Report Template

An Analysis of the Effects of Precipitation on Soil pH

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Abstract

In this experiment, the goal was to find the correlation between soil pH and precipitation. This is in order to show the importance of preserving the environment because global warming is causing increased precipitation. This increase in precipitation causes soil to acidify, hurting the plants. It was hypothesized that an increase in precipitation would decrease the pH because the precipitation replaces basic ions with hydrogen ions that increase acidity. The findings showed that soil pH does decrease with the increase of precipitation. We used provided materials such as pH test strips, laser thermometer, test tubes, and other lab equipment. In conclusion, the effect of precipitation is apparent in relation to soil pH.

Introduction

The Effects of Precipitation on Soil pH

The agricultural industry, one of the most important industries on the planet, is expected to be feeding 10 billion people by the year 2050 (*Agriculture and Food*, n.d.). However, global warming and climate change threaten to damage this vital industry. Specifically, global warming is causing a rise in precipitation above the historical record, which in many ways can damage soil and harm plant growth. The experiment intends to explore the effects of precipitation on soil pH.

In recent years, global warming has become an increasingly public and concerning problem on the world scale. We chose this topic of study in order to better understand how global warming is affecting the world. For example, in comparison to the average temperature during the early and mid-1900s, the average temperature in the Great Lakes region has increased 0.83℃, with much of that occurring in the last decade (*Great Lakes*, 2024). Future projections predict this number to be anywhere between 1.9℃ and 3.6℃ by 2050 (*Great Lakes*, 2024). By the end of the century, the temperature is expected to increase even more in the Great Lakes region. This could prove detrimental to the lakes, which are one of the world's largest reservoirs of freshwater. The Great Lakes region is also home to a large population of people and vital farmland for the country's agricultural production. It is important to find out how global warming is affecting the area so that further measures can be taken to preserve it.

Along with temperature, precipitation has increased significantly in the Great Lakes region compared to other regions. Between 1958 and 2016, every northeastern state experienced at least a 40% increase in extreme precipitation events (*Great Lakes*, 2024). In another study, it was found that the percentage of the country facing extreme single-day precipitation events was increasing at an average rate of 0.5% per decade since 1910 (*Climate Change Indicators Heavy Precipitation*, 2025). With a general increase in precipitation over time, it is important to learn how this affects our world.

An example of such effects would be on soil pH. The potential of hydrogen or pH of a substance is the measurement of hydrogen ion concentration produced by the substance itself

(Soil pH, n.d.). This is important as the pH range for optimal plant growth is between 6.0 and 7.0, which is considered a neutral pH (*Soil Acidity*, 2024). Soil is a mixture of many substances that work together and affect the soil pH, water from rainfall being a major component. Water from precipitation combines with carbon dioxide, forming a weak acid known as carbonic acid (Soil pH, n.d.). This acid releases hydrogen ions into the soil, decreasing pH levels and increasing the acidity of the soil. An acid subsoil, soil found about a foot from the surface, can be toxic to the plants when it has a pH lower than 5. This happens because the low pH increases aluminum and magnesium solubility, which when absorbed harms plant growth (Soil pH, n.d.). This lowers the overall crop yield, harming the food supply.

Today, there are about 2 billion people facing some sort of food insecurity (*Agriculture and Food*, n.d.). This impact from global warming can further cut crop yield. This means a backward progress towards ending world hunger. Fortunately, there is a way to control the pH levels in farm soil. This is done by using a method called liming, adding lime to the soil, which increases the pH level and gives some nutrients to the plant. However, this process could take 1-2 years to do and could be affected negatively by the amount of rainfall, which can reduce its effect (*Soil Acidity*, 2024).

The best way to counteract acidic soil pH is by removing excess precipitation. If there is an increase in precipitation, then the pH will decrease because the precipitation replaces basic ions with hydrogen ions that increase acidity. Excessive precipitation issues can be prevented by slowing and reversing climate change. Otherwise, the agricultural industry could be in danger. This would affect many more people’s food supply and would reduce the chance of solving world hunger within the next decades.

