Breaking Ground UBC Soil Asset Management Plan

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EXECUTIVE SUMMARY/ABSTRACT

This paper explores the concept of natural capital applied to soil as a component of green infrastructure, and thereby support the advancement of improved urban forest management practices across campus. This work helps position Building Operations, Campus and Community Planning and Sustainability Engineers in a better place to deal with the complex decision-making that comes with managing soil in a holistic, sustainable and logical manner. It advances UBC as an innovative leader in the realm of sustainable urban development and growth, and recognizes the role that the UN Sustainable Development Goals play in this capacity.

The research presented in this paper hopes to achieve three outcomes:

1. To provide a rationale for why UBC Building Operations should consider integrating soil in their new infrastructure asset management software, Planon.

2. To provide a data inventory framework that UBC Building Operations, Campus + Community Planning (C+CP), Academics and Sustainability + Engineering can use to develop management objectives and actions for a green infrastructure asset management plan.

3. To share potential and existing data sources that would address any knowledge gaps found in the data inventory framework for soil.

These outcomes are intended to support ongoing initiatives from Campus + Community and Building Operations that deliver nature-based solutions to scalable challenges, such as: public heath; public recreation;, climate adaptation and mitigation; infrastructure repairs and maintenance, and storm-water management.

INTRODUCTION

RATIONALE FOR THIS STUDY

The direction for sustainable development on campus is driven by strategies and goals to minimize the impact of land use change on Earth's systems. Strategies such as UBC's Sustainability Strategy, the UN's Sustainable Development Goals and Smart Cities in Canada have advanced the call for more efficient and sustainable city systems. Given that 65% of the world's population will live in cities within the next twenty years, not only will cities face the challenge of balancing densification with greener spaces, they will also be the centers generating demand from natural resources beyond urban containment areas. This paper focuses on the impact of urban development and land use change within cities and offers an economic argument that engineers value for soil as a natural asset. The argument presented in this paper hopes to be of use for better prioritization of soil management strategies during planning, development and construction phases of land use changes.

UBC'S HISTORY

In 1907, the University Endowment Act was established, and provided funding for the University of British Columbia. In 1910, board members were elected to secure a site reported in the University Site Commission Act; in their report, the board proposed the acquisition of 250 acres for the University and 700 for experimental purposes in agriculture and forestry. Point Grey was selected as the site amidst all of the municipalities of BC specifically because of its rich and fertile soil, and the delta by which it set (Logan, H., 1958). From its early onset, the University's purpose was tied closely to the study of soil, and the soil's fertility and richness was a significant factor in its site selection; this speaks volumes about the necessity of soil stewardship at Campus and Community Planning. The emergence of plan structures and policies like that of the Urban Forest Management Plan and Biodiversity Strategy demonstrates a willingness for campus to meet, and perhaps even exceed expectations for sustainable and responsible urban land management, including the management of soil on campus.

There is ample opportunity to improve the University's leadership in its management of urban natural resources given that Building Operations is now transitioning into a new infrastructure asset management software called Planon. As the University advocates for Climate Change adaptation and mitigation through planning and policy devices such as the Climate Action Plan; forums such as the UC3; and student-initiated clubs like the Climate Hub, natural assets need to be considered more seriously for sustainable campus growth. Nature-based solutions to climate adaptation and mitigation are quickly becoming a topical point in sustainable development decisions, as evidenced by the UN Sustainable Development Goals 3 [Health]. 7 [Energy], 11 [Sustainable Cities and Communities], 13 [Climate Action], and 15 [Life on Land] (UN Sustainable Development Goals). Canada recently delivered an Integrated Bilateral Agreement of Infrastructure Investment which funded green infrastructure to support greenhouse gas emissions reductions, enable adaptation, improve climate-change resilience, mitigate disasters in the long term, and ensure that more communities can access clean air and safe drinking water (Government of British Columbia, 2018). These political and financial movements also indicate a growing opportunity for UBC to demonstrate academic leadership on the interface between climate resilient finance, natural assets and sustainable urban growth.

Lastly, soil is the foundation of civilization (Setala, H., 2009). There are no technological solutions that can replace its function in urban or earth systems. Sensitive chemical, physical and biological activity all work in the pedosphere (the layer of the earth that is made of soil) to process constituents from the atmosphere, lithosphere, hydrosphere and biosphere to deliver the building blocks of life: proteins. This process takes time and delivers irreplaceable and essential services and products to enable human existence. However, soil is a sensitive entity that is easily degraded in quality and function by conflicting land use changes; the main threats found in urban environments include compaction, contamination, erosion and ponding. These threats have implications for the level of service soil can deliver to the urban environment as green infrastructure and can in some cases result in disservices that result in lawsuits. For example, the Bouygues Building Canada Inc. group (Business in Vancouver, 2019) sued the Vancouver School Board on the grounds of discovering contaminated soil on the site after contracts had been negotiated. In this case, the contamination of soil lead to a loss of reputation, stakeholder trust and $10.9 million in the lawsuit.

