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Student Research Report

Comparing the Level of Carbon Sequestration Capability of Different Soft Landscape in UBC

Prepared by: Yichi Zhang

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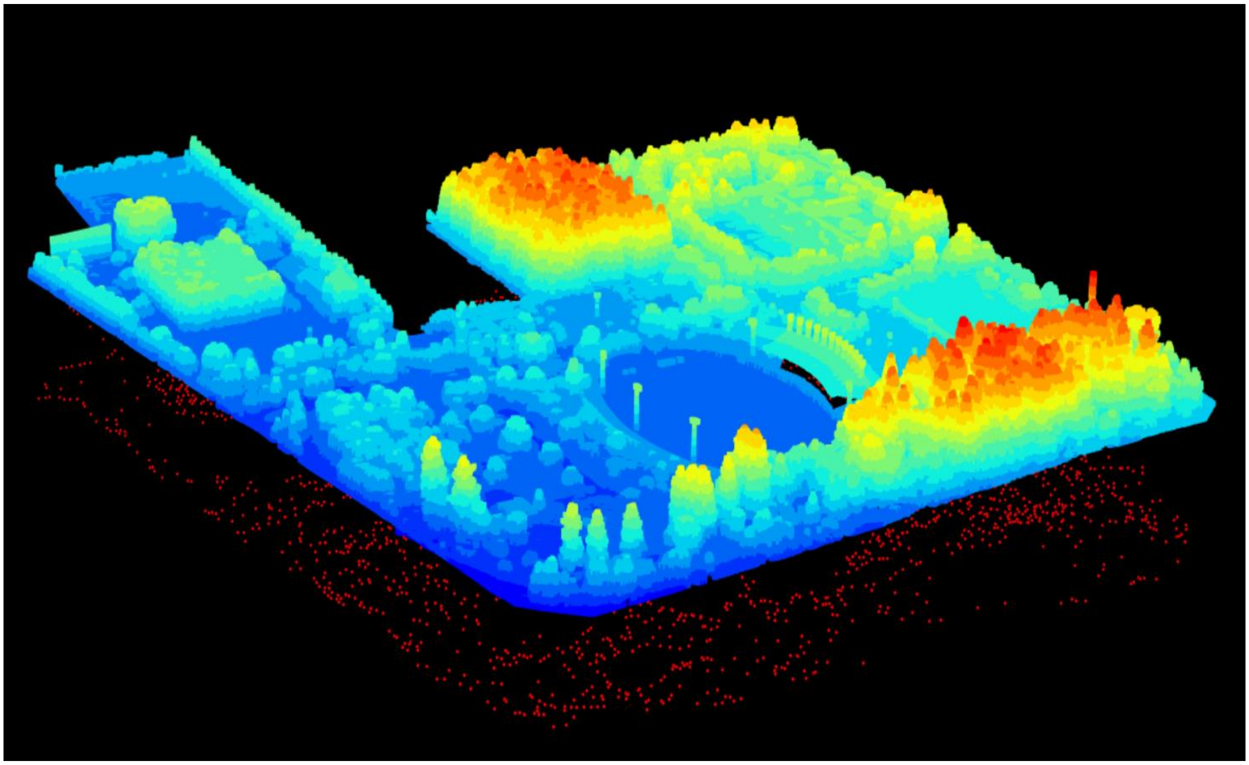

Comparing the Level of Carbon Sequestration Capability of Different Soft Landscape in UBC

Name: Yichi Zhang

Current Degree: MSc in Environmental Engineering and Management

Topical Mentor: Rowan Waldron

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Abstract

In response to growing concerns about carbon emission and climate change, recent studies have investigated in carbon storage, carbon neutralization and carbon sequestration. In this study, I expanded on this body of work by investigating the carbon sequestration rates of soft landscapes in the University of British Columbia Vancouver campus and compare their carbon sequestration capacity. The significance of carbon sequestration rates in soft landscapes is discussed in the context of urban planning and the role of vegetation in mitigating climate change. LiDAR data and aerial photos are used to estimate above-ground carbon sequestration, and GIS and R are used for data analysis. The research objectives are to compare the attributes of different soft landscapes, estimate their carbon sequestration rates, identify which soft landscapes have the highest carbon sequestration capacity, and discuss the limitations of the study and possible improvements for future research. The proposed methods include data pre-processing, developing a canopy height model, and estimating carbon sequestration capacity for each soft landscape area. The study aims to provide valuable insights for optimizing urban soft landscape services to increase carbon storage in cities, and to explore the potential for incorporating soft landscapes as a sustainable urban infrastructure element for carbon sequestration. Moreover, the findings of this study may inform decisions regarding the implementation of sustainable landscape design practices that can be applied to new and existing urban green spaces, with the goal of maximizing the potential of soft landscapes to provide ecosystem services that benefit human well-being and the environment.

Key words: carbon sequestration, soft landscapes, urban planning, LiDAR, above-ground biomass, ecosystem services

Introduction

1.1 The significance of comparing carbon sequestration rates in soft landscapes

Climate change, resulting from carbon emissions, has created increased concern about carbon sequestration rates (Roux, 2020). Carbon sequestration refers to the technology of carbon capture and carbon storage as an alternative to the direct emission of CO_2 into the atmosphere (Goel, 2021). Human will achieve the goal of slowing the growth of CO_2 concentration in the atmosphere through carbon sequestration combined with increased efficiency in energy production and use and increased production and use of low-carbon or non-carbon fuels. The uptake of CO_2 by terrestrial ecosystems is a natural carbon sequestration process. Land plants need to use CO_2 to synthesize organic matter during their growth, and they can absorb CO_2 at various concentrations, thus saving the expense of technologies that separate and purify it.

