SEEDS KNOWLEDGE EXCHANGE:

Tree Inventory Toolkit

Toolkit Guide

Acknowledgements

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1. *The UBC SEEDS Sustainability Program is an internationally recognized Campus as Living Laboratory initiative, that advances UBC's sustainability and wellbeing commitments through applied student-led research and interdisciplinary partnerships between students, faculty, staff and community partners.

2. ***Climate Crisis in Urban Biodiversity (CCUB) is an initiative aimed towards co-creating interdisciplinary, demand-driven, diverse, and inclusive student-led research that informs urban solutions to the climate and biodiversity crises simultaneously. CCUB was launched as a PURE (Program for Undergraduate Research Experiences) funded pilot as part of the SEEDS Sustainability Program in partnership with the Faculties of Arts, Forestry, Science, and others.

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About this Tree Inventory Toolkit

Toolkit Purpose:

Each Toolkit in the **Urban Biodiversity in a Changing Climate ToolTree** aims to support applied student-led research projects in partnership with UBC faculty and staff in ways that can help advance UBC's sustainability and wellbeing commitments. This Toolkit is designed to share learnings from the student-led Campus Tree Inventory on the UBC Vancouver Campus (2018-present), which has been identified as an important part of supporting healthy urban ecosystems, and interdisciplinary and applied research to advance UBC's sustainability commitments. This Toolkit describes the general process of conducting a tree inventory, and uses the ongoing UBC student-led Campus Tree Inventory as a case study to show how this practice can be implemented.

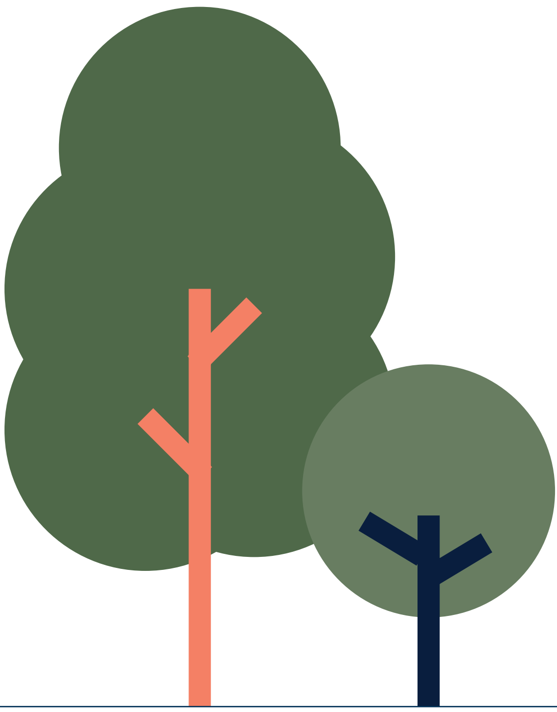
Who is this Toolkit for?:

UBC STUDENTS:
Tools can be used to support student applied research to inform UBC's guiding sustainability policies and commitments, and professional skills development related to the complex challenges connected to climate change and its impacts on biodiversity.

UBC OPERATIONAL STAFF:
Serve as a collection of summarised knowledge and lessons learned from student-led research, to continue and inform UBC's guiding sustainability policies and commitments and the areas of work which have inspired and guided the direction of SEEDS research.

UBC FACULTY:
Serve as a resource to integrate biodiversity and climate topics into curriculum, and support student research and professional skills development.

UBC COMMUNITY:
Promote community engagement and collaboration on biodiversity and climate change challenges and opportunities at UBC and beyond.



What will you Learn?

This toolkit covers a number of topics related to the student-led campus tree inventory. Learning outcomes include:

1

Learn about tree inventories, including key concepts, how they are carried out, why they are important, and how they relate to urban biodiversity in a changing climate.

2

Learn about key takeaways from applied student-led research on a tree inventory at UBC, and how it can apply to landscape planning and design.

3

Learn about the steps and tools to conduct a tree inventory on your own.

How to Use This Toolkit to Conduct Your Own Tree Inventory:

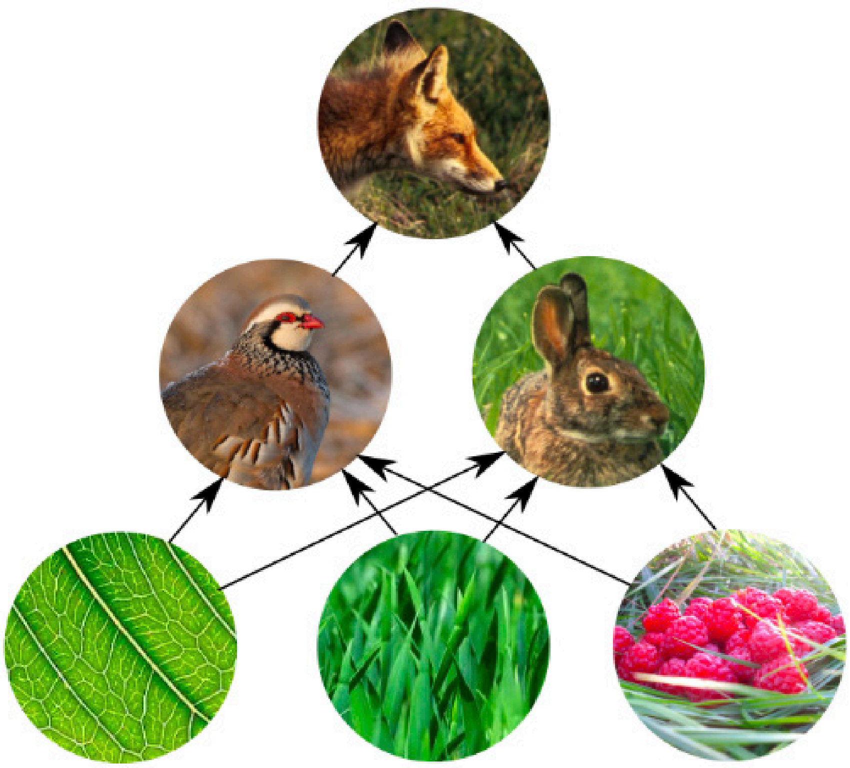
This Toolkit can be used by anyone who is interested in conducting a tree inventory of their landscape. A completed tree inventory enables many different variables of the urban forest to be measured, which can help to inform estimates of regulating ecosystem services provided by trees (carbon sequestration, erosion control etc.). These estimates are crucial in informing urban landscape management and planning considerations. This Toolkit includes the steps to complete a tree inventory including: an overview of foundational terminology, data collection process and tools, analysis and visualisation.

About Tree Inventories

What is a Tree Inventory?

A tree inventory refers to a systematic process of gathering information on various attributes of trees including tree species, health, location, size and ecosystem services. There are many different types of tree inventories that serve various purposes. Inventorying has been used in a broad range of forest management practices, from conservation to conducting analyses of urban natural assets. Tree inventories can provide a critical foundation to inform effective urban forest and landscape management practices, policy, planning, and design of urban greenspaces. Inventories play an important role in understanding the contributions of forested ecosystems to local communities.

Tree inventories and the datasets they produce also act as a starting point to inform future greenspace and biodiversity research which can include observations of other species besides trees. One way of doing this is by building a trophic web (see right). In natural systems, all organisms (animals, plants, fungi) are arranged in a web of interactions. This web can roughly be categorised into different categories, often referred to as the trophic levels. These levels show what species in a food web rely on for sustenance and habitat. At the base of each web stand the "autotrophs" — trees and other photosynthesizing plants that can make their own energy from sunlight (Tavella et al. 2022). Cataloguing this base level by looking at trees first can give insight into what other organisms the foodweb can support. This makes the urban forest inventory a crucial tool in informing sustainable management of campus greenspaces.



An example of a trophic web, showing the relationship between a fox, partridge, rabbit and plants. Courtesy of Wiki brain, CC BY-SA 4.0, via Wikimedia Commons.

Key Terms used in this Toolkit

BIODIVERSITY

Biodiversity of an urban forest refers to the number of different tree species found within a given area. This diversity has a direct impact on the roles, ecological niches, and ecosystem services performed (Reis et al. 2021). Species richness, the number of species in a specified area (Conway and Bourne, 2013), is a central theme of this inventory and is the basis for UBC's sustainable management.

ECOSYSTEM SERVICES

Ecosystem Services refer to the benefits humans and other living organisms gain from natural systems, resulting from processes conducted by actors within the system (Munang et al. 2013). Evaluating ecosystem services is a complex process and is quite contested, with multiple different frameworks existing. It is important to acknowledge that not only do trees have their own intrinsic value, but also the subjectivity of the benefits provided by ecosystems to human users. However, measuring these services can highlight the monetary value these trees contribute to an area and provide a sort of economic capacity, incentivizing maintenance/expansion of the urban forest.

SPATIAL ANALYSIS

In this project, spatial analysis is referring to observations made on the composition of the urban forest and how this composition affects its productivity, adaptation capacity, and health. For the UBC Vancouver Student inventory the spatial analysis is conducted predominantly in ArcGIS utilising the model builder function to visualise data of interest to sustainable planning initiatives.

