The Change in Soil Acidity on the North Shore of Long Island, New York: Using Depth as a Window into the Past

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Long Island has undergone changes in soil acidity over the past 100 years due to acid rain. A study conducted on the North Shore of Long Island, in 1922 by Edgar T. Wherry, found the topsoil pH to be 6.5. Interestingly, when this test was repeated in 1985 by Andrew M. Greller, a lower pH of 4.1 was recorded. The purpose of the current study is to determine how the topsoil pH has changed since 1985 with depth, how wildfires impact pH, and if human interaction and undisturbed sites will provide insight into how the environment has changed. This study was carried out by collecting soil from Caleb Smith State Park in Smithtown, New York: an area with similar characteristics to the previous studies. Our findings indicated that the average surface pH is 3.3 and became less acidic with depth. In human impacted areas, topsoil pH was lower, however, under undisturbed buildings, soil pH was higher. Contrastingly, a site impacted by a wildfire had a lower pH value with depth, but remained at 3.3 for topsoil. Overall, there have been alarming changes in soil acidity that will continue to have serious impacts on the environment in the future.

Introduction:

In today's environment, pollution has contributed to a rise in acid rain throughout the United States. As a result of large cities, the burning of fossil fuels, and the prevailing wind direction, the Northeastern United States is one of the most affected areas by acid rain, shown in figure 1. Due to the influences of these factors, the pH of soil has become drastically lower over the last century (Greller, 1985). The effects of acidic pH are unknown, but it is evident that acid rain is increasing which, therefore, is decreasing the pH levels of soil. Acid rain is widespread because it can be carried thousands of miles by wind (Mohnen, 1988). Acid rain occurs when sulfur dioxide and nitrogen oxide, products of burning fossil fuels, combine with atmospheric moisture and air pollutants, shown in figure 2. Sulfur Dioxide (SO2) and Nitrogen Oxide emissions (NOx) are carried from the Midwest portion of the U.S. to the Northeastern portion by the prevailing winds. The amount of pollutants determines the acidity of the rain (Mohnen, 1988). Air pollutants are carried by the prevailing winds and are deposited back to Earth's surface through precipitation (Burgess, 2012). In the United States, the typical pH for soil is 3.6, but recordings have been to 2.6 (Mohnen, 1988). By determining the pH changes in an ecosystem, its effects can be explored, and by looking at the relationship of depth and the pH change, it can be determined how far acid rain penetrates into the ground.

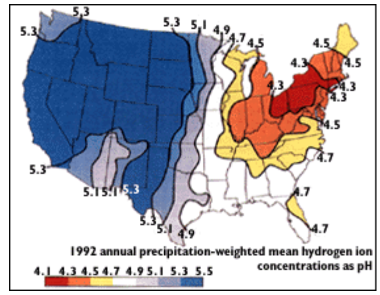


Figure 1: The areas of greatest acidity (lowest pH values) are located in the Northeastern United States; red ("Geological Distribution of Acid Rain", USGS Water Science School).

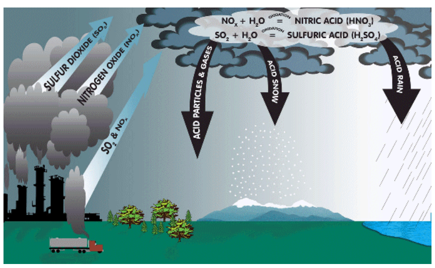


Figure 2: Acid precipitation is formed when pollutants such as oxides of Sulfur and Nitrogen react with the moisture in the atmosphere ("What is Acid Rain?", Indian Institute of Tropical Meteorology)

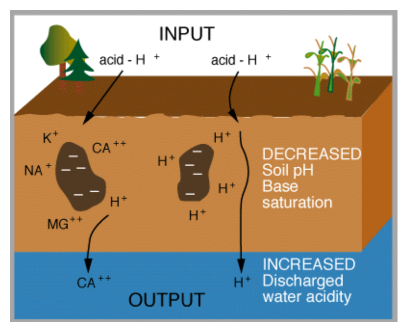


Figure 3: The H+ ions attach to the soil particles and displace them so the runoff is composed of Calcium ("The Effects of Acid Rain", The Global Water and Nitrogen Cycle).