Scientists and decision-makers have long acknowledged the vegetation's contribution to the sequestration of CO_2, and interest in using plants to mitigate climate change is on the rise (Nepal et al., 2012). A significant part of the carbon cycle is the storage of carbon by vegetation, with live forest biomass accounting for 20% of all terrestrial carbon (Bonan, 2008). Global GHG emissions are significantly influenced by urban planning (Engel et al. 2012), urban planning activities have an impact on GHG emissions because they specify the uses and characteristics of the lands that can be developed as urban areas as well as the land occupation model that includes those areas (Zubelzu, 2016).

Soft landscape is the non-structural components that enhance the aesthetic appeal of many outside space, such as a garden or backyard (Venner, 2021). It is in direct contrast to hard landscaping, including asphalt, roadways, pathways, steps, and stones. There have been many studies on the carbon sequestration rate of plants, especially forests, but from the aspect of urban planning, there need to be more studies on the carbon sequestration rate of soft landscapes. Although soft landscapes must not have the same carbon sequestration capacity as forests, if we do the best soft landscape planning for carbon sequestration at the beginning of urban planning, we can decrease the carbon in the city to the maximal extent.

1.2 Research objectives

This study aims to estimate the level of above-carbon sequestration of soft landscape due to the lack of discussion regarding how the level of carbon sequestration could provide insights in creating future planning strategies.

LiDAR data and aerial photos will be combined and to be analyzed with GIS to estimate the carbon sequestration capability of the soft landscape in University of British Columbia.

The objectives of this study are:

1. To compare the attributes of different soft landscape in UBC
2. To estimate the level of above-ground carbon sequestration of different soft landscape communities in UBC

3. To compare and conclude which soft landscapes within UBC have the greatest carbon sequestration capacity, summarize their characteristics, and analyze the application of this finding to future landscape planning
4. To discuss the limitations of the study and what improvements can be made for future research

Vancouver has set aggressive goals reduce carbon pollution in 50% by 2030, and to be carbon neutral by 2050 (City of Vancouver, n.d.), this research aims to provide suggestions for establishing analysis and management plans in optimizing urban soft landscape services that enable Vancouver and UBC to boost resilience towards global climate crisis.

Study site

The University of British Columbia's Vancouver campus is located at the western tip of the Point Grey Peninsula in the city of Vancouver in British Columbia, Canada. The breathtaking campus, which spans more than 400 hectares, is only a 30-minute bus ride from Vancouver's downtown core and is bordered by forest on three sides and the ocean on the fourth. For the majority of its 100-year existence, the college has been situated on this land, which is native territory to the Musqueam people. The site has a mild topography with an average height of 87 m above sea level in terms of the landscape and climate (Government of Canada, 2021). Summers are dry and warm and winters are wet and moderate in this area of Vancouver Island's rain shadow, with an average annual temperature of 11°C and 146cm of precipitation (Government of Canada, 2021).

In Figure 1, we can clearly see that the soft landscape is mainly gathered in the area around UBCBG, UBC farm as well as Totem park and UBC food garden. We therefore scope our study to focus on the three sites with the most soft landscapes (Figure 2) and analyze their carbon sequestration capacity.

Figure 1. UBC soft landscape distribution

Figure 2. Three study sites with UBC Botanical garden in light green, UBC farm in green and UBC food garden in red.

Data Summary

In order to compare the level of above-ground carbon sequestration between different study sites at UBC, 2 data sets were used to estimate the above-ground carbon including the point cloud data of trees and a grassland attributes in these three sites.

3.1 University of British Columbia Point Grey Campus LiDAR

The LiDAR collected point cloud data utilized in this study was acquired from the Abacus Library at the University of British Columbia in 2021, and is considered the most current LiDAR data available for the UBC campus that can be obtained and downloaded. Although the data is reported to have a high level of accuracy with horizontal and vertical deviations of +-0.3m and +-0.15m respectively, the absence of any reference control raised concerns regarding its absolute accuracy. The data was utilized to generate a canopy height model and estimate the height of trees.

3.2 Grassland attributes of UBC Botanical Garden, UBC Farm and UBC Food Garden

To calculate the above-ground carbon storage of the three sites, the grassland area and location attributes were required. As digital data on grassland areas was unavailable, ArcGIS Pro was used to obtain this information. With these attributes, the above-ground carbon storage of each site was estimated, providing insight into the role of grasslands in the carbon cycle.

4. Method

4.1 Overview

Multiple methods were used to compare the ecosystem services offered by different soft landscape communities and quantify the amount of above-ground carbon sequestration, including data pre-processing, calculation of the area size of each soft landscape, development of canopy height model and estimation of carbon sequestration capacity of each soft landscape area. The proposed data processing workflow is shown in Figure 3.