Infrastructure Asset Management

Asset Management is a relatively novel concept that was developed by the National Research Council of Canada to optimize municipal infrastructure management. It is defined as “a business process and decision-support framework that: (1) covers the extended service life of an asset (2) draws from engineering as well as economics; and (3) considers a diverse range of assets” (Vanier, D.J., Newton, L.A., Rahman, S., 2006). Traditionally, this approach is used to manage hard infrastructure such as roads, bridges or buildings; this paper explores its application to the evolving concept of green infrastructure, using ecosystem services as the primary framework for understanding what products users benefit from natural assets.

Figure 1 provides an overview for the asset management process, guided by its goals and the facets an asset can be dissected into. This paper specifically provides insight into what data can be collected for the development of a soil inventory, and thereby help itemize soil as a natural asset. Every step of the process section in this graphic is applicable to each facet. For example, a group of stakeholders would develop a protocol for how to inventory soil using the research conducted in this paper. The data would then be used to count and measure the asset with the specific purpose of delivering a report on its performance in the ecosystem service desired by stakeholders clearly during the “selecting protocols” process. Assets would then be inspected to confirm they exist, and data would be collected or updated to determine whether current management strategies are working, or whether they need improvement using a scorecard to report its state. Errors or omissions would be corrected during this stage. Lastly, soil assets would be compared to each other based on performance metrics to strategize which soil assets are to be prioritized for improved management so as to derive more productive ecosystem services from them.

Figure 1. An Asset Management Plan example outlining three hierarchies within a typical infrastructure asset management plan. One would complete each facet of asset management using the process outlined to achieve the example objectives listed above.

Applying this framework to the management of campus natural assets (soil in particular) allows the campus to focus on developing a soil management system that optimizes its indirect and direct services, captured in Figure 2. One of the ecosystem service categories defined by the Millennium Ecosystem Assessment Report is "supporting" services, which ensures that services supporting ecosystem function is optimized as well as services supporting human comfort and lifestyle.