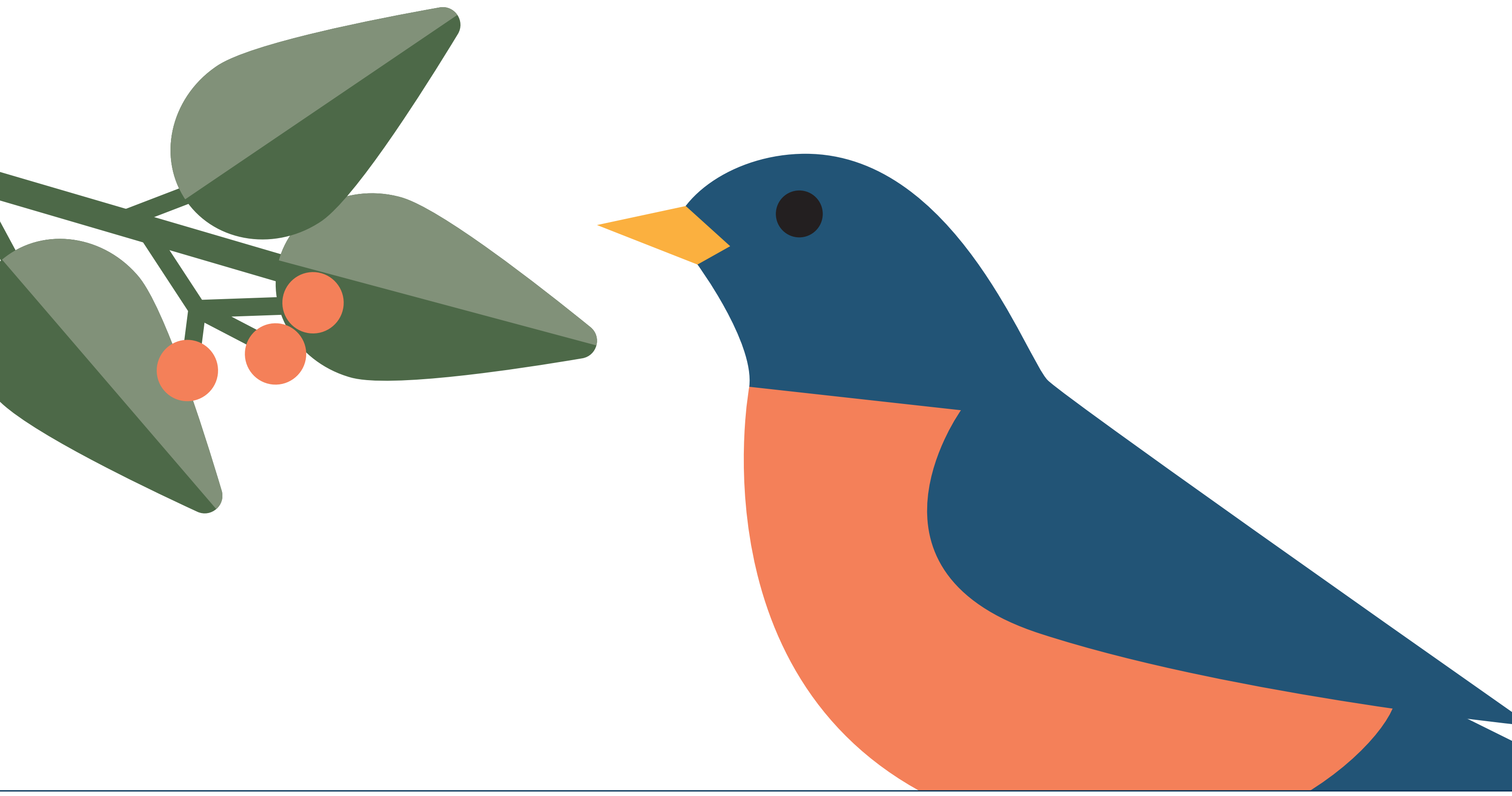
Why are Tree Inventories Important?

Tree inventories can provide the most accurate ecosystem service assessments and provide the best possible data for green space planning considerations. Accurate data on tree conditions can mitigate risk of injury, minimise late stage pruning or replacement costs, and give feedback on the effectiveness of tree protection policy.

An inventory's purpose defines the goals it aims to meet and informs the methodologies and data that needs to be collected in the process. The purpose serves as the guiding vision for the inventory and can greatly influence the deliverables. For example, the UBC Vancouver Student Tree Inventory is a complete and dynamic tree inventory with measurements of multiple variables that are used in ecosystem service assessments. Having a detailed report on the services provided by natural assets is vital for greenspace management and planning. Additionally, valuing these ecosystem services can quantify the economic benefits of urban natural assets, allowing stakeholders to better understand the financial incentives of expanding the urban forest.

In the face of the climate emergency, cities and institutions need to guide their landscape management decisions by maximising their ability to mitigate and adapt to climate change. Having a detailed report on the health, capacity, and spatial distribution of one's natural assets is crucial in sustainable land-use planning. Expanding the urban forest and landscape service capacity can be used to actively combat environmental issues such as stormwater runoff and the associated soil erosion.

