University of British Columbia

Social Ecological Economic Development Studies (SEEDS) Sustainability Program

Student Research Report

Effects of Manufactured Soils on Urban Forest Resilience Under Climate Change

A First Look at Belowground Biodiversity on the UBC Vancouver Campus

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University of British Columbia

December 2023

SEEDS Sustainability Program

UBC sustainability

EXECUTIVE SUMMARY

Urban trees and vegetation are becoming increasingly vulnerable to harsh growing conditions brought on by climate change. For example, the trees on the UBC Vancouver campus must overcome increased drought periods during summer months and increased storm events during winter months. This issue is becoming more prominent due to the widespread use of manufactured soil blends (MSBs) across campus soft landscapes, which is a relatively new growing medium codified within the Canadian Landscape Standard that is not well studied. This project examines the physical and biochemical properties of soil blends installed over a period of 33 years on the UBC Campus, to understand whether MSBs are developing favourable characteristics over time to support urban trees and vegetation. The properties of depth, bulk density, and carbon and nitrogen content were analyzed across 56 study sites, covered by 3 vegetation cover classes. Data collection was completed by students in the Urban Forest Ecosystems Lab within the Faculty of Forestry between June to August 2022.

The implications of this research project are aligned with the UBC Climate Action Plan 2030 and will be used to inform the Integrated Stormwater Management Plan and the UBC Green Building Action Plan.

Key findings of this project are as follows:

There are 3 major takeaways from the results of this project:

1. Currently, there is no evidence of carbon accumulation over time in MSBs on the UBC Vancouver campus.
2. Soil carbon accumulation is influenced by vegetation cover.
3. Soil depth, a key factor in climate resilience, is influenced by vegetation cover.

Overall, it appears as though MSBs did not develop favourable qualities over time to support trees and other vegetation against climate stressors. More importantly, soil depth was found to be relatively shallow across UBC campus due to the abundance of turf grass landscapes, which is a major limiting factor for increasing campus biodiversity. Since depth dictates what type of vegetation can be planted, transformations from lawn to pollinator gardens in future landscape designs may be challenging.

Lastly, it is important to acknowledge that soils set the foundation for all biodiversity on campus. Therefore, it is crucial to recognize the role soils play in climate resilience in the renewal of UBC climate policy documents. Further research into differences between native soils and MSBs can provide a better understanding of how urban soils can be sustainably managed to provide better growing conditions. Expansion of the current soil inventory is also critical to enhance the baseline understanding of belowground biodiversity across UBC Vancouver's Campus.

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LIST OF ABBREVIATIONS

CLS - Canadian Landscape Standard

HAHT - Human Altered and Human Transported

MSBs - Manufactured Soil Blends

SOC - Soil Organic Carbon

1. INTRODUCTION

1.1 RESEARCH TOPIC

Urban trees are subject to increasingly challenging environments due to climate change. Some common urban soil management practices, such as the replacement of native soils with blended soil mixes during land development, are not well studied and may increase the vulnerabilities of urban trees against stressors such as extreme heat and prolonged drought periods. In particular, there is little existing research on whether blended soils develop favourable characteristics for supporting vegetation such as increased aggregation and carbon accumulation in the long term. Therefore, it is unclear whether these widely used soil blends can function as a resilient growing medium to support trees and other vegetation against novel climate conditions.

We will examine the physical and biochemical properties of soil blends installed over a period of 33 years on the University of British Columbia Vancouver campus. Study plots include several vegetation cover classes allowing us to assess soil carbon accumulation patterns associated with different plant communities. The results will reveal age-related patterns by assessing permeability, soil organic carbon (SOC), aggregation, and compaction in 56 sites. We will discuss findings in relation to potential for soil blends to adequately support urban trees against current and future climate stressors. Our findings will inform best practices for urban forest managers, designers, and planners to ensure the long-term resiliency of urban ecosystems against the effects of climate change.

We hypothesize that MSBs experience slow pedogenic development, thus leading to challenges associated with climate resilience for trees and native vegetation. Hypothesis 1: Water-Holding capacity will be lower in MSBs than in nearby native soils with similar vegetation. Hypothesis 2: Soil organic carbon, aggregation, and water-holding capacity will increase over time in MSBs.

1.2 RESEARCH RELEVANCE

As this project focuses on biodiversity within soft landscapes on the UBC Vancouver campus, it is interdisciplinary and aligned with multiple campus policies and plans:

Climate Action Plan 2030 - This project fully embodies the goal of using campus as a living laboratory to increase resiliency, capacity, and diversification of UBC's green infrastructure in climate change mitigation and adaptation. Project results will enhance current understanding of biodiverse ecosystems on campus and the climate adaptation benefits they provide. Additionally, results will be used to produce a geospatial inventory of soil assets on campus as a part of the ongoing efforts to quantify UBC's natural assets.