Immediately after a wildfire, the nutrients and characteristics of soil are affected. A fire's impact on an area is determined by the fires severity, temperature, fire frequency, soil type, moisture, vegetation present, topography, and the season of burning. Fires are known to release H+ ions into the soil, which decreases the soil's pH, however, ash deposited by fires contains a high content of salts which can increase soil pH. In terms of physical effects, a reduction of the soil's structure and organic matter often causes reduced porosity ("Fire Effects on Rangeland").

Location:

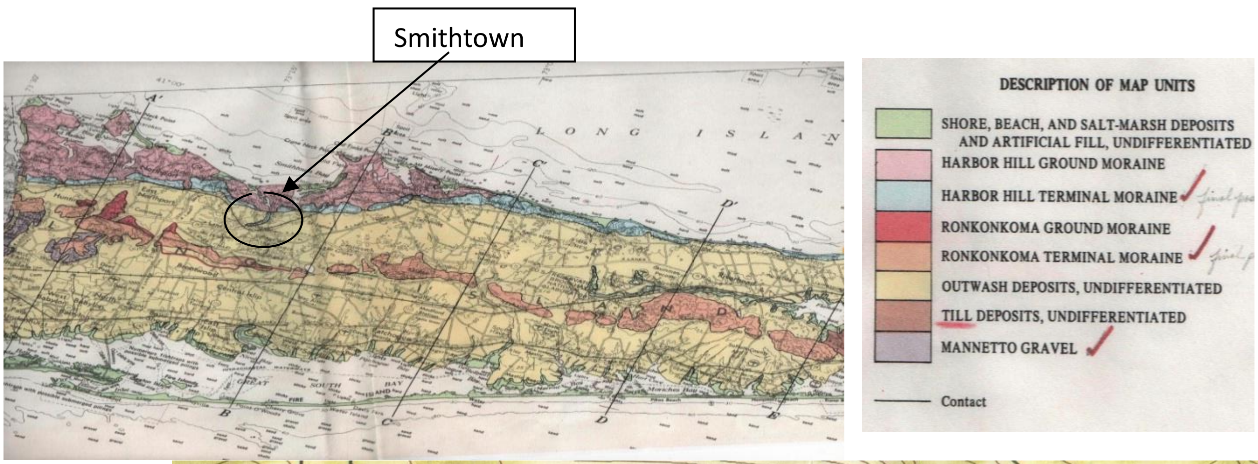


Figure 4: Shows the geologic history of Long Island with the corresponding key. Blue=Harbor Hill; Yellow=Outwash.