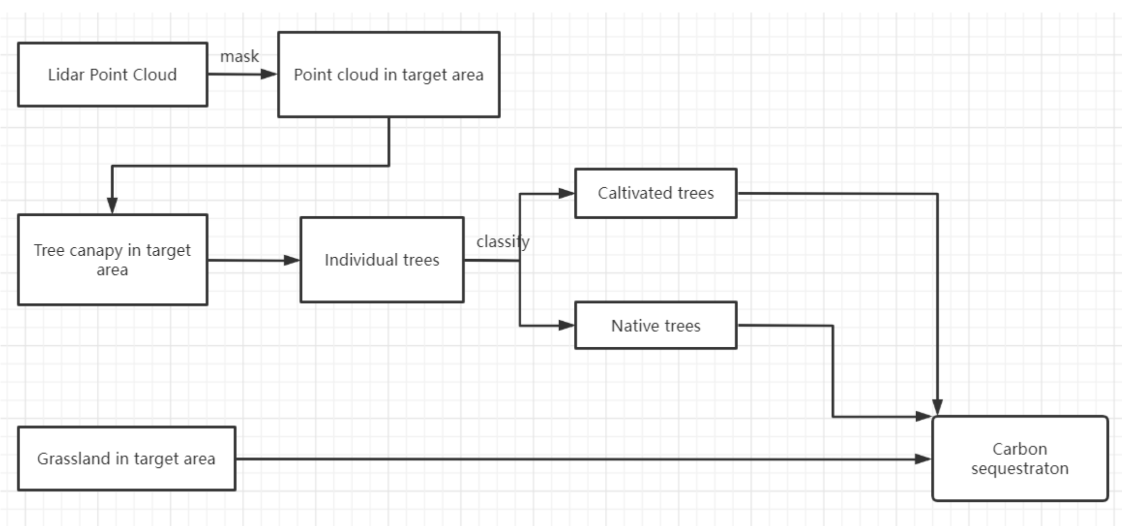

Figure 3. Workflow of the project

4.2 Data Pre-processing

Due to the spatial coverage of LiDAR being incompatible with the study area, pre-processing of the data is necessary. The entire UBC Vancouver Campus was covered by the LiDAR data, and the point cloud data extraction process began by identifying the tiles that include the soft landscape. The lidR package in R was used to mask the boundary polygon of three soft landscape areas using the chosen tiles, removing the LiDAR point cloud outside the three soft landscape sites.

4.3 Development of Canopy Height Model

The vertical difference between the Digital Terrain Model (DTM) and the Digital Surface Model is known as the Canopy Height Model (CHM) (Hanssen et al, 2021). In this project, the point-to-raster function found in the R package "lidR" was used to directly create the CHM at a resolution of 50 cm (Roussel, 2021). Before the CHM was created, potential outliers were removed, the data was filtered, and it was necessary to reduce the data's noise and normalize it to increase the efficiency and accuracy of the geoprocessing (Hanssen et al, 2021). After that, a raster layer of the CHM was created. In this project, we can see the CHM of the three sites shown in Figures 4 to 6.

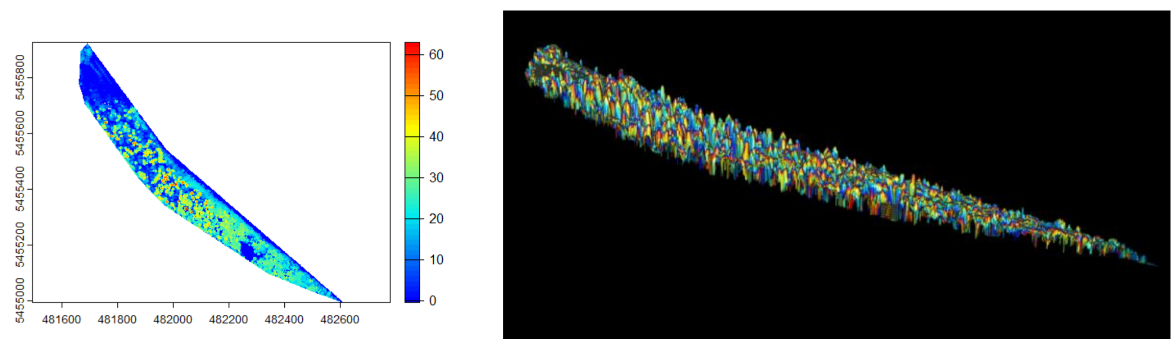

Figure 4. 2D and 3D CHM (Canopy Height Model) for UBC Botanical Garden. From the 2D plot, we can find out that most high trees are concentrated in the middle part of the garden, and from the 3D plot, we can directly observe the distribution of trees in UBCBG.

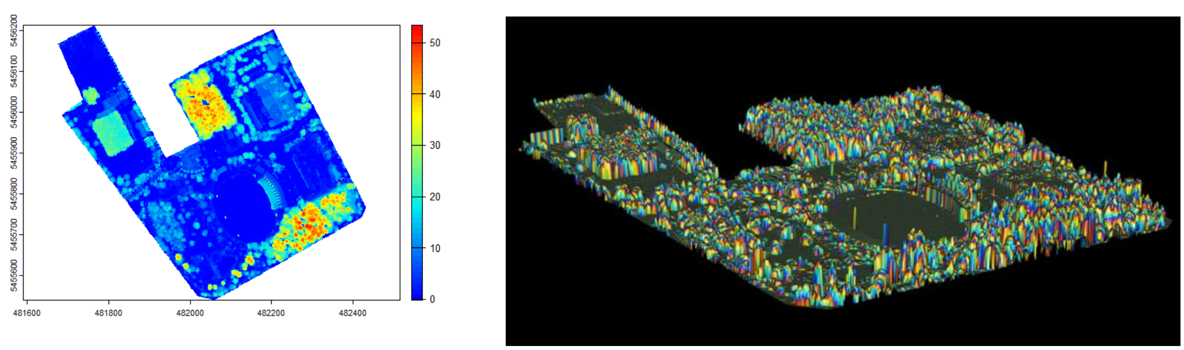

Figure 5.2D and 3D CHM (Canopy Height Model) for UBC Food Garden. From the 2D plot, we can find out that most high trees are clustered at 2 areas of the site, and from the 3D plot, we can directly observe the distribution of trees.

