Clink building on West Mall along with Triple O's restaurant and Henry Angus building on the Main Mall.

The land in our site is primarily dominated by educational buildings, food outlets, coffee shops, a library as well as parking spots. A majority of the users of this site include UBC students, staff, workers followed by visitors or tourists. The image on the right shows various educational building in the site along with Parking spaces, cafes, etc. (Source: Google Maps)

On detailed analysis, it was found that there are areas within the site which includes run-down buildings and area with limited human activities. The site also included two trees which were missing from the online app. The trees were marked M1 and M2 in the inventory data, and their accurate coordinates were noted using Google Maps.

Methodology

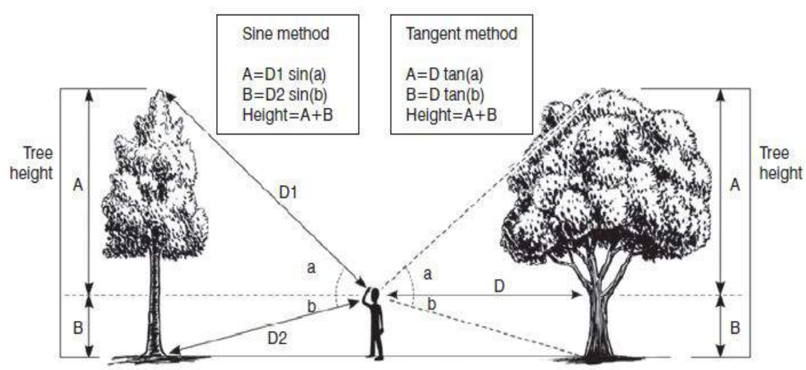
<table>
<tr><th>Methodology</th><th>Tools</th><th>Description</th></tr>
<tr><td>Total Tree Height Measurement</td><td>Clinometer
Eslon tape</td><td>

- We chose a place where the distance is about the tree height or more than tree height. Making sure that the top and the base of the tree can be seen clearly from the space and the sighting to the top of the tree is no greater than 60° and the sighting to the base of the tree is larger than -15°. Otherwise, there would be an error during the measurement.
- After choosing the place, the next step is to hold tight the tape and measure the horizontal distance between the eyes of the person and the tree that will be measured by using the eslon tape and then read the value.
- Using the clinometer to look at the top (a°) and the base (b°) of the tree and read the value at the same place. There are left and right two scales that can be read. The left scale is the degree and the right scale is the percentage. The one we chose is the left scale which shows the degree of the line of sight to the horizontal distance.
- We estimated the tree height by using trigonometry. Taking the values that we read before and using the formula:

  $Tree\ Height = (tan\ a^\circ + tan\ b^\circ) \times Distance$ (Upslope)

  $Tree\ Height = (tan\ a^\circ - tan\ b^\circ) \times Distance$ (Downslope)

  Then we got the final estimation of tree height.



(Ferrini,2017)

</td></tr>
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Height to Crown Base	Clinometer Eslon Tape	**Method 1 (High Crown Base)** ● We chose a place from where the crown base and the base of the tree can be seen clearly. ● After choosing the place, the next step is to measure the horizontal distance between the eyes of the person and the tree. ● We chose the lowest live foliage on the last branch in the live crown as the crown base. ● Using the clinometer to look at the crown base (a°) and the base (b°) of the tree and read the value of the left scale which shows the degree at the same spot. ● We used the formula: ● $Crown\ Base\ Height = (tan\ a^{\circ} + tan\ b^{\circ}) \times Distance$ (Upslope) ● $Crown\ Base\ Height = (tan\ a^{\circ} - tan\ b^{\circ}) \times Distance$ (Downslope) ● Then we got the final estimation of Crown base height. **Method 2 (Low Crown Base)** ● We chose the lowest live foliage on the last branch in the live crown as the crown base. ● Using the eslon tape to measure the height from the ground to the lowest live foliage on the last branch in the live crown.
Diameter at Breast Height	Diameter Tape	● For consistency, one member was dedicated to measuring the DBH. ● DBH measured 1.37 meters above ground, using the diameter tape, measure from ground 1.37 meters on the person's body and make a mark. (Avoids measuring 1.37m from the ground for every tree). ● Stand as close to the subject tree (uphill side if slope present), label the point on the tree that corresponds/is parallel to the point on the person's body. ● Using the diameter tape, measure the DBH from that point, record the data. ● Repeat **Tree with multiple stems** ● Measure DBH of up to six stems (selecting largest ones if more than six total) ● Overall DBH = the square root of the some of all squared stem DBHs **Tree with irregularities at DBH** ● Measure slightly above 1.37 meters where there are no irregularities/branches.

Crown Width	Eslon tape	● Two people required ● Using observations, deduce the side with the longest crown width, start measuring from that position. ● One person holds the Eslong tape and stands directly below one end of the tree crown, the other extends the tape to the other parallel end of the crown, take the measurement and record. ● Rotate 90 degrees and repeat. ● Take the average of the two measurements.
Percent Crown Missing		● Two people need to participate when assessing the percent crown missing. Both should stand perpendicular to the tree so that they can see the entire tree while making an assumption about the percent foliage absent. Percent of Crown missing estimation mainly relies on observation, and the conclusion is made after combining two people's feedback. The difficulty confronted during fieldwork was that deciduous trees do not have foliage covering during winter. Although the assessment could be accomplished, the result for percent crown missing might slightly imprecise.
Crown Light Exposure		● The crown light exposure indicates the different directions of trees receiving sunlight. The maximum of crown light exposure is from five sides, which include front, back, left, right and top. Not all the trees have five sides, trees that planted close each other will not receive direct light due to other trees blocking.
Data collection		● During fieldwork, one person in the group is responsible for recording the data and marking down trees that have already measured. While organizing the data, there is more information that should include are tree tag (if exist), tree ID, tree species and particularly land use. Most of the info can be found on the tree app, and land use is determined according to the i-Tree Eco categories.

Summary of the inventory data

Effective management and ecosystem services evaluation are impossible to be carried out without detailed data collections on the location, structure, and condition descriptions of trees

(Nowak et al., 2008). The variables we measured during the inventory mainly fall under the categories of location(land use), 1D structure(DBH, total tree height, base height, and crown width), and condition(crown light exposure and crown missing) (Ferrini,2017). We calculated the original data and expanded into more categories, for example, the 2D structure(basal areas). Interpreting the quantitative data into the graphs help us and the end users understand the integral structure of the forest in the area.

	Live	SD	dead	trees with missing data	trees not in the app
Tree	82		0	20	2
Species	26				
DBH mean(cm)	30.33	±23.25			
BA mean(m)	0.11	±0.16			
total height mean(m)	11.90	±7.40			
crown base height mean(m)	3.94	±16.45			
crown width mean(m)	8.13	±7.86			
crown missing					
<10%	26				
11-30%	26				
31-50%	16				
51-80%	3				
>80%	0				
unclear	11				
Crown light exposure					
0	5				
1	4				
2	8				
3	15				
4	28				
5	22				

Table 1: Summary Table

As we can see from the summary table, the SD(standard deviation) of the DBH is the highest among that of all the attributes. However, this does not mean that the diameter varies the most among all the attributes. When converted into meters, the crown based height shows the highest diversification. That is because, during measurement, we see some of the trees have their lowest branch on the ground, which means the base height is zero. We also notice that the DBH as well as the basal area show low variation among different trees in the inventory area.

Most trees in the inventory area have the crown missing rate under 50%, which shows a decent average health condition of trees and the maintenance work conducted by the concerned personnel. No trees in the area have a canopy missing above 80%. Additionally, the proportion of trees which are growing with little exposure is low. Although the construction on campus can block some of the sunlight, most of the trees enjoy light exposure from 3 or more directions. There are no dead trees in the area.

Photo1(by Yiyang Wang): The stem covered by dense leaves.

It should be noted that there are two trees which are missing from the App. In order to supplement the database of the App, we collected all their information and put down the coordinates of their longitude and latitude using google map. During the measurement, we missed some of the data due to the inconvenient condition of the tree location. Some of the trees have a dense crown cover at breast height, where we are not able to measure the DBH (Photo 1); some surrounded by the large thorn shrub, which means we cannot measure the total and base height using Elson tape.

Photos by Yiyang Wang

Table 2: Land use distribution

According to the pie chart derived from the data, about 58% of the trees are located in the institutional areas (Greenland close to faculty buildings). The vacant land, including the large unmaintained area, takes up the second largest share at 12.15%.

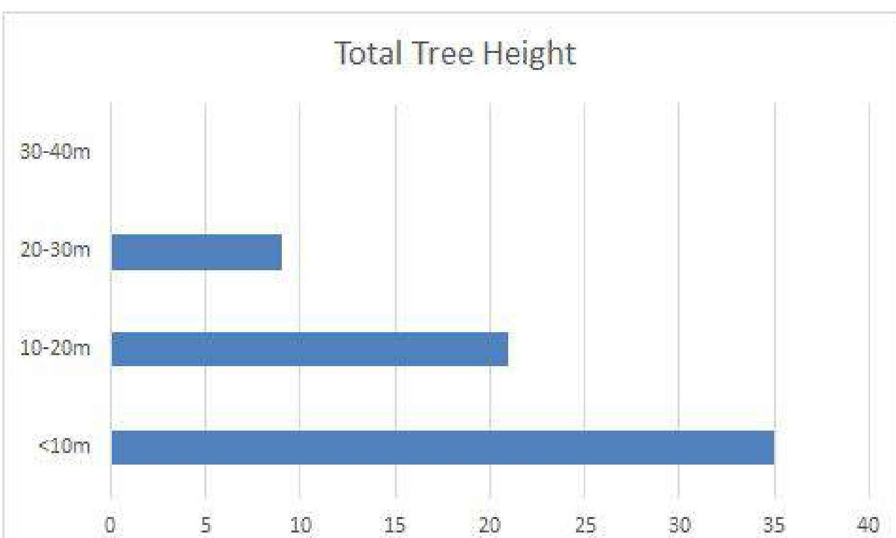

Table 3: Total height classes

It is evident from the graph that most of the trees in the inventory areas are no more than 20 meters. Also, the trees that are not higher than 10 meters have the largest population. The reason why those trees are relatively short is that they are planted in recent years. The average of the total tree height is 11.90 meters, with a moderate standard deviation at 7.4 (see summary table). There are no trees taller than 30 meters in the area.

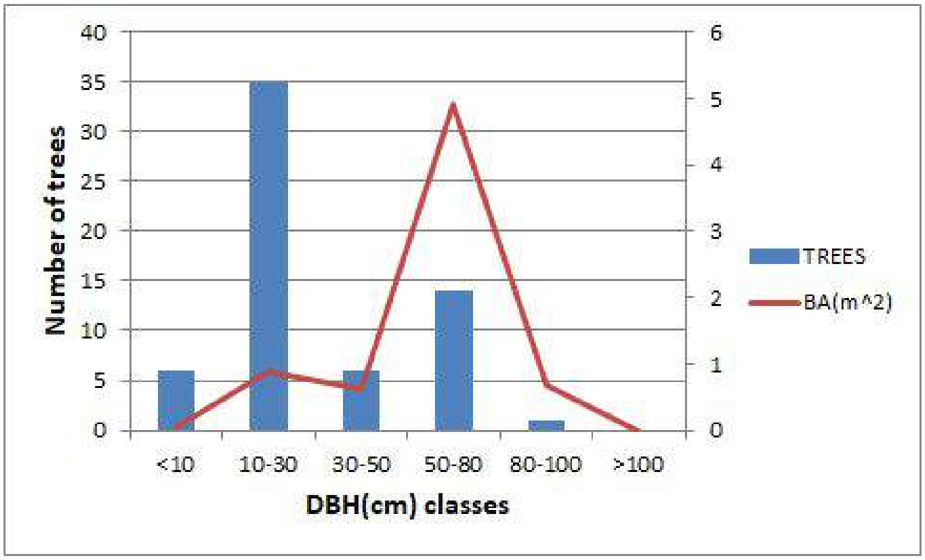

Table 3: DBH classes

As for the DBH classes, the trees are mainly in the range of 10 to 30 cm in DBH. The basal area is the highest in the DBH classes of 50-80 cm. The number of trees which are in the range of 80-100 has the lowest number. We can see that there are mainly small trees in this plot.The tree species in 50-80 DBH classes have the medium number of trees.

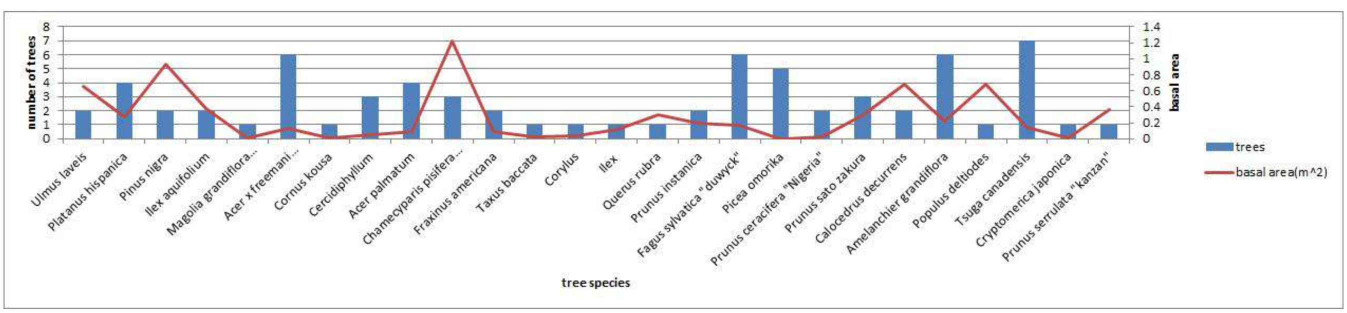

Table 4:Tree composition and abundance

There are 26 tree species in total in the inventory area. As for the tree composition and abundance, the *Acer x freemani "armstrong"* and *Fagus sylvatica "duwyck"* and *Tsuga canadensis* are the dominant tree species in the plot. The number of *Tsuga canadensis* is the highest, while the number of *Magnolia grandiflora "little gem"* is the lowest. The *Tsuga canadensis* is known as the eastern hemlock, which is a native species around Canada (NAL

Digital Repository). As for the basal area, the *Chamecyparis pisifera squarrosa* has the largest sum of the basal area, while the *Cryptomerica japonica* has the lowest. From the graphic, we can see that the richness of the plant in the plot is high because there are more than 20 species in the plot, but the evenness is low because the number of some tree species such as *Acer x freemani "armstrong"* and *Tsuga canadensis* is more than 5, while the number of most of the tree species is 1 or 2. Some trees have the small basal area with the large number of tree species such as the *Amelanchier grandiflora*, while some trees have the large basal area with the low number of tree species such as *Chamecyparis pisifera squarrosa*. There is a large number of *Acer palmatums*, for the reason that this tree species has high aesthetic value for students, faculty members, and visitors. The *Chamecyparis pisifera squarrosa* in a row is used as the separation between different park lot.

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Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E., Walton, J. T. and Bond, J. 2008a. A ground based method of assessing urban forest structure and ecosystem services. Arboriculture and Urban Forestry, 34, 347–358

NAL Digital Repository.Temporal and spatial variation of terpenoids in eastern hemlock (tsuga canadensis) in relation to feeding by adelges tsugae. Temporal and Spatial Variation of Terpenoids in Eastern Hemlock (Tsuga Canadensis) in Relation to Feeding by Adelges Tsugae,

Ecosystem Services Assessment and Analysis

Group #5

April 3, 2019

Tyler Doucet
Jeannine Felix
Diana Satkauskas
Michael Spenrath
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Contributions:

Tyler Doucet:

- Regulating Ecosystem Services
- Wilderness and Nature Significance

Michael Spenrath:

- Visual Mapping Images
- Photoshop Images
- Introduction
- Cultural Significance
- Cultural Ecosystem Services

Maija Wootton:

- Site Description
- Photos

Diana Satkauskas:

- Introduction
- Diversity and Species Richness Significance
- Management Recommendations
- Editing

Jeannine Felix:

- Value Mapping Introduction
- Social Cohesion Significance
- Aesthetics
- Editing

Introduction:

The purpose of our ecosystem services assessment and analysis is to use our site data collected throughout the term, along with the results from i-Tree Eco, i-Tree Canopy, and the numerous value mapping exercises performed to inform the UBC stakeholders about the ecosystem services in the site. With this information we can provide some management recommendations to maximize the benefits our site provides to the campus as a whole.

Ecosystem services are the benefits that people obtain from ecosystem functions. These benefits can be direct or indirect (Bolund & Hunhammar, 1999). They are divided into four broad categories: supporting, regulating, provisioning, and cultural. Supporting services are derived from the basic functioning of any ecosystem. These services can include nutrient cycling, photosynthesis, and soil formation. Services which help regulate air quality, stormwater, pollination and water purification are referred to as regulating services. Provisioning services provide people with food, fresh water, medicine, and energy. Lastly, cultural services which cannot be monetized, include the benefits gained towards mental and physical health, recreation, ecotourism, aesthetics, and spirituality. However, in this report only regulating and cultural ecosystem services will be assessed and analyzed in depth. The maps depicting supporting and provisioning services may be found in the Appendix.

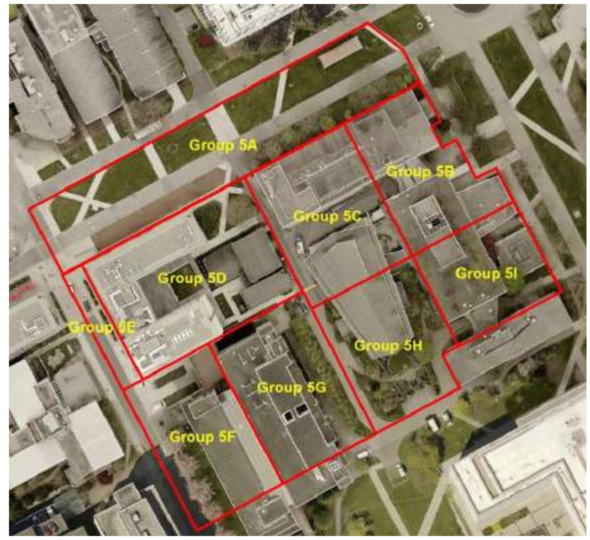
The stakeholders of our site include: UBC SEEDS, Campus and Community Planning, Building Operations, the current students and staff of UBC who interact with its urban forest, along with prospective students and guests of the campus. Using the results of our ecosystem services assessment and analysis, these UBC stakeholders can obtain information that can better inform their decisions when creating a management plan for UBC's urban forest.

Due to there being an unforeseen large amount of trees on our site, we only completed a tree inventory of subzones 5B, 5C, 5I, 5H and half of 5A. To create the ecosystem services maps of the site seen later in the report, we used the results of i-Tree Eco and i-Tree Canopy to the rank the prominence of the ecosystem services in these subzones. The ranks of the other subzones, 5D, 5G, 5F, 5E and the other half of 5A, were based on visual observation alone.

Site Description:

Centrally located on the UBC campus, site 5 sits on the northwest corner of the Martha Piper Plaza, known for having the UBC fountain. Being located on school grounds, the site was classified as an institutional land type, providing services to students, faculty, and staff on campus. To evaluate the ecosystem services, the block was further divided into nine subzones, visible in Figure 1, to be able to further elaborate on the details of the different areas and variances between them. The site is bordered by a service road, the Scarfe building itself, frequently used walkways, and an open courtyard between buildings.

Figure 1



Observing how the land is used, not many recreational activities were noticed in the area while completing the tree inventory. There is a large abundance of impermeable surfaces across the block, mostly for vehicle accessibility and areas with heavy foot traffic. The green spaces and trees throughout perform a sufficient job at mediating the harsh impact of the hard surfaces. An example of this would be the courtyard, as it serves many purposes: celebrating Aboriginal culture by showcasing their artwork (Figure 2), providing a garden for people to enjoy, and adding an aesthetic appeal for the surrounding offices that overlook it (Figure 3).

The trees themselves serve different purposes. There were much more trees than shrubs throughout the entirety of the site, with the majority of the trees planted in close proximity to the buildings in the area. This aids in regulating temperature by mediating winds, decreasing the amount of harsh sunlight that enters the building, and providing a natural view for the people inside. Trees were also used to create multiple smaller areas within larger ones, in order to create multipurpose spaces. An example of this is shown in Figure 4, where a parking lot is separated from the garden by a row of trees and shrubs.

Figure 2

Figure 3

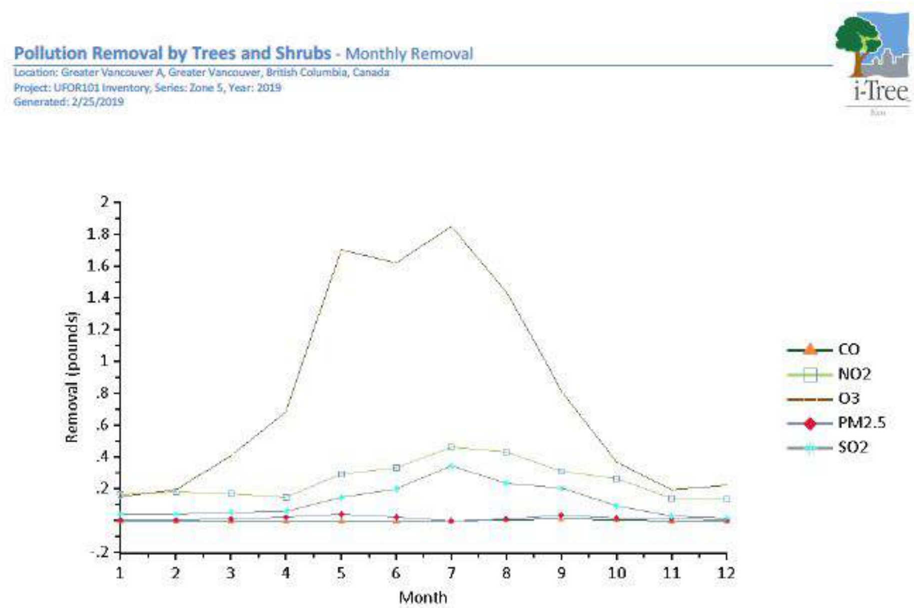
Figure 4

Regulating Ecosystem Services:

The regulating ecosystem services results were drawn from i-Tree Canopy's and i-Tree Eco's analysis and benefits assessments of the site. Using the data compiled by i-Tree Canopy and i-Tree Eco, the group's observations, and course content, we were able to use prominence mapping to hone in on the services provided by each subzone in the site (seen in Figure 5). Various regulating ecosystem services were considered, including carbon sequestration and storage, pollination, air control, moderation and removal of pollution, water regulation, among others.

Upon using both the i-Tree Canopy and i-Tree Eco programs to assess the site's function and value, it became evident that little variation existed amongst the results. i-Tree Canopy estimates tree benefits based on the canopy cover of areas, results for our site can be seen in the Appendix. i-Tree Eco provides assessments based on not only groupings of trees, but individual trees and their species composition and structure. The benefit results from both methods were examined and considered when compiling results for mapping to err on side of caution. The values of the benefits appeared to be the same with both softwares, however a benefit of using i-Tree Eco was because more variables other than canopy cover are taken into account, it is more accurate upon estimating the values of individual trees. For example, the results of the i-Tree programs found the site to have a gross carbon sequestration of 164.15 kg/yr. However, i-Tree Eco assessed the species *Salix spp.* to sequester 25.34 kg/yr, allowing further assessments and data to be compiled on specific subzones, specific species, and individual trees. When looking at individual trees, i-Tree Eco has a more comprehensive assessment because of its ability to compile data on individual trees as opposed to groupings of canopy.

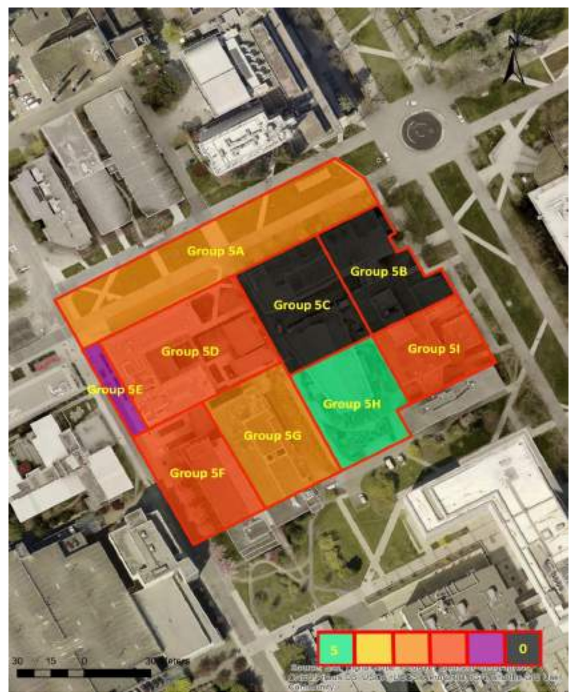
Figure 5



The advantages of using the i-Tree Canopy and i-Tree Eco models to assess regulating ecosystem services are that the results provide a quantitative, numerical value, providing an accurate representation of the site's benefits as a whole. i-Tree Canopy and i-Tree Eco however do not account for all variables, rather just the trees inventoried. It is limited in identifying other variables, such as the bee habitat found in the site. These variables are not accounted for in i-Tree, thus when using only this software users are restricted in their ability to understand the full value of their site and manage it accordingly. Compiling the i-Tree Canopy results and our personal observations to create a prominence map proved to be the most effective means of evaluating regulating ecosystem services.

Our i-Tree Canopy results concluded that our area currently has approximately 25% canopy cover with a 4.29% Standard Error. As a site, the i-Tree Canopy survey determined that annually the trees in the site removed 1.53 kg of NO2, 10.20 kg of O2, and 3.19 kg of PM10, contributing to the overall pollution removal of the trees in the site. Graphed above (Figure 5) is the i-Tree Eco report on the monthly removal of pollution, displaying similar results of pollution regulation as i-Tree Canopy. Currently stored in the site is approximately 56.12 tonnes of CO2, equivalent in weight to roughly 10 Asian Elephants (weighing ~ 5.4 tonnes) and has a gross carbon sequestration of 164.15 kg/yr, equivalent in weight to one Fraser's dolphin (weighing ~164 kg).

Figure 6



Upon mapping the site, it ranked on average 2 points out of a potential 5 on our point system scale. Significant variations between different subzones exist within the site. Two areas, Groups 5C and 5D received zero points in terms of regulating ecosystem services, as they were predominantly composed of buildings. Area 5H has a pond contributing to stormwater regulation, as well as a bee habitat introduced by UBC students, which ultimately contributed to the site receiving a full 5 points. While it is not calculated within i-Tree, "insect pollination of wild plants is a critical life-supporting mechanism underpinning ecosystem services (Vanbergen. A, 2013, p.251)", and provides benefits to not only the trees and plants in its subzone, but in the surrounding area as well. Group 5I which received two points, includes the two large *Salix spp.* that contribute to roughly 15% of gross carbon sequestration at 25.34 kg/yr.

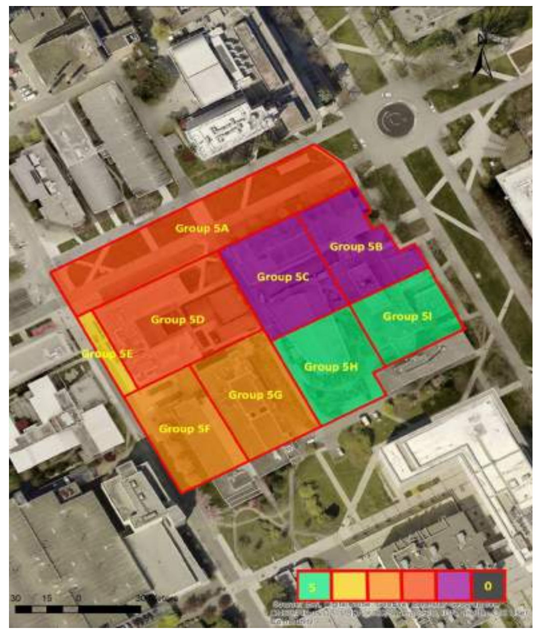
The site's trees were relatively small as determined in our initial inventory and assessment, as seen in the i-Tree Eco assessment which states that 75.7% of trees were less than 6" in diameter. This was evident in the low scoring for regulating ecosystem services, as they did not provide as many functions and benefits as fully mature trees may have.

Value Mapping:

As part of the cultural assessment of the site, the subzones were each ranked on a scale from zero to five in terms of the prominence of the value in the subzone. Each member ranked the value based on their own opinion, then the average of these numbers represented the ranking of the subzone. The values assessed and illustrated in the following section are: Diversity and Species Richness, Aesthetics, Social Cohesion, Wilderness and Nature, and Cultural Significance.

Diversity and Species Richness:

Figure 7



The site had a wide variety of diversity and species richness. In groups 5C and 5B even though the back maintenance alley was fully paved, there were still some vines and shrubs along the wall. The score may be low, but the area still deserved some recognition that there are some species present. 5H and 5I were given a perfect five because there were many trees present in a variety of species. These trees were purposely planted to be diverse, as they are near a seating area and large windows of the Neville Scarfe Building. Not only is species diversity excellent ecologically since it reduces the impact of pathogen infestation, but it is also very aesthetic (Keesing, Holt & Ostfeld, 2006). The appearance of a group of many diverse trees is very pleasant and may attract people to these areas.

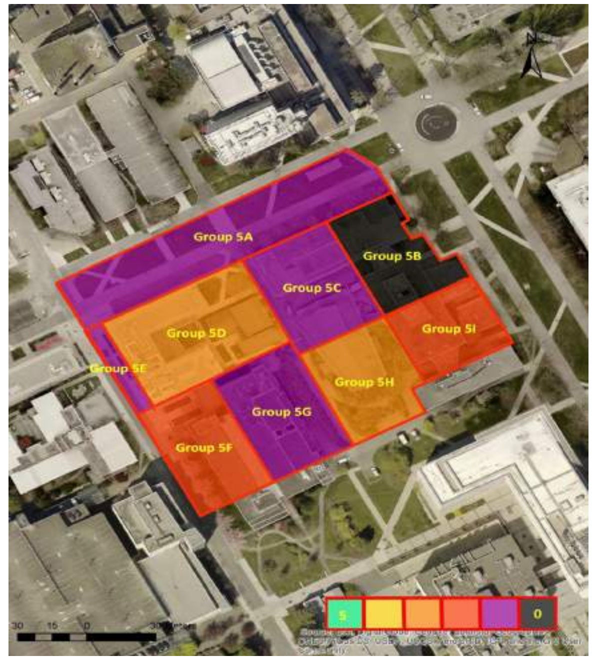
Aesthetics:

Figure 8

The site was highly variable as a whole regarding aesthetics. The subzones that scored the lowest (5B and 5C) were ranked so low because there was very little space for greenery around the building. When there was vegetation it was not diverse or particularly appealing to view. Section 5D ranked one of the highest because of its beautiful trees and the public Ponderosa courtyard that has a pleasant outdoor area. The courtyard is a calming space because the Ponderosa Commons buildings that surround it keep it quiet and secluded from the noisy, fast paced sidewalks and roads in sections 5A, 5E and 5F.

Social Cohesion:

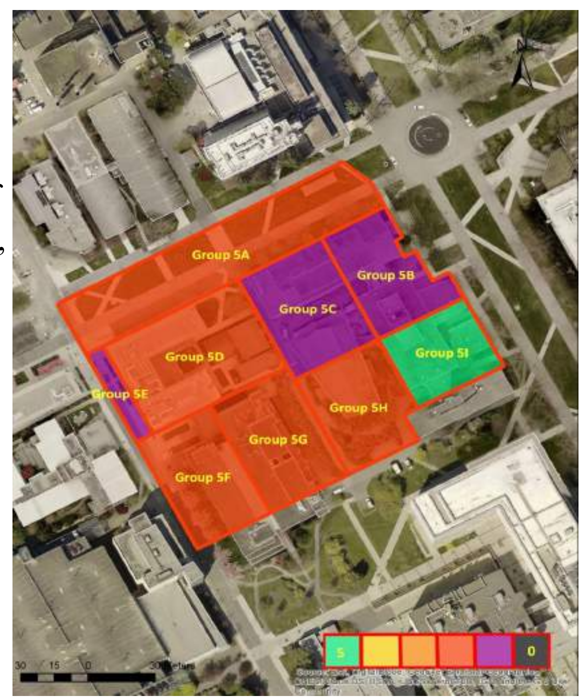
Figure 9



The site ranked relatively low in terms of social cohesion. The maximum score given was three out of a possible five. One of the subzones that scored highest was section 5H. It was given a higher score because it includes a very aesthetically pleasing garden with benches provided for people to sit and relax. The high diversity of vegetation planted in the area makes the site interesting to look at and lets users of the space feel captivated, averting boredom. Despite the beauty of the garden, the space is not frequently used due to the fact that it is difficult to find or come across. The site overall consists mostly of buildings and concrete back alleys and it is quite secluded. Unless someone is trying to find a shortcut to their destination, they are unlikely to walk through the area. Even section 5A did not score high even though it is the most heavily trafficked area of the site. This is because it is a fast-moving pathway in which people do not tend to stand around and talk or admire the outdoors. There are no benches along the path for people to sit and enjoy the area. However, this may be because of the sloped topography.

Wilderness and Nature:

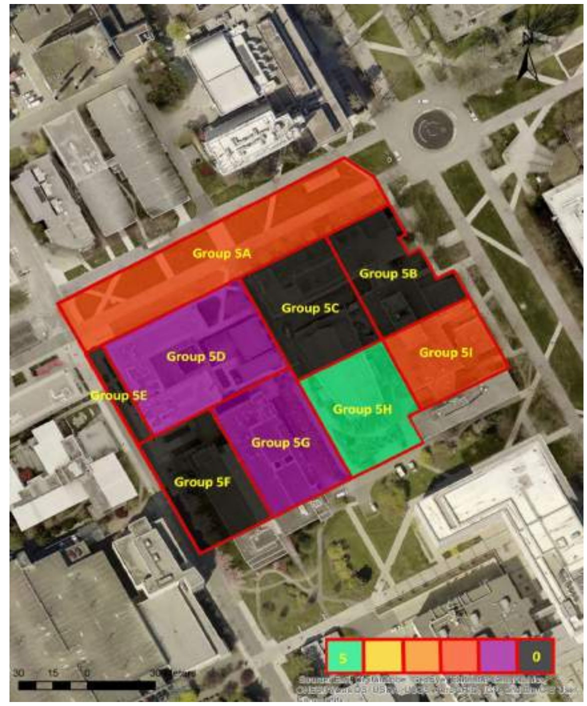
Figure 10



The site scored in the mid-range for wilderness and nature. UBC campus is very urbanized and densely populated, and thus all areas provoking wilderness and nature in the site were placed through human intervention. In group 5H areas of wilderness included a pond, a bee habitat, and a gardened area, which were all placed there by either students or university staff. However, group 5H scored in the mid range, while area 5I received the full five points because unlike the nature in 5H which was manicured and highly managed around a seated area, 5I has a less conformed planting pattern and evoked more of a sense of nature and wilderness.

Cultural Significance:

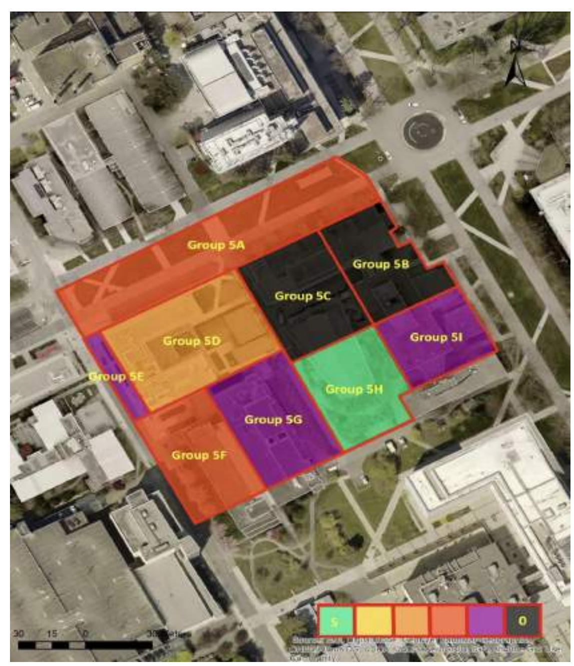
Figure 11



While mapping the cultural significance of our zone, we evaluated how well each subzone was able to demonstrate the following characteristics: Opportunity for Research & Education, Sacredness, and Aboriginal People's Traditions. The value mapping performed for cultural significance of the site produced low results, with the exception of subzone 5H. Subzones 5B, 5C, 5E, and 5F received a rating of zero due to these subzones being dominated by buildings and roads while severely lacking in vegetation and culturally significant attributes, such as native tree species or aboriginal symbols. Subzone 5H demonstrated a high score for cultural significance due to the Aboriginal Art located in the site along with the presence of native tree species such as *Tsuga heterophylla* (Coastal Western Hemlock) and a diverse range of vegetation present.

Cultural Ecosystem Services:

Figure 12



Upon mapping the different values of the subzones in the site, we considered the different cultural ecosystem services our site has to offer: mental and physical health benefits, recreation and ecotourism, aesthetic values, and spiritual and religious values. Overall, our site as a whole received a score of 1.67/5 for its cultural ecosystem services. Meaning, our site is severely lacking in cultural ecosystem services and provides insufficient benefits to users.

Most of the subzones rank low, scoring around the zero to two range. These low ratings are primarily due to the high number of grey infrastructure and impermeable surfaces, such as walkways and service roads that are present in the site along with low amounts of vegetation. More specifically, subzones 5B and 5C are ranked at zero due to these areas being dominated by the Neville Scarfe building and its maintenance alley, which provides little to no cultural services to users. Additionally, subzones 5A, 5E, 5G, 5F, and 5I received low ratings due to the zones also being dominated by grey infrastructure, as well as having scarce culturally significant aspects.

Subzones 5H and 5D scored higher for their cultural significance. Subzone 5D is characterized by containing some green spaces and a variety of vegetation for users to interact with. The maximized value of 5H can be attributed to the following: a lush array of vegetation which is indicative of high species diversity and composition, abundant aesthetic values and most importantly the Aboriginal art that is present in the seating area of the zone (Figure 2).

The mapping exercise we performed resulted with our site having very little cultural ecosystem services present. However, the exercise itself may not have provided completely accurate results of the services since this was an individual exercise and the results are based on the aggregation of only five students' objective perspectives and values chosen to be assessed in the subzones. To achieve more accurate results in the future, increasing the number of individuals performing the value mapping would minimize the standard error. Moreover, the non-material benefits received from the site, such as spiritual enlightenment, aesthetic values and experiences, and cognitive development are some of the unique cultural services provided, but since these benefits are often based on individual's perspectives, it is difficult to monetize the value these services produce.

Urban Forest Planning and Management Recommendations:

Because climate change is becoming more severe and its effects are becoming more noticeable, we recommend adapting to climate change. It is predicted that Vancouver's winters will become even wetter than they are now, which will lead to intense flooding if the city is not prepared (Jakob, McKendry & Lee, 2003). For this reason, we propose increasing stormwater regulation in our site. This can be done by increasing canopy cover because canopies intercept raindrops and decrease the amount of runoff (Asadian & Weiler, 2009). Also, a large proportion of the site was covered with impermeable surfaces, such as buildings, sidewalks, and paved roads. As seen earlier, the fully paved back alley in the site (subzones 5C and 5B) scored a 0 for regulating ecosystem services. These surfaces do not allow water to absorb into the earth and cause it to pool, so to regulate stormwater it is important to decrease the amount of impermeable surfaces on the site.

Currently the site has 25% canopy cover, and we advise increasing it to 30%. This can be accomplished by planting at least 35 new trees. 35 trees would increase the amount of trees on the site by approximately a half. Even though this is relatively a large number of trees compared to how many are already on the site, the planted trees will be young, so their canopies will not be as large. As they mature, the canopy cover will increase. In addition, rainwater swales may be created. Rainwater swales are basins which are covered with plants that often grow in wetlands. Not only do they regulate rainwater, but they are very aesthetic and may increase social cohesion (Echols & Pennypacker, 2008).

Figure 13

Figure 14

Figure 13 is a bare patch in the site along University Boulevard. There is a great deal of planting potential in this area. We propose planting a proportion of the 35 trees here, as well as creating a rainwater swale (seen in Figure 14). This is a high traffic area at UBC, and the view is currently unpleasant. With proper landscaping, this area will have a completely different impression and increase stakeholders' satisfaction of the aesthetics in this space.

To decrease the amount of impermeable surfaces on the site, we advise replacing the roads with permeable pavers and the sidewalks with gravel paths. These substratums have spaces which allow water to get through and be absorbed. We understand because the roads and sidewalks are currently not cracked and in good condition, this recommendation may seem useless and a waste of funds. However, this action is preemptive and will save the university money in the long run. Instead of paying continuously for recurring water damage from flooding, the university would only pay a one time fee for the road replacement.

Figure 15

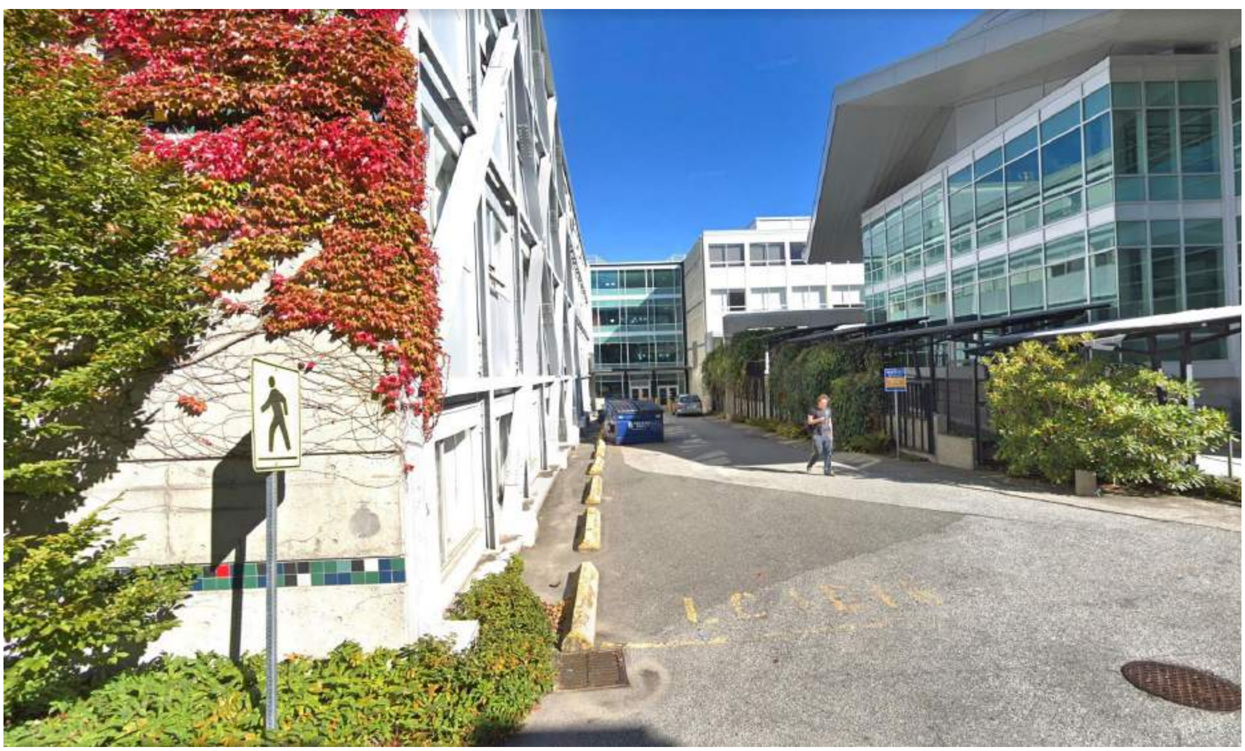


Figure 16

Figure 15 is the maintenance alley behind the Neville Scarfe Building. It is completely paved and has a slight downward slope towards the building. If there is more flooding than usual, immense problems may occur. Figure 16 depicts our vision of this area with permeable pavers and rainwater swales.

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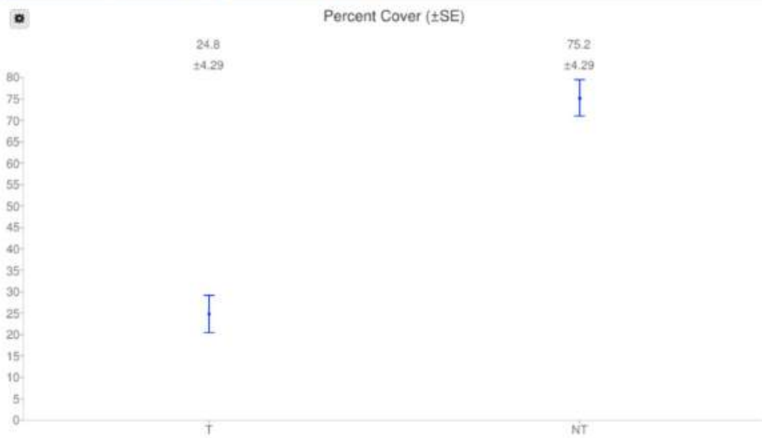
Appendix:

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 2/15/19

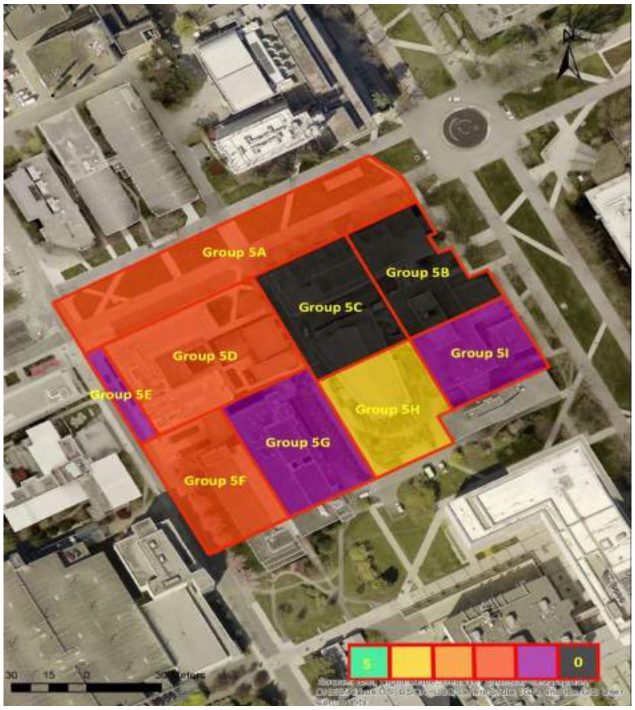


Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	25	24.8 ±4.29
Non-Tree	All other surfaces	NT	76	75.2 ±4.29

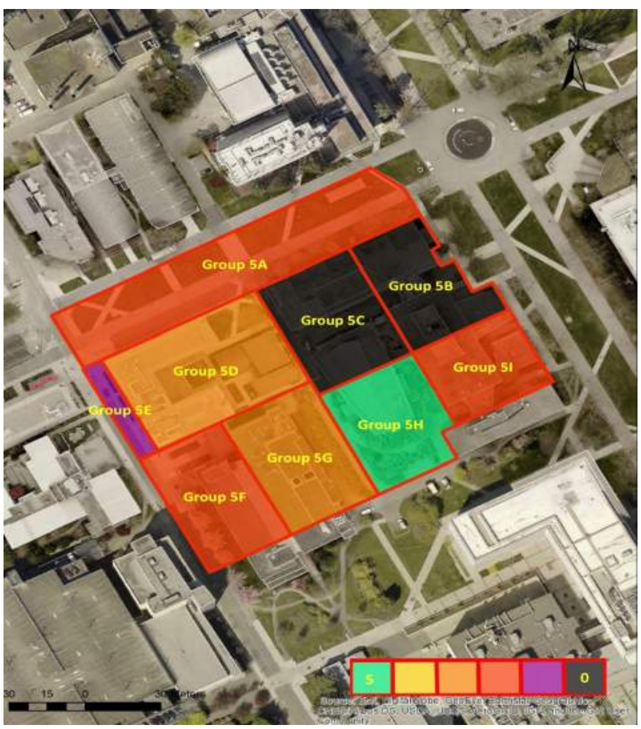
Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.34 CAD	±0.06	0.00 t	±0.00
NO2	Nitrogen Dioxide removed annually	0.88 CAD	±0.15	1.53 kg	±0.27
O3	Ozone removed annually	55.82 CAD	±9.68	10.20 kg	±1.77
PM2.5	Particulate Matter less than 2.5 microns removed annually	160.10 CAD	±27.78	0.00 t	±0.00
SO2	Sulfur Dioxide removed annually	0.13 CAD	±0.02	0.00 t	±0.00
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	29.24 CAD	±5.07	3.19 kg	±0.55
CO2seq	Carbon Dioxide squestered annually in trees	151.73 CAD	±26.32	2.23 t	±0.39
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	3,810.41 CAD	±661.07	56.12 t	±9.74

i-Tree Canopy Results



Provisioning Services Mapping



Supporting Services Mapping

UBC Urban Forest Inventory and Assessment

Group 5

February 10th, 2019

Contributions:

Jeannine Felix:

- Summary
- Checked all clinometer calculations
- Editing of report

Diana Satkauskas:

- All graphs and tables
- Calculations for graphs
- Clinometer calculations
- DBH calculations
- Found coordinates for missing trees
- Editing of report

Maija Wootton:

- Data entry
- Site Description
- Clinometer calculations

Tyler Doucet:

- Data entry
- Summary
- Clinometer calculations
- Checked DBH calculations
- Conclusion

Michael Spenrath:

- Introduction
- Methodology
- Clinometer calculations

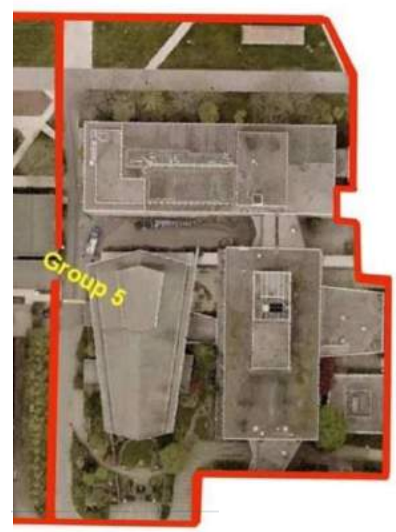
Introduction:

The purpose of an urban forest inventory and assessment is to record detailed characteristics of urban trees to help determine the benefits they provide, as well to assess the physical conditions of the trees (Bond & Buchanan, 2006). More specifically, the purpose of our inventory is to record the data of trees located on the UBC Vancouver Campus which will be further used in an assessment of the campus' urban forest as a whole. The data we collected is critical for assessing future conditions of trees while also providing an estimate of the many ecosystem services they currently provide. Our data will further help UBC determine a plan of action for maintaining and managing these trees in the short and long term.

Our inventory data will be presented to the stakeholders of the UBC urban forest and to the UFOR101 class. The stakeholders include: UBC SEEDS, Campus and Community Planning, Building Operations, and the students and staff of UBC who interact with its urban forest. With the data we collected, the stakeholders of UBC's urban forest can develop a plan to maintain and manage the trees individually and as a whole, while also implementing ways to improve the area.

Site Description:

Figure 1



Our site was centrally located on the UBC campus in Vancouver, BC. Most of the trees were measured were surrounding the Neville Scarfe Building (visible in Figure 1), found on the south west corner of Martha Piper Plaza. Being located on school grounds, the site was classified as an institutional land type.

The site is bordered by a service road, the Scarfe building itself, walkways which are frequently used, and an open courtyard between buildings. The courtyard serves many purposes: celebrating aboriginals by showcasing their artwork (Figure 2), providing a garden for people to enjoy, and adding an aesthetic appeal for the surrounding offices that overlooked it (Figure 3). Observing land use, not many recreational activities were noticed in the area while tree inventories were being taken.

The trees themselves served different purposes. Because a majority of the trees are planted in close vicinity of the buildings in the area, they take part in regulating temperature by mediating winds, decreasing harsh sunlight entering the building, and providing a natural view for the people inside. Trees were also used to create multipurpose spaces in close proximity by using them as dividers. An example of this is shown in Figure 4, where a parking lot is separated from the garden by a row of trees and shrubs.

Figure 2

Figure 3

Figure 4

Methodology:

Over the course of three weeks our group performed numerous on-the-ground measurements of trees located in UBC's urban forest. These measurements and corresponding data are vitally important for quantifying the value of the urban forest and the numerous benefits it provides. Measurements performed included: Diameter at Breast Height (DBH), Total Tree Height (TTH), Live Crown Height (LCH), Crown Base Height (CBH), Crown Width, Percent Crown Missing, and Crown Light Exposure (CLE). Among these, numerous other non-measurable characteristics were recorded, such as: tree ID, tag number (if applicable), tree genus and species, whether the tree was alive or dead, and the use of the land where the tree was located. This section of our report will further demonstrate how these measurements were performed and the importance of the measurements for the inventory.

Prior to this inventory, the group members had some experience using the equipment (from past courses taken at UBC). However, this inventory allowed for the students to further perfect their skills and become more efficient when using the devices. Equipment used for the measurements included: DBH tape, clinometer, compass, measuring tape, chalk, a clipboard, and a data collection sheet on water proof paper to ensure the recorded measurements could not be affected by external agents. Over the two-week period of on-the-ground data collection, each group member actively participated during and outside of the scheduled class time. Each member had an opportunity to work with each and every piece of equipment; this ensured that each member could be able to become familiar with the equipment and adequately perform required measurements.

Having specific guidelines to follow during the inventory, the group members followed a similar pattern when measuring and recording data for each tree. First, members would record the tree ID number (from the ArcGIS mobile app) and the tag number of the tree (if applicable). Then, it was determined if the tree was alive or dead. Using the ArcGIS app, the tree genus and species was recorded. Lastly, the land use type on which the tree was located was determined, Our zone was determined to be completely Institutional. After recording the non-numerical data of the tree, the supplied equipment was used to measure and record characteristics of each tree.

Starting from the northwest corner of the plot (seen in Figure 1 in the Site Description), the inventory was performed in a counterclockwise manner, measuring each tree in an orderly fashion. Individual measurements for each tree were not performed in a strict order, but rather group members worked as a team to perform numerous measurements simultaneously to ensure maximum efficiency of time and effort. For trees with a diameter greater than 2.54 cm or 1 inch at breast height (approximately 1.37m from the base of the tree), the DBH tape was wrapped around the trunk of the tree on the uphill slope side and the measured diameter was recorded. For instances where a tree had more than one stem, up to six of the largest possible stems were measured and recorded. These measurements were later used to determine the aggregated DBH using the following equation:

Overall DBH = the square root of the sum of all squared DBH stems.

Total Tree Height (TTH) was measured using the clinometer. Using the right scale on the clinometer (% values), the values for the top and base of the tree were measured and recorded. Then, the distance the individual measuring the TTH was standing from the tree was recorded as well. To determine the TTH, the recorded values were input into the following equation:

$$TTH = (\% \text{ at top} + | \% \text{ at bottom} |) \times \text{Distance}$$

Live Crown Height (LCH) was also measured using the clinometer. The distance and value for the top of the tree remained the same, but the lowest hanging point of the tree's crown was measured and recorded in % value. The same equation used for TTH was used to calculate LCH, but using the value of the lowest hanging point of foliage instead of the base of the tree.

If needed, the clinometer was used to measure Crown to Base Height (CBH) as well. If used, the distance, live crown base, and base of tree values were the same as the prior measurements. However, in most cases this method was not required, as the students could just use the measuring tape to measure the distance from the live tree crown to the base of the tree.

Crown width of the tree was measured by two group members using the tape measure. The long and short widths of the crown were measured in metres and recorded. These two values were then used to determine the average crown width of the tree.

Crown Light Exposure (CLE) and percent canopy missing were estimated by the group members using their best judgment. For CLE, a maximum of 5 sides could be exposed to light, but given the locations of our trees, this was not often the case. In most circumstances only a few sides of the crown were exposed due to coverage from other larger trees or infrastructure located in our zone. Percent canopy missing was an estimated value based on how much of the tree group members believed was missing due to factors such as maintenance, growing conditions, or external agents (i.e. wind or climate).

The recorded data of the trees in our plot was put into a Microsoft Excel spreadsheet so all the values could be organized efficiently and make the graphing component of our Summary easier to complete. Using Excel, a group member was able to graph Species Abundance, DBH

Classes, Species Dominance, Species Composition: Abundance and Dominance, Total Height Classes, and DBH Classes: Abundance and Composition and the DBH and Height Relation. These graphs visually represent the data we collected within our plot and the characteristics of trees located in the UBC Vancouver Campus' urban forest.

Summary:

The following is a collection of our data, visually represented through various graphs, examining trends in measurements, species composition, and relations between the two. A summary table of the data is in the Appendix.

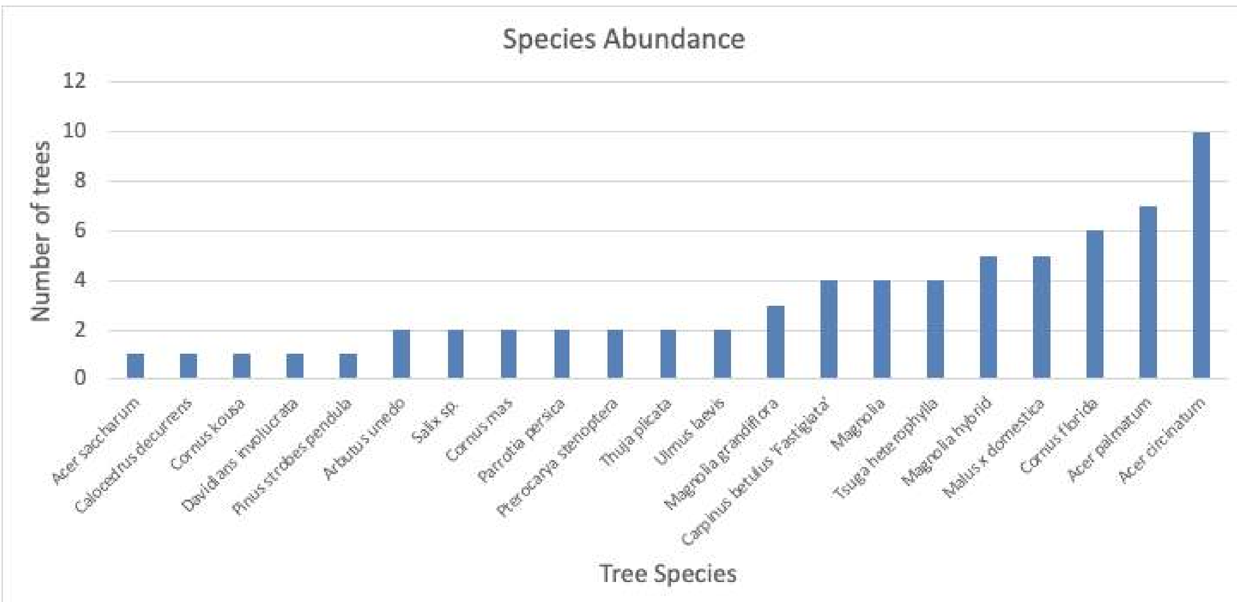


Figure 5

Upon graphing the species abundance of the tree population in the site, it is evident that urban foresters, municipal arborists, and UBC community attempted to plant with diverse species composition in mind. The 67 trees inventoried in the plot totaled to 21 different species. This species richness contributes to the overall diversity of the tree community. This genetic diversity provides basis for resistance and resilience against external stressors from the environment, the introduction of large scale disease or pest devastation, or climate change.

Furthermore, a diverse urban forest with abundant populations means the ecosystem services the trees in the population provide are derived from multiple different sources, rather than the smaller pool of functions one may find in an urban forest with fewer species. Ecologists have concluded, "biodiversity is not just a matter of the number of species in a community. The truly important measure is diversity of functional traits." (Beck, 2013).

The diversity in the site also provides aesthetic values, creating a complex urban forest through the selection of both non-native and native trees, deciduous and coniferous, with varying size, forms, and physical characteristics. The species of highest abundance in the plot was *Acer circinatum*, a tree native to southwest British Columbia. The community as a whole is very rich in diversity, with ten of the 21 species being native to countries outside of North America, most notably in Asia and Europe.

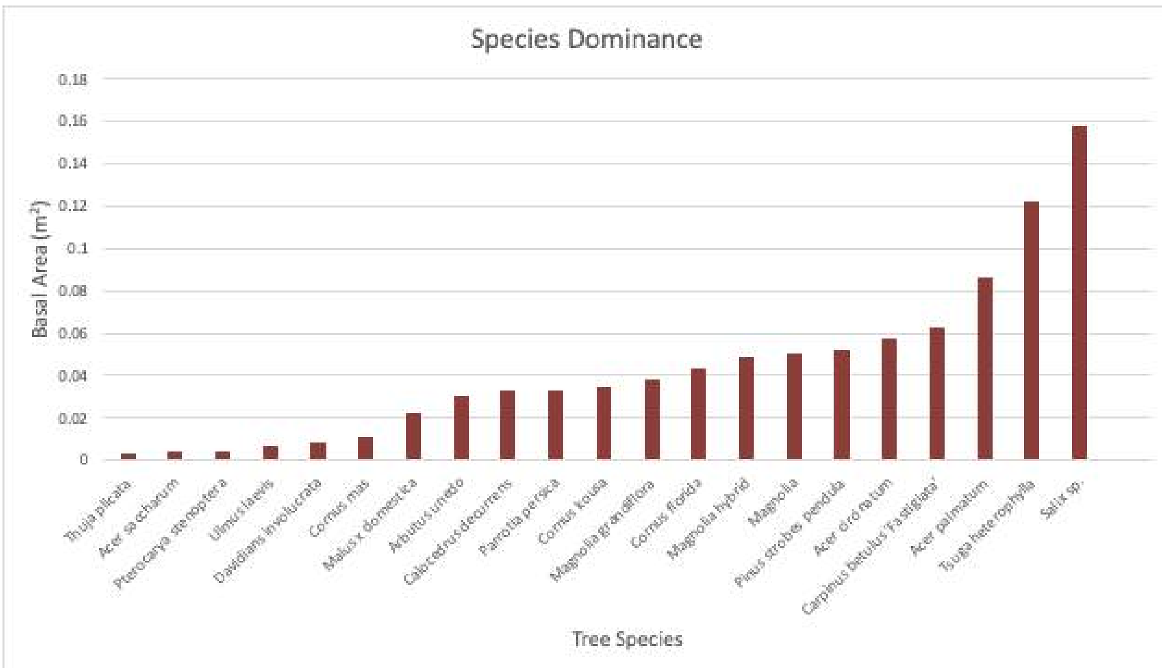


Figure 6

One way to define species dominance is through the measurement of the basal area of each tree, which can be calculated using the diameter at breast height. Basal area refers to the amount of area a species takes up in relation to the area of the plot and is represented in meters squared. The basal area calculated for plot 5 is visualized in the graph above. *Tsuga heterophylla*, more commonly known as Western Hemlock, is considered the dominant species for this plot because it has the largest basal area in relation to the other tree species present. *Thuja plicata* is the least dominant.

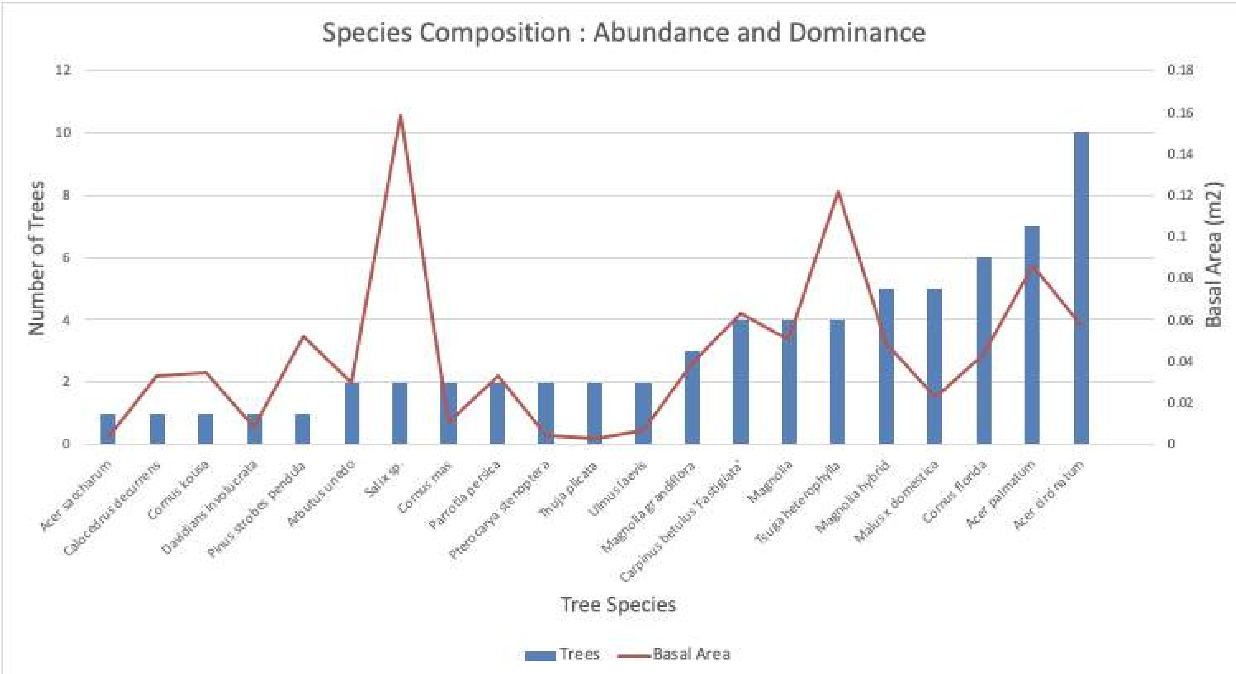


Figure 7

Fig. 7 represents species abundance in relation to species dominance. Observing the graph, it is easily seen that the dominant species is not necessarily the species with the highest abundance. *Acer circinatum* (commonly known as vine maple) has the highest abundance. However, it has a basal area less than half of the basal area of the most dominant species, *Salix sp.*. *Tsuga heterophylla* has the highest basal area, yet there were only four individuals of this species located throughout the plot. This means the *Tsuga heterophylla* located on the plot were quite large compared to the other trees. It can also be inferred that the *Acer circinatum* were quite small, as ten of them were located on the plot, but overall had a lower than average basal area.

