Physical Soil Disturbance Effects On Soil pH In The Greater Vancouver Area

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Abstract

As human settlement is expanding, and agricultural practices are becoming increasingly detrimental to the soil to cope with the increasing demand of food, it's important to understand the impact of physical disturbance on soil. Soil pH level varies across a landscape and is dependent on microbial and fungal content, as well as the type of disturbance it experiences. This study investigates the relationship between soil pH level and its physical disturbance, and hypothesizes an increase in soil acidification as soil disturbance increases. Across the Greater Vancouver Area, Canada, 48 soil samples were obtained from four different classes of soil disturbance, whereby the pH of each soil sample was recorded with chemical pH test kits. Following this, a one-way ANOVA test was carried out to assess the means between different soil classes, resulting in a p value of 0.054. As a consequence, it was concluded that the means were not statistically significant, thus failing to reject the null hypothesis. However, as the p-value indicated that the means were not statistically different, it was concluded that the experiment needs to be replicated with a larger sample size to obtain a clearer interpretation of the results.

Introduction

Soil pH and soil disturbance are both key factors of soil health. The pH indicates the amount of hydrogen ions present, which is dependent on the type of rock that formed the soil as well as external environmental factors (Queensland Government, n.d.). Soil pH determines the quantity of soluble nutrients is available to plants, and thus determines the type of plants present (Queensland Government, n.d.). On the other hand, soil disturbance is the result of natural or human activity resulting in soil erosion (State of New Jersey Department of Agriculture, 1976).

The three main types of soil disturbance are, biological, chemical, and physical (Fuhrer, n.d.). These disturbances are distinguished by their causes (Fuhrer, n.d.). For instance, tilling is an example of physical disturbance, overgrazing is an example of biological disturbance, and overuse of pesticides is an example of chemical disturbance (Fuhrer, n.d.).

Changes in soil pH are dependent on the type of soil disturbance inflicted on the soil. For example, the application of a chemical disturbance such as sulfur lowers soil pH (Mississippi State University Extension, n.d.). Lowering soil pH below 7 is acidification and is a natural process, however its effects are accelerated by agriculture. For instance, the application of ammonium-based nitrogen fertilizers and the removal of plant material leads to acidification (Queensland Government, n.d.). Contrastingly, an increase in pH to a value higher than 7 is alkalinization, and is caused by the processes that oppose acidification. For example, the presence of considerable amounts of bacteria and fungi oxidizes calcium oxalate resulting in a pH shift towards alkalinity (Martin et al., 2012).

When specifically considering physically disrupted soils caused by human activity, the result in the removal of plant material, fungi, or bacteria, impedes terrestrial nitrogen fixation (Zheng et al., 2020) and results in the removal of alkalinity from soil, resulting in soil acidification (Gazey, n.d.).

Globally, approximately 10 million hectares of cropland of soil is lost to erosion per year (Pimentel, 2006). When soil is lost, carbon is released into the atmosphere. Therefore, conserving soil is critical in mitigating climate change (Frouz, 2020) through sequestering over 10 percent of human-made carbon emissions from the atmosphere, due to plants absorption of carbon (Food and Agriculture Organization, n.d.). As a result, plants are needed, and plants can only grow on healthy soil. Particularly in British Columbia, soil is a crucial resource because it supports resources that the BC economy heavily relies on such as wood and food (Government of British Columbia, 2018).

Exploring literature that investigates changes in soil pH, it is evident that there is less research on physical disturbance and its effects on soil pH. Therefore, this study aims at filling the gap by concentrating on physical soil disruption. Moreover, the British Columbia Soil Information Finder Tool (2018) has only surveyed soil in areas outside the Greater Vancouver Area, hence this study explores soil pH within the Greater Vancouver Area, to shed light on how cities can use their soil effectively in aiding with the mitigation of climate change.

This study hypothesizes that if an increase in physical soil disturbance results in soil acidification, then soil samples that are collected from areas that have a greater degree of physical soil disruption would show a lower soil pH compared to soil samples collected from less disrupted areas.

