Forest and Inorganic Parameters Monitoring Program in Stanley Park

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Executive Summary

As a city garden and horticulture in Vancouver, Stanley Park is known for its unique natural and cultural landscapes. Currently, an integrated urban action plan is being implemented by the Vancouver Board of Parks and Recreation. The action plan consists of a series of strategies, including bird strategy, urban forest strategy, biodiversity strategy, Vancouver Climate Change Strategy, and the Greenest City Action Plan, which is called Vancouver's Playbook (VanPlay). The target of the plan is to make Vancouver become an environment-friendly city.

VanPlay provides a guideline for the implementation of these strategies, including urban land-use or forest cover planning, biodiversity conservation on urban parks, public and private land, conservation of native birds and habitats, urban monitoring, and adaptation programs to address climate change, etc. The Vancouver Board of Parks and Recreation is applying these strategies to ensure that the action plan is implemented entirely and is trying to create a unique new urban model of "human and nature".

In our proposal, we will conduct inorganic environment and forest coverage analysis for Stanley Park, and our goal is to establish a comprehensive park inorganic environment and forest monitoring programs to assess the ecological status of Stanley Park. We have developed this set of monitoring procedures because inorganic environments and forests, as essential components of the ecosystem, are the cornerstones for the stable delivery of ecological services and the proper completion of VanPlay. Our monitoring program involves water, air, soil quality, and forest cover analysis. By considering the current state of the park's ecology, we will eventually design an overall assessment method as well as a hierarchy for the ecological status in Stanley Park.

Ultimately, we will use the datasets from our monitoring program to determine whether Stanley Park responds to these strategies positively. We will assess the park's compliance with the VanPlay through the results. We will also identify the park's current potential environmental problems or obstacles to the action plan and provide possible solutions to these problems. From a large scale, the assessment method we have designed, can not only be the reference of evaluating the ecological proceeding of Stanley Park, but it can also apply to other parks as an indication for the assessment of the ecological status.

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Stephen Li is in the Global Earth System concentration within the Environmental Sciences degree. Stephen has taken Hydrology, Soil Science, River Geomorphology, Earth Science, and Remote Sensing, which is vital for the methodology designing.

Xiangyu Zhang is an Environmental Science student at SFU, major in Applied Biology. He has taken several ecology courses related to this project, such as population, community ecology related to the environment and ecosystem study experiment design and analysis.

1.0 Introduction

Our study site is Stanley Park in Vancouver, BC (Figure 1). The purpose of this project is to develop a methodology to evaluate the ecological status of Stanley Park by monitoring its inorganic components as indicators and trying to analyze how the ecosystem is performing under the Greenest City Action Plan. Specifically, we choose Beaver Lake as our main scope and fieldwork location (Figure2). Beaver Lake is a recreational lake located in the center of Stanley Park, and it also contains unique wetlands and other natural sources. Beaver Lake is a representative site because we can access to all the factors that we need in our project; for example, soil, air, forest, and most importantly, the freshwater. Freshwater is crucial for our project because it is one of our indicators, and it closely relates to soil quality.