Figure 8

By using diameter at breast height (DBH) at 1.37 meters as the standard to measure tree diameter, it creates consistency across all trees in the plot. With those measurements, data can then be interpreted to estimate biomass or carbon storage. As seen in the graph, over half of the trees in the plot fell into the 1-10 cm DBH class, and the majority of trees had a DBH below 20 cm. Of the 67 trees inventoried, less than ten fell into the 20-30 cm and 30-40 cm DBH classes. While interpreting this data, it is important to look not only at the species of trees planted, but the space that they occupy, and the potential space they could occupy at maturity. "Regardless of the size class of the tree species, reduced planting space resulted in reduced maximum DBH." (Cowie, Grabosky, and Sanders, 2013).

The section of the plot along University Boulevard, in between Main Mall and Education road, housed trees with some of the largest DBHs in the plot. Although the large areas did not have unlimited soil, the trees were not in tree pits or small plantings strips. Trees in the plot that had been densely planted along the sides of buildings, in tree pits, and in planting strips account for the large number of trees falling in the 1-10 cm DBH class. Access to unlimited soil and sufficient area for root growth directly control all measurements of tree size, as "tree canopy volume is proportional to natural height and DBH" (Cowie, Grabosky and Sanders, 2013). A tree with a large root system is able to support a broad canopy.

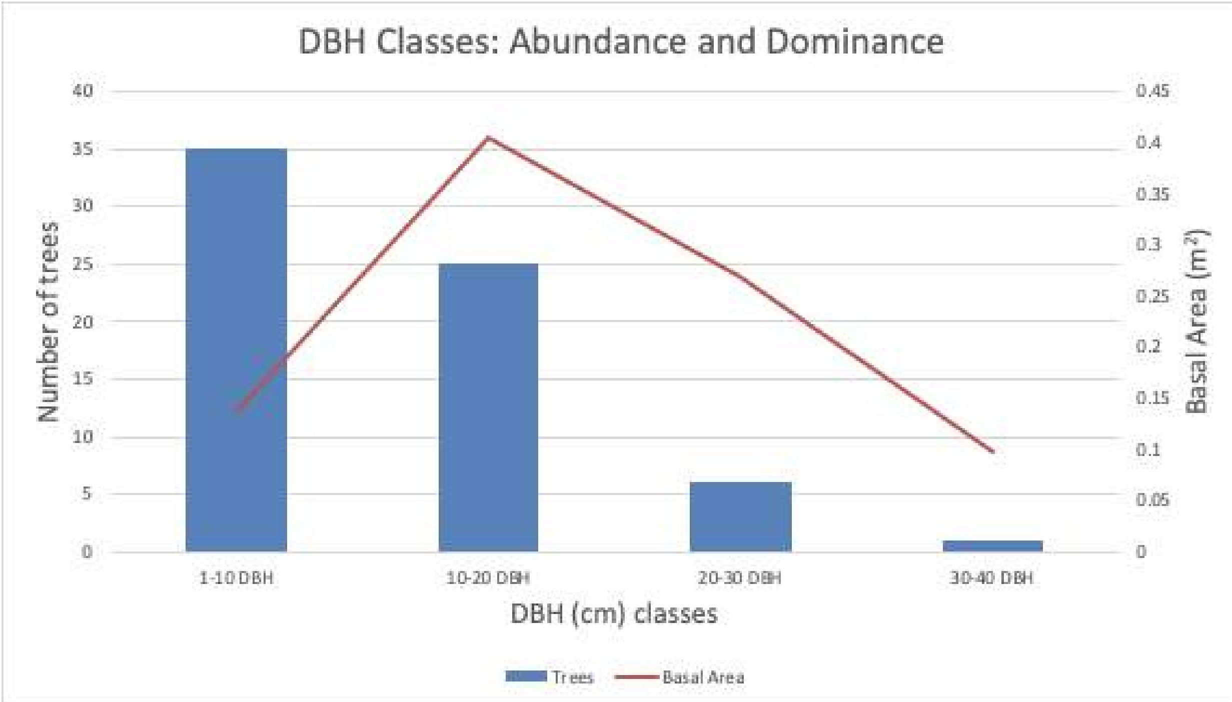


Figure 9

Fig. 7 depicts the DBH classes in relation to species abundance and dominance. It can be observed that the DBH class with the highest basal area has a range between 10 and 20 centimeters, and is not the class with the most trees. The DBH class with a range from 1-10 centimeters has the most individual trees. However, since the DBH is so small, they do not take up enough space to have a high basal area. The two largest classes (20-30 cm and 30-40 cm) included trees with larger diameters than the 10-20 cm class, but there were not enough trees in each of those classes to merit a high basal area overall.

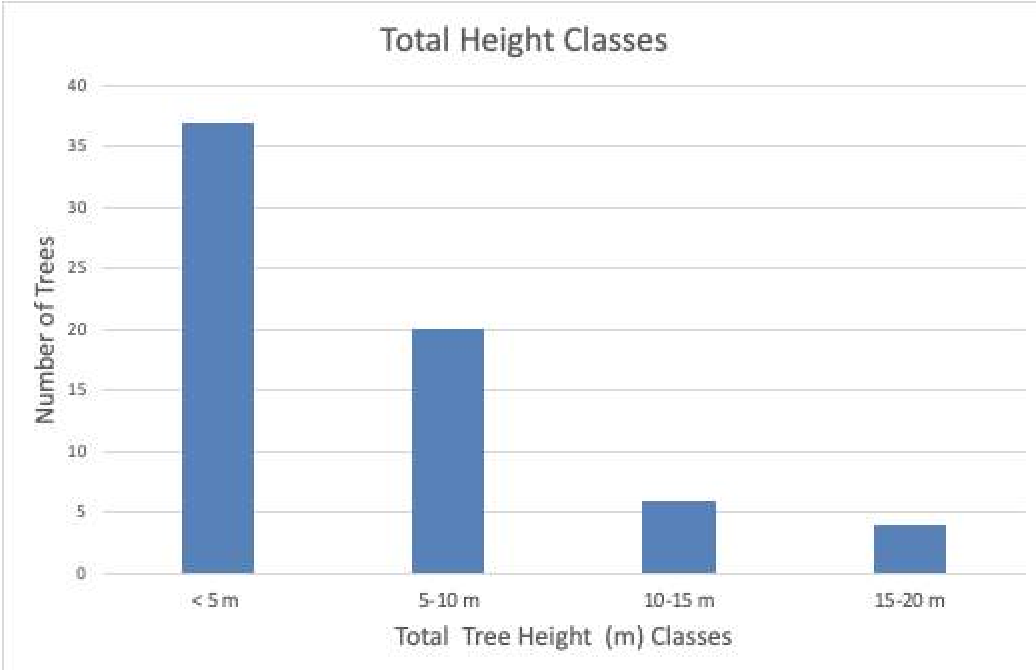


Figure 10

The graph above portrays the relationship between the total height of the trees (grouped into classifications of five metres) and the number of trees present in the plot. It is apparent that most of the trees on the plot measured less than five meters in height. This is likely due to the limited amount of space, nutrients, and sunlight available to aid their growth in the urban setting.

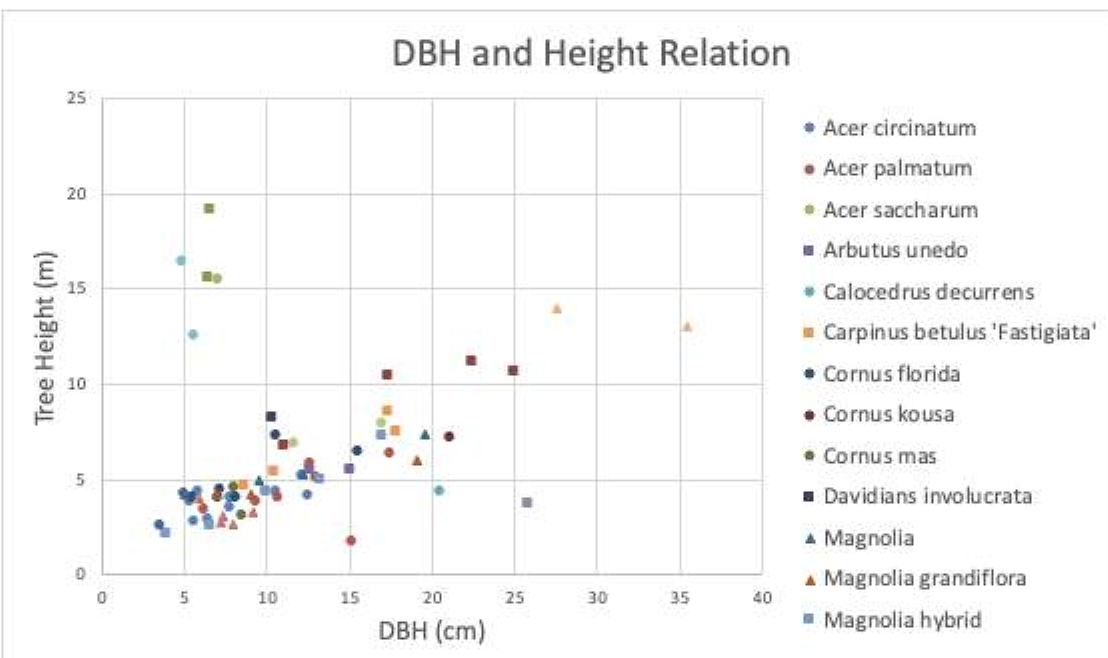


Figure 11

When plotting the DBH and height relation with respect to each species, it became apparent the two measurements were correlated. There is a high concentration of species at certain areas on the graph with little variation, despite the range of different native and non-native trees. The graph may be interpreted to paint a larger picture of the environment that the trees are growing in, as unfavourable environmental conditions affect the entire tree phenotypically. This graph could also be further used to predict the growth of the trees if the age of the trees were known and the growth rates of each species were understood.

Conclusion

Through the data collected in this inventory, the variation within UBC's urban forest became evident. Not only did the plot exemplify diverse species composition, it also illustrated variations within species and within measurement classes. Plant growth is controlled by various environmental factors, including competition, accessibility to water, availability of nutrients, and temperature. Although a tree may be genetically predisposed to have certain characteristics, ultimately a combination of genotype and environment will determine the trees phenotype. In plot 5, some environmental factors that controlled plant growth were confined spaces such as planting beds and shared spaces. As some trees mature and grow larger, they require more resources, ultimately stunting growth of nearby smaller trees and plants. Urban trees require more maintenance than forests in non-urban areas because of the stressors that urbanization and density create. "Crown spread and trunk diameter reduced as non paved surface is reduced" (Watson, 2013); this is evident in the dense and confined areas of plot 5, as the majority of trees fell within the lowest measurement classes. Although trees in urban forests are limited in their potential growth, with proper maintenance and tree selection, a tree may grow and persist in suitable planting conditions. Of the 67 trees sampled, all were alive and the canopy missing rarely totalled over 50%. With the data collected in this inventory, we hope the UBC stakeholders, staff, and community have a better understanding of the species diversity, health, ecosystem services in its urban forest that will aid and shape the future growth the forest will eventually incur.

References:

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Sanders, J, et al. (2013). *Establishing Maximum Size Expectations for Urban Trees with Regard to Designed Space.* International Society of Arboriculture. Accessed February 10, 2019 from: www.reasearchgate.net

Watson, G.W and Himelick, E.B. (2013) *The Practical Science of Planting Trees.* Champaign, IL: International Society of Arboriculture.

Appendix:

Summary Table

	Live	**SD**	**Dead**	**SD**
Trees	67		0	
Species	21		0	
DBH mean (cm)	11.5087	(±6.4076)	0	0
BA mean (m^2)	0.0136	(±0.0166)	0	0
Total height mean (m)	6.0655	(± 3.7428)	0	0
Crown base mean (m)	1.2127	(± 0.9915)		
Crown width mean (m)	4.9099	(±3.9410)		
Canopy missing:				
< 10%	7			
10-30%	35			
31-50%	23			
51-80%	1			
> 80%	1			
Crown light exposure				
1	6			
2	17			
3	17			
4	21			
5	6			

UFOR 101 AS02
Group 6
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Urban Forest Inventory and Assessment

Group 6 individual Contribution:
Chang Liu: Methodology and Zone A to Zone E analysis of cultural ecosystem assessment
Finnley He: From I-Tree Eco methodology to Evapitransiration
Wendy Liu: From i-tree canopy to addition analysis from results of i-tree canopy
Finnley He and Wendy Liu: together finish compare and contrast part
Xuan Chen: Intruduction & Recommendation
Zhenjie Bao: Site description, cultural ecosystem assessment from Zone F to K

Introduction

The intrinsic functionality of ecosystem services has progressively reached a consensus among the ideology of sustainable city. As being defined, ecosystem services are a variety of beneficial goods and services which humans obtain from ecosystem (Christensen, et al., 1996). According to the conceptualization of the Millennium Ecosystem Assessment (2013), ecosystem services are classified into four categories including provisioning (e.g. food, water, raw materials), regulating (e.g. climate regulation, air quality regulation), supporting (e.g. soil formation, nutrient cycling) and cultural services (e.g. recreation, aesthetic value), while only two services (regulating and cultural) will be evaluated in this assessment. In order to gain more attention from the stakeholders, environmentalists have created ecosystem service assessment to provide readers with a better understanding of current ecosystem service, and it helps urban planners and decision makers to effectively adjust the current situation and increase the value of ecosystem service. At the Vancouver UBC campus, the *Land Use Plan* gives the significant stands of urban trees, and these natural vegetation areas are designated on *Schedule C: Plan Areas* as 'tree guideline areas' to receive further planning process; for example, trees over 15 cm DBH will be replaced with an appropriate size tree to ensure the safety (Land Use Plan, 2015).

Site description

The site (see figure 1) where we accessed is made up by the UBC Earth Science Building (ESB) excluding Main Mall area in front of the ESB and the UBC Centre for Interactive Research on Sustainability (CIRS). Earth Science Building is a building for the Faculty of Science. Specifically, it is home to Earth, Ocean and Atmospheric Sciences, Statistics, the Pacific Institute of the Mathematical Sciences, and the dean's office of the Faculty of Science. CIRS is a living lab of UBC and is used to test new ideas regarding human well-being and environmental issues. There are multiple faculties such as agriculture and Forestry share this building for interactive researches, and some of UBC services department office such as water supply department are set up in this building as well. The land use type of this site is belong to the institutional land use category. Users in this area are students, instructors, staff and visitors. Academic activities were the dominant activity type was observed by operators in this area, activities including teaching, studying, researching and some group working. And, most people just pass through this area rather than staying. Pedestrian circulation in this area is huge due to its location is close to the West Parkade and West Mall.

Regulating ecosystems services assessment

Regulating services of urban forestry are defined as the benefits obtained from the regulation of ecosystem processes such as reduce stormwater runoff, carbon dioxide sequestration, air pollutants removals and cool summer air temperature. To define regulating service assessments, two different i-tree tools have been used such as i-tree canopy and i-tree eco.

i-Tree canopy:

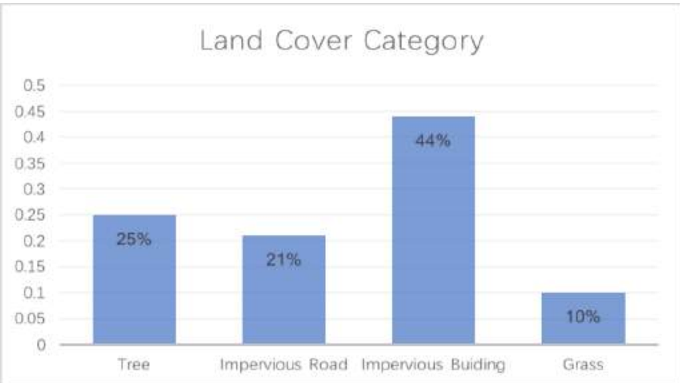
i-tree canopy is one of the models which indicate tree canopy coverage and its benefit estimates based on percent tree canopy of a specific area.

Methodology:

There are three main steps to use i-tree canopy: determining boundary outlines which Draw the boundary of the inventory area, defining land cover class descriptions which has defined as tree, impervious road, impervious building and grass. Last step is deciding cover type category since i-tree canopy generated random sample points which has detailed 100 points for each municipality to define a significant cover class characterization. The strengths of those methods are easy-control and make users easily to learn how to use this model. Also, it has a fast efficiency which means users will quickly get the report since all the steps has finished. The weakness of those methods which have low ability to manipulate GIS shapefiles through the 'Define Project Area' tool and Google Mapmaker to determine boundaries. The i-tree Canopy program determines the percentage of the coverage category by detecting random points in satellite images covering the current Google map. As the number of points increases, the accuracy of percentage estimation will increase with the decrease of standard error. But the number of points increases, the more time will be needed. In addition, since the Google Maps satellite imagery in i-tree canopy is not high definition enough and some of the new planted trees will not be covered, then the error will be increase.

Results of canopy cover:

After those steps, i-tree canopy has provided a report. The table (figure 2) below is showing canopy cover percentage. There are around 25 percent of tree canopy and overall about 75 percent of non-tree areas. Non-tree areas represent around 21 percent of impervious road, 44 percent of impervious building and 10 percent of grass surface.



(Figure 2)

Results of benefit estimates:

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	1.03 CAD	±0.18	1.16 lb	±0.20
NO2	Nitrogen Dioxide removed annually	1.98 CAD	±0.34	9.26 lb	±1.60
O3	Ozone removed annually	107.68 CAD	±18.65	56.54 lb	±9.79
PM2.5	Particulate Matter less than 2.5 microns removed annually	425.45 CAD	±73.69	4.38 lb	±0.76
SO2	Sulfur Dioxide removed annually	0.27 CAD	±0.05	3.32 lb	±0.58
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	80.74 CAD	±13.98	19.42 lb	±3.36
CO2seq	Carbon Dioxide squestered annually in trees	452.72 CAD	±78.41	7.34 T	±1.27
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	11,369.46 CAD	±1,969.25	184.26 T	±31.91

(Figure 3)

The second data (figure 3) shows benefits based on those 25 percent of tree canopy of the inventory area. The i- tree canopy currently uses the county-level multipliers to estimate annual air pollutant removals and associated monetary values. There are 7 categories that is in an annual amount and monetary value: carbon monoxide removal(CO), nitrogen dioxide removal(NO), ozone removal(O3), particulate matter less than 2.5-micron removal(PM2.5), sulfur dioxide removal(SO2), particulate matter greater than 2.5 microns and less than 10-micron removal(PM10*), and carbon dioxide sequestration in trees(CO2seq). The amount and monetary value of carbon dioxide stored in tree which indicate as a non-annual rate and it is a total biomass amount(CO2stor).These annual estimates are based on values in lbs./acre/yr. and CAD$/T/yr. i- tree Canopy currently uses the county-level multipliers to estimate annual air pollutant removals and associated monetary values. The SE means the standard error. To sum up, the annual carbon dioxide sequestration has the highest amount around 6.07 to 8.61 tonnes and highest monetary value of 374.31 to 531.13 Canadian dollars. Annual carbon monoxide removal has the lowest amount about 0.96 to 1.36 lbs. And annual sulfur dioxide removal has the lowest monetary value that is around 0.22 to 0.32 Canadian dollars. Overall, the total monetary for all of those air pollutants removal annually is around 1069.87 Canadian dollars. In addition, the 25 percent of tree canopy of inventory area has already stored carbon dioxide in trees around 152.35 to 216.17 tonnes and monetary of 9400.31 to 13338.71 Canadian dollars.

Addition analysis from results of i-tree canopy:
From research, an average Vancouver household will produce around 7.2 T of carbon dioxide per year and a typical passenger vehicle emits about 4.6 T of carbon dioxide annually. In the inventory area, carbon dioxide sequestered annually in trees is about 7.34 tonnes. So, it is equal to around one Vancouver household carbon dioxide emission and about 1.6 vehicle carbon dioxide emission per year. However, the tree canopy of the inventory area has stored carbon dioxide in trees around 184.26 tonnes that emitted by 25 Vancouver household CO2 emissions and 40 vehicles.For further analysis from the results of tree canopy percentage, tree canopy of the inventory area is lesser than non-tree areas. The reason is because trees of inventory area are mostly scattered and smaller compare to trees at UBC main mall. This map (see figure 4) is showing the general tree canopy of the inventory area for group 6 which has been indicated by green lines.

I-Tree Eco methodology
The I-Tree Eco is a flexible software application in accessing and managing the community trees and forests. To be specific, this is a suite of tools designated to quantify the community forest's structure, environmental effects and ecological value by providing environmental services. Under the sampled area, detailed information on ecosystem services regulation can be obtained by the further extensive data collection. In a simple way to say, the location of the tree inventory should be clarified at first, and which is followed by the data collection through selecting species, DBH, Land use, total tree height, crown size and crown light exposure in I-Tree Eco software in order to let the system identify the variables needed for

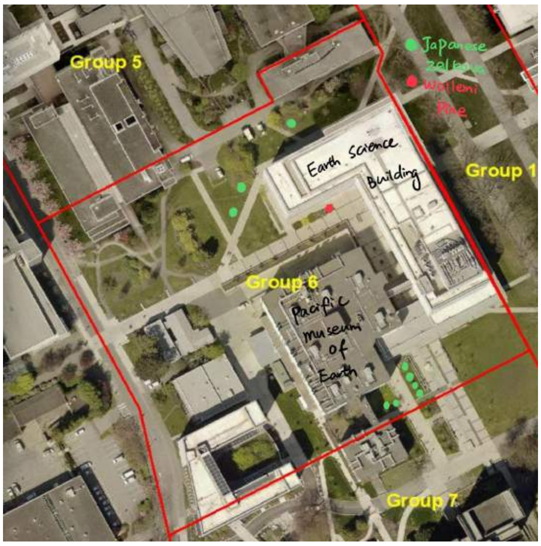
analysis. Then, inputting the inventory data that has been created in assignment 1 is important for the system to do the categorization. As a result, the I-tree Eco will generate ecosystem provision results which are reported as both quantities and economic value.

Analysis from the results of I-tree eco, benefits and shortages of this system

Carbon storage, sequestration

Carbon storage is a method of capturing carbon dioxide emissions and store them in tree's biomass such as roots, stumps and branches. This is frequently mentioned as a potential way to mitigate the heat island effect. From the result of I-tree Eco, two Tulip trees and seven European beeches belong to those with the relative high capability for carbon storage, intaking around 11.5 ton respectively from the sample area. The monetary value produced from these tree species is up to 1225.36 Can$ (Tulip tree) and 1182.02 Can$ (European beech), whereas three golden-chain trees could absorb 13.72 ton of carbon that is worthy 1430.07 Can$. Throughout the tree inventory area, ten Japanese zelkovas have the strongest ability in absorbing around 20 ton carbon into their structures and they can save 2000 Can$ to the UBC campus. In comparison, only one Wollemi Pine is planted, and from the reported table about the hydrology effects and the carbon storage of tree by species, Wollemi pine has the lowest ability in restoring 0 ton carbon, and it has almost no contribution in enhancing the community forest performance. Generally, the amount of carbon dioxide that trees sequester from the atmosphere depends on tree size, growth rate and tree condition through the process of photosynthesis.

Leaf area is what provides most of the environmental services. The greater the leaf area, trees have the greater the shade that is provided, the greater the carbon that is sequestered, the greater the amount of air pollution that is removed, and the greater the amount of storm-water that is intercepted as well as the greater value of avoided runoff. It is reported that in I-tree Eco, leaf area from Japanese zelkovas is 0.40 acre (12.6% of leaf area in the sample area) which is the highest value in removing pollution from the environment. The combined effect of average DBH (26.43 in) and height (2.88 ft) reveal the fact that as the stands of tree grow, the tree structure develops stronger and the canopy cover from overall 10 Japanese zelkova trees turns greater, accounting for 4907.5 ft^2 in the inventory area and that is equal to approximately five Olympic-size swimming pools (Hallett Taylor, 2018). The oxygen production by those trees is around 800 lb annually. Each year, the total benefits that can be obtained by the carbon storage, gross carbon sequestration, pollution removal, energy savings are 2091.83 Can$. In the campus, Japanese zelkovas are located in the open space beside the Earth Science Building and Pacific Museum of Earth (shown in green dots in graph 5). The spatial distribution of tree is great and most of them are planted with sufficient developing space. Buildings around them function as an office area, and this do not create too much pollution and disrupt the carbon sequestering ability for trees. Overall, this phenomenon explains why Japanese zelkovas have the greatest supply in environmental services.



However, for the single Wollemi Pine, this tree species' leaf area is 0.003 acre with the 0.001 leaf biomass. 5.9 in DBH and 12.8ft of height result in the low canopy cover (21.6ft^2). In a normal case, a mature tree will grow around a meter a year. If the plant is not fertilized and kept in a low light condition, it will grow slowly. Even though the Wollemi Pine tolerates a wide range of soil types, it favors a well-drained, slightly acid fertile soil (Taking care, n.d.). This tree species is inventoried during the winter, the lack of moisture makes it hard to observe the mature plant's

(Graph 5)

growth and do further evaluation of ecosystem services. Thereby this explains why Wollemi Pine has the least impact in regulating the environmental services. In the sampled area, Wollemi Pine is located between Earth Science Building and Pacific Museum of Earth (shown in red dot in graph 5). These two blocks significantly affect the tree's healthy structural development by obstructing the process of photosynthesis.

Therefore, the table provided by the I-tree Eco software estimates the leaf surface area and leaf biomass for each single tree species inventoried by size classes. This report are quite beneficial to stakeholders, managers and foresters to determine the amount of leaf area and biomass each species have, which species are providing those services, and in which size class the majority of those services could be provided. In other words, this can help managers to have a clear understanding to plan for urban forest sustainability. Tables about pollution removal and carbon storage by measured trees are provided to show the existing tree's ability to remove the pollution in the atmosphere, and this helps for the plan the future development strategies. But from the I-Tree Eco, data shown in the result of the system is inaccurate, and this is not suitable as an indicator for the long term urban tree's coordination. Wollemi Pine is a typical tree that contradicts the I-Tree Eco software's data due to those staff (as well as our students) do the measurement in height and DBH under the undesirable season for the tree's development. And this is hard to evaluate the true and reliable economic value from the tree.

Evapotranspiration

The potential evapotranspiration is an indicator meaning the amount of water which would be lost from a surface completely covered with vegetation, and this is important to part of the water cycle to evaluate the demand of moisture in soils. From the I-Tree Eco, the avoided runoff value by Japanese zelkova is calculated by the price 15.76 Can$ annually. But for the Wollemi Pine, only 0.14 Can$ can be saved for the avoided runoff. As a result, the hydrology effects by measured trees can tell stakeholders and urban tree planners in deciding the promising planting area for each tree species. After considering the provision of water in each precise area, the tree species' planting can possibly be ensured . Overall, the analysis from I-

Tree Eco provides a comprehensive assessment and serves as a platform on which to develop strategies to enhance environmental performance as well as human wellbeing and health.

Compare and contrast the I-Tree canopy and I-Tree Eco

Generally, both software are used to evaluate the regulating services in the ecosystem by outputting data in order to strengthen stakeholders understanding to trees in the inventory area. Through the discussion, analysis and conclusion, a vibrant environment might be provided for citizens to enjoy a healthy life. The similarity between the two software is the carbon storage and sequestration which is valued by money. The air pollutant removal including CO2, SO2, PM2.5, NO2, O3 can be evaluated through the results of two systems as well. By comparison, the results of I-Tree canopy is presented through random dots in the map of inventory area using the Google Maps satellite imagery. Each time it needs to define each dots' categories. As for the I-Tree Eco, the related variables for tree analysis such as the carbon storage and hydrology of trees are categorized into different parts systematically. By looking at different data tables and graphs, it can be easy to find out each detailed figure such as each tree species tree canopy, whereas in the I-Tree Canopy, only the general tree canopy for all of the tree species can be found. What's more, structure summary by stratum and species, composition and structure, species distribution by DBH classes, hydrology effects of trees by species are a bunch of tables in I-Tree Eco. However, I-Tree Canopy has only provided tree canopy or non-tree area cover and the benefit estimates based on percent tree canopy which covers by different air pollutants removal amount and their monetary value.

Cultural ecosystems services assessment

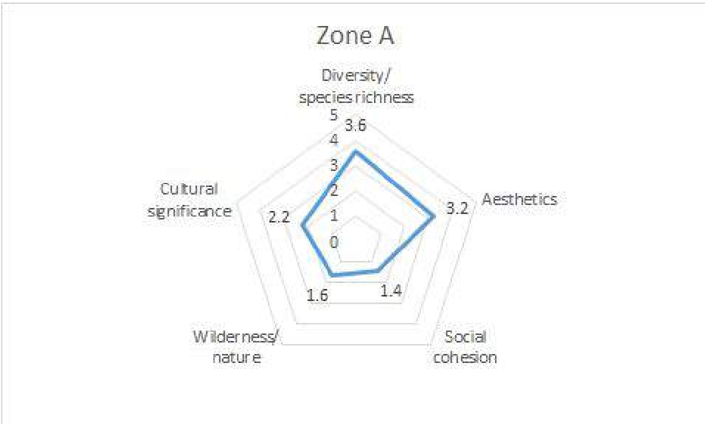
Cultural ecosystem services states the importance of human well-being in ecosystem services assessment and decision making (IUCN, 2015).

Methodology

The value mapping process of cultural ecosystem services is divided into five steps. The first step is to learn what is cultural ecosystem services assessment, that is defined as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences" (Sarukhán and Whyte 2005). In the lecture, there are the five dimensions of evaluations in different aspects of cultural services that need students to value, which includes species richness (diversity), aesthetics, social cohesion, wilderness (nature), and cultural significance. The next step is valuing different zones individually based on 0 to 5 scales to represent the extent of each dimension. The third step is to record all data from each group members on an excel data sheet. Then, calculating the sum of each value in each zone from all group members separately, getting the average scales of every single value in different zones, and putting all results in a new data table (e.g. under the value of diversity, Average=(scale 1+ scale 2+...+scale n)/n). The final step is using the table to analyze each feeling dimensions in different zones, which can use graphs in analysis.

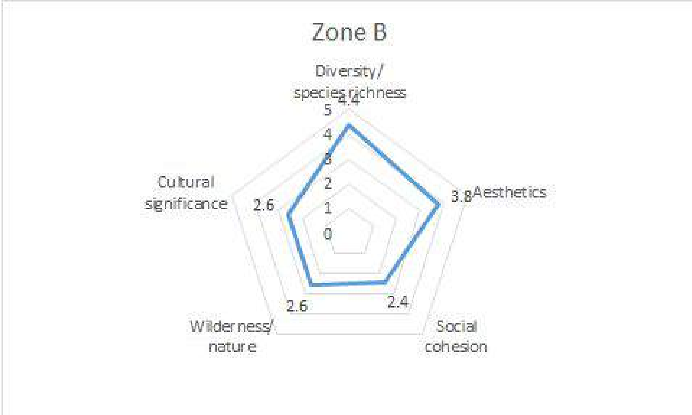
The benefit of this methodology is that researchers can personal experience the values and give the score base on personal and actual feelings. Also, they can have a better understanding of cultural ecosystem services and remember well by looking at the map to have spatial analysis. However, the scores can vary with people, and it is a subjective research, so different people can have different scores, which does not have the correct answer and can vary differently. Also, another disadvantage is that the number of participants is only a few, which is less accurate and objective than the research that has more participants. Therefore, the method is good for having personal experience, but it still needs more participants to value different dimensions to decrease the deviation.

Zone A is an area beside the Main Mall, which contains part of the Earth Science Building and Neville Scarfe Building and the green space between these two buildings (see figure 6). This area has a higher scale of species richness relates to other values because there are at least three different tree species along the side of the building (see figure 8). Also, many small green vegetations were planted beside trees, which increases the values of both diversity and aesthetics. The scores of social cohesion and wilderness are the two lowest values in Zone A, The area is near the side door of ESB building, which means most students who pass by the area are on the way to the classed, even though there are benches near the green area, only a few people may sit their. Also, some trees, that are not domestic species, were designed to be planted in this area, so the area is a highly artificial managed area, which makes the scores of wilderness and social cohesion to be lowest in the area.



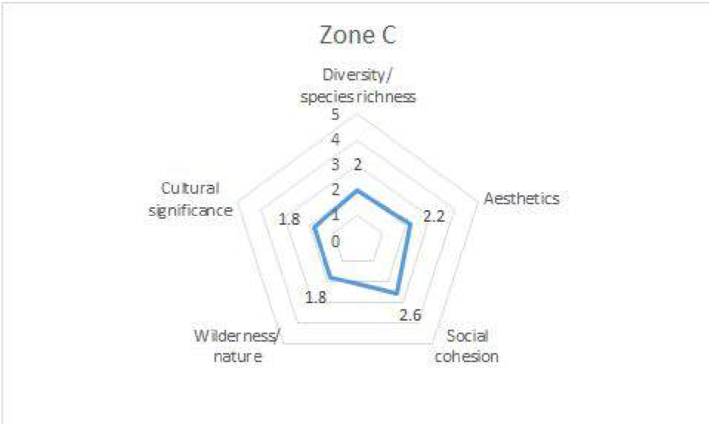
(Figure 7)

Zone B is the area from the edge of the Earth Science Building NW to the West Mall. This area is the biggest section with the most green spaces. Trees were planted massive and messy in the middle part (see figure 10). On both sides, trees that near ESB are new planted, which is organized and formed a small bosque. Trees on the other side on West Mall are also along the street and pedestrian road. That is the reason why wilderness is in the middle of the scales. Also, the pedestrian circulation is very high in the zone, but there is no space to seat, so the scale of social cohesion is also the at the middle level. The cultural services also do not significantly reflect on the site. The diversity of species is the highest in all zones because of its largest green area and the most tree species and vegetations, which form a beautiful place for people in surrounding buildings.



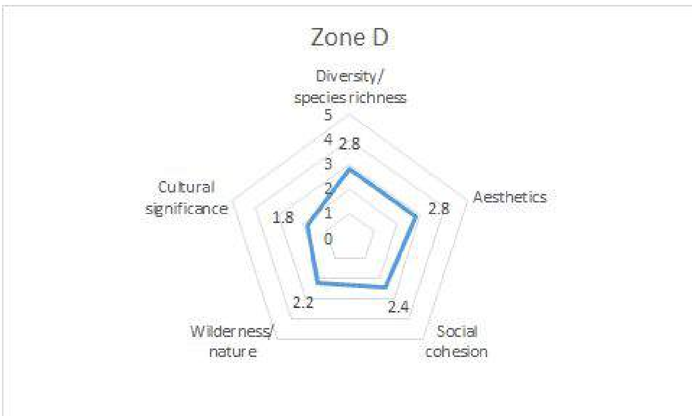
(Figure 9)

Zone C (see figure 12) is a thin rectangle area with parallel pedestrian road and a line of trees on a slope. The green cover is very low because the trees were planted in recent years. The distributions of the scores are similar also low compares to other zones. Trees were planted in a large parterre that is separated with people, and it provides shades to pedestrians, so social cohesion is not high. There is only one tree species in the parterre and has been well-managed, so the wilderness is low. The rest of the values does not have significant impacts and feelings to people.



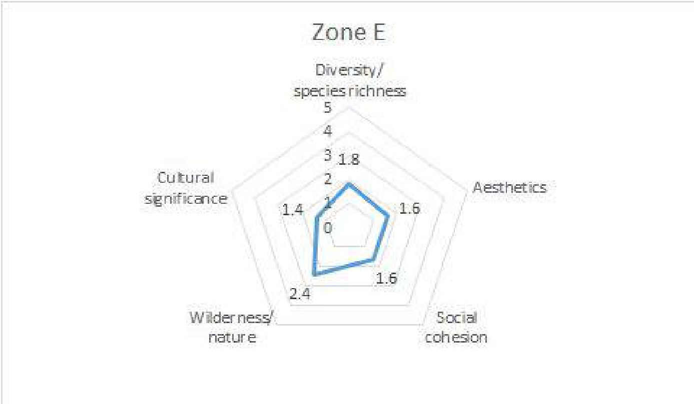
(Figure 11)

Zone D (see figure 14&15) is a small rectangle area around an office department with a small green alley between Campus and Community Planning Building, which has a relatively high species richness and aesthetic scores according to two areas beside it, Zone C and E, but except Zone B. The small alley has several different species and seats. It is a beautiful and peaceful area for social interactions, so its social cohesion value is high. The species near West Mall is the highest in the whole inventory area, and the species in the alley are small and diverse, so the species richness and aesthetics are the highest values. For the cultural significance, the place does not reflect many cultural aspects, so the score is the lowest. Overall, Zone D is focusing on the impacts that green space brings benefits in social interactions.



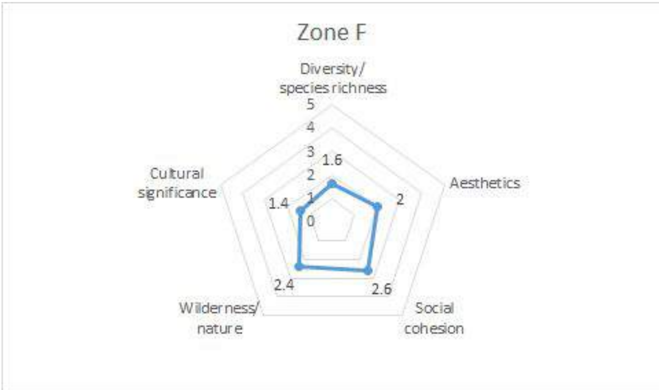
(Figure 13)

Zone E (see figure 17&18) contains the Campus and Community Planning Building and its relevant green spaces. There are shrubs and small vegetations near the tree and the building, which gives the sense of messy and has a greater value of wilderness. Also, the species diversity is low because there is only one tree in the whole space. The cultural significance is not obvious in the zone. Aesthetics and social cohesion values are very low. The reason is the place is lack of management in shaping an aesthetic view and the vegetation that between building cannot get enough sunlight, so the aesthetic level is very low. The value of cultural significance is one of the lowest in all zones because there is only one tree without any cultural significance that is also exist in another zone, so it is not very important.



(Figure 16)

Zone F is the zone with smallest area and least green cover in our cultural value assessment. It is in front of the CIRS building and West mall. The table (see figure 19)obviously indicated that the cultural value appearance in this zone is weaker than other because its scores are between one to three. The strongest felt dimension is Social cohesion, which caused by large number of pedestrian circulation. The species richness as well as cultural significance part of this zone are both the second lowest if compare to the rest zones due to its limited green cover area and species diversity. Basically the regulating value is greater than the cultural value in this zone.

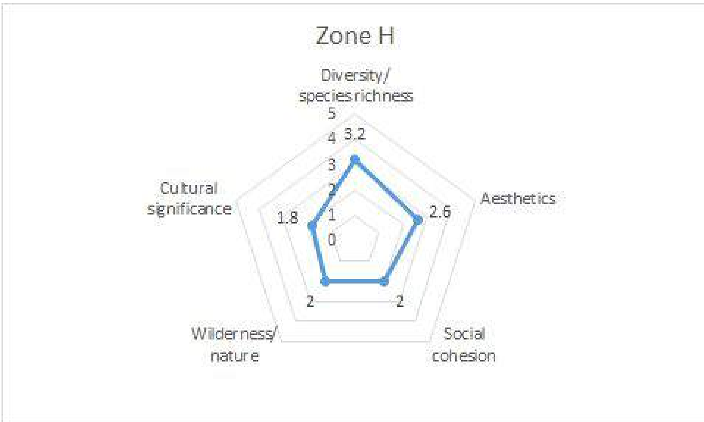


(Figure 19)

Zone G is located at second floor of CIRS building (see figure 20). it can be recognized as a community garden of CIRS building. The mapping table (see figure 21) shows it has a strong sense of species richness, and this is a truth, there are many species of trees are actually plant at the second floor platform. However, Aesthetics and Cultural significance score are comparatively low caused by lacking of management. On the opposite, the wilderness and nature feeling are higher, mostly like people feel unmanaged urban forest as a sense of wilderness. Superisely, the social cohesion value is high. Consider this site location is at second floor of CIRS building, and have a direct contact with indoor area with a lot of furniture. As a result the social cohesion part is higher than expect although there is not very much pedestrian circulation there.

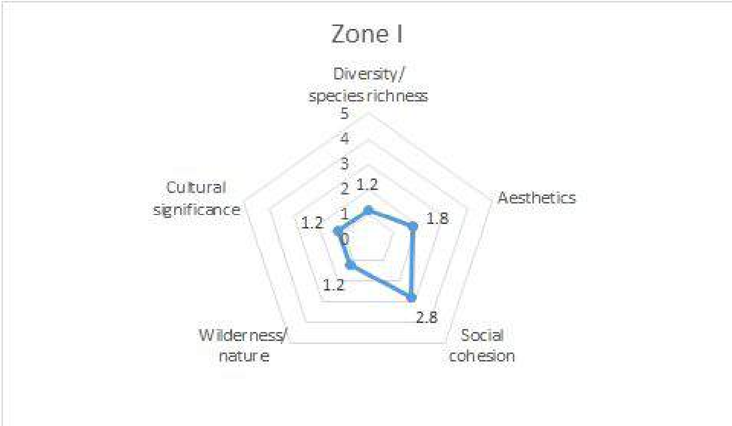
(Figure 21)

Zone H is waded between CIRS building and the pacific museum of earth. There are very few pedestrian circulation in this zone compare to others. As a result, the social cohesion, especially the feeling of community part is significantly decreased as shown in the table (figure 22). The highest dimension of this zone is the species richness and diversity even through there is not very much species are actually plant there, and the reason might be those tall pine trees create a feeling of diversity. This zone is extremely lack of cultural significance among zones have been accessed. The reason is the main area of this zone is road, and coordinate to few people circulation, the historical feeling decrease as the feeling of community decrease.



(Figure 22)

Zone I (see figure 23) is a zone that building area accounts for 99% and green space only have 1% of the total. As the table (figure 24) shown below, each dimensions have comparatively lower average score than other zones. For its species richness part, there is only one species plant there, and this is the reason cause the low species richness dimension. Cultural significance and wilderness feeling are also cause by less green space area. The aesthetic experiences a bit higher than dimensions mentioned above, and this is because those single tree sites create more open space and add some landscaping. On the contrary, the social cohesion part is the highest score dimension in this zone. Our operators observed several benches are set there, and we may conclude that basic social infrastructure are able to benefit the social interactions.

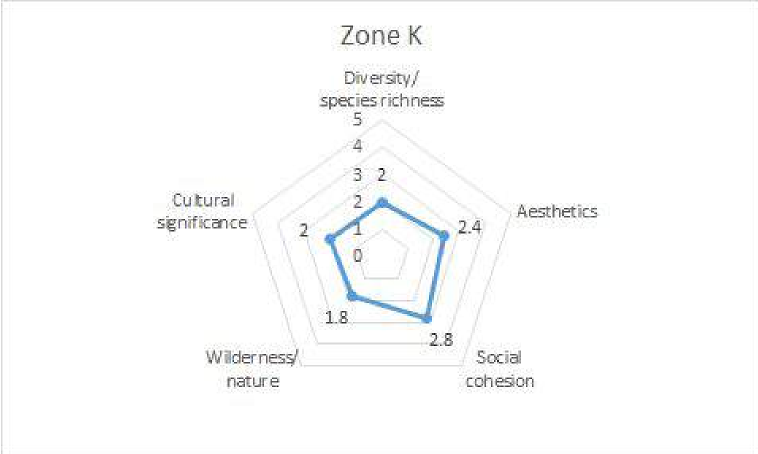


(figure 24)

Zone J is the only total closed space in our site. the general green space is tiny. This zone can be recognized as a community garden of the Pacific Museum of Earth. Based on the table (see figure 25)Landscape elements in this zone is rich. There are about 2-3 species of trees are actually plant here and in terms of the species richness part is not way too low. The social cohesion value is the highlight of this zone, many different types of users are observed in this zone. The wilderness and nature score is at the average, there is not quite obviously feeling of nature or calm feeling exist in this zone. Lastly the cultural significance part is comparatively higher than most of other zones.

(Figure 25)

Zone K is the open space (see figures 26) in front of the ESB and South west side of the Mall mall. Through our observations, this area is superisely popular for students. Based on our value map (see figure 27), the aesthetic experiences here is above the average, which is cause by large open space and well-designed landscape. The social cohesion part is also very high due to high concentration of benches and large number of pedestrian circulation. The wilderness feeling is the least among five dimensions, most likely because the landscape gives a strong sense of urban area, and lack a sense of nature. Cultural significance score is the third highest among eleven subzones. Diversity score is below average since the open space contain a lot of grassland rather than trees, and the tree species are limited.



(Figure 27)

Urban forest planning and management recommendations

Based on the results of previous regulating and cultural ecosystem service assessment, this section mainly focuses on the analysis of both services and provide the realistic recommendation in terms of urban forest planning. I-tree canopy has provided the percentage of land cover in the site indicating a relatively high percentage of tree canopy (25%) compared with other group areas, but within the 25 percent, most trees are planted in zone A and zone B. From the observation, the lack of green cover predominantly appears in zone C and north part of zone H (as highlight in while bars in figure 28). As previously described the zone C, the pedestrian road is exposed to the sun especially during the moon time, while a line of small-size trees in the parterre paralleling with the road fails to provide shed to the pedestrians. Close to the parterre, Wollemi Pine is the individual tree standing at the side of the road. Based on the regulating service assessment of this single tree, it has the least impact on the regulating service in terms of water interception, avoiding water-runoff and evapotranspiration. Therefore, it is not effective management at this point, when UBC urban planners only consider the aesthetic value of Wollemi Pine. In addition, on the path to the intersection of zone C to zone I (as shown in Figure 23), there is a couple of Ginkgos biloba planted beside the Pacific Museum of Earth. According to Royer, Hickey and Wing's research (2003), Ginkgos is a relatively shade-intolerant species. Since the building blocks the most sunlight, these growing trees might struggle with the low sunlight condition in the future. Therefore, it is suggestable to replace these trees with medium-size and shade-tolerant trees such as Japanese maple, Western arborvitae, and et al.

Another exposing area is the north part of Zone H (figure 29) where lacks green cover. When the sunlight reaches the concrete pavement, this area generates a high temperature disturbing the surrounding infrastructure. Even though a Juglans ailantifolia has been planted behind the Campus and Community Planning (Figure 30), the shed only covers a small part of the pavement. One possible solution counting this issue is to plant a higher tree with larger leaf area behind the Campus and Community Planning; the larger tree can provide a better shed as well as a greater impact on the ecosystems for the long-run.

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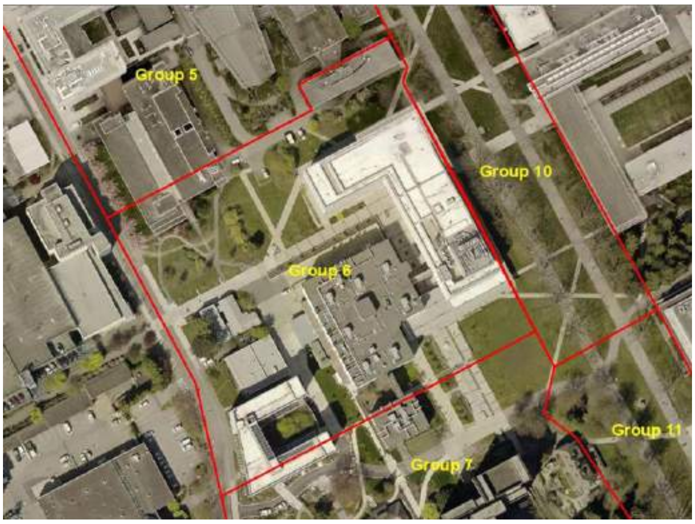
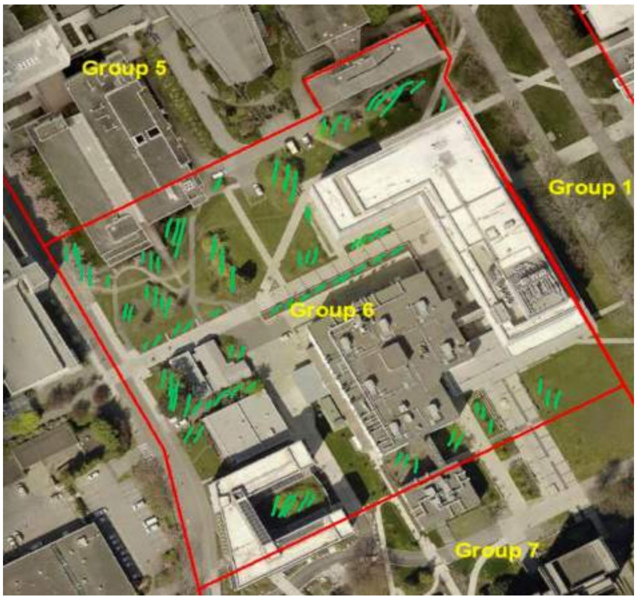
Appendencies



(figure 1)



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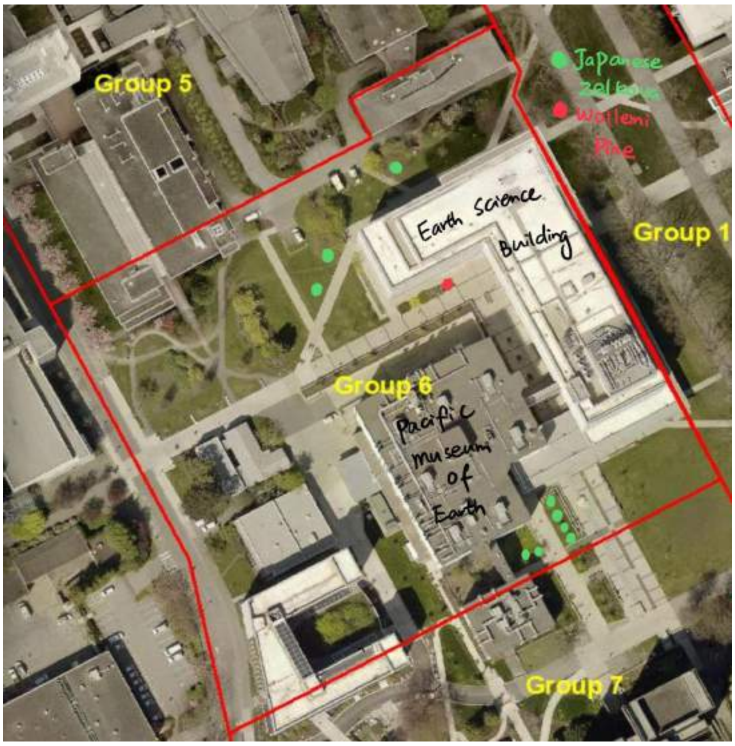
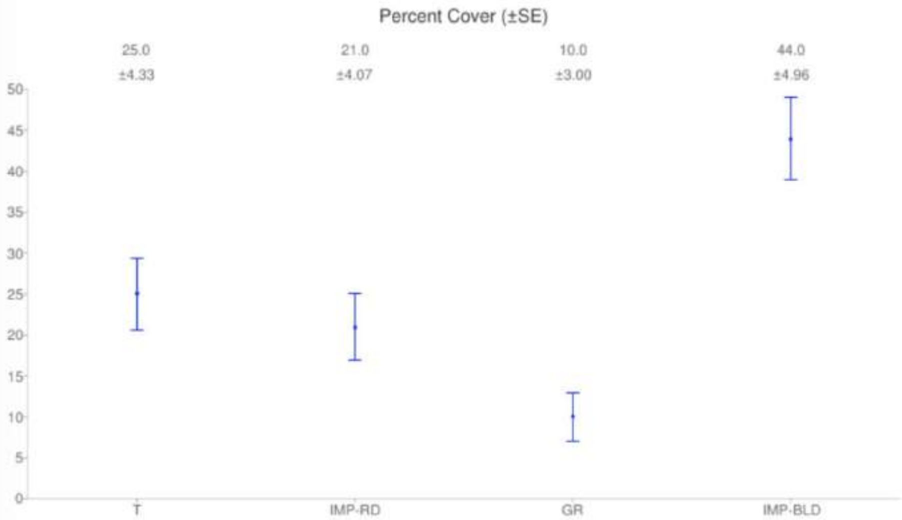


(Figure 5)

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 4/01/19



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	25	25.0 ±4.33
Impervious Road	Impervious roads and walks	IMP-RD	21	21.0 ±4.07
Grass	Grass surfaces	GR	10	10.0 ±3.00
Impervious Building	Impervious structures	IMP-BLD	44	44.0 ±4.96

Tree Benefit Estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	1.03 CAD	±0.18	1.16 lb	±0.20
NO2	Nitrogen Dioxide removed annually	1.98 CAD	±0.34	9.26 lb	±1.60
O3	Ozone removed annually	107.68 CAD	±18.65	56.54 lb	±9.79
PM2.5	Particulate Matter less than 2.5 microns removed annually	425.45 CAD	±73.69	4.38 lb	±0.76
SO2	Sulfur Dioxide removed annually	0.27 CAD	±0.05	3.32 lb	±0.58
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	80.74 CAD	±13.98	19.42 lb	±3.36
CO2seq	Carbon Dioxide squestered annually in trees	452.72 CAD	±78.41	7.34 T	±1.27
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	11,369.46 CAD	±1,969.25	184.26 T	±31.91

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and CAD/T/yr: CO 0.791 @ 1,775.33 CAD | NO2 6.314 @ 430.25 CAD | O3 38.570 @ 3,822.30 CAD | PM2.5 2.985 @ 195,133.90 CAD | SO2 2.267 @ 160.75 CAD | PM10 13.247 @ 8,345.36 CAD | CO2seq 10,010.267 @ 61.92 CAD | CO2stor is a total biomass amount of 251,395.359 @ 61.92 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

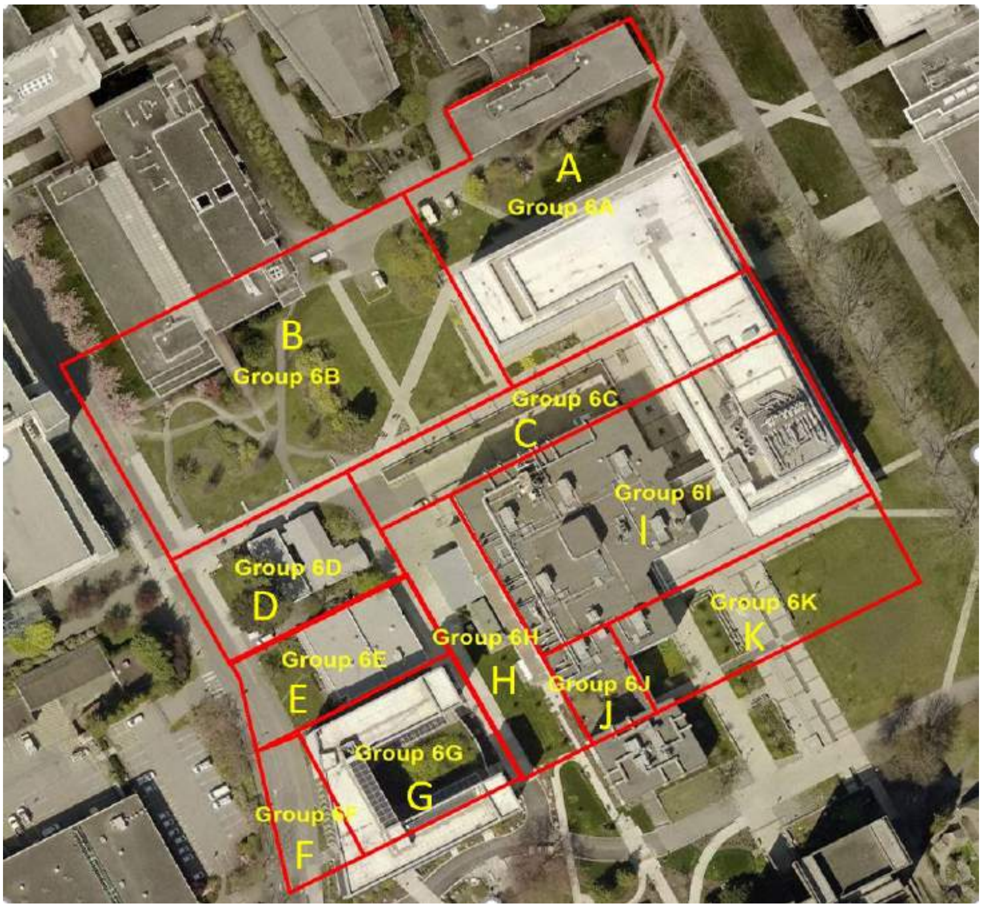
The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard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

A Cooperative Initiative Between:

DAVEY Arbor Day Foundation sma ISA Casey Trees

www.itreetools.org

(Images of report from i-tree canopy)



(Figure 6)

Zone A:

(Figure 8)

Zone B:

(Figure 10)

Zonc C:

(Figure 12)

Zone D:

(Figure 14)


(Figure 15)

Zone E:


(Figure 17)


(Figure 18)

Zone G


(Figure 20)

Zone I

(figure 23)

Zone K

(figure 26)

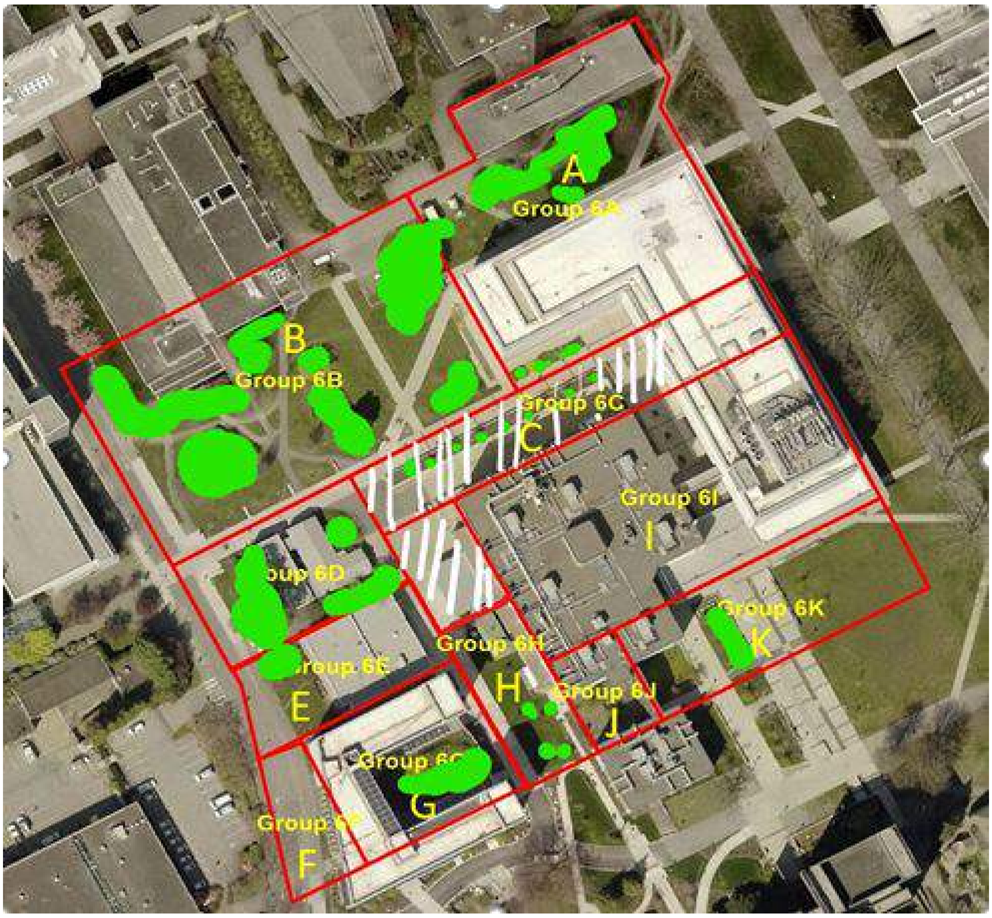


Figure (28)

Figure (29)

Figure (30)

UFOR 101

Group 6 Campus Tree Inventory Report

February 10, 2019

University of British Columbia, BC

All data is collected by the Group 6 members. Below is for individual contribution:

Zhejie Bao: Site description & methodology

Wendy Liu: Introduction, Graph 3, excel organization & calculations

Finnley He: Table 2, Graph 4, Table 3, Graph 5, Table 4 and its linked summary

Chang liu: Table 1, Graph 1, Graph 2, summary of species trees & its linked summary

Xuan Chen: Graph 6, Table 5, Table 6, its linked summary & final editing

Introduction

Urban forests are an integral part of the community. Whether street trees, park trees, tree in the schools, or in less structured open Spaces. Urban trees contribute a great role to community life and the quality of life of the inhabitants. Urban trees offer many benefits, including improved air quality, reduced stormwater runoff, reduced psychological stress, and provide recreation and aesthetics. Therefore, urban forests are important natural resources that communities care about protecting and preserving. Urban forests need to be protected and managed. Street tree inventory is an important tool to manage and plan urban tree population. Through the data have measured and collected by researchers, the information about the diversity, condition, and age of its trees have been analyzed and provided. Street tree inventory enabled communities to care about contemporary urban forests such as determine the extent, which is a tree is susceptible to pests and disease, and to evaluate tree performance to biotic and abiotic factors. In addition, urban forests inventory can assess ecosystem services which provided by urban forests such as carbon storage, water filtration, etc. And value its benefits for citizens or communities. Lastly, the most important purpose of inventory is to assist urban forest planning of schedule planting, maintenance removal activities, and then the authorities will inform management, budgeting decisions, and future plans. Therefore, the urban forest inventory is an indispensable part of urban forestry.

Site description

The site (see figure 1) where we accessed is made up by the UBC Earth Science Building (ESB) excluding Main Mall area in front of the ESB and the UBC Centre for Interactive Research on Sustainability (CIRS). Earth Science Building is a building for the Faculty of Science. Specifically, it is home to Earth, Ocean and Atmospheric Sciences, Statistics, the Pacific Institute of the Mathematical Sciences, and the dean’s office of the Faculty of Science. CIRS is a living lab of UBC and is used to test new ideas regarding human well-being and environmental issues. There are multiple faculties such as agriculture and Forestry share this building for interactive researches, and some of UBC services department office such as water supply department are set up in this building as well. Both ESB and CIRS belong to the institutional land use category. Users in this area mainly consist of students, teachers, stuff. Academic activities were the dominant activity type was observed by operators in this area, activities including teaching, studying, researching and some group working. The pedestrian volume in this area is huge due to its location is close to the West Parkade and West Mall.

Methodology

To analyze the tree inventory, some fundamental data and variables were recorded during the fieldwork. Data including Tree ID, Tag existence and specific Tag ID, Live/Dead, Species, Land use type, DBH (DBH height is included), Total tree height, Live crown height, crown base height, crown width, crown miss, and the crown light exposure (CLE).

Inventory Data

Tree ID, Tree Tags existence, Tag ID, Species, and Land use type are all provided by Collector APP.

Live/Dead status of trees is judged by investigators. Based on whether the tree performs leaves, fruit and sprout.

DBH is measured at 1.37 meters elevation above the ground normally. Tree with multiple stems will be considered as one tree. DBH measurement is up to six stems, choose from largest to smallest, the aggregated DBH for that tree will be calculated by the square root of the sum of all squared stem DBHs. Other trees with irregularities will not measure at 1.37 meters above the ground, see figure 2.

A clinometer is used for measuring tree height. The method for measuring tree height is different with various scales. Firstly, measure the distance from a tree, the distance should be perfectly level if the ground has no slope. If a slope is not possible for avoiding, stand uphill and measure a horizontal point on the tree is the best method. Secondly, use the scale. For the left scale in the clinometer which is the degree scale, take value to the top of the tree and bottom of the tree (should be negative) separately. After that, use trigonometry to determinate the total tree height, the formula is Tree height = (tan A + tan B) * distance. For the right scale in the clinometer which is the percent scale, use formula (A%+ |B%|) *distance to determinate the total tree height.

Live crown height is the height from the ground to the most top live crown of the tree. If the most top live crown is the same as the top point of the tree, the live crown height is equal to total tree height. If the most top live crown is not the same as the top point of the tree, the operator measures the live crown height through the clinometer method for total tree height.

Crown base height is the height from the ground to the base of the live crown. If the lowest live crown can be reached, the operator will measure it directly. If the lowest live crown cannot be reached, the operator will measure it the same way while measuring the tree height.

Crown width is the width of the crown in two directions, the long side and the short side.

Crown miss and CLE. For the crown miss, four operators standing at four angles and visualize the typical crown outline for the species and estimate the percentage of crown missing. Finally, take an average of four estimate value. For CLE, in the fieldwork, the whole group observes the tree light exposure and finally make decisions by discussing.

Analytical Data

Common analytical variables used in this report are the basal area, average tree height and standard deviation.

Basal area is the cross-sectional area of a tree stem measured at breast height, it is calculated by a formula – BA=pi *DBH/40000.

Average tree height is determined by cumulative tree height divided by the total number of trees (or category of trees).

Standard deviation (SD) is a measurement of the variability of a data set.