Methods

Soils categorized into four types of Soil Disturbance Class were collected across the BC. Lower Mainland in order to compare each soil class' acidification level. Sampling was limited to four areas within the Lower Mainland based on each colleague's location: North Vancouver, Vancouver 1 (Oakridge area), Vancouver 2 (West area) and Surrey (Figure 1). Soil was collected in these areas prior to the COVID-19 restrictions limiting non-essential travel.

Soil class was divided into four treatments and was classified based on Napper's (2009) classification for soil disturbance levels: "Class 0" soil was defined as undisturbed soil from lack of human activity such as soil from forest-floor layers. "Class 1" soil was defined as forest-floor layer soil that is slightly disturbed from few traces of human activity. "Class 2" soil consists of soil that includes partially missing forest-floor layers and more disturbed by human activity and "Class 3" soil has no forest-floor layer and is greatly disturbed from industrial human activity. Identification of each Soil Disturbance Class within each of the four BC. areas were labelled using location coordinates (Figure 1).

Figure 1. Map site of the BC. Lower Mainland. Soils were collected in Surrey (purple), North Vancouver (yellow), Vancouver 1 (blue) and Vancouver 2 (green).

In order to collect the soils, a digging tool large enough to dig a few inches below the surface such as a garden shovel was used to dig the soil about five inches below the surface prior to soil sampling. Soil is highly acidic on the surface, so collecting soil below the surface ensured accurate pH reading of each soil environment. Three soil samples for each Soil Disturbance Class in each BC. areas were collected in order to later determine if the pH results in each class were consistent. A total of 48 soil samples were collected across the Lower Mainland. Each collected soil sample was half-way filled in a plastic cup to obtain sufficient soil amount for pH measurement and all plastic cups containing the soil samples were labelled to identify each soil sample by its sample number and class.

Debris remains such as twigs, rocks and roots found in each soil sample were removed and separated from each soil content in order to prepare each individual soil sample for its pH reading. The soil samples were then added with an enough amount of distilled water to create a dark liquid and muddy solution as soil pH testing on dampened soil was most effective in producing pH results. Using a pH chemical soil tester kit, the acidity level of each soil sample from each Soil Disturbance Class was determined. By comparing each measured soil pH results from the Soil Disturbance Class, a one-way ANOVA test was conducted on the measured soil pH results in order to determine the statistical difference among the pH results of the four Soil Disturbance Classes.

Results

Each class disturbance contained 12 representative soil samples, and Figure 2 illustrates the soil pH per soil class in the Greater Vancouver Area. The graph below shows that there is no clear trend, and that the average pH level in soil class 0 (M = 6.29, SD = 0.84), soil class 2 (M = 5.42, SD = 0.56), and soil class 3 (M = 6.17, SD = 1.01) are similar, with soil class 1 (M = 5.83, SD = 0.81) having the lowest soil pH.