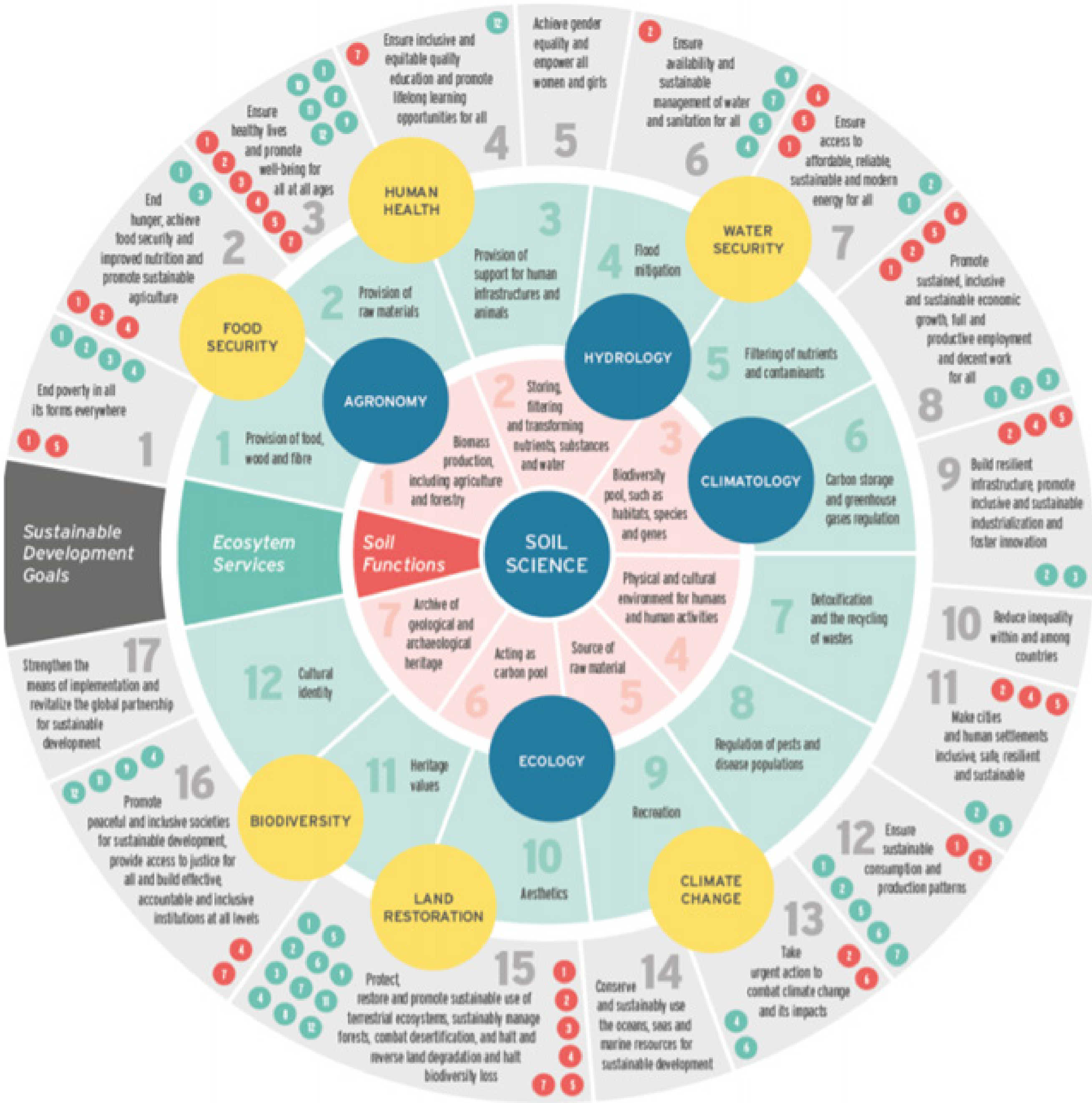


Figure 2. A model demonstrating how soil functions deliver ecosystem services that support sustainable development goals set by the United Nations (Deltares, 2018).

ECOSYSTEM SERVICES OF SOIL

Soil is a multi-beneficial infrastructural asset that benefits multiple policies, plans and communities across the campus. Though Point Grey was originally sought for its high-quality soil, little is known about our soils today which contributes to their continued absence in campus development decision making. To illuminate its value and worth, a vested interest must be taken to investigate the relevant ecosystem services soil delivers to stakeholders involved in campus development. Some of these services include sustainable urban rainwater management; public health; microclimate regulation; microclimate adaptability; pollution control; recreational opportunity; and clean water and food supply. Many of these services could benefit existing plans at the University, such as the Integrated Stormwater Management Plan, Public Realm Plan, Climate Action Plan, emerging Urban Forest Management Plan and emerging Biodiversity Strategy.

Green Infrastructure Services

Green infrastructure, and by association soil, is valuable to the campus' community for a variety of reasons spanning academic research, climate adaptability, quality of life, rainwater management, cultural history, landscape, and recreational space. These services can be categorised via the order of the Millennium Ecosystem Services framework, under provisioning, regulating, cultural and supporting services (Millennium Ecosystem Assessment Board, 2003); for example, landscape may serve a cultural, regulating and providing service, while rainwater management serves a regulatory service. In the same way, the condition of the soil influences whether providing, regulatory and cultural disservices are delivered. For example, instead of enhancing water quality through its natural filtration capabilities, brownfield soils contain so many contaminants due to previous industrial and urban use, that any water infiltrating it is likely contaminated. Such rainwater exacerbates existing challenges to manage for resilient ecosystems beyond the boundary of brownfield sites, as this water is capable of polluting rainwater sources.

Green Infrastructure Disservices

These disservices occur when soil is degraded to a point where remediation is not feasible given its state. Subsequently, they are abandoned, and their condition deteriorates, introducing risk to the general public and the environment. In March of 2019, Bouygues Group sued the Board of Education of School District No. 39 (Vancouver) for the construction of a new school for the "Kitsilano Secondary School Renewal Project" went south; upon discovery of contaminated soils and fill on lands which would have cost millions to remove and delay the project, the contractor sued the institution for not extending the contractor (Business in Vancouver, 2019). Such examples demonstrate the liability contaminated urban soils can carry if not proactively managed as an asset; the effects can ripple from environmental loss to litigative action and a loss of reputation by all parties involved. But rather than managing to mitigate this risk, the approach that this paper encourages is managing soil as an asset capable of multi-beneficial services.

Requirements for service delivery

Soil is the foundation of green infrastructure, but the formation of this foundation is not merely a mixture of different composites. Pedogenesis (the development of soil) takes millennia to develop; it is a very slow process that integrates biological, physical and chemical processes. Soil is known as "Earth's Critical Zone" precisely because of this; it is where the hydrosphere, lithosphere, atmosphere and biosphere interact to form products the sustain life, quite literally. Primary producers are responsible for the production of oxygen, without we which we would not breathe; it is also responsible for the production of carbon, where we receive our energy from through metabolic processes (and which recently has received a bad rep); primary producers are also responsible for supporting all other hierarchy of trophic organisms); the roots of vegetation help develop soil aggregates which are capable of retaining rainwater better. These products (e.g. soil aggregates, roots) deliver the service of attenuated stormwater management, which meets the ambitions of our Integrated Stormwater Management Plan.