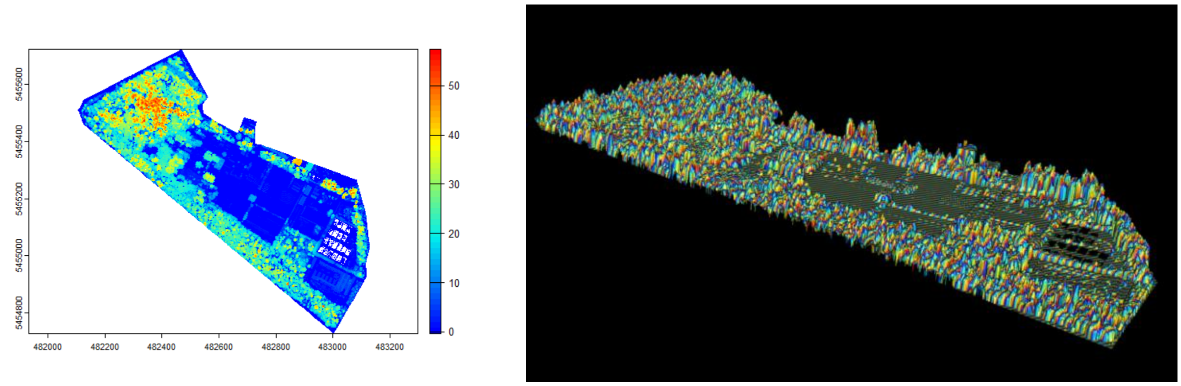

Figure 6. 2D and 3D CHM (Canopy Height Model) for UBC Farm. From the 2D plot, we can find out that most high trees are concentrated in the northern part of the farm, and from the 3D plot, we can directly observe the distribution of trees.

4.4 Segmentation of Individual Trees

The Dalponte algorithm will be used for the segmentation of individual trees in this project. The Dalponte algorithm uses a region-growing technique to identify specific tree tops and crowns from point cloud data (Dalponte & Coomes, 2016).

Using the lidR package, a local fixed filter was used in this method to locate treetops (Roussel, 2021). With a 5x5 grid, this technique filtered the CHM's pixel data (Gülçin & Konijnendijk, 2021). First, using the individual tree data, individual tree tops were extracted and reclassified as species in different soft landscape sites and then the tree crowns were identified. The information of attributes such as treetop location, tree height (TH), canopy width (CW), and canopy area (CA) was generated together with a vector layer of each individual tree.

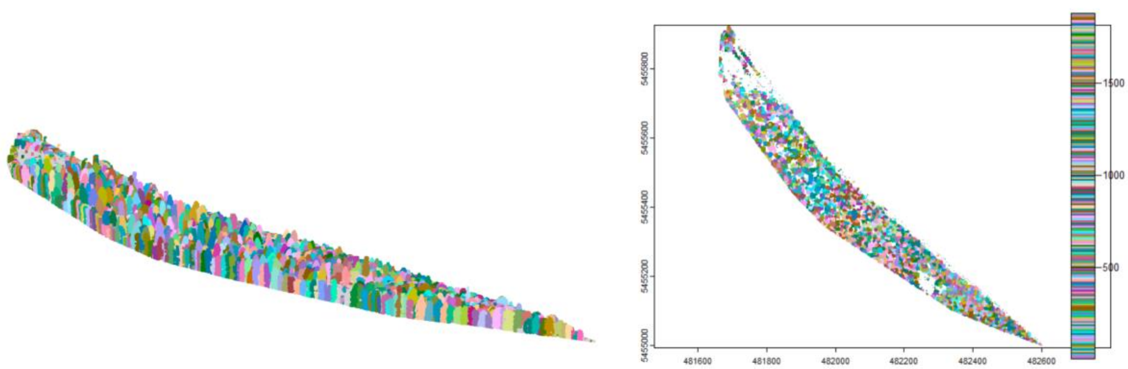

Figure 7. Individual tree segmentation of UBCBG, from which we can observe the individual tree distribution and calculate the canopy area.