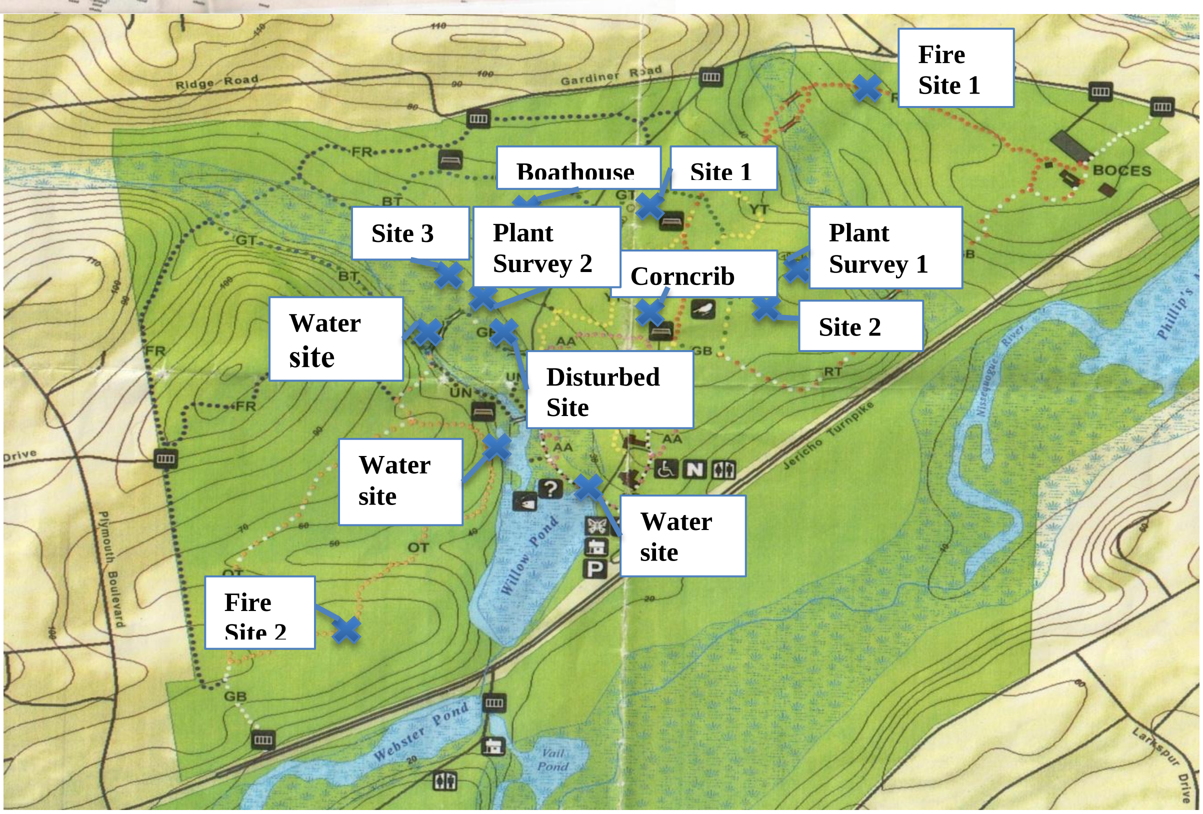


Figure 5: Map of Caleb Smith State Park showing where sample sites and studies were conducted.

Caleb Smith State Park is located in Smithtown, NY, on Long Island. All data was collected at this location. Long Island has a very diverse geology due to its glacial formation. Smithtown consists of outwash plains, or areas of sorted sediments from glacial melt water, shown in yellow. Additionally, a small portion of Smithtown is part of the Harbor Hill Terminal Moraine, shown in blue in figure 4. Moraines are unsorted sediments from a glacier moving thorough an area. Caleb Smith State Park contains ponds, small rivers, mowed fields, and undisturbed forests ("Caleb Smith State Park"). It is considered a temperate deciduous forest, meaning that all of the trees (excluding pine trees) lose their leaves in autumn, to contribute to the topsoil layer. The sites resemble the areas studied by Wherry and Greller on the North Shore of Long Island in 1922 and 1985

Materials and Methods:

Collecting Soil Samples:

First, an area was located away from human interference at Caleb Smith State Park to obtain soil samples. At each site, locations approximately 50 feet by 50 feet were chosen. Next, GPS coordinates were recorded using the Etrex 10 GPS. For each hole, topsoil (0 cm) was removed with a small shovel and placed on plain paper to observe its characteristics: color, texture, and moisture. Next, the sample was placed into a plastic bag labeled with depth, date, and hole number. The auger was placed into the depression and twisted downward to reach each desired depth which is measured with a measuring tape. The soil was scooped out of the bottom of the auger and observed. This process was conducted for each depth. These steps were repeated for each hole and each site, and the soil was replaced after each hole.

pH testing:

To begin, the collected soil samples were placed onto paper towels and left out to dry for 24 to 48 hours. Each individual sample was then weighed with a digital scale and sifted using a 2 mm sieve. The sifted and non-sifted portions of the sample are weighed and recorded. Next, 10 mL of sifted soil from each depth is placed into a test tube labeled with the hole's number, date, and site. Subsequently, 0.01M calcium chloride ($CaCl_2$) solution is prepared using this equation: 1.47g/1000mL=X/500mL → .735g. Calcium chloride was used because it naturally simulates rainwater. To make this solution, the $CaCl_2$ is weighed using a digital scale and graduated cylinder is filled with 500 ml of water. Add .735g of $CaCl_2$ to the water, cover the top of the graduated cylinder with Para film, and shake it to dissolve the $CaCl_2$. Each test tube is filled with $CaCl_2$ solution and soil in a one to one ratio. Place the test tubes into the ultrasonic bath for five minutes to break up the grains and then let them sit overnight. When the pH was taken the following day, the pH meter was calibrated. Hanna HI 2211 and LabQuest 2 pH meters were used at the research institution. Each meter was calibrated using 7.01 and 4.01 buffers and cleaned with distilled water between calibration points. Re-calibrate the meter after each sample set and record calibration and end times. Repeat this process accordingly for protected, disturbed, and wildfire sites.

