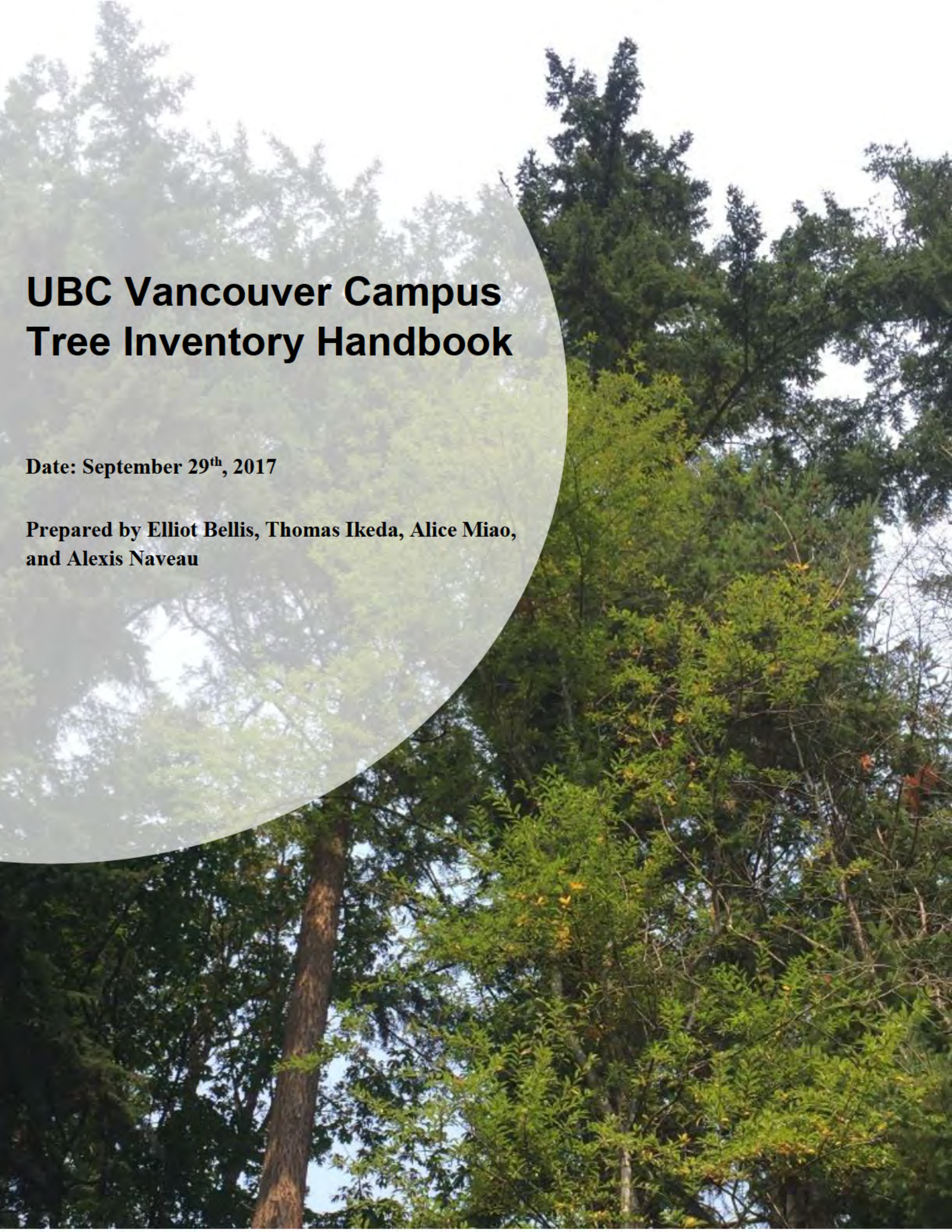

UBC Vancouver Campus Tree Inventory Handbook

Date: September 29th, 2017

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Dear Tree Inventory Participants,

With your help, the University of British Columbia will collect valuable records on the campus tree population. This information, upon the request of Campus and Community Planning, will be used to implement the Urban Forest management plan and Biodiversity Strategy and provide detailed information on the UBC campus urban forest.