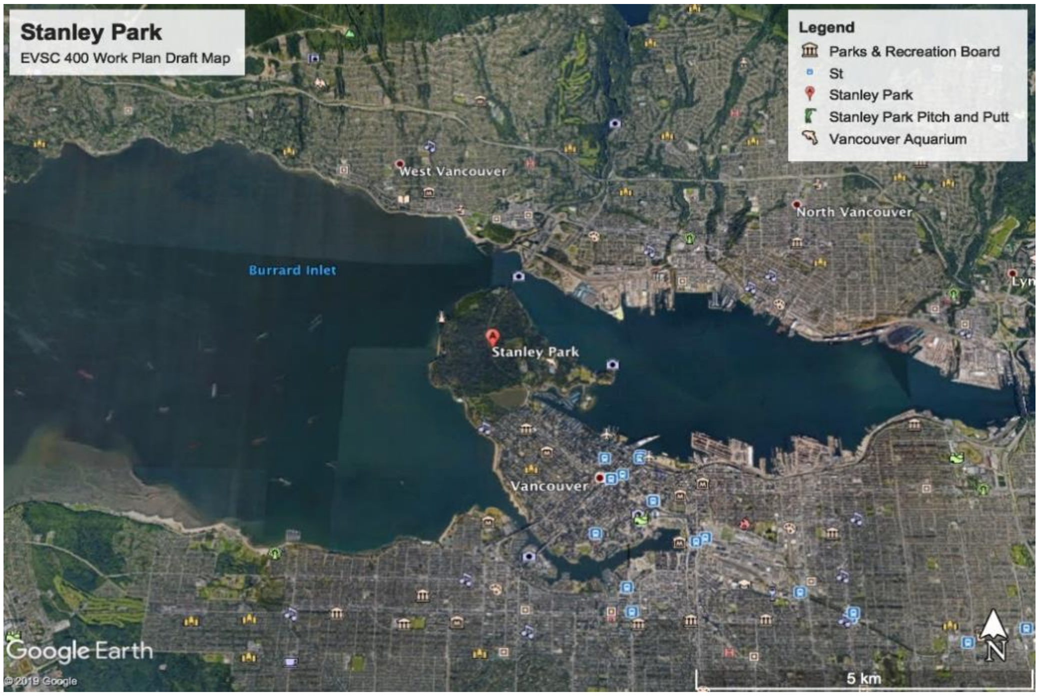

Figure1: Stanley Park Map

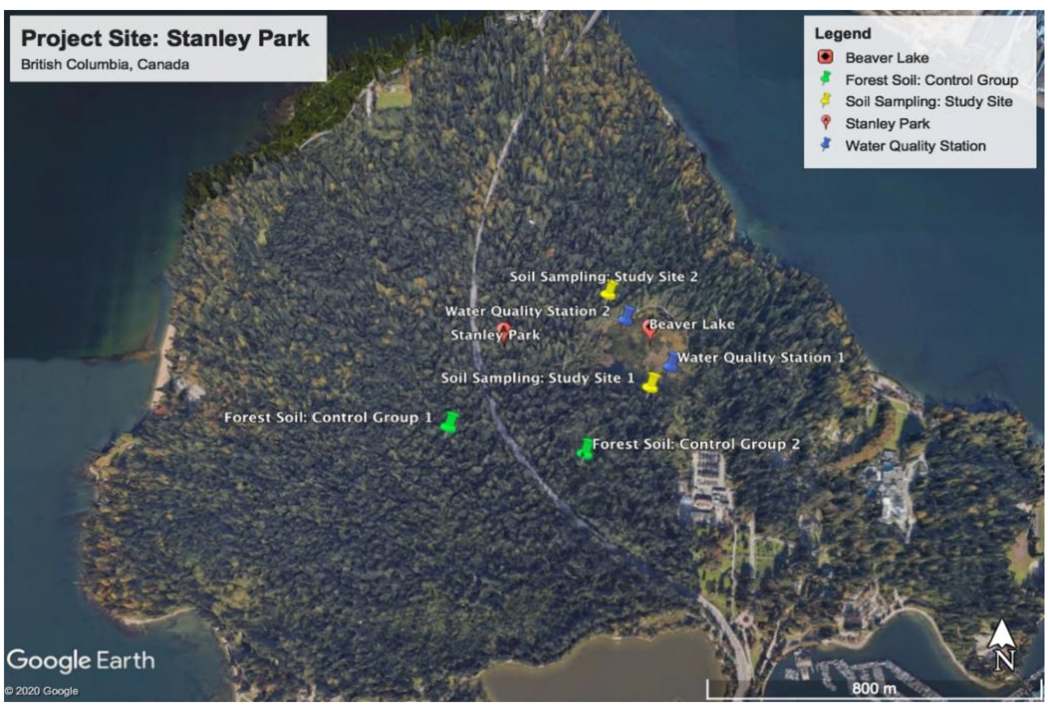

Figure2: Study Site Map

The main goal of this project is to design a methodology and conduct a series of environment experiments by analyzing the inorganic components of air quality, water quality, and soil quality in the Beaver Lake area to infer the ecology in the entire park.

In terms of air quality, we will assign air an index by evaluating the Greenhouse gases (GHGs) and aeoreals concentration in the air.

To evaluate the water quality, we will analyze the water content in Beaver Lake. The quality index is coming from the physical properties of the water body.
To explore the soil quality, we have designed a statistic model to assess the soil property. The statistic model consists of data analysis and comparison test model.
Finally, we will give our client an overall assessment of Stanley Park's ecological status.

2.0 Literature Review

2.1 Introduction

Recently, the City of Vancouver and the Vancouver Park Board have implemented a set of adaption plans for Vancouver and its parks. They are aiming to make Vancouver a resilient and healthy city under the persistent climate change and to allow humans and animals to live harmoniously within the community. As one of the main focus, Stanley Park is experiencing a comprehensive adaption plan by the City of Vancouver and the Vancouver Park Board. The adaption plan consists of Urban Strategy, Biodiversity Strategy, Bird Strategy, Vancouver's Playbook, Climate Change Adaption Strategy, and the Greenest City Action Plan. This plan points out the current targets to the public, and it also directs the ways to reach the targets.

The perfect implementation of the adaption plan cannot be done without involving the ecology assessment and monitoring systems. The assessment of ecological status and monitoring system is essential to the adaption plan because the parks in Vancouver vary in their characteristics and status. In order to ensure the adaption plan is successful in all parks, different parks need environment-specific plans. As a representation of Stanley Park, firstly, we have developed the following assessment methodology to evaluate the ecological status in Stanley Park, and we have also designed a monitoring methodology to check how Stanley Park performs under the adaption plan from the City of Vancouver and the Vancouver Park Board.

In this literature review, we will compare our designed methodologies to the methodologies in the reports from the City of Vancouver and the Vancouver Park Board. This comparison can reveal the knowledge gaps in our project, and then we will try to fill these gaps by referring to the background of each strategy. For instance, our current proposal does not link the urban forest strategy and Vancouver's Playbook very well. We will make a connection between these strategies to our project to explain how Stanley Park contributes to these strategies, and how we can help Stanley Park to track the ongoing Vancouver's Playbook. Moreover, we will also involve the public and cultural parameters into our assessment, and to reach that goal, we will refer to Vancouver's playbook because it provides us with a clear structure and different approaches to relating the park with people.

However, again, the uniform adaption strategy cannot be applied to all parks for their environmental and ecological difference. Therefore, we will add a section to describe the insufficiencies and limitations of some strategies when we use them to Stanley Park. We will also balance the importance and efficiency to narrow our focus down to some strategy within the limited pages. In the following paragraphs, we will reanalyze each of the strategies that we will be referring to in our project. For each of the strategies, firstly, we will describe how we used them in our program and how we can improve our original methodologies. Secondly, we are going to mention what we have changed for these strategies in order to make them Stanley Park-specific strategies. Lastly, we will state our future goals to make our assessment from specific to a comprehensive plan.

