Soil Organic Matter Content Analysis

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Abstract

Soil organic matter (SOM) can be a great indicator of soil quality. However, land cultivation can result in a decrease in SOM, thus decreasing farmers' ability to grow crops. To combat this, farmers employ techniques to increase the SOM content of their soil. To understand the effectiveness of these techniques and the effect of cultivation on SOM content, we tested the SOM content of farm soil and uncultivated soil from backyards under the hypothesis that farm soil would have higher SOM content. The soil was sampled from two different general locations: Squamish and Vancouver. In each location, three soil samples were taken from two different farms and a backyard. In Squamish, the farms were Lavendel and Nutridense. The farms in Vancouver were Snow and UBC. Samples were dried and then reacted with hydrogen peroxide to remove SOM through oxidation. The mass of the soils pre and post-treatment with hydrogen peroxide was compared to determine the SOM percentage in each sample. All of the data from both general locations were grouped into either farm data and backyard data. The mean SOM percentage for the farm group and backyard group was calculated as 1.825 and 1.098 respectively. An unpaired t-test was then run on the data to determine whether the difference in means between the two groups was significant. After calculating a p-value of 0.1806, we determined the difference in means was not significantly significant. Therefore, we failed to support our hypothesis that farming techniques increase SOM content and concluded that techniques employed by farmers are not effective in raising SOM past pre-cultivation levels.

Introduction

Soil health is one of the most important aspects of plant growth. It is linked to pH, water retention, and erosion prevention (Doran and Zeiss 2000). Soil organic matter (SOM) is strongly linked to soil quality due to its effect on the factors mentioned above (Doran and Zeiss 2000). For this reason, maintaining a high level of SOM is important to the agriculture industry. However, long periods of cultivation have been shown to decrease organic Carbon and Nitrogen, the main components of SOM, leading to decreases in crop growth and production (Mills and Fey 2013). The continual growth and removal of vegetation due to farming prevents the soil from naturally regaining normal levels of carbon or nitrogen (Doran and Zeiss 2000). To prevent this, the agriculture industry relies heavily on the addition of compounds that contain carbon and/or nitrogen to artificially increase SOM content. These compounds include manure, synthetic fertilizer, mulch, bone meal, and many others (Bot 2005).

To determine the effectiveness of these techniques at preventing the decrease of SOM, we created an observational study that compares the SOM of cultivated land (farm soil) vs uncultivated land (backyard soil). By comparing the SOM of farm soil to backyard soil, we could determine if techniques to raise SOM levels are effective in raising SOM levels past pre-cultivation levels. To accomplish this we collected 3 samples of farm soil from two different farms and compared them to 3 samples collected from a backyard. This was performed in 2 locations Squamish and Vancouver for a total of 12 samples of farm soil and 6 samples of backyard soil. The level of SOM was measured by comparing the weight of the dried soil to the weight of soil with the SOM removed. The removal of SOM was accomplished by reacting soil with hydrogen peroxide, a powerful oxidizing agent. Hydrogen peroxide would react with the Carbon and Nitrogen in the soil resulting in the formation of carbon dioxide and to lesser extent ammonia (Mikutta et al. 2005). SOM concentration was measured by dividing the weight of dry soil by the weight of dry soil post-reaction with hydrogen peroxide to find the percentage of SOM in soil. The percentages of SOM from the farms were compared to the percentages of SOM in the backyard. An unpaired t-test was used to analyze if there were differences between farm SOM and backyard SOM that were statistically significant. We hypothesize that farm soil will have a higher level of SOM than backyard soil because of techniques employed by farmers to increase SOM level. While there have been studies observing the effect of fertilizers to raise SOM, many of these are in different climates than BC (Mills and Frey 2013). Our study will focus on soil in BC making it important to the BC agriculture industry in determining if techniques used to improve SOM are effective.

Methods

First, we collected 3 soil samples of about ½ cup from each farm (enough for multiple trials) and labeled each sample with the name, location, and date of collection as shown in figure 1. When home, we collected another 3 samples in the same manner from our backyard.