Methods and Materials

Materials:

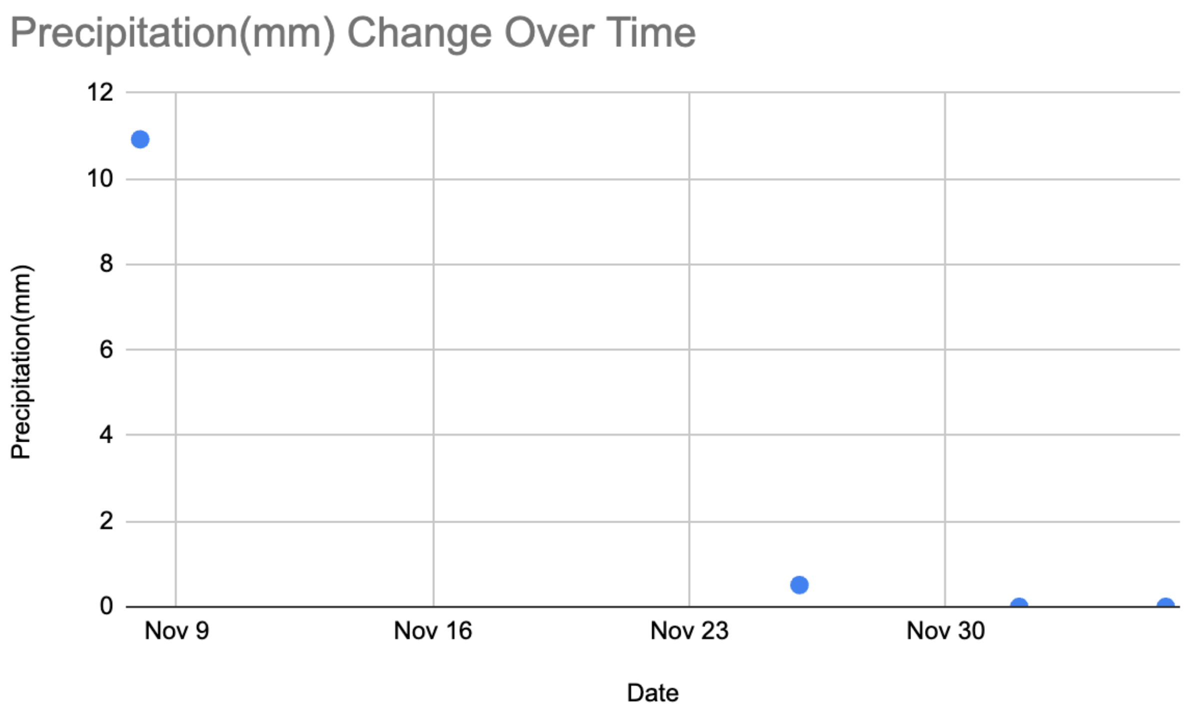
- Etekcity Infrared Laser Thermometer
- Test tubes
- Styrofoam cup for each soil sample (3 total containers)
- A pencil (to label the test tubes and styrofoam cup)
- Tape
- Test tube rack
- Clean water (from the sink)
- pH test papers (Hydrion test papers)
- Soil from 3 different places
- A shovel to dig the soil

Procedure:

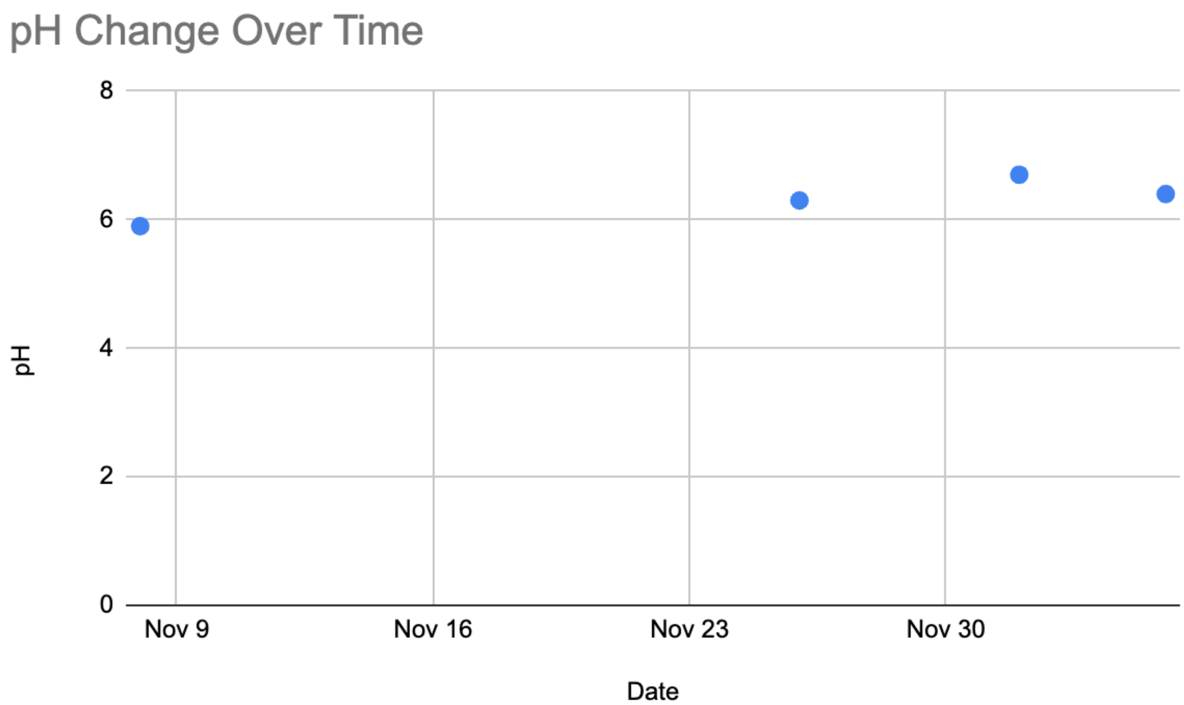
First, label three styrofoam cups with sample numbers. Then, bring the styrofoam cups, a shovel, and the infrared thermometer outside. Find three separate areas with exposed soil for sampling. Using the shovel, remove approximately 5 grams of soil and place in the cup. Next, measure and record the temperature of the soil area using the Etekcity infrared thermometer, holding it approximately 10 centimeters from the ground. Repeat the previous soil sampling and temperature recording steps for the other two test sites. When back inside, mix distilled water with the soil in a 1 to 1 ratio of grams to milliliters. Mix for 3 minutes in periods of 30 seconds mixing and 30 seconds resting. Dip a pH test strip in the soil-water mixture, then place on a paper towel. Label each pH test strip to correspond with the styrofoam cup's number. Compare the color of the test strip with the pH container to determine the pH of the soil-water mixture, then record the value. Repeat this process until you do all 3 samples. Next, using the website wunderground.com, record the amount of precipitation in millimeters for the previous 48 hours. Repeat the previous steps for three more sampling dates. Make sure to keep the three test sites consistent for each sampling date.

This should be done for a total of 4 trials or N = 4. Each trial would have 3 samples for a total of 12 data points for soil temperature and 12 data points for soil pH. The project's trials were conducted on November 8th, November 26th, December 2nd, and December 6th and on those were the dates used for the recording of precipitation.