Integrated Stormwater Management Plan - The key objective of this plan is to incorporate the natural hydrologic cycle and natural systems approach into the long-term planning and design of the stormwater system. Understanding the role of soft landscapes and soils in stormwater mitigation amidst more frequent and severe storm events due to climate change is crucial. UBC campus faces unique stormwater challenges associated with its topography, the north side of campus experiences increasing erosion risk. Quantifying the capacity of campus soils to alleviate stress on below ground "grey infrastructure" systems is essential in integrated stormwater management planning. MSBs serve as a filtration medium for environmental contaminants and improves water quality before entering receiving bodies.

UBC Green Building Action Plan - This project is tied to rainwater management and overall biodiversity objectives outlined within this plan. For example, understanding the role of soft landscapes in rainwater management can lead to reduced impervious surfaces, thicker topsoil, and climate-adaptive soft landscapes. Since soils act as the foundation for all biodiversity on campus, physical and biochemical properties assessments can be used to inform design guidelines and identify feasible areas for biodiversity improvements. These improvements can be in the form of new planting designs such as pollinator gardens, bio swales, or new wildlife habitats.

1.3 PROJECT CONTEXT

The use of MSBs as a growing medium in urban development has been a standard practice since the 1980s (Smith and Augarde, 2013). Typically, native soils are removed during the construction excavation process and replaced with MSBs. This practice is codified within the Canadian Landscape Standard (CLS), and informs aesthetics of planting design and functionality of soft landscapes. Landscape architects must follow this standard, although the section on soils is currently being revised as of August 2023 (CSLA, 2023) due to challenges such as soil subsidence among other unfavourable outcomes which will be covered in the discussion section of this report. MSBs are the chosen growth medium for trees and vegetation through this standard,

MSBs are classified as part of the Human Altered and Human Transported (HAHT) soils in the US soil classification system (Galbraith, 2018). These blends are created by mixing a pre-determined ratio of sand, compost, and sometimes fertilizer to meet landscape specifications. At first glance, MSBs look very similar to native soils in composition, but its textural breakdown is very different. MSBs are very sandy in texture and typically contain uniformly sized sand particles that make up the bulk of its mineral composition, while the organic portion is filled by compost material.

Figure 1 - The push tube sample on the left is a MSB while the sample on the left is native soil. One key feature of the MSB is the uniform white sand particles.

1.4 PROJECT PURPOSE, GOALS AND OBJECTIVES

Project Purpose: Understanding whether MSBs on campus are developing favourable characteristics over time to support trees and other vegetation types against the effects of climate change.

Objectives:

- Evaluate 56 sites on campus to understand age-related development patterns in manufactured soil blends across campus across 3 vegetation cover classes (trees, shrubs and herbaceous plants, and turf grass).
- Understand the long-term impacts of MSBs on drought tolerance, carbon sequestration, stormwater management, and belowground biodiversity.
- Create a baseline geospatial campus soil dataset including physical and biochemical properties using ArcGIS.
- Develop recommendations for climate resilient soil and soft landscape management in both planning and operational practices.

2. METHODOLOGY AND METHODS

2.1 RESEARCH METHODOLOGY

This project is an observational study which involves field data collection and comprehensive data analysis in a laboratory setting.

Data was collected by members of the Urban Forest Ecosystems Lab (UFEL) within the Faculty of Forestry from June to August 2021.

2.1 RESEARCH METHODS

Site Selection

100% of construction projects on campus used MSBs after 1980s. Site selection was done using a combination of UBC Building Archives for soil age (https://archives.library.ubc.ca/buildings-grounds/ubc-buildings-chronology/) and Google Satellite Imagery for ground truthing. 56 sites with construction completion dates between the period of 1990 to 2011 were selected for data collection and analysis. Soil age was inferred from construction completion dates as the addition of manufactured soil blends is typically one of the last steps in construction. This was also verified from Google Maps as site staging areas are clearly visible from historical satellite imagery.

All sites had a vegetation cover class of either grasses, shrubs, or tree canopy cover. Vegetation cover affects the type of organic material that is deposited into the soil through decomposition, in addition to stormwater infiltration capabilities.