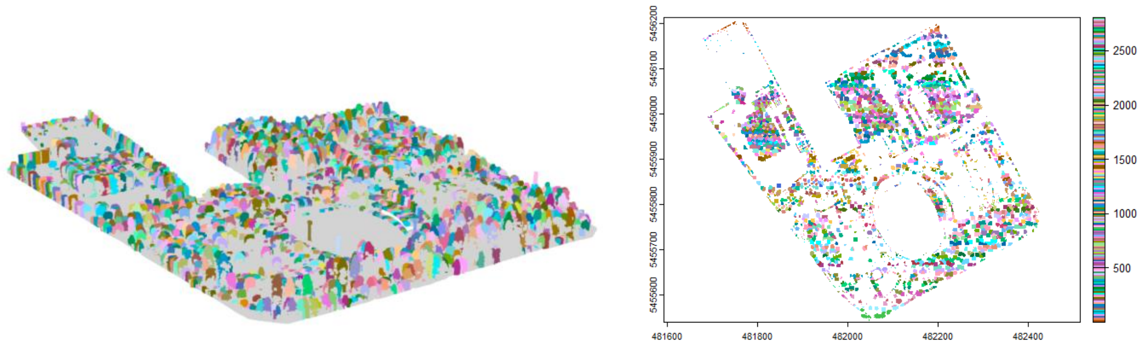

Figure 8. Individual tree segmentation of UBC food garden, from which we can observe the individual tree distribution and calculate the canopy area.

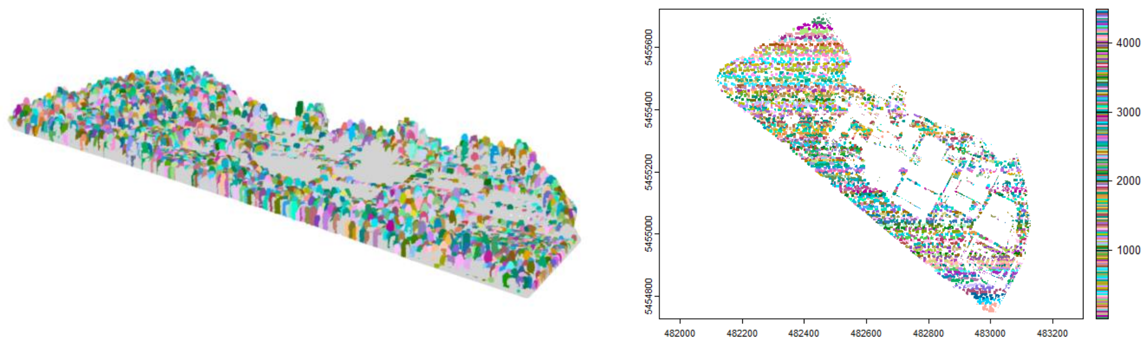

Figure 9. Individual tree segmentation of UBC farm, from which we can observe the individual tree distribution and calculate the canopy area.

4.5 Estimation of Carbon Sequestration Capacity of Each Soft Landscape Area

A combination of algorithms was utilized to estimate the above-ground carbon sequestration level of individual trees using the tree height, canopy area, and DBH after segmenting individual trees and validating the segmentation model. The following non-linear equation model represents the mathematical relationship between tree height (TH), canopy area (CA), crown base height (CBH) and diameter at breast height (DBH) of native and farmed species in the study by Schreyer et al. (2014):

$$\text{CBH} = \text{TH}*0.5$$

$$\text{DBH} = 0.95 + 0.7 \cdot \text{TH} + 3.14 \cdot \text{CW} + 0.37 \cdot \text{CBH}$$

$$\text{Above-ground carbon storage } (C_{ag}) = \exp(-2.48+2.4835 \cdot \ln(\text{DBH}))/\ 2$$

According to the Kyoto Protocol on Climate Change for Europe, created grasslands sequestered 52 g of carbon per square metre per year (Ghosh & Mahanta, 2014), thus, multiplying this number by the area of the grassland gives the amount of carbon sequestered.

Final results

5.1 Soft landscape attributes

The University of British Columbia (UBC) has three tree clusters: the UBC Botanical Gardens, the UBC Farm, and the UBC Food Garden. According to data extracted from Lidar, the number of trees in these gardens are:

- UBC Botanical Garden: 1693 trees
- UBC Farm: 4495 trees
- UBC Food Garden: 2807 trees

In addition, the UBC Farm and UBC Food Garden have grasslands in the following areas.

- UBC Farm meadow: 91993.23 square meters
- UBC Food Park Meadow: 54,699.67 square meters

It should be noted that the information provided is extracted from Lidar, and the actual numbers may vary.

Table 1. Soft landscape attribute table, illustrates the number of trees of different area (UBCBG, UBCFG, and UBC Farm) and the size of grassland in UBCFG and UBC Farm.

	UBC Botanical Garden	UBC Food Garden	UBC Farm	Grassland in Food Garden	Grassland in Farm
Number of trees	1693	2807	4495	NA	NA
Vegetation Area (m^2)	118012.31	45649.56	247931.65	54699.67	91993.23

Based on Figure 10 to Figure 12, we can infer that the distribution of trees in the three UBC sites - the UBC Botanical Garden (UBCBG), the UBC Farm, and the UBC Food Garden (UBCFG) is not uniform.

The density of trees in UBCBG is higher than the other two sites, meaning that there are more trees per unit area in UBCBG. This suggests that UBCBG is likely to have more mature trees and a more established canopy cover. In contrast, UBCFG has the sparsest distribution of trees, and the vegetation cover is the least, even including the grassland cover.