Air, water, and soil quality are three essential inorganic environmental factors. In this literature review, we will focus on these three parts and find different sources that can guide our methodologies design. Worcester (2010) discussed the designed methodology of the Stanley Park Ecology Society (SPES) to assess the ecological integrity of Stanley Parks and gives future directions and recommendations. The main idea of this report is that using environmental indicators as a framework to evaluate the present state and evaluate the future trend of natural resources in Stanley Park. In our report, we will use a similar methodology structure with this article by using environmental indicators as a framework to assess the ecological integrity of Stanley Parks.

Indicators used in this report provide a broad representation of key factors influencing the park's ecosystems, including climate and atmosphere, aquatic ecosystems, terrestrial ecosystems, and native biodiversity. For our group, the indicators we only focus on the abiotic components include the aquatic, terrestrial, and atmosphere (water quality, soil quality, and air quality). SPES claims the ecosystem, not institutional boundaries, define all the key factors influencing the park's ecosystems. We strongly agree with this principle; it is suitable for giving a reliable evaluation for ecological health level, avoiding stakeholder influence.

The knowledge gap between our group and this article is the lack of organic indicators in assessing the ecosystem level for Stanley Park. The ecosystem contains abiotic and biotic components, and there are many connections between two parts, for example, soils support life, provide nutrients for plant growth, filter the water, and provide habitats for many organisms. This report lists a balance between organic and inorganic, as well as their relationship. We will try to make a connection between these parameters in our assessment to improve the integrity of our evaluation.

2.2 Air Section

Air is a part of the ecosystem, which is interdependent with other living or non-living components. Pollutants destroy the balance and energy flow of ecosystems. Air pollution may make ecosystems different from those we are familiar with or depend on (Climate Change Canada, 2020), leading to changes in ecosystem functions (UNECE, n.d.). At the same time, air pollution leads to the degradation of water, trees, and soil quality, which ultimately affects the ability of the ecosystem to provide "ecosystem services" (UNECE, n.d.). Therefore, air quality is an essential index to evaluate the ecological health of Stanley Park in our project.

The term 'smog' refers to what happens when polluted air is trapped near the earth's surface. And, for today's smog, it refers to a photochemical mixture of harmful pollutants, especially ozone, PM 2.5, nitrogen oxide (NOx), and volatile organic compounds (VOCs). Surface ozone and PM 2.5 are the leading causes of poor air quality in North America. These pollutants are also the main components of smog and, together with no2 forms the basis of AQHI in Canada (Robichaud et al., 2016). To assess Stanley Park's ecological health, we first evaluate air quality. In this project, we will use ozone, PM 2.5, and NO2 to determine the air quality of our study site in Stanley Park. Besides, the AQHI design represents the combined health risks of exposure to these pollutant mixtures, and we use the Canadian AQHI as the primary tool of our air quality methodology (Robichaud et al., 2016).

Ozone exists in both the earth's surface and atmosphere, but ozone in the ground-level is a harmful air pollutant and an important greenhouse gas. Ground ozone has a severe impact on the environment (Karlsson et al., 2016). The ozone(O3) is detrimental to the water cycle and ecosystem, including forest, park, and so on (EPA, 2017). At the same time, the ozone (O3) is one of the essential parameters of the air quality health index (Robichaud et al., 2016).

NO2 is an important air pollutant. All combustion in the air will produce nitrogen oxides, mainly NO2 (Government of Ontario, n.d.). Nitrogen oxide emissions are deposited in the form of "acid rain" in water, vegetation, and soil, thus increasing acidity, and ultimately, as with ozone (O3), acidification affects the ecosystem's ability to provide "ecosystem services" (UNECE, n.d.), then change the ecological health status.

Fine particles (PM2.5) are one of the most hazardous pollutants in the air. Particles can be blown over a long distance by the wind and then fall on the ground or water. The effects of such subsidence may include: making lakes and streams acidic, changing the nutrient balance in coastal waters and large river basins, and consuming nutrients in the soil (EPA, n.d.). These impacts cause the health of ecosystems to worse.

In our methodology, we will combine the data of the Ozone (O3), NO2, and fine particles (PM2.5) to calculate the overall score from the AQHI model. The higher the number of AQHI, the greater the health risk of the air and more reduced air quality (Robichaud et al., 2016).

Water is the foundation of ecology; all the operations of ecological services are relying on water. In contrast, water quality is also representing ecological health (the Vancouver's Play Book, 2018). In terms of the climate change effect on water quality, the Climate Adaptation Working Group

(2020) updated the Climate Change Adaption Strategy this year. This strategy mainly points out the Vancouver development direction. As climate change is a global issue, Vancouver and its parks have to respond to it appropriately. Climate change has the most direct impact on water, and it is an additional stress factor that will be difficult to overcome (Magadza, 2000; Kashyap, 2004; Pachauri, 2004). This strategy leaves us a vast space to develop. In our current assessment, our focus is mainly on the evaluation of ecological health in Stanley Park through different parameters. Primarily, we want to use the water quality index to reflect the ecological health of Beaver Lake, then expand from the water quality of this lake to the entire park.