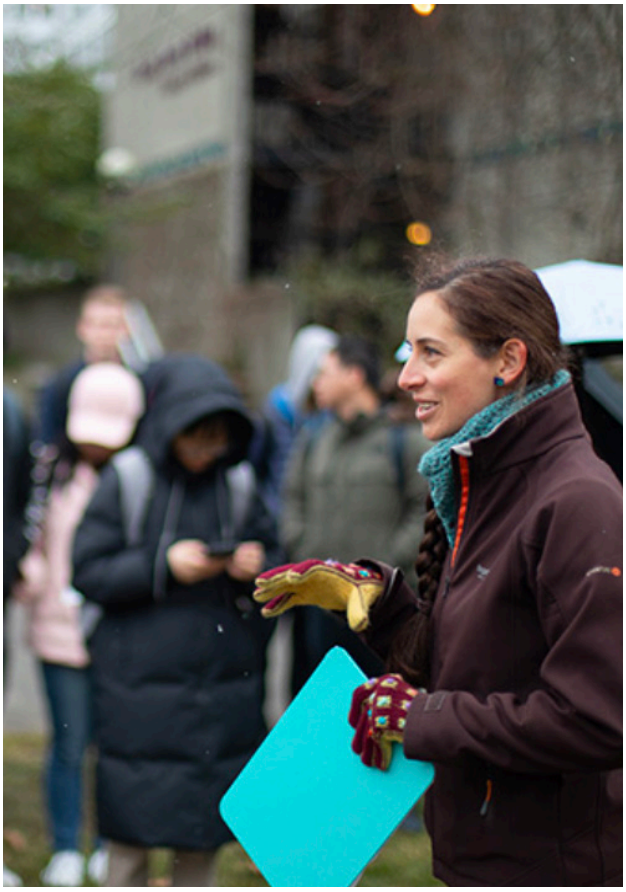
Studies have also found a direct relationship between ecosystem services and a green space's biodiversity (Minixhofer et al. 2021). By increasing biodiversity in the urban forest we can help to maximize ecosystem services. Species data from measured trees in the inventory communicates concrete biodiversity levels, and shows how species richness is distributed in the landscape. This information can inform planting changes to expand areas with little diversity.



Tree Inventory Categories

Tree inventories come in all different shapes and sizes (much like the trees themselves!), depending on the data collection type and frequency. An overview of the different data collection type and frequency categories of tree inventories is provided below. Deciding on what type to use is dependent on factors such as the study area, budget constraints, and number of people available to conduct the inventory, to name a few.

There are three different data collection types: sample, partial, and complete. Complete inventories consolidate data on all trees in an urban forest. Sample and partial inventories differ in that they only contain data on samples or locations of interest or importance. In addition to collection type, frequency of data collection also influences how an inventory can be used. There are two frequency categories: Static and Dynamic. A Static inventories are when measurements are taken at a single point in time. Dynamic inventories refer to when measurements are taken repeatedly over a period of time to assess change of the population.



Dr. Tahia Devisscher explains the tree inventory assignment to the Forestry students. This inventory project is an ongoing collaboration between the SEEDS Sustainability Program, Campus and Community Planning, and UBC Building Operations. Photo by Phillipe Roberge. (https://planning.ubc.ca/news/mapping-ubcs-biodiversity)

DATA COLLECTION PROCESS CATEGORIES:

Sample: Measures a representative subset of trees from the urban forest

Partial: Measures all trees meeting particular conditions in the urban forest

Complete: Measures all trees in the urban forest population

DATA COLLECTION FREQUENCY CATEGORIES:

Static inventory: Collecting data from a single point in time

Dynamic Inventory: Repeatedly measuring over time to assess change, or monitoring certain variables over time to inform decision making

The student-led tree inventory on UBC's Vancouver Campus aims to be both **complete,** and **dynamic.**

The Tree Inventory Process

A general process that can guide the planning and development of a tree inventory is provided below. This process will then be further illustrated by using a case study on the UBC Vancouver Campus.

STAGE 1: ESTABLISHMENT

- The first step of making an urban tree inventory is **defining an area** one wants to measure.
- After the area has been agreed upon, the **type of inventory needs** to be chosen from the categories above.
- The next step is **mapping the trees that will be studied.** This can be conducted in multiple ways using different devices, but usually a preliminary assessment can be done using a GPS device.
- An optional step is **subdividing the area** into different phases and subzones to divide and organise the inventory across different participants.

STAGE 2: MEASURING

- Participants are **provided tools to conduct measurements** with guides explaining how to use the gear.
- **Measurements are taken** in the field at the groups respective subzone and data is tabulated in worksheets outlining all the variables measured. The exact variables that are measured will depend on the needs of the specific tree inventory, however some key measurements are needed for reliable analysis — including Species, Tree Height, and Diameter at Breast Height (DBH).
- After field measurements are done, all **data should be tabulated and formatted** to reflect the correct units and data entry options.
- **Data sheets should be cleaned** of obvious errors.

