A comparison of soil pH and temperature at the UBC Farm

Christie A. Crews*

Abstract

Both soil pH and soil temperature have a strong impact on biochemical properties of soil and plant growth. The objective of this study is soil pH and temperature between forest and production fields at the UBC Farm. I measured pH and temperature at a depth of 10cm at random coordinates in each the forest and farm areas, sampling on two separate days due to time constraints. Forest soil (M = 4.70 ±0.18) was significantly more acidic than production area soil (M = 6.35 ±0.24). On day one, there was not a significant difference between the forest soil temperature (M = 8.63 ±0.38°C) and farm soil temperature (M = 8.72 ±0.58°C). However, on day two, the forest soil (M = 7.03 ±0.46°C) was significantly warmer than the production area soil (M = 5.93 ±0.31°C). There was also a significant interaction between location and day. The acidifying effect of coniferous tree species in the UBC Farm forest likely had an acidifying effect on the soil, and forest litter likely acted as a thermal insulator, keeping the forest soil warmer.

1. Introduction

Together and individually, soil pH and temperature have important consequences for the growth of vegetation and the health of ecosystems. For one, soil pH controls the bioavailability of nutrients in the soil (Rorison, 1980). Micronutrients, like Mn, Fe, Zn, are most soluble in acidic soils and decrease solubility as pH increases, due to increased adsorption (Rorison, 1980; Neina, 2019). However, these elements can be toxic to plants at high concentrations (Rorison, 1980). In addition, macronutrients, like P and Ca, are tied up and immobile in very acidic soils, which limits their availability for uptake into plants (Rorison, 1980). Alkaline soils, on the other hand, also limit the availability of some essential nutrients and contributes to elemental toxicity (Luna et al., 2016). Thus, the ideal soil pH is a delicate balance between nutrients and depends on the needs of a specific plant species.

Additionally, temperature is a key factor controlling microbial activity in soils. Microorganisms play a significant role in nutrient cycling, including mineralization of organic

Address correspondence to Christie Crews; christie.crews@alumni.ubc.ca

matter and nitrification (Onwuka, 2018). Without soil microorganisms, much of the nitrogen present in the soil is in an unusable form for plants, which negatively impacts growth (Onwuka, 2018). The ideal temperature range for most microorganisms is 10°C-35.6°C, with microbial activity increasing with temperature (Onwuka, 2018). However, when temperatures are too high, microorganisms may die, and when temperatures are too low, enzyme activities cease (Onwuka, 2018).

Given the importance of soil pH and temperature, the University of British Columbia (UBC) Farm offers a unique opportunity to study how land use may effect changes in ecosystems. The objective of this study is to compare soil pH and temperature between forest and production areas at the UBC Farm in order to examine factors contributing to ecological differences between these locations. Tree species influences soil pH, with coniferous species, like pine, having a stronger acidifying affect on soil than deciduous species like oak (Blonska et al., 2016). Production fields, on the other hand, tend to have a more neutral pH because farmers can add substances to raise or lower soil pH to an ideal value for plant growth (British Columbia Ministry of Agriculture, 2015). Thus, because the UBC forest is dominated by coniferous tress, I hypothesize that the forest will have a lower soil pH than farmed areas. In a forest, the canopy shades the ground, limiting the amount of solar radiation that can heat the soil (Onwuka, 2018). Bare soils, like those found in farmland, absorb large amounts of heat (Onwuka, 2018). I also hypothesize that farmed areas will have a higher soil temperature than forest because of the warming effect of solar radiation.

2. Methods

2.1 Study Site

I focused my research at the UBC Farm, a 24-hectare farm located at the south end of UBC's Vancouver campus (UBC, n.d.). I generated 25 random coordinates each for the production and forest areas of the UBC Farm using Plot Random Markers by Daft Logic. Figure 1 shows a map of the sampling locations. I divided the coordinates for each location in to two sampling days due to time constraints.