2.3 Water Section

In Stanley park, the two most significant wetlands are Lost Lagoon and Beaver Lake (Worcester, 2010); This inspired us to use the parameter water quality from Beaver Lake. Beaver Lake is one of Vancouver's last natural wetlands, which helps our group to choose the Beaver Lake areas as our study site. Although this lake does not provide drinking water for people, many people come to exercise every day. The quality of this lake is closely related to the quality of life of locals. For example, higher surface water temperatures will promote algal blooms (Hall et al., 2002; Kumagai et al., 2003) and increase the bacteria and fungi content (Environment Canada, 2001), and this may lead to a bad odour and taste in chlorinated drinking water and the occurrence of toxins (Moulton and Cuthbert, 2000; Robarts et al., 2005). So, testing water quality is essential and necessary.

Water quality is one of the decisive factors for ecological health and plays an essential role in monitoring the ecological environment. ("Water quality," 1993) We decided to use multiple indicators to determine the water quality index and investigate the water quality of Beaver Lake in Stanley Park. We will use the factors of pH value, turbidity, conductivity, TDS, temperature data in the lake.

Our current assessment has developed the methodology to test the response of Stanley Park under climate change. Our next step is to combine the different water quality indexes by seeing how these variations will affect human health and the local community. The higher the vulnerability, the higher the risk to its ecosystem, the resilience is the capability that the park can endure the changing climate or other perturbations.

2.4 Soil Section

For soil quality monitoring, the VanPlay City of Vancouver (2018) provides a general instruction of managing the majority of natural areas in the city and its greatest ecological assets. In recent years, environmental contaminants in the air, water, and soil impact wildlife. (Vancouver's Playbook, 2018). As a city, Vancouver has made a strategy of setting out to create a new "Parks and Recreation Service Master Plan." The Playbook also advocates for system-wide thinking and integrating how to analyze the quality of soil, water, and air.

Ecology provides vital habitat for plants and animals. Thus, the soil, water, and air are important factors that affect the health of the habitat. Through the establishment of the inorganic environment and forest monitoring program, vanplay recreational activities set up in Stanley Park. We are developing the methodology of analyzing the inorganic area, which also was useful in our Beaver Lake project. By analyzing the inorganic parts, for example, soil, water, and air quality parameters in the Beaver Park, we can evaluate the ecological integrality of Stanley Park (Vancouver's Play Book, 2018).

Because soil is an essential part of ecosystems and connects all the components of the ecosystem (NRC, 2016), it is not only the hotbed of life systems on earth but also plays a crucial role in ecological services (NRC, 2016). Soil quality is the ability of a specific land to perform all its functions in one particular ecological range (NRCS, n.d.). Soil quality is an indicator to identify the environmental health condition in Stanley Park. The physical, chemical and biological properties as the sub-indicators determine the quality of the soil (USDA, 1996), which can help us choose physical and chemical properties to assess soil quality in Stanley park, such as bulk density, pH value. From those articles, we decided to select the soil quality as one of the environmental indicators in our methodology of evaluation. As the article (Urban Forest Strategy, 2018) mentioned, there is about 400 ha of forest in Stanley Park, and Stanley Park is an iconic urban forest in Vancouver. (Vancouver's Playbook, 2018) said that soil testing and analyzing could help scientists to predict Stanley Park forest health. Also, there are many micro-organisms in the soil which support the tree's growth. It is a good way to help protect large shade-providing trees, and our urban eco-systems help preserve the region's plants and animals and help enhance the quality of life that we all enjoy (Greenest City, 2020). Therefore we will focus more on the soil quality as an indicator in the evaluation of the ecological integrity of Stanley Parks.

2.5 Conclusion

This literature review gives us a better understanding of the adaption plan, which is implemented by the City of Vancouver and the Vancouver Park Board. Our current assessment is limited by ecological status; however, the ecosystem in Stanley Park has multiple potential effects on society as well. Therefore, for the following research, we will focus on the concepts of human and nature, the different strategies above provide us with a framework of how to connect the ecosystem to local people. The gap between the articles and our project is the relationship between the ecosystem and animals, such as the biodiversity strategy and bird strategy. Unfortunately, we cannot include all the parameters within the limit report. Still, we will try to go behind our assessment by using the inorganic parameters to indicate the biotic factors within the park. Once we assess the overall ecological status and social status of Stanley Park, the final result can allow us or others to do further study in Stanley Park.

Methodology

A. Air Quality Monitoring

Air quality is a directive factor in the ecosystem. As one of the critical components of inanimate parameters, air quality usually represents the external environment from a large scale, but it also affected by the internal environment within the park. In this section, we are going to analyze the air quality in Stanley Park through the nearest Air monitoring station, Vancouver-Downtown station. We will directly achieve those data from the metro Vancouver air map.

A-1. Data Procurement

We will use the Air Quality Health Index (AQHI) to quantify the air quality in Stanley Park (Terminology A-1, Appendix 2). We can assess the air quality within the park based on eh AQHI system. We will directly achieve those data from the Vancouver- Downtown Station through metrovancouver GIS-Air Map website, as it is the nearest air monitoring station from Stanley park. The AQHI will tell us about the overall air quality around the Stanley Park area, and it will integrate into our overall ecological assessment.

A-2. Data Analysis

The three leading indicators we will use in this equation, which are ozone(O3) at ground level, particulate matter (PM2.5), and nitrogen dioxide (No2), the reason we chose those three variables is that they are the critical target of Canada air quality index. Their units are micrograms per cubic meter (µg/m3).