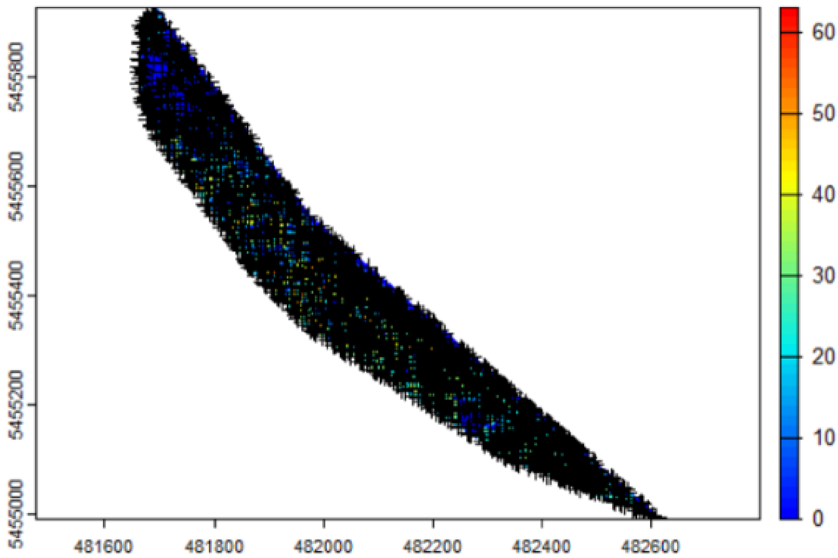

Figure 10. Individual tree detection of UBCBG, we can see the CHM of UBCBG with tree tops displayed

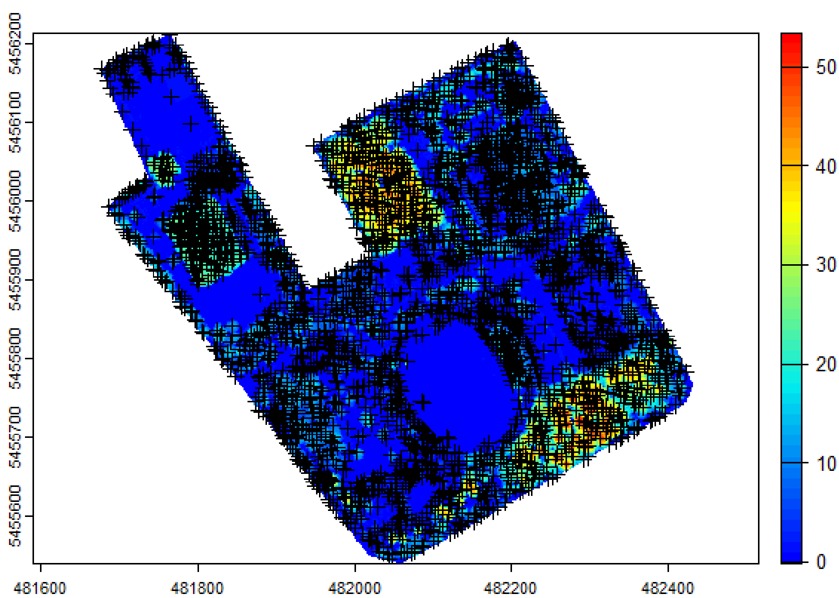

Figure 11. Individual tree detection of UBC food garden, we can see the CHM with tree tops displayed.

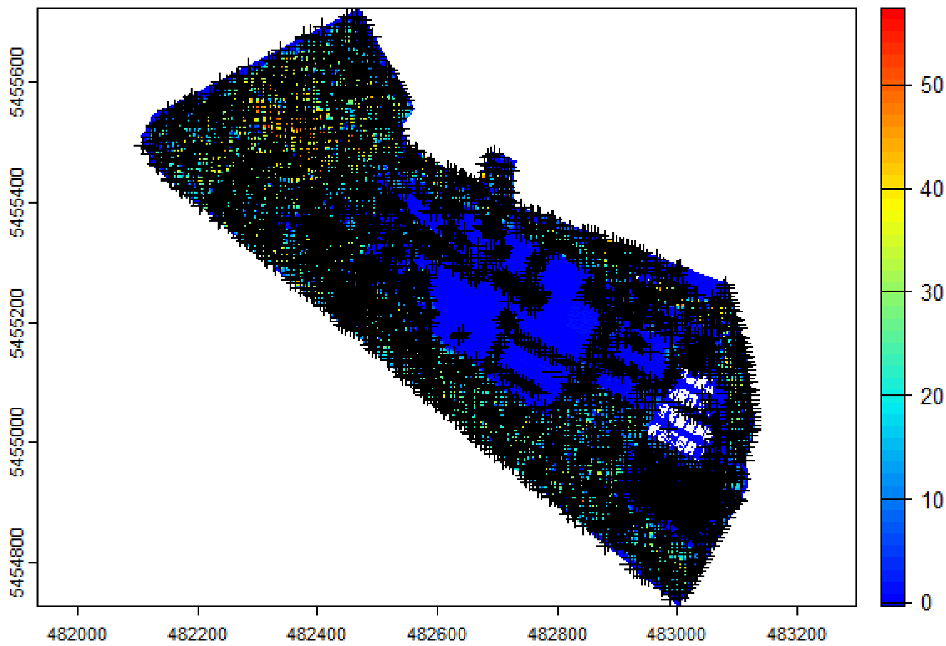

Figure 12. Individual tree detection of UBC farm, we can see the CHM with tree tops displayed.

1.2 Level of Above-ground Carbon Sequestration of Segmented Trees and Grasslands

Above-ground carbon sequestration refers to the process of capturing and storing carbon dioxide (CO2) from the atmosphere in vegetation such as trees, shrubs, and other plants. The amount of carbon stored in these plants varies depending on factors such as their species, age, size, and overall health. This session is discussing the above-ground carbon sequestration capacity of three study sites: UBC Botanical Garden, UBC Food Garden, and UBC farm.