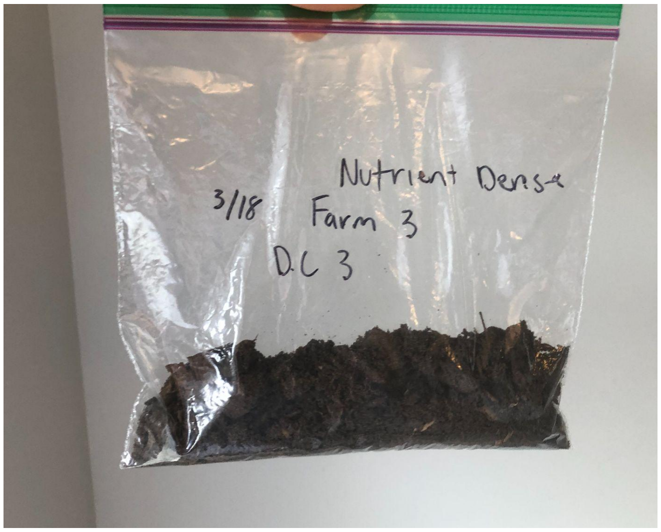

Figure 1: Example of labeling technique for each soil bag collected.

After collection, we made enough double-layer tinfoil boats for 3 trials for each sample ((2 farms + 1 backyard)*3). We then labeled each boat with the farm name and a number, either 1, 2, or 3, and weighed each empty tin foil boat, making sure to record the weight in our lab notebook. We placed each tinfoil boat on the scale and added approximately 20g of the appropriate soil and recorded the exact weight in our lab notebooks. We then preheated the oven to 170 degrees celsius and placed the boats on the baking sheet to begin the drying process. After an hour and a half, we removed the boats and allowed them to cool (if weighed too early out of the oven, it will affect the recorded weight). To determine whether the soil samples were completely dry, we weighed and recorded each sample then placed them back in the oven. After 20 minutes, we removed the samples, allowed them to cool, and weighed each sample again. If the weight had continued to decrease, we put it back in the oven for another 20 minutes until two consecutive 20-minute intervals resulted in the same weight. If the weight remained the same, we recorded the weight as “weight of dry soil + tin foil boat”. Once all soil samples were dry, we calculated the amount of hydrogen peroxide needed to react with the soil by using the following formula (remember to subtract the weight of the tin foil boat to get the mass of the soil):

$$M_{\text{dry soil}} * 2 = M_{\text{hydrogen peroxide}}$$

We placed the appropriate amount of 3% hydrogen peroxide in each boat and allowed the reaction to proceed overnight. We noted any signs of reaction such as bubbling and crackling sounds. Then we dried the samples using the same process as used to dry the soil for the first time. Once the soil was dried we used the following formula to calculate the SOM content (remember to subtract the weight of the boat to get the weight of the soil):

$$((M_{\text{dry soil}} - M_{\text{after reaction with hydrogen peroxide}}) / M_{\text{dry soil}}) * 100 = \text{Percent SOM}$$

Once the SOM was calculated for each sample, we grouped all the farm data and backyard data together. Using an unpaired t-test, we determined whether the difference in means among the two groups was significant.

Results

A total of 18 samples were collected and tested for SOM content. This included 12 samples of farm soil and 6 samples of backyard soil. For the statistical analysis, we defined the null hypothesis as there is no difference in SOM content between farm and backyard soil and the alternate hypothesis as there is a difference in SOM between farm and backyard soil. An unpaired t-test was performed to compare the farm and backyard soil and an alpha level of .05

was used to determine if differences in SOM percentages were statistically significant. All analysis was done using GraphPad Prism 9.1.0.