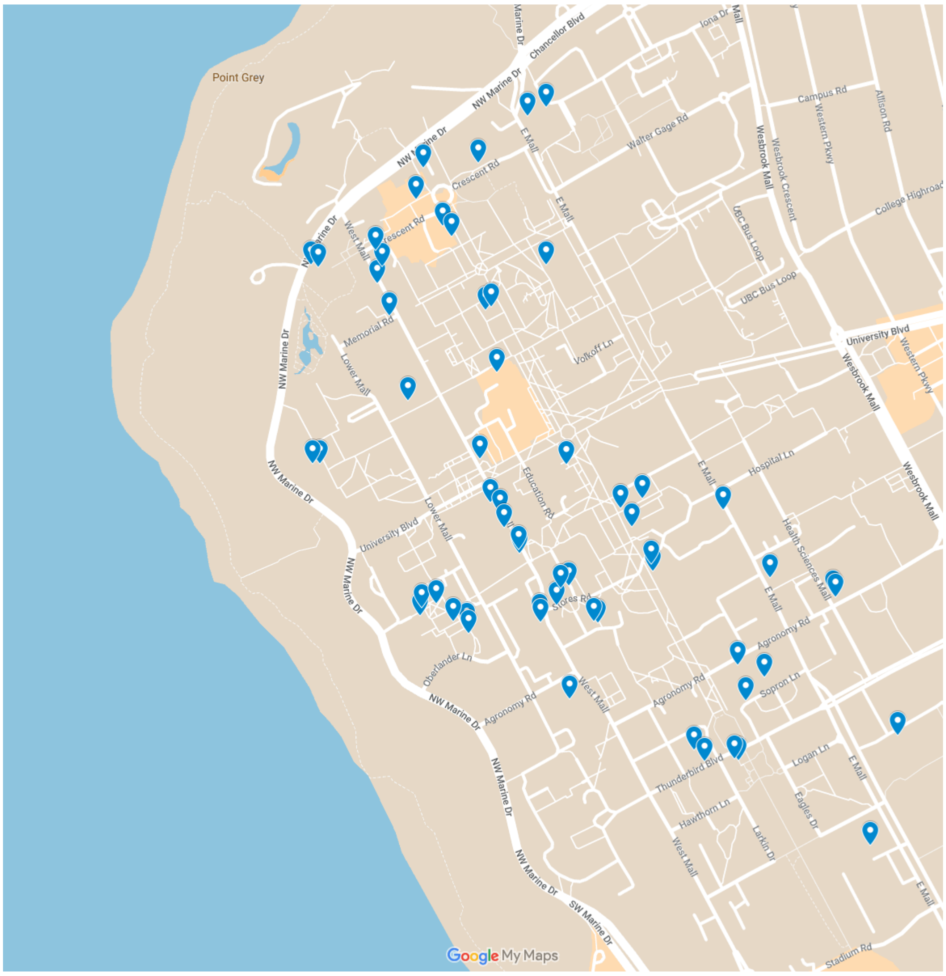

Figure 2 - An overview of all 56 study sites distributed across campus on Google My Maps. Each study site had the vegetation cover of tree canopy, shrub, or grass, which influences organic matter input and stormwater infiltration ability.

Bulk Density

Bulk density measurements determine how compacted a MSB site is, which influences plant root growth in addition to water and nutrient uptake. Bulk density data was gathered by a soil core sampler (https://www.ams-samplers.com/3-x-6-scs-complete/), which uses a linear hammer to extract entire soil cores for bulk density calculations in a laboratory setting. Two soil cores were obtained per sample site and then oven dried at 70 Celsius. Bulk density in g/cm^3 was then calculated by dry weight divided by volume of cores (Blake, 1965). This was completed in the Urban Forest Ecosystems Laboratory at Forest Sciences Centre during August 2022.

Depth

The depth of each MSB site was taken by a soil penetrometer (https://www.humboldtmfg.com/penetrometers-for-soil-evaluations.html). This is a handheld device that measures soil depth by insertion pressure. There is a pressure gauge at the top of the penetrometer and users can determine how much pressure in psi is added to the desired depth. For MSBs, 300 psi was set as the threshold because that is when soil is overly compacted for root development. Experimentation in field sampling proved that 300 psi is when the penetrometer needle hit the substrate layer beneath MSBs, which is made up of extremely compacted material that has no soil like properties. Five to six depth samples were taken per site to avoid bias, and final depth measurement is the average of these distributed measurements.

Carbon and Nitrogen Content

Soil carbon and nitrogen are dynamic measurements as they change depending on various factors such as organic input from litter, microbial community establishment, decomposition rate, and weather. These measurements were conducted during the hot and dry summer of 2022. The sampling method was to collect a composite sample of 5 push tube samples of soils at the depth of 5-10cm from the surface. The composite was stored in a brown paper bag and stored in a cooler during data collection to avoid soil respiration. Each brown paper bag was then air dried in a lab setting prior to manual breaking off soil aggregates and grinding in preparation for encapsulation.