STAGE 3: ANALYSIS

- Once all the data is available and organised, **various analyses can be used** to learn different things about the urban forest.
- **iTreeEco ecosystem service report** can be used to determine many relevant metrics from the data, including valuing ecosystem services like Pollution Removal, Carbon Sequestration, Carbon Storage, and Avoided Runoff. It is important to note that iTree Eco is not a standard part of conducting a tree inventory, it is a tool used to conduct further analysis with data in this case study.
- **Value mapping:** Some ecosystem services are not as easy to measure as others due to their subjectivity. For these services, one can utilise value mapping, a process that rates a landscape based on previously agreed upon criteria.
- **Spatial analysis using ArcGIS** can be used to perform other analyses, such as mapping biodiversity, connectivity, highlighting a specific ecosystem service, or comparing differences from an older tree inventory.
- **Bonus: Making the tree data collected publically available** also enables anyone to conduct their own spatial inquiry and get to know their urban forest!

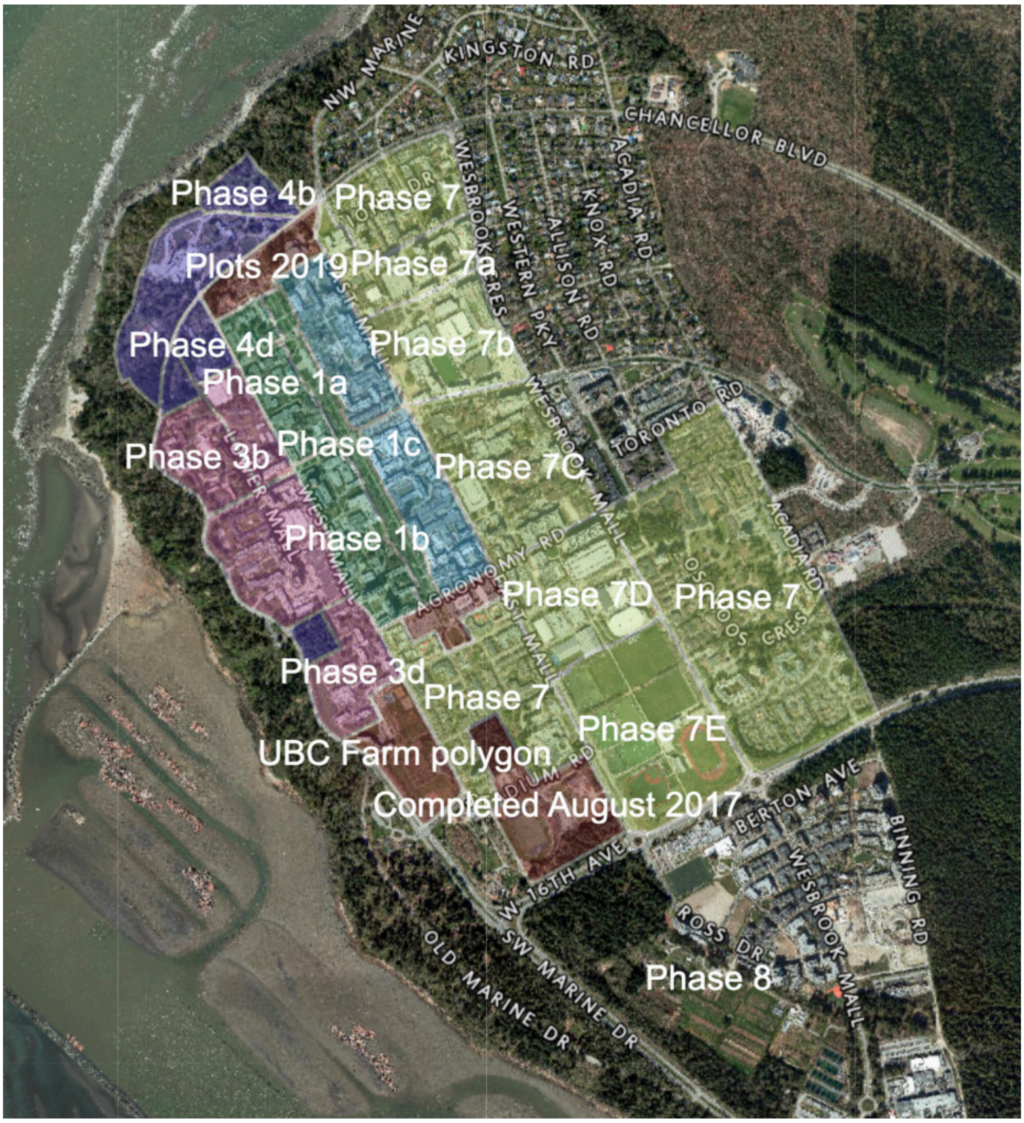
Case Study:
The UBC Vancouver Student Tree Inventory

ABOUT:

The UBC Vancouver Student Tree Inventory is a multi-year project that commenced in Fall 2018. This project was developed in collaboration between Dr. Tahia Devisscher, UBC Campus & Community Planning, the SEEDS Sustainability Program, and the students & teaching teams in the Faculty of Urban Forestry's UFOR 220 - a second year course offered by UBC Forestry, focused on an Urban Forest Inventory and Assessment.