Objective of Study

The aim of this Directed Study is to provide a rationale for why UBC Building Operations should consider integrating soil into their new infrastructure asset management software, Planon; to provide an inventory framework that UBC Building Operations, Campus + Community Planning, and Sustainability + Engineering can use to develop management objectives and actions for a green infrastructure asset management plan; and to share potential and existing data sources that would address any knowledge gaps found in the data inventory framework for soil.

Methodology

To deliver a framework for a Green Infrastructure inventory (focusing on the component of soil), data gaps had to be identified in order to understand what needs to be measured about the soil component of green infrastructure. Therefore, a survey was created and conducted among UBC staff and academic experts. An open-ended comment survey was determined to be the best method for collecting information on what types of data should exist on campus soils, what types of data may exist and where they existed to illuminate; this was thought to be the best method because it allowed for the most depth and range for answers, and respondents would be best equipped to provide relevant information at a stage when little is known. Further desktop research was then conducted to determine which identified knowledge gaps needed to be prioritized for a preliminary assessment of the condition of soils, where these data sources were recorded, and where they were likely to be if there was no existing record of them.

The survey was targeted towards two demographic groups based on their career role in the University, Campus + Community Planning Staff and academics who's work entailed soil. The questions asked were the same between both groups but reworded to be more applicable to each demographic group. The academic group of respondents were asked the following mix of qualitative and quantitative questions:

1. On a scale of 1 – 5, 1 being strongly disagree and 5 being strongly agree, would you consider yourself to be highly experienced in the area of soils?

2. How would you describe your areas of interest in this field?

3. Are students engaged in fieldwork in any soil-related courses? If yes, what type of data do they collect? If no, do they engage with data collection, analysis or management to some degree?

4. On a scale of 1 – 5, how well aware are you of UBC's soil management practices? (1 = not aware, 5 = fully aware)

5. What would you say are three important knowledge gaps to fill when inventorying urban soils in the face of climate change?

6. What would you say are three important issues to consider when managing urban soils in the face of climate change?

7. Would you be interested in having access to more soils data on campus? If you answered Yes or Maybe, what types of data would you like to have access to, and why?

8. Do you feel that the University's soil management policies and practices are doing enough in the face of Climate Change?

9. What do you think the campus could be doing better when it comes to managing urban soils as a natural asset to climate change?

Staff groups of respondents were asked the following mix of quantitative and qualitative questions:

1. What role do you play and how does it relate to greenspace?

2. How well aware are you of UBC's soil management practices on a scale of 1 – 5? (1 = not well, 5 = extremely well)

3. On a scale of 1 – 5, how would you rank the importance of soil management on campus given the umbrella of responsibilities under your role in Campus + Community Planning? (1 = not important, 5 = highly important)

4. What information or data does UBC

currently have on file about their soils or growing medium?

5. How would you use that data/what purpose would it serve?

6. On a scale of 1 – 5, do you think the university's current landscape management policies gear the University's landscape management policies as climate resilient landscapes?

7. What are the knowledge gaps that the C+CP or Building Operations need to fill in to better understand how to manage their soil?

8. In your experience, what common issues do building operations/C+CP find in managing plants on campus?

The delivery of the survey impacted the quality of information obtained from it. Respondents were given the option to be guided through the survey on a phone call, or to take it through a Qualtrics platform. It was found that respondents who had chosen to answer the survey through Qualtrics answered to only a few of the questions asked, and often provided minimal information with little to no insight. Respondents who chose to discuss the questions further in phone conversation could be asked follow-up questions in real time, and this resulted in a clearer and more in-depth discussion that yielded a higher quantity and quality of information.

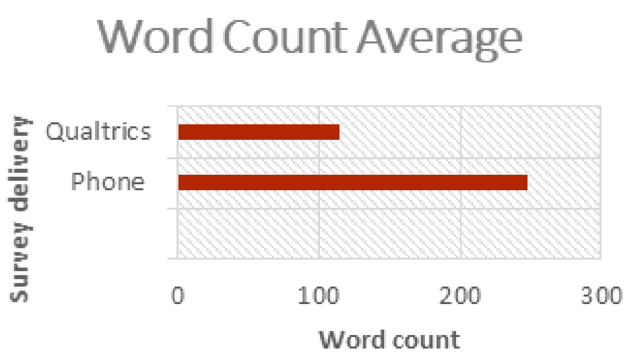


Figure 3. Word count of respondents demonstrating volume of information available by type of communication

There are a few reasons for why the delivery of this survey over the phone worked better than through a web-based platform like Qualtrics. Firstly, the topic of inventorying green infrastructure is a niche topic that requires an explanation of the context and rationale, and an opportunity for respondents to ask further questions of clarification about the subject of the survey. Through the phone, the survey's purpose as a means to improving urban soil management on campus could also be highlighted more clearly and was likely to motivate more in-depth answers from respondents who were not already steeped in the subject. Secondly, the questions asked were fairly broad questions that were designed to capture a wide array of information, but instead were confused as questions asking the same thing due to the similar sentence structure through which they were developed. Hence, respondents who answered on the phone could clarify the difference whereas Qualtrics respondents either did not answer the question or responded, "same answer as above".