Each bag was then thoroughly mixed and 25 grams was extracted for grinding. First, each sample was passed through a 2mm sieve to remove all coarse fragments. Second, the sample was added to a mortar and pestle and manually ground until it was the texture of flour, or smooth to the touch. Large roots and rock fragments were removed from the sample prior to grinding. Lastly, the mortar and pestle was cleaned out with 75% isopropyl alcohol between each sample. Each sample then encapsulated with tin foil and processed through the organic analyzer ELEMENTAR vario-cube (https://www.elementar.com/en/products/organic-elemental-analyzers/vario-el-cube) for carbon and nitrogen content.

Figure 3 - Photo of soil samples in beakers after manual grinding, darker soils indicated the presence of higher organic matter and higher carbon content while lighter soils indicated less organic matter and lower carbon content.

3. RESULTS

3.1 DATA ANALYSIS RESULTS

Bulk Density

Bulk density measures how compacted soils are across campus. Compaction is typically a major problem in urban areas, as most trees and plants do not grow well in compacted soils as it limits nutrient and water intake. One major advantage of using soil blends is that they are very sandy in texture and less prone to compaction. The dark blue on figure 4 showcases areas where compaction should be monitored. Additionally, sites with grass cover tend to be more compacted in comparison to shrub and tree canopy cover sites.

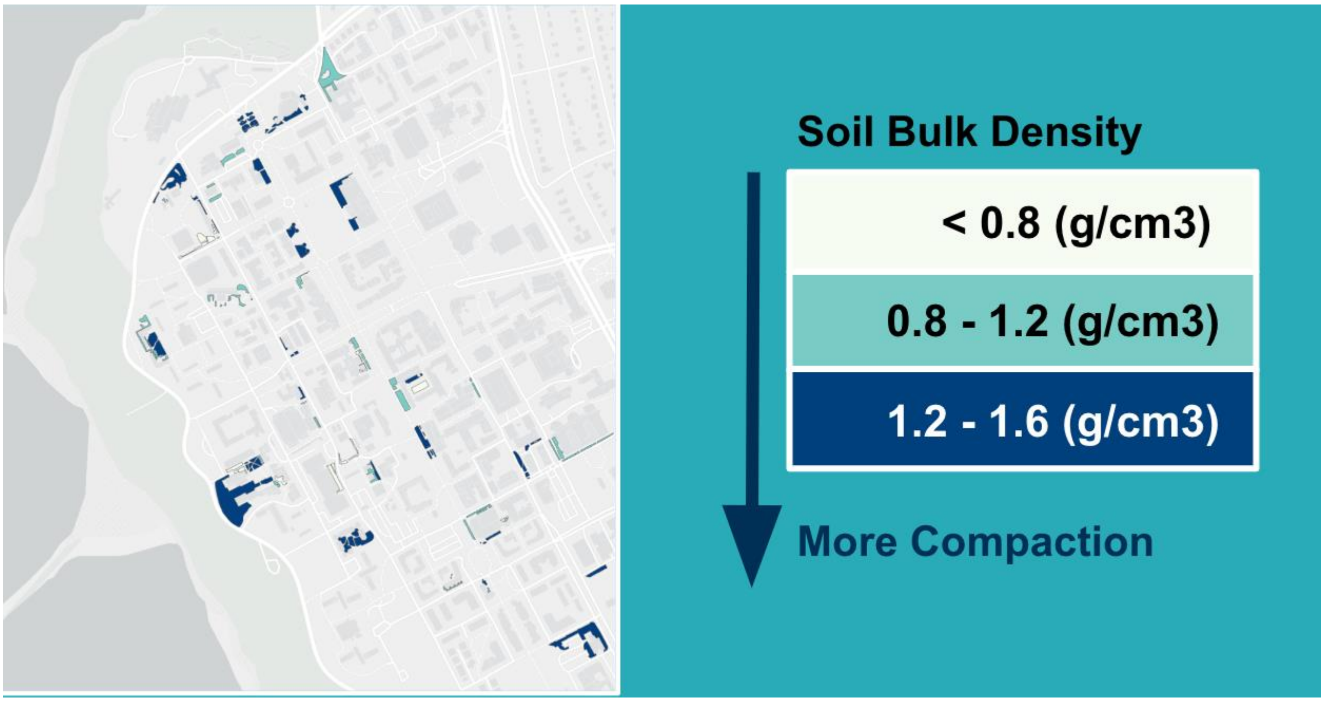

Figure 4 - Bulk density map of campus soils. Dark blue sites indicate areas where there is higher bulk density, indicating compaction or areas prone to further compaction.