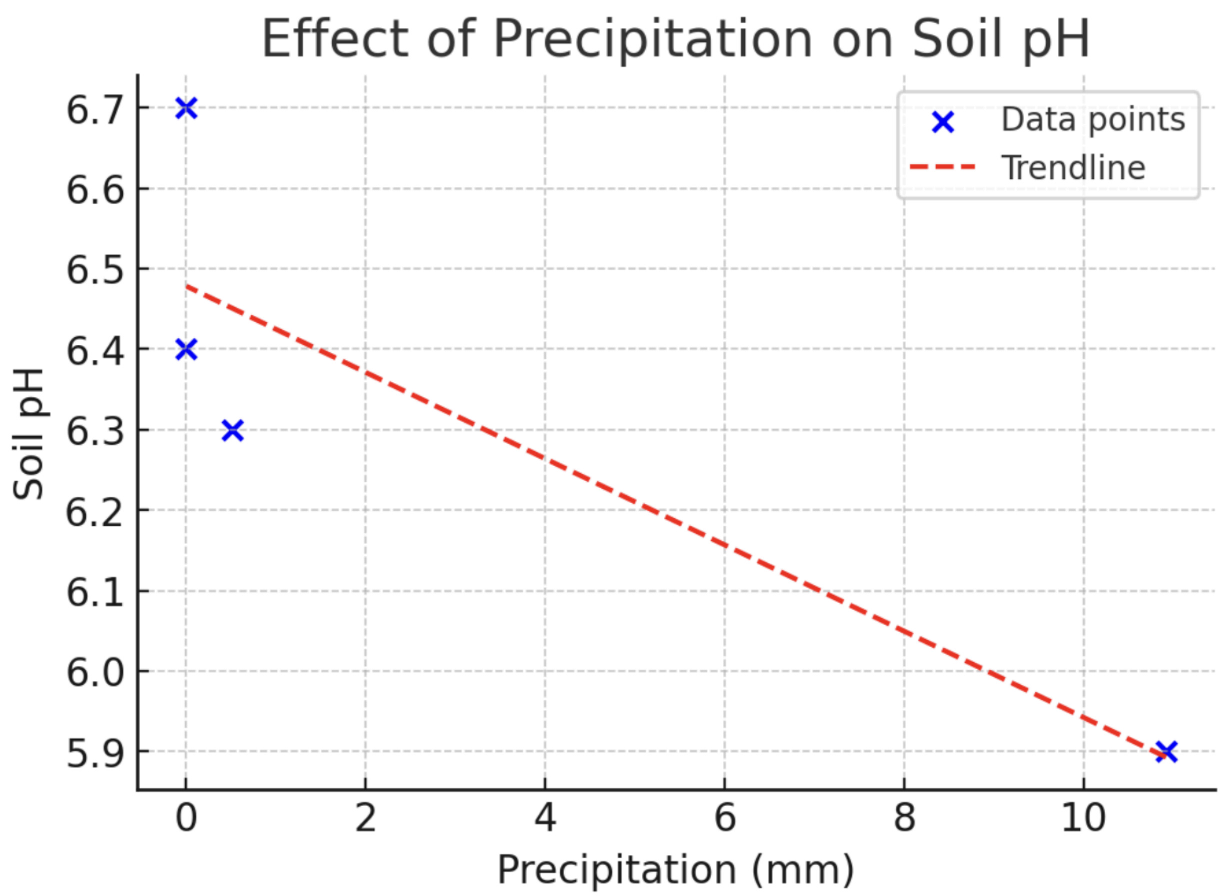
Presentation of Data and Results



Data points for the trend of precipitation over time.



Data points for the trend of average measured soil pH over time.



Effect of precipitation on soil pH with a trend line.

By comparing the two graphs, we can see that at 0 precipitation the pH of the soil was between 6.2 and 6.8, with all data points landing in this range. At 0.51mm precipitation, the pH of the soil generally dropped to an average pH of 6.3. At 10.92mm of precipitation, the pH averaged 5.9, ranging between 5.8 and 6.0. The relatively small change between 0mm and 0.51mm showed no significant change. However, when the precipitation was greater than 10mm, the change in pH became more significant. Comparing the two graphs, one can see that while there is a significant decrease in precipitation, the pH had a slight increase.