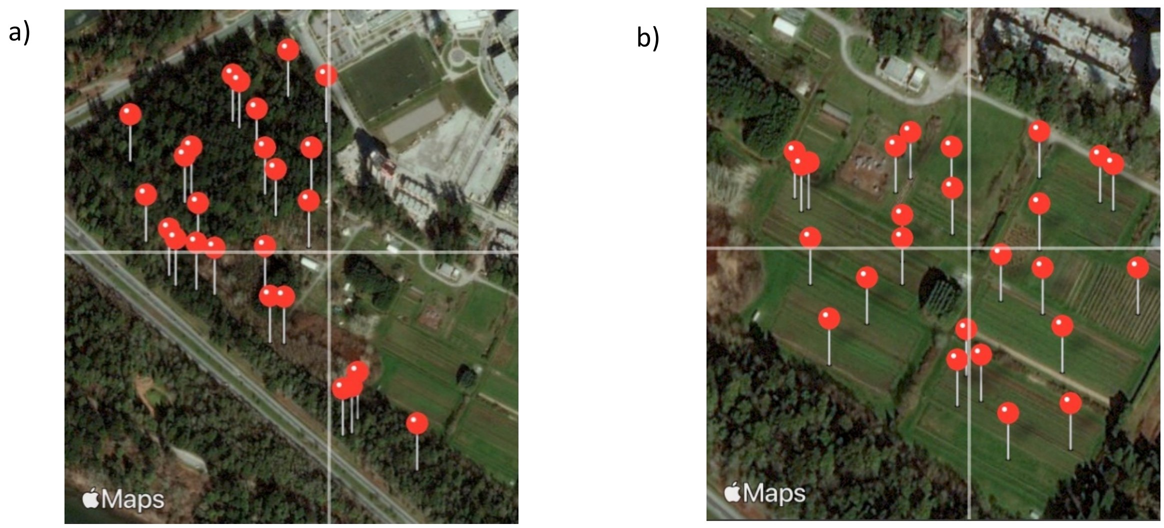

Figure 1. Randomly generated coordinates displayed on a satellite image of the UBC Farm. a) Sampling points in the forest area, b) sampling points in the farm production areas

2.2 Data Collection

I used a bluelab combo meter and bluelab leap pH probe for pH measurements and a DOQAUS digital thermometer for temperature measurements in Celsius. On November 7th and November 10th, 2020, I inserted the probes at a depth of 10 cm into the ground at each sampling point and allowed readings to stabilize before recording the value. In forest areas, I cleared the top layer of leaf litter to access the soil.

2.3 Statistical Analysis

I performed diagnostic plots to test the assumptions of equal variance and normal distribution. There was one outlier in the pH data, however, the rest of the data points followed a normal distribution, and removal of the outlier would violate the equal variance assumption, so I retained the outlier for subsequent analysis. In addition, excluding the outlier only decreases an already significant p-value, and only changes the mean by 0.1. I also excluded one data point from the forest location because tarping prevented me from measuring much deeper than about 5cm into the ground.

In R, I modeled the data in two ways for both pH and temperature, first a linear model with sampling day as a random effect, and then a linear model with an interaction term between location and sampling day. I compared the two models for each data set and performed an ANOVA on the model with the best fit. I also used Tukey's multiple comparison test

3. Results

For pH, adding an interaction term did not significantly improve the model, $p > 0.05$, and sampling day did not have a significant effect ($p > 0.05$), so pH values from the two days were pooled as one group. For temperature, on the other hand, adding an interaction term significantly improved the fit of the model ($p < 0.001$).