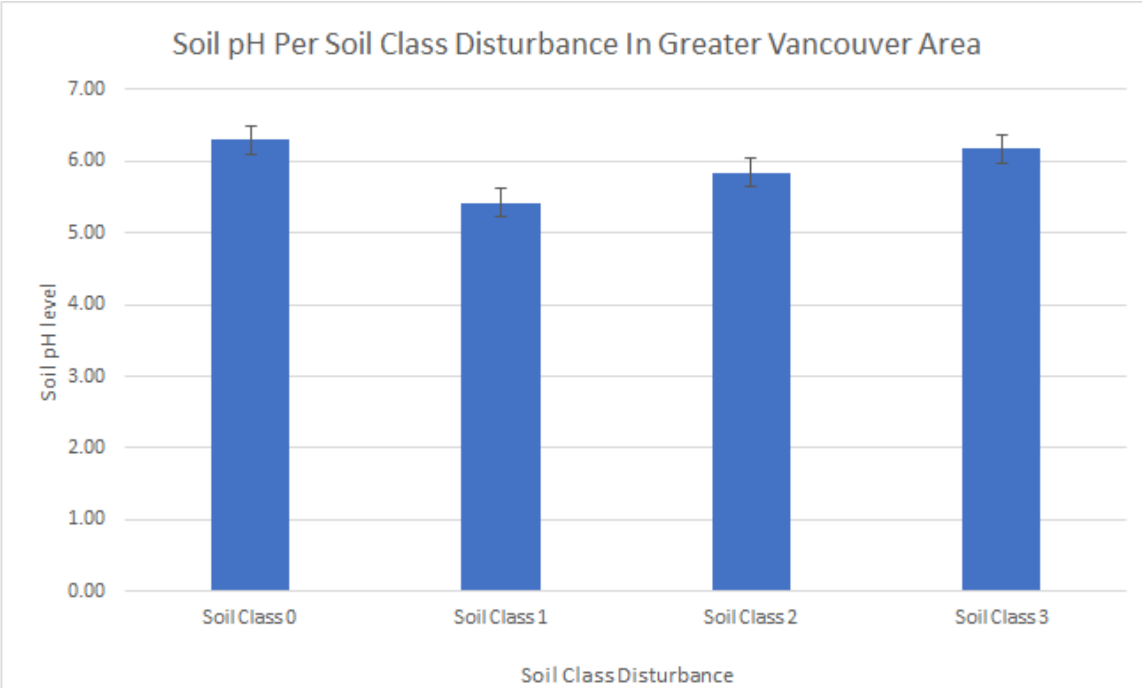

Figure 2. Bar chart with error bars illustrating the soil pH per soil class in the Greater Vancouver Area. The Greater Vancouver Area being two locations in Vancouver, one in North Vancouver and another in Surrey.

The figure above shows very little variation in the pH level across soil classes, which is evident in the one way analysis of variance. At a significance level of 0.05, the ANOVA showed that the effect of soil disturbance was not significant, $F(3,47) = 2.774$, $p = 0.054 > 0.05$.

Discussion

In analyzing the results, we can see that the mean pH of the soil samples varies little despite being taken in different locations. This is further strengthened by the fact that the ANOVA test gives us a non-significant result where $p = 0.054$, which is greater than our alpha value of 0.05. This means that we fail to reject the null hypothesis that there are no differences between the mean. Instead, soil disruption and other environmental factors we expected to have an effect on soil pH did not cause any significant difference. However, it is worth mentioning that our p-value was extremely close to the cut off line between being significant and insignificant, being only larger by 0.004. If it had been smaller by just 8 percent, we would have rejected the null hypothesis and turned to the alternate hypothesis where environmental factors do indeed cause a difference for soil pH. This intermediate p-value prompts the need for further research on the subject, as several factors could have contributed to the results of our experiment. For example, our fairly small sample size was a possible contributor, since there are only four members collecting data for this experiment and because we could not bring in new samples after the new Covid restriction rules. These rules stated that we were no longer allowed to remove soil from the environment. Thus, those factors hindered our tests and results from telling us where the differences existed.

There are also a few other possible reasons for our result to be insignificant. For one, despite taking multiple samples the area we took our samples from included only Vancouver and Surrey, both of which have similar environments. Namely having a cold and wet winter with many trees growing around. Additionally, although the debris like twigs and leaves had been removed beforehand, it most likely had already left a lasting impact on the soil pH. When these pieces of debris begin to decompose, they release their own plant and rock minerals into the surrounding soil, affecting the soil pH in the process. These changes in pH occur because minerals like calcium and sulfide emerge from the debris decomposition and are subsequently converted into acids and alkalis, thereby decreasing or increasing the pH, respectively (Tribe, 2017). In most cases rainwater has a pH of around 7, which can also affect and increase soil pH.

The high amount of debris caused by human activity is another factor for consideration, as human presence and disruption plays a role in soil composition (Rothacker et al., 2018).