Analysis and Results

This study suggests that precipitation does have an effect on soil pH, causing the pH to decrease as precipitation increases. Referring to the data with the trend line, it can be seen that when there was an increase in precipitation there was an overall decrease in soil pH. The trend line was calculated using the line equation $y = mx + b$. The slope m was found using the formula, $m = \Sigma[(x_i - \text{mean}(x)) \cdot (y_i - \text{mean}(y))] / \Sigma[(x_i - \text{mean}(x))^2]$. Where the sum of the difference between each x point (precipitation) and the mean(x) multiplied by each y(soil pH) point minus the mean(y) added together. For this data the sum is about -4.66. This goes over the sum of the difference of each x point (precipitation) and the mean(x). For this data the sum is roughly 86.85. Dividing -4.66 by 86.85 gives the slope of -0.054. Then the b is calculated by using the equation of $b = \text{mean}(y) - m(\text{slope}) \cdot \text{mean}(x)$. This gives a y-intercept of 6.5, so the overall equation for the trend line is $y = -0.054x + 6.5$. This represents the correlation between precipitation and soil pH. The data also shows that the lowest pH was corresponding with the highest precipitation. Following this trend, the second highest precipitation yielded one of the lower values of pH. However, there is an outlier that could indicate other variables that affect the pH, since at 0 precipitation there was a noticeable change in soil pH. Using the data, we calculated the Pearson correlation coefficient using the equation $r = [n(\Sigma xy) - \Sigma x \Sigma y] / \sqrt{[n(\Sigma x^2) - (\Sigma x)^2][n(\Sigma y^2) - (\Sigma y)^2]}$. This equation uses the soil pH and precipitation values to assign a value of correlation, with 1 being perfect positive correlation and -1 being perfect negative correlation. This value was equal to approximately -0.8362, implying an inverse correlation as we already observed from the data. We then used this value to calculate a p-value to find the significance of the data in the form of a t-distribution, using the equation $t = r\sqrt{(n-2)}/\sqrt{(1-r^2)}$.

The value for t was approximately -2.15, which, when compared to a t-distribution chart, gave a value of slightly less than 0.10. This means that the overall significance of our data is between 90% and 95% confidence. In the hypothesis, it was predicted that soil pH would fall as precipitation increased. In the end, this was supported by the data. The data also fits well with the expected values and other previously published studies. This is likely due to the fact that rain water usually carries dissolved carbon dioxide, which reacts with water in the soil to form carbonic acid. Carbonic acid is a weak acid that releases hydrogen ions, thus acidifying the soil. The experiment could be improved in the future by taking more data points, as well as by taking several samples of soil at each location in order to obtain accurate results of the pH of soil. While it could be improved in the future, the experiment accurately tested the hypothesis by finding the pH and precipitation on various days and comparing this data.

Conclusion

The experiment aimed to find the relationship between precipitation and soil pH by recording the pH of soil in three locations and the amount of precipitation encountered in the previous 48 hours. This was done over four days between November and December. This resulted in a trend that supported the hypothesis, claiming that soil pH and precipitation would have an inverse relationship. There may be a common misconception that precipitation would neutralize the soil, due to the neutral pH of distilled water. However, rainwater is not perfectly distilled, and contains components like dissolved carbon dioxide, which can acidify the soil. Research performed before the experiment allowed us to set theoretical values and a hypothesis that was different from this misconception.

Discussion

This project can be improved by collecting more data. Currently there are a total of 9 data points. 1 data point per location, totaling 3 data points per day for only 3 days. An improvement would be taking more data points per location and having overall more locations to collect samples from. These data points can also be collected over more days, with an emphasis on days with varying precipitation measures, in order to better verify the presence of a trend in the data. These findings are very impactful to the world since plants need a more neutral soil pH in order to grow optimally. However, due to climate change, there is an increase in precipitation, which according to our data is decreasing the soil pH and affecting plant growth.

Acknowledgments

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