The figures accompanying the study use different colors to represent different levels of carbon sequestration capacity. In this case, the lightest color in the figure is being used to represent the strongest carbon sequestration capacity, which suggests that the areas with the lightest color on the figure have the highest amount of above-ground carbon stored.

Overall, visual representations of data can be used to help understand and compare the above-ground carbon sequestration capacity of different locations. By using color to represent the amount of carbon stored, the figures can provide a clear and easy-to-understand picture of how much carbon is being sequestered at each location.

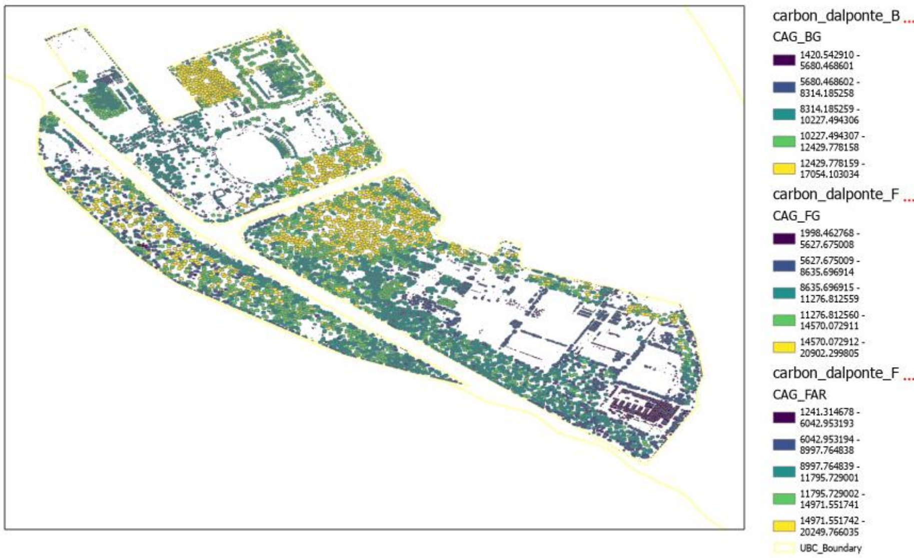

Figure 13. The Above-ground carbon sequestration of segmented trees and grasslands stored in three study sites.

Figure 14. The Above-ground carbon sequestration of segmented trees and grasslands stored in UBC Botanical Garden.

Figure 14. The Above-ground carbon sequestration of segmented trees and grasslands stored in UBC Farm.

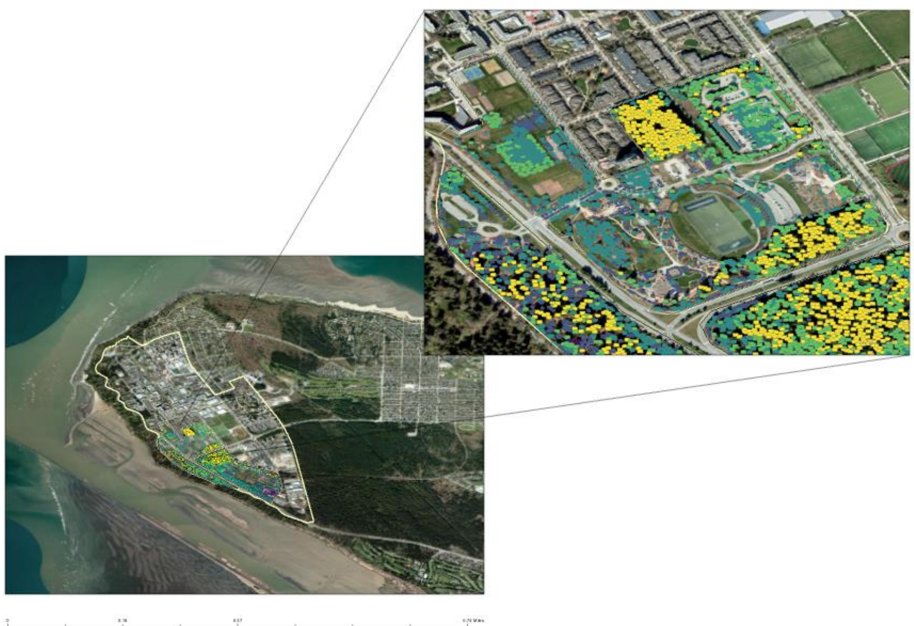

Figure 15. The Above-ground carbon sequestration of segmented trees and grasslands stored in UBC Food Garden.

Table 2 contains data related to tree carbon stocks at three UBC addresses: the UBC Botanical Garden (UBCBG), the UBC Farm (UBCFG), and the UBC Food Garden (UBCFG).

Table 2. The total above-ground carbon storage and average carbon storage of UBCBG, UBCFG and UBC Farm.

	UBCBG	UBCFG	UBC Farm
Total Carbon (kg)	8236.35	16516.38	25935.65
Average Carbon (kg/m^2)	0.07	0.16	0.08

Although UBCBG has the highest tree density and the most uniform tree distribution, it is biased towards landscape plants. This means that UBCBG may have a higher proportion of ornamental trees and shrubs, which are typically shorter in height than mature forest trees. As a result, the average height of trees in UBCBG is lower than in UBCFG and UBC farms.