There is also the fact that many of our samples came from near school grounds or even from our backyard, meaning that fertilizer was or is still present in a good number of soil. Since the ideal soil condition for crop growth is with a pH of around 6-7 with many nutrients around us, fertilizers may very much affect soil pH in similar ways around Vancouver and Surrey. (United States Department of Agriculture, 2018). Nowadays, the components of most fertilizers include nitrogen, phosphorus, and potassium, which are elements that are essential to plant growth (United States Environmental Protection Agency, n.d.). Furthermore, different plants require different pH levels in order to be in the optimum conditions for growth, therefore fertilizer additives must be included to change the pH adequately. To increase the pH, agricultural limestone is usually added, while sulfur is added to decrease the pH (Mississippi State University Extension, n.d.). The soil samples that we collected may have been surrounding plants which thrive at a certain pH, and fertilizers were likely used to maintain a specific range, which was reflected in the pH values that we collected in those samples.

In future experiments, we would for one, increase the number of trials to decrease the chances of one imperfect result from affecting the overall value. Increasing our sample size will offer greater accuracy in our results as we will have more data to include when doing our analysis. Doing so will increase the odds of finding a statistically significant difference between physical disturbance and soil pH. We would also focus on taking soil from more spread out locations in order to account for soils in varying conditions. It is worth noticing that, despite our tests giving us a pH range of only around 5 to 7, soil around the world can have a pH level as low as 3.5 to as high as 9 (United States Department of Agriculture, 2018). Thus, it is quite likely that redoing the same experiment at different locations can give us completely different results.

Conclusion

Our hypothesis stated that soils with a greater degree of disruption will result in a lower observed pH value. After collecting data on samples from two different areas in Vancouver, one in North Vancouver, and one in Surrey, and conducting statistical analyses on each sample, our results concluded that there was no significant difference present within our data. This meant that we failed to reject our null hypothesis, which predicted that there is no correlation between the soil pH and degree of disruption found within our soil samples. Due to a variety of factors that could have affected this experiment, our results prompt further studies to be conducted. These studies are crucial to analyzing the relationship between our two variables in diverse conditions, such as areas with more or less human activity, and with a larger sample size to strengthen the results. With the understanding of the potential relationship between soil pH and degree of disruption, we may be able to identify the biological processes that are impacted when soils are disrupted. Once this is done, we can then assess how these biological processes change the environment along with it, which is important for upholding environmental standards.

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Appendix

Appendix A: Raw Data for North Vancouver, Vancouver site 1 and 2, and Surrey

Below is the raw data collected on site for North Vancouver, two Vancouver sites and Surrey. It includes the area coordinates of the site where three samples are collected, notes on the general area, the class soil disturbance level, soil pH per soil sample, and notes on the soil, such as texture and colour.

North Vancouver Site				
Area Coordinates	**Notes on Area**	**Area Soil-Disturbance Category**	**Soil pH**	**Notes on Soil**
49.341972, -123.001694	Area of mudslide (2012) and construction to rebuild the bridge. By a river. Almost no plants, tiny amounts of grass.	Class 3	5.0	Dark brown with lots of debris. Very hard to dig, very compact.
			5.0	Soil grey in colour, very compact.
			4.5	Grey in colour, very compact.
49.339542, -123.000114	Constant water flow, water is lead through pipe. Unique plant growing in the area. High pooling of water.	Class 2	5.5	Very muddy, very compact.
			6.0	Very muddy, very compact. Site of grass.
			4.5	Light brown, site right next to water pipe.
49.3311650, -123.0038990	Site of trees such as Western Red Cedar. Ground was just soil and mulch	Class 0	6.0	Mulch texture.
			6.0	Lots of rocks and small twigs and debris.

	type texture. Old growth of trees, no shrubs.		6.5	Mulch like texture, very dark brown, close to a big tree.
49.3281820, -123.008202	Grass patch, on island, in between two roads. No trees around just grass.	Class 1	5.0	Sandy soil.
			5.0	Very dark sandy soil
			6.0	Sandy soil.