Depth

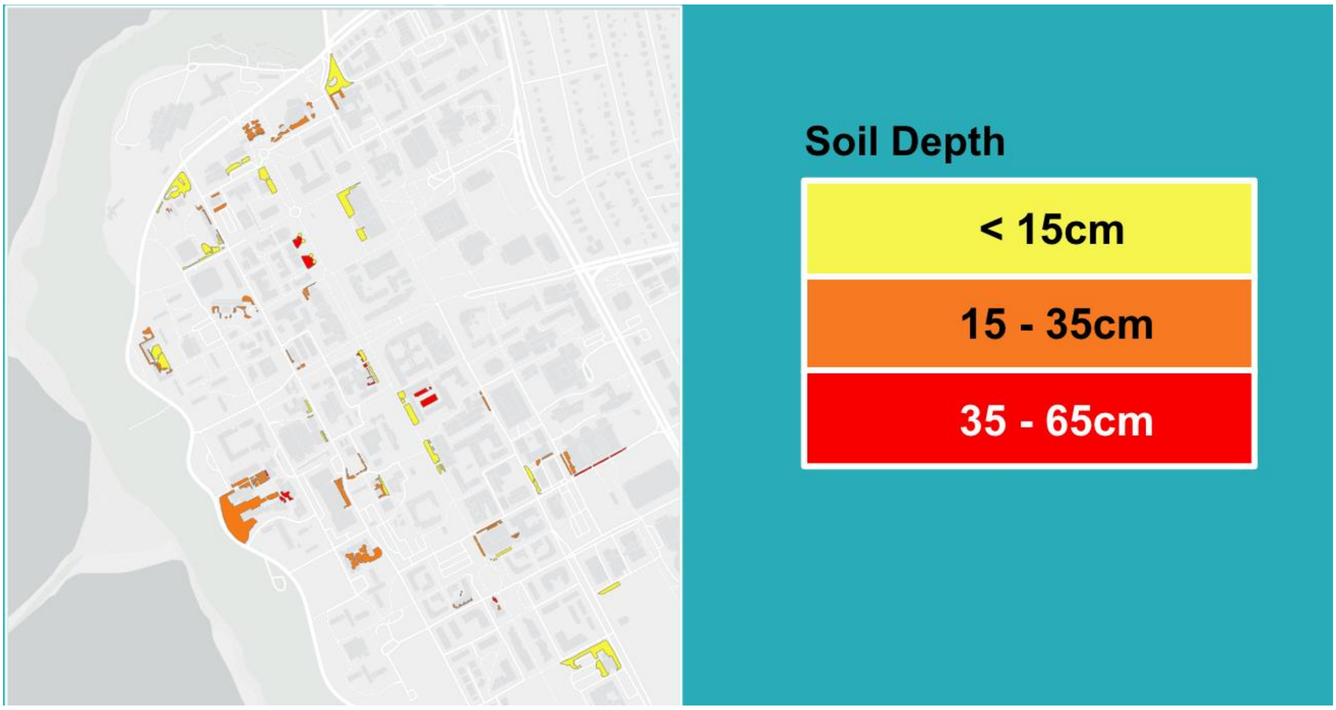

Figure 5 - Average depth was extrapolated and added to the campus soft landscape polygons. This map showcases soil depth across campus. The plots in yellow have very shallow soils, and are usually associated with turf grass sites.

As illustrated by figure 6, sites with trees had the deepest MSBs on average. This was not surprising because it aligned with the planting guidelines outlined in the Canadian Landscape Standard. Soil depth is a limiting factor as it dictates suitable planting locations for trees and shrubs. More importantly, depth influences climate resilience because sites with turf grass cover cannot be converted into shrub or tree sites in the future to offer more ecosystem services. As seen in figure 5, UBC is populated with many shallow turfgrass sites which presents challenges for improving campus biodiversity,