Ozone (O3) at the ground level is extremely harmful to the human body. Some people who are prone to allergies will suffer from skin itching, eye tingling, weak breathing, cough, rhinitis, and other symptoms when they are exposed to the environment with ozone content of more than 180 micrograms per cubic meter for a long time (Achcar et al., 2012). According to experts, an increase of 100 micrograms per cubic meter of ozone in the air will reduce the respiratory function by 3%, so ozone is a vital indicator for air quality (Achcar et al., 2012).

PM 2.5 has a substantial impact on air quality and visibility (Cao & Zhang, 2015). PM 2.5 is small in particle size, rich in a large number of toxic and harmful substances, and has a long duration time in the atmosphere and a long transport distance. PM 2.5 is part of the air pollution index.

Nitrogen oxides such as NO2 mainly damage the respiratory tract in the human body. There are eye and upper respiratory tract irritation symptoms, such as pharyngeal discomfort, dry cough, etc. (Yu et al., 2017). If we are exposed under high NO2 concentration air, late-onset pulmonary oedema and adult respiratory distress syndrome, chest tightness, respiratory distress, cough, phlegm, and cyanosis. It has very significant harm to human health (Yu et al., 2017). Therefore, NO2 is an essential indicator of air quality.

In our analysis, we record the 30 days concentration change of all indicators (O_3, $PM_{2.5}$, NO_2) from metrovancouver GIS-Air Map website. We then apply these data into the formula to calculate the AQHI (round to the nearest integer). The result of AQHI is 2.08, and Air quality is assigned to be low risk. (Method A-2, Appendix 1)

Table 1: Air quality scoring criteria (AQHI) system

Air Quality Indicators	Concentration ($\mu g/m^3$)	AQHI	Score	Air Quality
O_3	20.3 ppm	2.08	7.92	Low Risk
$PM_{2.5}$	2.5 ($\mu g/m^3$)			
NO_2	10.8 ppm			

B. Water Quality Monitoring

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. Water quality is one of the decisive factors for ecological health ("Water quality," 1993). Water quality detection plays an essential role in monitoring the ecological environment.

B-1. Water sampling

We decided to use multiple indicators (with different weights) to determine water quality by sampling in Beaver Lake. If some parts of the lake remain frozen during the period of water sampling data collecting, we assume 1 degree of diurnal thermal variation, which based on freezing conditions in winter. The factors we are going to use are as follows.

We used multiple indicators (with different weights) to determine water quality by sampling in Beaver Lake since. Currently, some lake part is frozen. Hence, we assume 1 degree of diurnal thermal variation, which based on freezing conditions in winter. To investigate the water quality of Beaver Lake in Stanley Park, we choose to use the factors of pH value, Turbidity, Conductivity, TDS, Temperature data in the lake since they are the most representative variable of Beaver Lake. pH data collected through a pH test paper. Turbidity shows how transparent the associated water is. These particles decrease the passage of light through the water. The turbidity sensor measures the murkiness by measuring the quantity of light scattered at ninety degrees. And for the conductivity, pure water has poor conductivity; thus, for water to be pure, its ability to conduct current should be poor. Conductivity is measured with the help of two conducting plates. (G. H. Raisoni Institute Nagpur India et al., 2014) Total dissolved solids will determine by multiplying the conductivity by a factor, and typically this factor is taken as 0.67. TDS = 0.67 X conductivity. (G. H. Raisoni Institute Nagpur India et al., 2014) In the whole measurement system, we used a high precision thermometer device to measure the temperature of the water. The details of each variable are in the Appendix. (Terminology B-1, Appendix 1)

B-2. Sample Analysis and Assessment

After we acquire all the variables, we will use the following variables to quantify water quality through the Water Quality Index (WQI) Calculator. We assign the WQI index to the water dataset beacuse water quality is one of the direct indicators for the status of the ecosystem. The water quality is also closely linked to the status of soil and forest in the park. (Method B-2, Appendix 1)

Table 2: Water quality scoring and weighting system

water quality index				
variable	units	test result	Weight Factor	subtotal
pH	N/A	8.85	1.1	9.735
Conductivity	$S \cdot m^{-1}$	74	0.125	9.25
TDS	ppm	37.5	0.24	9
Temperature	Celsius Degree	9.8	1	9.8
Overall				37.785

C. Soil Monitoring

The primary soil type in Stanley park: Sandy loam

Soil is an essential part of the ecosystem and connects all the components of the ecosystem. (NRC, 2016) It is not only the hotbed of life systems on earth but also plays a crucial role in ecological services. (NRC, 2016) Soil is a natural material that combines organic and inorganic components. We will analyze it from both of two. In Stanley Park, the main threat to the soil is salinization, and it has multiple effects on the environment. (Terminology C-1, Appendix 1)

Soil quality is the ability of a specific land to perform all its functions in one particular ecological range (NRCS, n.d.). Soil quality is an indicator to identify the environmental health condition in Stanley Park. The physical, chemical, and biological properties as the sub-indicators to determine the quality of the soil (USDA, 1996); we will then use those properties to make a matrix to evaluate the soil quality. Besides, a comparison will be involved in our soil monitoring section, which is using the soil samples from different parts of the Park to make the evaluation more representative.