This handbook was designed to assist your understanding of the project and the methods to conduct and carry on the tree inventory in the original intended manner. It will serve as a reference for data collection and data input associated with this inventory.

Hopefully, you will gain knowledge of urban tree management while giving back to a valuable database for the UBC community. This project will not only aid in providing campus planners with up-to-date tree information, but will also contribute to a historical log of the University of British Columbia's campus tree canopy.

Sincerely,

UBC Student Tree Inventory Team

forestry
university of british columbia

1. Introduction

Tree inventories are a foundational part of an effective approach to urban forest management. They can enable managers and planners to quantify ecosystem services (such as storm water management, energy efficiency, cooling, air quality improvement, contributions to public health, etc.), provide data to prioritize tree and urban biodiversity management, and aid in future campus development (Elmendorf, 2015). Additionally, a regularly updated tree inventory allows urban forest managers to monitor and manage campus forest resources as they change over time. Moreover, it also provides an opportunity for identifying and conserving heritage and other special trees.

In contrast to a conventional forest inventory, which is commonly conducted in remote, sometimes mountainous areas with uneven terrain and relatively few tree species, an urban landscape requires a slightly different approach. Due to the greater focus on individual trees and the need to develop inventory methods that are effective and (cost-)efficient, remote sensing technology is an important tool. Specifically, lidar is a valuable tool for an urban forest inventory because tree location, height, and crown area can be extracted remotely. Also, it is possible to identify the species of every tree lidar identified when used alongside rectified orthographic photos. Finally, UBC collects lidar data of the Vancouver campus regularly every year. These factors make lidar the most efficient option for a campus tree inventory.

This handbook was created to outline the next steps for the UBC Vancouver Campus Tree Inventory Project following the initial pilot project at the Stadium Neighborhood conducted in the summer of 2017 (Bellis *et al*, 2017). This handbook provides information on how to develop an urban forest inventory relying on lidar as well as detailing field work procedures in relation to this project.

This report presents a step-by-step guide for future inventory projects and the monitoring of the urban forest. First, it introduces how lidar will be used in the future inventory. Next, it describes how to approach a field work, the equipment used in-field and measurement attributes needed, and how to incorporate GPS software. Finally, it presents how to conduct a simple tree health and risk assessment[1].

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[1] *This handbook outlines only general steps that are involved in the campus-wide urban forest inventory project. Adjustments may be required as the project evolves*

2. Steps of Lidar Tree Crown Identification Accuracy Analysis

Before creating a tree inventory based on lidar data, it is critical to have highly accurate lidar data. To assess this accuracy, a ground-truthing survey (i.e field data) of all trees is required as the first step of an accuracy assessment as well as the first step for the creation of a tree inventory. Each algorithm used for the creation of the lidar data should be tested with an accuracy assessment. Due to the variety of forest types on campus, different algorithms will need to be tested periodically. For the 2017 Pilot Project, our team did not achieve a high accuracy, so it must continue to be improved before having a tree inventory based on lidar. This process involves two steps: 1) ground truthing field work and 2) lidar tree crown identification accuracy analysis and algorithm adjustment.

2.1 Ground Truthing Field Work

To assess the accuracy of the lidar data, a ground-truthing survey is needed to measure all trees in the project area. Therefore, field work is required by measuring at least the height, crown width as well as diameter at breast height (DBH) for all the trees within the project area (See Section 4 of this Handbook for more details on "How to Approach Field Work").

2.2 Lidar Tree Crown Identification Accuracy Analysis and Algorithm Adjustment

As mentioned earlier, for the creation of a tree inventory, it is desirable to get as close as possible to 100% accuracy of lidar tree crown identification. To address this, accuracy assessment is needed to test each algorithm. A different algorithm may be needed for different forest types on campus due to different forest structures. This portion of the project will be handled by the Integrated Remote Sensing Studio (IRSS) lab.