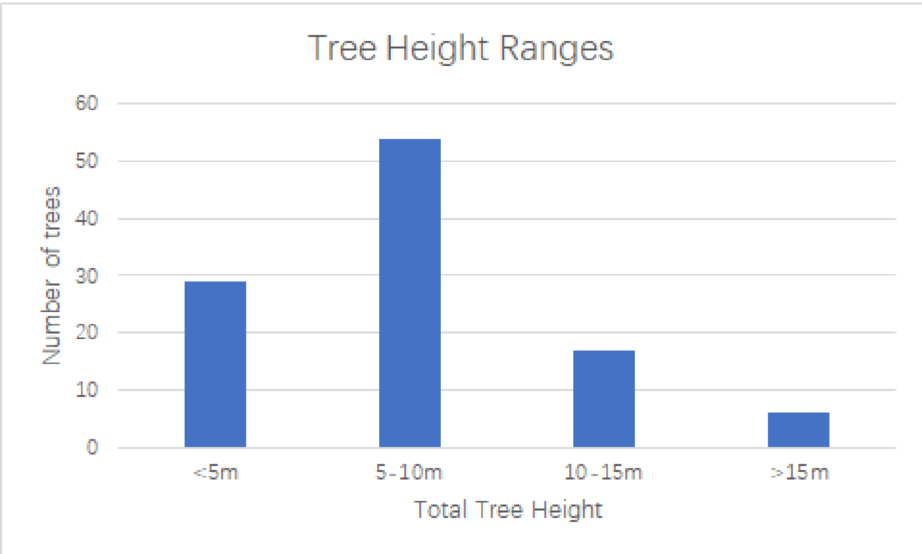
Predicted height is a prediction of the future tree height.

Summary

Total tree height	# Trees
<5m	29
5-10m	54
10-15m	17
>15m	6

Data Analysis

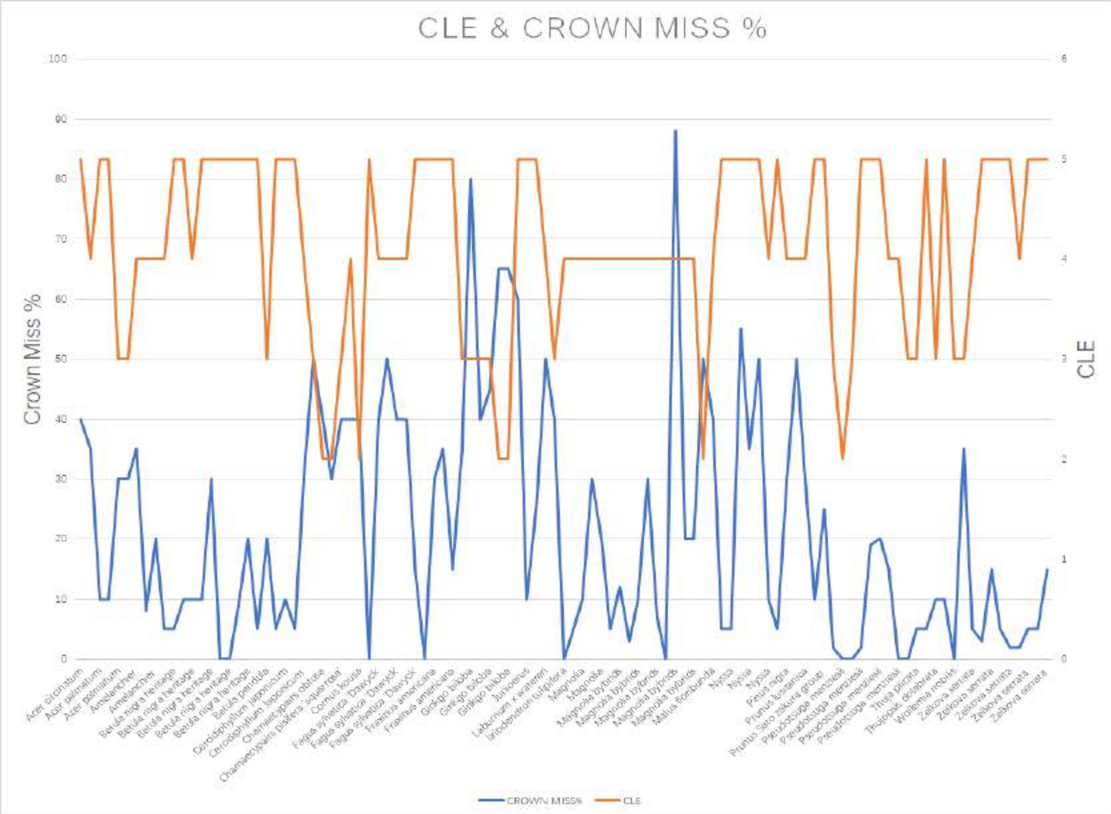
Table 1: Total Tree Height and Number of Trees (Liu, 2019).



Graph 1: Tree Height Ranges (Liu, 2019)

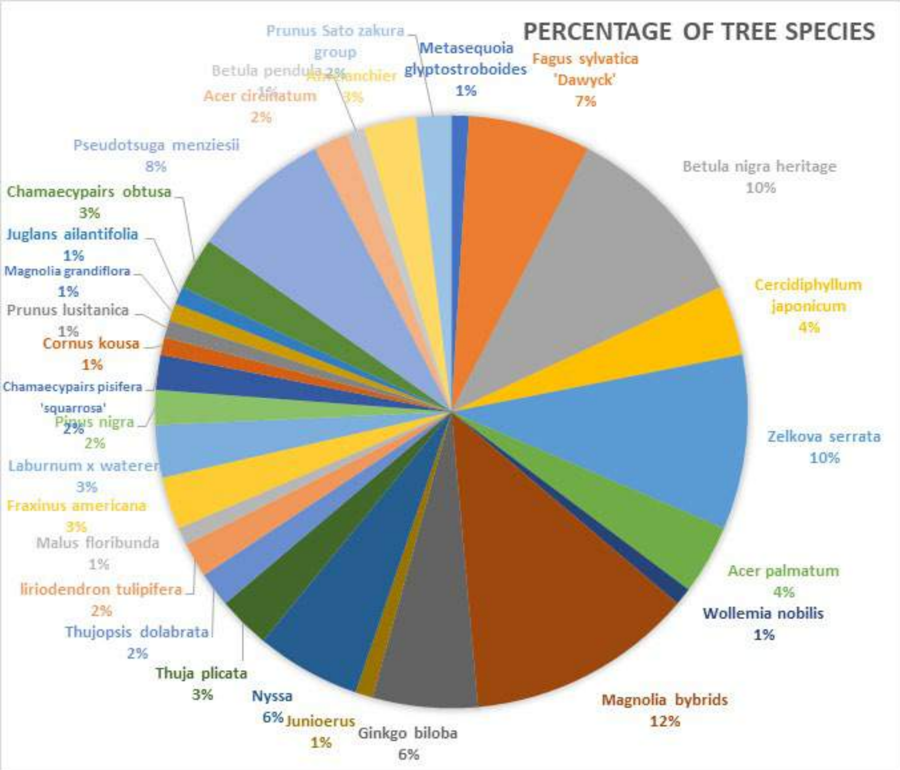
In the inventory area, the total tree heights are varied from 2.1m to 17.8m. In table 1 above, all tree heights have been separated into four ranges by the same periods of 5 meters. Most of the trees are lower than 10m. About 27% of the trees are lower than 5m. Over half number of trees are distributed in 5m to 10m period within 51%. The other 16% of trees are from 10m to 15m. The rest of them, only 6% of them are taller than 15m, and the tallest one is 17.8m. Species like liriodendron tulipifera, Chamaecypairs pisifera 'squarrosa', Thuja plicata, and Pinus nigra are supposed to have a relatively taller height in all species in this area. Also they only have a small amount of population. Therefore, there is no huge tree, and most of them are normal heights.

The reason why there are only a few big trees that taller than 15m in this site, may because of the slope of the landform and the age of trees. Because almost half of the site is on a slope, the choice of choosing the species is not supposed to be very high, and the gradient also influences the tree growth (McNab 1989). The other factor, the age of the tree is also important, there are a few trees that are just planted. If there is enough time for growing, the total tree height is going to increase and the distribution of those periods also will change.



Graph 2: The Relationship of CLE and the Percentage of Crown Miss (Chang, 2019)

The line chart above (Graph 2) shows the relationship between CLE and crown miss. CLE is the acronym of Crown Light Exposure, which has 5 scales to represent how many sides can be exposed under sunlight. Also, the more sides are lighted, the higher scale of CLE that a single tree would have from 1 to 5. The crown miss is measured in the percentage of crown missing like broken branches or unexpected missing parts. It also can represent the health degree of a tree. In the chart above, the x-axis labels every single tree in the inventory area, and y-axis labels crown miss percentage in blue line and CLE in the orange line. For the CLE, the light exposure scales of all trees are above 2, most of the scales are 3 and 4, and many trees' scales are 5, so the average scale is high. The distribution of the scales means that most of the trees in this area have a good growing environment, the general condition is that they are not growing too close to each other and not close to the building. The crown miss is related to CLE; they have a negative relationship. In general, the more light exposure on a tree, the less percentage a less percentage of crown miss will have; the less light exposure on a tree, the more percentage of crown miss will have.



Graph 3: Percentage of Tree Species (Wendy Liu, 2019)

According to the graph 3, there are 29 different species in this site within 105 trees. Magnolia Bybrids takes the most places of 12% in this area. The second species are Zelkova Serrata and Betula Nigra Heritage, which are both 10%. The rest of them are all less than 10%, and most of them are 1% to 3%.

Special trees

1. Metasequoia glyptostroboides (Dawn Redwood)

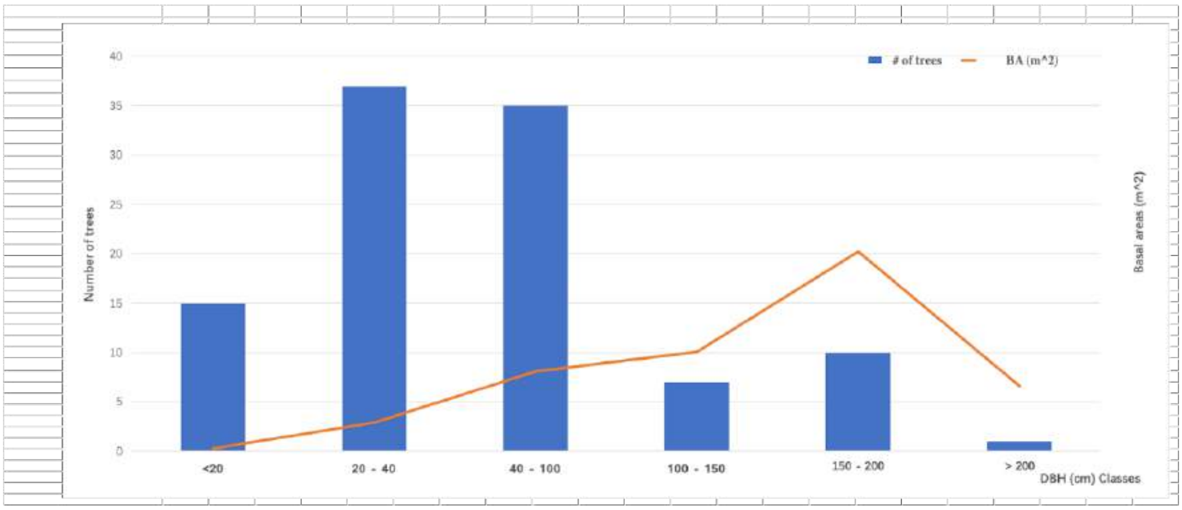
The species was discovered in China in the 1940s, "one of the greatest botanical discovery of the twentieth century" (Ma&Shao, 2003). It is defined as the "living fossil" in plants and trees because the fossil has recorded the species that was existed in the early Cenozoic taxon(Fulling, 1976, 1977). Metasequoia glyptostroboides now is one of the endangered species in the world. The reason for the decreasing number or even becoming extinct of the species is the temperature decrease, and it cannot live in cold weather. Therefore, the species was found in a warm area in China during discovery. Also, because of the large number of deforestation and less seed spreading, the number of it decreased. At that time, the government was not giving enough protection for habitat of seedlings, so there were many seedlings that are around the old one, which was not good for seedling establishment (Bartholomew, Boufford & Spongberg, 1983) In order to protect the species and recover the loss, it is cultivated to all around the world. Many of them survived and grew in a healthy condition because of its features, fast growing.

2. Wollemia Nobilis

The species was found in Australia, which also has been existed for a long time and its fossil records "exhibits a number of vegetative and reproductive morphological features that are somewhat intermediate between Agathis and Araucari" (Chambers, Drinnan & McLoughlin, 1998). The "stochastic mortality of adults and low survival of seedlings" makes the species has a small population can survive and has the possibility of extinction (Zimmer, Auld, Benson & Baker, 2014). Firstly, global cooling and the northward movement of Australia caused a decreasing number of Wollemia. Then in the next stage, climate change increases the rate of wildfire, which also destroys the Wollemia forest. The seedling of Wollemia is the period which is the most dangerous in its life stage. The roots of seedling are very small and easy be influenced by drought. Also, it is easy to get fired because of its “thick bark and lignotuber development” and low fire point(2014). Therefore, the tree in the site is planted in a perfect position because it is surrounded the Earth Science Building, so it would not be exposed under direct sunlight, except at noon the light directly light the tree. But at the same time, the building is made by light color walls and glasses, so the light will not directly toward the tree but reflect through the wall to it, which makes the temperature to it will not too high and not exceed its burning point.

DBH (cm)	# of trees	BA (m^2)
<20	15	0.293660373
20 - 40	37	2.905522386
40 - 100	35	8.069318956
100 - 150	7	10.10424869
150 - 200	10	20.19368634
> 200	1	6.605198554

Table 2. Relationship between DBH, number of trees and basal area. (He, Z.,2



Graph 4. Relationship between DBH, number of trees and basal area. (He, Z., 2019)

The distribution of different-sized diameter at breast height (DBH) is created to figure out the relationship between the tree number and basal area in the sample place (near Earth Science Building and Pacific Museum of Earth in UBC).

According to the graph shown (Graph 4), a remarkable height is found in the bar chart that most of the trees’ diameter at breast height is lower than 100 cm, and specifically, there’re more than half of the inventory trees’ DBH ranging from 20 to 100 cm. However, the corresponding trend for the basal area saw a relatively low increase. This illustrates that recently, a bunch of young and new-planted trees are located in the investigated region, and due to the short period growth, they are incapable of suiting new surroundings by gaining sufficient moisture or nutrients from the underground soil. In addition, because of the combination of the chemical, physical and biological factors, a significant pressure is placed on these trees’ growth and thus decreases the basal area value.

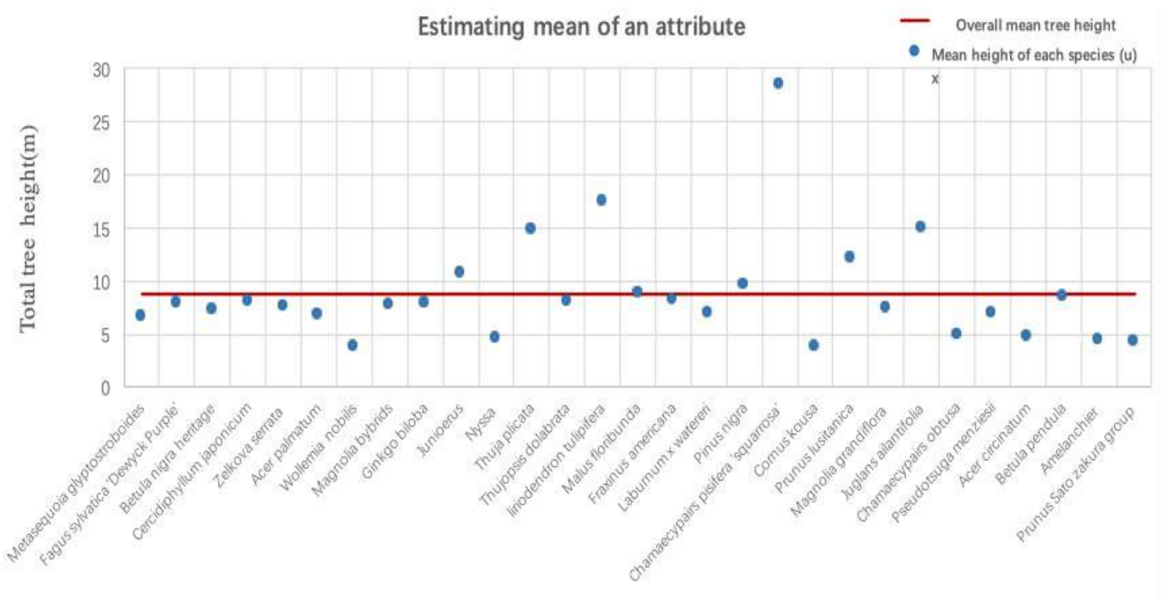
In comparison, a particular greater basal area is shown (Graph 4) on DBH from 100 to 200 cm, and its value reaches the peak within 150 to 200 cm class of DBH. But which is closely followed by an urgent downward tendency in the number of tree and BA while DBH is higher than 200 cm. This reflects that normally as the stands of trees grow, older trees develop a larger DBH which is accompanied by higher basal area. In other words, the trees' capacity for increasing annual ring growth is stronger (Nix, 2018). Exceptionally, it can be observed that there is an only surviving tree which DBH is higher than 200 cm, and this is exemplified by that older trees experience destructive forces from the weathering, human activities, and biological environment. Throughout the long-term competitiveness, nature favor those are strong enough to adapt to the environment best, and therefore, this explains why only one tree left in the largest DBH. Furthermore, this tree reaches to the upper limit for growth and then its basal area is small.

Generally, in normal circumstance, the greater the basal area is, the smaller the number of trees survives finally as the value of DBH increases. In the aspect of timber harvest, basal area will be reduced to a point where the remaining trees regain the ability to enhance the growth, and turn into a valuable and mature forest product (Nix, 2018).

Tree species	Value of each species's mean height (m)
	x
Metasequoia glyptostroboides	6.66
Fagus sylvatica 'Dewyck Purple'	7.94
Betula nigra heritage	7.23
Cercidiphyllum japonicum	8.14
Zelkova serrata	7.595
Acer palmatum	6.87
Wollemia nobilis	3.85
Magnolia bybrids	7.72
Ginkgo biloba	7.87
Junioerus	10.7
Nyssa	4.625
Thuja plicata	14.8
Thujopsis dolabrata	8.11
liriodendron tulipifera	17.45
Malus floribunda	8.91
Fraxinus americana	8.23
Laburnum x watereri	7.01
Pinus nigra	9.705
Chamaecypairs pisifera 'squarrosa'	28.5
Cornus kousa	3.9
Prunus lusitanica	12.1
Magnolia grandiflora	7.45
Juglans ailantifolia	15
Chamaecypairs obtusa	4.88
Pseudotsuga menziesii	7.01
Acer circinatum	4.8
Betula pendula	8.54
Amelanchier	4.41
Prunus Sato zakura group	4.38
sum	254.385
mean	8.7718

Table 3. The relationship between species mean height and overall height. (He, Z. & Liu, 2019)

The table and the scatter plot (Table 3, Graph 5 on next page) outline the tree species' mean and overall height, in order to estimate the variance by using the standard deviation (5.48m on table 4). In the scatter plot, the majority of dots that represent each species' mean height are positioned near the overall mean value (8.7718m on Table 4), except for several species including Chamaecyparis *pisifera 'squarrosa'* (28.5m), Liriodendron *tulipifera* (17.45m), Juglans *ailantifolia* (15m) and Thuja plicata (14.8m) that are fair amount of distance away from mean height. Those exceptions' high standard deviation indicates the high degree of variability, and this phenomenon can be stated by the following possible explanations.



Graph 5. The relationship between species mean height and overall height. (He, Z., 2019)

Firstly, Chamaecyparis *pisifera 'squarrosa'* is the tallest tree species in the sampled area. It is a non-native species from Japan, and the normal height ranges from 15 ~22m (Chamaecyparis pisifera 'squarrosa', n.d.). The mature plants will grow the long filamentous branches, and with the growth habitat, there is an irrelevant relationship between annual growth rate and tree size. Rather, the height of the tree is mainly dependent on the individual (Olszyk, 2017), and therefore this species tree height in the investigated area is exceptional with 28.5m.

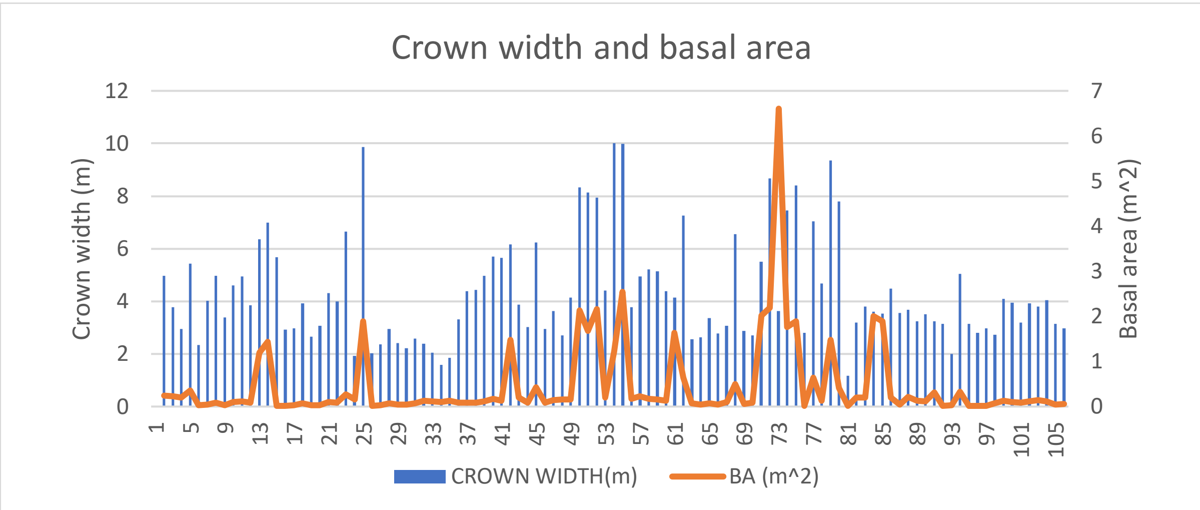
Secondly, Liriodendron *tulipifera* is native to the eastern deciduous forests of North America and belongs to the tallest hardwood species. Its' height typically grows around 16 - 18m while an initial moderate to rapid growth rate occurs but which is followed by a decreased development with age. The survival rate is high due to the low pruning requirement, resistant to breakage, the moderate drought tolerance and resistance to pests (F. Gilman & G.Waston, n.d.). The important factors supporting its height growth in UBC are the full exposure to sunlight and the preference to moist conditions. Due to the geographical location where is close to the sea, every year, the high humidity from precipitation and long sunny days in UBC at Vancouver create a favorite ecological habitat for Liriodendron *tulipifera*. Therefore, the height of this species (17.45m) is much higher than the other species in the sample area. The First nation's people construct this tree into the canoe for utilizing the long and straight featured wood. Its' properties such as fine, uniform grain and coloring ability made it an ideal wood which is useful in objects construction (Mosquin, 2015).

Thirdly, Juglans *ailantifolia* is a deciduous tree which is native to Japan as well. The common tree height is from 15 ~ 20m (L. Graney, n.d.). And this kind of species can grow on almost any soil only if providing the fertile soils. Not only this, the availability of a spacious area is another factor for Juglans *ailantifolia* to develop a good and regular crown (Juglans ailantifolia, n.d.). The tree height grown within the campus (UBC) is measured as 15m which is in the normal tree height range, indicating that soil fertility and growing area is great for the development.

Lastly, Thuja plicata is commonly called western red cedar, and this species is abundant in Western North America with 15 ~ 22m. This type of tree is best grown in moist, fertile soils with many nutrients in full sun to part shade (Thuja plicata, n.d.). And specifically, it often occurs at low to mid elevations along the coast due to the climate there is mild and moist. It is known that western red cedar is British Columbia's official tree, and coastal people often use them for dugout canoes, house planks, and clothing. The durability of the tree makes it a great material for decking, fencing and outdoor furniture (Western redcedar, n.d.).

	u---->	7.6375			
Tree species	Value of each species's mean height (m)				
	x	x-u	(x-u)^2		
Metasequoia glyptostroboides	6.66	-0.9775	0.95550625		
Fagus sylvatica 'Dewyck Purple'	7.94	0.3025	0.09150625		N=29
Betula nigra heritage	7.23	-0.4075	0.16605625		
Cercidiphyllum japonicum	8.14	0.5025	0.25250625	sum / # of popilation	30.08899
Zelkova serrata	7.595	-0.0425	0.00180625		5.485343
Acer palmatum	6.87	-0.7675	0.58905625		
Wollemia nobilis	3.85	-3.7875	14.34515625		
Magnolia bybrids	7.72	0.0825	0.00680625		
Ginkgo biloba	7.87	0.2325	0.05405625		
Junioerus	10.7	3.0625	9.37890625		
Nyssa	4.625	-3.0125	9.07515625		
Thuja plicata	14.8	7.1625	51.30140625		
Thujopsis dolabrata	8.11	0.4725	0.22325625		
liriodendron tulipifera	17.45	9.8125	96.28515625		
Malus floribunda	8.91	11.9225	142.1460063		
Fraxinus americana	8.23	1.0675	1.13955625		
Laburnum x watereri	7.01	6.5375	42.73890625		
Pinus nigra	9.705	-0.1075	0.01155625		
Chamaecypairs pisifera 'squarrosa'	28.5	16.5775	274.8135063		
Cornus kousa	3.9	2.8325	8.02305625		
Prunus lusitanica	12.1	5.5625	30.94140625		
Magnolia grandiflora	7.45	7.5575	57.11580625		
Juglans ailantifolia	15	-1.5775	2.48850625		
Chamaecypairs obtusa	4.88	2.0475	4.19225625		
Pseudotsuga menziesii	7.01	1.4475	2.09525625		
Acer circinatum	4.8	-2.7575	7.60380625		
Betula pendula	8.54	10.1175	102.3638063		
Amelanchier	4.41	2.3625	5.58140625		
Prunus Sato zakura group	4.38	2.9325	8.59955625		
sum	254.385		872.5807313		
mean	8.7718				

Table 4. The estimating of standard deviation of an attribute (He, Z., 2019)



Graph 6. The relationship between the crown width and the basal area (Chen, 2019).

The graph 6 indicates the relationship between the basal area and the crown width within the measured 105 trees. On the x-axis, the range indicates the numbers of trees adding from 1 to 105. While the crow width is to determine the longest branch of the tree, it also can demonstrate the total mapping of the tree which links to the basal area. As a whole observation, the crown width is proportion to the basal area of the trees. From number 21 to number 24 trees, the value of crown width arises (4.005m to 9.875m) to the top accompanying with the rising of the basal area (0.09079m^2 to 1.8869m^2). Furthermore, from number 49 to number 53, the rising of the crown width (8.33m to 10.02m) follows with the rising of the basal area (1.6742m^2 to 2.5447m^2). This proportion indicates a phenomenon that the greater of the crown of the tree is, the greater of the basal area is. In other words, the trees who occupy a large space of the crown will generally have thick stems. For example, large tree such as liriodendron tulipifera which is the tallest of eastern hardwoods generally has the thick stem supporting the large tree crown (Beck, n.d). Moreover, because the tree locates at an open area which there is no building or other constructions beside it, the tree is able to spread out its crown without disturbances.

SPECIES	Height average	Predicted Height	Average DBH
Metasequoia glyptostroboides	6.66	18.72770533	55
Fagus sylvatica 'Dawyck'	7.94	18.61832429	54.12
Betula nigra heritage	7.23	16.44672983	38.98
Cercidiphyllum japonicum	8.14	19.91622611	65.39
Zelkova serrata	7.595	19.51197237	61.68
Acer palmatum	6.87	17.4891906	45.72
Wollemia nobilis	3.85	10.76587089	15
Magnolia bybrids	7.72	19.1370634	58.404
Ginkgo biloba	7.87	16.24018396	37.75
Junioerus	10.7	25.3077699	137.3
Nyssa	4.625	6.810446141	29.25
Thuja plicata	14.8	26.42807603	159
Thujopsis dolabrata	8.11	17.9837508	49.25
liriodendron tulipifera	17.45	26.10766704	152.5
Malus floribunda	8.91	18.54033569	53.5
Fraxinus americana	8.23	17.18679366	43.67
Laburnum x watereri	7.01	23.82564746	112.67
Pinus nigra	9.705	29.26846924	228.5
Chamaecypairs pisifera 'squarrosa'	28.5	26.10766704	152.5
Cornus kousa	3.9	10.39610902	14
Prunus lusitanica	12.1	22.18066357	90
Magnolia grandiflora	7.45	25.29119904	137
Juglans ailantifolia	15	20.58939694	72
Chamaecypairs obtusa	4.88	16.39519852	38.67

Pseudotsuga menziesii	7.01	21.14381054	77.875
Acer circinatum	4.8	11.4515396	17
Betula pendula	8.54	19.87468222	65
Amelanchier	4.41	10.39610902	14
Prunus Sato zakura group	4.38	13.67961589	25

Table 5. The predicted Tree height (Chen, 2019).

The table 5 shows the comparison between the average tree height and the predicted tree height within the 29 species. By predicting the future tree height, the relative personnel will be able to assess the impact of the tree to the surrounding buildings and the pedestrian. Pinus nigra has the largest average DBH comparing with other species, so based on the calculation of the predicted height, it is predicted as the tallest tree (29.26846924m) in the inventory area. Pinus nigra is a fast-growing evergreen conifer commonly reaching 30 m high (Enescu, Rigo, Caudulo, Mauri & Durrant, 2016). Grew the exposing space in the campus, pinus nigra has the environmental advantage to occupy the large area. Except the advantageous geography, pinus nigra is seemingly the older species than other new planted species in the campus. In additional, there are two Laburnum x watereri where locates at the western-side of the pavement predictably reaching 23m in the future. As a considerable height, these two Laburnum x watereri might cause significant impact to the surrounding buildings and the pedestrians who walk cross the sidewalk.

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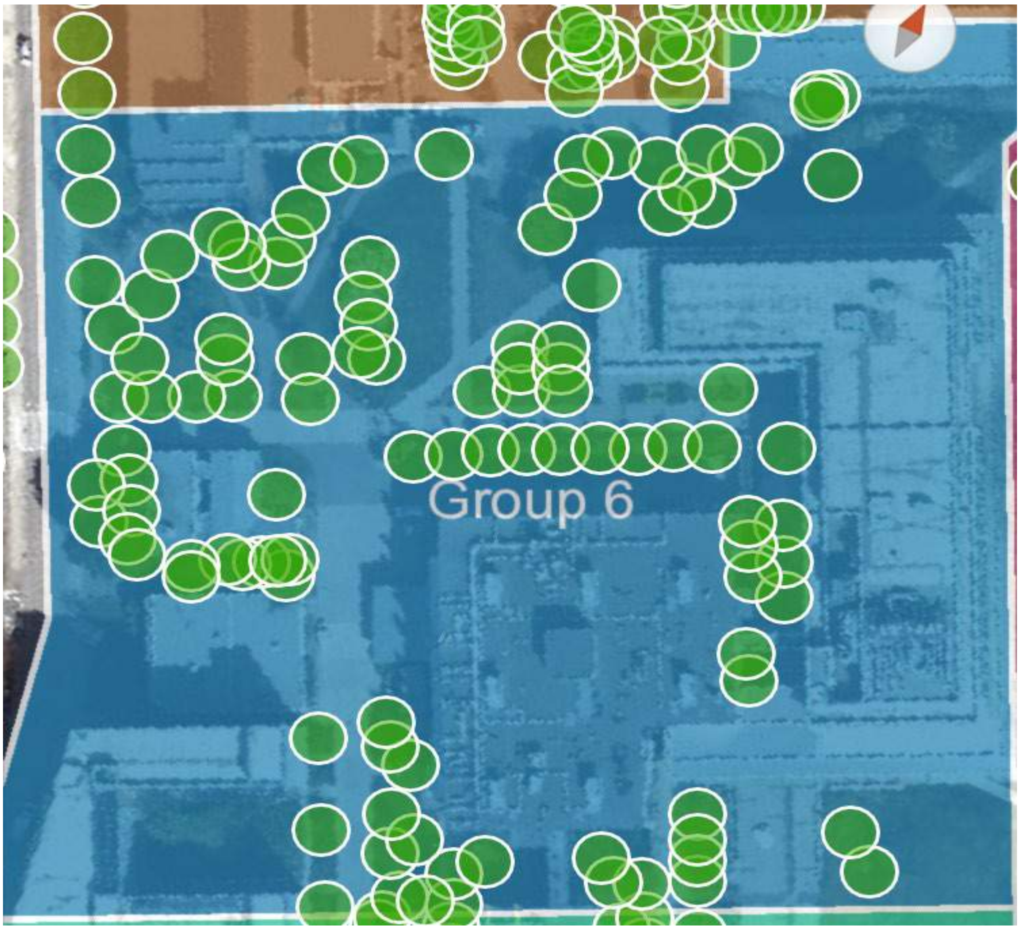

Figure 1, Zone Map

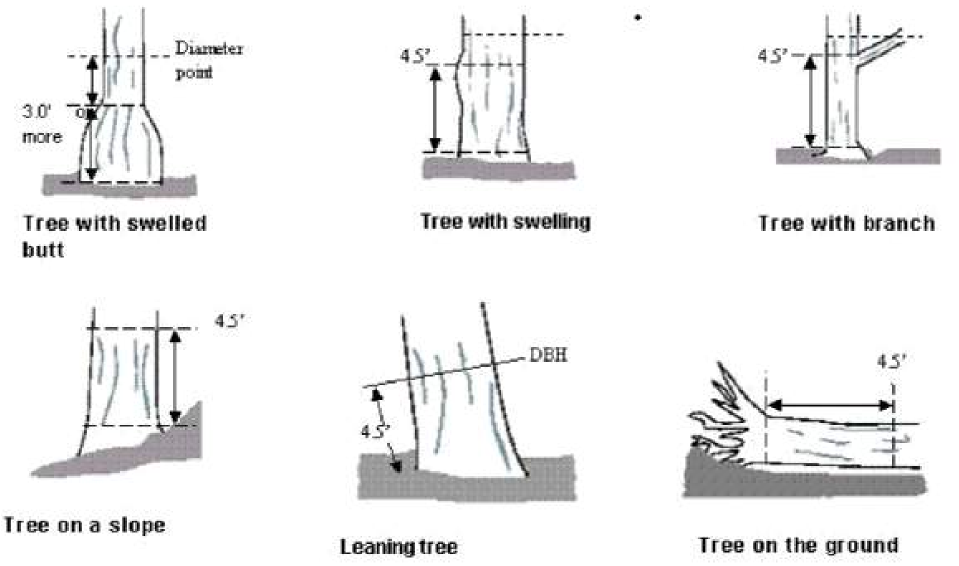

Figure 2, Special DBH measurement

	Live	SD
TREES	105	
SPECIES	29	
DBH mean (cm)	58.5952	50.089074
BA mean (m^2)	0.4642	0.878746915
Total height mean (m)	7.6375	3.714628683
Crown base mean (m)	1.1574	0.750080667
Crown width mean (m)	4.3202	1.97170049

Crown miss (%)	
< 10%	35
10 - 30 %	40
31 -50 %	24
51 - 80 %	4
> 80 %	2
Crown light exposure	
0	0
1	0
2	7

3	17
4	37
5	44

Table 6. The summary of the overall data (Chen, 2019).

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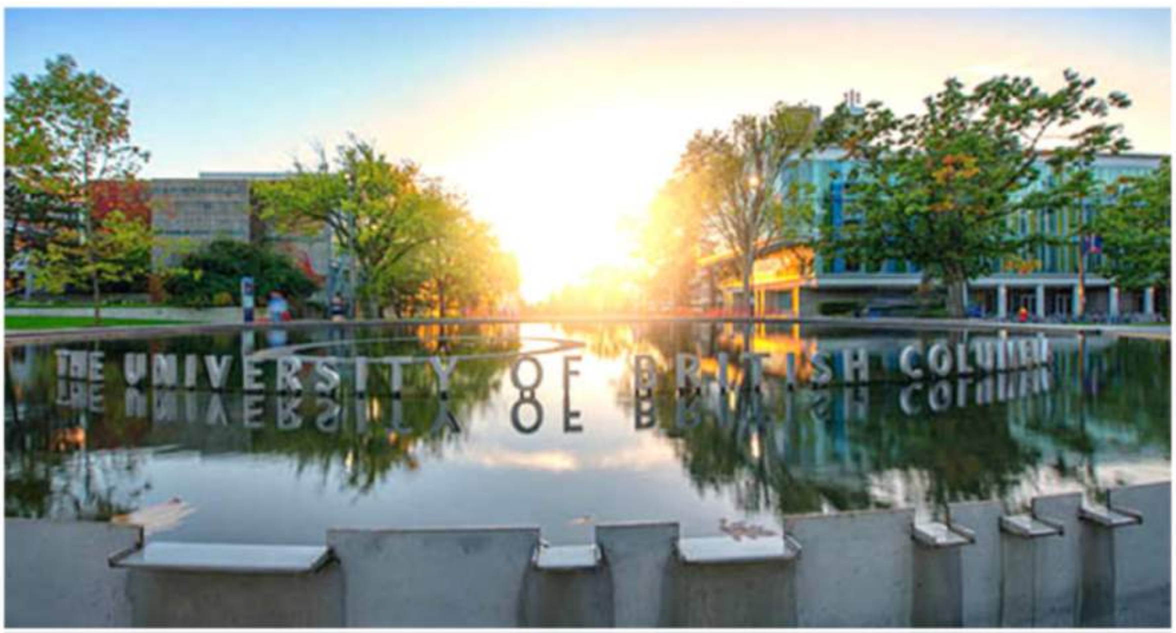

Group 7

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Date: 03/04/2019

Contribution Page

Yvette Jiang	• Introduction • Cultural ecosystem services: "The cultural ecosystem help ... view about the cultural ecosystem services." • Formatting
Tait Sun	• Site description • Regulating ecosystem services: "3.1 To assess and quantify … based on the two models" • Formatting
Yixuan Yu	• Regulating ecosystem services "3.2., 3.3., 3.4." • Appendix • Formatting
Lauren Chen	• Cultural ecosystem services: "The cultural ecosystem services can … cultural services are created"; "According to Figure … of the zone"; all pictures • Formatting
Yanbo Liu	• Urban forest planning and management recommendations • Appendix • Formatting

1. Introduction

This report is about assessing the ecosystem services provided by urban forestry in Zone 7 of the University of British Columbia (UBC) campus, based on the inventory data collected in the Assignment 1, i-Tree Canopy, i-Tree Eco and cultural services value mapping. Due to the campus environment development, it is more likely to focus on the development of urban forestry. More specifically, the ecosystem services assessment is helping the development of campus forestry, which could help the urban planners building up the better ecological environment. According to those, this report would give corresponding recommendations and suggestions to the campus ecological environment, and it helps the future ecological environment of campus more likely conducive to the stakeholders.

The following section is site description which would provide the overall view of the Zone 7, the detail information about the ecological environment in Zone 7. The regulation ecosystem services part is by using i-Tree Canopy, and i-Tree Eco to determine the ecosystem services. The cultural ecosystem services part is combining with diversity/species richness, aesthetics, social cohesion, wilderness/nature, and cultural significance to quantify ecosystem services in the subzone. And the last part is urban forest planning and management recommendations, which is analyzing the regulation ecosystem services and cultural ecosystem services, and give corresponding constructive recommendations.

2. Site Description

As Figure 1 shows, the fieldwork area is a block located at Midwest of the UBC campus between West Mall and Main Mall. The location on the coordinate system is 49°15'42.8"N and 123°15'08.5"W. From Figure 2 shows, there is a small road called Stores Rd across the field and connected Main Mall and West Mall. This little road will become very busy during the class shaft period because a lot of people will use this road across the file and take the class in the West Mall or Main Mall. Also, the Stores Rd is a downward slope from Main Mall to West Mall. During the rainy day, water will be keeping stream down from the uphill (Main Mall) to the downhill (West Mall). So, there is a sewer connected to the Main Mall and West Mall. The drain well managed the rainwater and avoid water flooding on the Stores Rd.

Figure 1. Google Map satellite picture view

There are few buildings in our field. The building in the southwest corner is "Horticulture Sunlight house laboratory," on the right side is "Stores Road Annex" teaching building" next one is "Department of Materials Engineering" Building." And the house on the east side is a kindergarten. As you can see the kindergarten is surrounded by vegetation which provided a privacy environment for those children in the kindergarten. Also, two buildings only have some parts in our field which are the CIRS building and "Earth, Ocean and Atmospheric Sciences" building.

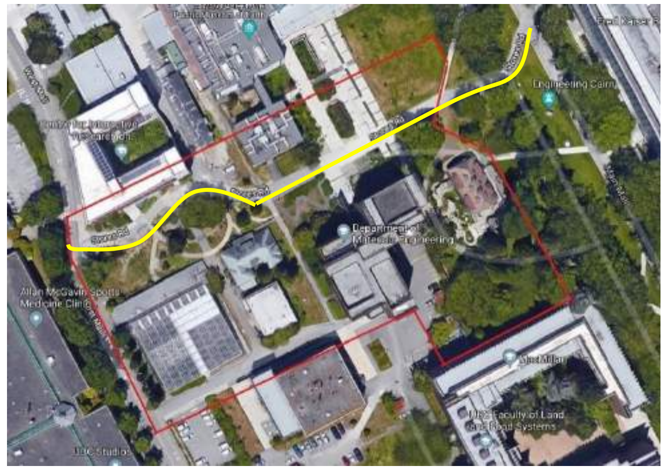

Figure 2. Google Map satellite picture small view for our field

Moreover, there are a few different Stakeholders in the area. UBC Campus and Community Planning is the most critical stakeholder in the area; they're responsible is the field's daily maintaining and future improvement. Most of the building in our field use for the educational purpose, so students and professors will be important stakeholders too. Also, because of the small kindergarten in our area, children can be our field's stakeholders as well. And UBC is a famous university, so a lot of visitors come to visit it every year. Thus, visitors can be one of the stakeholders.

In our zone, there are a total of 83 trees and 25 different tree species. However, many species have only one tree. The dominant tree species are Acer Circinatum (so-called Vine Maple) and Zelkova Serrate (so-called Japanese zelkova). Overall, tree species diversity is relatively high in our zone.

3. Regulating Ecosystem Services

3.1. Methods

To assess and quantify ecosystem services in the conducted zone, two main tools are used for the purpose which are i-Tree Canopy and i-Tree Eco. i-Tree Canopy is a web application which use to calculate the percentage of canopy area for a specified region. We created 100 examine points in the i-Tree Canopy, and the result shows that the canopy area in our field around 40%. It is a pretty good result. i-Tree Eco is "a model that uses tree measurements and other data to estimate ecosystem services and structural characteristics of the urban or rural forest" (Tree, 2019). Comparison with i-Tree Canopy, the i-Tree Eco is much complex to use it, but i-Tree Eco can get more data about the ecosystem services. More detailed comparisons will be explained in the following part.

For the specific steps of using i-tree eco, we transfer our inventory data to the requested format in Excel first. In the i-Tree Eco application, under the Project Definition, we choose Nation in

Canada, choose Province is British Columbia, and District is Greater Vancouver. The population we import 16133 and use 2010 as Weather & Pollution Year. Then, use 718920-99999 as Weather Station for accessing local weather information. Next, import inventory data and fix errors to adjust the data. Afterwards, we introduce Benefit Prices for each benefit description. We import the prices of Can$1,348 per ton (carbon monoxide), Can$95 per ton (ozone), Can$13 per ton (nitrogen dioxide), Can$5 per ton (sulfur dioxide), Can$3,414 per ton (particulate matter less than 2.5 microns), Can$0.07 per ft^3 (avoided runoff). For the last step, the inventory data is uploaded and submitted to i-Tree Eco for processing. Finally, a comprehensive ecosystem services report from the i-Tree Eco is exported which comes with all the input data and the detailed analysis and results. The following part will demonstrate specific regulating services based on the two models.

3.2. i-Tree Canopy Analysis

The selected area uses i-Tree Canopy model as one of regulating services assessment model to conduct two main aspects of urban forestry condition, basically tree canopy cover and tree benefit estimates.

For tree canopy cover, 100 points are randomly selected and put into tree and non-tree cover class. 40 points are examined as tree canopy, which is a relatively large number.

For the tree benefits estimates (Table 1), there are 8 types of removal benefits. See table below for specific descriptions, amounts, values, and standard errors of each benefit categorize.

Table 1. i-Tree Canopy tree benefit estimates

Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	1.30 CAD	±0.16	0.00 t	±0.00
NO2	Nitrogen Dioxide removed annually	3.33 CAD	±0.41	5.81 kg	±0.71
O3	Ozone removed annually	212.02 CAD	±25.88	38.67 kg	±4.72
PM2.5	Particulate Matter less than 2.5 microns removed annually	608.09 CAD	±74.22	2.45 kg	±0.30
SO2	Sulfur Dioxide removed annually	0.49 CAD	±0.06	2.14 kg	±0.26
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	111.04 CAD	±13.55	12.12 kg	±1.48
CO2seq	Carbon Dioxide squestered annually in trees	576.27 CAD	±70.34	8.47 t	±1.03
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	14,472.30 CAD	±1,766.51	212.83 t	±25.98

Among the annual benefits (except CO2stor), the removal of PM2.5 creates the highest value for 608.09 CAD. CO2 sequestration value is 576.27 CAD annually, ranking secondly in the list. The values provided by removed SO2, CO, and NO2 are weigh more slightly which is less than 5 CAD per year.

To sum up, the i-Tree canopy presents brief results that help with quick information pick-up of the zone.

3.3. i-Tree Eco Analysis

Based on standardized field data and local hourly air pollution and meteorological data, the regulating services results analysis will mainly focus on air pollution removal, carbon storage and sequestration, oxygen production, and avoided runoff (i-Tree Eco Report, 2019).

3.3.1. Air pollution removal

Air pollution removal estimates are derived from calculated hourly tree-canopy resistances for ozone, sulfur and nitrogen dioxides based on a hybrid of big-leaf and multi-layer canopy deposition models (Baldocchi 1988; Baldocchi et al 1987). Air pollution removal by trees in the conducted zone is estimated by 34.19 pounds per year with an associated value of Can$2.18, including ozone (O3), carbon monoxide (CO), nitrogen dioxide (NO2), particulate matter less than 2.5 microns (PM2.5), and sulfur dioxide (SO2). Among those, the ozone takes the greatest proportion (around 23 lb). CO, NO2, and SO2 are all less than 5 lb, making small contribution to the overall removal (Figure 3).

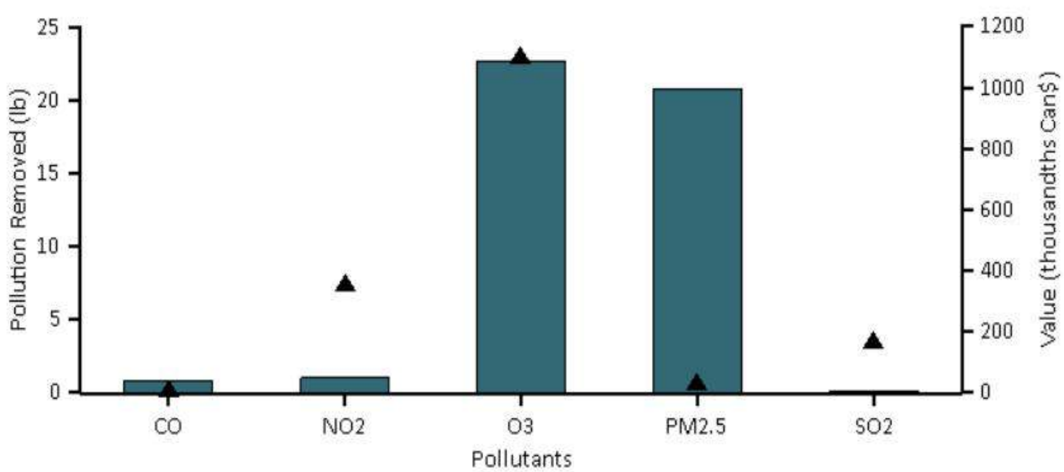

Figure 3. Annual pollution removal (points) and value (bars) by urban trees, i-Tree Demo UBC

3.3.2. Carbon storage and sequestration

Carbon storage and sequestration are conductive to climate change mitigation. For identification, carbon storage is the amount of carbon bound up in the above-ground and below-ground parts of woody vegetation while carbon sequestration is the removal of carbon dioxide from the air by plants (i-Tree Eco Report, 2019).

Detailed data of carbon storage and sequestration are shown in figure. Overall, the gross sequestration of i-Tree Demo UBC trees is about 1649 pounds of carbon per year with an associated value of Can$85.9. Trees are estimated to store 29 tons of carbon, which is about value of Can$3.03 thousand.

By contrast, both graphs show the matched weight and monetary value of CO_2 by each tree species. The first three most functional trees of the species sampled are the same in both graphs, basically Red Maple, Pin Oak, and Northern red oak. Red maple stores and sequesters the most carbon (approximately 27% of the total carbon stored and 19% of all sequestered carbon.)

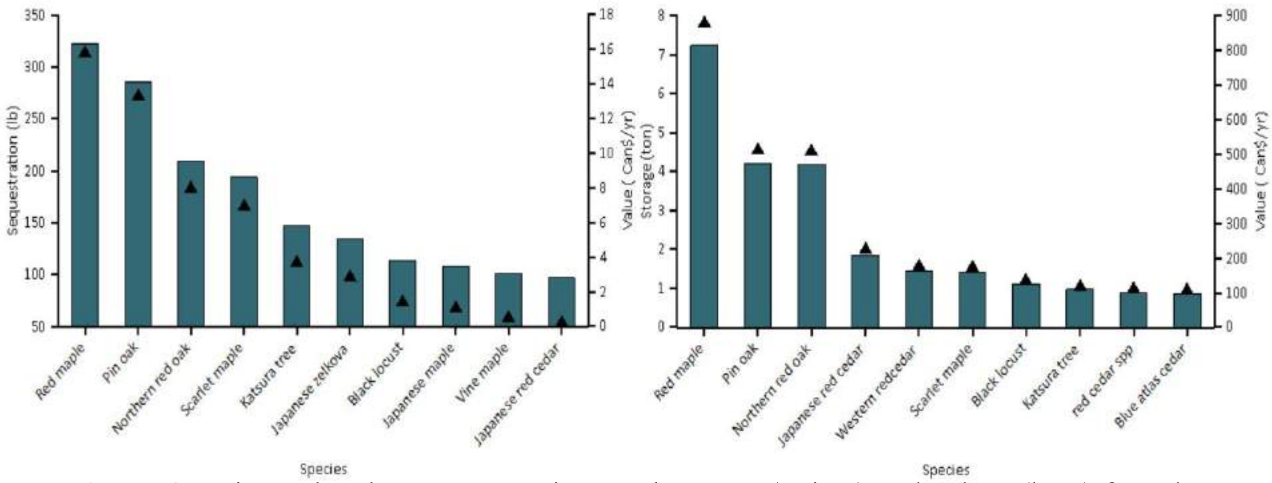

Figure 4. Estimated carbon sequestrations and storage (points) and values (bars) for urban tree species with the greatest storage

3.3.3. Oxygen production

Oxygen production can be considered as a most commonly benefits of urban trees. The annual oxygen production is directly related to the carbon sequestration, which explains the same ranked species between top oxygen production and carbon sequestration in results. The oxygen produced by trees in the zone is estimated to be 2.199 tons per year. However, this tree benefit is relatively insignificant because of the stability and large amount of the oxygen.

3.3.4. Avoided runoff

Avoided runoff is calculated according to the difference between rainfall interception with or without vegetation. Only leaves are accounted for this calculation. In general, the trees and shrubs in zone 7 help to reduce runoff by an estimated 2.87 thousand cubic feet a year with an associated value of Can$189 per year.

To highlight relative water management benefits, the subzone B (figure 5) is worth more attention since it has an existing drainage system located at the site. According to UBC Integrated Stormwater Management Plan (2016), there are several types of stormwater management system on our campus. The open drainage channel (figure 6), as a commonly distributed component of the drainage system, effectively contributes to the regulating ecosystem services by utilizing the urban forest landscape on the characteristic slope. Although trees are not densely planted along the slope area, they do help to avoid water runoff and enhance the soil capacity of water infiltration. The potential threat of flooding is also be addressed by the particular allocation of vegetation.

Figure 5. Subzone B in the Zone 7

Figure 6. Open drainage channel

3.4. Similarities and Differences of i-Tree Canopy and i-Tree Eco

By comparing the results of two assessment models, there are some apparent similarities and differences. For the similarities, the two models use some consistent elements for tree benefits measurement, including the removal quantity of O_3, CO, CO_2, NO_2, SO_2, and $PM_{2.5}$. Meanwhile, both models use monetary value to directly reflect the tree benefits, which is clear and easy to understand. When considering long-term urban forestry governance, both of them help examine the current situation and help guide urban forest management and monitory.

On the other hand, the differences between the two models are obvious. As the model name indicated, these two models apply distinctive data collection and processing approaches. Therefore, although these two models use similar measurement criteria, the results show a range of variance. By contrast, the i-Tree canopy results shows a larger number of values than i-Tree Eco results due to the higher tree coverage.

Besides, i-Tree Eco uses the inventory database on local field data and hourly meteorological and pollution data (e.g. i-Tree Demo UBC) to calculate regulating service, which comes out with relatively higher data accuracy. It also means that the process requires a big effort to complete the field work and also time-consuming. While i-tree canopy allows users to easily photo-interpret Google aerial images of the area to produce statistical estimates, which contains some uncertainty for calculations (Ferrini, et al., 2017).

4. Cultural Ecosystem Services

The cultural ecosystem services can be produced by the value mapping approach that has five elements, including diversity/species richness, aesthetics, social cohesion, wilderness/nature, and cultural significance. Our zone is divided into seven subzones, and then the group members marked seven subzones from 0-5 through field experiences, following these five elements. By summing and averaging individual scores, the summary chart is shown below (Figure 7). Besides, our group communicated with reasons of grade and roughly decided which subzones have higher cultural services and which subzones have lower cultural services in class. Eventually, the value mapping of cultural services is created (Figure 8&13).

The cultural ecosystem services help stakeholders getting the non-material spiritual satisfaction in the ecological environment. Determine the strengths and weaknesses in the subzone for five branches of the cultural ecosystem services. The value mapping approach are based on the group members, the weakness is monotonous because of the group members' ages are similar, and members are all represent the group of students which is not able to represent other stakeholders. For the value mapping, it needs a larger number of sample size to get more accurate data analysis. The strength is basing on each members' life experience, they have own view about the cultural ecosystem services.

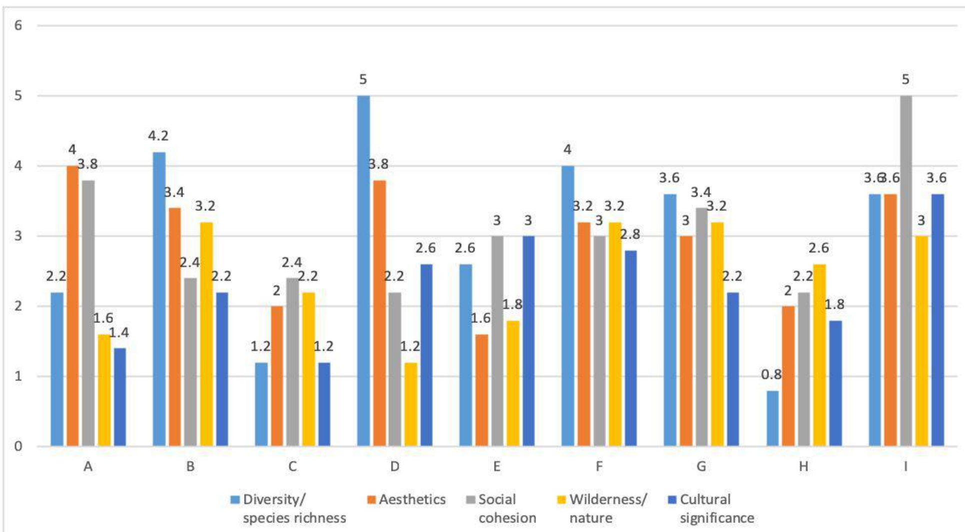

Figure 7. Average Value mapping results

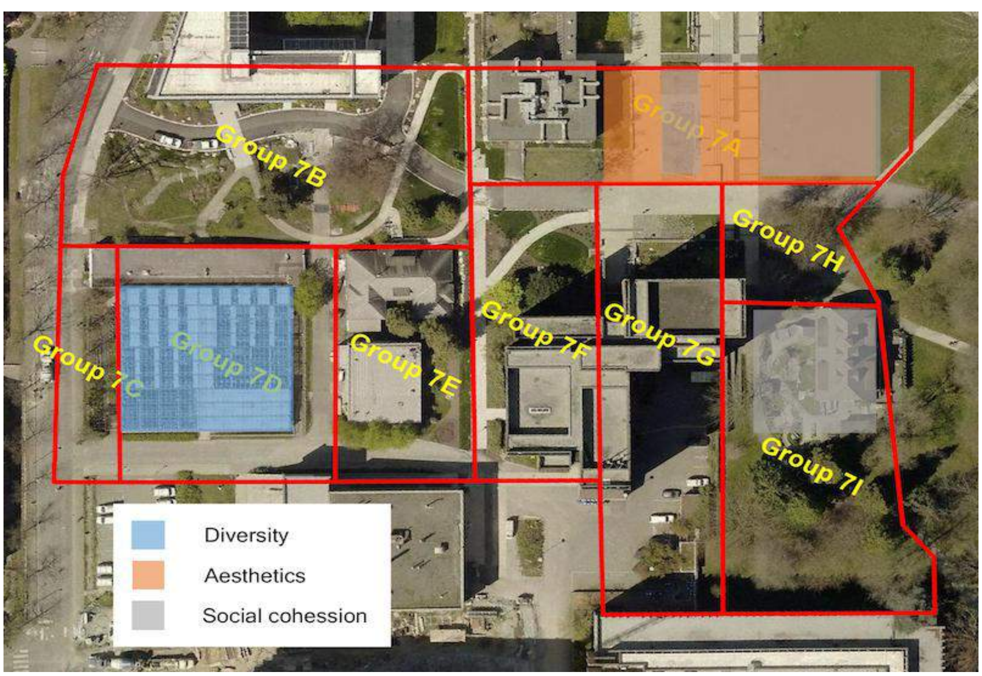

Figure 8. Strengths of cultural services

8

According to Figure 7 above, it can be seen that some subzones have strengths of cultural services, including diversity, aesthetics and social cohesion (see Figure 8). First, Subzone B, D, F get the high marks of diversity, with 4.2, 5, 4 separately. Notably, Subzone D obtains the full grade of diversity, because of Horticulture Building. It can be seen from Figure 9 that various seedlings are cultivated in this greenhouse, such as pine, ornamental plants, climbing plants and other potted plants. Second, Subzone A is the most beautiful area of all, comprising lawn, lightings, benches, trees (Figure 10). The layout of Subzone A is designed formally. To be more specific, trees are planted to surround the benches regularly, and benches have different shapes for people to sit and lie. Besides, flowering trees have ornamental value, which reflects the seasonality of tree selection. In Subzone F, several trees are blooming, adding more aesthetics and human flow in this place (see Figure 11). Third, owing to a kindergarten, Subzone I gets the full mark of social cohesion. As can be seen from Figure 12, there are some trees in the kindergarten with infrastructure, like benches, stairs, swing and pavilion. Children have strong dependence with trees since they can do many activities around trees, such as playing a swing, climbing, having a rest, and so on. Also, in Subzone A, different kinds of benches increase the likelihood of passersby to stay, which is a sort of example of social cohesion. For the lawn in Subzone A, it is an excellent place for individuals to do large-scale activities, like camping, playing frisbee, and other outdoor games.

Figure 9. Horticulture Building

Figure 12. Kindergarten

Figure 10. Subzone A

Figure 11. Flowering trees

Figure 13. Weaknesses of cultural services

Figure 14. Sundial

However, some subzones have apparent weakness of cultural services, in terms of cultural significance, aesthetics and wilderness (Figure 13). As for cultural significance, two subzones have room for renovation. There is a sundial in Subzone E that was constructed in 1984 (Figure 14). However, this sundial is broken and discarded, as well as the soil around the sundial is muddy, so the sundial sometimes is ignored by passersby. It seems like to be unimportant how much historical meaning the sundial embodies. Apart from this, in Subzone G, a retro patterned wall is constructed by different shapes of bricks, as a part of the Department of Materials Engineering.

Figure 15. Brick wall

From Figure 15, it may be seen that the surroundings, including trees and lawn, do not have a good combination with the brick wall. Also, there is no trail to access this wall, which makes the design of brick wall lose its intention. Moving to aesthetics, the arrangement of tree planting and maintenance ought to be considered. As shown in

Figure 16. Areas lacking aesthetics

Figure 16, some areas in the zone are messy and lack of management. If these areas can be well-managed, the aesthetics of the entire zone will be improved. Finally, the grades of wilderness in seven subzones are under 4. That is to say, the zone is an urban area, and most green areas are artificially designed, which may mitigate the feeling of nature from passersby. Therefore, the mental benefits of green space have been relatively weakened.

Overall, our zone does not provide high cultural ecosystem services and still has some opportunities to enhance that. Moreover, increasing green infrastructure and paying attention to maintenance are an approach to connect the subzones and increase more functions of the zone.

5. Urban forest planning and management recommendations

5.1. SWOT Analysis

SWOT analysis is a useful technique for understanding strengths and weaknesses in our site, and for identifying both the opportunities open to you and the threats you face. And we use this method to conclude the key concepts about regulating ecosystem services and cultural ecosystem services. In terms of strengths, our site has many young trees, which can provide more potential shade, temperature cooling for people. The diversity in our site is relatively higher than other sites, and there are 25 species in our site. As regulating ecosystem services part mentioned, the topology in our site is particular, which is a slope. And the trees on the slope can absorb the rainwater in order to mitigate the runoff when the precipitation is high caused by global warming. Base on those strengths, there are some opportunities for our sites. Those young trees in our site will provide more potential shade for stakeholders, like more people can have a rest or read under the shade because more shade will be provided by young trees. Also, the recreational space will be increased because the trees will grow bigger and bigger. The social cohesion will be bonded between trees and people's recreational activities. Also, the high resilience in our site can mitigate the negative effects of human activities.

However, there are also some weakness and threats to our site.   The first weakness is that the distribution of our trees is not even. Literally, some areas have fewer trees, and some areas have less trees. Although our resilience is high, the imbalance of distribution will reduce the resilience of our site. Then, in the cultural ecosystem part, some areas in our site lack of green infrastructure, and the aesthetic and social services will be affected by the lack of green infrastructure. Also, the monitoring and maintenance of trees are lacking. In terms of threats, the broad threats in our site are climate change, and climate change has huge impacts on the vegetation. Climate change will drive the increase in temperature and precipitation in summer. When the precipitation is high, the threat of flood increases in our slope. Also, the other threat is the pest. For example, some of the individual trees are not able to resist pest. Finally, human intervention is a threat to urban trees because human activities indirectly damage and affect the growth of trees.

5.2. Recommendations

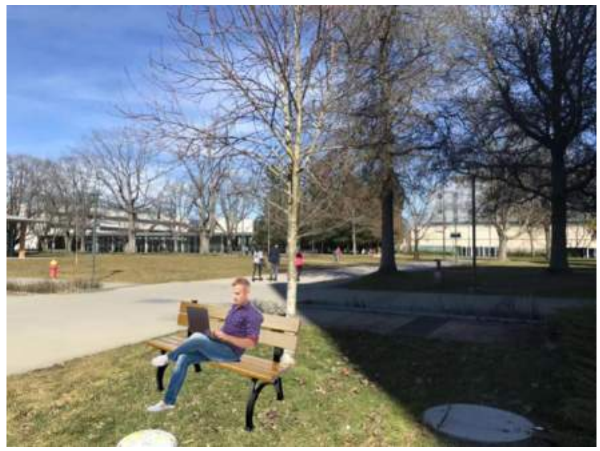

Figure 17. The future scenario

Figure 18. The future scenario

According to the SWOT analysis, there are three recommendations we proposed. The first two recommendations are related to the urban forest planning, and the last recommendation is an innovative idea about urban forest management. The first recommendation is that we propose to install green infrastructure around some trees (*Figure.*17&18). Actually, many trees on our campus only have regulating ecosystem services. If there are some benches under the tree, the students and other staff can have a seat or have a rest under the tree. And the connectivity between green space and stakeholders will be enhanced in this process, which means the cultural ecosystem services can be improved, and the social cohesion can be increased similarly. Then, planting more trees in particular subzones is our second recommendation. This recommendation mainly focuses on the regulating ecosystem services in our site. Although the regulating ecosystem services in our site exist, it also can be improved based on the previous analysis. Basically, we try to plant more trees on the upper stream of the slope, which is grassland (Subzone A). If there are more trees on this grassland, those planted trees can absorb more water (*Figure.*19). The runoff of slope can be reduced, and the threat of flood can be avoided. Also, we can plant more trees on the slope (Subzone B). When there are many trees on the slope, the speed of runoff will be decreased (*Figure.*20). Also, a large part of runoff will be absorbed. More than that, we also propose to plant more trees in some subzones where the number of trees is small. Like Subzone D and Subzone E. Because there are fewer trees in these subzones, we try to increase the number of trees in them. Broadly, the second recommendation not only can enhance stormwater absorption, but also can increase canopy cover in our site and regulate temperature for this site.