Results/Conclusions:

pH with Depth:

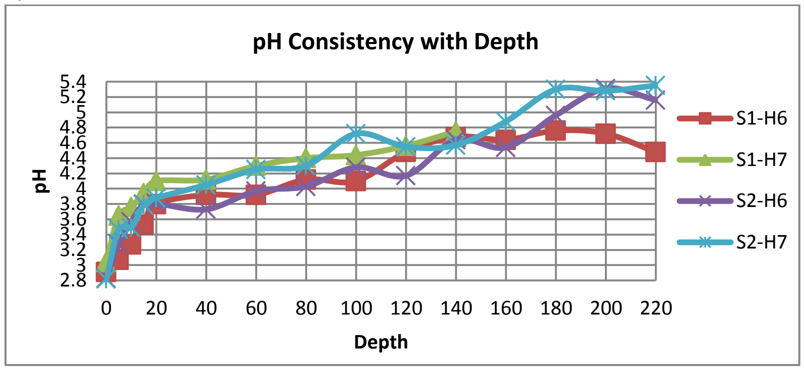
Figure 6: Site 1 at Caleb Smith.

Figure 7: Site 2 at Caleb Smith.

Figure 8: Site 3 at Caleb Smith.

In order to determine whether or not the pH of soil has changed since the work of Wherry (1922) and Greller (1985), three relatively undisturbed, flat forest sites were chosen to take samples: Site 1, Site 2, and Site 3 shown in figures 6-8.

Figure 9: Shows the pH consistency among select holes from Site 1 and Site 2. Depth goes up to 220cm.



For each hole, pH was determined as a function of depth in the three sites. As shown in figures 9-11, the topsoil begins at range of 3 and ends at a range of 4 with a maximum depth of 220cm. As depth increases, pH begins to increase and become less acidic. This demonstrates how far acid rain has already impacted soil in addition to how the topsoil pH has changed over time by looking at depth to see how they were in the past. As shown in the accompanying graphs, acidic rain has affected soil as far as 220 cm (7.2 ft.).

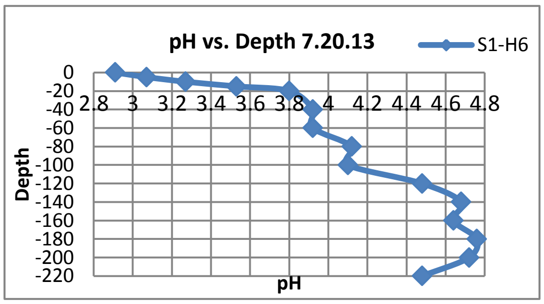


Figure10: Shows the trend when comparing pH with depth up to 220cm at Site 1 taken on 7/20/13.

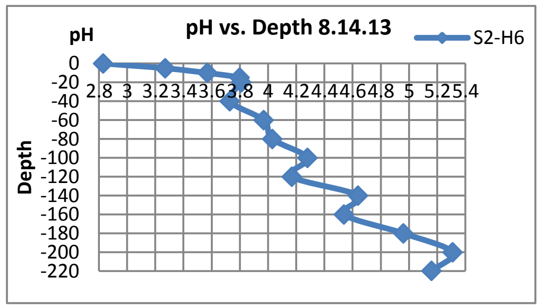


Figure 11: Shows the trend when comparing pH with depth up to 220cm at Site 2 taken on 8/14/13.

Protected Soil:

The fact that pH remains so consistent, but changes when near human interaction, leads to the question of whether an undisturbed building will show a more basic pH and give insight to pre-acid rain conditions. By looking at this, a baseline to what soil pH might have started at would be known, and the current pH of topsoil could be compared.

A boathouse with a roof was tested because the soil was shielded from precipitation over the past 100 years. The other is a corncrib destroyed in Hurricane Sandy in late October of 2012.

Although the corn crib was not standing anymore, the site was interesting to study to determine if a pH change would occur in the limited amount of exposure it had to acid rain.