3. Steps to Create an Urban Forest Inventory Using Lidar Data

Once the lidar tree crown identification has reached a high level of accuracy (roughly 75% – 99%), the lidar data can be used as the foundation for the UBC Vancouver Campus Urban Forest Inventory. It will provide highly accurate data on tree identification, tree height, and tree crown area. This inventory data will also allow us to monitor canopy cover change over time on campus, and further calculate tree volume, campus carbon storage status, above/underground biomass which, in turn, will help to assess campus carbon balance.

This process can be organized in these four steps (See **Figure 1**):

1. Tree Census Using Lidar Data and Rectified Orthographic Photos

Extract a tree census from lidar data with attributes, including:
1. GPS locations of each tree (X,Y)
2. Crown Size
3. Height
Record deciduous or coniferous (or other species groups) from rectified orthographic photos

↓

2. Ground Survey

Collect sampling data in-field via stratification:
1. Classify trees from census from step 1 based on small, medium, large crown size class, height class and by species groups.
2. Divide the number of sample trees by the total number of possible combinations of all strata.
4. Determine the number of trees to be sampled in-field based on time limits and randomly select this number of trees from each stratum.
5. Find the exact tree on site based on GPS locations from the census data.
6. Record species and DBH and other desirable attributes.

Note: Stratification can be more detailed depending on species groups (down to genus).

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3. DBH Model(s)

Use statistical analysis tool "R" to develop a DBH model in relation to height and crown size for each species/species groups.

Add estimated DBH to the census.

Note: Other models can also be built. For instance, DBH model in relation to lidar hits and crown

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4. Continuous Tree Inventory Maintenance

1. Obtain new photo/lidar data every year (UBC already collects this data annually).
2. Compare previous year's census with new tree census.
3. Conduct in-field survey when needed (i.e. when anomalous data identified).
4. Update the tree census annually.
5. Import data into the model to estimate DBH in census.
6. Complete inventory updates when there is new planting of trees/cut downs on campus. Can be completed by community engagement or a UBC employee who will be assigned for this particular task.

Note: This inventory data will allow us to further calculate tree volume, campus carbon storage status, above/underground biomass which, in turn, will help to assess campus carbon balance.

Figure 1: Tree Inventory Methodology

4. How to Approach Field Work

4.1 Field Work Process[2]

To conduct the field work for a tree inventory, there are seven steps to follow:

First, define the area to be measured. This step includes drawing boundary lines for this area, defining proper terminology for the area selected, and calculating an estimate for the number of trees to measure and the amount of time required.

Second, select the attributes you wish to measure for the tree inventory in addition to DBH. Included in this handbook are the attributes measured for the Stadium Area, but these can be adjusted based on the time frame and the type of additional information to be analyzed.

Third, after determining the attributes, create a field card showing these attributes that will be printed and used to record the field measurements.

Fourth, acquire the tools necessary for measuring each attribute.

Figure 2*: Overview of steps for approaching field work*

Fifth, divide the area into subzones depending on the size and topography of the area. Doing so allows for easier planning and simplifies the final database that will be created for the tree inventory area. Again, agree upon the terminology that will be used for each subzone and make note to the use of the terms throughout the project consistently.

Sixth, determine what method will be used to locate trees. While the 2017 team used the Avenza Maps ™ application, there are other ways to locate these trees such as printing out paper maps. These maps will be used to incorporate the lidar into the field work.

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[2] *Refer to **Figure 2** for an overview of steps*

Finally, conduct the field work. After each day of field work, please remember to manually enter the information from the field cards into the database and save all paper copies of the field card as reference.