An anomaly occurred with one of the staff participants, whereby the survey questions were disregarded and instead they presented their findings from the experience they developed in attempting to manage for urban soil considerations for a recent neighborhood development. Their findings were largely relevant to gaps in UBC's practices during building proposals and development processes, which struggle to enforce and support sustainable urban ecological management.

Findings

The survey found that there were several data attributes Building Ops could inventory in conjunction with the UBC Data Governance Panel, Campus Biodiversity Initiative Research and Demonstration (CBIRD) and owners to the Urban Forest Management Plan. On a high level, most academic respondents relayed a range of data attributes specific to their area of research on soil that covered topics from the soil's biological state to its chemical state, providing a broad overview of what data components to obtain. For example, Cindy Prescott relayed that her area of expertise was soil biology, and as such recommended collecting data on soil rooting depth, organic matter and researching further on plant species that benefited the soil; however, Thomas Andrew Black focuses on carbon fluctuations in biomass, and therefore suggested collecting data on carbon loss and storage using the Eddy Covariance technique. The data gaps recommended are organized into their usability for future academic research and/or their usability towards C+CP, Building Operations and Sustainability Engineers' green infrastructure inventory.

Academic Respondents Key Findings

Academic experts that had agreed to be surveyed included Cindy Prescott, Thomas Andrew Black, Maja Krzic and Mark Johnson; other identified experts included Sean Smukkler, Dan Moore and Hans Schreier, but these had not been interviewed. The following highlights key findings from their responses

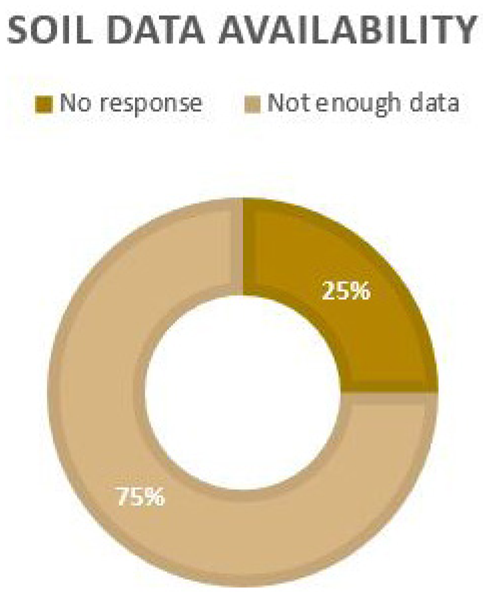


Figure 4 illustrates that 75% of all academic experts on the UBC campus felt that there was not sufficient data on the campus' soils.

Figure 5.

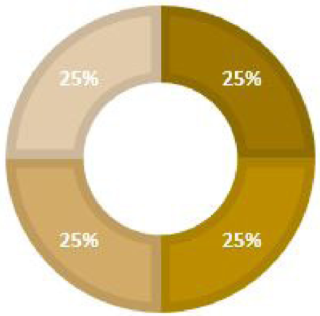
A detailed grouping of the types of data recommended by academic experts at UBC's Campus.

Geographical data

Map all inventoried data to a GIS based system that locates information to a space.

Biophysical data

- Plant combinations that contribute high organic matter
- Implications of fertilizer and drip irrigation on soil root systems
- Compaction vis-à-vis infiltration
- Soil moisture
- Soil temperature
- Bulk density
- Soil structure



Earth system interactions

- Evapotranspiration
- Rooting depth
- Monitoring carbon levels in soils (carbon loss, gains, storage)

Chemical data

- Sodic conditions from salt applications
- Nutrient content

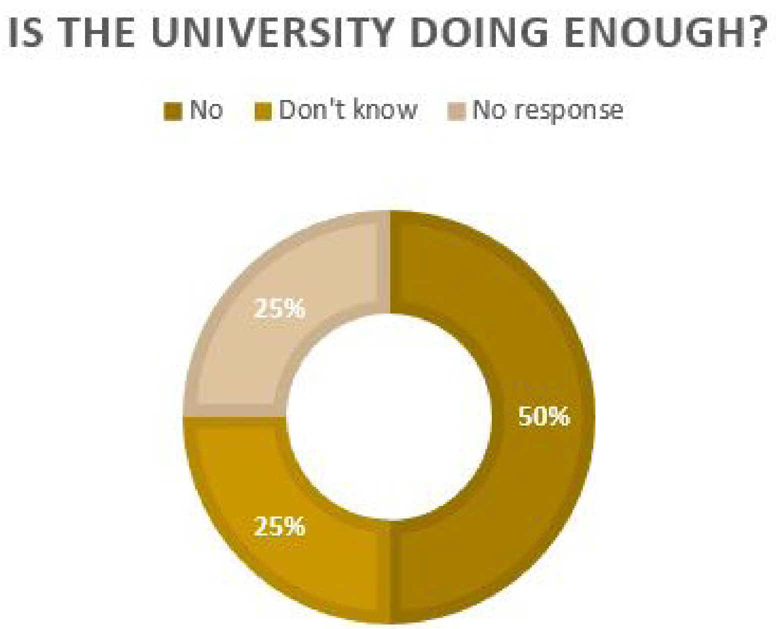


Figure 6 demonstrates academic perceptions on whether the University was doing enough to manage its soil