C-1. Soil Sampling

Soil sampling is the way we acquire data, the sampling method needs at least ten sites, with half of them at Beaver Lake, and the rest are at undisturbed forest areas. The sites should be chosen in a different environment such as open area, near and undisturbed forested sites (avoid drainage channels). The pits in the open area (near the Beaver Lake in Stanley Park) will set to be the experimental group, other undisturbed sites such as forest can be set as the control site; keeping the number of the treatment sits as many as the control sites. Soil samples are taken from all soil pits with half from the undisturbed forest location and a half from the disturbed forest and a few months (at least ten months) later after the occurrence of logging treatment. Soils from three levels of depth, 10 cm, 30 cm, and 50 cm, being collected from each soil pit in each location (experimental and control site).

C-2. Chemical Components Analysis

The chemical indicator we used is soil ph. Soil pH calculates the acidity and alkalinity of the soil. Soil Ph indicates the solubility of the nutrients in the soil. (SQ, 2011) We take those samples from sites and do a soil Ph test. We will determine the salinization of soil and its effects on the ecosystem and environment within the park. (Method C-1, Appendix 1)

C-3. Physical Indicator Analysis

We focused on the five physical aspects of soil quality physical property, which are bulk density (BC), gravimetric water content (GWC), volumetric water content (VWC), and gravel content (GC), should be measured for each soil sample. (Terminology C-3, Appendix1) The following is the dataset we can calculate directly based on the two groups of soil samples.

Table3: Matrix of soil property between control group and treatment group

	Properties	10 cm		30 cm		50 cm	
Physical	Soil quality property	Control	Treatment	Control	Treatment	Control	Treatment

		N=?	N=?	N=?	N=?	N=?	N=?
	Bulk density (BD) (g/cm3)						
	Gravimetric water content (GWC)						
	Volumetric water content (VWC)						
	Gravel content (GC) (%)						
Chemical	PH						

In Table 3, we can quantify the soil quality in two soil groups visually for further studies.

Because local measurements cannot represent soil quality throughout the Park, we have developed the following steps to make the results more representative. First, we will compare the two groups of soil samples to see the similarity of two datasets (one is control group/ soil from the undisturbed forest, and another one is experimental group/ soil samples from Beaver Lake), and now the question becomes contingent. If they are high in similarity, we say that the soil quality in Stanley Park does not show a considerable variation among our study site and the undisturbed forest, so our results can be a functional soil assessment for the entire Park. (Method C-3, Appendix 1)

C-4. Experimental Hypothesis Test Setting

However, what if the two datasets do not show a high similarity? Based on the soil analysis results, to make the result more representative, we will involve a statistic analysis, which is the hypotheses test to compare the two groups of data more precisely. Directly speaking, the hypothesis test will give a more accurate similarity between the two datasets. Assume the results show some variation among two datasets that cannot be ignored; we need to use GIS to calculate the proportion of forest cover areas to the entire terrestrial regions of the Park. This proportion can be relevant to the weight of the soil from the disturbed areas to the soil from the undisturbed area. Finally, according to the weight, we can integrate them to provide a better assessment of the soil quality in Stanley Park as a whole. The specific methods and explanations show in the Appendix. (Method C-4, Appendix 2) After all, the following Table can be made based on the results.

Table 4: Criteria for assessing soil quality

Percentage of forest coverage	The dominance of the control and experimental group	Significance interval	Soil quality
[80% - 100%]	Control group dominated	[0.8, 1.0]	Excellent
[60% - 80%)		[0.6， 0.8)	Good
[40% - 60%)	Experimental group dominated	[0.4, 0.6)	Marginal
[0% - 40%)		[0, 0.4)	Poor

Conclusion

Based on the three indicators inorganic indicators, we calculate the quality index by using sampling collecting and analysing. We intergrade all indicators together to get the overall Stanley Park ecology quality index and give the final evaluation for the ecological status of Stanley Park.
Since there are many parameters in each indicator index calculation, we will be using a simplified integration to represent the final result concisely, the Overall Stanley Park Ecology Quality Index. Comparably, the Quality Status will give our client a clear understanding of our results.

Table 5: Overall ecological quality assessment

Integration Ecology Index and Status		
	Index	Quality Status
Air Quality	7.92	Low Risk

Water Quality	37.79	Good
Soil Quality	N/A	N/A
Overall Stanley Park Ecology Quality	N/A	N/A

Based on Table 5, the term “Overall Stanley Park Ecology Quality” can be a good reference to determine how good does Stanley Park underline with the four strategies as well as the Greenest City Action from the Vancouver Board of Parks and Recreation. Hopefully, our proposal could serve as a reference for the ongoing environmental or ecological actions.

In general, the potential problems that Stanley Park is facing are: N/A

The possible adaptations to the problems we might suggest are: N/A

Recommendations

Due to current events, we were unable to complete the laboratory analysis of our data.
Although we could have analyzed other data that we did not collect, we chose not to do this because our assessment is unique. It leaves us a goal and direction for future programs. Therefore, we may not conclude the overall quality status of Stanley Park due to the lack of soil data; however, this methodology can become a possible model to assess the park's ecological status whenever the access is available.