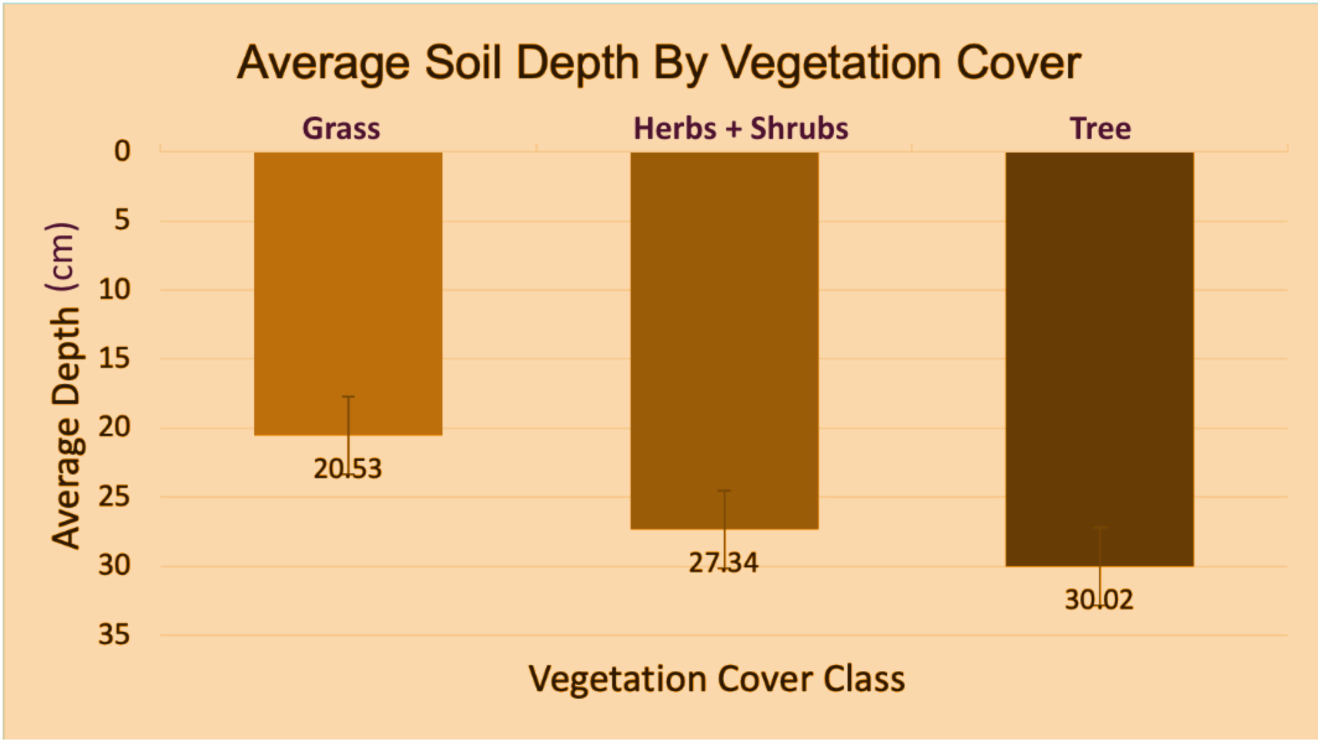

Figure 6 - Average soil depth classified by vegetation cover class. On average trees are associated with deeper soils because it is the planting standard outlined in the Canadian Landscape Standard.