Figure 19. The future scenario

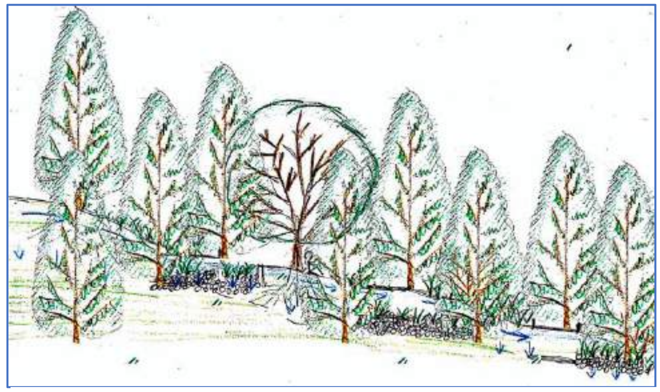

Figure 20. The future scenario

Moreover, the third recommendation is the tree-as-pet campaign. In order to enhance tree management and the connectivity between human and trees, we propose this campaign. Generally, cats and puppies can be our pets, we propose why trees can't be our pets. Based on this idea, our campaign came out. In this campaign, we propose to set up a website as a platform which can support this campaign. In this website, every tree has a specific ID, like a student ID, and people have access to choose their tree. When people adopt their tree, they can record their trees, for example, the growth of the tree, the soil condition, and diseases. They also can upload these records on our website as feedback. And these records will be good for the urban foresters. The core concept of this recommendation is to engage people and to increase connectivity between people and trees.

Appendix 1 - Cultural ecosystem services value mapping

	EXPERIENCE DIMENSIONS				
Subzone ID	Diversity/ species richness	Aesthetics	Social cohesion	Wilderness/ nature	Cultural significance
SUMMARY					
A	11	20	19	8	7
B	21	17	12	16	11
C	6	10	12	11	6
D	25	19	11	6	13
E	13	8	15	9	15
F	20	16	15	16	14
G	18	15	17	16	11
H	4	10	11	13	9
I	18	18	25	15	18
AVERAGE					
A	2.2	4	3.8	1.6	1.4
B	4.2	3.4	2.4	3.2	2.2
C	1.2	2	2.4	2.2	1.2
D	5	3.8	2.2	1.2	2.6
E	2.6	1.6	3	1.8	3
F	4	3.2	3	3.2	2.8
G	3.6	3	3.4	3.2	2.2
H	0.8	2	2.2	2.6	1.8
I	3.6	3.6	5	3	3.6

Scale: (no feeling) 0 1 2 3 4 5 (very strong feeling)

Appendix 2 - i-Tree Eco Report complements

Structural and Functional 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.

Urban trees in i-Tree Demo UBC have the following structural values:
• Structural value: Can$131 thousand
• Carbon storage: Can$3.03 thousand

Urban trees in i-Tree Demo UBC have the following annual functional values:
• Carbon sequestration: Can$85.9
• Avoided runoff: Can$189
• Pollution removal: Can$2.18

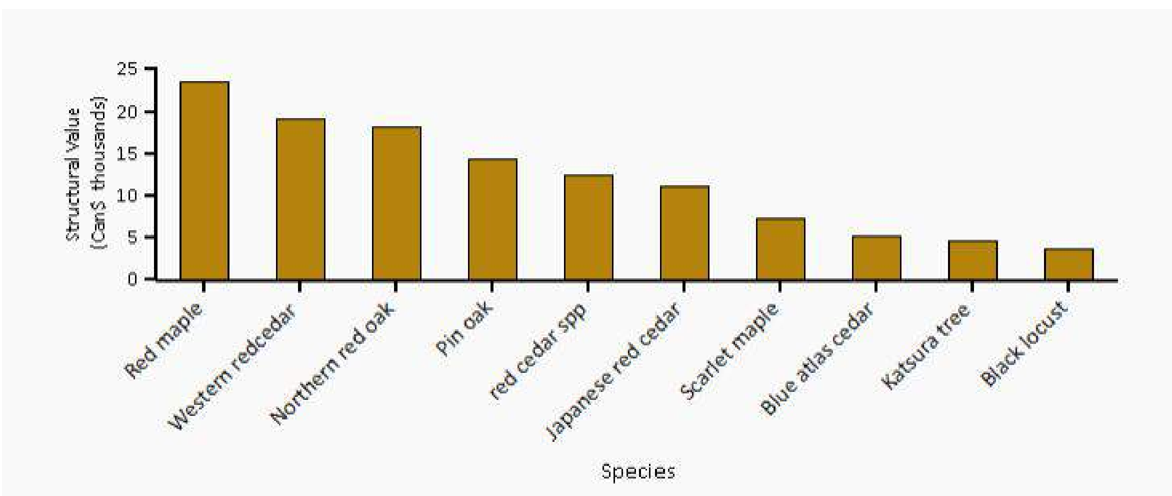

Figure 21. Structural and Functional Values

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Urban Forestry Inventory Report

UFOR101

Group 7

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Date: 10/02/2019

Contributions page

<table>
<tr><td>Tait Sun</td><td>1. Inventory table: typed live/dead, species, land use;
2. Site description;
3. Methodology:
Describe the Collector App-“Collector is a smartphone...corresponding tree ID.”,
How to use Collector App to find tree species-“To know tree species... with “No name”.”
4. Analysis of tree inventory data:
Analysis the tree species in our field-“As the graph (see Figure 4) ... to some extent.”
5. Conclusion:
The diversity of tree- “The diversity of tree...in that area”
6. Formatting</td></tr>
<tr><td>Yanbo Liu</td><td>1. Inventory table: typed the other data of 38 trees
2. Methodology:
Describe DBH in the third paragraph
How to calculate DBH and BA-“While some trees have multiple stems”
3. Analysis of tree inventory data
The content about Figure 5,6 and 7.
4. The landmark and specific trees part
5. Formatting</td></tr>
<tr><td>Yixuan Yu</td><td>1. Inventory table: typed the other data of 23 trees
2. Introduction: “This report...inventory program.”;
3. Methodology:
total tree height - “The total tree height of trees are measured using clinometer...by trigonometric functions” and “The TTH data are categorized into 5 height groups...by analysis of the circled area of TTH groups.” ;
4. Analysis of tree inventory data:
summary sentence - “Overall, this selected area has 83 trees being measured...minimum demand of a tree.”
total tree height - “According to the inventory data...vary from 14-18m.”
5. Conclusion: “"In conclusion...While it emerges ...Meanwhile... individual trees."
6. Formatting</td></tr>
<tr><td>Lauren Chen</td><td>1. Inventory table: typed the other data of 23 trees
2. Introduction: “As the resource...in the Zone 7.”;
3. Methodology:
Summary sentence - “The data includes...are presented below.”, and “In addition...relative information.”
Crown base height and crown width- “The Distance Tape... estimated by the eyes.”, and “For analyzing the data...TTH minus CBH.”;
4. Analysis of tree inventory data:
Crown base height and crown width - “As can be seen...the basis for pruning.”</td></tr>
</table>

	5. Formatting
Yvette Jiang	• 1. Methodology: • Crown percentage missing - “For the crown percentage... members’ data” • Crown light exposure - “Crown light exposure...calculating the average.” • 2. Analysis of tree inventory data: • Crown light exposure - “from the diagram ‘Crown light exposure’...percentage of crown missing.” • Crown percentage missing - “The majority trees... in the fieldwork.” • 3. Conclusion: Trees cultivation - “there are a number of trees…considered for surrounding buildings.” • 4. Formatting

Introduction

This report examines a part of the urban forestry tree inventory in the University of British Columbia (UBC) campus. The conducted object of the report is all individual trees existing in Zone 7 supported by the data collector application. The selected area is worked by five students. The data will serve for the UBC campus tree inventory program. As the resource of urban forest management, tree inventory is a fundamental stone and has the multiple uses. The data collection and analysis can contribute to assessment of tree growth condition as well as the benefits provided by urban forests as ecosystem services.

The following section is the site description which provides an overall site image of the Zone 7. The methodology that explains the on-site data collection methods and the data processing approaches is detailed in the third section. The last section is the analysis of tree inventory data which summarizes the results of data measurement in the Zone 7.

Site description

Figure 1. Google Map satellite picture for our field.

The fieldwork area is a block located at Midwest of the UBC campus between West Mall and Main Mall. This area has a kindergarten, the Material Engineering Building, a sunlight room and an office room. The primary purpose of this area is education. Thus, most of the users are students. The green space in this field are dispersive, almost every building has surrounded by few trees or grassland. From the satellite picture figure (see figure 1), we can find the most of green area located at the east corner, those trees planted around the kindergarten, provided a privacy environment for those children in the kindergarten. And there is grassland and few bushes located at the north corner. Almost all the Zelkova Serrata in our field planted at these bushes. And this grassland provided an open and broad view for the Pacific Museum of Earth. At the south corner, before the sunlight room has a row of Acer x freemanii 'Armstrong' trees along with the West Mall. A huge Quercus Rubra located at the corner between the Stores Rd and West Mall. Above the Quercus Rubra until next intersection on Stores Rd has a huge Acer Rubrum. Both trees can provide a shadow for people who walk at Stores Rd during the summer. Therefore, from observing the satellite picture, there are has around 40% of the canopy area of this field.

The small road Stores Rd connect with the West Mall and Main Mall. People will use this road to come and go to take the class in the West Mall or Main Mall. Thus, this road will become extraordinary busy during the class shaft. And, a lot of people will visit and watch the nearby landscape when they pass through this road. There has a large slope from Main Mall to West

Mall; the Main Mall has higher lever then West Mall. So, during the raining day, water will be keeping stream down from the Main Mall to the West Mall. To manage rainwater and not destroy the lovely landscape, a rainwater sewer mixed with nearby vegetation along with the Stores Rd is designed in this site. As the figure 2 and 3 shows, the rainwater will come from the uphill, then flowing into the sewers. That rainwater will be absorbed by nearby vegetation first. If its nearby plant cannot absorb all the water, then the water will be flowing the sewers going underground through by the outlet at the very bottom of this hill. Thus, avoid Stores Rd flooded during the raining day, and provide beauty and convenience to passers-by.

Figure 2. Google Map satellite picture for rainwater management system

Figure 3. Google Map street view for rainwater management system

Methodology

The raw data are measured base on five tools, including Collector App, Diameter Tape, Clinometer, Distance Tape and Compass**.** The data includes seven components, basically tree species, diameter at breast height, total tree height, crown base height, crown width, crown missing and crown light exposure. The detailed methods of data collection are presented below.

Collector is a smartphone application and essential tools for this fieldwork. In the Collector App, each tree will display as a green point shows on the map. And once click the green point will present the Tree ID and species. Therefore, we measure each tree in our field shows in the App and record data under the corresponding tree ID.

Regarding the measuring criteria of American, DBH is normally measured at 1.37 meters above the horizontal ground. While the value of DBH is greater than 2.54 centimetre, the records would be written on the raw datasheet. However, there are some trees with irregularities. For instance, some trees grow on the slope, and DBH should be measured at 1.37 meters on the upper slope. Also, some trees with swelling at 1.37 meters should be measured at higher than 1.37 meters until there is no swelling on the stem. Meanwhile, if trees have branches at 1.37 meters, the method would be similar with swelling trees at 1.37 meters.

The total tree height of trees is measured using clinometer. The clinometer can estimate the tree height using by trigonometric functions. To simplify calculation, our group choose to use the percent scale. Generally, there are three regular steps during the process. First, the horizontal distance (HD) from tree stems is supposed to be equal to the tree height by visual estimates. This step is to ensure that the angle between the line of sight to top of tree and the horizon is less than 45 degree where the percent is 100%. Secondly, use the clinometer to read the value of sightings to the top and base of the tree at percent scale. Record the percent of top (TP) and base (BP) with positive or negative sign representing the visual direction. At last, calculate the total tree height by trigonometric functions:

$$TTH = HD \times (TP - BP)$$

The Distance Tape is used to measure the value of CBH and crown width. Crown base height (CBH) refers to the height between the ground and the base of the live crown. The base of the live crown means the lowest live foliage on the last branch in the live crown. Nevertheless, most of the trees in our zone do not have leaves in this season so that the lowest branch will represent the crown base. Also, if the live crown base touches the ground, the CBH is zero. When the CBH cannot measure by hand, the clinometer will be used for this height.

Based on the width of the crown has two directions, long side and short side, and the crown width is the average of these sides. In practice, the long side is estimated by the eyes, and the direction is perpendicular to the long side defined as the short side. If one of the directions is hard to access, the distance parallel to that direction will be measured, or the unmeasured distance will be estimated by the eyes.

For the crown percentage miss, team members need to imagine each tree is in fully symmetrical shape, and calculating the missing portion as a percentage of the entire crown. Asking at least two team members stand on different position of the tree to see the crown percentage miss, then calculate the average of the members' data. Crown light exposure refers to the number of trees rims are exposed to sun. For measure CLE is similar as crown percentage missing, as some trees are in the specific and complicated location, that needs to ask at least two team members' opinions, and calculating the average.

In addition, for dealing with the rare data, Excel is the main method for gathering the data and producing the relative information. To know tree species, we use Collector App compared the tree number and trees location to find out most of the tree's species. But four trees do not have species name shows on the Collector App. The species that could not be explicitly identified are noted with "No name."

While some trees have multiple stems, and each DBH of stem at 1.37 meters should be measured, but only the six biggest DBH should be recorded oh the datasheet. Then, the final DBH should be calculated based on the following formula:

$$DBH = \sqrt{(DBH1)^2 + (DBH2)^2 \cdots + (DBH6)^2}$$

In order to display the structure of urban trees through raw data, the DBH should be classified into some classes based on the distribution of data (<10 DBH, 10-30 DBH, 30-50 DBH, 50-70 DBH, and >70 DBH), which can help urban foresters to analyse and clarify data. In terms of these data, bar charts and line charts are the best geographic ways to show distributions and features of each class. When the calculation of DBH be finished, BA would be calculated based on the results of DBH. The following formula shows how to calculate BA:

$$BA(m^2) = pi * DBH(\text{cm})^2/40000$$

The TTH data are categorized into 5 height groups, identically <5m, 5-10m, 10-15m, 15-20m, and >20m. Those groups will be displayed on another layer of the field map to create a TTH distribution map. Tree growth condition can be assessed by analysis of the circled area of TTH groups. For analysing the data of CBH and crown width, the mean and standard deviation are produced by the Excel. Then, the data of crown height is obtained from TTH minus CBH. Finally, through ranking, maximum and minimum of data and relative tree ID and species is demonstrated below. The crown percentage missing is classified into the set of 0-10, 10-30, 30-50, and more than 50.

Analysis of tree inventory data

Overall, this selected area has 83 trees being measured. Tree 4017 displays on the map while its information does not be counted into the data analysis because its DBH do not meet the minimum demand of a tree.

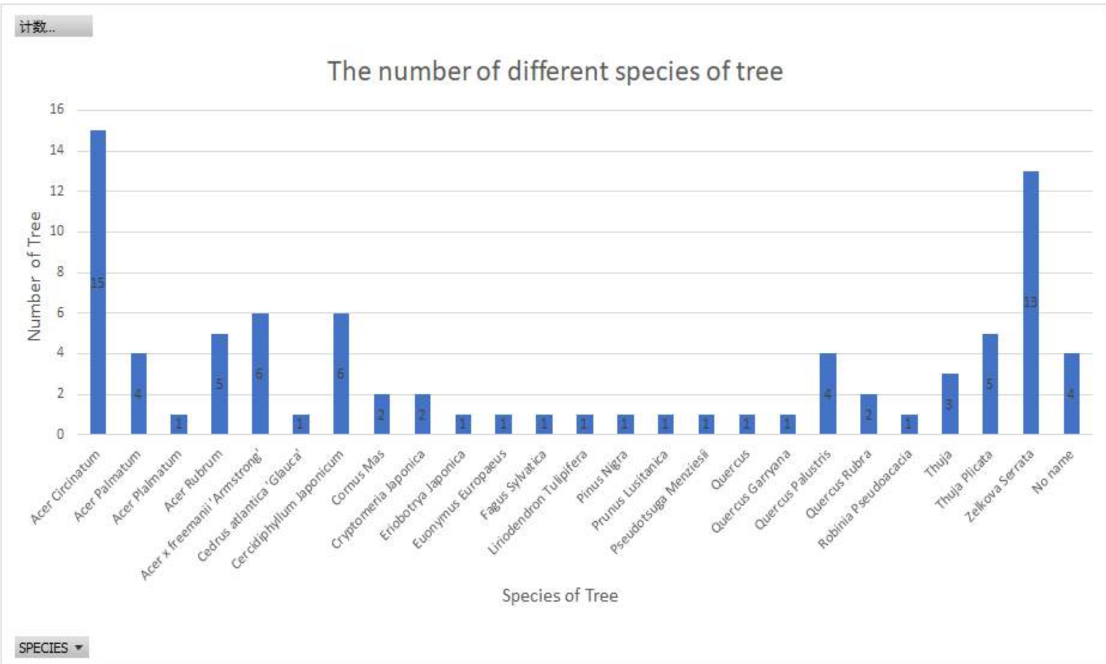

Figure 4. The number of different species of tree

As the graph (see Figure 4) shows, the total number of tree species is 24. 4 trees are no name recorded (2184, 2187, 4074, 4075). The dominant tree species in this field is Acer Circinatum, about 15 Acer Circinatum in our area. Another is Zelkova Serrata, ranking secondly with 13 individual trees. Acer x freemanii 'Armstrong' and Cercidiphyllum Japonicum both have 6 trees in this field, but has 5 Acer x freemanii 'Armstrong' did not shows on the Collector App. There are 5 for each Acer Rubrum and Thuja Plicata, and 4 for each Acer Palmatum and Quercus

Palustrus. And 2 Quercus Rubra and Cryptomeria Japonica, and 3 Thuja. Rest tree is only 1 for each species in this field. From this graph can easily find out, the 31 Acer (Maple) take up about one-third total population of the tree in this area. And almost all the Zelkova Serrata are growing together in a very close area, which reflects the lack of diversity of tree species to some extent.

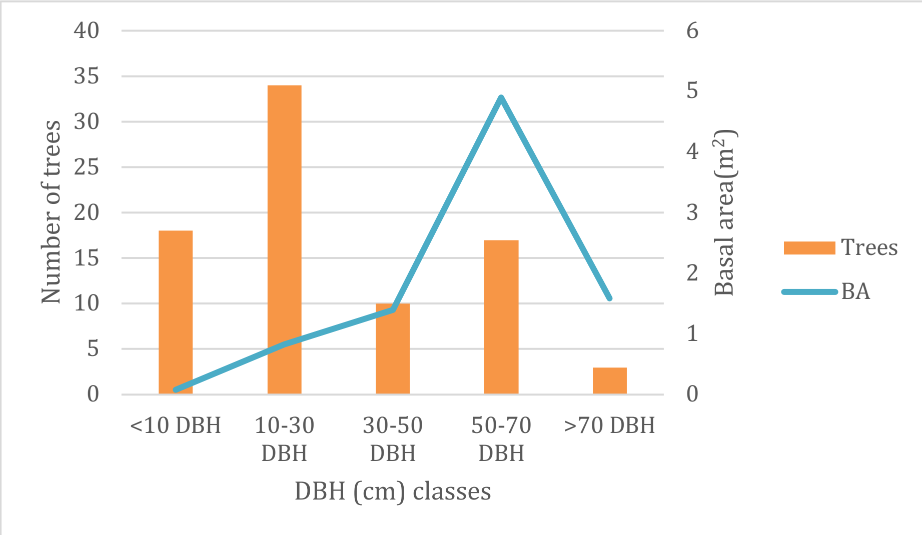

Figure 5. The comparison between the number of trees and the basal area based on each of the DBH classes.

In terms of the Figure 5, the 10-30 DBH class has the greatest number of trees, which is followed by <10 DBH class with number of 18. It means many trees in our zone are centralized in <30 DBH class, which are more than half of all trees measured. We consider that UBC focus on the construction of greenest campus, there are more and more trees planted in the campus. This is to say, those trees planted recent year or few decades ago, and the DBH of them are not too

Figure 6. The south side of Earth and Ocean building

Figure 7. The west side of the Kindergarten

high. And those trees are still young compared their lifespan. For example, there are three rows of young trees in front of the south side of Earth and Ocean building (see Figure 6.). However, UBC also has a lot of trees with a long history. Regarding the bar chart, the >70 DBH class has three trees, while the remains are 30-50 DBH class and 50-70 DBH class with the number 10 and 17 respectively. In our zone, there was an area with many big trees, and it seems like a small forest (see Figure 7.), so the number of trees with DBH greater than 30 accounts for significant amount.

Furthermore, the basal area reaches the peak in the 50-70 DBH class. Although the tree quantity in 10-30 class are the largest, the basal area in this class are not that big, which ranks the third position among all classes. In addition, <10 DBH class has the second number of trees, but the basal area in this class is the smallest than other classes.

According to the inventory data, the average TTH is 10.59m with ±6.72 as SD. The tallest tree in this field is No.4046, Quercus Rubra. The TTH of the tree is 26.46m. Tree No.4082, Acer Circinatum, is the shortest tree in this selected area which is 2.3m. The pine chart (see Figure 8) illustrates that the different total tree height groups in this inventory field. Overall, trees in this field are not that high. More than half are less than 10m. Trees those are from 5 meters to 10 meters has the most significant group number, occupying 35% of the trees. 19 trees are under 5m height which has the second largest group number. The other three groups have a similar proportion (about 14%).

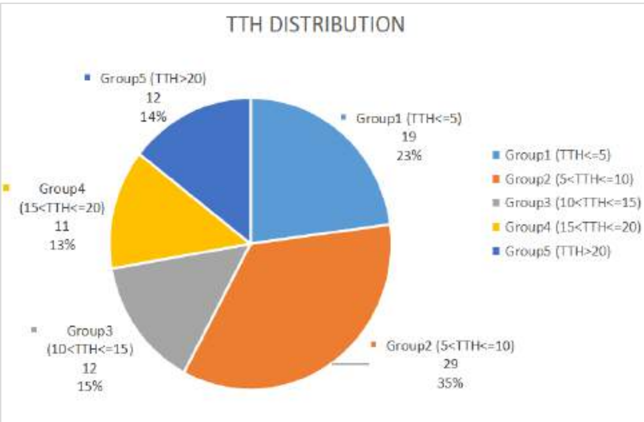

Figure 8. Different total tree height groups

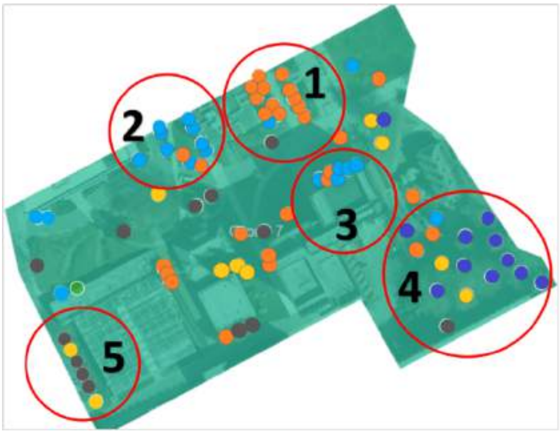

Figure 9. Distribution map of TTH groups

To create a more vivid view, Figure 9 illustrates the TTH distribution by the different colourful points representing the different tree height groups same as Figure 8. Areas in circle 1, 2 and 3 are close to both trails and buildings. The grow space and light exposure are limited, which in some way explains the relatively less TTH of those trees. Grand trees generally gather in circle 4 because of the large soil space. Meanwhile, the area in circle 4 is right near the Main Mall where trees are always planted as landmarks with aesthetic value. All trees in circle 5 are the same species, Acer x freemanii 'Armstrong' and the TTH vary from 14-18m.

As can be seen from the table (see Table 1.), the mean of crown height is 9.39 m, and SD of that is ±6.46 m, while the mean of crown width is 6.84 m and SD of that is ±4.83 m. From the comparison of the mean and SD, the degree of variability is relatively high in this zone. This means that the crown sizes are various with these trees. According to the crown width and crown height, the crown volume can be estimated roughly; thus, the largest crown volume in this zone is from 2207, Acer Rubrum. The highest crown height and longest crown width are 23.28 m and 23.25 m respectively. They are 4046, Quercus Rubra, and 4049, Acer Rubrum.

Table 1. Basic Data of Crown Height and Width

	Crown Height (m)	***Tree ID***	***Species***
Maximum	23.28	4046	Quercus Rubra
Minimum	0.80	4082	Acer Circinatum
Mean	9.39		
SD	±6.46		
	Crown Width (m)	***Tree ID***	***Species***
Maximum	23.25	4049	Acer Rubrum
Minimum	1.8	4082, 4075	Acer Circinatum, No name (maybe Zelkova Serrata)
Mean	6.83		
SD	±4.83		

Note: SD: standard deviation

Although the higher crown height does not represent the longer crown width, the scattered chart (see Figure 10) shows that the crown height and crown width have a positive correlation approximately. Besides, the most of points is distributed between the 0-10 m crown width and 0-15 m crown height. That is to say, these trees have more room for growth in the future. The crown is the most significant part of trees since foliage in the crown is responsible for the photosynthesis. The bigger crown is likely to create more ecosystem services from trees. Moreover, through compared to the same species, the crown shape and size can be predicted. Standing on the tree inventory, the measurement of CBH and crown width can effectively monitor the growth of trees and provide the basis for pruning.

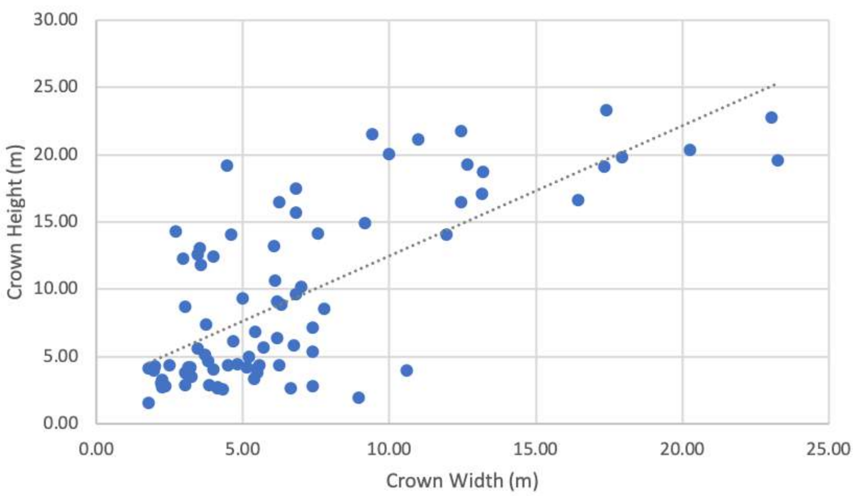

Figure 10. Crown Width vs. Crown Height

From the diagram "Crown light exposure" (see Figure 11.), that could see clearly that there are 34 out of 82 trees have 5 sides crown light exposure which is in majority. There is a correlation between sides of tree exposed to sun and crown percentage missing. The effects of sunlight on tree are not only the growth of tree, but also the shape of trees, in the other words, the sunlight exposed is impacting on the crown percentage miss. For the tree which just have less than 3 sides exposure to sun, which is more likely to have higher percentage of crown missing.

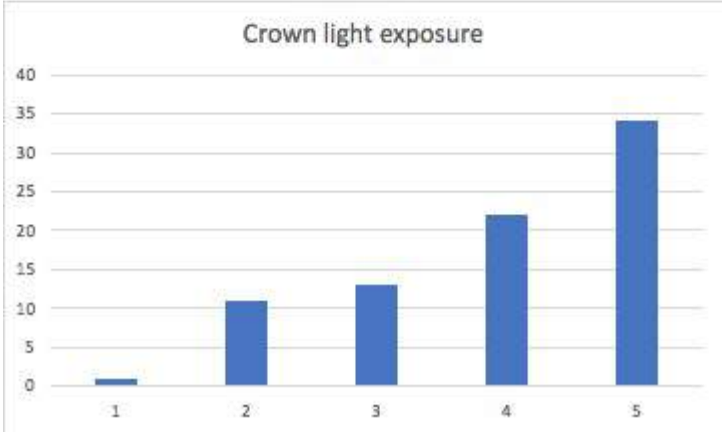

Figure 11. Histogram of crown light exposure

The majority trees have around 10 to 30 percent of crown missing, and there are small number of trees having more than 50 percent of crown missing (see figure 12.). In the fieldwork, it is an error range with the measurements for crown percentage miss. Because of during the winter, the most of trees leaves are gone, that makes the data about the crown percentage missing is not so accurate. For the crown percentage missing, members need to imagine for most every tree with leaves, however, despite the imagination, that still have no way to determine the accuracy of this data for each tree. Due to the light receiving in tree's rims, the species of trees different, and nutrient absorption varies in different seasons, that causes the accuracy of the crown percentage missing. Nevertheless, the crown missing percentage needs to ask at least two team members' opinions in the different points of view, there still would be so issues affecting the data we collected, for example some of trees have a completely different shape of crown at an unobservable angle, only partial observation is way to limited in the fieldwork.

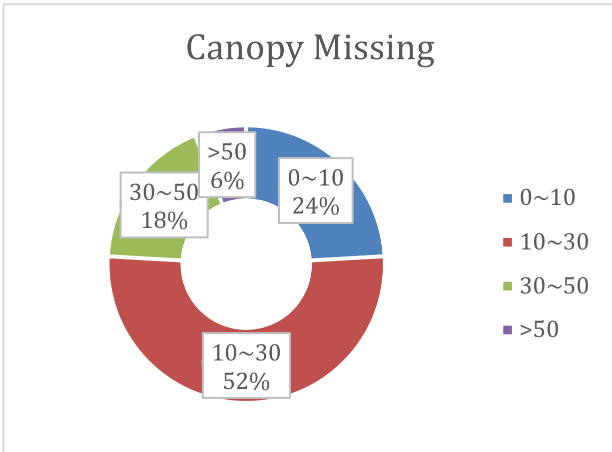

Figure 12. Pie chart of Canopy Miss percentage

Table 2. Summary Table

	Live	SD
Trees	83	
Species		
DBH mean (cm)	28.96	(±23.23)
BA mean (m^2)	0.11	(±0.14)
Total height mean (m)	10.59	(±6.73)
Crown base mean (m)	1.15	(±0.75)
Crown wide mean (m)	6.83	(±4.83)
Canopy missing		
<10%	20	
10-30%	43	

31-50%	15
51-100%	5
Crown light exposure	
0	0
1	1
2	11
3	14
4	22
5	34

Note: DBH: diameter at breast height; BA: basal area; SD: standard deviation

Landmark and Specific Trees

In our zone, there are many interesting landmark trees and some specific trees. One of trees has tag on the stem but we have no access to see the number on the tag (see Figure 13.). The photo shows the problem of this tag, and the tag already was covered with the growth of tree. Therefore, some trees in our campus lack of maintaining. One of the smallest trees is located in the front of The Horticulture Lab because the DBH of it is less than 2.54cm (see Figure 14.). Athough it has an ID number on the Collector App, it can't be count in the measurement. Also there is a tree with specific crown shape compared other trees, the upper two-third part of crown is almost the same width, and the one-third bottom of crown is double width of the upper crown. This tree doesn't have species information on the Collector, but we suspecte it belongs to pine according the needle leaves on the tree (see Figure 15.). On the other hand, some trees grow in specific conditions. One tree grows in the side of Centre of Interactive Research on Sustainability. Obviously, we can find the direction of waterflow regarding the shape of those grass. It means this tree grows in a lower slope stream. In summer, this place would happen waterlogging, which have some negative effects on the growth of this tree (see Figure 16.). Then, there is a tree with narrow space to grow. We can find this tree was planted in a limited

Figure 13. Specific tag

Figure 14. The smallest tree

Figure 15. Specific shape of crown

Figure 16. Lower slope condition

Figure 17. Narrow living condition

area, which means the root of this tree only can grow in two directions, and the other two sides are concrete wall for its root (see Figure 17.).

Conclusion

In conclusion, the various aspects of tree inventory data analysis present some accordant information of urban forestry condition in the fieldwork area. Above all, many trees are in the small to median size according to the DBH, TTH and CW. This is coincident with the strategic planning and management of urban forestry which is committed to plant more trees in campus. While it emerges some problems at the same time. The standard deviation of DBH, TTH and CW are considerable which indicates a high-level variation of individual trees.

Meanwhile, the light exposure and tree growing space are affected sharply due to the high density of buildings and trails. There are a number of trees are not able to exposed to sunlight. And the relationship between the crown missing and tree light exposure shows that the lower sunlight exposure would cause higher crown missing percentage. In some areas, there are higher density of trees, they would not able to grow in fully symmetrical shape. For trees cultivation needs to have a certain density, and it also needs to be considered for surrounding buildings.

The diversity of tree species is relatively good. However, the problem is that the species of the Acer tree are too much compared with other species. Over one-third species are Acer (Maple) which has five different types. Also, they located at a different position on the field. Therefore, this not be given to a significant effect on the lack of tree diversity. However, for the artistic reason, all the Zelkova Serrata are planted at two bushes, thus decreased the diversity of tree in that area.

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Urban Forestry Ecosystem Service Assessment Report

Group 8

April 3, 2019

Contributions

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Joshua contributed to the introduction and site description as well as method of i-Tree Eco assessment and strengths and weaknesses. Also formatted and proofread the document.

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Introduction

UBC Vancouver campus is a major hub of activity in Vancouver, as it currently supports close to 56 000 students (UBC Overview and Facts, 2018) and is recognized as one of the largest employers in the city (Yerema & Leung, 2018). As a core location for a diverse group of people, it is crucial that the urban forest is able to support the high demands it constantly receives. Not only must the urban forest endure environmental factors, but also day to day anthropogenic disturbances such as construction, vehicle use, and pollution.

The results of programs such as i-Tree Eco and i-Tree Canopy will provide a detailed qualitative insight of UBC campus' urban forest, and an analysis of the ecosystem services we obtain. These two programs quickly analyze various regulating services which would usually be difficult to assess without proper background knowledge. Ultimately, the compiled data will provide a basis for potential future management and planning of an improved urban forest. Constructing an urban forest management plan is necessary for UBC because there is currently a lack in policy surrounding it (Emma Luker, Biodiversity and Urban Forest Planning, January 6 2019).

There are a diverse range of programs and groups who are invested in the results of the tree inventory such as building operations, planning and design, and sustainability and engineering. Guest lecturers representing SEEDS Sustainability Program, and Campus and Community Planning came in to one of the UFOR 101 lectures at the beginning of our inventory to provide insight into this project. These organizations will be benefiting from the information that we collect on UBC campus' urban forest, and are the end users of our project. The two representatives that we are collaborating with from SEEDS are Emma Luker and Egan Davis; who is the planning analyst and the UBC Botanical Garden Horticulture Instructor respectively. Ultimately, an analysis of UBC's urban forest - using multiple programs - allows us to plan ahead and consider the best tree for the best future, thus preparing us for forthcoming changes from climate change and infrastructure development.

Site Description

The UBC Vancouver campus is located on the western tip of the Point Grey peninsula. This 400 hectare area is surrounded on four sides by Burrard Inlet to the north, Wesbrook Village and Pacific Spirit Regional Park to the South, the Pacific Ocean and Vancouver Island to the West, and the rest of the Greater Vancouver Area to the East (UBC, n.d.). Vancouver is in a coastal temperate rainforest climate zone; therefore, it experiences high amounts of precipitation during colder seasons and dry periods in warmer seasons (Earth Eclipse, 2019).

Our inventory area - Zone 8 - was within the boundaries of Main Mall, West Mall, and Agronomy Road, which contains a diverse set of infrastructure. Some examples include institutional and residential buildings (refer to Figure 2 in Appendix) such as Orchard Commons Student Residence and H.R. MacMillan building. The area we inventoried was roughly 27 200 square metres. Zone 8 consists mainly of concrete or brick infrastructure and does not have a significant number of green spaces. Orchard Commons – and its surrounding areas - was completed in 2016 and is one of the relatively newer buildings on the UBC campus (Perkins+Will, 2016). The area between Orchard Commons and the Landscape Architecture Annex building did have a small area of grass and large trees, but is more of an area to pass through, rather than an interactive space. However, there is a large green space in front of Orchard Commons and along West Mall, that serves as a recreational area for students.

The space between Main Mall and West Mall is on a slight incline, with Main Mall being marginally elevated above West Mall. Looking down from Main Mall onto Agronomy Road, the trees are adjacent to the road, and are mostly shaded by the concrete walls of Orchard Commons. The patch of land these trees are planted on are around 1.5 m wide, stretching from Main Mall to West Mall, which is approximately 130.5 m. Turning the corner onto west mall, trees are also planted on the sidewalk of a soil patch of approximately the same width and length. Additionally, our inventoried area contained the courtyard in the H.R Macmillan building. Though the courtyard might have been intended for recreational use when it was first built, this space is now simply meant as a route to and from classes for students.

In Zone 8, the dominant land users consists mainly of students. There are first-year students living in Orchard Commons Residence and students in the Faculty of

Land and Food Systems from the H.R. MacMillan building. Lastly, there is a kindergarten/daycare centre built around the famous *Arbutus menziesii* (refer to summary of inventory data) which adds parents and toddlers to the users of Zone 8. Furthermore, there is a parking lot directly south of Zone 8 at the intersection of Main Mall and Agronomy Road, which increases traffic of both students, faculty, and other visitors.

Regulating Ecosystem Services

i-Tree Eco Methods of Assessment

Much of the data is collected during the leaf-on season to have the most accurate tree canopy measurements. i-Tree Eco measurements such as air pollution removal, structural value, oxygen production and more, are calculated based on local standardized data. If local data is not available, i-Tree Eco will not be able to assess the desired subject. For example, a complete potential pest risk analysis is unavailable for any countries that are not USA.

i-Tree Canopy: Strengths and Weaknesses

i-Tree Canopy analysis provides information of the approximate amount of gasses that is removed and sequestered annually by trees that are within a selected area. In addition the percentage canopy coverage is also generated through this analysis. Allocation of i-Tree Canopy date in high density urban areas can allow city planners to create a sufficient plan to increase regulating ecosystem services in parts of a city.

However, there are a few flaws of using i-Tree Canopy. First, the data provided can only be interpreted into improving regulating services such as climate, air quality, carbon sequestration and storage. While lacking data to contribute to other regulating services such as disease, biological and soil fertility control. As the data calculated is generated by the percentage of canopy cover of a selected area, i-Tree Canopy lacks to inform users what process causes the removal of gasses and particles.

Another weakness to acknowledge with this method of analyzing an area, is that users are required to complete a classifying process of each point that is generated by the program. This process requires users to identify the point given into a variety of classifications, such as tree, non tree, shrub, water and concrete floor. As this classification cannot be done by computers, miss conception of multiple points can be made by the user, thus the outcome of data might not be completely accurate. Therefore, in order to extract the most accurate data, users are advised to classify multiple points, but will unfortunately slow down the rate of data extraction from i-Tree Canopy.

i-Tree Eco: Strengths and Weaknesses

i-Tree Eco provides informative data surrounding various regulating services of the urban forest. This program is able to provide scientifically reliable analysis of ecosystem services, that regular students like us would not be able to evaluate. Valuable data such as carbon sequestration/storage, avoided runoff, and oxygen production help inform and improve urban forest planning. However, it does have a few weaknesses.

One weakness, is how values such as carbon storage/sequestration and avoided runoff are not contextualized in understandable values. It would be comprehensible for a variety of stakeholders, if it was converted to a recognizable value, such as the equivalent number of average car emissions.

Another weakness, is i-Tree Eco's inability to calculate tree effects on building energy use/consumption; the values for energy saving were left as 0. i-Tree Eco does not provide these values, because energy related data were not collected. Without these values, it is difficult to provide urban forest planning recommendations for mitigating energy use and the urban heat island effect. If this data was evaluated in i-Tree Eco, it would have been reliable evidence to support implementation of various plans.

i-Tree Canopy Results

Canopy Cover

i-Tree Canopy measured the canopy cover of Zone 8 to be 13.4%, and impermeable surface area to be 86.6%. This data is considered to be great concern for our zone as there are lack of permeable surface for stormwater runoff, which can contribute to flooding during high rian seasons. Also, the lack of tree canopy may affect the health of residents and other users of the zone as air quality regulation is performed at a much slower and lower rate.

Gas Removal

Alongside canopy cover, i-Tree Canopy uses the generated data of canopy coverage to calculate and present a monetary value of gasses removed annually by trees in the selected area. In Zone 8, the gasses that are shown to be removed are Ozone (O3) Valued at the highest annually removed price at C$3.63 and 38.90lbs annually removed. Nitrogen Dioxide (NO2), at value of C$0.07 with an 3.91lbs annual removal, Carbon Monoxide (CO) having a value of C$ 0.04 and 11.40 oz annual removal, Finally, Sulfur Dioxide (SO2) with annual removal price of C$0.01 and 2.46lbs of sulfur removal.

Particle Removal

The canopy coverage not only relates to the ability of removing harmful gas but also affect the particle removal. In Zone 8, particulate matters less than 2.5 microns removed annually 1.89lbs which values C$7.50. Meanwhile, particulate matter greater than 2.5 microns and less than 10 microns removed annually 13.03lbs which values C$2.64. These particulates are very small in size, with a sufficient amount of respiratory by humans it could lead to multiple respiratory sickness. Shown by the data provided, particles in zone 8 are not removed in large amounts, with the high density of residents, continuation of low particle removal rates will be a concern for residents health with the area.

Gas Sequestered and Stored

Tree canopy could convert the gas to carbon which could be sequestered and stored. And i-Tree Canopy monetize the value of this function. In Zone 8, Carbon Dioxide sequestered annually in trees reaches 3.98Ts which values C$245.72. Finally, around 99.86T Carbon Dioxide would be stored in trees which values C$6170.97.

i-Tree Eco Results

Carbon Storage and Sequestration

i-Tree Eco saw a gross sequestration of 945.1 pounds of carbon per year for Zone 8; this has an associated value of C$49.2 per year. The greatest carbon storing species is the *Arbutus menziesii*, which is able to store around 141 pounds of carbon, followed by *Liriodendron tulipifera* which can store 118 pounds, and *Cornus kousa* which can store 110 pounds (refer to Figure 4 and 6). Many of the highest carbon storing trees also happen to be the largest trees within our zone. This demonstrates the relationship between overall tree size and carbon sequestration capability. *Cornus kousa* is the third greatest carbon sequestering specie, only because it comprises of 47% of the total tree population within our zone. A single *Cornus kousa* would in fact, only be able to store roughly 2 pounds of carbon. Compare this to the single *Arbutus menziesii*, which can store around 70 times the amount of a single *Cornus kousa.*

Oxygen Production

Oxygen production capabilities of an urban forest is one of the most recognized benefits. The amount of oxygen that a tree is able to produce, is related to the amount of carbon it can sequester or store; both values are directly associated with tree biomass. The top oxygen producing species are *Arbutus menziesii, Liriodendron tulipifera*, and *Cornus kousa* (refer to Figure 4). Similar to carbon storage/sequestration properties mentioned earlier, *Cornus kousa* produces a significant amount of oxygen only because of its abundance within our zone (refer to Figure 4). A single *Cornus kousa* would only be able to produce 5.4 pounds of oxygen. Ultimately, it is the trees with the greatest biomass (based on height, canopy area, DBH, etc) such as *Liriodendron tulipifera* and *Arbutus menziesii* which are able to produce the most oxygen.

Avoided Runoff

Stormwater runoff is an issue in Zone 8, because of the high impermeable surface area. Although there are areas consisting of open grass and shrubs, the canopy cover of our zone is only 13.4% - according to i-Tree Canopy. Much of the zone consists of concrete and brick pathways, courtyards, a parking lot, and buildings. i-Tree Eco measured the avoided runoff according to tree species, and found that *Liriodendron tulipifera* by far had the highest avoided runoff of 700 cubic feet (refer to Figure 8). Despite *Cornus kousa* being the most dominant tree species in the zone, total avoided runoff was very low at around 100 cubic feet. Similar to carbon storage and sequestration, the tree species that reduced runoff the most were large trees. These would be species such as *Liriodendron tulipifera*, *Acer rubrum*, and *Fagus sylvatica*.

Structural and Functional Value

Structural and functional value are two different measurements of a trees worth. Structural value is based on the physical characteristics of the tree itself, such as having to replace it. Functional value is based on the ecosystem services - primarily regulating services - either positive or negative, that a tree provides. These values vary depending on the number and size of healthy trees; therefore, having an abundance of healthy mature (large) trees would increase the value. Overall, the structural and functional value in Zone 8 greatly differed from each other.

Structural value has two components: structural value and carbon storage. i-Tree Eco recognizes the structural value as C$118 thousand, and the carbon storage value as C$1.57 thousand (refer to Table 1). This high structural value signifies - and is based on - Zone 8's demographic of abundant young trees and several large trees. Figure … depicts the structural value of individual tree species, and the majority of these species - excluding *Cornus kousa* - are large trees. *Liriodendron tulipifera* has the greatest structural value out of all trees, because it has the greatest height and leaf area (refer to Figure 4).

Functional value has 4 main components: carbon sequestration, avoided runoff, pollution removal, and energy costs and carbon emission values (many of these various values are analyzed earlier in this report). These components are primarily based on the regulating services that urban trees provide. Unlike the structural values, the functional values are significantly lower. Carbon sequestration is valued at C$49.2, avoided runoff at C$122, pollution removal at C$1.39, and energy costs and carbon emission at C$0 (refer to Table 1).

Based on the results of the structural and function value that i-Tree Eco calculated, we now know that Zone 8 has a very low functional value and a high structural value.

Potential Pest Impacts

Zone 8 has a lack of species diversity, which makes it highly susceptible to attack from numerous insects and diseases. The main pests that pose a high risk to our zone, are the pine shoot beetle (PSB), southern pine beetle (SPB), sirex woodwasp (SW), and dogwood anthracnose disease (DA). Figure 7 shows the cost to structural value and number of trees affected by 36 pests; these pests were chosen by i-Tree Eco to be analyzed, but not all have host trees in our zone, thus having no impact.

Insects which pose the greatest negative impact on structural value are PSB, SPB, and SW. All three species would individually affect 3.5% of the tree population, causing a loss in structural value of C$40.2 thousand (refer to Figure 7). Only 3.5% of the population would be impacted, because PSB, SPB, and SW are insects which attack pine trees. 3 out of 19 tree species within our zone are pine species, which makes up 3.5% of the tree population - 3 out of 118 total trees. From only these three pests, already 10.5% of the urban forest is threatened. Asian longhorned beetle (ALB) is an insect that does not greatly impact the structural value compared to the aforementioned insects, but does threaten 28.7% - much more - of the population.

Out of the 36 pests analyzed to have a potential impact on the urban forest, dogwood anthracnose disease (DA) threatens 47% of the population (refer to Figure 7). This disease impacts close to half of our zone, because it targets dogwood species, and *Cornus kousa* - is a dogwood species - makes up 47% of our tree population. Despite this astoundingly high percent of trees impacted, the negative effect on structural value is only C$3.21 thousand. The structural value to replace all these trees is relatively low, due to the young age and small size of *Cornus kousa* trees within our zone.

Cultural Ecosystem Services

Ecosystem services sustain human livelihoods and provide not only basic needs directly, such as food, but also cultural and spiritual experiences that we benefit from indirectly.

In our survey, we rated five types of ecosystem services on a scale of 0 to 5: species diversity, aesthetics, social cohesion, wilderness, and cultural. Then, we used different colored stars to represent the symbolic trees according to the five experience values (Figure 2). Overall, wilderness and cultural significance are relatively low in all sobzones, whereas aesthetics and social cohesion are relatively high.

If we were to look at our subzones in more detail, subzone H shows the highest ecosystem services on average, and species diversity hits a record high at 3.7 (Figure 10 and 19). Subzone H is an area that has a small recreational space, pathway, and a mix of small and large trees in different areas. This diversity ultimately gives subzone H a diversity of highly recognized values. On the other hand, subzone D has the lowest values of ecosystem services, especially cultural significance and wilderness at 0.7 and 0.8, respectively (Figure 11).

As for other subzones, both A and E have significant aesthetic values at 2.9 and 3.1, and is higher than other values (Figure 12 and 13). However, social cohesion in subzone A is very low at 1.6, and the biodiversity values in subzone E are also low at 1.2.

In summary, each subzone has positive and negative characteristics. Some like subzone H have well-balanced species diversity and social cohesion, however, subzone D's cultural services are low. Besides, subzone C is situated by the parking spaces with impermeable ground, deteriorating the capacity of water storage.

Furthermore, it is worthy to note that the aesthetic value in subzone A is lower than subzone E, despite the several mature trees within the subzone A's courtyard (refer to Figure 18). This highlights the difficulty of evaluating intangible ecosystem services, and demonstrates how one zone can have a diversity of ecosystem services in various subzones. We explored our subzones starting from A, H, G, E, D, C, B, F, so the previous experience affects the next subzone evaluation. Also, it is conceivable that personal backgrounds influence how we individually rated the ecosystem service. Therefore, developing a proper method for evaluation of ecosystem values is necessary.

Urban Forest Planning and Management Recommendations

Based on the analysis and assessments we have done, our group found that Zone 8 has a significant weakness in providing regulating and cultural services. After discussing the results of our data from inventory, i-Tree Eco and i-Tree Canopy, we have devised several objectives for future developments.

The first objective is to reduce stormwater runoff. Trees are able to help avoid stormwater runoff, by capturing and storing rainfall in the canopy, and releasing water into the atmosphere through evapotranspiration (refer to Figure). Additionally, tree roots and leaf litter create soil conditions that promote the infiltration of rainwater into the soil. According to i-Tree Canopy, the canopy cover in Zone 8 is only 13.4%, which is low; therefore, we need to plant trees with rough leaves, a big crown, and a strong root system to improve the ability to manage stormwater. Moreover, we could install rain gardens or pavers, to reduce the high amount of impervious surface area.

Our second objective, is to reduce building energy consumption and use for heating and cooling throughout the year. Last year, Vancouver had reached 26 Celsius on June 18th, and it will continue to get hotter because of global warming. However, air conditioning is not the best choice to cool down; it would release harmful chemicals that would cause irreversible damage to the ozone layer. Rather than using air conditioning, installing green infrastructure such as a green wall would reduce our need for it. Also, we could plant more huge trees which could provide shade for buildings, thus reducing the urban heat island effect.

Lastly, we hope to have higher biodiversity within our zone. Biodiversity is consisting of richness, evenness and heterogeneity. According to the tree inventory, *Cornus kousa* is our dominant species which makes up 47% of the tree population. This indicates that the zone has a significant weakness on evenness of species, which will have a non-linear effect on ecosystem functions. Those effects will reduce resource capture, biomass production, decomposition, and nutrient recycling. The ecosystem function is directly connected with the quality of ecosystem services. Therefore, we should plant more other trees to improve evenness and quality of services that the ecosystem provides for stakeholders.

Ultimately, we hope our zone could become an attractive urban forest that is able to provide enjoyment for people. The zone is supposed to support multiple activities and be able to provide pleased ecosystem functions.

Facilities and Solutions

Due to the low tree canopy cover (17%) and insufficient green facilities, tree species diversity and integrity of human beings and nature are urgent problems to be solved. To solve these issues that are closely related to public life, it is necessary to come up with corresponding solutions. In this section, several specific solutions and possible green structures or facilities will be introduced.

First and foremost, all the buildings in Zone 8 do not have any green facilities. Green rooftops and walls not only provide aesthetic views, but also diverse ecosystem services, such as cooling down the building, reduction of stormwater runoff, and energy-saving features (refer to Figure 14 and 15). It also increases the accessibility to green areas with positive psychological benefits (R. Kellert, S. 2018). The green roofs and green walls on high and low buildings can provide diverse prospects to people from different buildings. Moreover, the green walls can act as a visual refuge for the indoors with the sense of safety and privacy. However, ecological conditions of buildings are quite different from that of the ground. Hard-leaved xerophytes are more suitable to growing on buildings with environmental conditions of strong sunlight, strong transpiration, strong wind and thin soil layer. Due to high rates of evaporation on roofs, replenishing water in time to meet the need for growth is very significant. Another difficulty in maintenance management, is lacking irrigation of water. Hence, implementing a plant satisfying for these conditions is necessary for having successful green facilities. For example, plants such as a “Wisteria [like] a slightly acidic… well-drained soil. This lushly blooming vine also craves for fertile, consistently moist, but not soggy soil.” (Plant care today, n.d.); it is not hard to be maintained, which can reduce the budget for maintenance.

Secondly, the parking lot besides Orchard Commons is an area of concern within our site. There are very few trees and vegetation around the parking lot, which makes the area extremely ‘grey’ with low permeability (refer to Figure 16). Due to the low permeability, stormwater runoff is a concern. Furthermore, a large area of grey concrete would increase the urban heat island effect, because of the high albedo of the surface. One efficient solution to this problem, is to incorporate grass bricks/pavement, as well as planting more trees around the parking lot. Tree species that are deciduous could be prioritized, such as *Acer truncatum*. The seasonal color change of specific tree species could also beautify the place. Even a simple experience of passing by the parking lot can potentially be enhanced.

When it comes to the integrity between green space and people, the interaction between nature and human beings is quite significant. Take Macmillan building as an example; there are a satisfying quantity of gigantic, aged trees. However, very few people would stop and take a rest in the courtyard of the Macmillan building due to the absence of amenities such as benches and swings. Instead of extensively adding green space and green structures, placing some more intrustracture appropriately is more efficient to enhance the connection between the people and green space. It can also raise the possibility of socializing which can, to some extent, increase the community social cohesion.

Based on the results of i-Tree Eco and Canopy’s data, we believe that it is necessary to increase the regulating and cultural services within our zone; ecosystem services such as decreasing stormwater runoff, reducing energy use/consumption for temperature regulation, and reducing the urban heat island effect are some of our key focuses. Ultimately, these objectives can be achieved by implementing green infrastructure - green roofs, walls, paving - and planting diverse tree species ideal for specific areas.

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Appendices

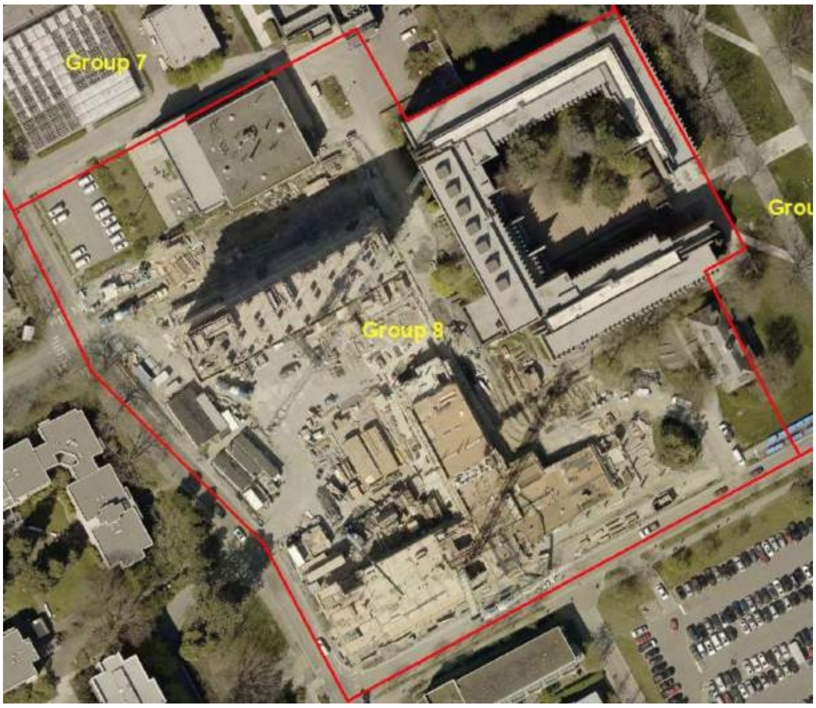

Figure 1. Satellite image of Zone 8. Red lines are the boundary

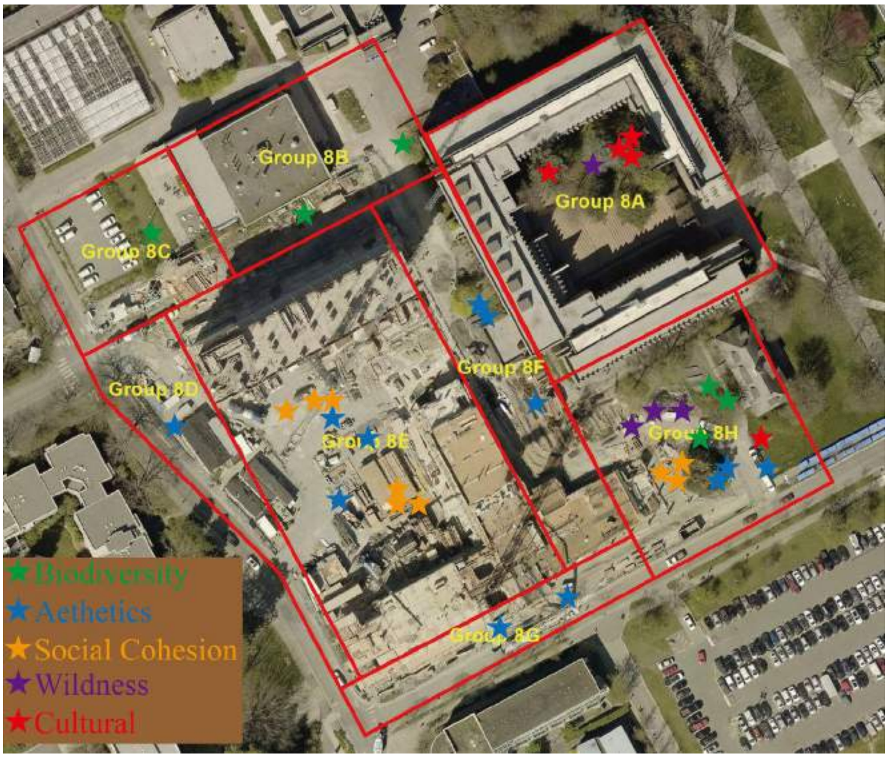

Figure 2. Map of 5 values in the 8 subzones

Figure 3. Arc GIS view of Zone 8. Each green dot represents a tree

Species	Oxygen (pound)	Gross Carbon Sequestration (pound/yr)	Number of Trees	Leaf Area (square feet)
Arbutus menziesii	376.13	141.05	1	0.01
Liriodendron tulipifera	315.49	118.31	2	0.06
Cornus kousa	293.72	110.15	54	0.01
Acer rubrum	290.39	108.89	9	0.02
Fagus sylvatica	269.84	101.19	2	0.02
Prunus serrulata	189.78	71.17	1	0.00
Pinus ponderosa	151.27	56.73	1	0.01
Pinus coulteri	111.96	41.99	1	0.01
Pinus nigra	87.25	32.72	2	0.00
Malus domestica	71.60	26.85	4	0.01
Acer	69.64	26.11	6	0.00
Acer circinatum	60.58	22.72	11	0.00
Pyrus calleryana	60.17	22.56	10	0.00
Aesculus flava	54.49	20.43	6	0.00
Acer platanoides	43.59	16.35	1	0.00
Abies bracteata	27.30	10.24	1	0.00
Cedrus atlantica glauca	22.62	8.48	1	0.01
Cupressus sempervirens	18.08	6.78	1	0.00
Liquidambar styraciflua	6.44	2.41	1	0.00

Figure 4. i-Tree Eco: Top 20 Oxygen Producing Species

Species Name	Percent Population	Percent Leaf Area	IV
Cornus kousa	47.0	4.8	51.7
Liriodendron tulipifera	1.7	39.2	40.9
Acer rubrum	7.8	14.3	22.1
Fagus sylvatica	1.7	11.1	12.9
Acer circinatum	9.6	0.7	10.2
Pyrus calleryana	8.7	0.6	9.3
Malus domestica	3.5	3.5	6.9
Acer	5.2	1.2	6.4
Aesculus flava	5.2	0.9	6.1
Cedrus atlantica glauca	0.9	4.7	5.6

Figure 5. i-Tree Eco: Importance Value of Species

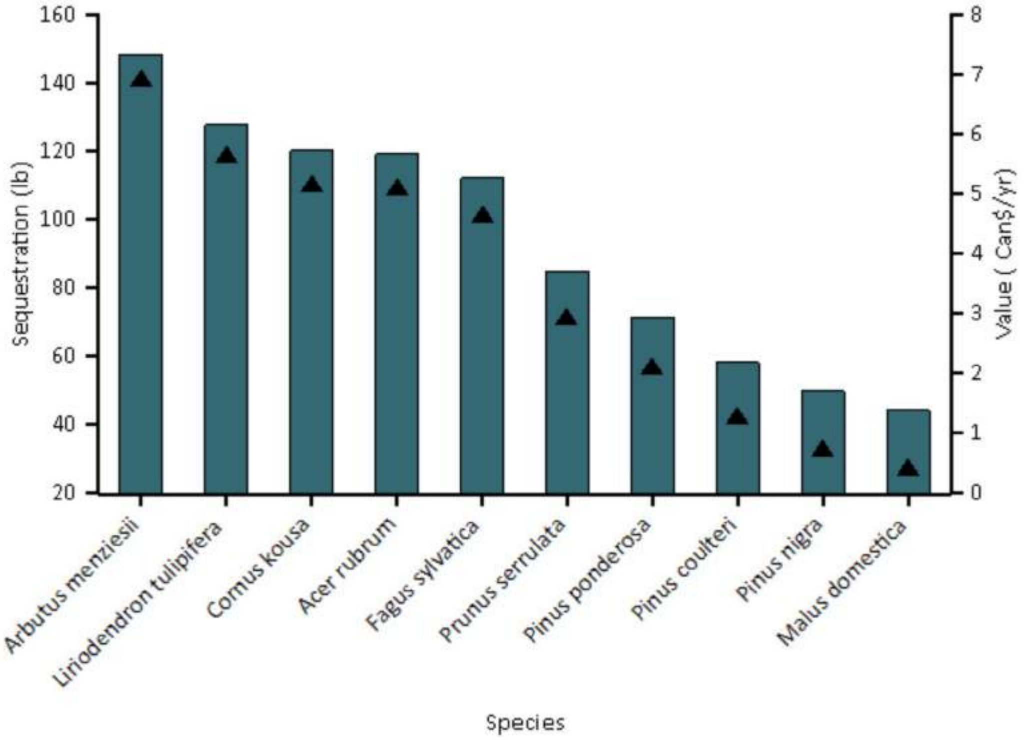

Figure 6. i-Tree Eco: Estimated Carbon Sequestration of Urban Tree Species

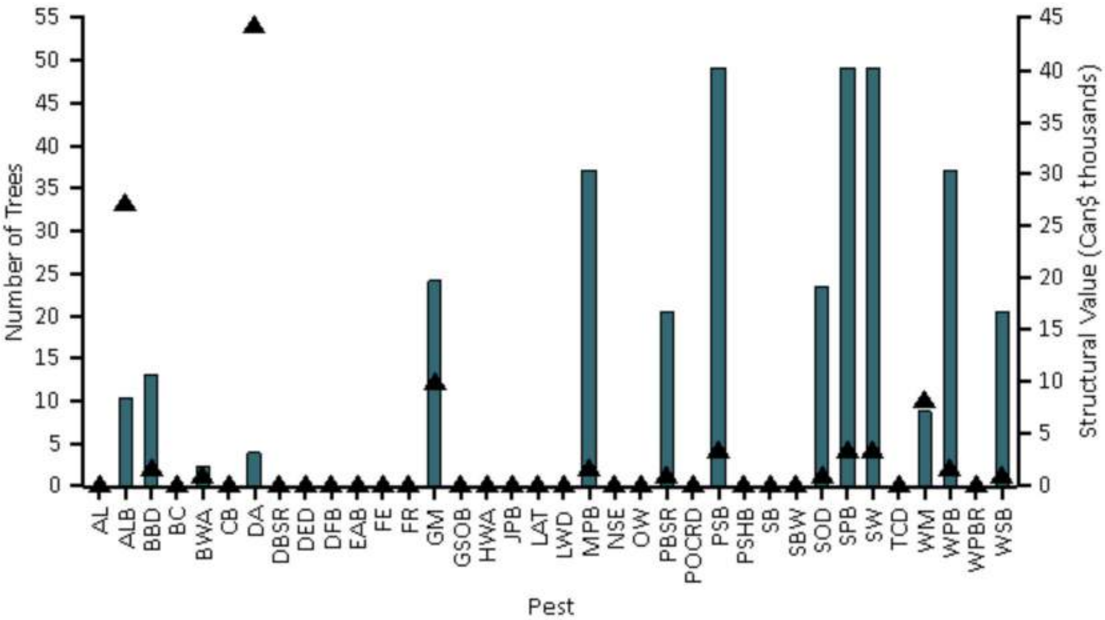

Figure 7. i-Tree Eco: Trees at Risk from Potential Pests

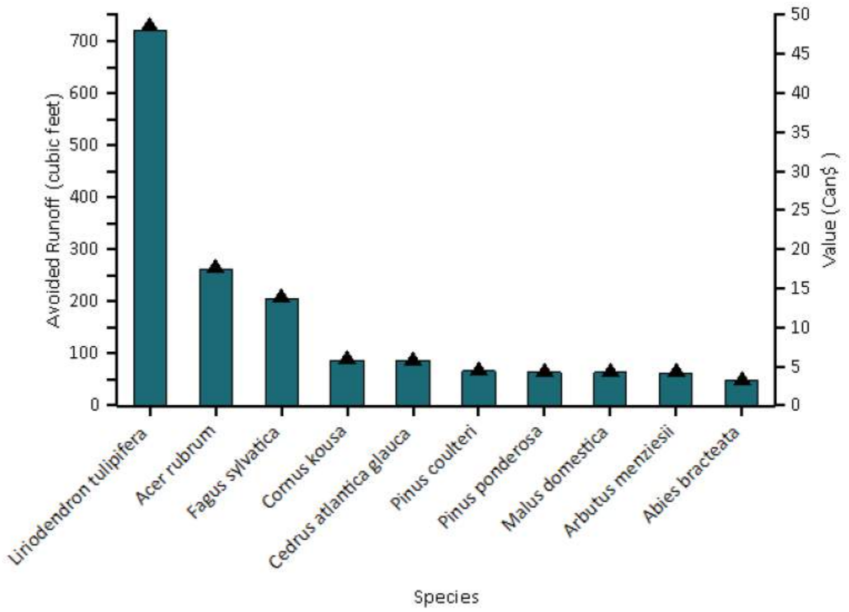

Figure 8. i-Tree Eco: Avoided Runoff of Individual Tree Species

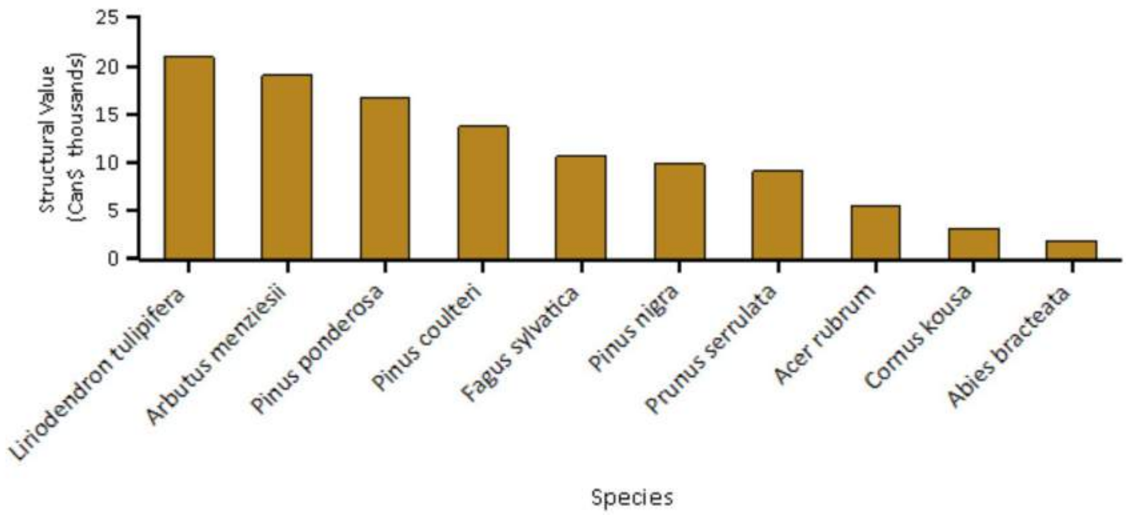

Figure 9. i-Tree Eco: Greatest Structural Value of Tree Species

Structural Value (C$)	
Structural Value	118,000
Carbon Storage	1,570
Functional Value - Annual (C$)	
Carbon Sequestration	49.2
Avoided Runoff	122
Pollution Removal	1.39
Energy Costs and Carbon Emission Values	0

Table 1. i-Tree Eco: Structural and Functional Values

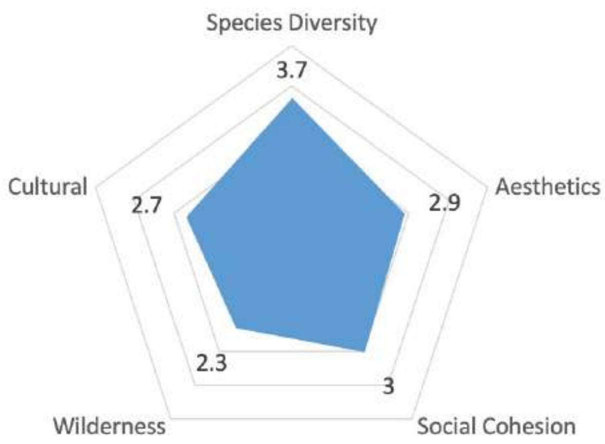

Figure 10. Subzone H Values

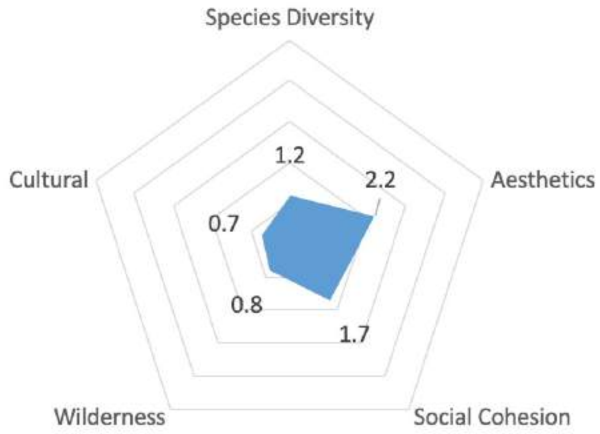

Figure 11. Subzone D Values

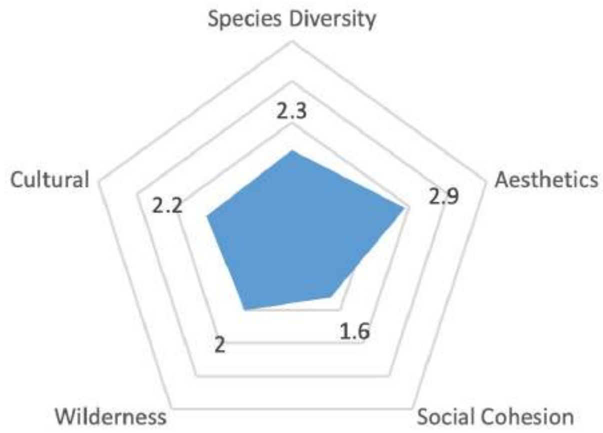

Figure 12. Subzone A Values

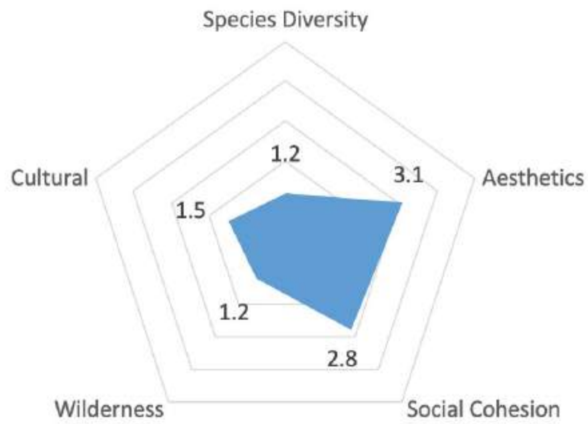

Figure 13. Subzone E Values

Figure 14. Potential Green Walls on Orchard Commons Residence

Figure 15. Orchard Commons Residence

Figure 16. Comparison of Original and Potential Parking Lot Improvements

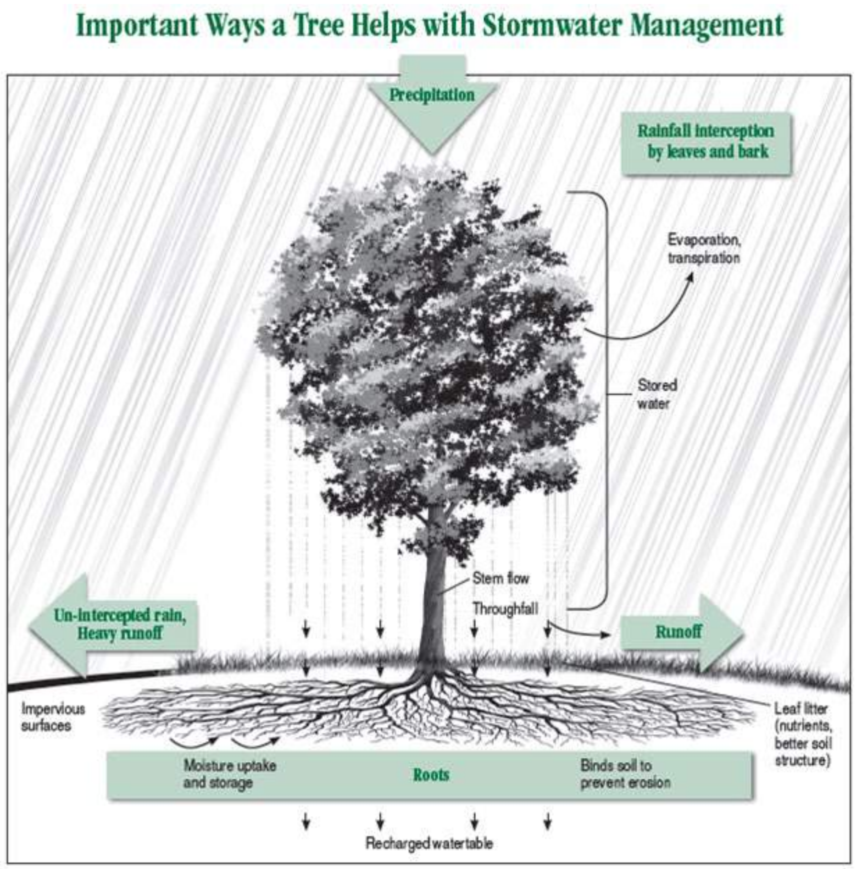

Figure 17. How Trees Help Manage Stormwater

Figure 18. Subzone A: H.R Macmillan Courtyard

Figure 19. Subzone H: Pathway next to Orchard Commons and Daycare Centre

Tree Inventory Analysis Report and Tabulated Data

Group 8

February 10, 2019

Contributions

Team Members:

Joshua Lee - 51275915

Josh contributed to the formatting of the assignment. He also contributed to the Introduction and Site description portion of the assignment. He also helped in writing the methodology as well as summary.