Initial collection of UBC tree geospatial and species data was conducted by contractors, student volunteers, and/or members of UBC's remote sensing lab. Building upon this initial data collection, the UFOR 220 students and teaching team collected tree data measurements on campus and created reports that analyse the ecosystem services of the campus' urban forest. These reports are shared annually with staff at UBC Campus and Community Planning and UBC Building Operations, facilitated by the SEEDS Sustainability Program. Reports and datasets are compiled and published on the SEEDS Sustainability Library and the UBC Geodata Repository.

This case study was supported by information from Finn Köpf, a senior UBC Urban Forestry student and member of the UFOR 220 teaching team for the 2021-2022 academic year.



Caption: The complete map showing the annual phases of the UBC Tree Inventory on the UBC Vancouver Campus. Retrieved from UBC Trees Viewer.

SCOPE

The UBC Vancouver Student Tree Inventory is focused on the trees growing and planted within the UBC campus borders. The inventory process is organised into different phases (pictured above) that are measured each fall semester by UFOR 220 students. The process started off with cataloguing the campus core along Main Mall (Phases 1a, 1b, and 1c) and has since extended down to the Lower Main Mall. The final goal is to have completed all phases of the tree inventory on campus.

MULTI-YEAR TIMELINE

The UBC Vancouver Student Tree Inventory is a multi year process that is estimated to take the UFOR 220 course team and students~7 years to complete. As of Fall 2022, the inventory is in its fourth year, and has covered large amounts of the campus core. Future phases will be determined in collaboration with the Faculty of Forestry, such as the UFOR 220 curriculum, which determines the number of phases that can be inventoried annually, and informed by the status of campus development projects which can affect areas that can be inventoried. After the completion of the inventory, the cycle begins from the beginning to have a temporal reference to compare growth rates of trees. The aim of the UBC Vancouver Student Tree Inventory is that it carries on as a continuous project to provide ongoing campus tree data that can be used to support baseline and monitoring efforts, and inform campus planning and practices.

WHY IS THIS INVENTORY IMPORTANT?

Tree inventories act as the primary baseline tool to inform sustainable land management that maximises climate change adaptability and resilience. Urban forests need to adapt to changing climates and having a detailed report of its composition is the most effective way of monitoring this capacity. The data from the UBC Vancouver Student Tree Inventory has been instrumental in many different planning processes since it began. Most recently, the preliminary results were published in the report: UBC Vancouver Campus in a Changing Climate: Urban Forest Edition, to facilitate further learning, applied research and collaborations amoung UBC staff, faculty and students. The data that has been collected by students was also recently used in training machine learning models to develop automated tree species identification algorithms using campus LiDAR data.

The UBC Vancouver Student Tree Inventory has also been a great opportunity for community engagement. Students get hands-on, urban forestry specific-experience in the field and have the chance to develop a relationship with the nature surrounding them on campus. Data made available through the UFOR 220 inventorying can be utilised in student-led research and provide management considerations on topics such as biodiversity and climate change adaptation strategies. An example of this includes an undergraduate research report on ecological connectivity conducted by Nicholas Mantegna, a Urban Foresty Student. (Mantegna, N. 2021).

METHODS

The methodology behind the UBC Vancouver Student Tree Inventory has been developed iteratively by integrating feedback from each year's student teams, however the data variables (i.e. tree height) that students have collected over multiple phases has stayed largely the same to keep the inventory dataset consistent.

Stage 1: Establishment

- **Define the geographical area:** In this case UBC's jurisdictional boundary
- **Identify the inventory type:** UBC Vancouver Student Tree Inventory is a complete, dynamic inventory
- **Determine the tree mapping tool to be used:** UBC Vancouvers's Student Tree Inventory is conducted with a combination of the Trimble gx-7 GPS device and the ArcGIS field map app
- **Subdivide the area:** UBC Vancouver's Student Tree Inventory is measured by students enrolled in UFOR 220 — each group of students is assigned a "subzone" as their term study area.

Stage 2: Measuring

- **Provide resources and tools to conduct measurement:** The teaching team provides equipment and an explanation on how to use the measurement equipment and ideally a "demo day" is held with participants to help them get familiar with measuring techniques.
- **Take measurements:** Tools for theUBC Vancouver Student Tree Inventory include DBH tape, laser rangefinder, eselon tape, compass, and clinometer, as well as hi-vis vests.
- **Tabulate and format data**: Students are given a datasheet, including a table outlining all the variables measured.
- **Clean data sheets**: All individual groups submit their tables into one central excel sheet, which is checked and cleaned by the teaching team.