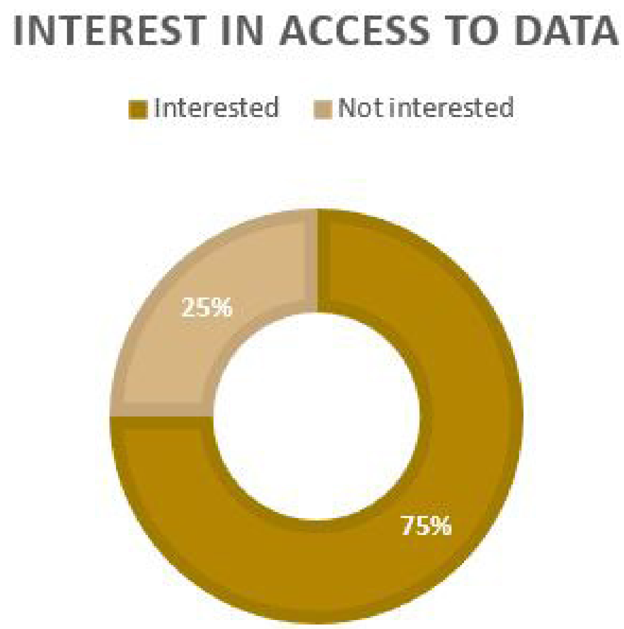


Figure 7 demonstrates the proportion of academics interested in accessing data.

Most academics were interested to gaining access to more data on campus soils, but only one clearly stated that they would not be interested unless there was clear purpose for their access to the data – in other words, unless they were asked to deliver some form of research with the data.

As shown in Figure 4.1 , a total of twelve data attributes were recommended by academic experts to monitor the biophysical and chemical state of the soil. Table 1 provides a different view of these attributes by mapping them to the asset management categorization they would be most useful for informing, hence demonstrating how they support such services.

Desktop research

Further desktop research was conducted to refine the list of collectable data on soil, and develop a tool that would help deliver asset management planning objectives and actions in relation to the data monitored. This tool is meant to be used by Building Operations for improved decision-making purposes in management but may also be useful to Campus + Community Planning.

Soil has a plethora of measurable attributes that can be used to assess its condition, but only a handful are useful for delivering management objectives that optimize asset condition, function and service without compromising security. Estelle Dominati underlines two types of soil properties that can be measured: inherent properties (or dynamic properties) and manageable properties. Inherent properties take stock of soil properties that develop ecosystem services through pedological processes, while manageable properties take stock of soil properties that are influenced by management techniques. The finalized list of data attributes selected for measurement take this into consideration, as well as inputs from the survey conducted in this directed study, and examples of current soil survey frameworks used by a consulting firm at UBC. This allows for consistency in data collection and known data variables to be collected and assess soil quality for the eventual improvement of its condition, function, performance and service. The final data framework also provides recommendations for management objectives and actions that may help provide guidance as to how the data framework should be used as a tool to improve soil management so that it may be recognized as an asset. It is attached separately to this document as an excel spreadsheet that takes UBC's land use zones into account, and therefore provides applicable recommendations towards these zones.

Outcome

This Soil Data Asset Management tool was developed to help users infer what the data type can indicate for the soil structure and function; each data type has an associated exemplar asset management objective it can help monitor progress upon.