Fumika Noguchi - 99424954

Fumika did her fair share and more, by contributing to introduction, methodology, site description, and making some graphs. She also helped to format the assignment.

Yue Yang (Joey) - 79096848

Joey contributed making the data table and contributing to the introduction and site description. Also helped in the summary.

Allen Qiu (Kai)- 17990896

Kai contributed in making graphs and tables, analysing data, site description, and the discussion on future projections.

Lingsen Kong (Chris) - 94066339

Chris contributed to Summary of Tree Inventory Data, Future Projections, and making some graphs and tables.

Yui Omori - 31329873

Yui added the information about special trees in zone 8 and suggested her opinions in the introduction and future projections.

Introduction

UBC Vancouver campus is a major hub of activity in Vancouver, as it currently supports close to 56 000 students (UBC Overview and Facts, 2018) and is recognized as one of the largest employers in the city (Yerema & Leung, 2018). As a core location for a diverse group of people, it is crucial that the urban forest is able to support the high demands it constantly receives. Not only must the urban forest endure environmental factors, but also day to day anthropogenic disturbances such as construction, vehicle use, and pollution. The results of this inventory project aim to provide a detailed qualitative insight of UBC campus' urban forest, and an analysis of the ecosystem services we obtain. Ultimately, the compiled data will provide a basis for potential future management and planning of an improved urban forest. Constructing an urban forest management plan is necessary for UBC because there is currently a lack in policy surrounding it (Emma Luker, Biodiversity and Urban Forest Planning, January 6, 2019).

There are a diverse range of programs and groups who are invested in the results of the tree inventory such as building operations, planning and design, and sustainability and engineering. Guest lecturers representing SEEDS Sustainability Program, and Campus and Community Planning came in to one of the UFOR 101 lectures at the beginning of our inventory to provide insight into this project. These organizations will be benefiting from the information that we collect on UBC campus' urban forest and are the end users of our project. The two representatives that we are collaborating with from SEEDS are Emma Luker and Egan Davis; who is the planning analyst and the UBC Botanical Garden Horticulture Instructor respectively. Ultimately, an inventory analysis of UBC's urban forest allows us to plan ahead and consider the best tree for the best future, thus preparing us for forthcoming changes from climate change and infrastructure development.

Site Description

The UBC Vancouver campus is located on the western tip of the Point Grey peninsula. This 400-hectare area is surrounded on four sides by Burrard Inlet to the north, Wesbrook Village and Pacific Spirit Regional Park to the South, the Pacific Ocean and Vancouver Island to the West, and the rest of the Greater Vancouver Area to the East (UBC, n.d.). Vancouver is in a coastal temperate rainforest climate zone; therefore, it experiences high amounts of precipitation during colder seasons and dry periods in warmer seasons (Earth Eclipse, 2019).

Our inventory area - Zone 8 - was within the boundaries of Main Mall, West Mall, and Agronomy Road, which contains a diverse set of infrastructures. Some examples include institutional and residential buildings (refer to Figure 2 in Appendix) such as Orchard Commons Student Residence and H.R. MacMillan building. The area we inventoried was roughly 27 200 square metres. Zone 8 consists mainly of concrete or brick infrastructure and does not have a significant number of green spaces. Orchard Commons – and its surrounding areas - was completed in 2016 and is one of the relatively newer buildings on the UBC campus (Perkins+Will, 2016). The area between Orchard Commons and the Landscape Architecture Annex building did have a small area of grass and large trees, but is more of an area to pass through, rather than an interactive space. However, there is a large green space in front of Orchard Commons and along West Mall, that serves as a recreational area for students.

The space between Main Mall and West Mall is on a slight incline, with Main Mall being marginally elevated above West Mall. Looking down from Main Mall onto Agronomy Road, the trees are adjacent to the road, and are mostly shaded by the concrete walls of Orchard Commons. The patch of land these trees are planted on are around 1.5 m wide, stretching from Main Mall to West Mall, which is approximately 130.5 m. Turning the corner onto west mall, trees are also planted on the sidewalk of a soil patch of approximately the same width and length. Additionally, our inventoried area contained the courtyard in the H.R Macmillan building. Though the courtyard might have been intended for recreational use when it was first built, this space is now simply meant as a route to and from classes for students.

In Zone 8, the dominant land users consist mainly of students. There are first-year students living in Orchard Commons Residence and students in the Faculty of Land and Food Systems from the H.R. MacMillan building. Lastly, there is a kindergarten/daycare centre built around the famous *Arbutus menziesii* (refer to summary of inventory data) which adds parents and toddlers to the users of Zone 8. Furthermore, there is a parking lot directly south of Zone 8 at the intersection of Main Mall and Agronomy Road, which increases traffic of both students, faculty, and other visitors.

Methodology

For Assignment 1, we were able to do a sample inventory which is the act of measuring only a subset of trees out of the entire urban forest (Tahia Devisscher, UFOR 101: Inventory Design Approaches, January 11, 2019).

Our method of inventory was an on-the-ground field survey of all the trees in our specified Zone 8. This was done through direct measurement and visual inspections of the various tree attributes. We used the app, *Collector for ArcGIS,* to locate the trees within the boundaries of our assigned area through its' GPS system. This insured that we were able to locate and measure all of the required trees, as well as providing us with the tree ID and species of each individual tree (refer to Figure 1).

Some of the major tree attributes that we measured were DBH (diameter at breast height), crown width, TTH (total tree height), crown base, crown light exposure, and crown percent missing (refer to Table 1 for full list and descriptions of each measured tree attribute). These characteristics will help make decisions in future urban forest planning. During the field survey, our collected data was recorded onto paper, and was later transferred to a pre-formatted Microsoft Excel spreadsheet file. We then used the Excel program to generate graphs for further interpretations of our inventory data.

Please note that our team was not directly able to measure 16 trees within the daycare at Orchard Commons. These trees were inaccessible as they were within a private, fenced area and we had not received permission to enter; therefore, this missing data was instead compiled for us by the UFOR 101 teaching staff.

Summary of Tree Inventory Data

During the field survey, we recorded a total of nineteen tree species. Table 1 below shows the value and species with maximum DBH and height and minimum DBH and height.

Table 1.

Maximum and Minimum Values of DBH and TTH

	Value	**Species**
Max DBH	100cm	Arbutus menziesii
Max TTH	48.8m	Liriodendron tulipifera
Minimum DBH	3cm	Cornus kousa
Minimum TTH	2.25m	Cornus kousa

The most abundant species around Orchard Commons - and in all of Zone 8 - was *Cornus kousa* (refer to Figure 4). Furthermore, the abundant *Cornus kousa* had an average height of around 4.49 m which was in the middle of the range of average total tree height for each species (refer to Figure 3). An analysis of the data shows a significant number of trees within the DBH class of 0 - 10 cm; the 0 - 10 cm DBH class had 101 trees, while the next largest DBH class of 10 - 20 cm had only 12 trees (refer to Figure 6). These numbers signify the young age and size of *Cornus kousa* in relation to the recent completion of Orchard Commons, as well as the dominance of the residential area within Zone 8. The average DBH of *Cornus kousa* is 5.4 cm.

Similar to DBH, most of the trees in our zone were distributed in lower height classes (refer to Figure 7). Twenty-seven percent are between 2 - 4 meters, thirty-six percent are between 4 - 6 meters, and thirteen percent are between 6 - 8 meters. Combined Figure 3 and Figure 4, we can get that most of trees in our plot are still young as they were planted in the past several years.

The mean DBH in Zone eight is 13.06 cm and has a standard deviation of 18.00. Mean of Height in zone 8 is 7.32 meters, and standard deviation of Height in zone eight is 7.46. The standard deviation indicates that DBH and height in zone 8 are very discrete.

Over half of the trees only have two or three sides exposed to sunlight (refer to Figure 8), which indicate that there is high building density and is a potential obstruction of sunlight. The distribution of infrastructure and the urban forest in Zone 8 is uneven and has a negative impact on tree development.

Based on knowledge of TTH correlating with DBH, we had predicted that a taller tree would have a greater DBH. Figure 10 shows the comparison of average TTH and average DBH of each species. There are a few varied cases with very tall trees having small DBHs, or short trees having large DBHs; *Liriodendron tulipifera* and *Prunus serrulata*. However, much of the relationship between TTH and DBH is direct. The average DBH of all the species are sorted from large to small (in red), and the TTH (in blue) decreases along with the DBH. Although this direct relationship between TTH and DBH is important and significant, the size of these trees' characteristics are always dependant on many factors: precipitation, nutrients, space, and biodiversity. Depending on some of these factors and many others, tree characteristics can be different from what they are usually expected to be.

<u>Analysis of Urban Forest at H.R Macmillan Building</u>

In contrast to Orchard Commons, is H.R Macmillan, an institutional building for the Faculty of Land and Food Systems. H.R Macmillan was completed in 1966/1967 (UBC Library Archives, n.d.), and is where the majority of the tall, mature trees are located. Trees such as *Pinus nigra* which have an average TTH of 19.1 m (refer to Figure 3), are all located within the H.R Macmillan courtyard. In addition, 9 out of 10 trees in the courtyard are the tallest trees measured in all of Zone 8, representing various height classes greater than 14 m (refer to Figure 7). These trees have a significantly greater average DBH and height than the rest of the trees in Zone 8.

<u>Analysis of Data: Basal Area</u>

Formula for BA (basal area) calculation:

$$BA(m2) = pi * DBH (cm)2 / 40000$$

Figure 9 illustrates the connection between tree species, abundance, and tree basal area. *Cornus kousa* is the most common tree in Zone 8, which consists of more than 40 trees. In addition, the majority of tree BAs are under 0.2 M^2. To some extent, there are a lot of young trees in Zone 8 with relatively fewer mature trees. Based on the location of the tree ID, most of the *Cornus kousa*, *Acer circinatum* and some other young trees are planted near the Orchard Residence. This is most likely because the Orchard Commons Residence is a new residential area in UBC.

Future Projections

There is a high abundance of *Cornus kousa* around Orchard Commons, which represents 47% of all trees in Zone 8 (refer to Figure 5). The *Cornus kousa* within our area have an average crown width of 1.75m, and many are all located in close quarters of each other. These trees will typically grow to a crown width/spread of 4.5 - 9 m (Missouri Botanical Garden, n.d.), and many of the current trees have potential to grow even more. This gives rise to the potential issue of overcrowding between the tree canopies. Figure 1 shows the density and overlapping of numerous *Cornus kousa* - represented by green dots - on the path between Orchard Commons and H.R Macmillan. As these trees continue to mature, there is a high possibility of overcrowding from natural growth and competition for space and sunlight. To combat this issue, annual pruning would be recommended. Additionally, extreme events are more likely to occur in the future, such as droughts. This is an issue for *Cornus kousa* because it requires frequent moisture during the summer season (Missouri Botanical Garden, n.d.). It is debatable whether this species would be able to survive in potentially hotter and more frequent heat waves of the future. On the other hand, despite the occuring monoculture, *Cornus kousa* are a resilient species that is resistant to disease and pests (Missouri Botanical Garden, n.d.) ; this is a positive aspect which reduces the need for maintenance of tree health going on into its development.

1. Growth of trees around Orchard Commons will gradually slow down because the serve competition. Even for now, some trees can't get enough sunlight for their basic needs (refer to Figure 8). The CLE will even become smaller when some trees grow up and become crowned between tree canopies.
2. Cornus kousa would die in one period. Dislike natural forests, all cornus kousa are in the same age group (refer to Figure 11). And such age structure is unstable.

Significant Trees within Zone 8

A unique tree that is located within our zone is the *Arbutus menziesii* which is within the daycare at Orchard Commons. We were not given permission to measure this tree, so it was measured in our place by the UFOR 101 teaching staff. This tree is a valuable and rare specimen on the UBC campus, as locally transplanted arbutus trees typically are not able to survive for long periods of time; however, this tree has lived long past its expected time. Furthermore, the tree canopy is close to great health with only 10% of its canopy missing. Some species of arbutus are very sensitive to the change in atmosphere and environment such as soil compaction. Before the construction of Orchard Commons and the connected daycare, this was a large grass area. In urban tree planting, it is also necessary to consider air flow (Egan Davis, Campus Tree Tour, January 20, 2019).

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Appendix

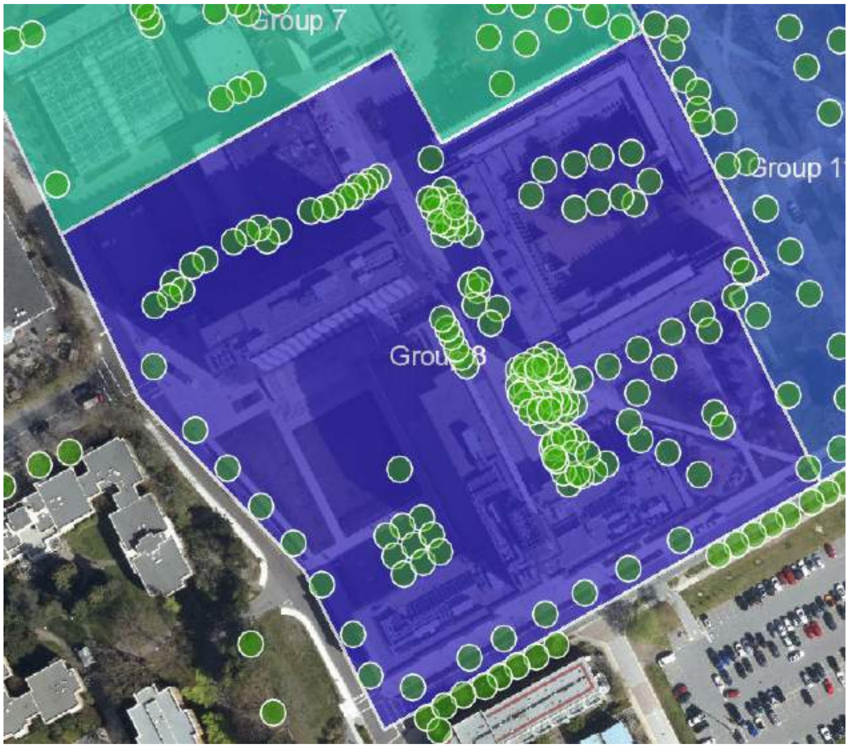

Figure 1. Satellite image of Zone 8 (highlighted in dark blue) on the Arc GIS Collector app. Each green dot represents an individual tree.

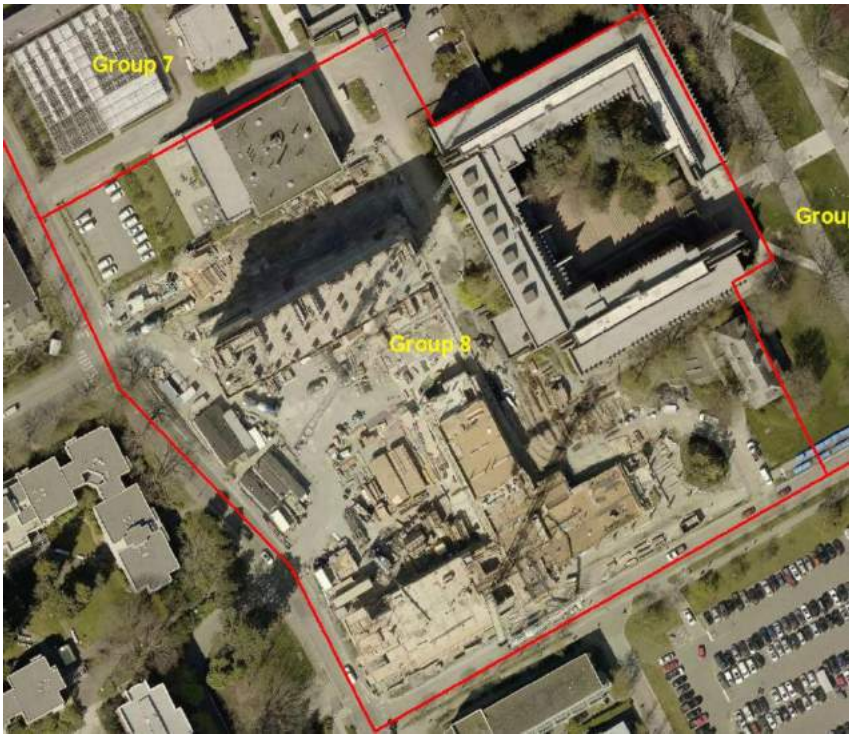

Figure 2. Satellite image of Zone 8. Area of inventory was within the red lines. This image was taken during the construction phase of Orchard Commons prior to its completion.

Table 2.

Measured Tree Attributes

Tree Attribute	Description
DBH - Diameter at Breast Height	Is measured at a height of 1.37m. DBH is measured using a diameter tape only for trees with a DBH greater than 2.54 cm.
Crown Width	The width of the crown in two directions. One direction is the longest width of the crown, while the other is the shortest. Crown width is measured using an eplon tape.
TTH - Total Tree Height	Height from the ground to the top of the tree (alive or dead). TTH is measured using a clinometer.
CBH - Crown Base Height	Height from the ground to the base of the tree crown. This can be the lowest point of a branch. CBH can be 0.

Crown % Missing	The percent missing of the crown volume. This value is measured/estimated visually with two people.
CLE - Crown Light Exposure	The number of sides that the tree is exposed to sunlight. There are 5 sides of the tree; 4 facing outwards, and one being the top of the tree.
BA - Basal Area	BA is the land area covered by the tree stem.

Note. Description of measured tree attributes. Obtained from UFOR101: Introduction to Assignment 1 by Tahia Devisscher on January 14 2019.

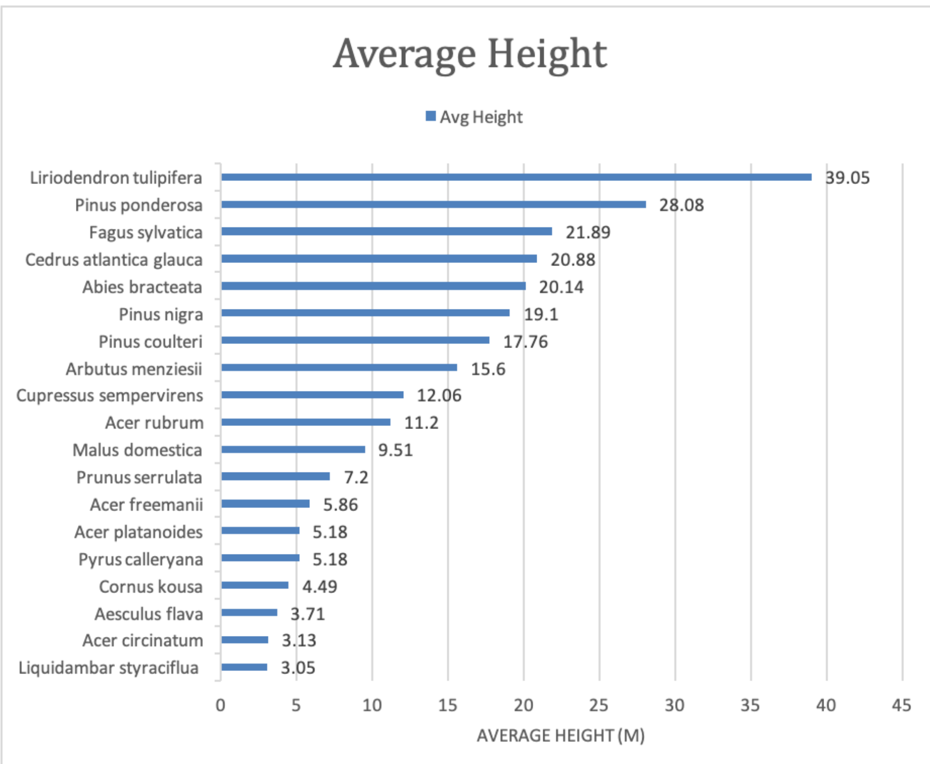

Figure 3. Average height of tree species within Zone 8

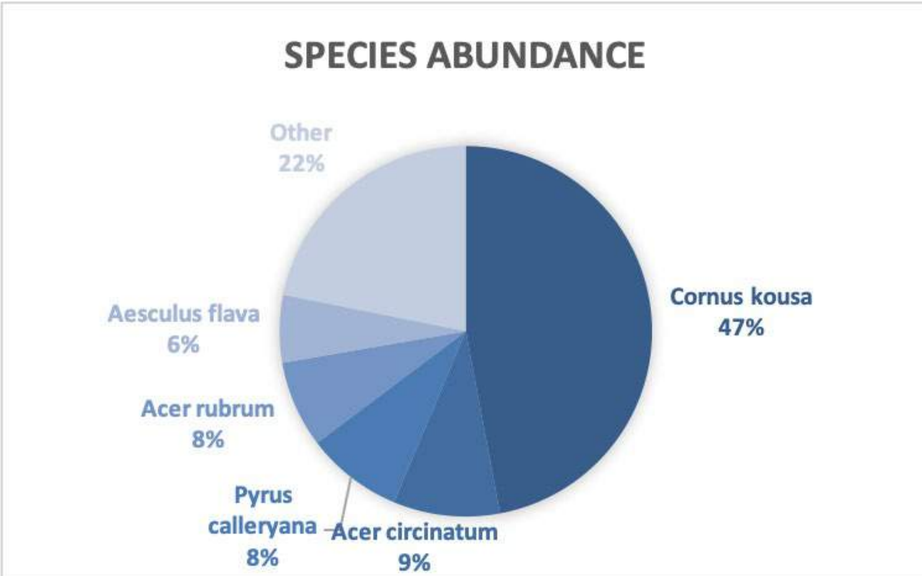

Figure 4. Abundance of individual tree species within Zone 8

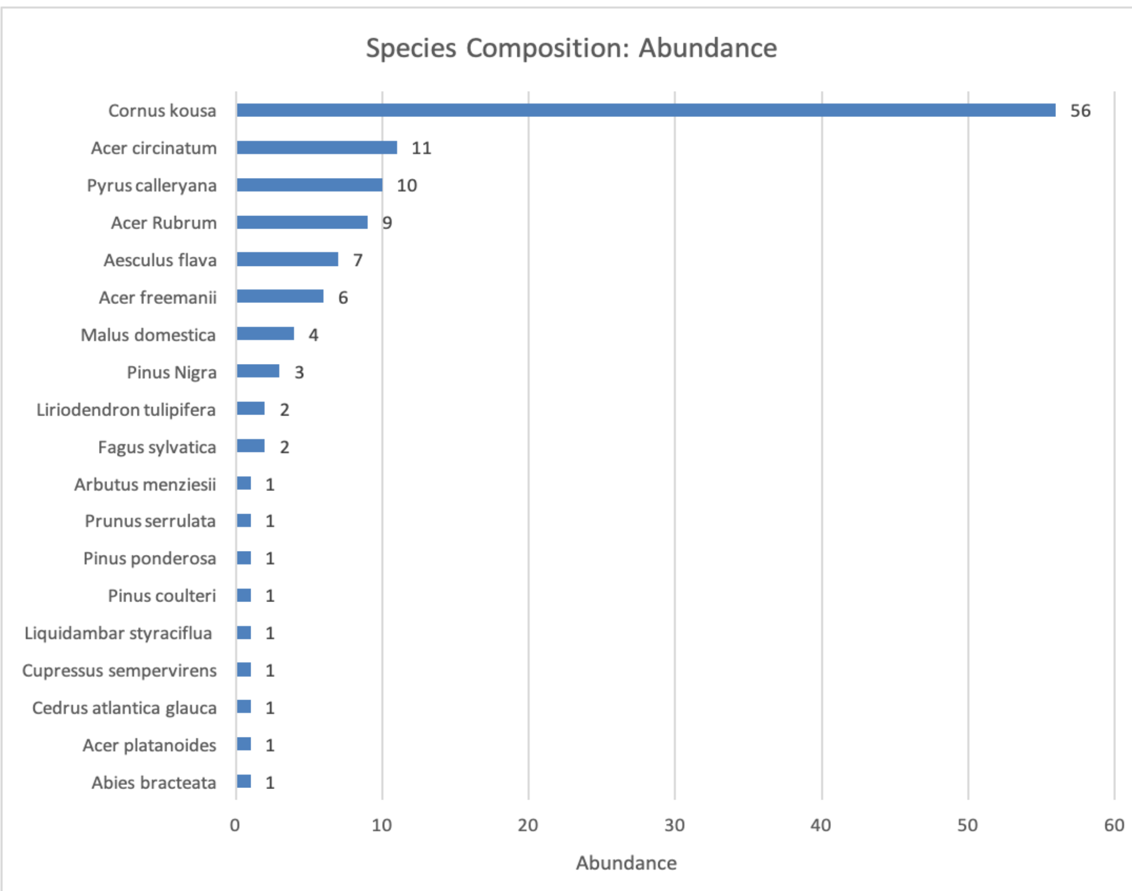

Figure 5. Distribution of most common trees in Zone 8

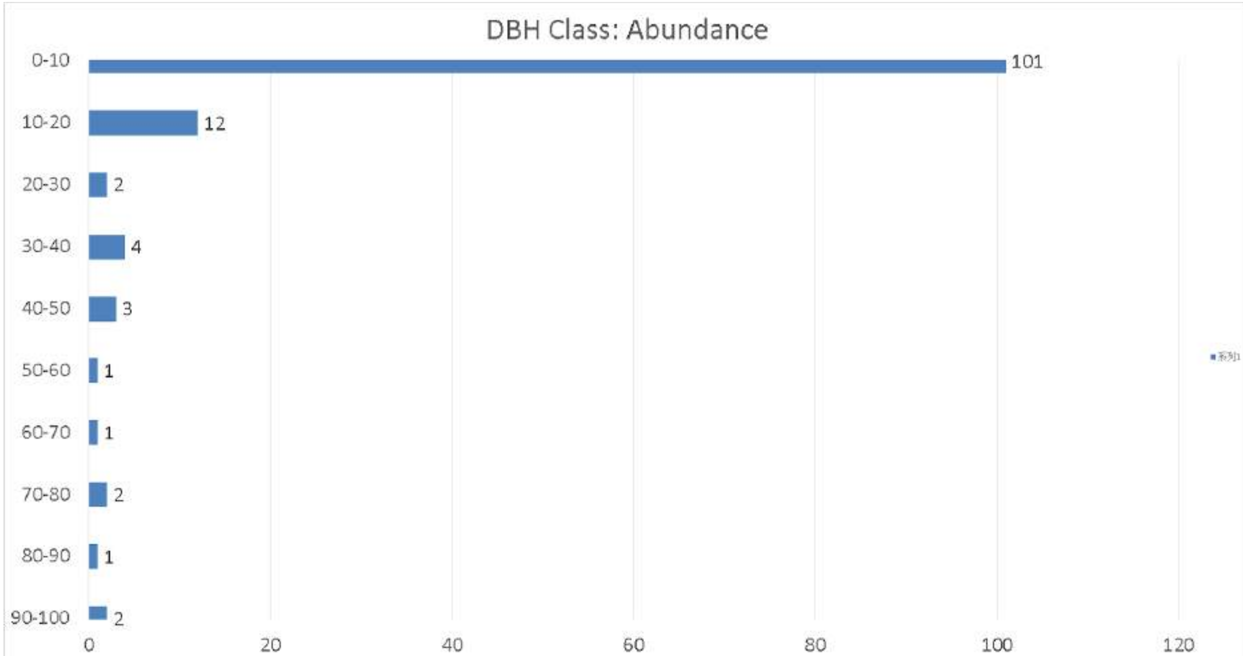

Figure 6. Abundance of trees in various DBH classes

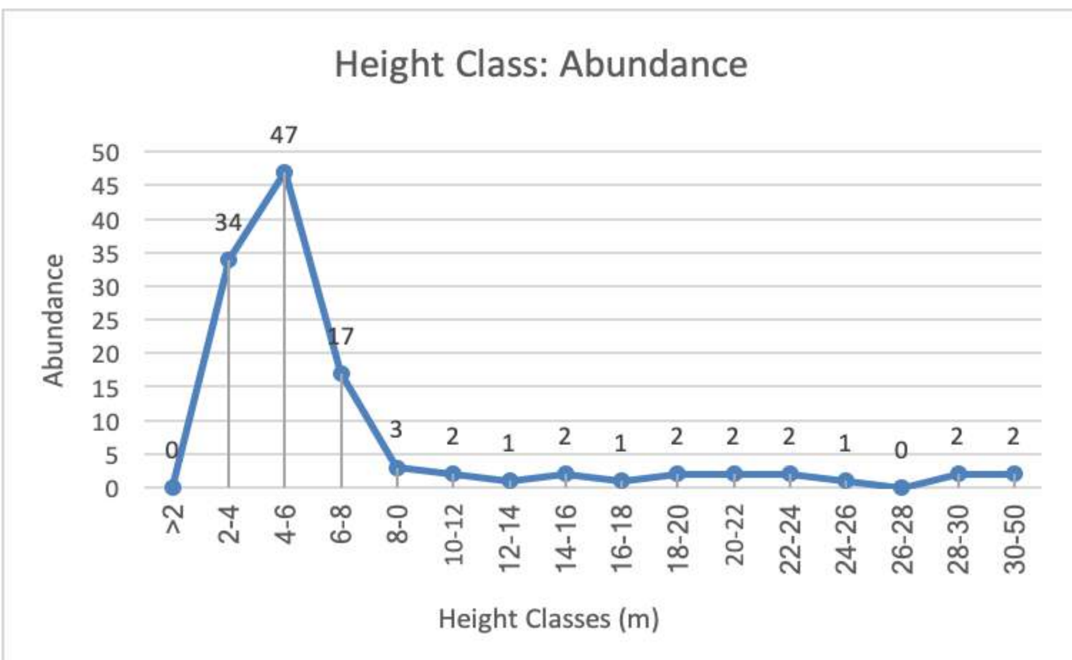

Figure 7. Abundance of trees in various height class

Figure 8. Distribution of crown light exposure (CLE)

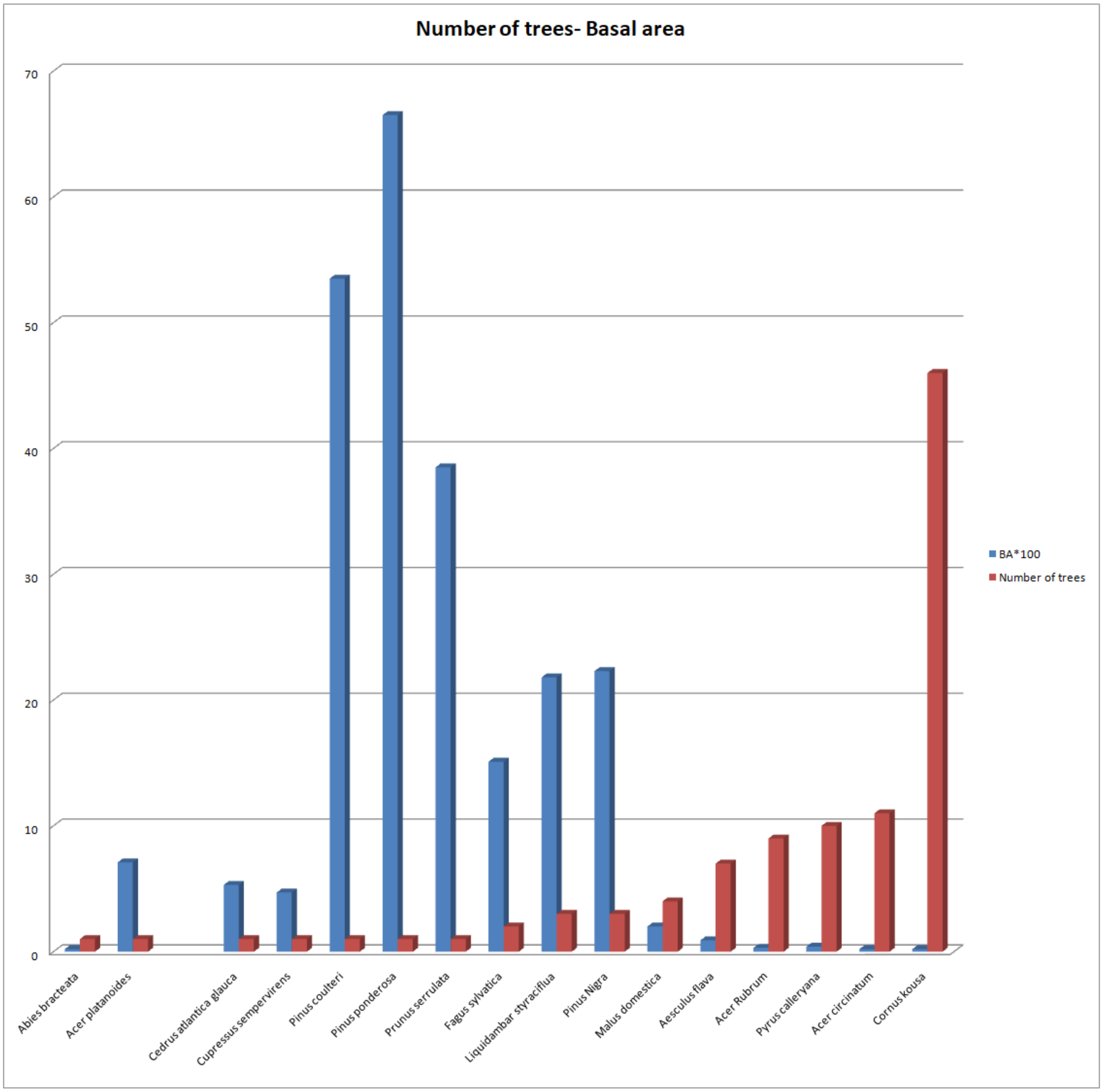

Figure 9. Comparison of basal area and number of trees

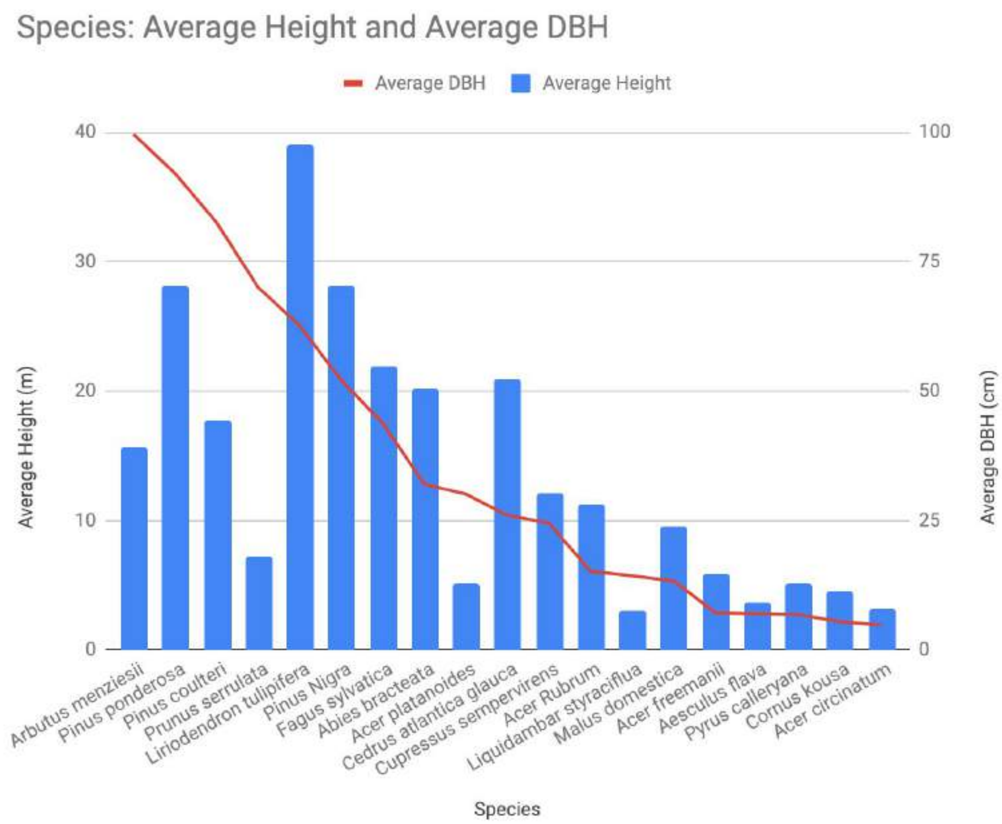

Figure 10. Comparison of average height and average DBH of each species

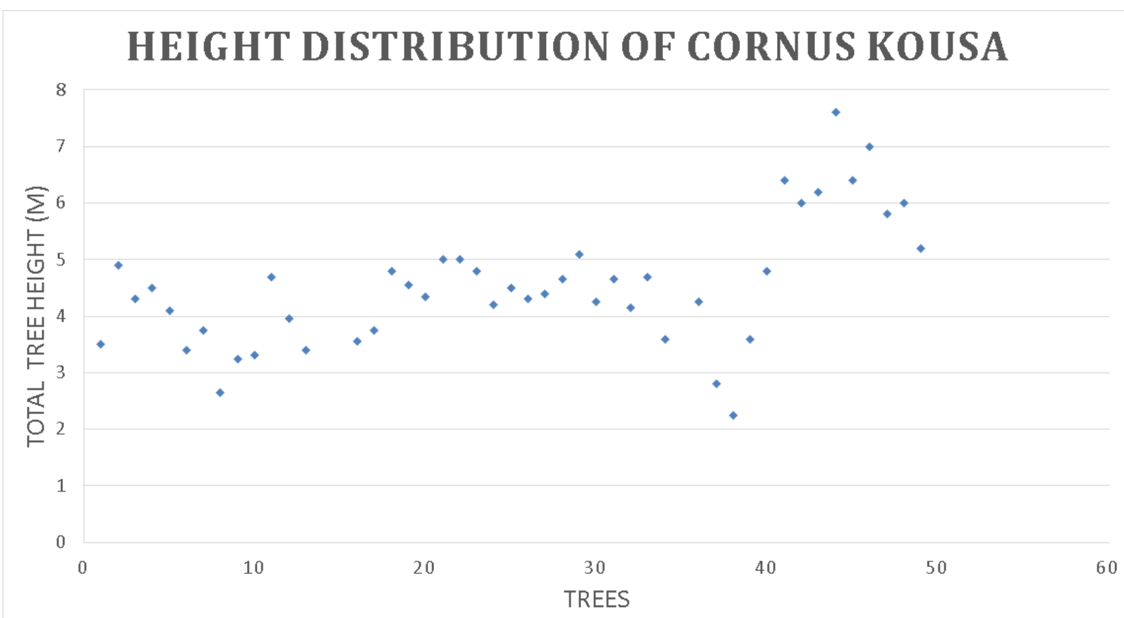

Figure 11. Distribution of Total Tree Height of Cornus Kousa

Ecosystem Service Assessment on Main Mall

Group 9
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Duola Jiang 72773419,
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Date: April 3rd, 2019
The University of British Columbia

Contribution:

Honghong Li	Regulating services
Wenyao Li	Regulating services + Recommendations
Duola Jiang	Cultural ecosystem services
Jessie Wen	Cultural ecosystem services + Recommendations
Alan Lu	Introduction + Site description

English usage and writing style was corrected by Jessie, Wenyao and Alan.

Introduction:
Urban forest ecosystem services assessment is an evaluation of ecosystem services from multiple perspectives. This report includes three main parts, which are regulating ecosystem services, cultural ecosystem services, and urban forest planning and management recommendations. Some other factors include species dominance, DBH classes, Height classes, users, and stakeholders will also be parts of the assessment.

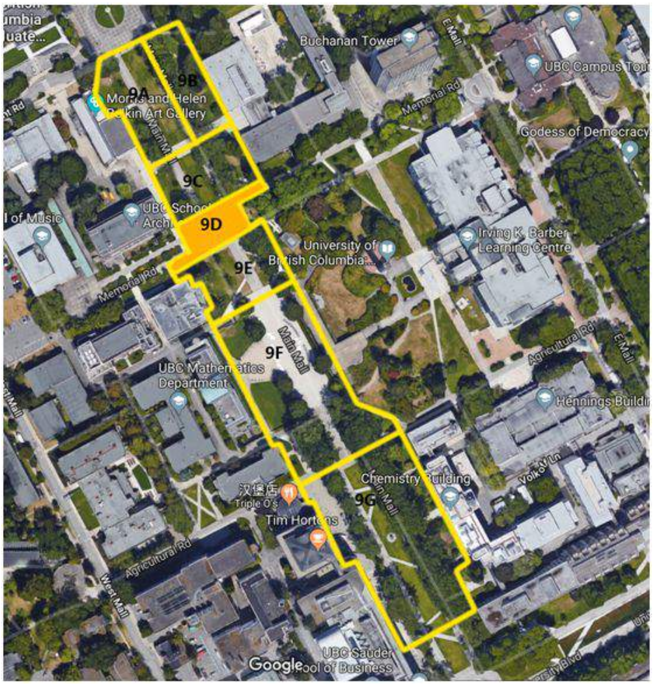
The concept of ecosystem services refers to "the benefits derived from ecological processes that are directly or indirectly provided to humans, and that maintain or improve their wellbeing " (Ferrini, Konijnendijk van den Bosch, & Fini, 2017, p. 51). The classification of ecosystem services which we used is the revised one from the first general classification proposed by De Groot, Wilson and Boumans in 2002. In this classification, there are four categories of the ecosystem services, including provisioning services, regulating services, supporting services and cultural services.

Our group used i-Tree Canopy and i-Tree Eco as tools for regulating ecosystem services. The purpose of using i-Tree, which is a bundle of free tools, is helping the management of urban green spaces, and showing some potential challenges for trees and forests' health in the future. i-Tree Canopy is a useful tool which shows the coverage of different categories. Also, i-Tree Canopy provides tree benefit estimates. i-Tree Eco is another useful tool. It is a software that using the data collected by users, and provides a detailed report that includes environmental data for measuring avoided runoff, structural value, and potential pest impacts in urban green spaces (Tahia, 2019). Also, our group has evaluated cultural ecosystem. The purpose of doing this is assessing the uses and quality of green space, allow community participation and identify the significance of green space for the different type of people (Tahia, 2019).

The benefits of urban forest are very obvious for everyone. It helps on "heat-island mitigation, CO2 reduction, and stormwater attenuation" (McPherson et al. 2005,). However, urban forest management is not as easy as it sounds. Urban forest management is complex, undetermined, and it includes various resources. Furthermore, urban forest planning is also a structured process to identify the values, combine multiplex information, and help in management to adapt to changing conditions (Lorien, 2019).

In the University of British Columbia, there has already been a plan, which is called "greenway", for the greenspace management. The purpose of implementing this plan is for creating a better environment for education. The policy of doing the work of green space management is ruled by the land use plan.

Site Description:



Picture credit by Wenyao Li

The site of our group is the northern part of the main mall started at the main fountain until the flagpole. The land use type of our site is institutional. The main users of this site are students, instructors, tourists, and staffs of the cafes since there is a Tim Horton's and a triple O's in our selected area. Students usually spend time on the cafes during their break time. The main stakeholders would be members of UBC Campus Community Planning and SEEDS. Also, our site is just between two libraries, so there are a lot of students at any time during the day. We also observed many students would love to ride bikes and board surfing through the roads. Even though the main fountain is not included in our site area, a little garden in a crossroad is present on our site (9D in the picture). The garden makes a good meet point for students in the buildings around that area. The green space of our site is pretty large because we do not only have trees, but also huge spaces of lawns. However, there are not many shrubs present in our area. As a result, we have soft surfaces at the vegetation covered areas such as the lawns in the middle of the roads and trees on both sides, and also the hard surfaces as the main road in this area.

Regulating ecosystem services:
i-Tree Eco uses standardized on-site data and local hourly air pollution and meteorological data to quantify urban forest structure and its many impacts (Nowak & Crane, 2000). The impacts include, but are not limited to, air pollution removal, carbon storage and sequestration, oxygen production, avoided the runoff, structural values and potential pest impacts. In this i-Tree Eco report, data includes land use, individual tree attributes of species, stem diameter at breast height, total tree height, crown width, the percentage of crown canopy missing, and crown light exposure.

For air pollution elimination, the removal rates of ozone, sulfur dioxide, nitrogen dioxide, nitric oxide and particulate matter less than 2.5 microns were calculated. When discussing the impact of air pollution on human health, Pm2.5 (which is a subset of PM10) is usually more relevant than PM10, PM10 is not included in this analysis. In this report, the pollutant removal value is calculated on the basis of the price of 1486 Canadian dollars per metric ton (carbon monoxide), 105 Canadian dollars per metric ton (ozone), 15 Canadian dollars per metric ton (nitrogen dioxide), 5 Canadian dollars per metric ton (sulfur dioxide) and 3772 Canadian dollars per metric ton (particulate matter less than 2.5 microns)(i-Tree Eco,2019).

As for carbon storage and sequestration, carbon storage refers to the carbon combination between the ground and underground parts of woody vegetation. In order to calculate carbon storage, the biomass of each tree was calculated by using the equation in the literature and the measured tree data. Compared with the biomass predicted by the forest biomass equation (McPherson, Nowak and Rowntree 1994), the biomass of open-grown and maintained trees are often less. To adjust for this difference, the biomass results of open-planted urban trees were multiplied by 0.8(i-Tree Eco, 2019). Carbon sequestration refers to the total amount of carbon dioxide in the air removed by plants. In order to estimate the total annual carbon sequestration, appropriate genera and diameter classes and average diameter growth of tree condition were added to the existing tree diameter(X years) to estimate the tree diameter and carbon storage for X+1 years. For this analysis, the value of carbon storage and sequestration is calculated at C$115 per metric ton(i-Tree Eco, 2019).

Estimating the amount of oxygen produced by carbon sequestration based on atomic weight: net oxygen release (kg/yr) = net carbon sequestration (kg/yr) ×32/12(i-Tree Eco, 2019). avoiding surface runoff every year are calculated based on the interception of rainfall by vegetation. Because there is vegetation in the site of Group 9 every year, the difference between annual runoff is small. For this report, the avoided runoff value is calculated at a price of C$2.32 per cubic meter(i-Tree Eco, 2019).

i-Tree canopy program randomly places any number of points on Google Earth images, then users classify the coverage categories of each point, finally, the program will display the estimated results throughout the interpretation progress. There were three steps in this analysis. First, imported a document that defines the boundary of the site of group 9. Then named the cover classes to be classified (tree and non-tree). Last, classified each point, the points were randomly located in the boundary document.

The data that the two models can analyze are far from each other, so they have different strengths and weaknesses. The greatest strength of i-Tree Eco is that it can analyze all kinds of data sampled and measured in the field and draw more pertinent conclusions. But the disadvantage of i-Tree Eco is that it is not friendly to other countries outside the United States. Because the project was developed in the United States, the list of vegetation species and pest analysis only records native species in the United States. In Canada or other countries, when using this procedure, many species will not be found or named. i-Tree canopy has the advantage of easy operation. Everyone can use this project to easily analyze the coverage categories of their areas of interest, which is very feasible. The disadvantage of the i-Tree canopy is that the program randomly chooses points. When the number of points is small, the data obtained has great randomness and low precision.

The overlapping part of the results obtained by the two models is the analysis and evaluation of air pollution removal and carbon storage and sequestration. Comparing with the i-Tree Eco, the results obtained by i-Tree canopy are of lower accuracy and less analysis content. It includes the coverage of different types (vegetation canopy) in the site (*Fig 1. i-Tree Canopy(part 1), group 9*) and the amount of removal of each air pollutant and the amount of carbon storage and sequestration are evaluated in the program. While i-Tree Eco analysis the data from more different perspectives and more specific.

The two tools used in analyzing regulating services for group 9's site are i-Tree Eco and i-Tree Canopy. Both of them provided tree benefits estimations. i-Tree Canopy showed a relatively simple estimation of tree benefits, which include which mainly include the amount of air pollution removal (Carbon dioxide, nitrogen dioxide, ozone, sulfur dioxide, PM2.5 & PM10), the amount of carbon dioxide sequestration and carbon dioxide storage. In order to help understanding, i-Tree Canopy converted amounts to value in USD. From *Table 1*, it is clear to see that the value of carbon dioxide stored in trees is the highest one, which reached 41,194.08 USD. The values of carbon dioxide sequestered annually in trees and PM2.5 removed annually are 1640,30 USD and 1730.86 USD respectively, which is a relatively high value on this site. The high value of carbon dioxide storage is due to the dominance of red oak on this site. Red oak is a medium-large tree with a big trunk and crown (Northern red oak, n.d.). The amount of carbon storage is proportional to the dry mass of trees (1B: Carbon Storage in Local Trees, 2018, October 16). Thus, the high amount of big red oak means high availability of carbon storage and carbon sequestration. In addition, different species of trees have different ability to absorb PM2.5, which relates to leaves morphology tightly. Trees with broad leaves and rough surface areas tend to have better ability to capture PM2.5 (Liang, D., Ma, C., Wang, Y., Wang, Y., & Chen-Xi, Z., 2016). Red oak's leaves are usually 10-20 cm long, with pinnate lobes and a wedge-shaped base, which is a good capture for PM2.5 (Northern red oak, n.d.). The high density of red oak on Main Mall is the reason why the amount of PM2.5 removed annually such high.

Tree Benefit Estimates

Abbr.	Benefit Description	Value (USD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	3.70 USD	±0.00	5.57 lb	±0.00
NO2	Nitrogen Dioxide removed annually	9.47 USD	±0.00	48.53 lb	±0.00
O3	Ozone removed annually	603.51 USD	±0.00	323.02 lb	±0.00
PM2.5	Particulate Matter less than 2.5 microns removed annually	1,730.86 USD	±0.00	20.50 lb	±0.00
SO2	Sulfur Dioxide removed annually	1.41 USD	±0.00	17.89 lb	±0.00
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	316.08 USD	±0.00	101.20 lb	±0.00
CO2seq	Carbon Dioxide squestered annually in trees	1,640.30 USD	±0.00	35.39 T	±0.00
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	41,194.09 USD	±0.00	888.81 T	±0.00

i-Tree Canopy Annual Tree Benefit Estimates based on these values in lbs/acre/yr and USD/T/yr: CO 0.787 @ 1,333.50 USD | NO2 6.863 @ 391.85 USD | O3 45.682 @ 3,749.93 USD | PM2.5 2.899 @ 169,479.81 USD | SO2 2.529 @ 157.74 USD | PM10 14.312 @ 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.

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Table1. Tree benefits estimates, group9 i-Tree Canopy

In contrast, i-Tree Eco showed a more detailed analysis of the benefits that trees provided. Besides benefits that i-Tree Canopy covered, i-Tree Eco also mentioned every type of trees' specific benefits, such as each type of trees' carbon sequestration in metric ton per year. From *Table 2*, it can be seen significantly that red oak has the highest gross carbon sequestration, which can prove the above paragraph 's analysis about red oak's carbon storage.

Annual Carbon Sequestration of Trees by Species

Location: Greater Vancouver A, Greater Vancouver, British Columbia, Canada
Project: Group9 i-Tree, Series: ZONE 1G, Year: 2019
Generated: 2019/3/2

Species	Gross Carbon Sequestration (metric ton/yr)	CO_2 Equivalent (metric ton/yr)
Japanese maple	0.02	0.07
Incense cedar	0.03	0.10
Eastern redbud	0.01	0.03
Hinoki cypress	0.01	0.02
Sawara false cypress	0.03	0.12
Pacific dogwood	0.01	0.03
Smooth hawthorn	0.02	0.06
Cedar-of-Goa	0.04	0.14
English holly	0.03	0.12
Tulip tree	0.05	0.18
Austrian pine	0.02	0.08
Daybreak yoshino cherry	0.05	0.18
Northern red oak	1.66	6.10
Deciduous Stewartia	0.02	0.07
Western redcedar	0.03	0.12
Total	**2.02**	**7.41**

Table 2. annual carbon sequestration of trees by species, group 9 i-Tree Eco

In addition, i-Tree Eco contained the amount of avoided runoff, the amount of pollution removal, structural value, hydrology effects of trees, net annual benefits in CAD, and VOC emissions. Avoided runoff is an important aspect because Vancouver's rainy season is pretty long and if too much precipitation cannot be filtered on time, it would cause some clogging problems. Plants can help to solve this problem by completing water recycle (All Your Utilities Under One Roof, n.d.). Plants and soils will help to purify the precipitation and keep the cleanliness of Main Mall. From *Table 3*, it's clear to see that the amount of avoided runoff is associated with plants coverage. Red oak occupies the most on Mail Mall, so its avoided runoff is also the highest. Structural value is another significant indication by using currency to value different species' value. This is not proportional to various species of plants coverage. Instead of that, it relates to many other factors, such as the ability of carbon sequestration and the ability of pollutants removal.

Table 3. Benefits summary by stratum and species, group 9 i-Tree Eco

Species	Trees	Carbon Storage		Gross Carbon Sequestration		Avoided Runoff		Pollution Removal		Structural Value
	Number	(metric ton)	(Can$)	(metric ton/yr)	(Can$/yr)	(m^3/yr)	(Can$/yr)	(metric ton/yr)	(Can$/yr)	(Can$)
Japanese maple	1	1.21	138.74	0.02	2.23	0.80	1.86	0.00	0.02	9,039.61
Incense cedar	1	1.52	174.87	0.03	3.06	2.97	6.91	0.00	0.08	20,140.80
Eastern redbud	1	0.10	11.41	0.01	0.93	0.56	1.31	0.00	0.01	995.24
Hinoki cypress	2	0.08	9.72	0.01	0.68	0.81	1.88	0.00	0.02	1,196.82
Sawara false cypress	2	1.44	165.73	0.03	3.80	5.24	12.19	0.00	0.13	22,174.58
Pacific dogwood	1	0.28	31.63	0.01	0.81	0.41	0.95	0.00	0.01	2,180.61
Smooth hawthorn	1	0.35	40.42	0.02	1.95	1.30	3.02	0.00	0.03	2,463.18
Cedar-of-Goa	2	7.65	878.98	0.04	4.24	3.81	8.86	0.00	0.10	58,487.26
English holly	2	0.63	72.09	0.03	3.61	0.35	0.82	0.00	0.01	5,514.28
Tulip tree	1	2.63	302.24	0.05	5.72	5.56	12.94	0.00	0.14	23,633.20
Austrian pine	2	1.51	173.36	0.02	2.43	4.24	9.87	0.00	0.11	19,435.44
Daybreak yoshino cherry	7	0.48	55.21	0.05	5.52	2.34	5.45	0.00	0.06	3,060.56
Northern red oak	49	100.18	11,507.99	1.66	190.99	158.62	368.74	0.03	4.07	630,649.45
Deciduous Stewartia	1	0.46	53.34	0.02	2.28	0.34	0.78	0.00	0.01	3,971.67
Western redcedar	2	4.24	486.97	0.03	3.74	10.66	24.78	0.00	0.27	56,227.51
Total	**75**	**122.77**	**14,102.72**	**2.02**	**231.98**	**198.03**	**460.36**	**0.04**	**5.08**	**859,170.21**

Cultural ecosystem services:

According to the Millennium Ecosystem Assessment (2005, p. 40), cultural ecosystem services are defined as "the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. " Cultural ecosystem services are important in a wide range of settings. It can influence the landscape planning, community engagement and landowner behavior (López-Santiago et al., 2015). For instance, in a prosperous society, there is an increasing number of landowners are motivated by a desire for cultural ecosystem services rather than by profit (López-Santiago et al., 2015). Furthermore, urban and rural communities have a stronger demand for cultural ecosystem services. As the continuous increasing of human use of ecosystem services and the awareness of its importance, mapping ecosystem services has become a widely concerned problem. Because cultural ecosystem services are characterized as being "intangible," "subjective," and difficult to quantify in biophysical or monetary terms (Millennium Ecosystem Assessment, 2005), there is a stronger need to map them to implement a more comprehensive landscape planning and management.

In order to gain a deeper understanding of green spaces on campus about their worth for individuals or society, and provide integrative information about campus green spaces status, we conducted recreational value mappings at UBC. In the course of recreational value mapping, our zone was divided into seven subzones (from 9A to 9G, *Fig 2*), and each group member was required to score five dimensions of these subzones based on their personal perceived experience. Considering each person's different criteria for the perceived experience, as well as different measurement methods, we unified the standards of value mapping from five dimensions—diversity/ species richness, aesthetics, social cohesion, wilderness/ nature, cultural significance and recreation. Field visits were then conducted based on these criteria. Each member scored these seven subzones based on their personal feelings, with zero being the lowest and five being the highest. Finally, the result of recreational value mapping was obtained by collecting each members' score and calculating their total and average values.