At the UBC Farm, forest soil ($M = 4.70 \pm 0.18$) was significantly more acidic than production area soil ($M = 6.35 \pm 0.24$), $p < 0.001$. Figure 1 displays the mean pH and the 95% confidence interval (CI) for each location. Forest soil pH has a slightly smaller CI than farm soil pH. Figure 2 displays the mean temperature and the CI for each location and sampling day. There was a significant main effect of location on soil temperature, $p < 0.001$, but also a significant interaction between location and day, $p < 0.05$ (Table 2). On day one, the forest soil temperature ($M = 8.63 \pm 0.38$°C) and farm soil temperature ($M = 8.72 \pm 0.58$°C) was not significantly different ($p > 0.05$), however, on day two, the forest soil ($M = 7.03 \pm 0.46$°C) was significantly warmer than the production area soil ($M = 5.93 \pm 0.31$°C), $p < 0.001$. For both forest and farm locations, soil temperature was colder on day two than day one, $p < 0.001$.

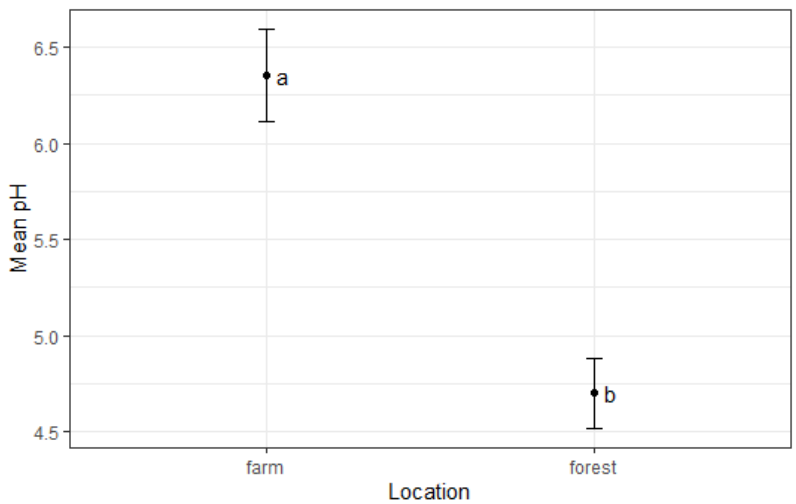

Figure 2. Mean pH with 95% confidence interval for each sampling location. Different letters indicate significance ($p < 0.05$).

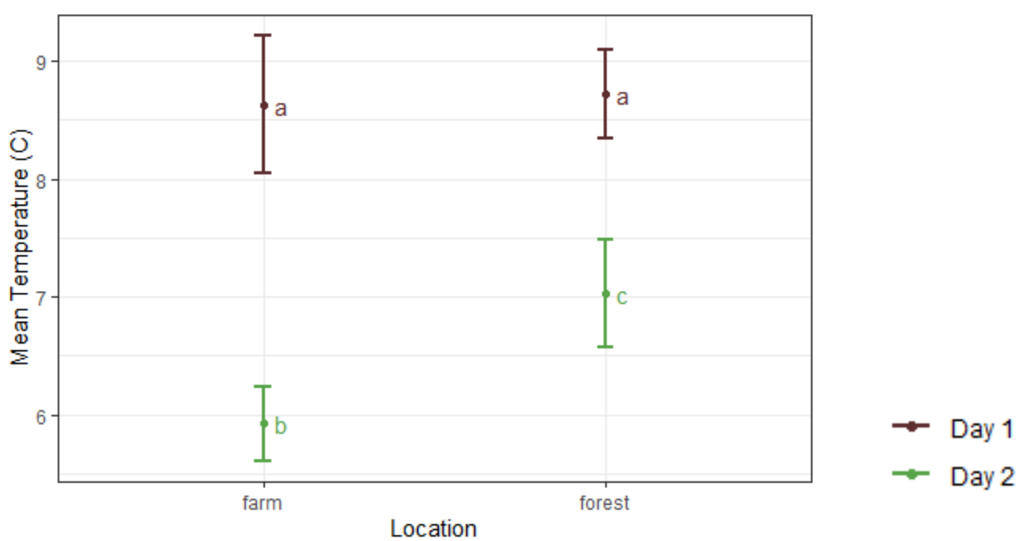

Figure 3. Mean temperature (°C) with 95% confidence interval for each sampling location and sampling day. Different letters indicate significance ($p < 0.05$).