Performance Indicator	Metric	SOIL STRUCTURE	Soil structure	Soil stability	Infiltration	Drainage	Water storage/Detention	Nutrient cycling	Aeration	Gaseous Exchange	Biomass production	SOIL FUNCTION	Water Quality	Air Quality	Greenhouse Gases	Biomass productivity	Biodiversity	Water storage	Flow and Flood Control	Aesthetics	Pests + Disease	Temperature Regulation	Filtration	Recommended Management Objectives that support the vision of improving or maintaining soil condition
			SOIL FUNCTION										SOIL SERVICES/DISSERVICES											
soil depth (cm3)	cm3					•			•					•	•				•					
slope (%)	%			•	•																			
sealed surface (Y/N)	Y/N				•																			
Bulk density	g/cm3		•		•									•	•	•	•		•				•	1) Maximize soil productivity 2) Minimize soil compaction
Aggregate stability	mm		•	•				•					•	•		•	•		•					1) Minimize soil erosion 2) Maximize soil productivity 3) Maximize soil hydraulic function
Available Water Capacity	% water in inch of soil						•				•					•	•	•	•				•	1) Maximize soil hydraulic function 2) Maximize soil productivity
Earthworms/ Microfauna	Count			•	•			•	•					•		•	•		•					1) Maximize soil productivity 2) Minimize greenhouse gas emissions 3) Maximize habitat quality 4) Maximize hydraulic function
Carbon fluxes using Eddy Covariance Technique	TBD									•	•			•	•	•	•							1) Minimize greenhouse has emissions 2) Maximize carbon storage in urban soil pockets across academic landscape, open spaces, landscapes and university endowment lands
Respiration	CO2-C lbs/acre/day (or kg/ha/d)		•					•						•	•	•								1) Maximize soil productivity 2) Minimize soil greenhouse gas emissions
Soil pH	pH			•				•		•	•			•		•					•			1) Maximize soil productivity 2) Minimize exposure to urban contaminants and pollutants
C:N ratio	%		•						•						•	•	•				•			1) Maximize soil productivity 2) Minimize greenhouse gas emissions 3) Minimize pest and disease
Soil fragment size	<2mm%, >2mm%		•			•			•		•		•	•					•				•	manageable except for managing supporting services.
Soil texture distribution	Sands % Fines %		•		•				•				•	•				•	•				•	1) Maximize soil hydraulic function 2) Maximize urban soil pollution filtration
Evapotranspiration rate	mm/time					•																•		1) Maximize soil productivity 2) Maximize soil hydraulic function

Total OM	%						•			•				•	•							1) Maximize soil productivity 2) Maximize soil hydraulic conduction 3) Maximize habitat quality
Total N	%						•				•			•	•							1) Maximize soil productivity 2) Maximize habitat quality 3) Minimize nutrient leaching
Potassium content	ppm						•							•								1) Maximize soil productivity
Nitrogen content	ppm						•				•			•	•							1) Maximize soil productivity
Calcium content	ppm						•							•								1) Maximize soil productivity
Magnesium content	ppm						•							•								1) Maximize soil productivity
Sodium content	ppm						•							•								1) Maximize soil productivity

The data asset management tool found nine objectives that could be used to guide improved management tools through a service-focused, risk-based framework. The tool demonstrates which available performance indicators can be used to monitor soil functions that deliver essential and co-beneficial soil services. Inventorying and monitoring these data points would enable better and more proactive management decision making within Building Operations to ensure that campus sustainability development goals are being met. One of these goals listed in UBC's 20 Year Sustainability strategy is to demonstrate "regenerative design" in the built environment, which is applicable to landscapes in the built environment. The management objectives were developed using the Food and Agricultural Organization's (FAO) Voluntary Guidelines for Sustainable Soil Management.

Soils and natural landscapes are capable of being resilient to the changes expected from global warming (or climate change), such as droughty summers and cooler winters in BC, but if these natural assets are in poor condition, the expense to maintain them (and thereby maintain UBC's landscape character) will only increase until they may have to be substituted or replaced completely. An example of this is the Oak Bosque, which was originally intended for use by the student population due to its proximity to the nest. As its condition deteriorated, the Bosque no longer became a culturally relevant space to students, and due to the soil compaction and subsequent crown dieback of the Oaks, the space has been deemed appropriate for development. This example illustrates another point of importance for baselining and monitoring the state of campus landscapes, beginning with the foundation of all landscapes: soil.

Data sources across UBC

Data gap (shaded cells)

Performance Indicator	Metric	Existing Data Source	Potential Data Source
Soil order + taxonomic classification	-	LUI Tool Sustainable Soil Management Course (Specifically for UBC Farms) Vancouver Soils Map Soil Sample records by Pacific Soils Analysis	[University of Victoria Environment BC Dataset]()
Soil depth (cm3)	cm3		Landscape specifications
Slope (%)	%		Landscape specifications
Sealed surface (Y/N)	Y/N		Engineering Drawings
Bulk density	g/cm3		
Aggregate stability	mm	Soil sample records obtained from contractors	Soil sample records
Available Water Capacity	% water in inch of soil		
Earthworms/ Microfauna	Count		
Carbon fluxes using Eddy Covariance Technique	TBD		
Respiration	CO_2-C lbs/ acre/day (or kg/ha/d)		
Soil pH	pH	Soil sample records obtained from contractors	Soil sample records
C:N ratio	%	Soil sample records obtained from contractors	Soil sample records
Soil fragment size	<2mm%, >2mm%	Soil sample records obtained from contractors	Soil sample records
Soil texture distribution	Sands % Fines %	Soil sample records obtained from contractors	Soil sample records
Evapotranspiration rate	mm/time		
Total OM	%	Soil sample records obtained from contractors	Soil sample records
Total N	%	Soil sample records obtained from contractors	Soil sample records
Potassium content	ppm	Soil sample records obtained from contractors	Soil sample records
Nitrogen content	ppm	Soil sample records obtained from contractors	Soil sample records
Calcium content	ppm	Soil sample records obtained from contractors	Soil sample records

Conclusion

This paper sought to present findings that would answer three objectives:

1. To provide a rationale for why UBC Building Operations should consider integrating soil in their new infrastructure asset management software, Planon.