Total Carbon Content

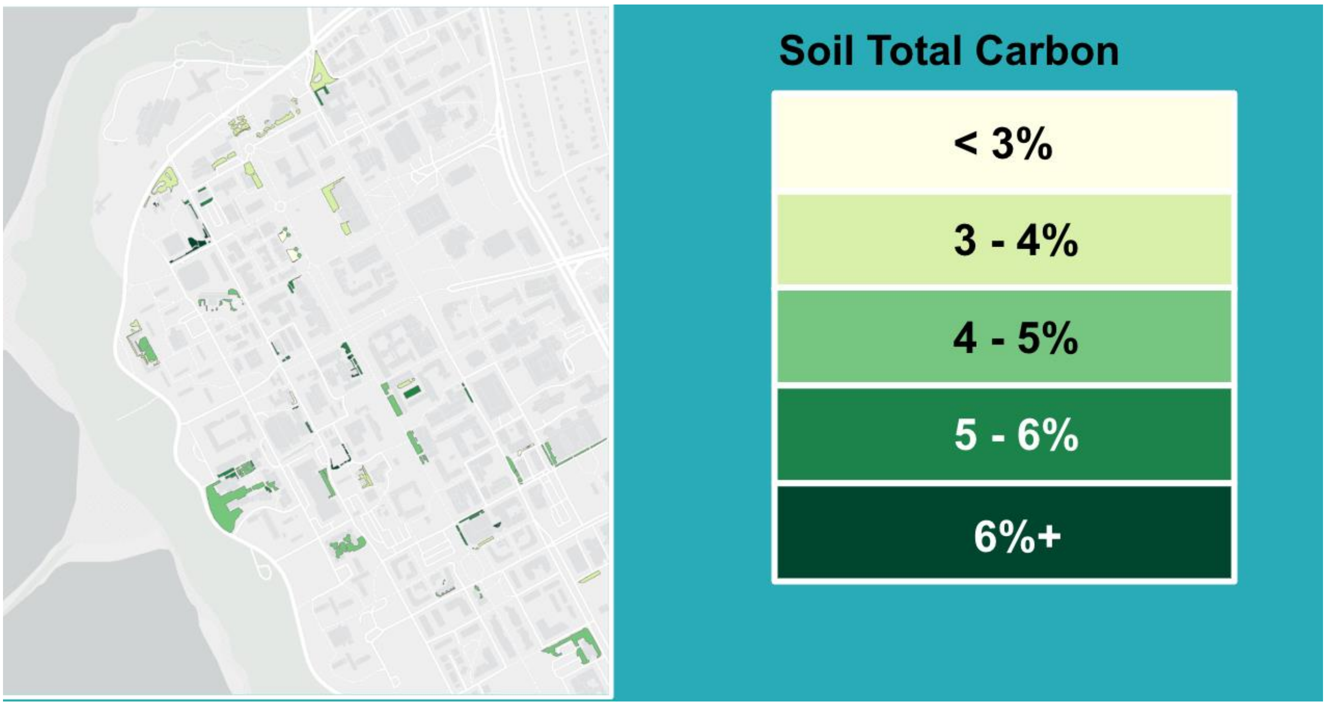

Figure 7 - Total soil carbon across campus. Soils on the North end of campus tended to have higher carbon storage compared to soils in the south end of campus.

When managed sustainably, soils can be an effective long term carbon store. Figure 7 showcases the percentage of total soil carbon across campus plots. Total soil carbon is made up of soil organic matter such as compost amendments, litter inputs, as well as microbial biomass. Figure 8 shows carbon accumulation over time as a function of total soil carbon. The primary carbon input in this case would be roots and litter. On average, trees had higher carbon content, which can be due to increased leaf litter input.

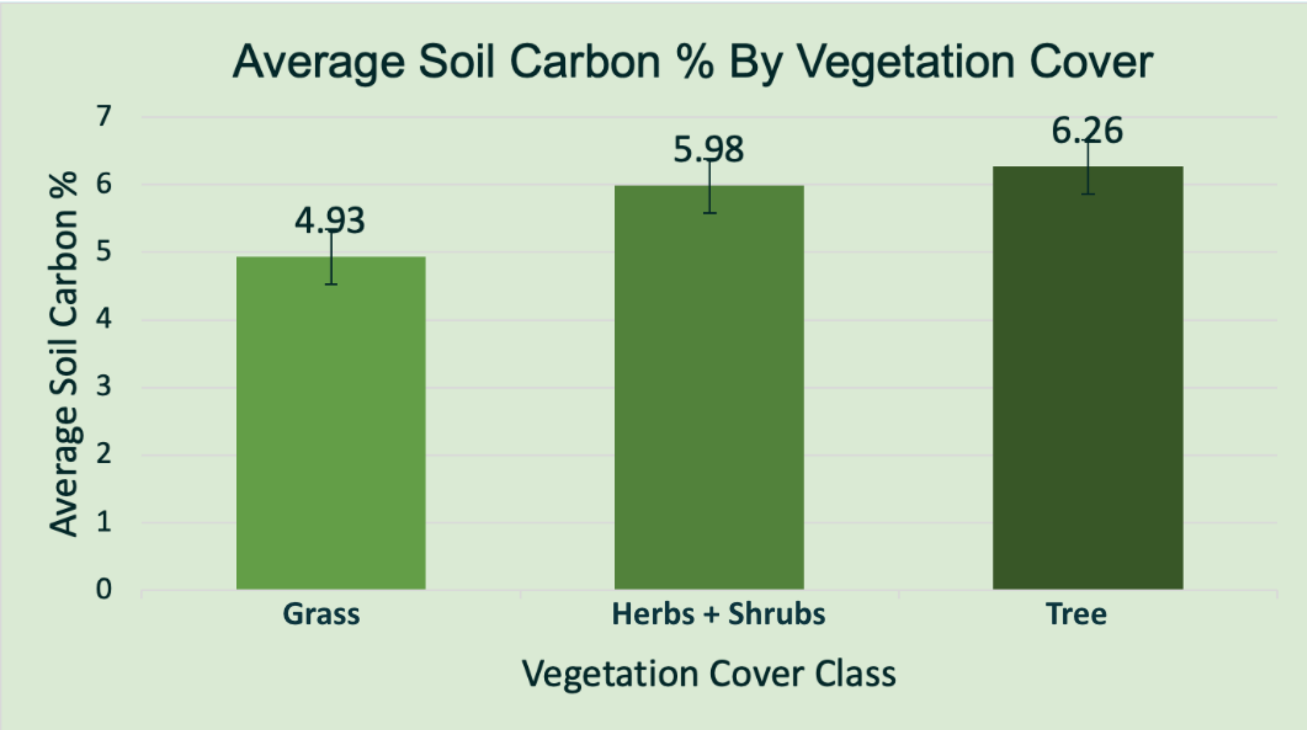

Figure 8 - Carbon accumulation over time as a function of total soil carbon. Sites with tree canopy cover had the highest total soil carbon content on average.