4. Discussion

My first hypothesis, that soil from the UBC Farm forest would be more acidic than soil from the production areas, is supported by the data as the forest has a significantly lower pH compared to the production fields. My second hypothesis, however, is not supported, but surprisingly, there was a significant interaction between location and sampling day. On day one, the soil temperature in the forest and farm areas was not significantly different, but on day two, the soil in the forest was significantly warmer than soil in the production fields.

It is not surprising that farmed fields would be slightly acidic to neutral because many crops, including those grown at UBC, have pH preferences ranging from 5.0-6.5 to 6.5-8.0 (British Columbia Ministry of Agriculture, 2015). Farmers often add compounds to adjust the pH of their soil to a more favourable value for their crops (British Columbia Ministry of Agriculture, 2015). In Vancouver, where heavy rainfall washes elements from the soil and lowers the pH, farmers may be extra conscious of perfecting their soil pH (British Columbia Ministry of Agriculture, 2015). Forests, on the other hand, are rarely adjusted for pH, and so the species present can have a long-lasting impact on soil pH. Conifers, which dominate the forest at the UBC Farm, have an acidifying effect on soil (Blonska et al., 2016). It is thought that these trees influence the composition of the soil by increasing the percentage of hydrogen (Blonska et al., 2016). Thus, altogether, it is quite logical to find significantly more acidic soil in the forest of UBC compared to the production fields.

Many researchers have found that soil temperatures in open areas are warmer than soil temperatures in forests; You et al. (2013), for example, reported higher mean soil temperatures in open sites compared to mountain forests during all months of the year. There are a few reasons why my results seem to contradict the expected trends, one being the effect of day-to-day variation versus longer term trends. The day one temperature results can be explained by the cloudy weather during sampling. Morecroft et al. (1998) found that soil temperatures in wooded areas and open sites were very similar on cloudy winter days. However, day two was also cloudy, so another factor might explain the interaction between day and location: leaf litter. For both locations, the mean soil temperature on day two was significantly lower than on day one, but the soil temperature decreased more in the production fields than in the forest. Leaf litter acts as an insulator and reduces day to day variation in soil temperature (MacKinney, 1929). In addition, the presence of leaf litter raises the mean soil temperature compared to uncovered plots (MacKinney, 1929). Thus, because leaf litter is more abundant in the forested areas of the UBC Farm, the soil temperature decreased less because of the insulating qualities of forest litter.

There are some limitations in this study. Firstly, the results should not be generalized to all forest/farm sites. It would be pseudo replication to assume the random coordinates in the UBC Farm are independent in such a comparison, and so my sample size would in fact only be one for each farm and forest. Secondly, there was an outlier in the pH measurements due to the acidophilic nature of blueberries. Excluding the data point would violate the assumption of equal variances, but including the outlier slightly violates the assumption of normal distribution. However, inclusion/exclusion of the outlier does not influence the results, so while some error is present from violations of the assumptions, the results of analysis are likely accurate. Finally, my sample size for comparing the interaction between day and location for soil temperature is relatively small, which limits my conclusions somewhat. Further study is needed to compare temperature changes in farm and forest sites at the UBC Farm.

5. Conclusion

Overall, at the UBC Farm, the forest is much more acidic than the production fields, which was expected given the acidifying effect of conifers and the relationship between pH and crop growth. Temperature, on the other hand, was in stark contrast to the expected results. The forest appears to retain soil warmth better than farm soils, possibly due to the insulative properties of forest litter. These results may have implications for the community structure of microbial communities at the UBC Farm.