Although the method of assessing recreational value from various dimensions have been discussed in lectures, individuals' perceptions of the region are subjective and there will be inevitable bias. As Dr. Tahia Devisscher said in a lecture on March 4, 2019, these differences may come from diverse individual lifestyles, ethnicities, religious faiths, and attributes. Therefore, the results obtained through this field observation exist differences. The data of only one group cannot fully represent the real cultural and ecological value of this region. However, on the other hand, mapping in this way can represent different people's feelings towards the recreational value of this area. As long as enough data are collected, a more comprehensive recreational value mapping can be obtained. Moreover, the intuitive feeling from on-site observation will be a relatively accurate result from the perspective of personal scoring.

Table 4 shows the overall results of our group's average scores in seven subzones. The detailed mapping results for each dimension will be interpreted in the following sections. Based on this table, it can be observed that the main scores of our group are concentrated in 1.5 to 3, and there are no significant differences in scores of each dimension in other subzones except for the subzone C and the subzone D. The aesthetic value of these two subzones is prominent and the data differences are relatively large.

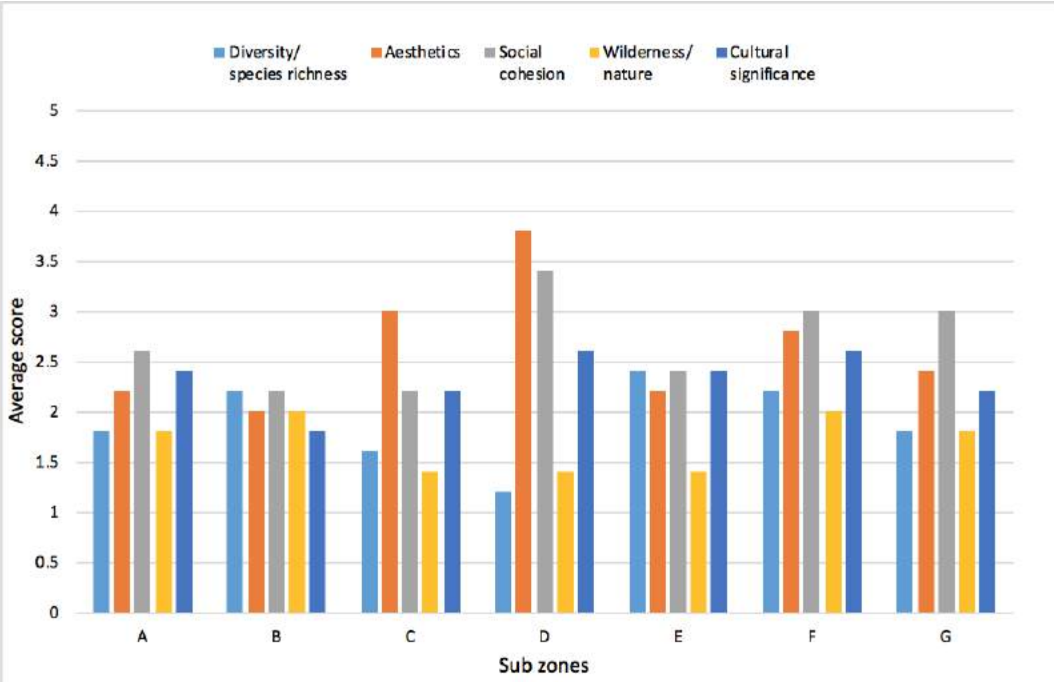
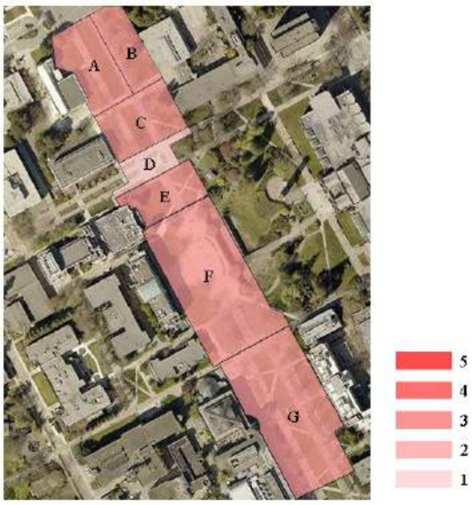


Table 4

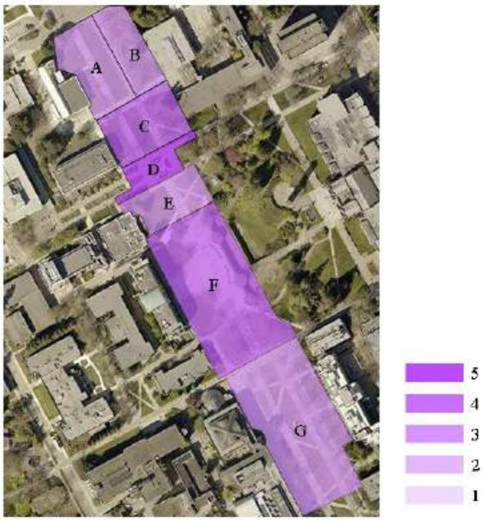
In general, as one of the main streets with important historical and cultural significance in the campus, Main Mall has high aesthetic value and strong social cohesion. Because of this unique location, our zone also has a relatively higher value of aesthetics, cultural significance and social cohesion. In contrast, the well-organized planning and management of street trees, as well as the high space occupied by traffic roads, resulting in its weak wilderness and the low diversity of species.



Diversity/species richness

Diversity/species richness

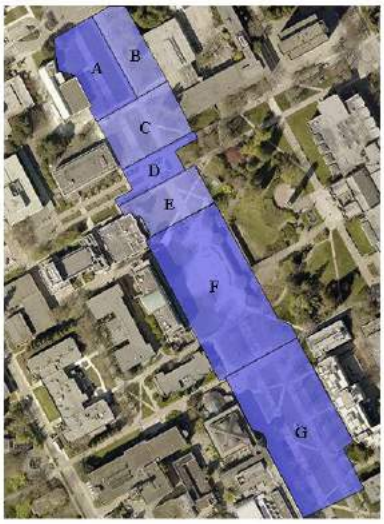
For species richness in our site, we valued six subzones as scale 2 and one subzone as scale 1, which indicates that our site is poor in species diversity. As we have measured, our zone is dominated by one tree species, red oak. Compared to other areas in UBC, our site is abundant in just one or two species instead of rich in species diversity. This is because our site is located on Main Mall, a road that many students passing by every day. Most of the trees on Main Mall are street trees and they are the same tree species for the sake of visual neatness. However, we still found the squirrels and some birds in subzone G and subzone E. And because the tree species in subzone B is the most abundant in our zone, it has a higher species richness.



Aesthetics

Aesthetics

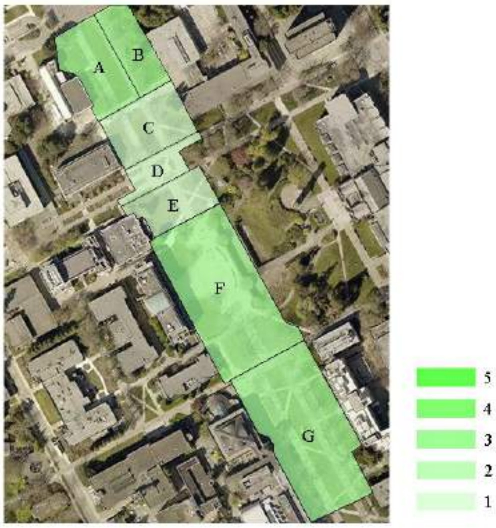
As for the aesthetics, our site has a high aesthetic value especially for subzone D. Subzone D is a parterre located near Buchanan. It is a crossway connected Main Mall and Memorial Road. Also, subzone F has a high aesthetic value. For this subzone, we value scale 3. It is located next to Irving K. Barber Learning Center. Subzone F also has a large flow of people passing by. The landscape in this area forms a beautiful scenery with the nearby clock tower and buildings, which is one famous attraction of UBC. The sight of people walking in our zone is broad. Although the tree crowns on both sides of Main Mall are large, they do not prevent people from looking at the scenery at the end of the road. At the same time, the canopy can provide people with shades. Overall, the landscape setting of our site will make people feel comfortable.



Social cohesion

Social cohesion

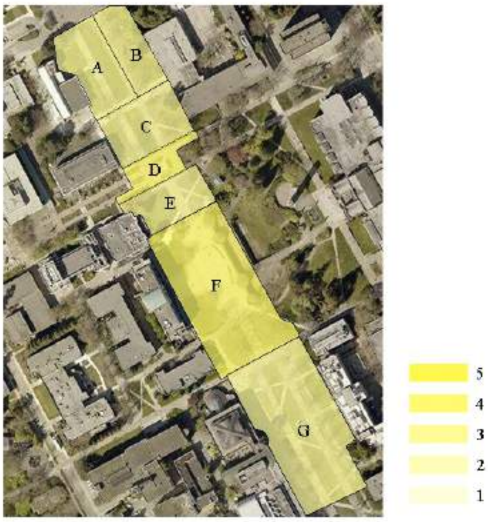
Main Mall, as a primary road in UBC, is also valued high in social cohesion. Benches are placed both sides along the whole road. For spaces like subzone D and subzone F, arc-shaped benches are set. This kind of benches could help people chat with others face to face, which is a good way to promote communication. During our fieldwork, we met a lot of students had lunch in subzone D and many students also use this area as a meeting point with their peers.



Wilderness/nature

Wilderness

We value that subzone A and B are richer in the wilderness. Subzone A and B are located at the end of Main Mall. The arrangement of the trees located there is less uniform than the other sections of Main Mall. There is a forest in the open space on both sides of the road, so we conclude that the wilderness of these areas will be higher than other subzones with street trees. In our opinion, subzone C, D and E have lower wilderness. These three subzones are the main thoroughfare for students to pass by. Human activity of these areas is quite high. As a result, less wilderness will appear in these subzones.



Cultural significance

Cultural significance

We value that subzone D and F have the highest cultural significance. There are clock tower and Walter C. Koerner Library located in this area. These two buildings are old and have great historical significance. As for subzone D, the parterre has a great contribution to the social and spiritual value. Besides this subzone, other subzones have a scale of 2. Since Main Mall is an iconic landscape campus area of UBC, the buildings and landscape in our site have a quite important historical and cultural significance.

Urban forest planning and management recommendations :
Our general goals for this assessment is to create an iconic campus landscape area and to improve the campus landscape framework. Thinking about what we can do to achieve these goals, we came up with the objects such as linking social activities to green spaces closely, increasing the biodiversity and gaining more information about how the green spaces on campus are being used.

SWOT Analysis

Strengths	Weaknesses
- Sufficient space & sunlight - High canopy cover rate (50%) - Historical & meaningful area - High aesthetic value	- Low diversity of tree species (49/75) - Require a lot of money and labor to maintain & manage - Red Oak needs acidic soil (<6.8)
Opportunities	**Threats**
- Education - Tourism - Climate change - Water- efficient campus	- Weak ability to adapt to environmental change - Easily to spread pest and diseases - Occurrence of accident

2

Table 5. SWOT analysis

First, we use SWOT to analyze our zone from various aspects. In our site, canopy cover is more than 50% which is a strength. Our site is also a historical and meaningful area on the campus, which can attract tourists and increase tourism revenue. Here also provides a good place for forest students like us to study and put in practice. While the tree species are relatively single, and this weakness may make it difficult for the trees to adapt to the environmental changes, but easier to spread diseases and pest.

Considering these key features of our site, our first recommendation is to add some rain gardens combined with gravel, shallow trenches to the areas which have a low terrain (subzone B). On the one hand, it can naturally filter and absorb the runoff, prevent it from entering the waterways. On the other hand, this structure provides pathways for pedestrians and it can increase social sustainability. In general, with this structure, we can enhance the sustainability of the campus landscape and increase the aesthetic value.

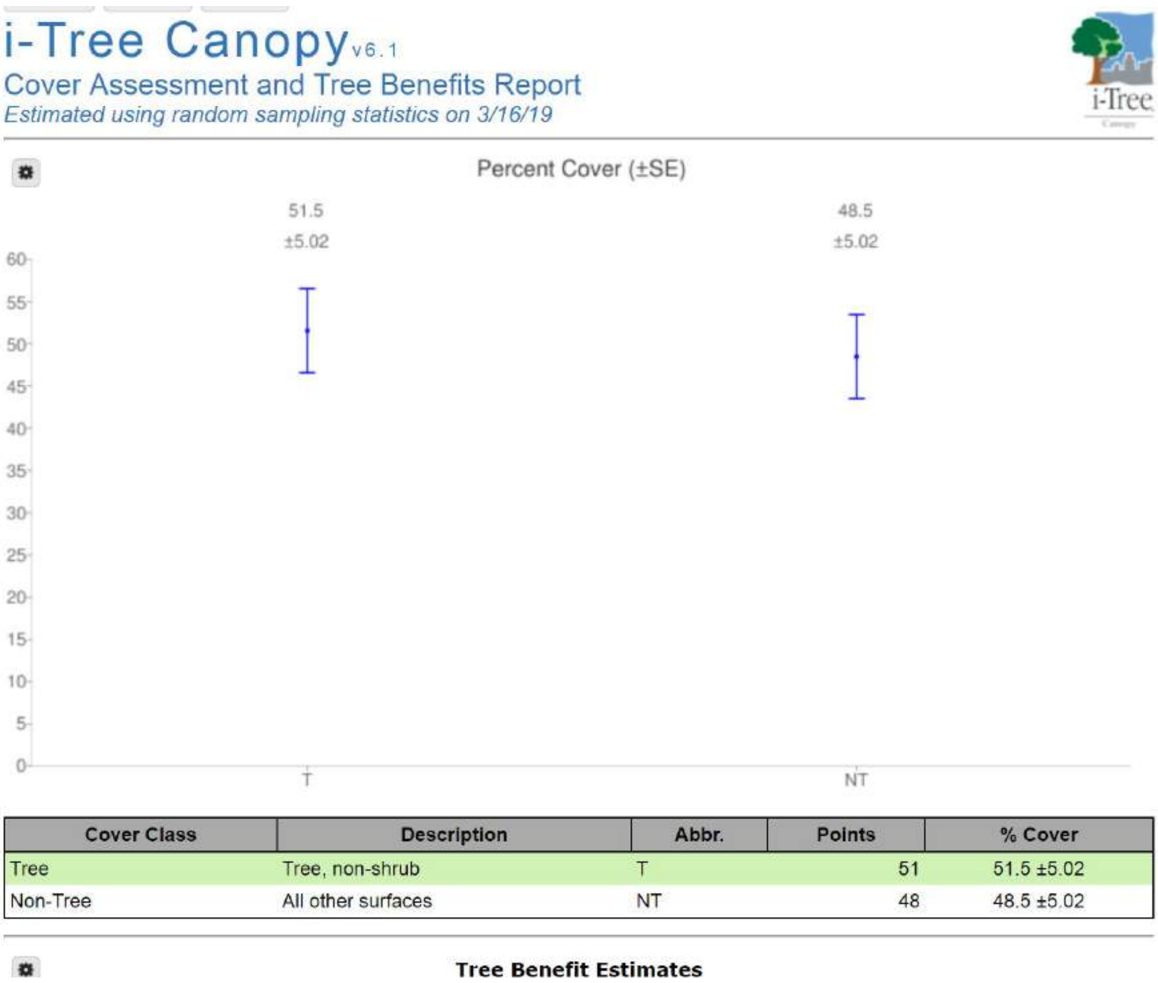
The second recommendation is to conduct a campus landscape survey. We will provide a campus map for people to map their routes through campus, identify their favourite places and they can make extra commons about the campus landscape. In this way, we can gain current information about how people use, enjoy, and think about the campus landscape to improve our campus landscape framework.

The last recommendation is about several Yoshino cherry trees, which were newly planted in front of the school of architecture in 2012. According to their growth situation, although the soil space seems abundant at present, in the next few years when their trunk grows stronger and the crown is larger, space here will not be enough to provide enough growth space for so many trees. The growth of these Yoshino cherry trees should be observed annually, the trees with poor growth should be removed when the growth space is insufficient for the other trees.

Pic. Yoshino cherry in front of the school of architecture

Appendix Ⅰ：

Some figures and tables which were described in the content.



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	51	51.5 ±5.02
Non-Tree	All other surfaces	NT	48	48.5 ±5.02

Fig 1. i-Tree Canopy(part 1), group 9

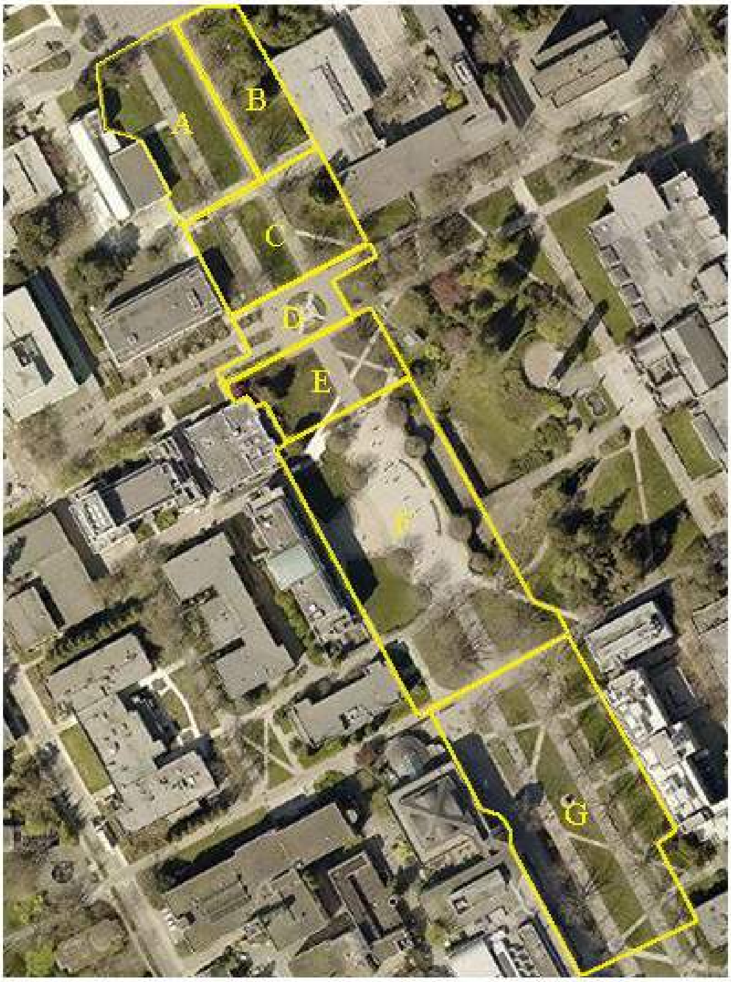


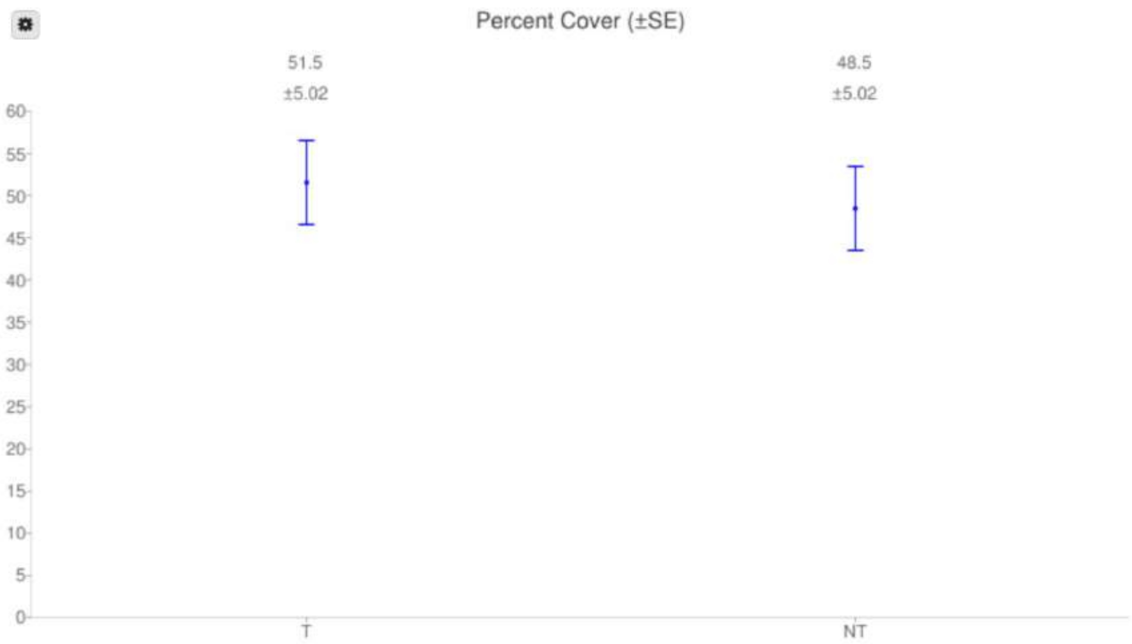
Fig 2. Group 9 subzones map

Appendix Ⅱ. i-Tree Canopy Result：

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 3/16/19



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Urban Forest Inventory and Assessment on Main Mall

Group 9

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The University of British Columbia

Contribution:

Honghong Li	Introduction part
Duola Jiang	Methodology part
Alan Lu	3 of the graphs(Figure 10, 11, 12) and ASSESSMENT(paragraph 9,10,11,12) of Summary part. (Specie dominance, Specie abundance, Total tree hight, and CLE)
Jessie Wen	12 of the graphs (table 3-5, figure 3-9, 13,14) and description (paragraph 5, 6, 7, 8, 13) of summary part (TTH & AVG of Crown Width; TTH Mean & DBH Mean)
Wenyao Li	Site description part(fig1); 2 of the graphs (table 1, 2. Species and quantity, Basal area) and the first 4 paragraphs of the summary part

Introduction

UBC as a developed community, over 20,000 trees are located on campus since 1925, which includes approximately 11,000 planted trees and 10,000 native trees. (The University of British Columbia, n.d.). These trees need efficient regulation to play different roles on campus. Tree inventory is a basic task for most communities in order to develop communities better and tree inventory that done in this class can help UBC the planning department to regulate better, which includes three main aspects. First, understanding the current living conditions of urban forests on the campus. Second, planning and managing urban forests in order to increase ecosystem services value. Third, reminding UBC planning department the importance of each tree on campus and making a better decision.

The living condition of urban forests may vary as time goes on so it is necessary to update tree information. Trees growth associated with many conditions, such as sunshine, precipitation, soil texture and soil structure (Robertson, Philip A. 1992). Variations of these factors will lead to different growths of trees, including getting diseases. A little variation will cause a big result on trees, which means people should always update tree information to make sure living conditions for every tree are well. People who take tree inventory would monitor current living conditions to determine whether trees are alive or dead, and then the updated data will be reported to the planning department. After the planning department gets all updated data of trees living condition, it can take some remedial measure for needed trees.

Trees are the main component which provides ecosystem services in UBC. Ecosystem services refer to benefits that people obtained from nature, which includes provisioning services, supporting services, regulating services and cultural services (Biodiversity Information System for Europe, n.d.). People's tradition views towards ecosystem services provided by trees are regulating services since trees purifying air and storing a high volume of carbon dioxide. However, trees have various functions can be utilized, except regulating services as long as people treat them in the right way. For example, there are lots of Oak trees on campus. Acorns are fruits of Oak trees and they become mature during October and November. Acorns are a king of nuts and they are food for squirrels on campus, which also can be eaten by humans after processing (Shea, Claudia, n.d.). Acorns are the representation of provisioning services because of their characteristics. However, if there's no tree inventory, oak trees' provisioning services will be ignored since nobody cares about oak trees' fruits and acorns' values will be underestimated. Thus, tree inventory can help to increase ecosystem services values so ecosystem efficiency can be improved.

Lastly, a good decision always made based on a well understanding. Tree inventory will collect the latest tree data which contain the most specific parts of trees, such as crown missing and DBH. These data will provide people with a 3-dimensional image of each tree. Urban forests comprise of individual trees and it is necessary to know the growing situation for every individual tree so they can form a well urban forest. Tree inventory gives a chance to the planning department to know each tree's situation so staffs can make a better decision according to different situations corresponding to different trees.

Site description

The site is located on Main mall street (shown in Fig.1. site location), from the main fountain to the flagpole. Main mall street, as the main street in UBC campus, is an important road to each college building. The type of land use is institutional, and the activities observed in this area are mainly the pedestrian traffic of students and teachers. The trees included in this area are mainly street trees on the main mall street, and some trees close to the buildings. The main facilities in this area are paving, there are benches on both sides of the pavement for pedestrians to rest on. From the main fountain to the Agricultural rd and Memorial rd to the flagpole, there are lawn green belts in the middle of the road and narrow hard pavement for pedestrians to pass through. In the middle of the two libraries, Walter C. Koerner and Irving K. Barber, the road widens and there are two rows of long benches. There is W. Robert Wyman Plaza at the intersection of main mall st and memorial rd. Citizens and researchers are the most common users in this area because this area is located on the UBC campus, students and professors are the main people who often operate in this area. As citizens, they will be greatly affected to improve their awareness of urban forests. Among them, there are many foresters, like us, who, as researchers, will make reasonable planning proposals for the region.

Fig. 1. Site location

Methodology

The area of study is the main campus of the University of British Columbia. The methodology section of the study describes the methods that were used to collect and analyze data on trees inside the school, to form the university's urban tree inventory. The campus was divided into 11 zones, and groups of five to six students were assigned to each one of those. We chose GPS mapping (using the Collector App) and observation as the appropriate methods of data collection because the study required students go to the area of research and spot, note locations, and take measurements of trees (Nielsen, Östberg, & Delshammar, 2014, p. 100).

The Use of GPS Mapping

The tool that was used in the collection of data through GPS mapping was the tree Collector App. GPS mapping was used to identify the species of trees, and to provide an accurate number and GPS location of all trees in the area of study (Nielsen et al., 2014). For instance, the Collector App was first used in the study to map out the boundaries of zones that each group of students was assigned. The restrictions of limits ensured that the groups did not stray into each other's zones, in their efforts to maximize the coverage of the whole area of study. Also, students were required to tag trees that did not have GPS identification numbers, to ease identification of the trees when they returned to the field.

Observation Method of Data Collection

Both the quantitative and qualitative methods of observation were used to collect data. The quantitative way of view is appropriate in situations where the information to be acquired from the object of study is definitive; that is, the data can be expressed in numbers that can be confirmed (Daniel, 2016, p. 94). An essential tool that was used in estimating the heights of the trees is the clinometer. Measurements of angles of trees at different slopes were taken using it, and then trigonometric calculations were used to estimate their heights. Through quantitative observation, researchers identified trees that were planted recently and were therefore unfit to become subjects of the study.

The qualitative method of data collection is useful where the data collected from the subject of the study is descriptive (Daniel, 2016, p. 92). The technique is also appropriate when the data that needs to be collected is broad and open-ended; that is when it can be analyzed from different perspectives. In the study, systematic sampling was used as a qualitative method of collecting data. For instance, one zone had 68 trees, and all of them could not be included in the study. Systematic sampling was used to identify trees that were ideal as samples. A sketch of the zone was drawn over 20*20-meter grid representation in the field-sheet. The most suitable tree-samples were isolated by excluding those that met the following criteria- if they were outside the zone, near the wall (10m), and on buildings. A total of 11 trees were chosen as samples in the identified zone. One disadvantage of systematic sampling is the decrease in the sampling pool, which can affect the overall precision of data (Elsayir, 2014, p. 115).

Measurement

Diameter at Breast Height (DBH)

When measuring tree stem diameter at breast height, use the diameter-tape to circle the trunk at a distance of 1.37 meters above the ground and record the DBH on the uphill side of the tree. There are special situations during measuring. If a tree has multiple stems at the height of 1.37 meters above the ground, measure the DBH of up to six largest stems separately and add them up to obtain the aggregated DBH. If a tree is found with irregularity at DBH, DBH is not measured at 1.37 meters above the ground (Fig. 2). This DBH measured is H DBH.

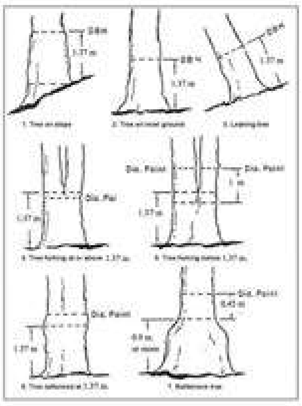


Fig. 2. Measuring DBH on irregular trees. 1.37 m = 4.5 ft; (Modified from U.S. Forest Service)

Total Tree Height

Total tree height is the length of the tree from the ground to its apex whether dead or alive. Live trees that were fallen were included in the measurements while dead trees that were on the ground were ignored. The clinometer is the instrument that was used to measure total tree height. First, measure the distance from the tree. Second, read the percent scale at the top and base of the tree. Third, sum the absolute value of the sighting to the top and bottom of the tree and multiply the total times the distance.

Crown Base

The crown base is the height from the ground to the base of the live crown. This height is primarily estimated according to students' height. When the base of the live crown is too high to determine, the method of measuring total tree height is used.

Crown Width

To measure crown width, students need to measure the width of the crown in the long side and the short side (perpendicular to each other).

Percent Crown Missing

Percent crown missing is the percentage of the tree that is not occupied by foliage and branches. It is estimated by two students. Each of them stands at perpendicular angles to the tree, visualizing the typical crown outline and estimating the percent that is absent.

Crown Light Exposure

Crown light exposure determines the number of sides that the tree is receiving light. The maximum sides should be five. The apex of the tree was considered as one side. The other sides were determined by splitting the section the tree was facing into four directions that were not obstructed by other objects.

Methods used to Analyze Data in Class

After measuring trees on campus, the data collected should be analyzed. First, draw a draft of the plot and estimate the sample cover. The result can be expressed in a pie chart. Furthermore, the analysis of species composition reflected in two aspects: species abundance and species dominance. Species abundance refers to the number of individuals per species. Creating a bar graph presenting the numbers of each tree species can help analyze species abundance. Species dominance shows how dominant species are by showing the basal area of each species. A tree basal area is the area of the cross section of a tree at DBH, and it is calculated as pi * DBH (cm^2) /40000. Another factor that should be included in the urban forest structure which is reflected in DBH classes and total height classes. DBH and total tree height can be divided into 5 to 6 classes based on the distribution of data. After that, estimate the mean by creating a scattergram and calculates the standard deviation by calculating the variance of the data around the mean of that dataset. Finally, create a summary table including trees, species, DBH mean, BA mean, total height mean, crown base means, crown width means, percent crown missing, and crown light exposure.

The List of Variables Measured in the Study

1.The species and genus of the tree `

2.The height of the tree

3.The thickness of the tree

Summary

We conducted a total of about eight hours (four times) of fieldwork on the selected area and completed the measurement of all the trees in the area. Because all of Abies grandis and Acer circinatum are recently planted, the soil is very loose and they are located on steep slopes. Considering the safety issues, we did not measure them, so we do not have any data about these two species.

species	trees
Acer palmatum	1
Calocedrus decurrens	1
Cercis canadensis 'Forest Pansy'	1
Cornus nuttallii	1
Crataegus laevigate	1
Liriodendron tulipifera	1
Stewartia Pseudo camellia	1
Abies grandis	2
Chamaecypairs pisifera squarossa	2
Chamecypairs obtusa	2
Cupressus nootkatensis	2
Llex aquifoliem	2
Pinus nigra	2
Thuja plicata	2
Acer circinatum	6
Prunus yedonensis 'Akebono'	7
Quercus rubra	49
17	83

Table. 1. Species and quantity

species	basal area
Abies grandis	no data
Acer circinatum	no data
Cercis canadenses 'Forest Pansy'	0.04
Chamecypairs obtusa	0.06
Cornus nuttallii	0.08
Crataegus laevigate	0.12
Stewartia Pseudo camellia	0.16
Prunus yedonensis 'Akebono'	0.19
Llex aquifoliem	0.22
Acer palmatum	0.31
Pinus nigra	0.74
Calocedrus decurrens	0.76
Liriodendron tulipifera	0.76
Chamaecypairs pisifera squarossa	0.77
Thuja plicata	2.48
Cupressus nootkatensis	3.87
Quercus rubra	20.79
17	31.35

Table. 2. Basal area

As shown in Table 1, there are 83 trees and 18 species in the selected area, mostly Quercus rubra (49 trees in total), which are planted on both sides of the Main mall street as street trees. Acer circinatum and Prunus yedonensis 'Akebono' are also relatively numerous, with 6 to 7 trees. The remaining 15 species are relatively rare in this area, with only 1 or 2 trees. According to Table 2, Quercus rubra has the largest basal area, which is also the largest number of trees in the area, and there is a big gap with other species. Cupressus nootkatensis and Thuja plicata ranked second and third in the basal area, but there were only two trees in both species. Indicating that the two species grew longer in this area, or they were better adapted to the environment in this area. The basal area of Liriodendron tulipifera ranks fourth with 0.76 m^2. This species has only one tree in this area, which means the tree is adapting and growing very well.

DBH (cm)	Trees	BA (m^2)
10-40 DBH	26	0.0448
40-80 DBH	23	0.252
80-120 DBH	22	0.7496
>120 DBH	4	1.9734

Table. 3. DBH classes

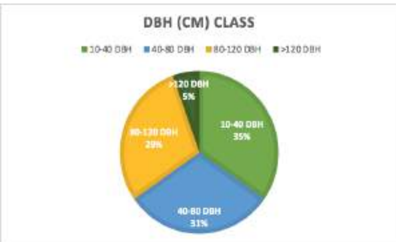


Fig. 3. DBH class (pie chart)

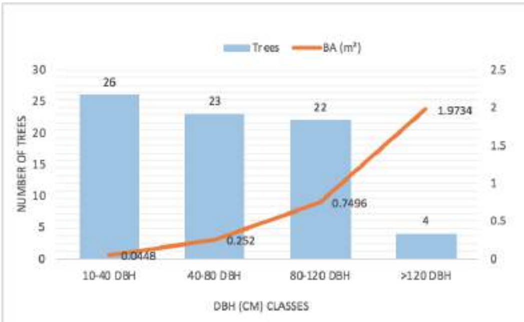


Fig. 4. DBH and BA

As can be seen from Table 3 and Fig. 3, the trees with DBH (Diameter at breast height) of 10-40cm are the most abundant, followed by 40-80 cm and 80-120 cm. There are only 4 trees whose DBH exceeds 120cm. Trees with DBH less than 40cm are mainly late planted trees. For example, there are some newly planted Quercus rubra on Main mall street to replace dead or diseased trees. The classification of DBH also shows that different species have different adaptability to the environment and different growth rate. According to Fig. 4, DBH classes are separated by 40 cm span. The larger the DBH, the larger the BA, but the fewer the trees. It is not difficult to conclude that DBH is proportional to the BA.

CROWN %MISS	TREES
no crwon miss	4
0-10%	22
10-20%	21
20-30%	5
30%-40%	14
40-50%	6
>50%	3

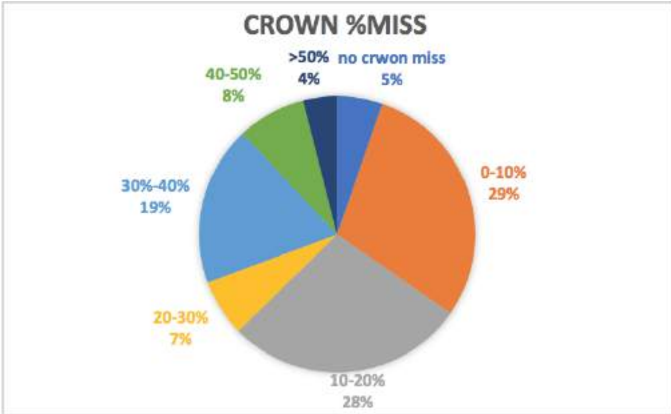


Table. 4. Crown miss

Fig. 5. Crown miss (pie chart)

As for the percentage of the crown miss, since it is winter now, most of the measured trees have fallen leaves, we can only judge the crown missing by observing the branches and trunks. According to Table 4 and Fig. 5, the number of trees with a crown miss of 0-20% is the largest, accounting for about 60% of all measured trees. The proportion of trees without a crown miss is 5%. And there are only less than 10% of trees have a crown missing more than 40%. It shows that trees on UBC campus, especially both sides of Main Mall street, are well managed and grow well.

Fig. 6. TTH & AVG of Crown Width

As it was found that from a variety of compared crown size characteristics, the crown radius, the maximum area of the crown and crown projection area were most closely related to individual tree growth. More importantly, we can conclude that the horizontal extension of a tree crown is often considered to be one of the most important drivers of tree growth (Seidel, Schall, Gille, & Ammer, 2015, p.735). Corresponding to our data, the average of the Crown Width is the most representative of the horizontal extension of the tree crown. And when we look at the Crown Width and the TTH (Total Tree Height) together, we can easily find that their downward or upward trend is almost the same. From this data, we can verify that when a tree has a larger canopy width, its tree height will be relatively high. Therefore, in the management of urban forestry, it is especially significant to give adequate space for crown growth if we want to obtain a tree with better growth.

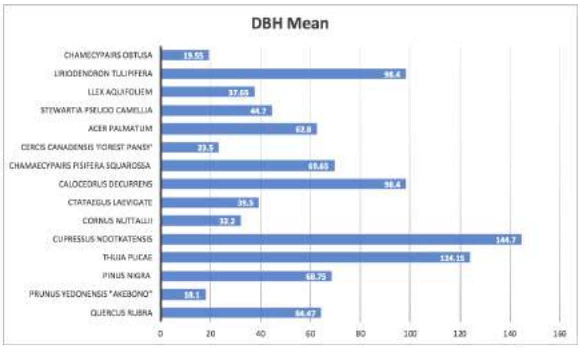


Fig. 7. DBH Mean

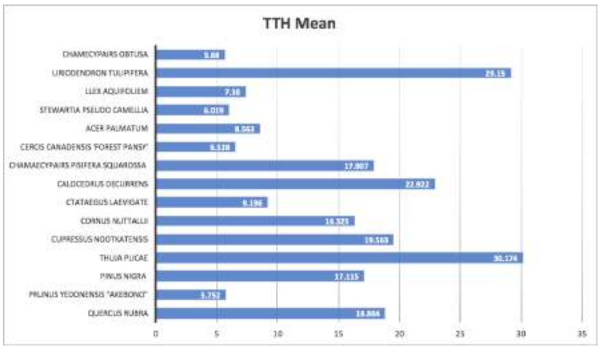


Fig. 8. TTH Mean

DBH and tree height are two important tree factors, and they are essential data in single timber volume calculation, stand growth and harvest estimation. Fig.7 and Fig.8 give us information about the mean of Total Tree Height(TTH) and DBH. As we can observe, the TTH of Thuja plicae species is the highest among all tree species we measured, and it also has a considerable magnitude in terms of the diameter of the breast (124.15cm). However, although the Cupressus nootkatensis has the largest DBH among 15 tree species, which is about 144.7cm. Its TTH is not as high as we expected, only 19.56 meters. Following the Thuja plicae, the TTH of Liriodendron tulipifera place the second (29.15m) and also have a relatively larger DBH about 98.4 cm. Besides, Chamecypairs obtusa and Prunus yedonensis “akebono” have almost the lowest tree height and DBH in both histograms.

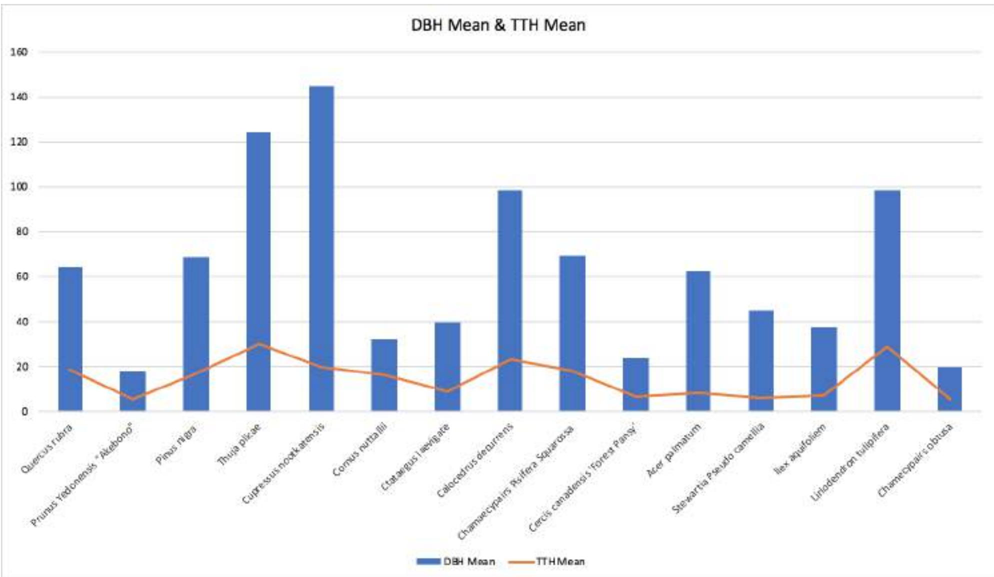


Fig. 9. DBH Mean & TTH Mean

The relationship between tree height (we use TTH to represent the tree height)and tree diameter at breast height (DBH) is an important element describing forest stands. The measurement of DBH is simple, convenient and accurate, while the measurement of tree height is relatively complex, difficult and not very accurate. For example, it can be hard to get a clear view of the treetop because of visual obstructions from neighboring trees or because of divergent crown forms.

We can see from the Fig.9. that two curves’ fluctuation trend is basically the same. But if we base on the change in the DBH of the tree species, in some cases the change in tree height is inconsistent with it. Such as Cupressus nootkatensis, when its DBH curve goes down, its tree height rises instead. In order to explore the reasons for this uncertainty, I realized that the H-DBH relationship varies between tree species and could be influenced by surrounding environments. For instance, understory tree species tend to have bigger trunks compared to canopy tree species at similar heights. The relationship also varies within the same species with different tree sizes, species compositions, stand ages and stand densities (Huang, Titus, & Wiens, 1992). And also, the height of trees is greatly affected by the site conditions even they have the same DBH. Furthermore, the tree height often reaches an upper limit asymptotically, while DBH of a tree increases at a more or less constant rate until the tree is lost to mortality (Friend, 1993).

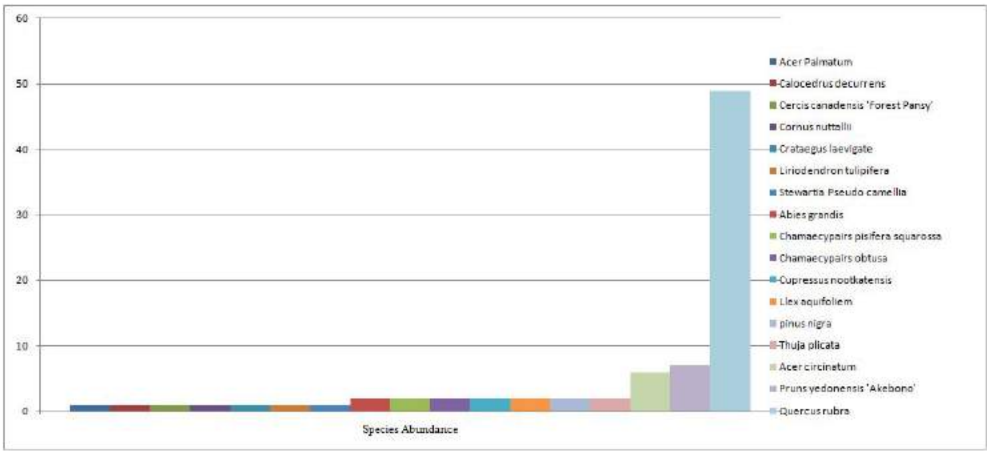


Fig. 10. Species Abundance

This is a bar chart that shows the amount of all 17 tree species that are found in the site of our group. As the chart show, the Quercus rubra (red oak) has the most quantity of 49 trees. Where the second greatest amount of trees, which is the Prunus yedonensis 'Akebono', have only 7 trees in total. After doing some research, we found that the University of British Columbia plant many red oaks at the main mall since red oaks are a symbol of timeless for the campus. Also, the red oaks are the representation of the history of UBC, that is why we have so many of them and maintain them very well (University of British Columbia, 2019). Furthermore, even though there are only 18 species discovered by our group in the North part of the main mall, UBC is holding more than 11,000 trees on campus. The reason of having less amount of trees other than red oak is that a lot of trees are dead or got the illness in the past 100 years, and the UBC tried their best to remove all the trees that might damage other tree species on campus (University of British Columbia, 2019).

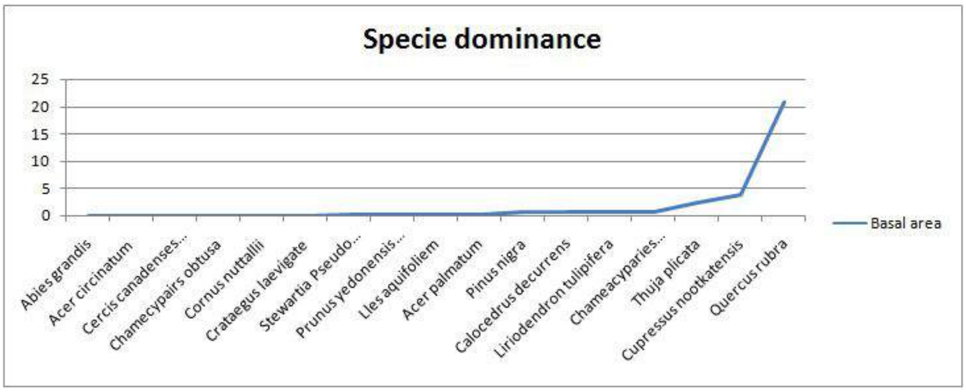


Fig.11. Specie dominance

This graph is showing the species dominance of the site our group was measured during the fieldwork week. As the figure shows, the most dominant species in our site is Quercus rubra. It has just over 20 cm of its basal area, and it is followed by Cupressus nootkatensis, which has a basal area of 3.87. On the other hand, the outer 16 species of trees we discovered on the site are very constant in the basal area, which is around 0-1. This graph shows that around the main mall of the University of British Columbia, Quercus rubra is very well adapted to the environment of the site. On campus, the oldest trees that had been planted since the 1920s are the Quercus rubra. Those trees own the most amount of trees at not only the main mall but also the whole university area (University of British Columbia, 2019). Since Quercus rubra is one of the oldest tree species on the UBC campus, it is not surprising that this species own the greatest basal area. Furthermore, Quercus rubra is very well-adapted to Vancouver's climate, which is dry summer and moist winter. The temperature of the Vancouver area is also a great reason of why Quercus rubra grows very well on the site. The winter is not extremely cold, and the summer is not very hot like other provinces of Canada since we are on the coast and close to the Rocky Mountains. In the future, the growth of the red oaks is going to be constant just like the past years until they reach their maximum height limit.

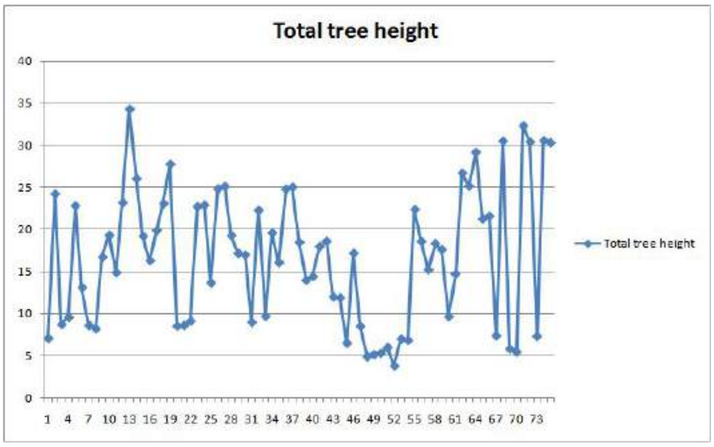
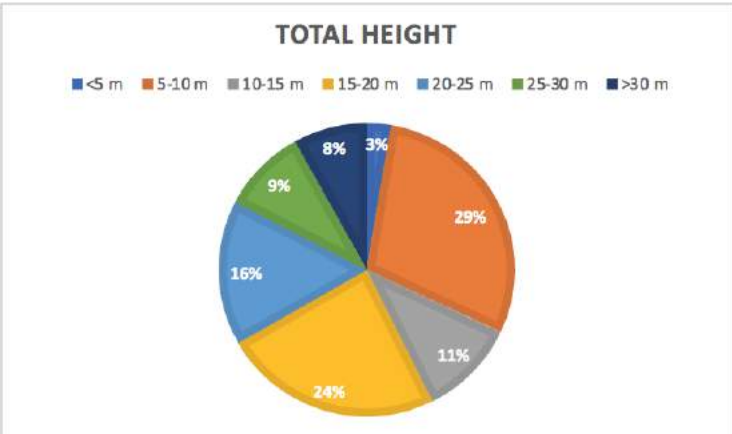


Fig.12. Total tree height



Total Height	Trees
<5 m	2
5-10 m	22
10-15 m	8
15-20 m	18
20-25 m	12
25-30 m	7
>30 m	6

Fig.13. Total tree height(pie chart)

Table.5. Total tree height

The graphs (Fig.12, Fig. 13 and Table. 5) above show the total tree heights of all of the trees we had measured in our group site. However, some of the trees that were too hard to reach and got the data from them. As a result, we counted 75 trees' total tree height out of 83. In the 75 trees that we measured, the tallest trees, which is a Quercus rubra, has just below 35 meters. The smallest tree, which is a Prunus Yedonensis 'Akebono', has just over 3 meters. Since the trees on campus are not all planted at the same time, some of the trees could be very young, and some of the other trees like red oaks could be fairly old. The result would appear great differences in the total tree heights of each trees. As we are trying to provide a clear scale of the data we collected from the total tree heights of those trees, we also created a table and a pie chart for showing the number of trees that are in different tree height categories. We can see the categories of 5-10 meters and 15-20 meters own the most population of trees in the research site. It shows most of the trees in the North part of Main Mall street are fairly young.

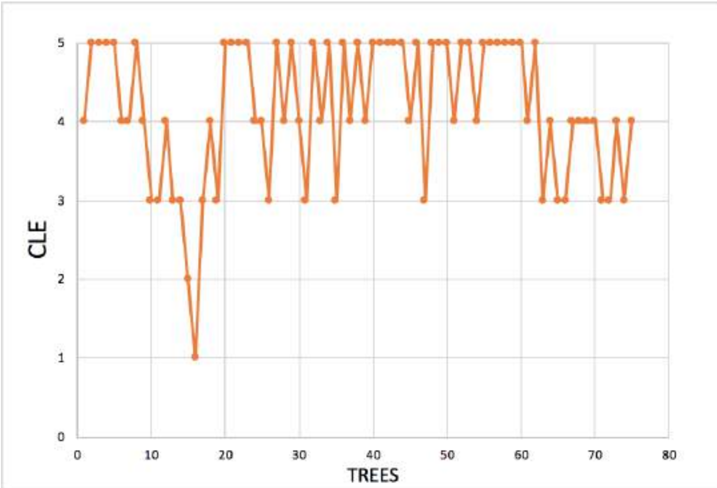


Fig.14. CLE

The chart above is showing the CLE of the trees that our group measured. It is very clear that most of the trees at the Northern Main Mall are fairly open to the environment. The 4 and 5 own the majority of the trees we measured. This result well-explained why those trees are usually tall and have a large crown area. The ones that own less than 3 CLE are mostly planted very close to each other, and they usually do not have large crown areas as the ones that have 4-5 CLE.

Picture 1

Picture 2

Picture 3

During our fieldwork, we also found some special trees. The tree in Picture 1&2, for example, is the only tree with full red fruits (maybe edible) that we consider to be the most beautiful tree. And the tree in Picture 3 is the only one with more than six branches. Most of the trees in our area have no moss on the trunk. Perhaps they are in a good location, and as street trees, they have good appearances.

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UFOR 101

Assignment 2

Lynne Kim, Angus Kwan, William Li, Dun Si, Daniella Zhang, Julie Zhang

April 3, 2019

Ecosystem Service Assessment of Urban Trees on Central Main Mall, UBC Vancouver
Group 10

Contributions of Group Members by Percentage

Group Members	Contribution by Percentage (%)
William Li	16.67
Angus Kwan	16.67
Lynne Kim	16.67
Dun Si	16.67
Daniella Zhang	16.67
Julie Zhang	16.67

Specific Contributions

Lynne Kim wrote the site description, diversity/species richness, wilderness/nature, aesthetics part of the cultural ecosystem service interpretation, and wrote the recommendation about the low shrubs and flower beds. She contributed to formatting and editing the report while reading through everyone's work, and assisting group members with any task when needed.

Angus Kwan went over the results given in the i-Tree Eco report for the regulating ecosystem services as well as editing and formatting. He also suggested leaving behind tree stumps for usage by campus members.

William Li wrote the methods used and reasoning behind methods used to assess regulating ecosystem, as well as the recommendation for staggered tree replacement. He also managed and processed the data that was processed through i-Tree Eco.

Dun Si wrote a part of regulating ecosystem services section by analyzing the results of i-Tree canopy and i-Tree Eco to determine the different ecosystem services the plants provide. He also takes charge of one recommendation of "giving a name for each single red oak tree".

Daniella Zhang wrote the introduction, analysis of cultural value mapping data, discussed cultural significance and social cohesion, as well as the recommendation of bike lane implementation. She also assisted in the general formatting and editing of this document to ensure uniformity and cohesiveness.

Julie Zhang wrote the methods for assessing cultural, regulating services and recommendation, which includes value mapping, i-Tree Eco, i-Tree Canopy and SWOT analysis. She also wrote the "effective use of fallen leaves" in the recommendation section. She contributes to the editing by providing many useful suggestions.

Introduction

Photo by Krista Jahnke

At first glance, it is easy to understand how The University of British Columbia (UBC) has gained its scenic reputation. Located at the western tip of Vancouver's Point Grey Peninsula, it is part of the Coastal Western Hemlock Biogeoclimatic Zone. The university was established on the traditional, ancestral and unceded territory of the Musqueam people. Currently, there are approximately 11,000 planted trees and 10,000 native residual trees on campus (The University of British Columbia, n.d.).

The purpose of this ecosystem services assessment is to inform stakeholders and policy makers of current urban forest conditions, which will help guide future planning decisions to manage these urban forests in such a way that will maximize ecosystem services. This report begins with an overview of zone 10, followed by data interpretation of the regulating and cultural ecosystem services, and lastly, recommendations for site improvement based on a SWOT analysis.

In this assessment, data interpretation focuses on the regulating and cultural ecosystem services provided. Different methods were used to assess each category of ecosystem services since they require different sets of variables. In general, regulating services, which are the short term "benefits from ecological processes", are more commonly assessed since they easier to quantify compared to cultural services (Ferrini et al., 2017). By measuring tree structure, researchers are able to quantify an urban forest's impact on air pollution, micro-climate, carbon sequestration, and storm water runoff (Kirnbauer et al., 2013, as cited in Ferrini et al., 2017). On the other hand, fewer existing studies have quantified cultural ecosystem services, which are the "non-material benefits from ecological processes", such as recreation and aesthetic services (Hasse et al., as cited in Ferrini et al., 2017). This is due to the subjective nature of many cultural service dimensions, as well as the fact that many dimensions are poorly defined. Since all categories of ecosystem services are heavily integrated with one another, management decisions must consider possible ecosystem service tradeoffs. For example, adding a corridor in the middle of an urban forest can increase the feeling of wilderness for visitors, however, it can decrease wildlife biodiversity through habitat fragmentation.

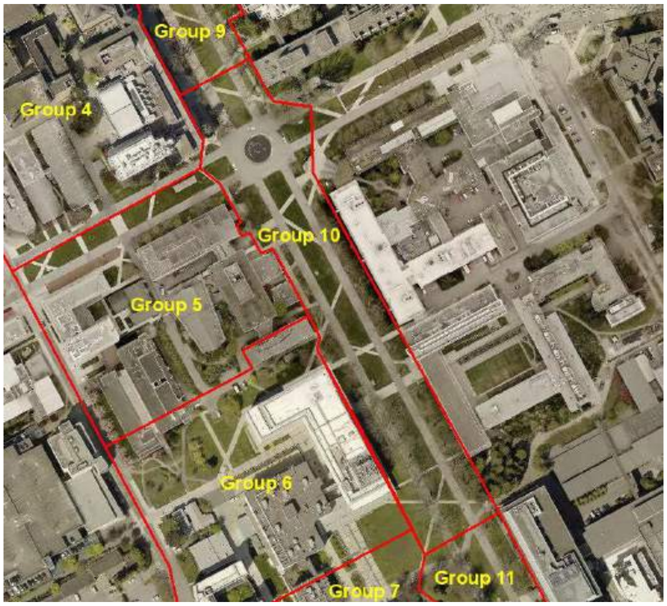
The desired outcomes from this assessment differ between stakeholders. Overall, key themes involve biodiversity preservation, climate change mitigation, risk assessment, and tree loss prevention (SEEDS, 2019). Firstly, planning analyst Emma Luker at the department of Campus and Community Planning elaborated on gaps in policy regarding managing the campus's natural resources, as well as gaps in whole-system approaches to consider the broader ecological, cultural and social value of assets (Luker, 2019). As a result, the findings of this assessment will be considered by multiple departments including building operations, planning and design, as well as sustainability and engineering (Luker, 2019).

Another stakeholder perspective stems from horticulturist Egan Davis, who is concerned with tree identification to prevent loss of heritage trees with intrinsic value that cannot be replaced. Davis is familiar with many special and exotic trees on campus and wishes to gather an updated species identification information along with other variables in order to prevent losses. This is because heritage trees provide significant regulating ecosystem services as well as cultural significance.

Currently, the urban forest governance structure at UBC Vancouver is shared between two departments, Campus and Community Planning and Building Operations. Generally, Campus and Community Planning is responsible for landscape planning and permits. On the other hand, building operations focus on maintenance, such as pruning and removal of trees (Lompart and Ikeda, 2017). One of the weaknesses of having a duo-department governance system involves conflicts of interests which can slow down implementation of new strategies. Therefore, a comprehensive ecosystem services assessment can prioritize highly valued regulating and cultural ecosystem services, which will in turn better define the roles of each department.

Ultimately, group 10 is optimistic that this report will benefit all users of the urban forest at UBC Vancouver, whether it be sheltering from the rain while running between classes or having lunch under shade trees on sunny days. It is found that green space is intrinsic to the total material fabric of university campuses and vital in setting the atmosphere for what a campus represents (Speake, 2013). Therefore, it is important that the outcomes of this assessment report prioritize the needs of the greater UBC community, placing more recognition and value towards the campus' irreplaceable natural assets.

Site Description



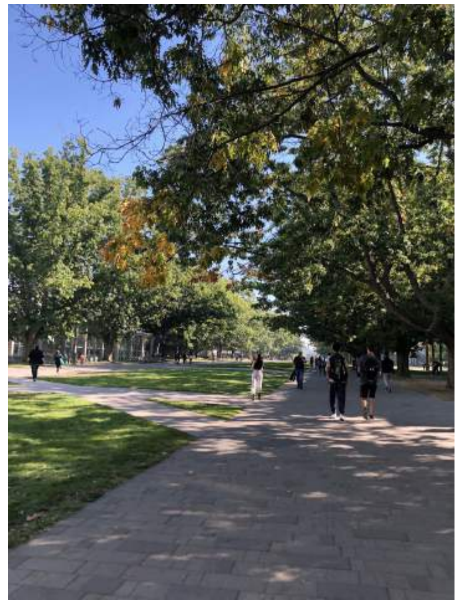


Figure 1: Devisscher, T. (2019). Retrieved from Powerpoint Slides via Canvas.
Figure 2: Kim, L. (2018). Main Mall in the late summer of 2018.

Main Mall is perhaps UBC's most recognizable urban forest. Our group measured the iconic red oak trees alongside pedestrian pathways from the Henry Angus building to the Earth Science building, including a small patch of cedar trees beside the Beaty Biodiversity Museum. The earliest red oaks on Main Mall were plants in the 1920s (The University of British Columbia, n.d.-a). For decades, the trees provide many ecosystem services to the users of the site. However, as the trees age, the university carefully monitors and prunes the red oaks to ensure the tree's longevity to "maintain the hallmarks of the original campus master plan" (The University of British Columbia, n.d.-a). Unfortunately, some oak trees were removed due to the natural decline of its life after the reconstruction of Main Mall, transforming the road to a pedestrian-only pathway (The University of British Columbia, n.d.-b). Main Mall experiences heavy pedestrian traffic daily from students, staff, faculty, dog walkers, and residents of UBC. The user activities include walking, biking, rollerblading, dog walking, recreational uses, and more, however, the primary use of the pedestrian pathway is for transportation from one end of the campus to the other. There are a variety of different land types such as grassy areas and cement pathways. Therefore, there are only a few young red oak trees taking its vacant place on our site. Furthermore, there is a lack of different facilities within our observed area, but there are a lot of different buildings used for lecture rooms, study rooms, and a large museum. Additionally, inside many of the buildings on our site like the Fred Kaiser, Earth Science, and Henry Angus building, there are small cafes where students use for dining and studying purposes.

Regulating Ecosystem Services

i-Tree Eco and i-Tree Canopy in Evaluation

The i-Tree Eco and i-Tree Canopy tools were used in analyzing our inventory data. After collecting data from our fieldwork and accessing information such as land type and tree species from the "Collector" app, we first imported our data to the i-Tree Eco tool. The hourly weather conditions and air-pollution levels are pre-programed into i-Tree Eco based on applicable data from Vancouver. This is for preparation of the following proceeding of local structural and functional information. We then selected the data collection fields under the tree information tab based on variables measured in the field. The i-Tree Eco will automatically generate forecasted regulating services on a monetary scale. The i-Tree Eco report covers a variety of regulating services includes hydrology effect (avoided water run-off), pollution removal, carbon storage, carbon sequestration and more.

We also use the i-Tree Canopy tool as a supplementary tool of our analysis. We first defined the boundaries of our zone on the map, and then we rejected pin points that fall on the boundaries and then selected pin points that we would like to focus on from all the spots identified by the i-Tree Canopy. It will produce statistical estimations of land cover types of predefined areas. The i-Tree Canopy tool uses aerial images from the Google Maps interface. The range of its estimation includes percentage canopy cover, impervious materials and benefits such as predicted pollutant removal etc.

Comparing the i-Tree Eco and i-Tree Canopy tool, i-Tree Eco tool has a high requirement of data quality. For instance, to achieve the highest accuracy, the data collection is highly suggested to be done in leaf-on season. However our data was collected in February 2019, which means there would be more errors occur especially for those measurements about canopy and crowns. The i-Tree Canopy use aerial imagery to detect the target area. Thus, the resolution of aerial imagery becomes critical. For complex projects, geographic information system (GIS) may be needed (Hotte et al., 2015).

Method for Measuring Regulating Ecosystem Services

Our group utilized four tools to assess the regulating ecosystem services provided by the trees on our plot. These include the usage of eslon tape, diameter tape, a clinometer, chalk, and visual assessment.

List of instruments used in the fieldwork

Instrument name	Usage
Clinometer	Measure total and live tree height (top, base) together with Eslon tape
Eslon tape	Measure distance and the crown width (longest and shortest sides)
Diameter tape	Measure diameter at breast height (DBH)
Chalk	Keep track of the trees we have measured
Visual assessment	Determining percent crown missing and crown light exposure

List of variables measured or estimated in the fieldwork

Variables	
1. Total tree height	
Elevation percentage Depression percentage Distance	
2. Diameter at breast height (DBH)	
3. Crown base height	
Elevation percentage Depression percentage Distance	Distance between crown base and the ground
4. Crown width	
5. Percentage crown missing	
6. Crown light exposure	

Explanation of Chosen Methods

In order to estimate tree height, we used an eslon tape to measure the distance between the observer and the tree itself. Its long length and convenient usage made it an excellent tool used in combination with clinometer measurements. The clinometer was also essential in measuring tree height, as it was virtually impossible to measure the height of any tree on our plot with only the eslon tape. While there were trees that were short enough to manually in other plots, all of our trees were mature trees that were out of the range of our group members, without the help of an aerial work platform to reach the top. Alternative tools include laser rangefinders that could automatically calculate both distance and clinometer measurements, but such technology was not available during our assignment.

For measuring tree trunk diameter, using diameter tape to obtain measurements was the best choice in this case because there were no trees on our plot that had fallen over and would consequently require the use of a tree calliper. Despite playing a small role, chalk was instrumental in assisting our group in organizing our inventory into the trees that we already measured and the ones we had yet to measure. Using visual assessments to determine the amount of light exposure and percentage crown missing was appropriate because we were asked to find the number of sides of the tree exposed to sunlight, as well as the estimated percentage of crown missing, both of which are best done with visual assessments. However, the estimation of crown missing was especially difficult for deciduous trees because these measurements were performed during a time where the trees did not have any leaves, so only a rough estimation obtained by looking at the locations of branches and guessing if there would be leaves there was possible.

Outline of Assessed Regulating Ecosystem Services

In total, there were four regulating ecosystem services that were measured of the trees on our plot. These include:

- Temperature and local climate regulation
- Air quality regulation
- Carbon sequestration and storage
- Runoff management and reduction

Significance of Assessed Regulating Ecosystem Services

The result of i-Tree Canopy indicates that 42.3% of area is covered by tree canopy, different types of air pollution (i.e. NO_2, O_3, PM2.5, SO_2, and PM10) are reduced by trees (3.63kg, 36.13kg, 1.76kg, 2.29kg, 12.1kg respectively in every year), and a large amount of CO_2 can be sequestered and stored (Table 1).