Age Related Patterns in Soil Development

Currently, preliminary data analysis on Rplot matrix as shown in figure 9 shows no distinct effect of age on the development patterns of MSBs. From this matrix, there are no distinct patterns associated between age and bulk density, depth, or carbon and nitrogen content. This means that MSBs are either developing at a very slow rate over time or that development patterns is not associated with age.

Figure 9 - Rplot matrix of different experimental factors such as depth, bulk density, carbon and nitrogen content against the factor of age.

4. DISCUSSION

Through our findings, it is discovered that the soils on the UBC Vancouver campus fail to allow carbon to accumulate over time in all vegetation covers of shrub, tree, and grass. This is due largely to depth being a limiting factor and MSBs being a somewhat sterile growing medium, which will influence the climate resilience of trees and vegetation. From the results, MSBs are experiencing little to no soil formation processes which allows for favourable characteristics to development in order to support plants during climate stressors. For example, as seen in figure 10, MSBs installed over 32 years ago experienced no significant aggregate formation and remains extremely sandy and loose. This indicates that there is a lack of soil microbial community or fauna to form aggregates (Denef et al, 2001).

Figure 10 - A photo illustrating the diverse colour range of MSBs. This is due to the varying amounts of organic matter content found within MSBs.

The sandy and loose texture of MSBs as seen in figure 10 can present additional problems such as water moving through the soil too quickly or too slowly. In some field observations it was discovered that there is hydrophobicity associated with some MSBs. As 100% of campus used MSBs since the late 1980s, it is essential to assess the biochemical and physical properties of these novel growing mediums because currently they appear as sterile systems that do not offer a wide range of ecosystem services besides the role of a growing medium. For example, there is little evidence that MSBs are designed to support long term carbon storage, water retention, and below-ground biodiversity.

As shown in figure 9, it appears that MSBs are not developing favourable qualities over time to support trees and other vegetation experiencing climate stressors. This is a major problem because climate change brings forward new challenges for urban vegetation such as increased drought periods in addition to more frequent storm events. MSBs do not function as a climate resilient growing medium because it has not displayed strong water retention capabilities or carbon storage capabilities. In addition, working closely with MSBs revealed that there is a lack of soil fauna that resides within soil blends, indicating that soil blends do not support belowground biodiversity.

One limitation within this study is that carbon data was only obtained from the top 20 cm of soil which contains many plant roots that can induce error in measuring total soil carbon. Ideally there would be samples from 1 meter below the soil surface to understand the amount of carbon stored deeper within the soil horizons.

5. RECOMMENDATIONS

5.1 RECOMMENDATIONS FOR ACTION AND IMPLEMENTATION

With these findings, I have 3 key recommendations for policy makers and landscape managers:

1. Recognize and include urban soils in the renewal of UBC climate resilience and biodiversity policy documents as an important natural asset in supporting aboveground biodiversity and stormwater management.
2. Development a Sustainable Soil Management Plan for campus as a holistic toolbox of best practices aimed to protect soil health under climate change stressors. Additionally, use our baseline data to complete a campus soil inventory to effectively allocate resources for sustainable management.
3. And lastly, identify suitable sites to convert turf grass into low maintenance pollinator gardens populated by native grasses, shrubs, and flowers. This presents a win-win solution as it reduces maintenance efforts and costs, while providing a food source for local pollinators.

5.2 RECOMMENDATIONS FOR FUTURE RESEARCH

- Expansion of current soil inventory to include more campus soft landscape polygons
- In depth textural analysis between MSBs and native soil, and comparison of physical and biochemical properties
- Expansion of biochemical and physical soil properties including nutrient content and year-round moisture level sensors

6. CONCLUSION

This project taught me that there is a large degree of uncertainty in the relatively new growing medium of urban soils and its role in overall ecosystem resilience. Soils set the foundation for all biodiversity on our planet, and further research into this relatively new growing medium can help us develop holistic management objectives in order to protect and enhance biodiversity on campus.

I would like to acknowledge that this project was jointly funded by the UBC Climate Emergency Fund through the SEEDS Sustainability Program and the National Science and Engineering Research Council of Canada. Special thank you to Shannon Guichon, Zach Johnston, Heather Bylsma, Phillip Beck, and Dean Gregory for their ongoing support, as well as everyone in the Urban Forest Research Hub for helping with the fieldwork component of the project.

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APPENDICES

Appendix A - Photo of field data collection for bulk density cores. Each site was irrigated prior to using the bulk density hammer because the texture of MSBs were too sandy to collect dry core samples.

polygon E

Appendix B - Sample of a field collection route that was taken by the data collection team. Each collection route was randomized to avoid sampling bias.