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Appendix

Table 1. Raw data of forest soil pH and temperature at random coordinates in the forest area of the UBC Farm

n	latitude	longitude	pH	temp (°C)	location	day
1	49.25162650	-123.24300920	4.7	6.0	forest	2
2	49.25173010	-123.24145400	4.4	5.9	forest	2
3	49.25173660	-123.24054808	5.8	8.0	forest	1
4	49.25257765	-123.24195150	4.6	8.8	forest	1
5	49.25266060	-123.24209220	4.4	8.8	forest	1
6	49.25297587	-123.24100140	4.4	8.6	forest	1
7	49.25265540	-123.24025650	5.0	7.9	forest	1
8	49.25047460	-123.24144560	4.9	6.6	forest	2
9	49.25046010	-123.24243610	4.7	7.6	forest	2
10	49.25057380	-123.24318890	4.8	7.0	forest	2
11	49.25069736	-123.24332590	5.2	7.4	forest	2
12	49.25113140	-123.24377930	4.7	8.1	forest	2
13	49.25174660	-123.24288760	4	5.6	forest	2
14	49.25215290	-123.24407950	4.4	7.5	forest	2
15	49.25222839	-123.24161480	3.7	7.7	forest	2
16	49.25146349	-123.24124304	4.7	7.8	forest	2
17	49.25106064	-123.24059111	NA	NA	forest	2
18	49.24866800	-123.23993933	5.0	9.8	forest	1
19	49.24983730	-123.24107792	4.9	9.0	forest	1
20	49.24870010	-123.23974990	4.9	8.6	forest	1
21	49.24823372	-123.23848308	4.3	9.0	forest	1
22	49.24888538	-123.23964810	4.4	8.7	forest	1
23	49.24985440	-123.24136050	4.9	7.3	forest	2
24	49.25052021	-123.24279440	5.2	7.5	forest	2
25	49.25103370	-123.24275170	4.8	6.4	forest	2

Table 2. Raw data of farm production area soil pH and temperature at random coordinates in the forest area of the UBC Farm

n	latitude	longitude	pH	temp (°C)	location	day
1	49.24840006	-123.23688938	6.4	5.5	farm	2
2	49.24846204	-123.23631522	6.7	5.6	farm	2
3	49.24873034	-123.23736531	6.1	5.5	farm	2
4	49.24875881	-123.23714136	6.6	9.8	farm	1
5	49.24891187	-123.23728301	6.4	6.7	farm	1
6	49.24893328	-123.23638655	6.9	8.4	farm	1
7	49.24936846	-123.23696080	6.7	8.8	farm	1
8	49.24929159	-123.23656934	6.5	8.4	farm	1
9	49.24929078	-123.23568581	3.8	9.3	farm	1
10	49.24967706	-123.23660531	6.4	8.4	farm	1
11	49.24991743	-123.23591909	6.4	8.8	farm	1
12	49.24996768	-123.2360418	6.3	8.6	farm	1
13	49.25011994	-123.23660182	5.9	9.1	farm	1
14	49.24897797	-123.23856390	6.6	5.6	farm	2
15	49.24922779	-123.23821617	6.6	5.8	farm	2
16	49.24946850	-123.23873697	6.4	5.6	farm	2
17	49.24946565	-123.23788078	6.5	5.6	farm	2
18	49.24960838	-123.23788174	6.5	5.4	farm	2
19	49.24992906	-123.23875820	6.5	6.0	farm	2
20	49.24999363	-123.23888721	6.3	5.6	farm	2
21	49.24976973	-123.23742089	6.2	6.5	farm	2
22	49.25002307	-123.23742527	6.5	7.5	farm	2
23	49.25010891	-123.23780470	6.2	6.2	farm	2
24	49.25002827	-123.23794723	7.0	6.6	farm	2
25	49.24991288	-123.23882400	6.4	5.9	farm	2

Table 3. Summary statistics for soil pH and temperature at farm production and forest locations on the UBC Farm

	n	Mean pH	SD	p value	Mean Temp (°C)		SD		p value
					Day 1	Day 2	Day 1	Day 2	
Forest	24	4.72	0.43	5.23E-15	8.7	7.0	0.53	0.79	0.00059
Farm	25	6.35	0.58		8.6	5.9	0.82	0.57	