4.2 Field Equipment

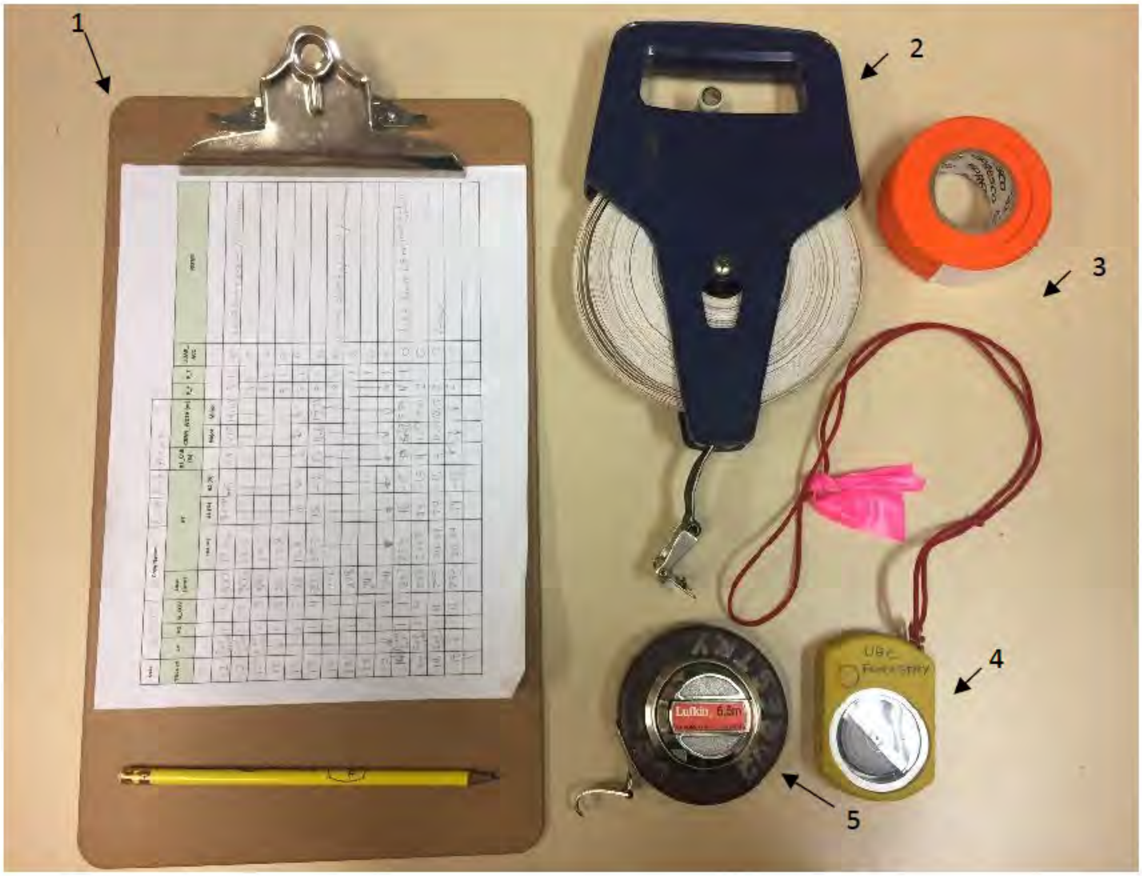

Image 1. *Suggested equipment; used by 2017 tree inventory team*

Each team should have access to (See **Image 1** above):

1. Clipboard with Field Card and pencil
2. Eslon tape
3. Biodegradable flagging ribbon
4. Clinometer or (not shown) laser range finder
5. Diameter tape (D-tape)
6. Field safety vests (not shown)
7. GPS locator (either with use of phone or professional grade unit)
8. Camera

4.3 Avenza Maps ™

There are various options in terms of choosing a method for finding trees and recording their GPS coordinates. Our team used the **Avenza Maps ™** application (See **Figure 3**), compatible with all Android and Apple devices (Avenza Systems Inc., 2017). The application makes locating a tree easy by allowing you to find your coordinate location and drop a pin as to where that location is on a user-uploaded map. Synchronicity with ArcGIS makes it easy to import a PDF map directly into the application; points marking each tree that are collected in the field can, in return, be uploaded back into ArcGIS.