Stage 3: Analysis

- **Generate an iTreeEco ecosystem service report:** While not an essential part of standard tree inventories, students in UFOR 220 were required to conduct an ecosystem service analysis using the iTreeEco software. This program uses the species data and field measurements to estimate different services provided by trees (mostly regulating services-erosion control, carbon sequestration, temperature regulation).
- **Develop value mapping:** For UFOR 220, students re-visit their zones and evaluate the features of their site as well as surveying other users of the space. The criteria one uses can vary — for UFOR 220 the following criteria were used: Perceived species richness, refuge, serenity, recreation, prospect, and cultural significance.
- **Conduct a spatial analysis using ArcGIS:** In order to contextualize the data collected by students in UFOR 220, the teaching team began to conduct a GIS analysis that can inform an ongoing assessment of biodiversity.
- **Optional:** Making the tree data collected publically available: Student reports and datasets are compiled and published into the SEEDS Sustainability Library and the UBC Geodata Repository.

What did the Students Measure?

For an overview of the exact metrics that were collected by student researchers, use the diagram below to visualise each of the characteristics on an example tree.

Tree Species

TTH
(Total tree height)

LCH
(Live crown height)
Height to which live foliage extends to, in case of die back

CBH
(Crown basal height)
Height from ground to base of live crown

Crown width
Longest and shortest crown width measurements and the average from the two

Crown percentage missing
Overall percentage of crown missing, such as gaps in the branches

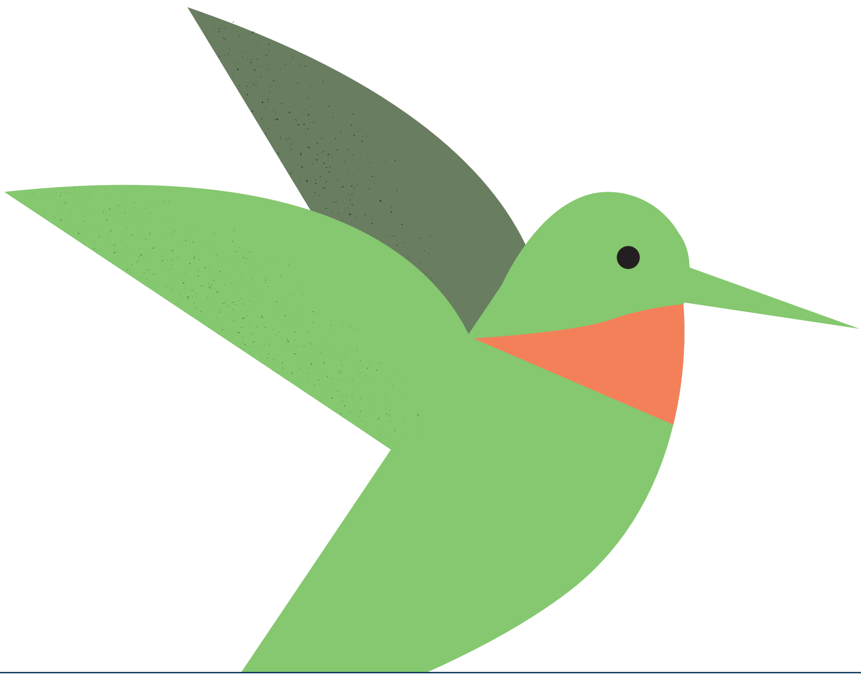
CLE
(Crown light exposure)
How many sides of the tree is exposed to sunlight (5 at most)

ECOSYSTEM SERVICES

The UBC Vancouver Student inventory is also accompanied by data on multiple different types of ecosystem services on campus, such as supporting, regulating, and cultural services.

Supporting and **Regulating Ecosystem Services** are determined by analysing the measurements taken by students in the field, including most physical attributes of a tree such as height, width, and DBH. These measurements are entered into iTreeEco, an urban forestry software used to estimate regulating services such as carbon sequestration, water runoff interception, air purification, and shade-cooling capacity and supporting services such as oxygen production water cycling, and habitat provisioning. .

Cultural Ecosystem Services are assessed by student value mapping conducted in the field, done by identifying the success of predetermined features of the greenspace such as aesthetics, refuge, or species richness.



Helpful Resources

Helpful resources

UBC Geospatial Open Data Repository: Campus Trees Dataset

This dataset contains the point data for all trees on the UBC Vancouver campus that have been recorded by the students to date. The dataset can be downloaded in a .geojson, or .csv format.

UBC Vancouver Campus Tree Inentory Handbook

This handbook, which was originally created as a student-led SEEDS project, was created to help participants conducting the treen inventory learn about the methodology and practices developed to analyze trees on UBC's Vancouver campus.

Template: Tree Inventory Datasheet (UFOR 220 Course)

Table 1. Datasheet template that UBC Urban Forestry students used to record their data

Zone Code																	
Tree ID	**TAG**	**TAG ID**	**LIVE/ DEAD**	**SPE- CIES**	**NA- TIVI- TY**	**TREE TYPE**	**LAND USE**	**H DBH (m)**	**DBH (cm)**	**TTH (m)**	**LCH (m)**	**CBH (m)**	**LONG (m)**	**SHORT (m)**	**CROWN %MISS**	**CLE**	**COM- MENTS/ MULTIPLE DBHS**

Datasheet Legend:

TREE ID: (Code) Unique identifier given to each tree

TAG: (Y/N) Verify if the tree has a tag already

TAG ID: (Number) If the tree has a tag, add the number

LIVE/DEAD: (L/D) Indicate if the tree is alive or dead

NATIVITY: (N/E) Indicate if the tree is native or exotic

TREE TYPE: (C/A) Indicate if the tree is coniferous or angiosperm

LAND USE (i-Tree Eco categories)

Agriculture (A): Cropland, pasture, orchards, vineyards, nurseries, farmsteads and related buildings, feed lots, rangeland, and timberland/plantations that show evidence of management activity for a specific crop or tree production.