Two main regulating services can be determined by analyzing the results of i-Tree Canopy. First, this area contributes to regulate temperature and local climate. Because this area has a high canopy cover, trees are able to provide shade for various surfaces (i.e. pathways, buildings, etc.); the cooling effect of boulevard or single street trees is distinct. Trees contribute to increases humidity by evapotranspiration, reduce energy consumption through decreasing air conditioning demand, and reduce wind speed. The majority of the trees on our site are deciduous trees, therefore these trees help save energy by providing shade in summer time without blocking sunlight in winter time. Moreover, because of the high canopy cover, this area has the capacity to reduce urban heat island effect and buffer the effects of climate change at UBC. In addition, a large amount of CO_2 is absorbed by the trees regulating the local climate. Secondly, the trees have large leaf areas, which have the ability to absorb gaseous pollutants (e.g. O_3) and remove particulate (e.g. PM2.5) regulating the air quality. The large leaves and surface roughness also helps the removal of harmful particulates.

From the results of i-Tree Eco report, there are three main regulating ecosystem services that are presented:air quality regulation, carbon sequestration and storage, and stormwater management. Graph 1 illustrates the air pollutants removed by the plants in the zone. As seen on the graph, ozone is the largest removed pollutant, followed by particulate matter (less than 2.5 microns). A total of 25.78 kilograms of pollutants was removed per year in the site, equaling to the weight of an average male bulldog. The plants along main mall provide air quality regulation services for people because poor air quality is a serious problem in urban areas that affect human health and damage to the landscape. Therefore, the ecosystem services of air quality regulation is important for urban areas. Additionally, a great amount of pollutants such as O_3 and PM2.5 can be removed by the plants.

The third graph explains the carbon sequestered by each species (Graph 2). The northern red oaks sequesters the largest amount of carbon due to their dominance on site. A total of 1.983 metric tons of carbon is sequestered annually, which equals the carbon emissions from 840 liters

of gas used by automobiles. Compared to i-Tree canopy, the result of CO_2 sequestration in i-Tree Eco is lower than that of i-Tree Canopy.
The fourth graph displays the amount of carbon stored in each species (Graph 3). Northern red oaks stores the largest amount of carbon, as the numbers of this tree species on the site vastly outnumber the other species by a wide margin. 92.9 metric tons of carbon are stored in the biomass of the plant annually, which is roughly the amount of carbon emitted from 21 people living in Vancouver. The result of carbon storage is also lower in i-Tree Eco than that in i-Tree Canopy (with a number of 92.9, 185.5 respectively).

The table (Table 2) shows the amount of oxygen produced by each species. Similar to the other graphs, northern red oaks dominates the category, producing over 89% of the area's oxygen. In total, the area produces an estimate of 5.287 metric tons of oxygen, just over half the amount of oxygen an average human uses per year. The number of trees in the zone is also displayed, and it is clear that northern red oaks is the most dominant species.

Lastly, avoided runoff is calculated and presented in graph 4. Corresponding with the previous models, northern red oaks provides the largest amount of avoided runoff. The removed runoff amount can fill roughly 415 standard bathtubs. Douglas fir comes in second, which contrasts with other models as American elm usually follows northern red oak trees. The plants along Main Mall provide the ecosystem services of runoff management and reduction. Trees have the ability to intercept rainfall by leaves, twigs, and branches and increase soil infiltration. The plants help to increase infiltrate surface water, absorb a great amount of water, and remove them by transpiration.

Overall, these models show some similarities in air pollution regulation, carbon sequestration and storage but the results of i-Tree canopy are typically higher than that of i-Tree Eco. i-Tree canopy can help to determine canopy cover for a given area while i-Tree Eco can determine ecosystem services in depth (e.g. runoff regulation). Northern red oaks dominates the area with 42 individuals, which increases the effect of regulating ecosystem services it provides.

Cultural Ecosystem Services

Value Mapping Method

Among the four categories of ecosystem services, cultural service is the most subjective and abstract, so we adopted the value mapping method to evaluate cultural ecosystem services through a brainstorming activity. Value mapping is a survey-like questionnaire where the broad pool cultural services was divided into five dimensions:

Dimension	Definition	Example(s) on Site
Cultural Significance	Historical content and cultural values	Heritage trees (Red Oaks)

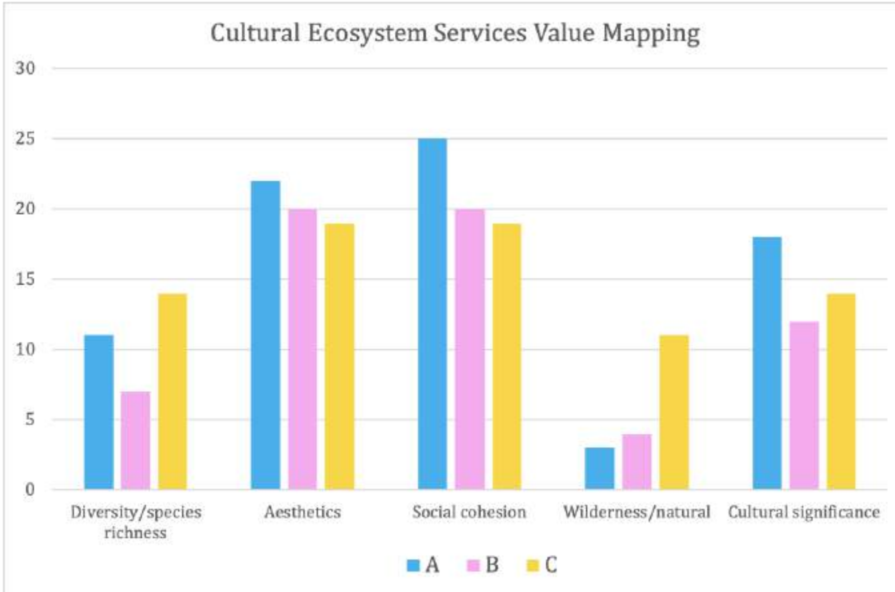
Social Cohesion	Degree of socialization and sense of community	Martha Piper Plaza fountain Benches
Diversity/species richness	Variability of flora and fauna	Black and Grey squirrels
Wilderness/nature	Sense of enclosure, feeling of being in a natural setting	Patch of forest next to the Beaty Biodiversity Museum
Aesthetics	Satisfaction obtained from visually pleasing sceneries	Uniformity of the monoculture plantation

Our zone was divided into three sub-zones for a more accurate and specific valuation. Our group assessed how strongly we felt about each category by individually rating them on a scale from zero to five. In the end, we finalized the evaluations by taking an average of our individual ratings. We then highlighted the different hotspots of five cultural ecosystem services on the cultural value map.

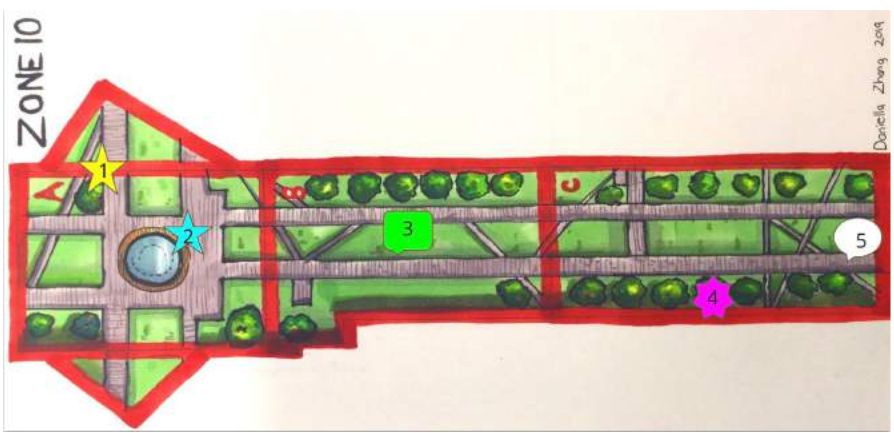
Strengths and Weaknesses

Value mapping through assessing individual perceptions of the surrounding environment has its strengths and weaknesses. One strength is the ability to enhance user connectivity with their surrounding atmosphere. This will inspire daily users to value and appreciate the urban trees, from aesthetics to shade-cooling. The chosen dimensions are easily quantified by personal judgement and does not require special tools or equipment. In other words, it is easy for individuals to describe the experiences derived from an urban forest. Ultimately, value mapping urban forests can recognize and prioritize certain cultural experience dimensions that may be otherwise ignored in decision making process. On the other hand, a major weakness of this value mapping approach is the fact that individual perceptions vary as our opinions are influenced by external social and cultural context, such as differences in lifestyle, personal experiences, and activities. As a result, priorities often differ between stakeholders.

Interpretation of Value Mapping Results



The graph above illustrates the average scores for each cultural service dimension labeled on the x axis. Overall, social cohesion is ranked the highest while the feeling of wilderness is ranked the lowest. This illustrates this zone to be a place having a strong sense of community and socialisation due to the location and surrounding landmarks. On the other hand, this area lacks the feelings of enclosure and escape that dense urban forests are able to foster. Ultimately, there is a cultural service trade-off between pedestrian accessibility and the feeling of nature. In the next section of our report each cultural dimension will be discussed in detail.



This marker rendering image is labeled with different colours and symbols, and numbers to showcase areas within this zone that best represent each of the five cultural dimensions.

1. Cultural Significance

Cultural significance is ranked high in this zone due to the historical context associated with this urban forest, located at the university's most prominent academic core. The aging northern red oaks on either side of main mall are heritage trees which are mostly planted in the 1920s. Their broad canopies offer a sense of "timeless dignity" to the campus, representing decades of history as the last standing hallmarks of the original campus master plan. These trees are currently being monitored for pruning and removal to ensure the safety of its users. Due to their significance, removal notices are publicly acknowledged through the campus planning department website (The University of British Columbia, n.d.). These trees are given special attention in order to preserve them for as long as possible, since they are highly valued by the UBC community.. Additionally, many visitors can sense the significance of these towering red oaks as they are unlike other urban trees on campus, as they play an important role in setting the university's atmosphere.

2. Social Cohesion

Photo by: The University of British Columbia

Social cohesion is valued the highest out of the five dimensions based on our valuation. This is because this urban forest is located in central campus which experiences high volumes of pedestrian and bike traffic. Hundreds upon thousands of students pass by daily, causing the zone to be lively and full of chatter. There are many benches on either sides of main mall under tree canopies, which increases the likelihood of students to socialize and escape the fast-paced traffic flow. On sunny days, people use the long grassy strip for sports as well as resting. Although, the most important landmark is the central fountain, which is a popular meeting spot on campus that is designed to be an inviting place to meet up with friends or enjoy a cup of coffee. Overall, urban trees along Main Mall play a crucial role in shaping how people interact and socialise with one another.

3. Diversity/Species Richness

Unfortunately, diversity/species richness is ranked low from our value mapping exercise. This is due to the monoculture of red oak trees on our site. Out of the 54 trees we measured, 42 of them are northern red oak trees (Quercus rubra) which is approximately 78% of all the trees in our site. The dominating Quercus rubras species provide high species density, but low in terms of species diversity. There are seven tree species in our zone and only 12 of the trees make up the other six species. The main issue with low tree species diversity is reduced resilience to disturbances such as climate change, pests, and diseases (C. Dobbs, M. J. Martinez-Harms and D. Kendal, 2017, p. 60). Potentially, if a disease were to infect the Quercus rubra trees, then only 12 of the trees in our zone would remain healthy. In contrast, one benefit of species diversity is that it provides ecosystem services to wildlife in the form of habitats and food sources. A greater diversity of tree species can potentially provide more nesting areas for birds, and more food sources other animals on campus. Although the prominent, mature, red oaks define UBC's urban forest, increasing species richness is essential to increase the resilience of the urban forest from specific threats and/or diseases.

4. Wilderness/nature

Wilderness is ranked as the lowest dimension in our site due to little feelings of wilderness "escape" provided to its users. The trees along both sides of Main Mall feel planted and artificial as they are uniform in structure and are organized in a straight line on each side. The only area in our site that is considered wild or natural would be the small forested area beside the Beaty Biodiversity Museum as it is less organized, and resembles coniferous forests in Vancouver like Pacific Spirit Park. Although the mature red oak trees provide ecosystem services like shade for pedestrians or rainwater interception to reduce stormwater runoff, having a wilderness spot on campus may provide a variety of benefits. For example, people can take a walk in the area to clear their minds, and small animals like squirrels may be able to find food or create habitats in the forest area. Therefore, increasing feelings of wilderness/nature is beneficial for UBC's urban forest because it would also increase species richness and potentially improve students' mental health as they can destress in a place that can seem like an escape from their busy, chaotic lives.

5. Aesthetics

Aesthetics is ranked as one of the highest cultural ecosystem services in our group. Trees add aesthetic value to their surrounds by adding vibrant colour to an area. With the middle area of Main Mall being vacant of trees, the view of the flagpole and mountains on the northern end and the view of the Reconciliation Pole on the southern end of campus is visible to users of the site. The uniform structure and size are key elements that enhances aesthetics throughout our entire site. The trees being similar in shape and age, also contributes to the aesthetic values of Main Mall. During autumn, the monoculture of red oak trees have similar amounts of foliage on each tree and the leaves simultaneously change colours to showcase the beauty of the west coast. However, during the winter and early spring, when all the foliage is gone, and the grasses turn yellow, Main Mall appears dull and lacking in liveliness. Ergo, perhaps planting low shrubs and small flower beds would increase the aesthetics during the winter and early spring.

Recommendations

To make our recommendations insightful and feasible, our group used the SWOT analysis technique, which is the abbreviation of "strengths, weaknesses, opportunities and threats" to help our group interpret "where are we now" and "where do we want to go". Based on the weaknesses we addressed in the SWOT analysis, our group discussed several possible improvements for our zone.

- Since zone 10 is a heavy traffic zone, the implementation of bike lanes can ease traffic flow during peak hours and increase the overall safety of this zone through reducing bike related accidents. Our group strongly believes that one of the reasons that discourage individuals from riding bikes is safety, therefore, implementing bike lanes would encourage more students to use their personal bikes or shared bike systems such as DropBike.

- In order to maintain aesthetic benefits of the trees planted on Main Mall, a staggered tree replacement plan should be created to manage the removal of mature/dying/dead trees. This involves planting saplings between each tree requiring replacement on Main Mall so that it does not seem as empty when the time comes to replace the older trees. It will also ensure that the new trees will grow in a similar pattern to what was present previously. This process can be repeated each time the trees need to be replaced.

- Another recommendation that could be implemented is the planting of low shrubs and flower beds in the grassy regions in the middle of Main Mall. This would help increase biodiversity in our site since it creates more habitats for small animals like squirrels. Also, the flowers could add more colour to Main Mall during the early spring time when the red oaks have not grown back their leaves yet. Therefore, this would increase the biodiversity and overall aesthetics of Main Mall.

- Increasing the sense of identity for each red oak tree is helpful to increase their value. For example, giving a specific name (i.e. someone's name or event) in order to commemorate a person/event is applicable to increase the meaning of red oak trees. People are likely to protect and maintain them due to the "stories" they have. Because these red oak trees all have large sizes, they are more valuable than young trees, so it is better to endure the health of our mature trees rather than replace them. Thus, it is a good idea to give a special meaning for each red oak tree in our site.

- Our group also recommend that the UBC campus maintenance team could effectively use the fallen leaves by allocating the excess fallen leaves to needed places. Since the majority of trees along Mail Mall are deciduous trees, there is a significant amount of fallen leaves in autumn. The amount of litter trees produced exceeds a soil's ability to decompose, so most of the litter is wasted. Moreover, the leaves may be blown to the pathways. As a result, allocating the litter to other places not only can increase soil organic content, but it also improves the soil quality and tree health, and it allows the footpaths of Main Mall to be safer for pedestrians.

- As the larger red oak trees are removed, leaving behind the stump to create a natural bench can increase social cohesion by allowing pedestrians to rest, mingle, or even use as a makeshift table. With multiple mature red oaks along main mall, there are many opportunities for these modifications. Having a natural multi-purpose structure can draw people away from the main pathway and allow the grassy areas on the side to be utilized for social interactions and/or a place of rest.

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Appendices

Table 1: i-Tree canopy results

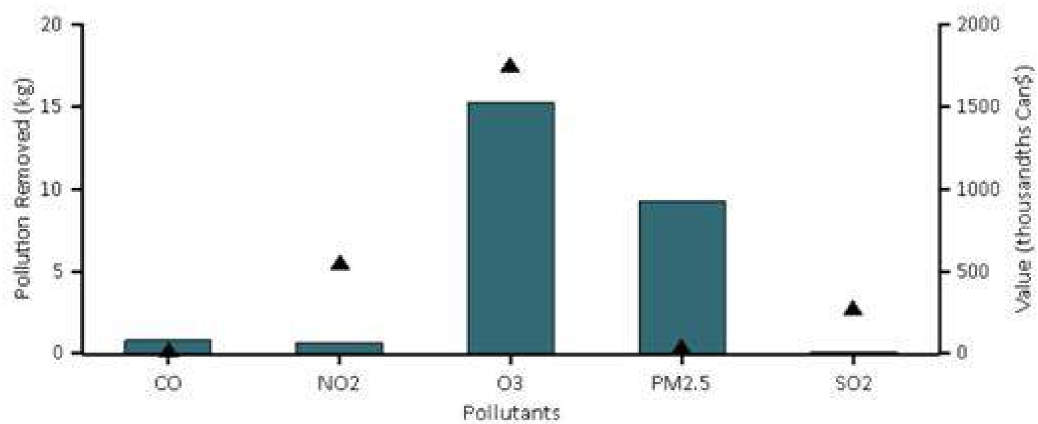
Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	22	42.3 ±6.85
Non-Tree	All other surfaces	NT	30	57.7 ±6.85

Tree Benefit Estimates

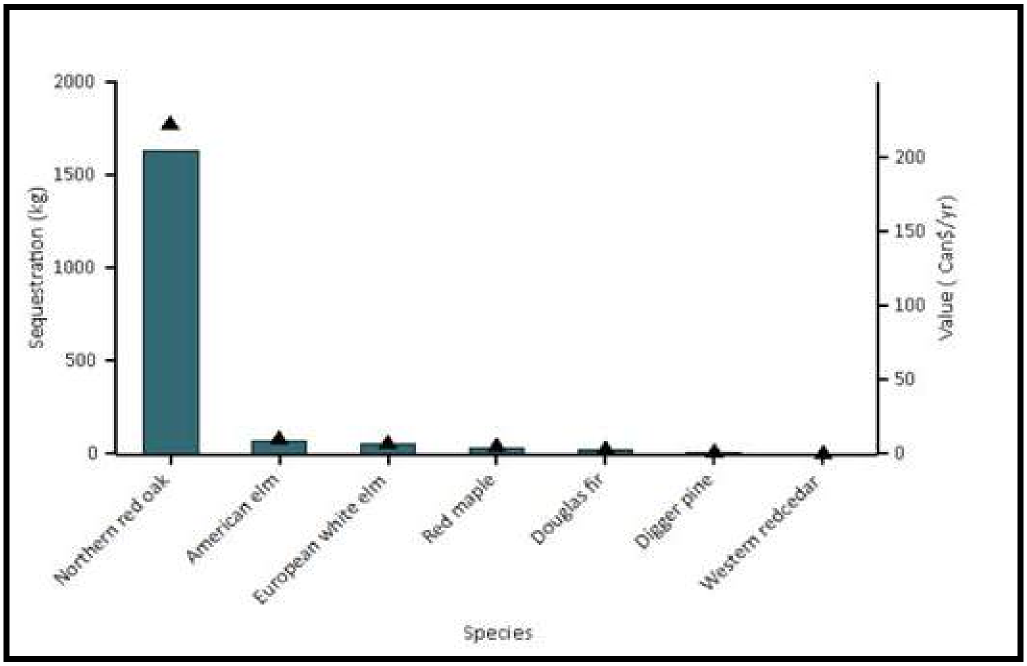
Abbr.	Benefit Description	Value (CAD)	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.08 CAD	±0.01	0.00 t	±0.00
NO2	Nitrogen Dioxide removed annually	0.14 CAD	±0.02	3.63 kg	±0.59
O3	Ozone removed annually	7.45 CAD	±1.21	36.13 kg	±5.85
PM2.5	Particulate Matter less than 2.5 microns removed annually	15.40 CAD	±2.49	1.76 kg	±0.28
SO2	Sulfur Dioxide removed annually	0.03 CAD	±0.00	2.29 kg	±0.37
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	5.41 CAD	±0.88	12.10 kg	±1.96
CO2seq	Carbon Dioxide squestered annually in trees	504.36 CAD	±81.67	7.39 t	±1.20
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	12,666.25 CAD	±2,051.14	185.50 t	±30.04

i-Tree Canopy Annual Tree Benefit Estimates based on these values in g/m²/yr and CAD/yr: CO 0.101 @ 124.90 CAD | NO2 0.551 @ 39.44 CAD | O3 5.489 @ 206.21 CAD | PM2.5 0.267 @ 8,772.63 CAD | SO2 0.347 @ 10.94 CAD | PM10 1.836 @ 446.93 CAD | CO2seq 1,122.090 @ 68.28 CAD | CO2stor is a total biomass amount of 25,177.630 @ 68.28 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

Graph 1: Pollution regulation



Graph 2: Carbon Sequestration



Graph 3: Carbon Storage

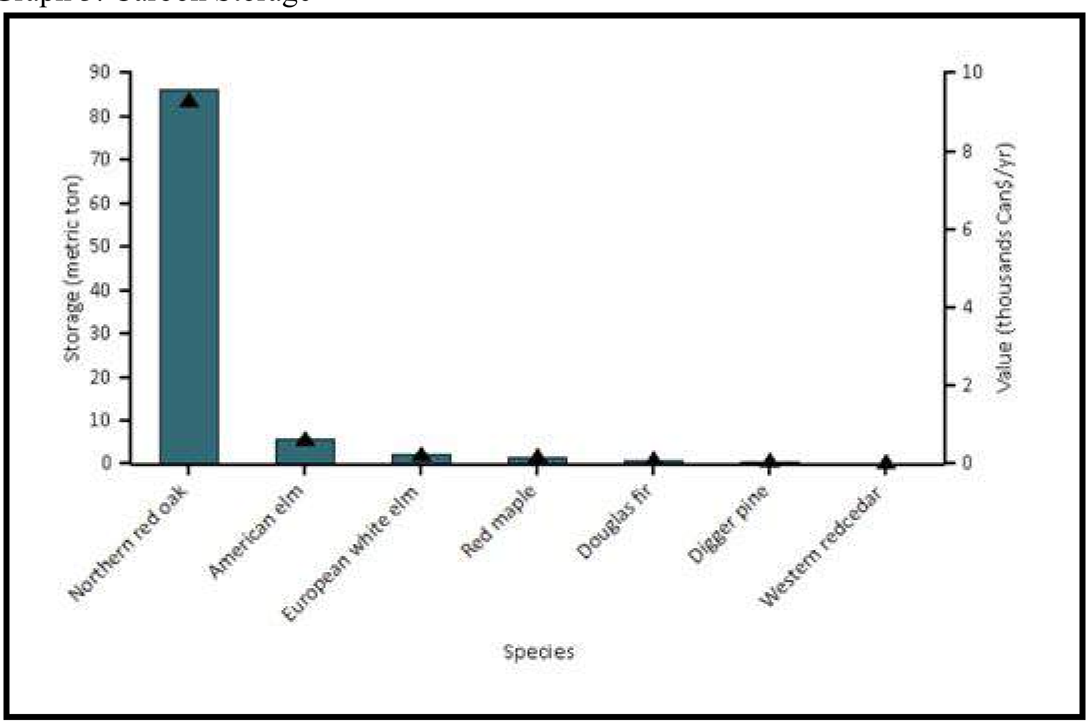
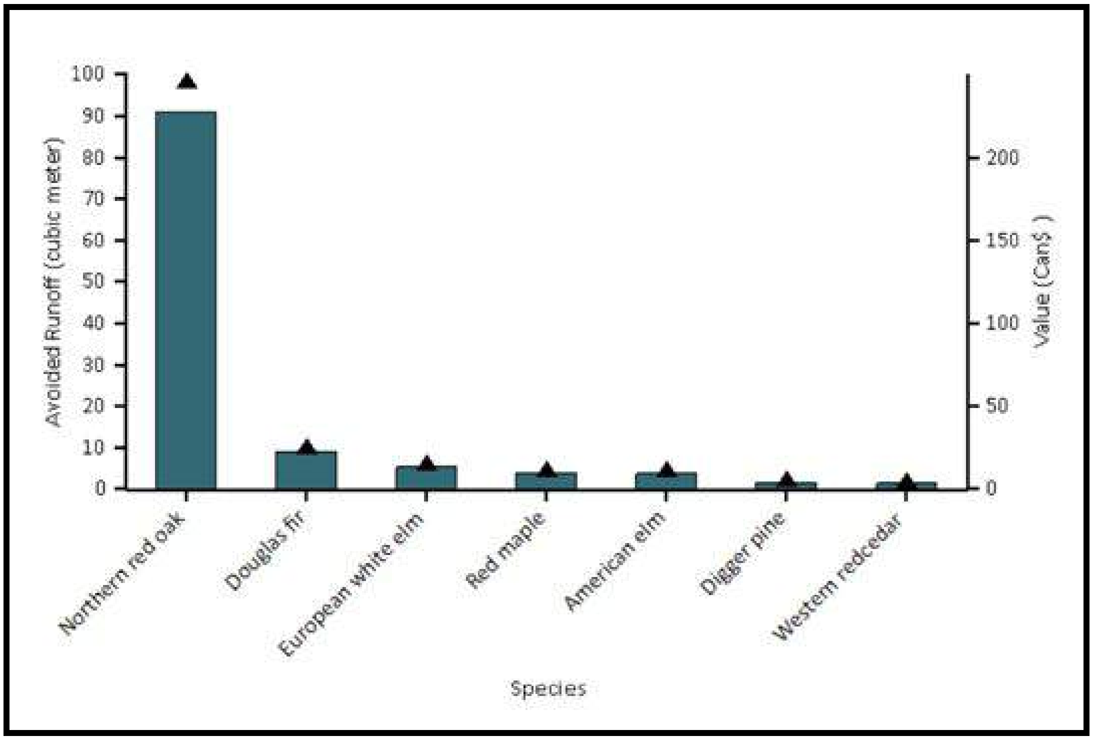


Table 2 : Oxygen Production

Species	Oxygen (kilogram)	Gross Carbon Sequestration (kilogram/yr)	Number of Trees	Leaf Area (hectare)
Northern red oak	4,737.65	1,776.62	42	2.13
American elm	202.37	75.89	1	0.09
European white elm	148.11	55.54	2	0.12
Red maple	97.40	36.53	1	0.09
Douglas fir	69.43	26.04	4	0.21
Digger pine	25.84	9.69	1	0.04
Western redcedar	6.02	2.26	3	0.03

Graph 4: Runoff Management



UFOR 101

Assignment 1

Lynne Kim, Angus Kwan, William Li, Dun Si, Daniella Zhang, Julie Zhang

February 10, 2019

SEEDS Project [Phase 1]: Inventory Report of Urban Trees on Central South Main Mall, UBC Vancouver

Group 10

Contributions of Group Members by Percentage

Daniella Zhang	16.67%
Lynne Kim	16.67%
Julie Zhang	16.67%
William Li	16.67%
Dun Si	16.67%
Angus Kwan	16.67%

Our group divided up the workload by the weighting of points on each section. Smaller sections were assigned to be individual work while larger sections (e.g. Summary of Results) is split between multiple students. In the end, we collaborated to ensure uniformity and clarity of information presented in this report.

Specific Contributions:

Daniella Zhang contributed to the fieldwork component of this project through her flexibility to take on any measurement role assigned to her. Daniella was responsible for writing the introduction and purpose of this report and making sure the summary of results reflect the proposed purposes.

Lynne Kim was in charge of keeping and bringing the equipment to each meeting and she assisted the group during the fieldwork component by measuring the DBH of trees and the crown width measurements. Lynne also wrote the site description portion of the urban forest inventory report, while proofreading everyone's sections and contributing to the proper formatting of the paper.

Julie Zhang contributed to measuring the DBHs, the total tree height as well as crown width in the fieldwork. She also participated in estimating the crown missing and crown light exposure. Julie was in charge of writing the methodology section of this tree inventory.

William Li spearheaded the group's efforts in creating a working tree inventory of our assigned area by delegating roles and responsibilities. He also tabulated the data in an Excel spreadsheet on-the-fly and presented all the data in a format that was easily usable by other group members to analyze.

Dun Si took charge of the measurement of the distance, crown width, and some of crown missing assessment during the fieldworks. Dun also contributed to the summary of results section such as making charts and analyzing data.

Angus Kwan helped with data management during the fieldwork as well as contributing to the paper through the summary of results and editing.

Introduction

Photograph by Krista Jahnke

At first glance, it is easy to understand how the University of British Columbia has gained its scenic reputation. Located at the western tip of Vancouver's Point Grey peninsula, it is categorized under the Coastal Western Hemlock Biogeoclimatic Zone. The university is established on the traditional, ancestral and unceded territory of the Musqueam people. Currently, there are approximately 11,000 planted trees and 10,000 native residual trees on campus (The University of British Columbia, n.d.).

Over recent years, the university recognized a demand for an updated inventory of its urban trees. In partnership with UBC Campus + Community Planning, this project granted current urban forestry students (2018-2019) an opportunity to gain valuable fieldwork experience. By updating the inventory of the most prominent trees at its campus core, this information can provide insight into the condition of these urban trees on a highly trafficked area of campus, which is used to guide future planning management strategies and plantations (SEEDS, 2019). This inventory report begins with clarifying its main purposes and end uses, followed by a site description of our working zone, the methodology explaining variables and tools used in the measurement process, and finally an analysis and summary of our collected data.

Urban forest inventories serve many valuable purposes ranging from risk management to climate change mitigation. However, the methods used to conduct an urban tree inventory is directly reflected by the desired outcomes. More specifically, which variables to include is solely dependent on the context and end uses (Ferrini et al. 2017). Effective management strategies begin with baseline information regarding existing resources, in which new management approaches and efforts can be developed. Additionally, a comprehensive set of variables is required to gain a better understanding and improve urban forest management (2017). The variables chosen in this inventory are discussed in detail in the methodology section of the report. In addition, a complete inventory approach was chosen since there are a manageable number of trees on site, as well as the high level of accuracy it provides.

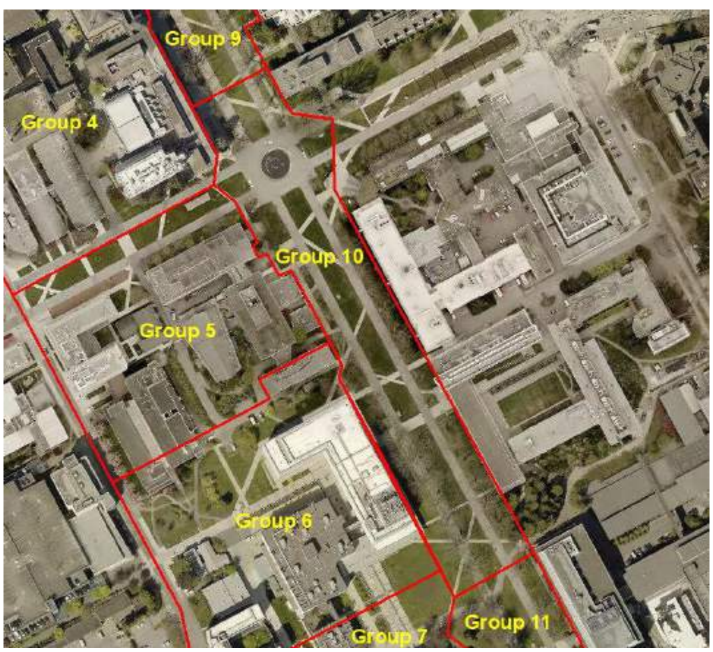
In preparation for the project, presentations were given by key stakeholders who each demonstrated their desired usage and outcomes from the inventory data. Key themes involve biodiversity preservation, climate change mitigation, risk assessment, improved management, and tree loss prevention (SEEDS, 2019). Planning analyst Emma Luker, representing the department of Campus and Community Planning at UBC, addressed several concerns that can be improved by an inventory. She recognized gaps in policy regarding managing the campus' natural resources, as well as gaps in whole-system approaches to consider the broader ecological, cultural and social value of trees (Luker, 2019). As a result, the data collected by this inventory will support the development of new resource policies and improve tree management, as well as providing long term guarantees in the preservation of biodiversity. Additionally, this information will be shared and used by building operations, planning and design, as well as sustainability and engineering departments at UBC (Luker, 2019).

Another stakeholder perspective stems from horticulture instructor Egan Davis, who is particularly concerned with tree identification in order to prevent loss of significant trees with intrinsic value that cannot be replaced. As a horticulturist, Davis is familiar with many special and exotic trees on campus and wishes to gather updated species identification information along with other variables in order to prevent losses of these heritage trees. Additionally, Davis believes the data collected from this project will impact planning decisions in terms of which areas on campus are in need of protection and which areas should be the focus of development.

Lastly and perhaps the most important stakeholders are the students, faculty, staff, and residents of UBC Vancouver's campus community. After all, they are the most active users of urban forests, whether it be sheltering from rain while running between classes or having lunch under shade trees on sunny days. It is found that green space is intrinsic to the total material fabric of university campuses and vital in setting the atmosphere for what a campus represents (Speake, 2013). Therefore, it is important that the outcomes of this campus tree inventory will offer benefits to the greater UBC community through detailed assessments, providing more recognition in these irreplaceable natural assets.

Site Description

Our group measured one of UBC's most recognizable urban forests along Main Mall, which experiences heavy pedestrian traffic everyday. The iconic red oak trees along both sides of the pathways from the Henry Angus building to the Earth Science building were measured by our group. In the middle section, there are patches of grass with cement pathways that are often mowed to enhance the beauty of Main Mall while allowing pedestrian traffic from one side to cross to the other. The earliest red oaks on Main Mall were planted in the 1920s and the broad canopies provided shade for the pedestrians. In addition, the trees brought "a sense of timeless dignity" to UBC's campus. The university monitors and prunes the red oaks to ensure the tree's longevity to "maintain hallmarks of the original campus master plan" (The University of British Columbia, n.d.). In addition, the towering red oak trees brought many aesthetic values to the users of UBC's campus from the luscious leaves changing colour every autumn. However, some of the mature red oak trees were removed due to the natural decline of its life after the reconstruction of Main Mall, transforming the road to a pedestrian-only pathway. Thus, there are a few young red oak taking its place on our site. Additionally, in a small forested area beside the Beaty Biodiversity Museum, there were a few Douglas-fir trees that we measured as well.



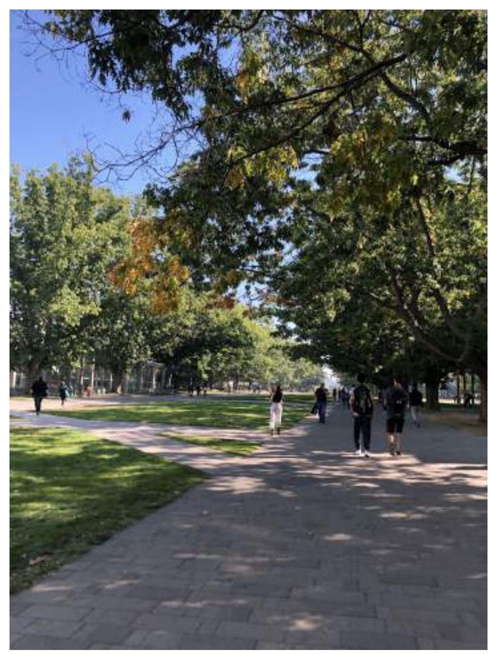


Figure 1: Devisscher, T. (2019). Retrieved from Powerpoint Slides via Canvas.
Figure 2: Kim, L. (2018). Main Mall in the late summer of 2018.

Main Mall is primarily used as an efficient route for pedestrians to walk from the north to the south side of campus, however, there are other activities along Main Mall, some of which include wildlife activity, and construction. There is not a huge variety of facilities within our observed area, but there are a lot of different buildings for classrooms, and a museum. Inside the buildings there are small cafes where students use for dining and studying purposes. In between class times, there are a mass amount of people walking or riding their bikes on Main Mall to get to their next location. With Main Mall being the central pedestrian pathway at UBC, the primary users of our zone would include students, faculty, staff, dog walkers, residents of the UBC community, and the occasional foresters who prune and manage the large, iconic red oak trees to better the university's urban forest.

Methodology

Our group conducted a complete tree inventory of the trees within our zone using the "Collector" app to identify tree locations, as well as gaining access to information such as tree ID and species. Our measurements started with the tree located at the very end on the west side of Main Mall. We measured the trees one by one till the other end and then switched to the other side of the road.

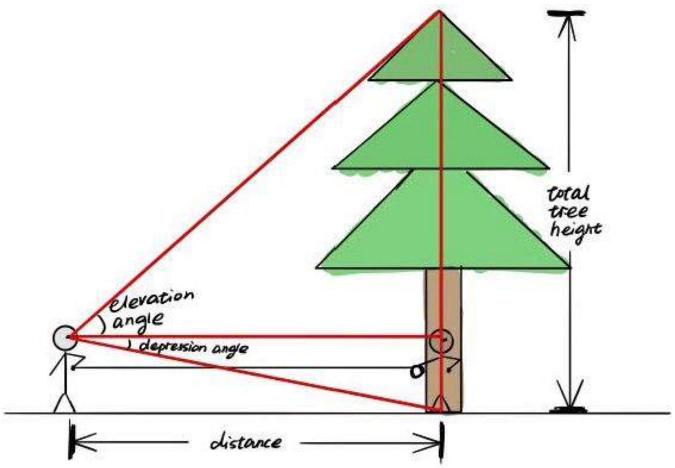
The list of instruments used in the fieldwork

Instrument name	Usage
Clinometer	Measure total and live tree height (top, base) together with Eslon tape
Eslon tape	Measure distance and the crown width (longest and shortest sides)
Diameter tape	Measure diameter at breast height (DBH)
Chalk	Keep track of the trees we have measured

The list of variables measured or estimated in the fieldwork

Variables	
1. Total tree height	
Elevation percentage Depression percentage Distance	
2. Diameter at breast height (DBH)	
3. Crown base height	
Elevation percentage Depression percentage Distance	Distance between crown base and the ground
4. Crown width	
5. Percentage crown missing	
6. Crown light exposure	

Zhang, W. (2019). Figure 3



The diameter of a tree trunk is measured at the average height of an adult's breast of 1.37m, otherwise known as the diameter at breast height (DBH). Firstly, the height of 1.37m was measured on our group members as a reference point. Secondly, we used the diameter tape to wrap around the circumference of the tree trunk at the breast height, standing on the uphill side of the tree if the tree is on slope. A special method was adapted for trees with multiple stems. The total DBH of multi-stemmed trees was calculated by taking the square root of the sum of the squared DBH values.

The total tree height is obtained by calculation using the values of elevation percentage, depression percentage and distance. To estimate the tree height, the cooperation of two group members is required. One person needs to walk away from the tree far enough to ensure the reading of the elevation percentage does not exceed the percentage scale. This person's eye height is the horizontal reference level. The percentages are read by using the clinometer. The person holding the handle of the Eslon tape should stand by the trunk and read the distance between the other person and the trunk after the tape is pulled tightly and horizontally (Figure 3). The value of the depression percentage can be obtained by the same method. The total tree height is equal to the sum of the elevation percentage and the depression percentage times the distance. To evaluate the live tree height, instead of looking at the very top of the tree, the reading of elevation percentage should be taken when the sight falls on the highest tip of the live branch.

For the measurement of crown base height (CBH), there are typically two occasions. CBH of those small trees whose crown bases can be reached is measured directly by the Eslon tape. The tape is hung vertically down on the lowest point of the branch rather than the area where the trunk forks into different branches. For the tall trees with unreachable crown bases, the CBH is measured using the same method as measuring total tree height.

The crown width is measured by two group members using the Eslon tape. Each person should stand at the edge of the crown, move around in either clockwise or counterclockwise directions and pull the tape tightly and horizontally when the distance reaches the highest or lowest values.

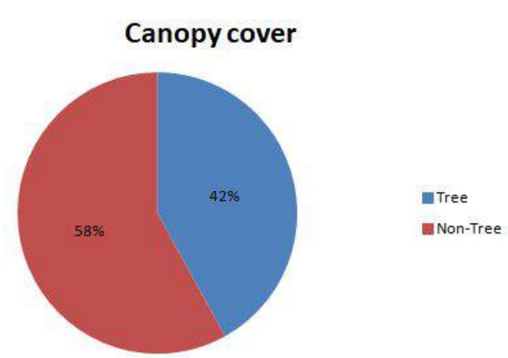
However, since some trees in our plot stand closely by the buildings, some of the branches have spread above the roofs. This makes it impossible to measure the distance from edge to edge. In this case, we measured the distance from one edge to the trunk and estimated the total width by doubling it.

When estimating the percentage crown missing, we justified dead or in-stressed crowns by evaluating any significant bud missing or branches missing. We considered the branched removed as a result of structural pruning to reflect our missing crown estimations. An average value of each individual group member's estimation was taken as the final value.

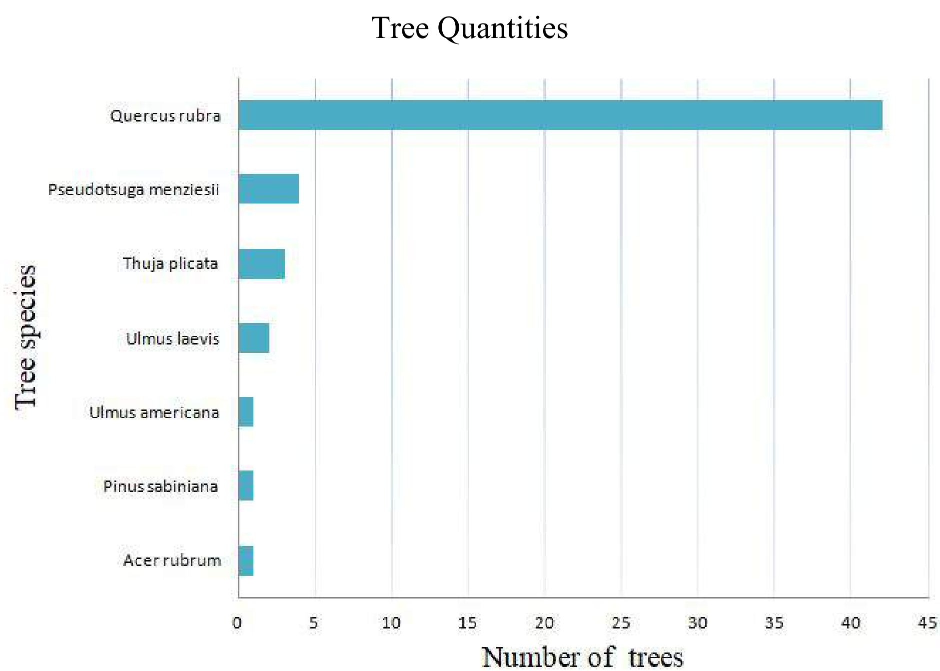
When estimating the crown light exposure, we found two main reasons that decrease light exposure—insufficient spaces between individual trees (due to crown competition) and between buildings and trees. While some trees have grown taller than the buildings beside them, we considered these trees to no longer be shadowed by the buildings.

In order to ensure the readers to have a clear overview of our zone , we added photos and a map to illustrate its scenery and location in the introduction. Additionally, several figures, tables and charts (i.e. bar chart, line chart, pie chart) were made to demonstrate the key attributes of the tree inventory in the summary section.

Summary of Tree Inventory

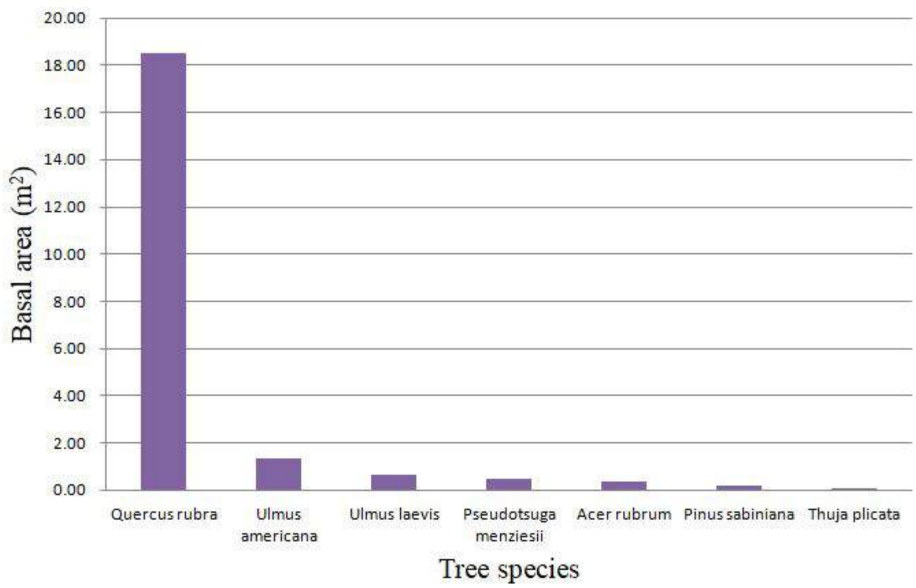


Since the plot area is located along the heavily trafficked Main Mall, the tree canopy does not cover a large percentage of the plot. Situated along the pathway perimeters, individual trees provide shade for pedestrians below without protruding into the open pathway. This roughly cuts the canopy cover to less than half, as the walkway constitutes a majority of the plot area. In the middle of two walking paths is a strip of grass, which houses no trees. Increasing tree canopy cover for this area would present a number of problems, as there would be conflicts regarding the coverage of the open paths. A solution could be to plant small residential trees in the middle strip of soil which do not impede on pedestrians.

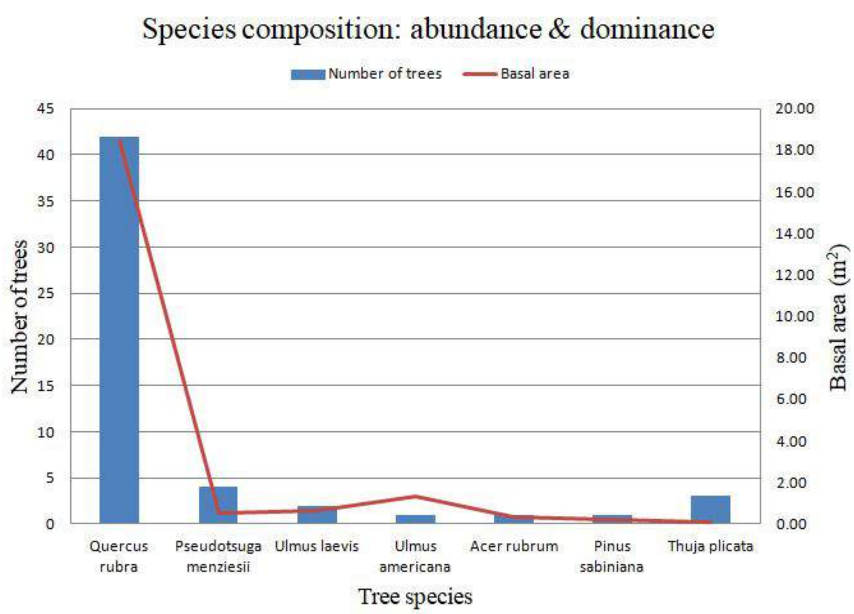


There are 54 trees spanning 7 species in the sample plot. The zone is dominated by *Quercus rubra* or Northern Red Oak, with 42 individual trees. Following the *Q. rubra* are the *Pseudotsuga menziesii* or Douglas-fir (4), *Thuja plicata* or Western Red Cedar (3), *Ulmus laevis* or European White Elm (2), *Ulmus americana* or American Elm (1), *Pinus sabiniana* or California Foothill Pine (1), and *Acer rubrum* or Red Maple (1). Because of Red Oak's ability to adapt to multiple growing environments, it is commonly selected as a street tree alongside its low maintenance and durability. (Tirmenstein, D. A., 1991) In the sample area, there is low species richness, as well as high species density. However, the density is shifted towards one species which is the *Q. Rubra.* This can become problematic as the area is susceptible to factors such as disease because of the uniformity of the species.

Tree Basal Area



In correspondence with the dominance in quantity shown by the *Quercus rubra*, the same species also has the highest basal area out of all the planted species. Basal area is the measure of a tree's occupancy in a given area (Devisscher, 2019). Because of the high number of *Q. rubra* planted, it is no surprise that they have the highest basal area measuring at 18.50 m^2. One significant species was *Ulmus americana,* which showed a high basal area contrary to its low representation. It measured 1.35 m^2, which trumped the other species. This can be attributed to its characteristics which allows it to become an old growth tree while reaching a substantial size (Coladonato, 1992). Its special characteristics also make it a rare tree in our site, as it stands out from all the other trees on campus.



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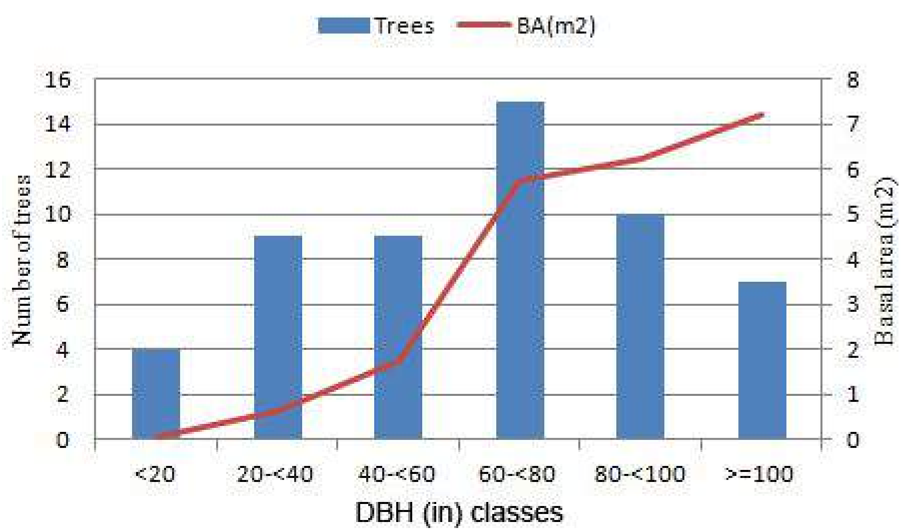
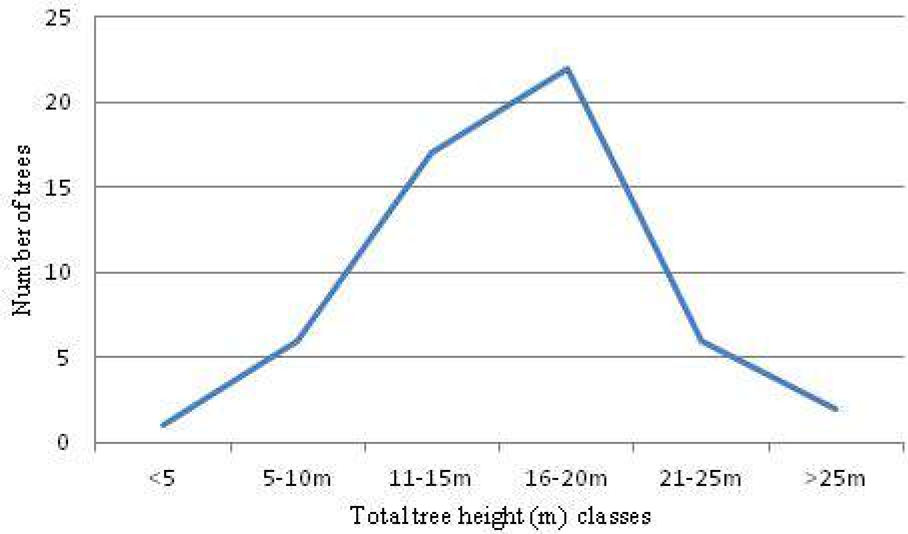
The number of unique species present is small enough to classify the trees on Main Mall as a monoculture. Most of the trees are *Q. rubra*, with the exception of a few trees that are part of a park or building. Consequently, the 10-20-30 diversity rule is not followed in our plot area. Dating back to 1920, the dominant presence of *Q. rubra* on Main Mall is because of its cultural significance to UBC and the amount of canopy cover provided for trees, making it an excellent choice to provide shade to people walking along Main Mall (University of British Columbia, n.d.).

Urban forest structure: DBH classes



DBH corresponds with the age of the tree, which explains why a large amount of trees have the same DBH. As previously stated, most trees along Main Mall were planted in 1920, so all of those trees have similar DBH values. Estimating the ages of the trees by looking at the graph shows that most trees are similarly aged, without much of a discrepancy in the number of young and old trees. Besides age estimations, DBH can also be used to estimate "tree growth, wood volume, and basal area" (Snyder, 2006).

Urban forest structure: Total height classes



The majority of trees in our plot fell within the 11-15 m and 16-20 m height class, as they were mostly trees that were planted when Main Mall was first constructed. Statistically speaking, 38.9% of trees have a height less than 15 m and 61.1% of trees have a height greater or equal to 15 m. The tallest measured tree in our plot site was a *Q. rubra*, with a height of 28.79 m. The same species also had the greatest crown width, measuring at an average of 28.98 m in diameter.

Summary of Collected Results		
	Live	Standard Deviation
Trees	54	
Species	7	
DBH mean (cm)	64.36	±30.84
Basal area mean (m^2)	0.4	±0.324
Total height mean (m)	15.93	±4.98
Crown base height (m)	3.66	±1.73
Crown width mean (m)	13.55	±5.86
Canopy Missing		
<10%	8	
10-30%	23	
31-50%	17	
51-70%	4	
>70%	2	
Crown Light Exposure (CLE)		
0	0	
1	0	
2	0	
3	0	
4	45	
5	9	

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Urban Forest Ecosystem Service Assessment Report

UFOR 101
April 2, 2019
Group 11

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Introduction

The purpose of the ecosystem services assessment is to provide the stakeholders of the University of British Columbia data that can be used to increase the benefits the urban forests provides for all its users. This assessment can be used as a basis for implementing new management plans or for further research in the urban forest. The data found in this assessment will also be useful in implementing new policies and procedures to support UBC's goals and values. One of UBC's main goals is to have a beautiful campus while having the characteristics of the west coast setting. Ecosystem services are important because users can benefit goods and services that the trees and the greenery provide. The four main ecosystem services are regulating services, cultural services, provisioning services, and supporting services. They are services that are provided by nature that benefit, sustain and support the well-being of Main Mall's users. This assessment of ecosystem services on this particular site will focus on regulating services and cultural services. The high tree canopy percentage is the area gives many benefits such as air regulation, in which the trees provide fresh air and a pleasant view. By integrating the urban forest, it will give us the ability to effectively manage the ecosystem services for all of its users and any future events.

In the first section, a detailed description of the data collection area on the UBC Vancouver Campus will be provided. The next section will consist of the regulating services the area provides followed by the many cultural services that students of UBC benefit from. Rounding up this assessment, the report will go over recommendations that can improve the overall quality the ecosystem services provide. This ecosystem services assessment report will aim to be comprehensive, rational and unbiased.

Site description

This section will attempt to describe the fieldwork location of Group 11. The selected tree inventory collection area is located on the Main Mall of the UBC Vancouver Campus. The area is located on the southern end of the Main Mall, and the south end of the collection area starts from Agronomy Road, and extends until the north side of the Fred Kaiser Building (Figure 1).

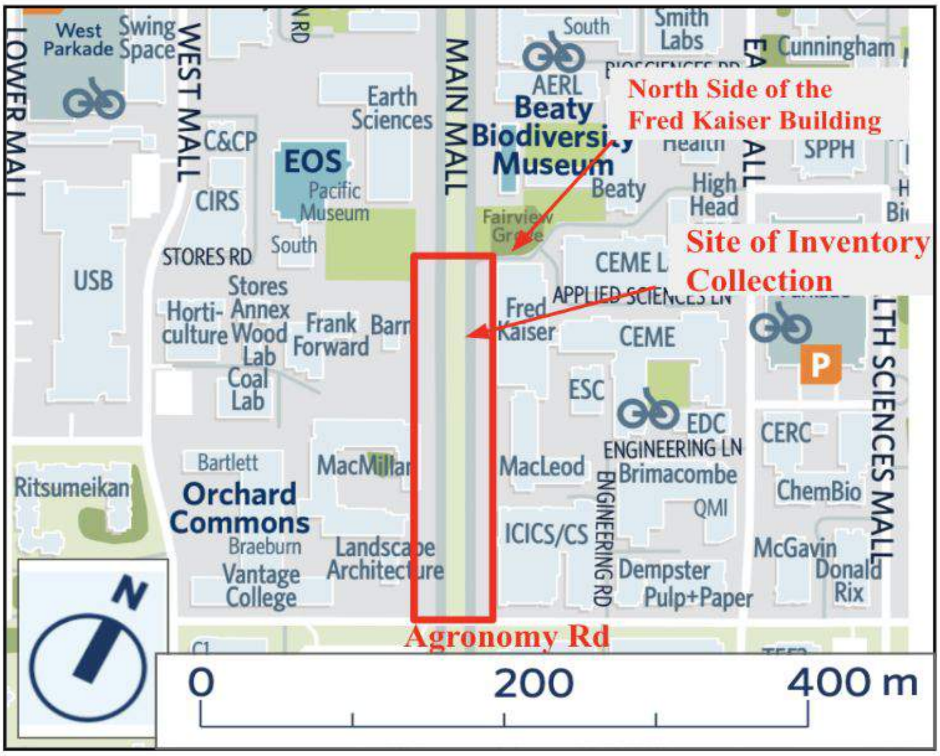


Figure 1: Map of the inventory collection site (The University of British Columbia, 2018)

The land use type of the inventory collection site is 100% park use. The inventory collection area does not include institutional buildings. From the satellite picture, the vegetations in this area is well distributed; it is flanked by tall red oaks in the two sides, providing a shadow for passes-by during the summer. The middle of the area is the meadow, it provides an open and broad view, also several paths are lying on the grass that lead to the college buildings on either side of the Main Mall. Since it is located between the education areas, the main users of this area are students and staffs of the Vancouver Campus. In addition, students will pass this area to come and go to class during the weekdays. Therefore, this road will become extraordinary busy during the class shift. Other than being used as scenery, the plants can also serve as water storage. The rainwater will be absorbed first by the nearby vegetation when it rains. So the Main Mall can avoid being flooded during the raining days. In addition, there are many types of facilities on the study area, which includes footpaths, benches, street lights, wayfinding signages, the UBC Engineering Cairn, and grass lawns. The facilities provide cultural services and some of them contributes to social cohesion of the site. In total, there are 51 trees located in this collection area and the age of trees ranges from young saplings to some of the earliest original Red Oaks that were planted in the 1920s (Figure 2) (The University of British Columbia, n.d.).

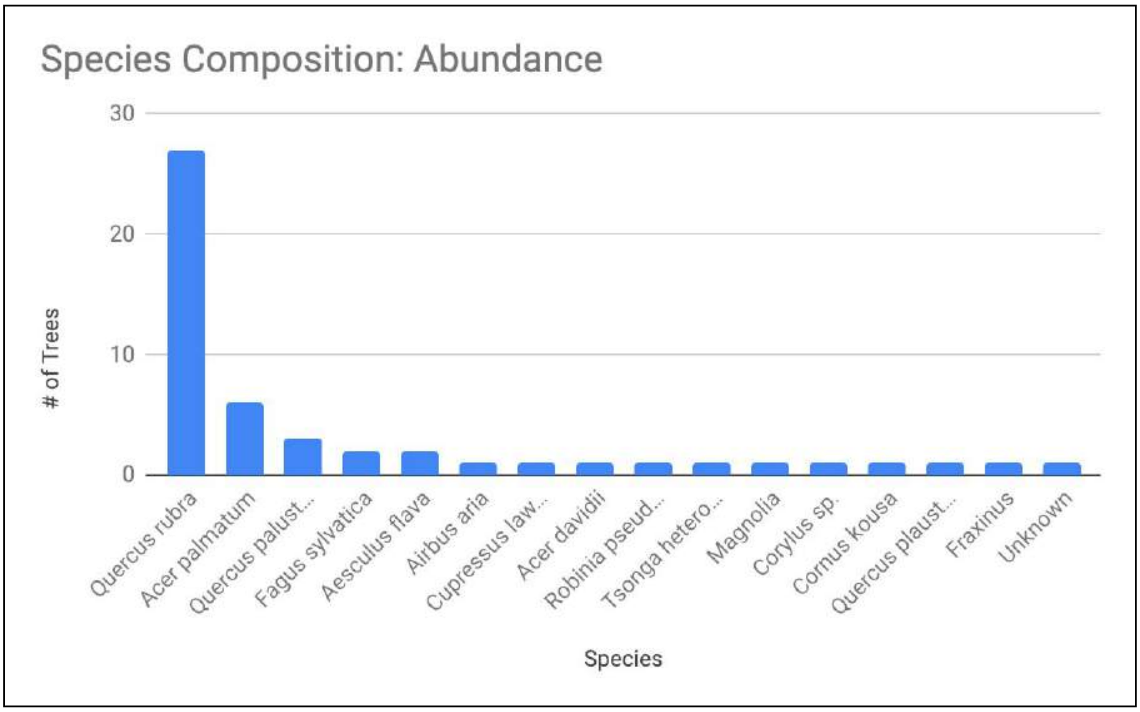


Figure 2: The tree species located on the inventory collection site

Figure 3: Satellite image of inventory collection site (Google Maps, 2019)

Regulating Services

The study area of Group 11 provides various regulating services. Regulating services are “benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazard regulation, water purification and waste management, pollination or pest control (C)." The regulating services include services such as stormwater regulation to temperature regulation. Regulating services is especially important for this specific area along Main Mall because of the high usage rate. The high number of trees in the section are needed to support all of its users. Improved air quality and stormwater management is vital for all of its users who walk down Main Mall so rain water can flow away from the pathways as well as improved health for the students who use Main Mall daily.

Just in the small area alone, the trees are able to store almost 200 tonnes of carbon as well as sequestering 8 tonnes of carbon a year. That equates to almost $13000 worth of carbon stored in trees and $500 worth of carbon sequestered annually. The trees in this area also remove around 100lbs of other pollutants such as fine particulate matter, carbon monoxide, nitrogen dioxide, ozone, and sulfur dioxide providing cleaner air in the surrounding areas.

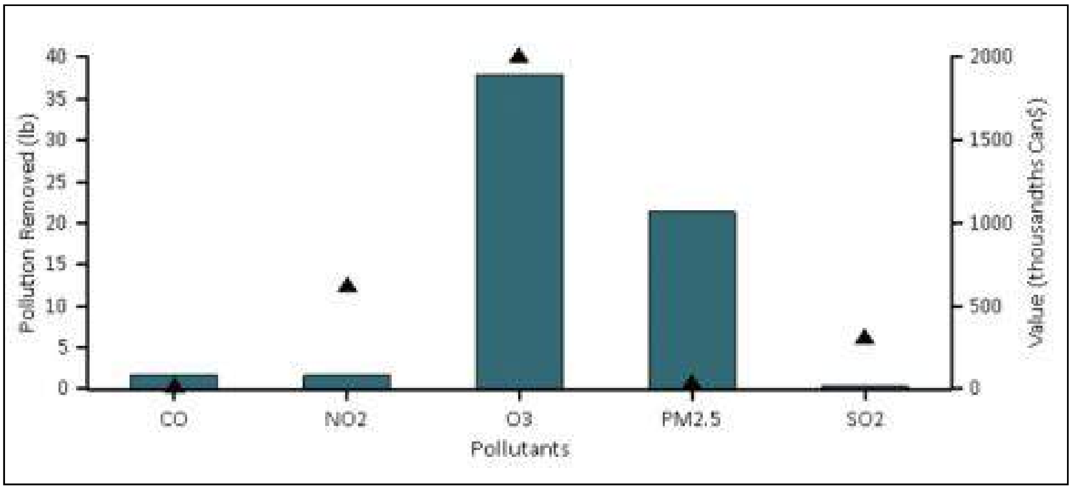


Figure 4: Pollutant removal and equivalent value by the trees on the inventory site.

Due to the high number of red oaks and the large area of green space, water storage and regulation is also provided by the trees. Since this section has no buildings and lots of grass and soil coverage, soil infiltration and rainfall interception by leaves, twigs, and branches then lead the stormwater runoff into the integrated stormwater management system UBC has. Based on i-tree eco, the trees in Zone 11 help reduce runoff by 4.29 thousand cubic feet a year that has an associated value of 280$ canadian. Furthermore, the high percentage of urban forest including lawns, grass fields, trees, and shrubs means that it reduces the strain on sewage systems, as the green spaces act like natural sponge and retain the water. According to the UBC drainage system map (C), the stormwater on this site drains through Pacific Spirit Park to a surface channel leading to the Fraser River. However, this outfall is experiencing significant erosion problems.