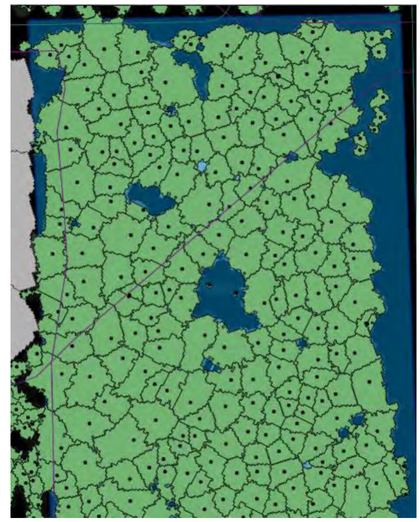

Figure 3*. Avenza Maps ™ example showing lidar tree crowns and tree tops*

4.4 Filling Out the Field Card

This section includes information regarding filling out the field card during the field work. Tree identification strategies, measurement methods, and tree health and risk ratings will be explained in the following sub-sections. After completion of each field card, data should be entered into an excel spreadsheet and combined with existing tree inventory database.

4.4.1 General Information

Survey Date and Time - the day and time of survey.

Crew Initials - list all present team members.

Stand ID/ Map ID - Number corresponding to GIS map view & reference dataset

4.4.2 Tree Information

Tree Tag ID - the tree ID number continuing from last recorded ID # (see 2017 database)

Species Name - enter scientific and common name of species. For instance, *Pseudotsuga menziesii*, Douglas-fir.

Alive or Dead - Record a '**1**' if tree is alive and **'0'** if dead.

Groundcover - an estimate of the vegetation around tree site measured 1 meter on all sides of tree based on rating scale. Reference **Figure 4** below:

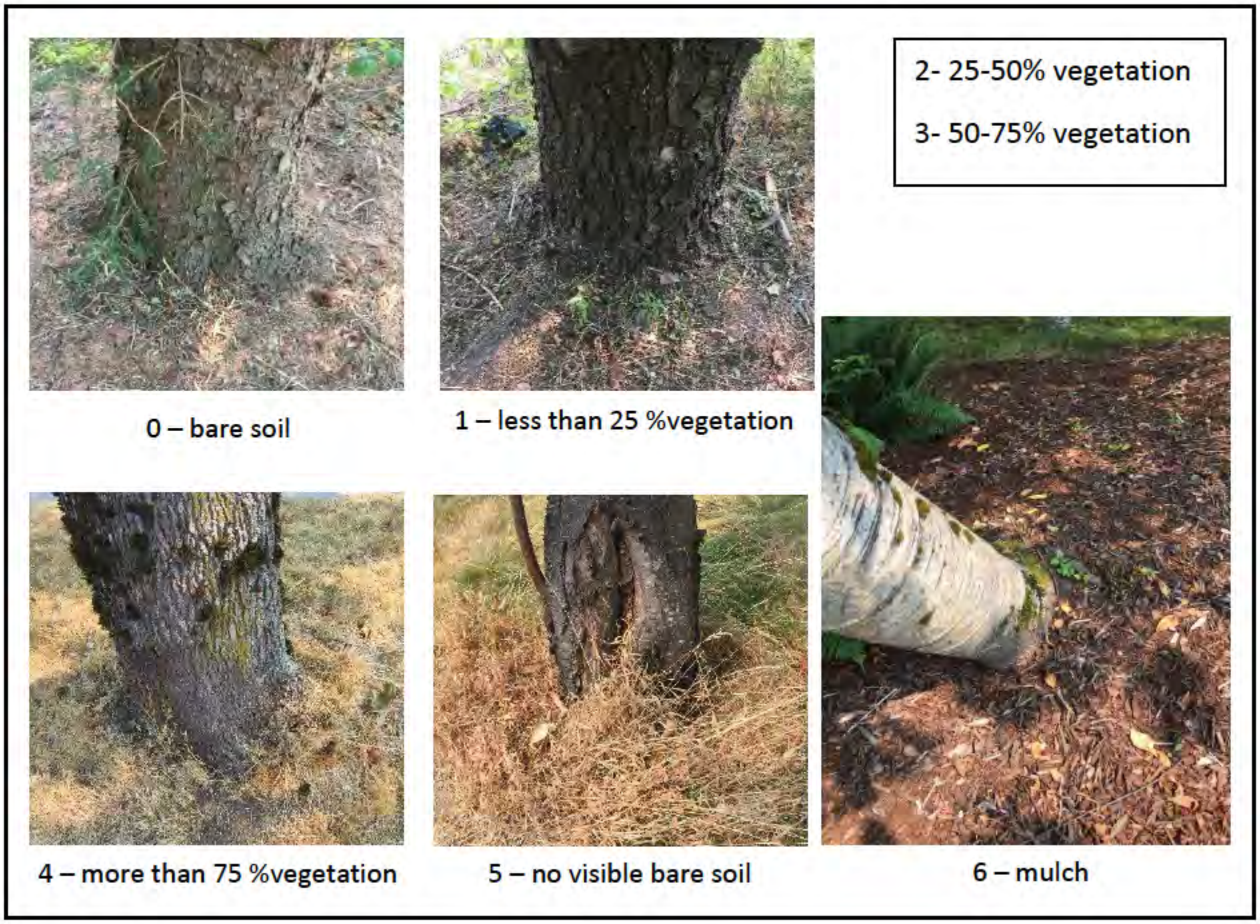

Figure 4*. Scale for measuring ground cover as a percentage*

Measured DBH - The diameter at breast height (roughly 1.3 m). Stick hook of a d-tape (see section 3.4) into the tree bark at breast height. Wrap tape perpendicular to the central axis of the trunk and record value in mm.

Total Tree Height - Using a clinometer or laser range finder (see **Image 2**), record top angle (a_1%) at the tree top, the bottom angle (a_2%) at the base of the tree and the horizontal distance (HD) between the surveyor and the tree using a measuring tape (see **Image 3**). Then calculate the tree height using **formula[3] [1]** in excel:

$$\text{Tree Height (m)} = \frac{a_1\% - a_2\%}{100} \times HD(m) \qquad [1]$$

[3] *The above equation is used only if using the clinometer method. The laser range finder will calculate height automatically.*

Image 2. Measuring the horizontal distance to surveyor

Image 3. Using a clinometer to record the top angle

Live Crown Height - The total height of the live crown in meters. Measure the distance from the tree top to the lowest branch of the living crown.

Tree Crown Area - The total area of the tree crown measured in m^2, acquired from the **lidar data**.

Crown Width - measured in the field on the major and minor axis in meters. See **Image 4**.

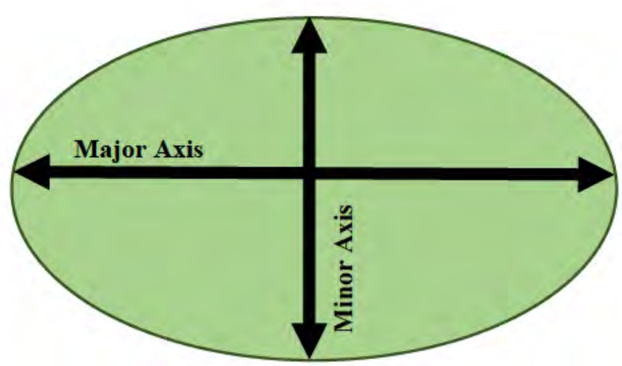

Image 4. Measuring crown width

Longitude and Latitude - GPS point location of tree measured as close to base of tree as possible. Can be measured in UTM and converted.

Probability of Failure - The probability that a tree will die / fail as indicated in the Tree Health and Risk Assessment section (see **Table 1**).