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Appendix 1

Terminology

A-1

Air Quality Health Index (AQHI) is a scale designed in Canada to help understand the impact of air quality on health, and it tells us the details of air quality in associated areas. ("Air Quality Health Index (Canada)," 2019)

B-1

pH: an index indicates acidity or basicity of a lake, which is from the index of 0 to 14, representing the water body from acid to alkaline. Unit: N/A

Turbidity: the measure of water clarity. The turbidity sensor makes use of LDR and LED. (G. H. Raisoni Institute Nagpur India et al., 2014) Unit: ntu

Conductivity: the power of the water to conduct electricity. Unit: S·m^-1

Total dissolved solid (TDS): the quantity of minerals and salts reside within the water. Unit: ppm

Temperature: a vital influence on water. Unit: °C

C-1

Soil salinization: The consequence of soil salinization is: Firstly, soil salinization limits the growth of plants due to too much salt existing in the soil leading to a concentration of water in the earth that is higher than healthy soil. As a result, the function of osmosis declined. It is much more difficult to extract water from the soil; as a result, the plants cannot grow well. Second, the infrastructure, including roads, bricks, and cables) is damaged as we know the salty soil existing a lot of ions. These ions would cause a chemical reaction with the infrastructure accelerating the erosion of equipment. The third one is a flood risk. Soil salinization would reduce the capacity of soil to absorb rainfall due to the plants reducing. The last one is the decrease in water quality. Usually, the river that is near the salty of soil would be influenced, the salt level in the river would increase, the consequence is that high-level salty level affects the test of drinking water, we know that there are many ions in water. Chloride lowers the taste of water; magnesium sulfate reduces the excretion of animals.

C-3

Physical property	Definition/ Formula
Bulk density (BD, g/cm3)	the dry weight of soil /volume of soil
Gravimetric water content (GWC)	the mass of water per mass of dry soil
Volumetric water content (VWC) gravel content (%)	the volume of water per volume of soil 100 x weight of gravel/ (weight of gravel + fine earth

Figure x: Definition of soil properties

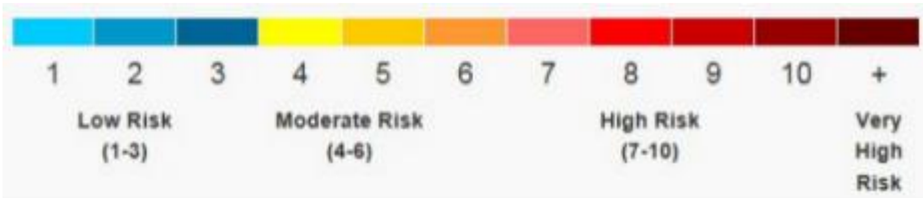
Methodology

The equation for AQHI:

$$AQHI = (\frac{1000}{10.4}) \times [(e^{0.000537 \times O_3} - 1) + (e^{0.000871 \times NO_2} - 1) + (e^{0.000487 \times PM_{2.5}} - 1)]$$

("Air Quality Health Index (Canada)," 2019)

Index and intervals of air quality:



("Air Quality Health Index (Canada)," 2019)

The graph scale is used to determine the condition of air quality.

The table is used to quantify the air quality and score of the air quality

AQHI	score	Air Quality
Low Risk (1-3)	100-80	Good
Moderate Risk (4-6)	70-50	Fair
High Risk (7-10)	40-20	Poor
Very High Risk (10+)	20-	Very Poor

B-2

Once we have translated our measurements in a Q value indicator, we use weighting factors for each variable based on the importance of each variable to reflect the quality of the water. Each variable will calculate independently and finally aggregated to get a final water quality index.

water quality index				
variable	units	test result	Weight Factor	sub total
pH	N/A			
Turbidity	ntu			
Conductivity	$S \cdot m^{-1}$			
TDS	ppm			
Temperature	Ceslsius Degree			

Water Quality Chart	
Good	**0-45**
Acceptable	**30-40**
Marginal	**20-30**
Poor	**<20**

These two charts allow entering the variables measured (any number of variables) in our water sampling sites and adapt the weighing factors to output a WQI from 0 to 100 and convert the number to the actual water condition.

C-1

Soil pH value and salinization measurement: the pH of the soil can be detected by pH indicator solutions. For the salinization of the soil, we will grid the sampling area and collecting at least one sample in each grid of the main plain region, and soil samples could be analyzed using the suspensions of 1:5 soil: water ratio. By measuring the Na+, K+, Ca2 +, Mg2 +, SO42 +, Cl−, CO32 – we can model and calculate the change of soil salinization by different years. (Wang, 2018).]

C-3

An excellent way to test the similarity of two soil sample groups (control group and experimental group): Taking averages and standard deviation from all samples at the same depth and location should work out with the AVERAGE and the STDEV functions in the excel, which can consider being a representative of the studied sites (disturbed and undisturbed forest). We will investigate how the soil indicators changed and the potential implications of these changes for root development (root development level is a reflection of ecological health level).

C-4

In this section, we are trying to test whether the soil quality in Beaver Lake differs from the soil quality from the undisturbed forest in Stanley Park by devising a hypothesis test as following:

The control group: the soil sample from undisturbed forest (Reference of good soil quality)

The experimental group: the soil sample near the Beaver Lake

Setting the sample mean and standard deviation of different properties in the experimental group as odd numbers, for example, the sample mean bulk density in the experimental group is Miu1, the sample standard deviation is SD1, setting statistical parameters in control as even numbers.