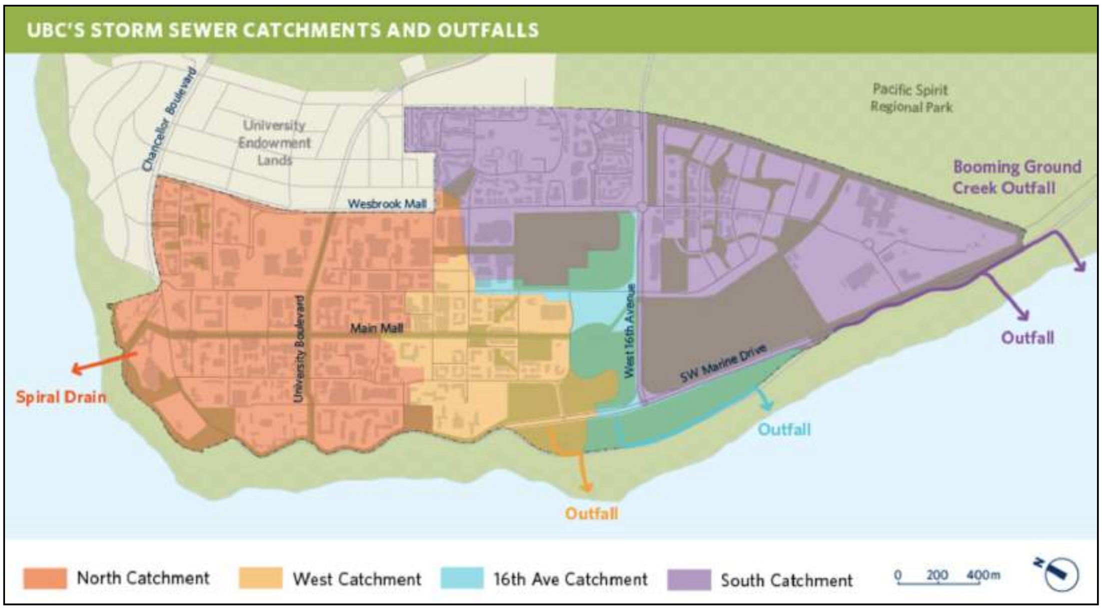


Figure 5: UBC Sewage Drainage Map (UBC Energy and Water Services, n.d.)

The urban forest can reduce the erosion problem at the outfall since less more stormwater is absorbed, so stormwater run-off does not enter the stormwater drains.

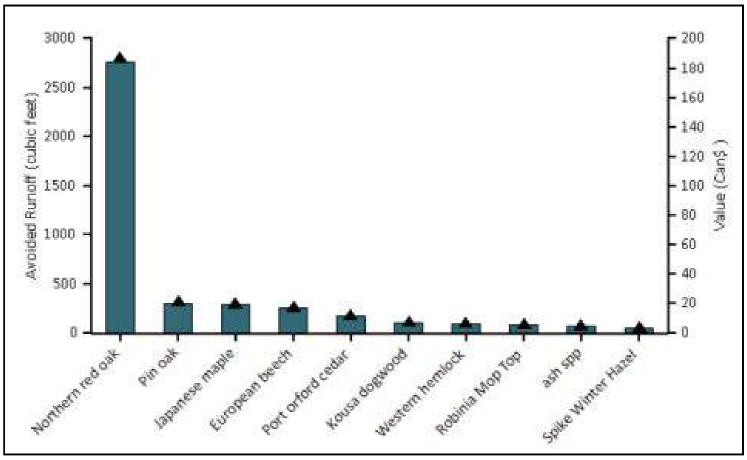


Figure 6: Avoided Runoff and equivalent value by the trees on the inventory site.

The 51 trees in the site examined provided an impressive 46% canopy cover. These trees line the sides of Main Mall providing shade for anyone who walks down Main Mall. The canopy cover is very high because of Vancouver's neighborhood's canopy cover range from only 6 to 28 percent. High canopy cover at the site means that it has more ability to regulate temperature and reduce the urban heat island effect. It also reduces the building energy use of adjacent buildings such as MacMillan and Fred Kaiser buildings. Moreover, the vegetation at the site can regulate air can increase air quality since the trees and bushes can remove pollutants or particles such as ozone, particulate matter, carbon monoxide, and sulfur dioxide from the air, as well as produce oxygen through photosynthesis. In the long run, approximately 196 tonnes of carbon dioxide is stored by the urban forests within the site, which reduces global warming by removing the greenhouse gas and combating climate change, and the monetary value of carbon store is equivalent to $6650.

I-Tree canopy provides many benefits such as quick and accurate assessment of a certain area. Tree canopy cover is often accurate and provides baseline data for further research. The accuracy of i-Tree canopy can be improved by adding more sample points to the assessment. Some downsides of using i-Tree canopy is that the amount of pollutants as well as the dollar amount may not be accurate because the program cannot assess the size and species of the tree thus not giving the most accurate data. Another downside is that i-Tree canopy is only available in certain geographical locations. Having no location in Canada meant that one had to choose the closest point which was located in Washington. I-tree eco has its own strengths as well. The program provides more accurate data as well as hydrology. Downsides to this is that one can never get truly accurate data unless actual fieldwork is conducted to measure the trees and vegetations.

Cultural Services

Lastly, this area provides many different cultural services for students to enjoy. Cultural services that forests provide to its users can be described as the non-material benefits users receive such as cognitive development, recreational space, an area of reflection, and nice aesthetics(Grabner, 2013). However, these benefits can be difficult to study because they are not easily quantifiable. For instance, a green space with ample area to socialize and relax cannot be quantified like a tree's canopy can. Rather, it is based on personal preference which makes evaluating cultural services quite subjective. Therefore, out of all the ecosystem services, cultural services is considered to be the least studied (Morgado, 2018). However, cultural services should not be overlooked as they are proving to be quite valuable to overall human health. For example, a study from the Nippon Medical School in Tokyo, Japan found that visiting forest parks can improve one's immune system and reduce levels of stress for approximately thirty days following a single visit. (Li, undated). Taking all of this into account and based on our value mapping exercise, Zone 11 has a substantial amount of space for social cohesion, is quite aesthetically pleasing, and contains symbols of cultural significance which is why there are many cultural services Main Mall has to offer UBC students.

The methods used to evaluate the cultural services at the South end of Main Mall was based off of the cultural value mapping exercise that was completed during class. During the exercise, the area of study was broken down into five sub-zones (figure 9) and each group member scored the subzones from one to five based on the following criteria:

- Diversity/Species Richness
- Aesthetics
- Social Cohesion
- Wilderness/Nature
- Cultural Significance

Following the individual analysis, the average of the combined score from each sub-zone can be seen in the table below.

Sub-Zone	Diversity/ Species Richness	Aesthetics	Social Cohesion	Wilderness/ Nature	Cultural Significance
A	2	3	2	3	2
B	2	3	3	2	2
C	2	3	3	2	3
D	3	3	2	2	3
E	2	2	2	2	2

Figure 7: Average scores for cultural services of the tree inventory site

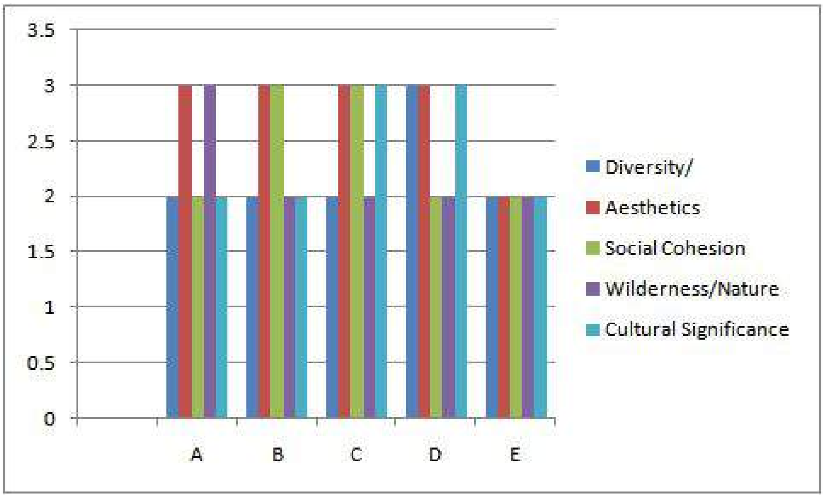


Figure 8: Graph of cultural values with the five criterias

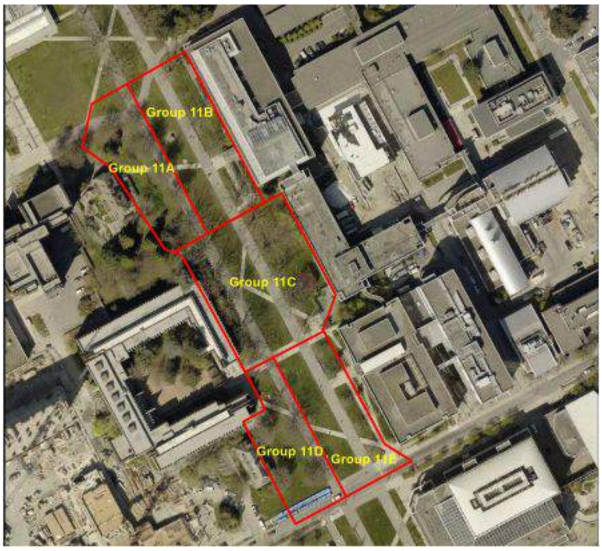


Figure 9: Subzones of the inventory collection site

Overall, the zone showed to have above average aesthetics while all other areas scored to be average.

Additionally, students have the ability to socialize in the urban forest because of the many park benches along Main Mall. This provides students a place to hang out, spend time on homework, or eat lunch while enjoying the urban forest. This area also gives students the ability to destress because of the spiritual connection one gets when being outside in the natural environment which can be directly related to the biophilia hypothesis. This hypothesis states that humans have an innate tendency to seek connections with nature due to our genetics, which can prove to be true as nature is universally enjoyed by all (Rogers, 2019). The green space along Main Mall also offers a lot of opportunities for recreational activities. For example, during imagine day, the majority of UBC students flood Main Mall to celebrate the start of a new academic year by showcasing all the different clubs and activities UBC has to offer all while enjoying the urban forest. Another symbolic structure within the area is the engineering cairn or the “E”. Although it was the target of vandalism by other student groups, the engineering cairn remained intact for nearly two decades. Clubs, fraternities and student societies have a tradition of doodling or repainting monuments in their own colors. Each act of vandalism was followed by a new coat of red and white paint. However, while promoting different school events, it is sometimes difficult to recognize as it is often subject of graffiti. Finally, this area also provides aesthetic purposes for all of its users. This is mostly due to the towering Northern Red Oaks that line the outer walkways along Main Mall. Dating back to the early 1920’s, these trees are iconic to UBC as they can be dated all the way back to 1914 in the University of British Columbia’s original master plan (UBC, 2019). These large trees are quite the spectacle to the users of the area as the large canopies and uniform layout stretch from the Forest Sciences building all the way to the flagpole where the breathtaking views of the North Shore mountains and Burrard Inlet can be seen.

Figure 10: Vandalism of the UBC Engineering Cairn

Main Mall is lined with lush, green trees and grass during the warmer months which is perfect for those to take pictures or just enjoy the view around.

The value mapping approach is a fast way of collecting data on how the environment around makes one feel. It is a simple process that gathers everyone's personal opinion in the site. There are also downsides to this method such as having a small sample size of six people which will not be accurate since thousands of people use this space each day. Everyone also has different opinions so a larger sample size would make the results much more accurate.

Recommendations

The following section will attempt to give recommendations that is specific to Zone 11 as it will draw on the previous sections, cultural services and regulating services. The recommendations will integrate the results and interpretation of the ecosystem services to strengthen the social significance of the area and other weaknesses observed. Furthermore, the recommendations will also be made to promote its urban forest strengths. The following recommendations will aim to be realistic, attainable and suitable for Zone 11.

One of the ways in which this portion of UBC's urban forest can be improved would be planting additional trees along the inner portion of Main Mall. To ensure the trees remain safe from the heavy foot traffic in the area, it would also be beneficial to include tree guards as an extra precaution. An example of a tree that could fit the area well would be the Red Maple because of its ability to control climate during Vancouver's warmer summer days and the fact that it prefers a wetter climate. Its large canopy cover would provide additional shade along the road, controlling the area's microclimate by limiting direct sun exposure. These trees tend to grow quite rapidly as well, so it would not take long for UBC stakeholders to reap the benefits that these trees provide and notice the results in the urban forest. During the fall, the changing colors of the leaves would help add to the aesthetics of the area. Moreover, maple trees could help add to the lacking cultural significance of the urban forest as the maple leaf is essentially the symbol of Canada. However, the roots of the Red Maple have the potential to cause damage to the pathway so it is crucial to not over-plant this species. By planting these trees, the canopy cover would increase significantly and therefore further reduce the amount of pollutants in the area through uptake via the leaf stomata.

In addition to planting trees that could add to the cultural significance of Main Mall and provide numerous benefit, it is also important to consider the level of volatile organic compounds that it emits. There are many tree species, such as black gum, oak and willow, that are high emitters of VOC. This directly affects the air quality in Zone 11 as it exponentially increase the ozone level as opposed to low impact trees. Therefore, it is recommended to plant low VOC tree species such as birch, tulip or linden that barely contributes to the ozone level. Maximizing the usage of low VOC-emitting trees can significantly reduce ozone and carbon monoxide formation, thus improving air quality.

Resident participation can also play an important role in tree management and benefiting ecosystem services of Main Mall. The users of this site are mostly students and UBC staff, so it might be necessary to organize students' outdoor activities such as field work, as well as to motivate staff and students to be environmentally conscious and carry out events for environment preservation. It obviously provides another way for developing the area other than only planting more trees. Needs, goals, and motivations provides three main part in urban forestry in multiple levels and are elements that could be utilized to develop volunteerism and then, finally getting more individuals engaged in making Zone 11 better, and ultimately the whole campus.

Another recommendation that would benefit the area would be introducing new tree species along the outer side of Main Mall where the Red Oaks are planted. While staying true to UBC's heritage, it is important to keep the healthy Red Oaks as they are one of UBC's defining features, however, new species would help mitigate the chance of widespread disease by increasing species diversity and help with pollutant control. With some of the Red oaks on campus dating back to the 1920s and some of these trees have died, so they are in need of replacement. It would be favorable to introduce some evergreen species as a replacement for the dying red oak trees. However, the red oaks do not look very visually appealing during winter since they shed their leaves. Evergreen species would ensure there are still green trees in winter months.

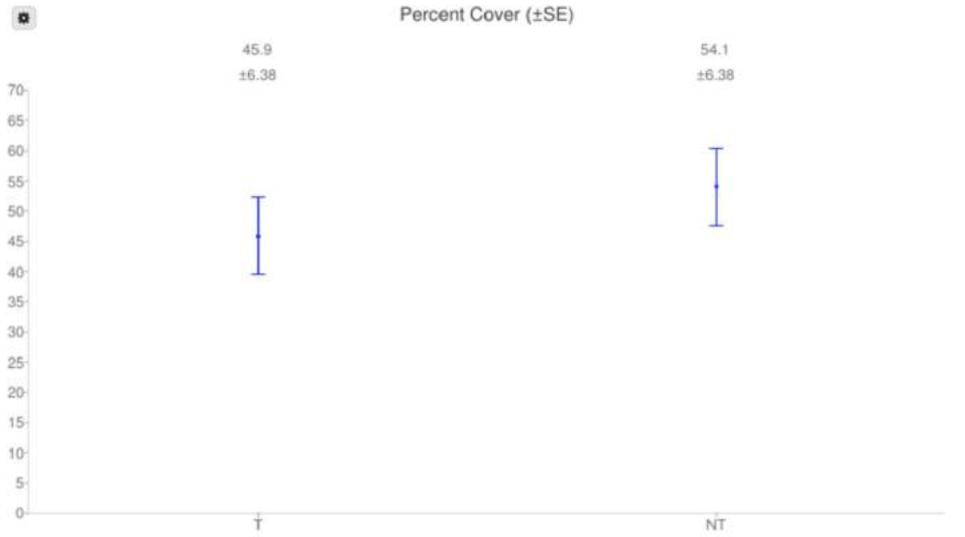
Other recommendations include ensuring tree inventory is up to date. This can be accomplished by performing annual tree inventory collections, as well as utilizing urban forestry classes to collect forest inventory data. Finally, it is important to ascertain that the young Aesculus flava trees along Thunderbird Blvd are a priority as they are young and more vulnerable to stress.

Appendix A

i-Tree Canopy v6.1

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 4/03/19



Cover Class	Description	Abbr.	Points	% Cover
Tree	Tree, non-shrub	T	28	45.9 ±6.38
Non-Tree	All other surfaces	NT	33	54.1 ±6.38

Appendix B

Tree Benefit Estimates

Abbr.	Benefit Description	Value	±SE	Amount	±SE
CO	Carbon Monoxide removed annually	0.03 CAD	±0.00	1.16 lb	±0.16
NO2	Nitrogen Dioxide removed annually	0.06 CAD	±0.01	11.37 lb	±1.58
O3	Ozone removed annually	2.34 CAD	±0.33	46.49 lb	±6.46
PM2.5	Particulate Matter less than 2.5 microns removed annually	19.65 CAD	±2.73	7.98 lb	±1.11
SO2	Sulfur Dioxide removed annually	0.01 CAD	±0.00	4.02 lb	±0.56
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	3.24 CAD	±0.45	25.09 lb	±3.49
CO2seq	Carbon Dioxide squestered annually in trees	482.30 CAD	±67.04	7.80 T	±1.08
CO2stor	Carbon Dioxide stored in trees (Note: this benefit is not an annual rate)	12,112.32 CAD	±1,683.61	196.00 T	±27.24

Appendix C

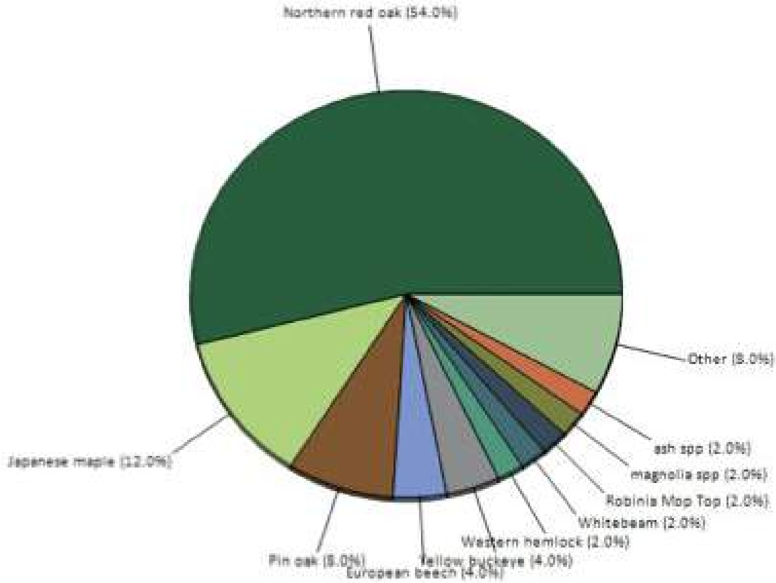


Figure 1. Tree species composition in i-Tree Eco Lab

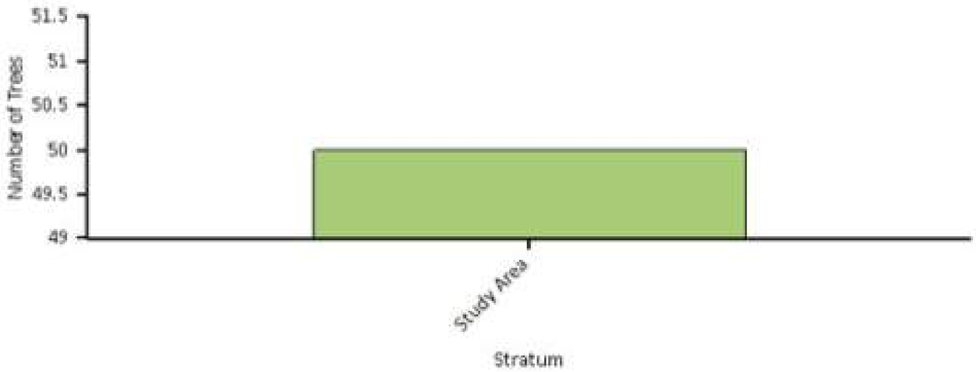


Figure 2. Number of trees in i-Tree Eco Lab by stratum

Page 4

Appendix D

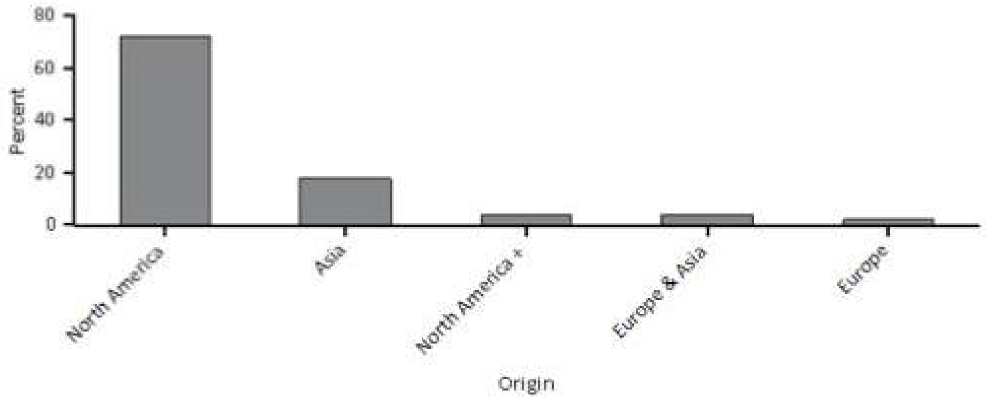


Figure 4. Percent of live tree population by area of native origin, i-Tree Eco Lab

Appendix E

Table 1. Most important species in i-Tree Eco Lab

Species Name	*Percent Population*	*Percent Leaf Area*	*IV*
Northern red oak	54.0	65.0	119.0
Japanese maple	12.0	6.8	18.8
Pin oak	8.0	7.2	15.2
European beech	4.0	5.9	9.9
Port orford cedar	2.0	3.9	5.9
Kousa dogwood	2.0	2.4	4.4
Yellow buckeye	4.0	0.2	4.2
Western hemlock	2.0	2.0	4.0
Robinia Mop Top	2.0	1.8	3.8
ash spp	2.0	1.7	3.7

Appendix F

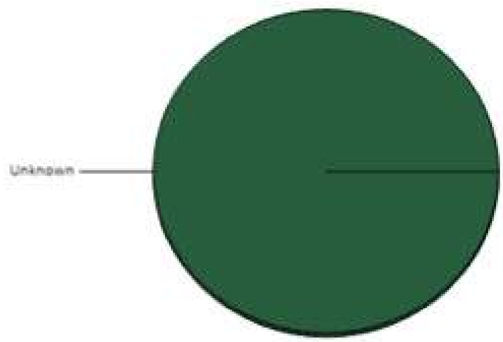


Figure 6. Percent of land by ground cover classes, i-Tree Eco Lab

Appendix G

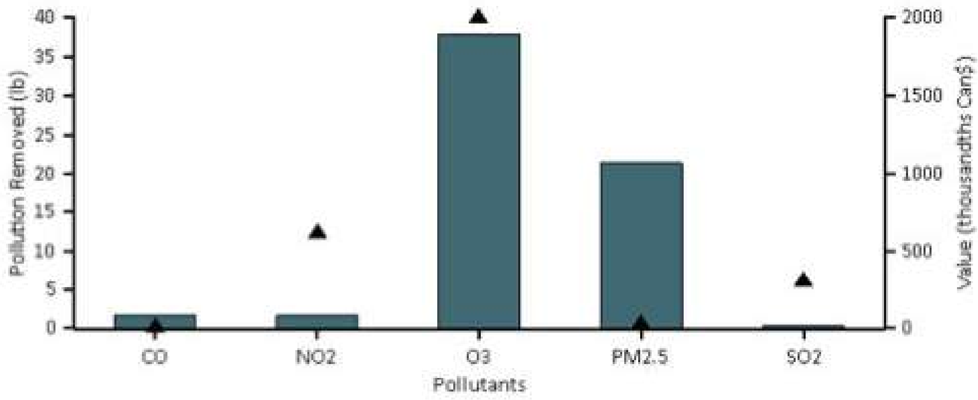


Figure 7. Annual pollution removal (points) and value (bars) by urban trees, i-Tree Eco Lab

Appendix H

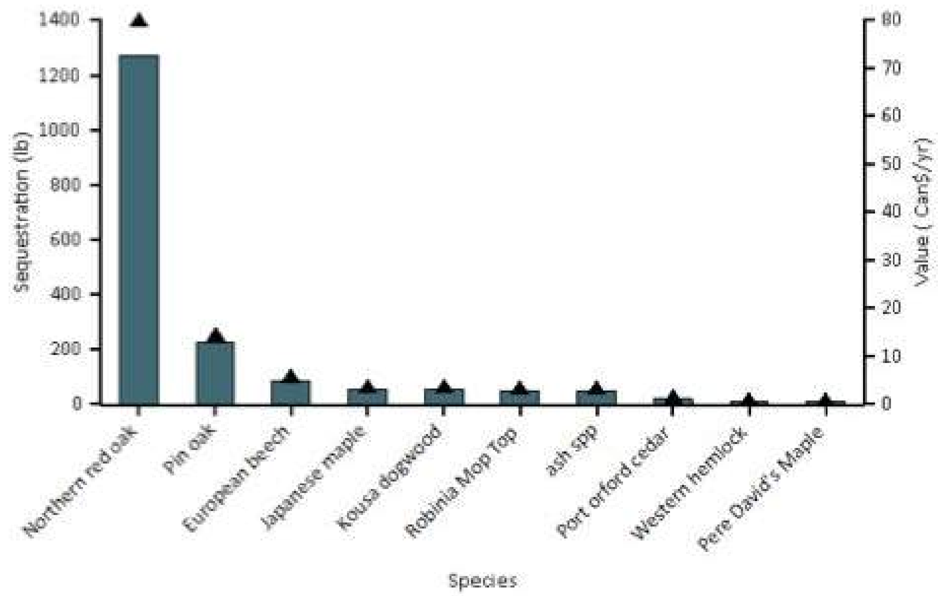


Figure 8. Estimated annual gross carbon sequestration (points) and value (bars) for urban tree species with the greatest sequestration, i-Tree Eco Lab

Appendix I

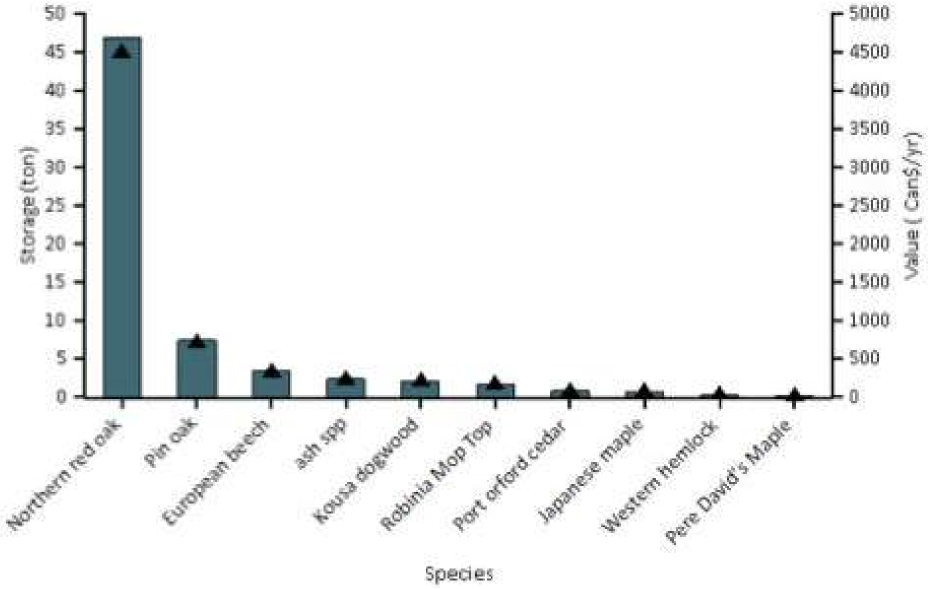
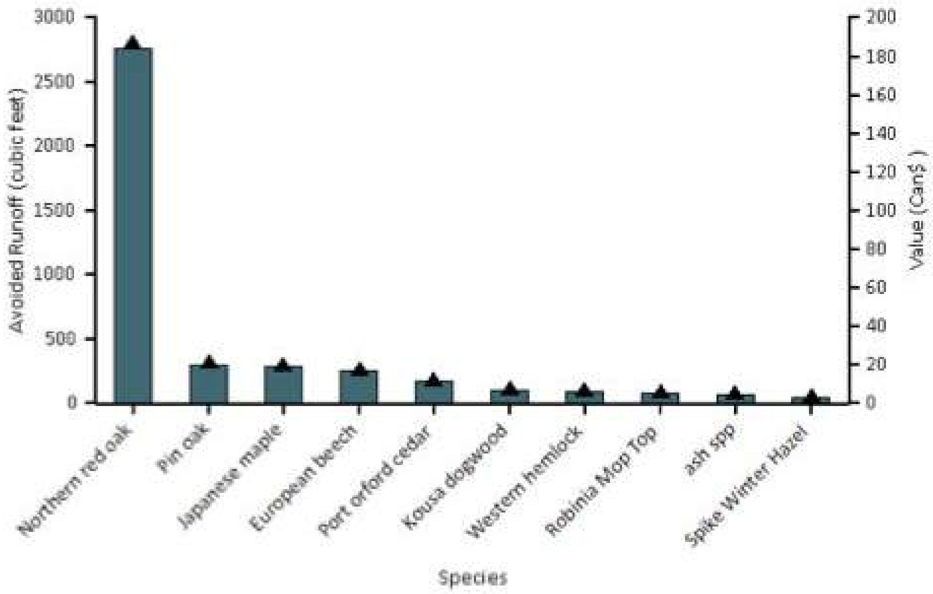


Figure 9. Estimated carbon storage (points) and values (bars) for urban tree species with the greatest storage, i -Tree Eco Lab

Appendix J



Appendix K

Table 2. The top 20 oxygen production species.

Species	Oxygen (pound)	Gross Carbon Sequestration (pound/yr)	Number of Trees	Leaf Area (acre)
Northern red oak	3,722.49	1,395.93	27	4.77
Pin oak	655.38	245.77	4	0.53
European beech	258.42	96.91	2	0.43
Japanese maple	164.43	61.66	6	0.50
Kousa dogwood	160.13	60.05	1	0.18
Robinia Mop Top	147.77	55.41	1	0.13
ash spp	146.17	54.81	1	0.12
Port orford cedar	59.22	22.21	1	0.29
Western hemlock	35.34	13.25	1	0.15
Pere David's Maple	31.65	11.87	1	0.07
Spike Winter Hazel	17.38	6.52	1	0.09
magnolia spp	17.22	6.46	1	0.06
Whitebeam	12.17	4.56	1	0.01
Yellow buckeye	11.11	4.17	2	0.01

Appendix L

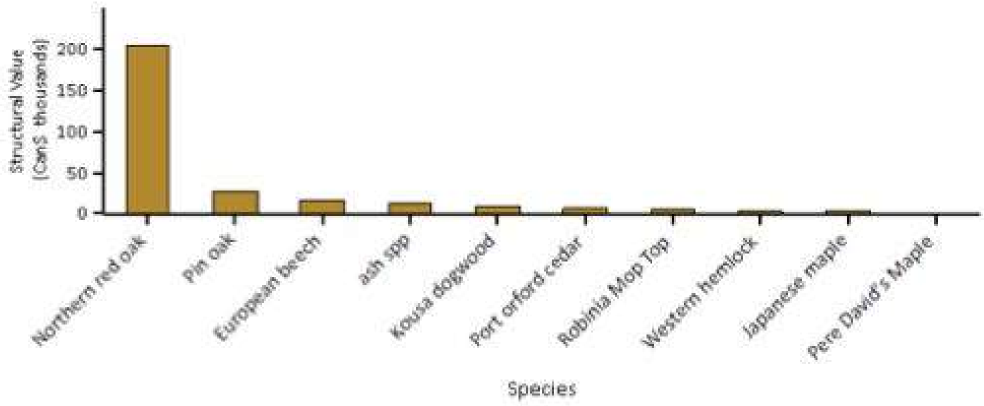


Figure 11. Tree species with the greatest structural value, i-Tree Eco Lab

Appendix M

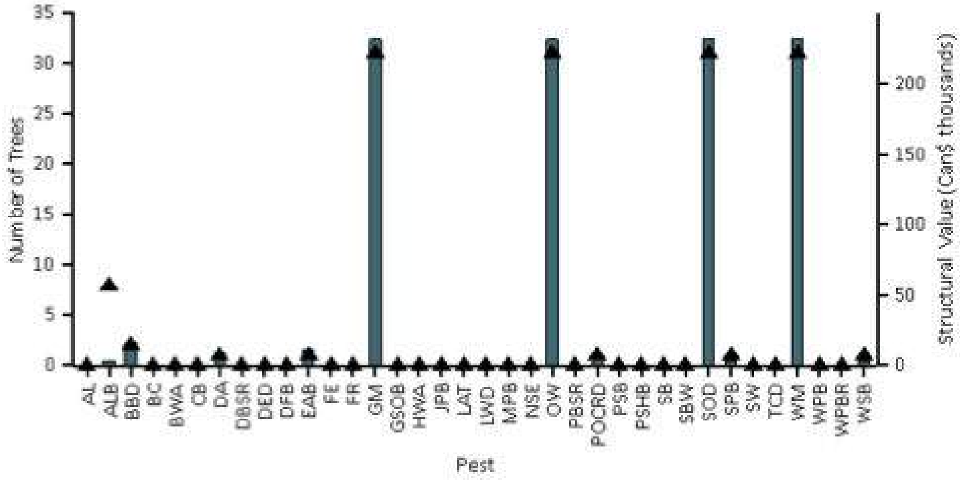


Figure 12. Number of trees at risk (points) and associated compensatory value (bars) by potential pests, i-Tree Eco Lab

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Contribution Description

Simon Lin	Site Description, Regulating, Recommendation, Proofread, Edit
Adrian Lee	Introduction, Regulating, Cultural
Paul Liu	Site Description, Regulating, Cultural, Recommendation
Xin Weng	Site Description, Regulating, Cultural
Jack Robertson	Regulating, Cultural, Recommendation
Ming Lou	Recommendation

Urban Forest Inventory and Assessment

UFOR 101
February 10, 2019

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1. Introduction

The purpose of collecting tree inventory data is to provide the end user with the population, location, species, condition, size, canopy cover, and health of trees. An urban forest cannot be efficiently managed without the characteristic of each tree. With the information gathered, one can also see the use of the trees and provide data for tree maintenance. The data enables park managers and urban forest managers to evaluate the different ecosystem services such as stormwater management, air quality improvement, and biodiversity management. UBC can also use this tree inventory to develop future endeavours and mitigate risks. Future planting of trees and risks such as damaged, decaying, or overgrown can easily be identified with the data. Tree canopy data collected is also important to increase the tree canopy in certain areas.

In the collected data, UBC can see how tree characteristics change over time. The given location has a lot of foot traffic which managers will need the most accurate information they can get about the trees. Tree pruning will be needed in areas such as the main mall to prevent any accidents that may occur without maintenance. Periodically updated tree inventories will be needed to maintain and monitor changes in trees overtime.

In the first section, a detailed description of the data collection area on the UBC Vancouver Campus will be provided. The next section will consist of the methods used in the field to collect data for the inventory as well as the techniques used to analyze the data. The summary will round out this urban forest inventory report. The analysis of the report, the summary section, will draw on the data collected, results, and figures. This urban forest inventory and assessment report will aim to be extensive, analytical and factual.

2. Site Description

This section will attempt to describe the fieldwork location of Group 11. The selected tree inventory collection area is located on the Main Mall of the UBC Vancouver Campus. The south of the collection area starts from Agronomy Road and extends along the Main Mall until the north side of the Fred Kaiser Building (Figure 1).

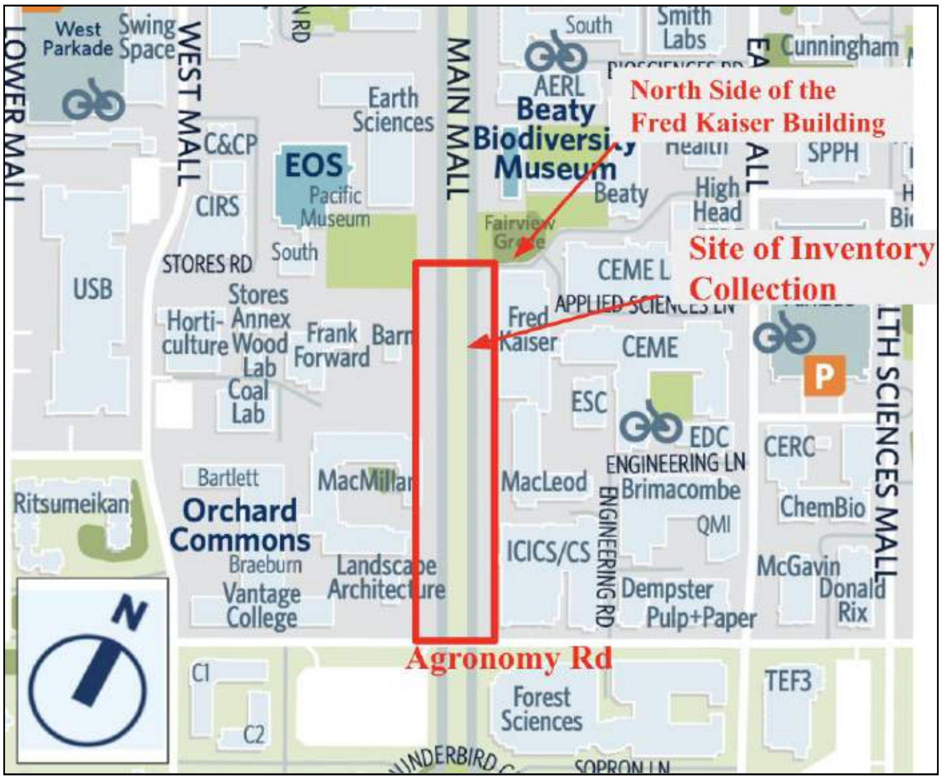

Figure 1: Location of the inventory collection site (The University of British Columbia, 2018)

The land use type of the inventory collection site is park use. From the satellite picture, the vegetations in this area is well distributed; it is flanked by tall red oaks in the two sides, providing a shadow for passes-by during the summer. The middle of the area is the meadow, it provides an open and broad view, also several paths are lying on the grass that lead to the college buildings on either side of the main mall. Since it is located between the education areas, the most of the users of this area are students and staffs of the Vancouver Campus as students will pass this area to come and go to class during the weekdays. Therefore, this road will become extraordinary busy during the class shift. Other than being used as scenery, the plants can also serve as water storage. The rainwater will be absorbed first by the nearby vegetation when it rains. So the Main Mall can avoid being flooded during the raining days. In addition, there are many types of facilities, which includes footpaths, benches, street lights, wayfinding signages, the UBC Engineering Cairn, and grass lawns. In total, there are 51 trees located in this collection area and the age of trees ranges from young saplings to some of the earliest original Red Oaks that were planted in the 1920s (Figure 2) (The University of British Columbia, n.d.).

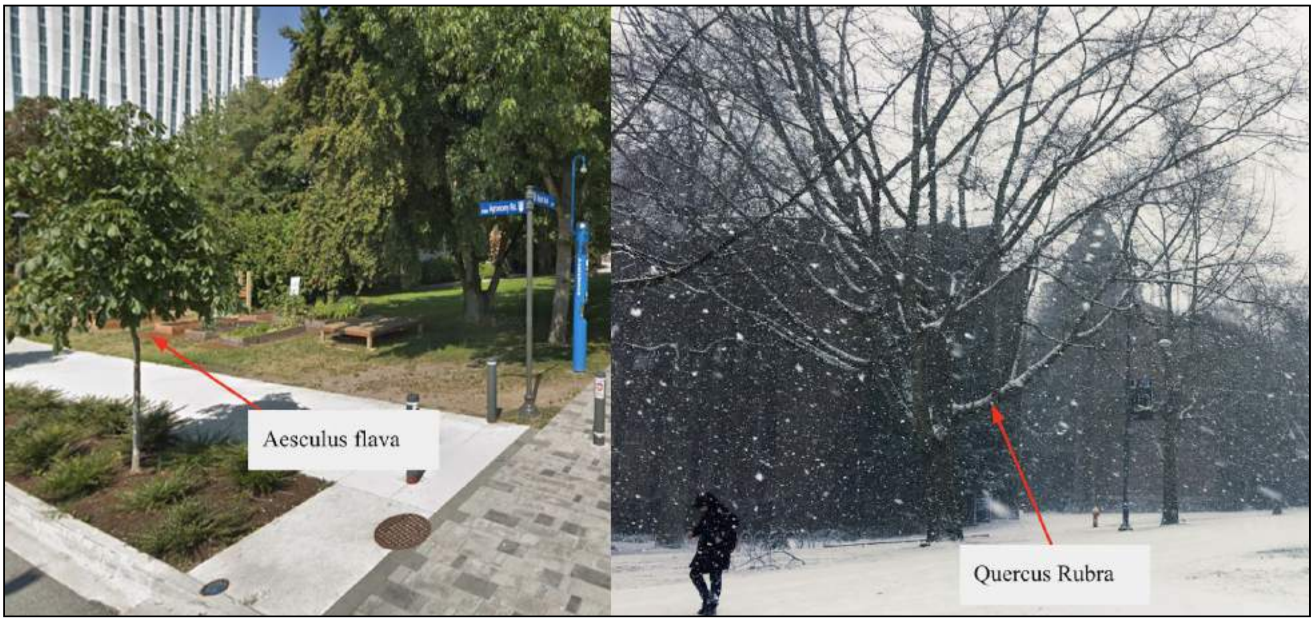

Figure 2: Young Aesculus flava tree (left, from Google Maps)) and old Quercus Rubra tree (right, taken by Xin Weng) in the collection site (Google Maps, 2018)

3. Methodology

Variables Measured:			Variables Calculated:
Living Status (L/D)	Degree Value of Sight to the Base of the Tree From Measured Distance (BASE-TTH)	Long Side of Crown Width (LONG)	Total Tree Height (TTH)
Height of Diameter at Breast Height (HT DBH)	Degree Value of Sight to the Top of Live Crown From Measured Distance (TOP-LCH)	Short Side of Crown Width (SHORT)`	Live Crown Height (LCH)
Tree Stem Diameter at Breast Height (DBH)	Degree Value of Sight to the Base of the Live Crown From Measured Distance (BASE-LCH)	Percent Crown Missing	Crown Base Height (CBH)
Distance from Tree (DIST)	Degree Value of Sight to the Top of Crown Base From Measured Distance (TOP-CBH)	Crown Light Exposure (CLE)	

Degree Value of Sight to the Top of the Tree From Measured Distance (TOP-TTH)	Degree Value of Sight to the Base of Crown Base From Measured Distance (BASE-CBH)		

Table 1: All variables involved in tree inventory collection

This section will describe the processes used for inventory data collection on Main Mall of the UBC campus. The various types of equipment and tools used to measure different aspects of the trees will be discussed. In addition, the specific methods used to analyze the raw and processed data will also be explained. Finally, a table with all the calculated and measured variable will also be added.

The first step of collecting data for a tree inventory is to record the Tree ID and species found in the ArcGIS collector app, a mobile app designed for fieldworkers. A tag ID should also be recorded if a physical tag is found on the tree trunk. In addition, one should also identify the land use around the specific tree being evaluated from various i-Tree Eco categories. To finish the initial data collection process, it is crucial to determine whether the tree is alive or dead.

The first variable measured is the tree stem diameter at 4.5 feet above the ground, the adult breast height convention (Oakville, n.d.). A diameter-tape is used to wrap around the trunk and the reading is recorded. Furthermore, it is important to note that this method only applies to trees with a single stem. Trees with multiple stems will require each stem to be measured separately and the overall tree stem diameter at breast height (DBH) of the particular tree is given by the square root of the sum of all squared stem DBHs (Devisscher, 2019). The second variable measured is the total tree height (TTH), the height from the ground to the top of the tree. This is done by using a clinometer, a device that encompasses two scales to measure tree height. Using the clinometer, a degree reading from looking at the top of the tree and the base of the tree should be recorded while standing from a measured flat (0 horizontal elevation) distance from the tree. The total tree height can be easily calculated with a simple trigonometry equation: Tree height = (tan a° + tan b°) * distance from the tree (Devisscher, 2019). An alternative process, also known as the percentage scale, can also be utilized to evaluate the TTH. To use the percentage scale, a percentage value should be taken instead of the degree when looking at the top and the base of the tree with a clinometer. The two percentages can then be used to calculate the TTH with the following equation: (|Top %| + |Base %|) * distance measured from the tree (Devisscher, 2019). Similarly, the live crown height (LCH) and crown base height (CBH) can also be determined with the same percentage or degree method aforementioned. The equations for the degree and percentage technique for LCH and CBH are as followed: LCH = (tan a° + tan b°) * distance, LCH = (|Top %| + |Base %|) * distance, CBH = (tan a° + tan b°) * distance, and CBH = (|Top %| + |Base %|) * distance (Devisscher, 2019).

The next variable measured is the crown width (CW); this can be accomplished with a tape measure. The width of the crown should be measured in two directions: long side and short side. Crown width can be found by taking the average of the two measurements: short side + long side = CW (Devisscher, 2019). To finalize the tree data collection, visualize the typical crown outline and estimate the absent foliage to make evaluate the percent crown missing. The final step is to find the crown light exposure (0-5) by counting the number of sides the crown is exposed to light.

Species composition, total tree height, tree stem diameter at breast height, and species dominance are some of the ways that one can use to interpret and analyze analyze the data collected. Bar graphs, pie graphs and scatter plots can also be used to present the aforementioned methods.

4. Summary

The section will analyze the data collected through various methods: species composition and dominance, total tree height, crown width and tree stem diameter at breast height. These methods will be presented with a variety of graphs and charts. Overall, the field area has 51 trees, all of which are alive. And there is one tree that has no name recorded (4065) and one tree's crown width was estimated instead of measured because of its proximity to the fence (2181).

4(a). Species Composition

Species	Trees	Species	Total Basal Area
Quercus rubra	27	Quercus rubra	7.36
Acer palmatum	6	Acer palmatum	0.17
Quercus palustris	3	Quercus palustris	0.92
Fagus sylvatica	2	Fagus sylvatica	0.57
Aesculus flava	2	Aesculus flava	0.01
Airbus aria	1	Airbus aria	0.01
Cupressus lawsoniana	1	Cupressus lawsoniana	0.26
Acer davidii	1	Acer davidii	0.04
Robinia pseudoacacia 'Unifolia'	1	Robinia pseudoacacia 'Unifolia'	0.34

Tsonga heterophylla	1	Tsonga heterophylla	0.16
Magnolia	1	Magnolia	0.02
Corylus sp.	1	Corylus sp.	0.02
Cornus kousa	1	Cornus kousa	0.41
Quercus palustris	1	Quercus palustris	0.25
Fraxinus	1	Fraxinus	0.57
Unknown	1	Unknown	0.02

Table 2: Species composition data, including abundance and dominance (basal area)

As the above table shows, the abundant tree species in this collection site is the Quercus rubra. There are 27 Quercus rubra in the collection area and six Acer palmatum. The third most abundant tree is the Quercus palustris with three, and is followed by Fagus sylvatica and Aesculus with two each. There is only one of each kind of the remaining species. From this graph, one can easily figure out that the 27 Quercus rubra take up about more than half of the total tree population in this area. Furthermore, the Acer palmatum are growing together in a very close area near the wall which reflects the lack of healthy place for the trees to grow. The dominant tree species in the collection site is also Quercus rubra, with a total basal area of 7.36 meters^2.

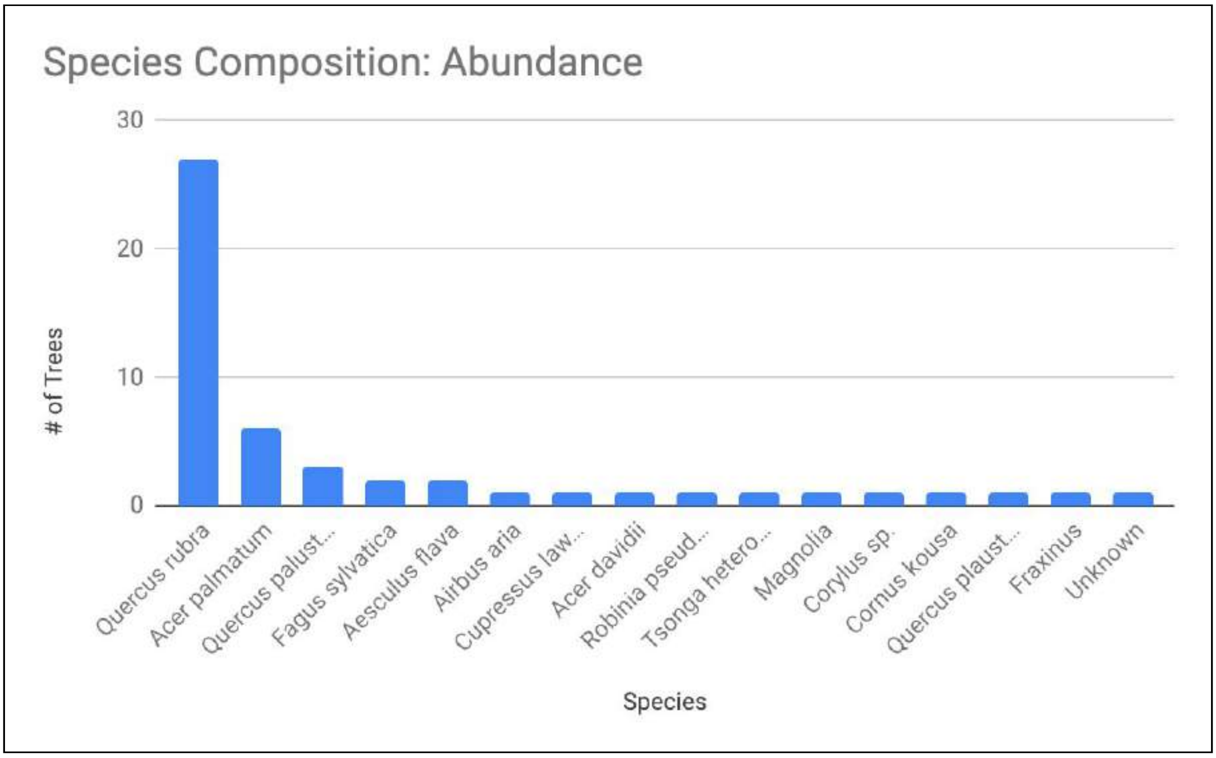

Figure 3: Species abundance of the tree inventory data

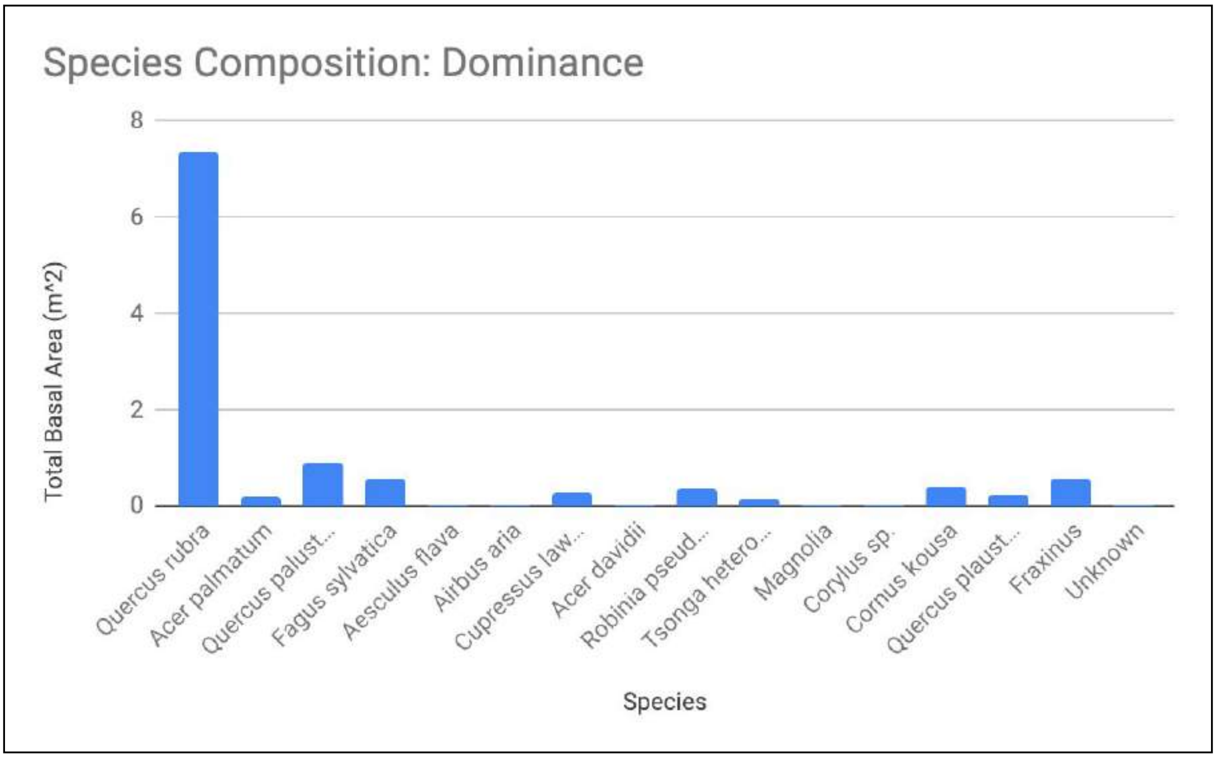

Figure 4: Species Dominance of the tree inventory data

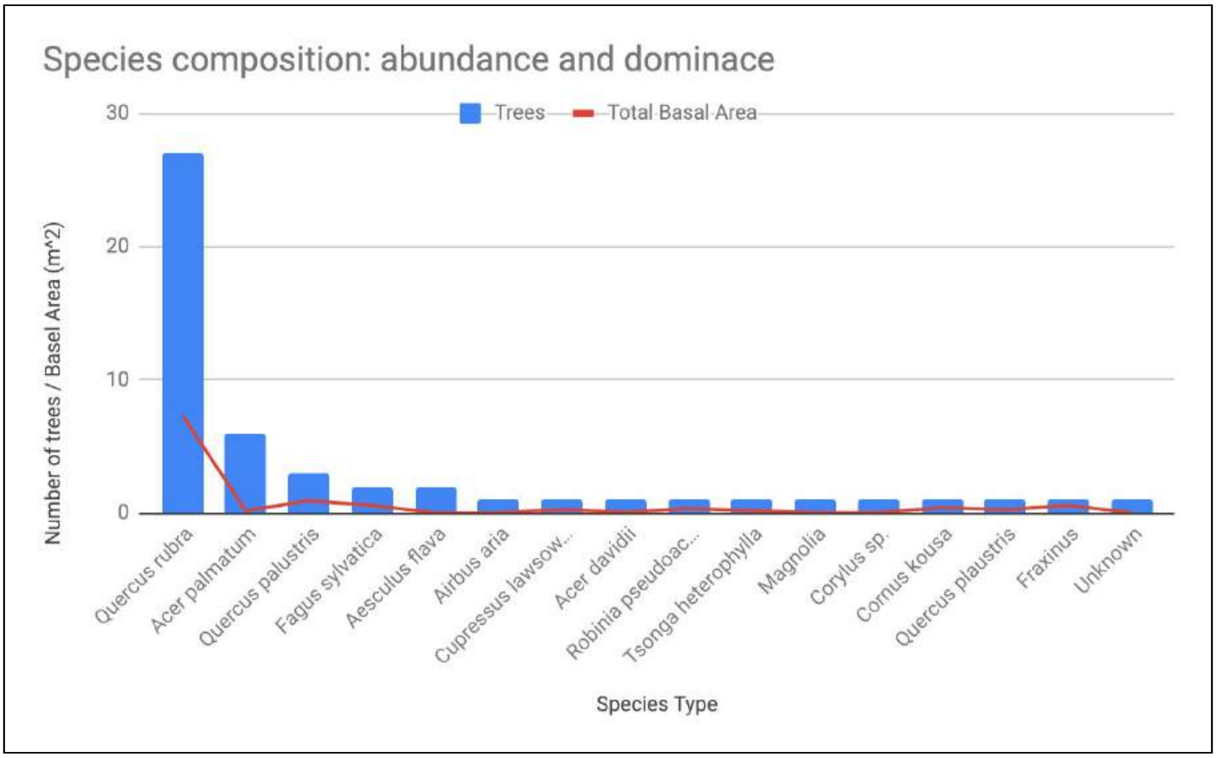

Figure 5: Species Abundance vs. Species Dominance of the tree inventory data

Figure 5 shows an anomaly that although Acer palmatum is the second most abundant tree in the collection site, but has a lower dominance than Quercus palustris and Fagus sylvatica. This can be justified for the fact that the Acer palmatum in the collection site are rather young, and have a much less basal area.

4(b). Total Tree Height

Figure 6: Total tree height of the trees

Out of the fifty trees that were surveyed at the South end of Main Mall, tree heights spanned from approximately three to thirty metres. However, the majority of the trees in this area can be categorized into the ten to twenty-metre group with twenty-five trees falling into this height range as shown by the graph. The category with the second most abundance of trees was the twenty to thirty-meter group with fifteen trees spanning between those heights. Finally, there are eight trees between zero and ten meters, and two that were taller than thirty meters in height. As for the tallest tree, a Quercus Rubra tagged 1950, was measured at 30.37 meters tall, where the smallest tree was a 2.97 meter Aesculus Flava tagged 2153. See the below graph for all height data

4(c). Tree Stem Diameter at Breast Height

The next aspect of the tree that is being analyzed is the diameter at breast height (DBH). A tree's diameter at breast height is important to know because it can help find other important values from a tree such as tree growth, wood volume, basal area, and other useful figures. For the trees surveyed, there was no category that dominated the others like previously shown in tree height. Fifteen trees had a DBH of fifty to eighty centimeters, fourteen with a DBH ranging from ten to thirty centimeters, and twelve trees with a DBH ranging from thirty to fifty centimeters. Of the remaining nine trees left in the area, two of them had a DBH of zero to ten centimeters and seven fell into the eighty to hundred-centimeter category. As expected, the Quercus Rubra that measured in at 30.37 metres also had the highest DBH of 96.2 centimeters to be exact. Likewise, the smallest tree, a 2.97 meter Aesculus Flava had a DBH of just six and a half centimeters.

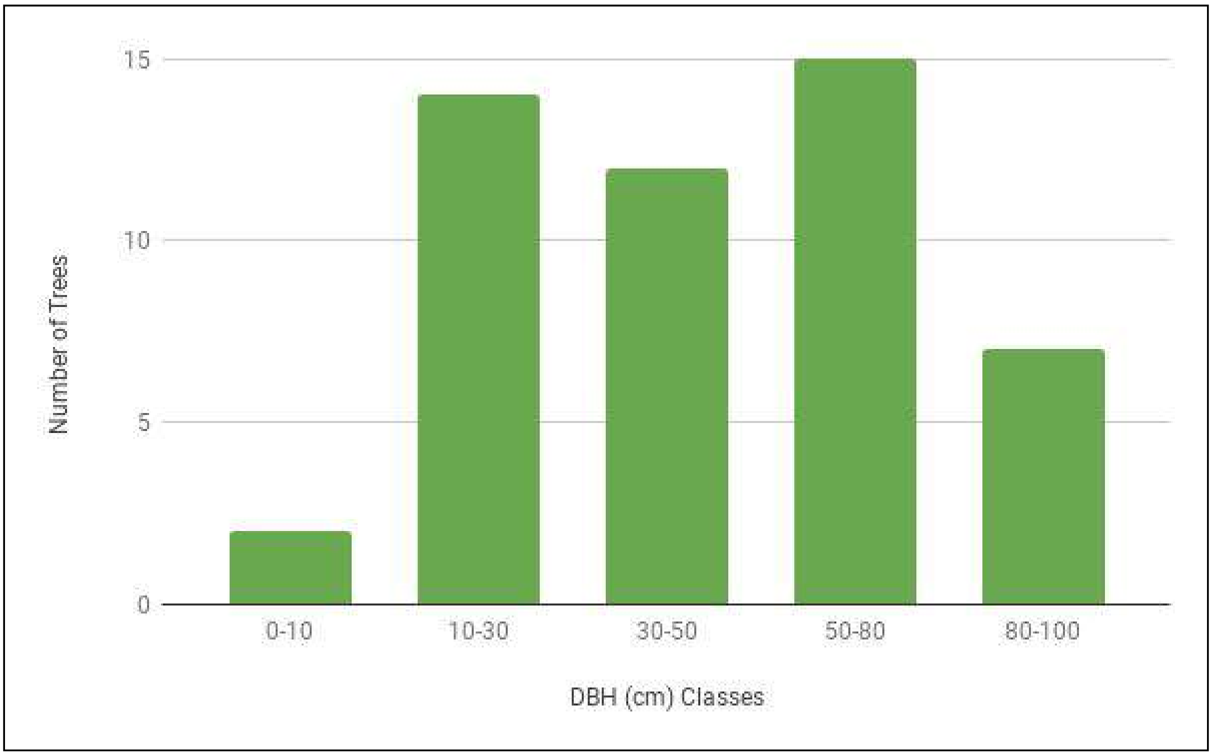

Figure 7: Diameter of Breast Height classes of the trees

4(d). Crown Light exposure

Crown Light Exposure	# Trees
1 side	5
2 sides	21
3 sides	24
4 sides	0
5 sides	1

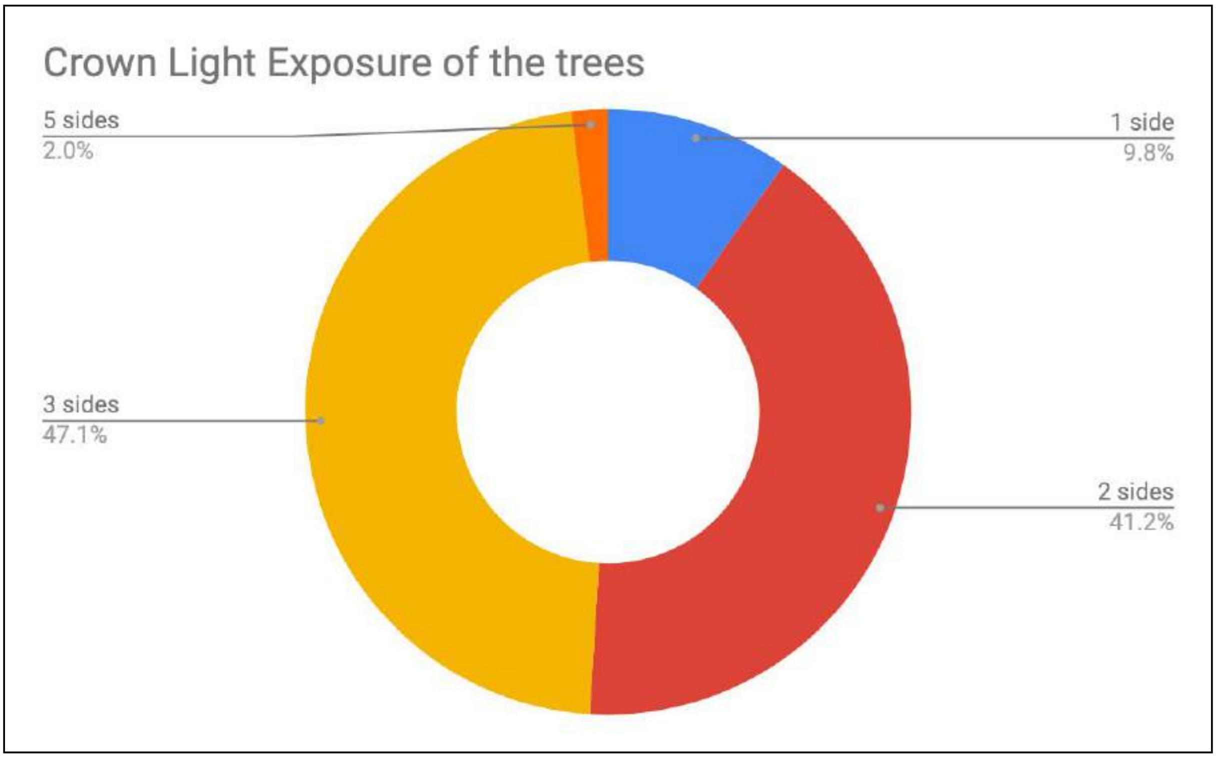

Figure 8: Crown light exposure of the trees

From the diagram "Crown light exposure", that could see clearly that 3 sides crown light exposure with 22 and 2 sides light exposure with 21 are the first two at most of the whole trees. The main reason for this is because these trees grow in rows and are planted next to buildings. And it has a connection between sides of tree exposed to sun and crown percentage missing, the more sides of tree exposed to sun, the less percentage of crown missing happened. Furthermore, Most of the trees along main mall are the Quercus rubra. Most of the Quercus rubras in this area are around the same 16 to 23 meters and have similar crown width and percentage of crown missing. The data suggests that most of these trees were planted around the same time due to the similarities and the fact that they were grown in the same environment.

5. Conclusion

The urban tree inventory conducted at the University of British Columbia provides the baseline data that is required for efficient and effective urban forest management. The inventory data acquired will allow managers to understand the full range of ecosystem services the trees at the University of British Columbia provide. The methods used to collect this data is highly accurate and organized. It can be concluded that the site has a vast biodiversity with Quercus rubra being the most dominant species along main mall.

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Contribution Description

Adrian Lee	Introduction, Conclusion, Summary of tree inventory data
Paul Liu	Inventory table, Site description, Summary of tree inventory data
Simon Lin	Methodology, overall editing and proofreading, organize/format
Ming Lou	Site description
Xin Weng	Inventory table, Summary of tree inventory data
Jack Robertson	Summary of tree inventory data