Since carbon storage is closely related to tree size, which in turn is related to age and height, the average carbon storage in UBCBG may be lower than in UBCFG and UBC Farm. Therefore, when comparing the carbon stocks of these three d addresses, not only the tree density but also the age, height, species and other plants of the trees should be considered.

For example, even though UBCFG has the lowest tree density, if it has a higher proportion of mature, tall trees than UBCBG, it may still have a higher carbon stock. In addition, the age and species of trees can also affect carbon storage, as older trees typically store more carbon than younger trees, and some species may grow faster and sequester more carbon than others.

Overall, a variety of factors must be considered when comparing the carbon stocks of different tree populations. The density and distribution of trees are important, but they should not be the only factors considered. Age, height, species, and other factors can all have a significant impact on the carbon storage of a tree population.

Discussion

The issue of climate change resulting from carbon emissions has led to increased concern regarding the rates of carbon sequestration, as acknowledged by scientists and decision-makers alike (Roux, 2020). There is growing interest in using plants to mitigate the effects of climate change, and it is widely recognized that vegetation plays a crucial role in the sequestration of CO2 (Nepal et al., 2012). The storage of carbon by vegetation is a significant part of the carbon cycle, with live forest biomass accounting for approximately 20% of all terrestrial carbon (Bonan, 2008). Urban planning activities are known to have a significant impact on global greenhouse gas (GHG) emissions (Engel et al., 2012), as they determine the use and characteristics of lands that can be developed as urban areas, as well as the land occupation model that includes those areas (Zubelzu, 2016). By analyzing the carbon sequestration capacity of different soft landscapes, this study aims to contribute to the development of effective strategies and policies for urban planning and management that promote the use of soft landscapes as a means to mitigate climate change. There were several significant results need to be highlighted. While UBCBG has the most trees per unit area and an even distribution of trees, it favors ornamental plants in its collection. This implies that there is a greater representation of shorter trees and shrubs that are typically used in landscaping, rather than tall, mature trees found in natural forests. Therefore, the average height of trees in UBCBG is lower compared to UBCFG and UBC farms. As tree size is strongly linked to carbon storage, which is determined by age and height, it is possible that UBCBG has a lower average carbon storage compared to UBCFG and UBC Farm. Therefore, it is important to take into account not only tree density but also other factors such as tree age, height, species, and other types of plants when comparing the carbon stocks of these three locations. These will be discussed in this section.

6.1 Tree density and tree height work together to determine the results of forest carbon storage

Tree density refers to the number of trees within a given area of forest. When there are more trees in a given area, there are more opportunities for carbon to be absorbed through photosynthesis and stored within the trees and soil. Tree height is also an important factor in determining the amount of carbon stored in a forest. Taller trees tend to have more biomass and can store more carbon than shorter trees. This is because taller trees have more leaves and branches, which allows them to photosynthesize more and store more carbon. Additionally, taller trees have more woody biomass, which also contributes to carbon storage.

6.2 Future planning and research directions of UBC forests and grasslands

The results of this study on the UBC forest have provided insight into the factors that contribute to the forest's ability to store carbon and mitigate climate change. Based on the results of the study, there are several planning directions that could be pursued to enhance the future development and management of the UBC forest and soft landscape.

One potential direction is to plant more trees with higher canopy area to tree height ratios. This approach could be used to increase the efficiency of the forest's ability to store carbon. This study found that tree height and canopy area were key factors in determining the forest's carbon storage capability. By planting more trees with higher canopy area to tree height ratios, the forest could potentially increase its carbon storage capacity and contribute more effectively to the mitigation of climate change.

In addition to planting more trees, the study suggests that planting grassland on bare land could also increase the carbon storage capability of the UBC campus. Grasslands can store carbon in the soil, and planting them on bare land can help prevent erosion and enhance soil health. This could be an effective way to increase the campus's overall carbon storage capacity and contribute to the mitigation of climate change.

Overall, the results of the study provide valuable insights into the factors that contribute to the UBC forest's ability to store carbon and mitigate climate change. By taking these factors into consideration, UBC campus planners and managers can make informed decisions about future development and management practices that will enhance the forest's ability to provide important services to the surrounding environment and community.

6.3 Limitations and suggestions

While this study provided valuable insights into the factors that contribute to the forest's ability to store carbon, there are some limitations.

One limitation is related to the accuracy of the data on tree height. This study relied on LiDAR data to extract information on tree height, but this method is not always perfectly accurate. Inaccuracies in the LiDAR data could have affected the results of the study, and it's possible that some of the findings may not be entirely representative of the actual situation on the ground.

Another limitation of the study is the lack of actual data on the number and height of trees on the UBC campus. The study relied on estimates and assumptions about the tree population, and this could have affected the accuracy of the results. Without actual data on the number and height of trees, conducting a rigorous accuracy test for the study was impossible.

However, by identifying the key factors that influence carbon storage in the forest, the study provides a useful framework for future research and planning efforts aimed at enhancing the forest's ability to provide important ecosystem services. It's important to note that further research is needed to address the limitations of the study and to improve the understanding of the UBC forest's carbon storage potential. By building on the insights provided by this study and addressing its limitations, researchers and planners can work together to develop more effective strategies for managing carbon storage.

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