2. To provide a data inventory framework that UBC Building Operations, Campus + Community Planning (C+CP), Academics and Sustainability + Engineering can use to develop management objectives and actions for a green infrastructure asset management plan.

3. To share potential and existing data sources that would address any knowledge gaps found in the data inventory framework for soil.

This paper has provided a rationale for users across UBC (primarily Property Trust, academic experts and Campus + Community Planning) to take a more responsible lead in actively monitoring, protecting and maintaining soil, the foundation of biodiversity, on this campus. In doing so, the campus will lead in translating academic literature into cultural shifts, which is one of the most striking impacts a University can have. The planning tool developed in the "Outcome" section of this paper is one such data inventory framework that can help shape the way this University sets a precedent for natural asset management on its campus. With ongoing initiatives such as CCUB and UC3, UBC must hold strong to its motto now more than ever in the age of demonstrating sustainable development leadership - that is *Tuum Est*.

APPENDIX

See attached file “Survey Results”
Resources on understanding the importance of mentioned data attributes for soil

- Soil moisture
- Soil Parent Material
- Bulk Density
- Soil TemperatureW
- Ecosystem Services provided by soils of urban, industrial, traffic, mining and military areas (SUITMA)

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Continuation of Appendix

The preliminary data framework inventory, complete with the facet of asset management it could be relevant to, stakeholders of relevance and ecosystem services.

Data attribute	Why this data attribute is important	Asset Management category	Who could use this attribute	Existing Data source	Potential Data Source
Soil order + classification maps	Life-supporting services delivered: All services.	Performance	C+CP	LUI Tool	University of Victoria Environment BC Dataset
			Academics		
				Sustainable Soil Management Course (Specifically for UBC Farms)	
				Vancouver Soils Map	
				Soil Sample records by Pacific Soils Analysis	
Rooting depth	Life-supporting services delivered: Vegetative growth	Soil [biophysical] condition	C+CP		Landscape specifications [for designed landscapes only]
			Building Ops		
			Academics		
Organic Matter	Life-supporting services delivered:	Soil [biophysical] condition	C+CP		Landscape specifications [for designed landscapes only]
	Vegetative growth; nutrient cycling; moisture retention		Building Ops		
			Academics		
Soil moisture	Life-supporting services delivered:	Soil [physical] condition	C+CP		
	Nutrient cycling		Building Ops		
	Biodiversity		Academics		
	Vegetative growth				
	Oxygen production				

Soil temperature	Life-supporting services delivered:	Soil [physical] condition	C+CP		
	Plant growth, plant resilience		Building Ops		
			Academics		
	Disservices:				
	Plant death [when too cold/hot]				
Evapotranspiration	Life-supporting services delivered:	Soil [physical] condition	C+CP		
	-Plant growth		Building Ops		
	-Water vapour content in atmosphere		Academics		
	-Solar radiation reduction (lower risk of skin cancer)				
	-Drought effects				
Bulk density	Life-supporting services delivered:	Condition	C+CP		
	-integrated stormwater drainage	Understanding soil compaction	Building Ops		
	-biodiversity		Academics		
Structure	Life-supporting services delivered: All services.	Soil [physical] condition	C+CP		
			Building Ops		
			Academics		
Cation exchange capacity	Life-supporting services delivered:	Soil [chemistry] condition	C+CP		Contractor/landscape architect responsible for maintaining designed landscape
	-nutrient cycling		Building Ops		
			Academics		
Sodic conditions	Disservices delivered:	Soil [chemistry] condition	C+CP		
	-poor plant growth		Building Ops		
	-poor root growth		Academics		

Infiltration rate	Life-supporting services delivered: -integrated stormwater drainage	Level of service	Academics		
Carbon fluctuations	Life-supporting services delivered: -Carbon sequestration	Level of service	Academics		
Biotic pest presence	Disservices delivered: -plant dieback -plant death	Condition		Records of Notification – Pest + Disease problems; UBC Head Landscape Technologist	
Purchase of soil organic matter		Life cycle cost	Building Ops Comptroller		Landscape costing estimate
Labour of Groundcrew		Life cycle cost	Building Ops		Landscape costing estimate
Contamination levels	Disservices delivered: -poor biodiversity health -loss of high quality soil	Criticality	Building Ops Comptroller	Soil samples by Pacific Soils Analysis	
Purchase of fertilizers		Life cycle cost	Building Ops Comptroller		
Cost of irrigation		Life cycle cost	Building Ops Comptroller		