Null hypothesis: the sample mean of the experimental group equals that in the control group. e.g. $\mu_1 = \mu_2$

Alternative hypothesis: the sample mean of the experimental group is not equal to that in the control group. e.g. μ_1 is not equal to the μ_2

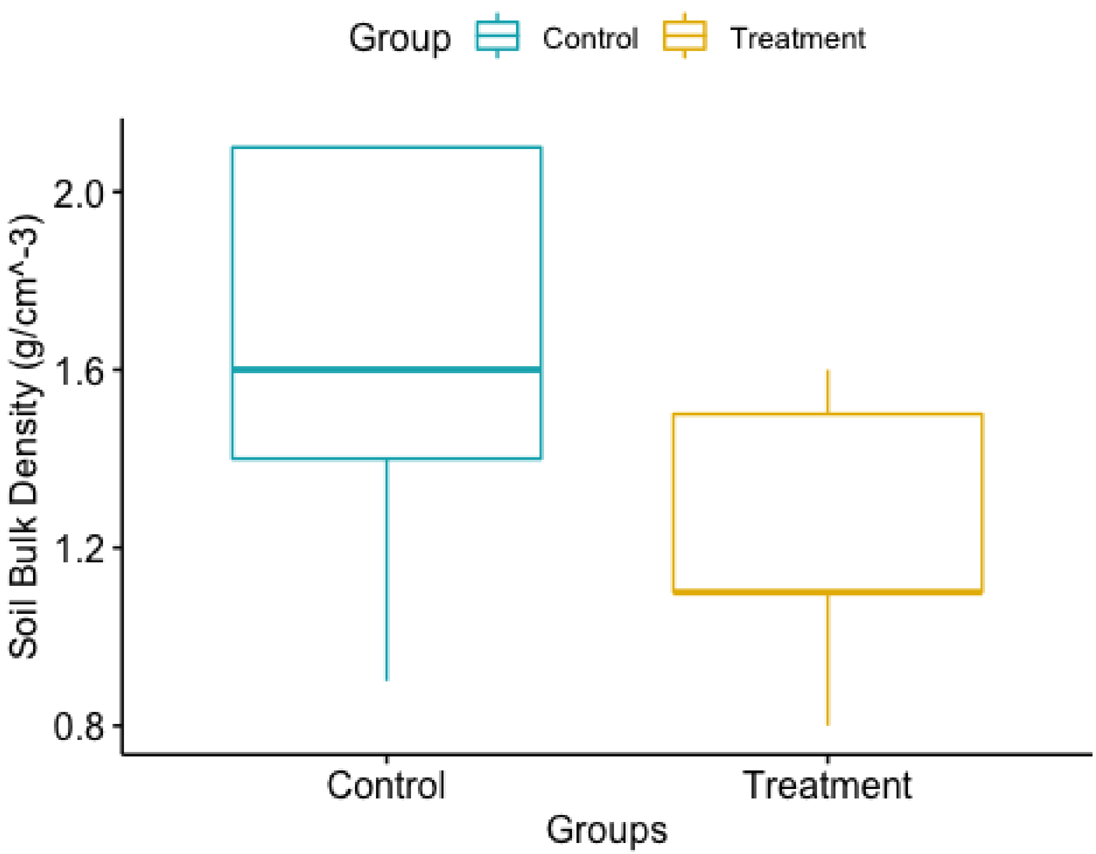
Based on the result of the hypothesis test, if it falls into the confidence interval, there is no significant difference between two samples mean in each group, i.e. fail to reject the null hypothesis, so we can conclude that the soil quality in Beaver Lake is good as the undisturbed forest in Stanley Park.

But if the result of the hypothesis test shows rejecting the null hypothesis, we will calculate the proportion of undisturbed forest areas with respect to the whole Stanley parkland areas by using the tools from GIS. Based on the percentage, we will assign an index according to their significance. We then divide the soil quality into four levels, which are from poor to excellent.

Our model is shown below.

```
library(ggpubr)

## Loading required package: ggplot2

## Loading required package: magrittr

library(dplyr)

##
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':
##
##     filter, lag

## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union

#Import two sites Bulk Density data:
(df <- read.csv("/Users/jijiexu/Desktop/BulkDensity_data.csv", header = T))

##    Soil_BD     Group
## 1      1.4   Control
## 2      1.6 Treatment
## 3      2.1   Control
## 4      1.5 Treatment
## 5      2.1   Control
## 6      1.1 Treatment
## 7      1.6   Control
## 8      0.8 Treatment
## 9      0.9   Control
## 10     1.1 Treatment

#Summarize each site count, mean value and standard deviation:
group_by(df, Group) %>%
  summarise(
    count = n(),
    mean = mean(Soil_BD, na.rm = TRUE),
    sd = sd(Soil_BD, na.rm = TRUE))

## # A tibble: 2 x 4
##   Group     count  mean    sd
##   <fct>     <int> <dbl> <dbl>
## 1 Control       5  1.62 0.507
## 2 Treatment     5  1.22 0.327

#Visualize the data by boxplot:
ggboxplot(df, x = "Group", y = "Soil_BD",
```

```
          color = "Group", palette = c("#00AFBB", "#E7B800"),
          order = c("Control", "Treatment"),
          ylab = "Soil Bulk Density (g/cm^-3)", xlab = "Groups")
```




```
#Hypothesis test:
(t.test(Soil_BD ~ Group, data = df, paired = TRUE))

## 
##  Paired t-test
## 
## data:  Soil_BD by Group
## t = 1.5811, df = 4, p-value = 0.189
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.3023912  1.1023912
## sample estimates:
## mean of the differences 
##                     0.4
```

We design a model for analyzing Soil indicators between two groups. We put the bulk density analysis as an example here, and we used the same model for other parameters.

Conclusion: From the t-test, we found that the p-value is greater than 0.05 significant level, so we don't reject the null hypothesis and conclude there is no difference in Soil bulk density between Stanley Park and Beaver lake sample sites.