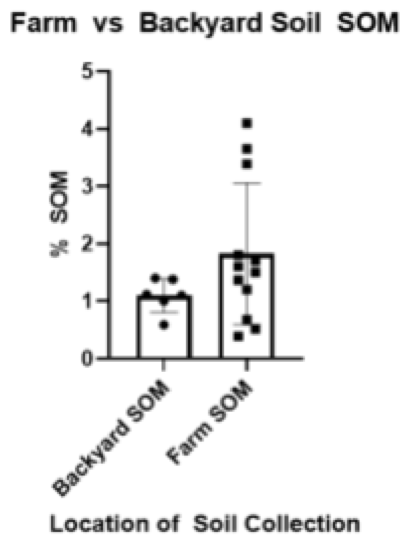

Figure 3: Graph of all data points and mean values for the study. There were 6 trials done for backyard soil and 12 for farm soil. Each data point is indicated by a dot and error bars were calculated at 95% confidence interval. The mean value for the backyard soil SOM was 1.098 and 1.825 for the farm soil. No outliers were taken out for these calculations.

From our unpaired t-test, we calculated a p-value of .01806 which is higher than our significance level of 5%. The mean SOM for backyard and farm was 1.098% and 1.825% respectively (Fig.3). Error bars were calculated with a 95% confidence interval and in farm SOM content we had 5 outliers outside of that error bar. One outlier was lower than the error bar in backyard SOM. In Farm SOM we had one outlier lower than the error bar and 3 values higher than the error bar. An F-test returned a p-value of 0.0055. This is lower than our significance level of 5%. In Figure 3 we can see that farm soil SOM has much larger variance than backyard soil SOM.

Discussion

The objective of this observational study was to determine if cultivated farm soil would contain a higher SOM percentage than soil from a backyard. The results would help discern if farmers' cultivation techniques effectively raised SOM percentage past levels of SOM found in uncultivated soil. Statistical analysis run on the data returned a p-value larger than our significance level, meaning we failed to reject our null hypothesis that there would be no significant difference between farm soil and backyard soil. Although farm soil did have an average that was .8% higher than that of backyard soil, it was not large enough to be deemed significant. These results suggest that farmers' techniques are not effective in raising SOM levels past pre-cultivation levels. Though these results do not support our original hypothesis that farmed soil would have a higher SOM percentage than backyard soil, these findings agree with many other studies that support the idea of land cultivation leading to a decrease in SOM despite the use of fertilizers (Mills and Frey 2013). A study done by Swaneopoel et al. 2016 found that cultivation would lead to between a 25% to 53% decrease in SOM levels in various precipitation zones of southern Africa. While South Africa is in a different climate than BC, a consistent trend of SOM reductions on cultivated land across all climates has been observed, with typically only variations in the amount of SOM lost (Ladha et al. 2011). Fertilizers have been shown to improve carbon and nitrogen levels in soil; however, these increases were only able to at best match decreases in SOM levels due to cultivation (Johnston et al. 2009).

A notable difference between backyard and farm soil was the higher variance in the SOM levels of farm soil compared to backyard soil. From an F-test, we determined that there was a statistical difference between the variances. From figure 3 we can see that farm soil has much larger error bars indicating that it has a higher variance compared to backyard soil. This high variance can be partially attributed to differences in techniques employed by farmers. Studies have shown that synthetic vs organic fertilizers result in a difference in SOM recovery in cultivated soil, with organic generally leading to a more significant recovery (Ladha et al. 2011). Differences in fertilizers used among farmers at each of our respective locations could have led to the high variance observed in our results. In addition to the treatment of soil, the length of cultivation can have substantial effects as well. A study done by Mills and Fey 2013 found that a large portion of total SOM loss in cultivated soil happens in the first five years of cultivation. Soil collected from farms only 1-2 years old would have much higher SOM levels compared to farms 5+ years old, completely independent of techniques used by the farmers.

Our results and their high variability could also be due to experimental errors that could have led us to inaccurately measuring SOM levels in the soil. Using 3% hydrogen peroxide could have limited the amount of organic matter that would be reacted with. Findings from the Mikutta et al. 2005 study found that while lower percentages of hydrogen peroxide could effectively remove SOM, the amount needed for those lower percentages was too large to be feasible in this experiment. Initial trials indicated that too large an amount of hydrogen peroxide would result in soil too saturated to be accurately measured, as seen in figure 4. In this trial, it was clear that 10g of hydrogen peroxide to 1g soil was far too much, as we were unable to dry the sample after the reaction.