Table 1. *Ratings of probability of failure*

Probability of Failure Rating	
1	Decay <25%, minor architectural problem
2	Decay 25-40%, single crack, minor root damage
3	Decay 25-40%, multiple cracks, moderate root damage
4	Decay 25-40%, dead wood, large cracks
5	Decay >40%, dead wood, severe damage

Probability of Target - The level of human use in the immediate vicinity of the tree as indicated in the Tree Health and Risk Assessment section (see **Table 2**).

Table 2. *Ratings of probability of target (International Society of Arboriculture, 2017)*

Probability of Target Rating	
1	Occasional Use; i.e. forest, quiet path
2	Moderate Use; i.e. quiet park, street trees
3	Heavy Use; i.e. school playground, popular park

Lidar Accuracy - An indication of an 'accurate' located tree. Scenarios and their codes include:

Table 3. Lidar accuracy codes (International Society of Arboriculture, 2017)

0	1:1 Only one tree in field is corresponding to one lidar canopy
1	1:0 Tree is identified by lidar but doesn't exist in field
2	0:1 Tree is not identified by lidar bust exists in the field
3	1:X Multiple trees are found under one lidar canopy.

Tree ID of Adjacent Identified Tree - the nearest tree identified by lidar[4].

Distance to 1 - measure the distance to the adjacent tree via Avenza[5].

Tree ID of adjacent identified tree #2 - Repeat for a second tree to allow for triangulation.

Distance to 2 - the distance to the second adjacent tree - Repeat for a second tree to allow for triangulation.

Notes - Record as detailed an observation you can give which may include mechanical damage and other damage/health problems.

Photo ID - Take picture if species cannot be identified in field or a further health and risk assessment needs to be conducted. Pictures can be referenced with the same Tree ID # and should be uploaded into a cloud storage program such as Flickr.

5.0 Identifying Tree Species

5.1 Tree Type

Determining whether the tree is deciduous or coniferous is the easiest step in narrowing option. Generally, conifer species have needle leaves and cones and deciduous species have leaves and berries/seeds. Important to note, a good tree identification handbook is critical. Some helpful books include "*Plants of Coastal British Columbia"* by Pojar and Mackinnon, "*National Audubon Society Field Guide to North American Trees*" by the National Audubon Society, and "*Trees of the Northern United States and Canada*" by John Farrar.

5.2 Leaves

It is important to look at both the overall leaf shape and the leaf margin (the edge of the leaf). These characteristics are important distinctions that can be made for different species and often allow for the identification or narrowing down of identification. The arrangement of the leaves, needles, branches, and buds can also allow for differentiation.

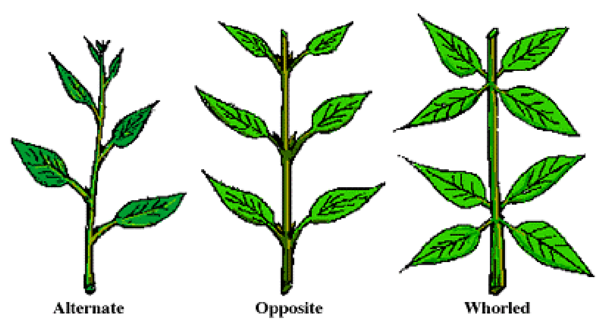

Figure 5. *Leaf arrangements from www.horton.ednet.ns.ca/staff/Richards, 2017*

For instance, how are the buds, leaves, or branches connected (See **Figure 5**)?

Opposite- 2 at a point directly opposite each other

[4] O*nly complete if tree scores a '2' in the Lidar accuracy*

[5] *Only complete if tree scores 2*

Alternate- staggering, no two buds, leaves, or branches are opposite

Whorled- bud, leaf, or branch is opposite with 3 or more at a connection point

5.3 Fruit/Seed

An easy indicator if present during the flowering season, the fruit or cone can be an important factor in the identification process. Look at type of fruit, size, and colour.

Figure 6. *Different plant fruits from Texas Forest A&M Service, 2017*

5.4 Bark

Some trees have very distinctive bark patterns or peeling patterns to look out for species identification. They can be smooth, rough, peeled, flakey etc.

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