Cemetery (E): Includes any small unmaintained areas within cemetery grounds.

Commercial/industrial (C): Land being used for commercial activities, including retail, services, and professional business. Also includes standard industrial land uses, such as manufacturing or processing, and outdoor storage/staging areas as well as parking lots in downtown areas that are not connected with an institutional or residential use.

Golf course (G): Includes entire grounds, whether maintained or not.

Institutional (I): Schools, hospitals/medical complexes, colleges, religious buildings, government buildings, etc. (Note: If a parcel contains large unmaintained areas, possibly for expansion or other reasons, treat the area as Vacant. However, small forested islands in a maintained landscape would be considered Institutional.)

Multi-family residential (M): Structures containing more than four residential units. (Note: A block of attached one- to four-family structures would be considered multi-family residential. A residential complex consisting of many separate one- to four-family structures would be also considered multi-family residential.)

Park (P): Includes parks in undeveloped (unmaintained) areas as well as developed areas. (Note: Trees or plots in forested stands are best categorised as being on the Vacant land use.)

Residential (R): Freestanding structures serving one to four families.

Transportation (T): Includes limited access roadways and related greenspaces (such as interstate highways with on and off ramps, sometimes fenced), as well as railroad stations, tracks and yards, shipyards, airports, etc. (Note: If plot falls on any other type of road, or associated median strip, classify according to nearest adjacent land use.)

Utility (U): Includes power-generating facilities, sewage treatment facilities, covered and uncovered reservoirs, and empty stormwater runoff retention areas, flood control channels, and conduction.

Vacant (V): Includes land with no clear intended use. (Note: Abandoned buildings and vacant structures should be classified based on their original intended use.)

Water/wetland (W): Streams, rivers, lakes, and other water bodies, natural or constructed. (Note: Small swimming pools and fountains should be classified based on the adjacent land use.)

Other (O): Land uses that do not fall into one of the categories listed. (Note: This designation should be used sparingly as it provides little useful information for the model.) Clarify with comments in Notes.

HT DBH: (m) Height at which DBH measurement was taken if not measured at 1.37 meters

DBH: (cm) Tree stem diameter at breast height (DBH) measured at 1.37 meters above the ground

TOTAL TREE HEIGHT (TTH): (m) Height from the ground to the top of the tree (alive or dead)

LIVE CROWN HEIGHT (LCH): (m) Height from the ground to the live top of the tree

CROWN BASE HEIGHT (CBH): (m) Height from the ground to the base of the live crown

CROWN WIDTH: (m) The width of the crown. Two measurements: longest and shortest

CROWN %MISS: (%) Percent of the crown volume that is not occupied by branches and leaves

CLE: (1 to 5) Crown light exposure (CLE) indicates the number of sides of the tree's crown receiving light from above or the side

References:

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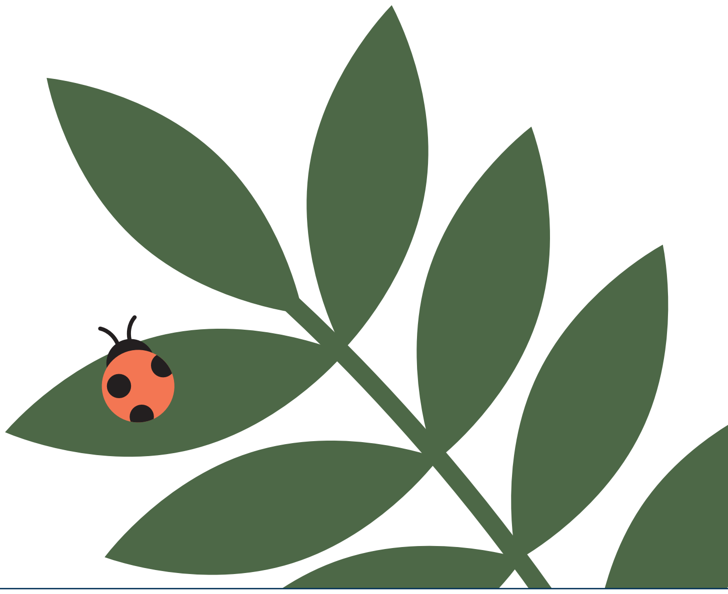

Thank you for reading! We hope you found the research summarized in this Toolkit useful.

Please email seeds.info@ubc.ca for any questions or comments.