Figure 4: An image from trial 1 showing the result of too much hydrogen peroxide added (10g of hydrogen peroxide per 1g of soil). With numerous rounds in the oven and allowing the reaction to proceed for days, we could not burn off excess hydrogen peroxide.

Using less hydrogen peroxide in later trials, we successfully burned off the excess hydrogen and redried our soil, as illustrated in figure 5. In doing so, we could get a more accurate weight of the soil post-treatment with hydrogen peroxide.

Figure 5: Trial 3 showing the result of using less hydrogen peroxide (2g of hydrogen peroxide per 1g of soil).

As seen in figure 5, there is no moisture left in the soil after the samples dried in the oven. Unfortunately, there is a tradeoff of using less hydrogen peroxide: it would need to be more concentrated to have a complete reaction with SOM (Mikutta et al. 2005). By using less hydrogen peroxide of a lower concentration, we likely prevented the chance of a complete reaction with a large portion of SOM in the soil samples. Moreover, a review by Mikutta et al 2005 also claims the removal of carbon from soil using hydrogen peroxide often requires several days. Since the soil reacted with hydrogen peroxide overnight in this experiment, this could have also contributed to an incomplete reaction. Less reaction with hydrogen peroxide could have led to less SOM removal leading to results with decreased SOM levels. Future experiments will most likely want to use a more concentrated hydrogen peroxide solution if they plan to use a smaller volume of hydrogen peroxide.

Inorganic matter in the soil could have also contributed to the variability in our results. The inorganic matter could consist of rocks, sticks, and roots that would have added to the soil's mass and ultimately affected the amount of SOM calculated. The side-by-side comparison between soil from the Lavendel farm in figure 5a and soil from the Nutridense farm in figure 5b shows that Lavendel farms had significantly more inorganic matter, such as bark, chips, and mulch, adding to the mass of the soil.

Figure 6
Fig 6a (left panel): shows the Lavendel farm soil after reaction with hydrogen peroxide.
Fig 6b (right panel): shows the Nutridense farm soil after reaction with hydrogen peroxide.

Adding mass to the soil that will not react with hydrogen peroxide may have decreased the calculated percentage of SOM. Future studies may want to include a technique that sifts the soil and removes any intrusive bits of inorganic matter.

Based on this study and the analysis of the results, we can conclude that farmers' techniques to raise SOM levels past pre-cultivation are not effective. They do not lead to a significant increase in SOM compared to uncultivated land. Should future studies wish to recreate our experiment, they will want to account for the experimental errors mentioned above. The agriculture industry in BC may want to re-evaluate the techniques it employs to increase SOM in cultivated soil. Future studies may want to compare the effectiveness of different techniques to raise SOM in BC farm soil.

Conclusion

After performing an experiment to test whether farm soil has higher levels of SOM than a backyard, we were able to conclude that there is no significant difference the two types of soil. Therefore we can conclude from our experiment that techniques employed by farmers are ineffective at raising SOM levels past pre-cultivation levels.

Acknowledgments

We would like to thank all of the farms who participated in this study, Lavendel Farms, Nutridense Farms, UBC Farms, and Snow Farms, and contributed to this data set. We would also like to thank Dr. Celeste and UBC for allowing us the opportunity to take this course and learn so much in the process. We would also like to recognize that this project was done through the help of UBC which is located on the unseated land of the Musqueam people/

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Appendix

Raw Data:

Location	Squamish BY	Vancouver BY	UBC Farm	Snow Farm	Lavendel Farm	Nutridense Farm
Trial Number	%SOM	%SOM	%SOM	%SOM	%SOM	%SOM
1	0.59	1.4	0.39	1.6	1.5	4.1
2	1.12	1	0.52	1.8	1.37	3.65
3	1.38	1.1	0.68	1.2	1.7	3.39