Vancouver Site 1				
Area Coordinates	**Notes on Area**	**Area Soil-Disturbance Category**	**Soil pH**	**Notes on Soil**
49.23572, -123.12242	Pure soil, slightly wet due to rain. No tree or grass on top. Fertilizer inside	Class 0	7.0	Very dark soft soil, small amount of wood within
			6.0	Dark soil, no debris
			6.0	Dark soil, small amount of grass
49.23732, -123.12239	Area near a school, thus also might include fertilizer. Top layer of grass removed	Class 1	5	Soil is in solid particles, include grass
			5.5	Brown soil, mulchy texture, hard to brake
			5	Overall more brown than black, dry twigs inside

49.23722, -123.12123	Area near construction. With many trees, grubs growing. May have fertilizer.	Class 2	7.0	Brown soil, with some very small rocks. Very wet due to rain
			7.0	Brown soil, have some decaying leaves that were removed.
			6	Brown soil, less wet since there were trees right above
49.23898, -123.12419	Patch of land near school. Includes trees and rocks and slight construction. Very wet due to rain	Class 2-3	6.5	Brown soil, many small rocks within. Very wet.
			6.0	Brown soil, more on the decaying leaves side. Less wet since there's trees above.
			6.5	Yellowish murky soil, more on the class 2 side than class three. Also very wet.

<u>Vancouver Site 2</u>				
Area Coordinates	**Notes on Area**	**Area Soil-Disturbance Category**	**Soil pH**	**Notes on Soil**
	Few to no grass		5.0	Soil is dark brown/ black. Debris/roots/ twigs observed within soil sample.

49.2676389, -123.2585295	growth, soil area presented by a paved street, few trees nearby. May have fertilizer.	Class 1	5.0	Soil is dark brown/ black and moist and compact. Debris of roots/twigs/ wood chips present.
			5.0	Dark brown/black, compact soil. Debris of rocks/ twigs observed.
49.2641587, -123.1594644	Water pipe presented in the area. No grass growth. Rocks and debris presented. Limited plant growth. Fertilizer may have been added.	Class 2	5	Soil is dark brown, moist and compact. Little chunks of pebble debris observed within the sample.
			5.0	Dark brown and moist. Debris of pebbles and twigs present.
			5.5	Soil is dark brown and moist, compact. Debris of thin dark roots observed.
49.2695160, -123.2581751	Little to no grass growth. Sample taken on the slope of a hill. Large rocks observed nearby	Class 3	5.5	Soil is dark brown, fine, sandy. Chunks of rocks observed at deeper depths when dug. Hard to dig.
			6.0	Soil is dark brown, mixture of sandy and compact, dry.

	observed nearby slope. Soil surface is grey.		7	Soil is dark brown/ grayish hue. Soil is dry, granular, little chunks of rock debris observed.
49.2712977, -123.2293748	Many large trees present nearby soil within the forest area. Soil covered by branches/leaves.	Class 0	5.0	Soil is brown/ reddish hue. Twigs, tree bark debris is observed in soil sample. Soil is dry in texture.
			5.0	Reddish brown colour, dry and granular in texture. Twigs/ pebble debris observed
			6.0	Soil is dark brown and moist. Debris of rocks/twigs observed.

Surrey				
Area Coordinates	**Notes on Area**	**Area Soil-Disturbance Category**	**Soil pH**	**Notes on Soil**
49.155828, -122.77729	Plant bed near townhomes. Soil is slightly wet due to overnight moisture. No trees nearby	Class 0	7.5	Soil is dark and moist, compact.
			7.0	Dark soil, some small rocks present (sample taken from near a bed of rocks)

	trees nearby. Taken care of by a professional landscaper, may be fertilized.		7.5	Dark soil, drier than other samples.
49.154136, -122.763828	Forest area, many trees nearby. Lots of debris from trees and other plants. No grass.	Class 1	6.5	Dark brown soil, contains lots of debris.
			6.0	Lighter soil with less debris but still a significant amount.
			6	Soil is more firm, rocks and debris present.
49.159502, -122.770570	Disturbed area of school field. May be some fertilizer present. Grass present around, but not fully grown on specific soil patch.	Class 3	7.5	Softer soil due to disturbance, medium brown in colour.
			7.0	Some grass debris present.
			7.5	Soil near a tree, dark and soft. Looks dry.
49.155431, -122,766599	Slightly disturbed area on a roadside. Grassy, and looks like a car may have ran over this area.	Class 2	6.5	Dark soil, moist due to rain.
			6.5	Dark and wet soil. Grass present in sample.
			5.5	Most disturbed portion of area. Dark and wet soil.