As shown in table 1, the pH values found at the boat house and corn crib were compared with depth at 2 cm intervals. The boathouse shows a topsoil pH of 4.3, whereas the corncrib shows a surface pH of 5.25. The pH varied slightly within the first 20 cm, however, both fluctuated around a pH of 4. Furthermore, the pH was never below a 3.8, a clear difference from the soil in Sites 1, 2, and 3. Additionally, the corncrib never went below a 4.1, showing that even though it was exposed to the elements for a short period of time, it still has a higher pH than Sites 1, 2, and 3 respectively. Overall, this shows that the protection they received from the buildings helped to protect the soil underneath it. This means the protected soil represents the soil pH from approximately 100 years ago. This shows that soil was, at one point, more basic than it is currently similar to the previous studies.

Table 1: Compares the pH found at the Corncrib and Boathouse.

OLD CORNCRIB		OLD BOAT HOUSE	
Destroyed-Oct 12'		100+ years old	
Depth	pH	Depth	pH
0-2 cm	5.25	0-2 cm	4.28
2-4 cm	5.23	2-4 cm	4.06
4-6 cm	5.11	4-6 cm	3.79
6-8 cm	4.36	6-8 cm	3.78
8-10 cm	4.2	8-10 cm	3.8
15 cm	4.12	15 cm	4.44
20 cm	4.15	20 cm	3.91
40 cm	4.14	40 cm	4.04
60 cm	4.32	60 cm	4.42
80 cm	4.42	80 cm	4.37
100 cm	4.43	100 cm	5.01

Figure 12: 100+ year old Boathouse where undisturbed soil samples were collected.

As we compare this to our current data of forests, we can see the same pH range of 4 throughout. This gives us excellent insight into what pre-acidic conditions on Long Island would have been like. The Boathouse is depicted in figure 12.

Protected soil can provide the basis to when acid rain started and how it has changed. The Corn-crib and Boat-house show less acidic levels even as depth increases. Since the Boat-house and Corn-crib were only taken up to 100 cm, it gives insight to previous acid rain levels. They both start between a pH of 4 or 5 and then stay within this range as depth increases up to 100 cm. The graphs show a 0.2 difference at each interval, demonstrating a relatively small increment of change. If the holes were to be sampled at deeper depths, the pattern would show how the pH of the past was. It is implied that the soil under the structures had relatively secure roofs to prevent rain from getting into it. Both of these sites made it evident that current interaction with acid rain causes soil pH to be between a 4 and 5, but maybe higher if the depth continued. By knowing when the structures were built can help to determine the age of the soil.

Human Interaction:

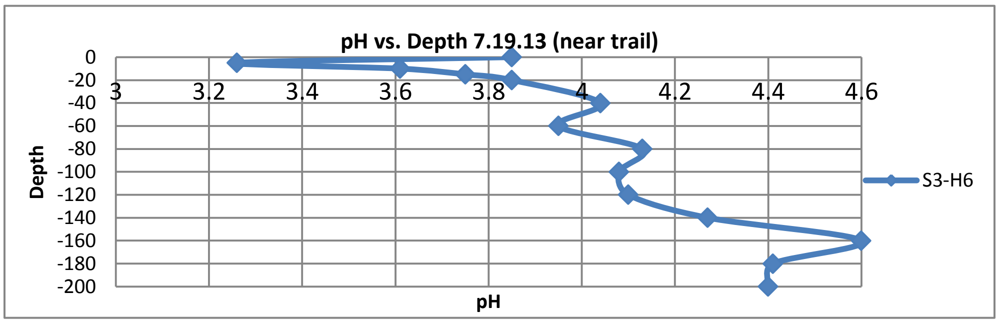


Figure 13: Shows the pH vs. Depth near a trail when human interaction plays a role.

Due to the consistency of pH and depth, a site near a hiking trail was tested to determine if it would have an effect on pH. A hole was sampled about 5-10 ft away from the hiking trail. As shown in figure 13, the surface pH of the soil shows a much higher pH level than the forested areas, even at the depth of 200 cm. In fact, it had a topsoil pH of 3.85 compared to the average topsoil of 3.3 and varied with depth up to 200 cm. This significant difference in soil pH of topsoil, questions the role of human interaction within an environment.

In particular, human interaction affects many aspects of our environment, including soil acidification. For example, at Caleb Smith State Park soil samples were taken near a trail about 5-10 ft. away. This would give a look at how pH values might change because they were in contact. Remarkably, we found that the pH values are very different than those found in the undisturbed forest sites. The topsoil was a 3.8, which is significantly higher different than the topsoil average of 3.3 and with depth, which shows diverse pH values up to 40 and 60 cm.

Wildfires:

The pH levels found in the fire burned areas show a lower pH value than the undisturbed sites. Where we normally see a major jump within the first 20cm in undisturbed sites, there is only a slight jump that occurs here, however. Additionally, from 40-80 cm there is a jump that occurs rapidly in site 2, which was seen in the undisturbed sites as well, but is not present in site 1. The trend shows that pH increases overall with depth. The results are shown in figure 14 and have an average topsoil pH of 3.0: lower than the average topsoil pH of undisturbed sites of 3.3.

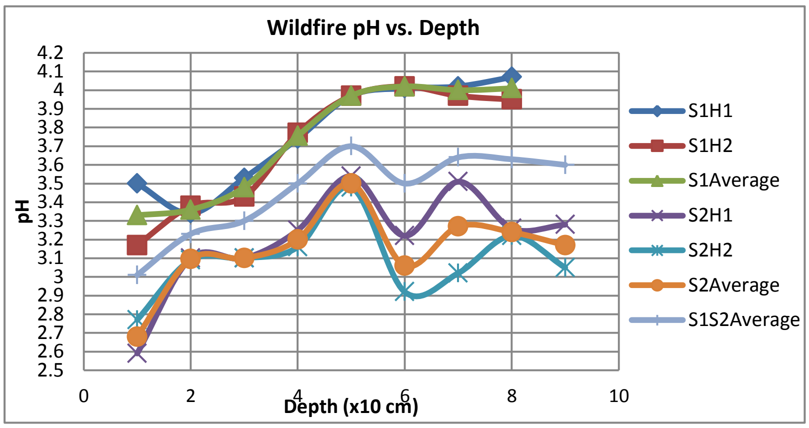


Figure 14: Site 1 of Wildfire affected areas showing the pH among two holes as well as its average up to 80cm.

Figure 15 & 16: Location where samples were collected for wildfire affected sites.

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t is interesting to note changes that occur when a wildfire affects an area. Fires may cause less of a dramatic difference in pH levels than undisturbed sites, but allow for a lower pH value for deeper depths to be present. The limited porosity in the soil as a result of a fire could impact soil pH because acid rain would not infiltrate into the soil as it normally would.

Fires generally increase pH levels to become less acidic because of the elements released (ash, calcium), which contributes to the pH levels that might be found there. This has not been seen by our results, however, because when compared to an undisturbed site, they have a lower pH value as depth increases. It seems to have less of a difference between depths as well. Fires take away the plant layer and the soil is then exposed to the elements more prominently, which might explain the lower pH value found for topsoil: 3.0. However, nutrients become readily available and replenished, so it does not show the exact pH of acid rain, which very well may be lower than 3.0. Also, with depth, the more acidic pH values show what the pH became before, during and after the wildfire occurred: all of which are lower than undisturbed sites which could have been caused by the wildfire's release of more H+ ions which increase soil acidity.

Final Word:

Ultimately, topsoil pH has decreased over time. Human interaction shows that people can affect the pH levels. Undisturbed buildings are good areas to test for pre-acidic soil from many years ago and could provide a baseline for future studies or even compare the pH found as far back as 1922. Lastly, since wildfires show an increase in soil acidity with depth, that wildfires cause a disruption to pH levels by making them more acidic. Overall, acid rain contaminates groundwater, erodes structures, and deteriorates coasts. However, there is a more immediate change in soil throughout Long Island. The continuation of acid rain poses a health threat to plants, animals, and even people (Zipper, 2012). What seems like a little change in the pH of soil is actually much more dangerous to life than we think.

In the future we can infer that the acidic pH levels will have drastic impacts on the environment. The quickly decreasing pH of soil proves how significantly we, as humans, have affected our environment and will continue to impact it. Acid rain may seem like a minor problem, but, in reality, it will only get worse in the future if nothing is changed.

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