Examining the Differences in pH Along the Elevation of the University of Houston Green Roof

Vuong Vu[1] | Michael Iacampo[1] | Asfand Moosa[1] | Hussein Hoballah[1]
[1]Department of Biology and Biochemistry, University of Houston

---

Abstract

Soil pH plays a critical role in ecosystem health, it influences plant fertility by controlling the solubility of nutrients, and microbial activity by soil acidification. Most plants can survive in a pH range of 5.2 to 8.0, though some plants have a narrower pH range than others when it comes to survivability. This means soil pH variation across an area can act as a determinant as to what and where specific plant species achieve optimal growth. Given this fact, and the general importance of pH, this study was devised to look at how the unique properties of green roofs, like slope and elevation, affect soil pH. Trend predictions were made based on three mechanisms, these are soil leaching of basic cations, soil acidification by decomposition, and wind erosion. Exploring these mechanisms, we predicted soil at the bottom of the roof would be more acidic than the top, and soil on the northwest side of the roof would be more acidic than the southeast side. Soil was collected from the University of Houston green roof along four elevation points across seven soil plots. Next, PH was measured using a PASCO pH probe and its accompanying SPARKvue app. Soil was then examined for differences in pH along the elevation and across the plots of the green roof. A statistical analysis was done in which a paired t-test was performed to determine whether a difference was seen within the means of the groups. A statistical significance was not observed throughout the green roof.

Keywords: Green roof, Elevation, Soil pH, Wind Erosion,

Introduction

Soil pH is a crucial aspect of ecosystem health. One prime example of this is the effect soil pH has on nutrient availability. The pH of soil directly controls the solubility of many nutrients in soil water thus affecting their availability to plants. (Ferrarezi et al. 2022). Another example is the effect it has on microbial activity. Sullivan (2017) discusses how diverse and beneficial microbial populations are harmed by soil acidification. As one might guess, given these reasons, soil pH is very important to farmers, gardeners, and those who wish to see healthy plants. These reasons are also what prompted this study of the soil pH on the UH green roof. As illustrated by Lake (2000), some nutrients are much more affected by fluctuations in soil pH than others; phosphorus–for instance–is much more sensitive to alkaline pH values compared to that of potassium or sulfur. Lake (2000) also talks about the optimal range for most agricultural plants being 5.2 to 8.0, but with some degree of variation between species. This is of particular importance in this study because if large differences in pH are found on the green roof they can either be corrected or can be utilized to ensure optimal environments for different plant species.

Is there a difference in the soil pH across the UH green roof? This is the question this study attempted to answer. Three main mechanisms are used to determine whether there could be a difference in soil pH on the UH green roof. The first is soil acidification by decomposing organic matter. Zhang (2017) stated that decaying organic matter produces H^+ which is responsible for acidity. The second is leaching. Neina (2019) talks about how the leaching of basic cations such as Ca, Mg, K, and Na, acidifies soil, leaving H^+ and Al^{3+} ions behind. The final mechanism is wind erosion. Zhao et al. (2006) discusses how soil pH increased in eroded areas, with the pH in severely eroded sites being significantly higher than that of control sites.

Applying our 3 mechanisms to the green roof we can make predictions as to how they might affect soil pH. For instance, looking at soil acidification by decomposing organic matter we can easily assume that the slope of the roof combined with rainfall will carry decaying organic matter down the roof. This supports a pH gradient with the bottom of the roof being more acidic and the top being more basic. Examining the mechanism of leaching we see that basic cations are removed from the soil and replaced with acidic cations H^+ and Al^{3+}. If we assume these basic cations are being carried and deposited near the bottom of the roof, this mechanism supports a pH gradient in the opposite direction. Clearly, these mechanisms support opposing pH trends but leaching being a little more unclear, we believed decomposition to be the major mechanism acting on the roof. This allowed us to predict soil at the bottom of the roof would be the most acidic and soil at the top of the roof would be the most alkaline.

Unlike leaching and decomposing organic matter, we expected wind erosion to mainly affect the pH across the length of the roof and not the elevation. This is because the amount of wind erosion is only affected by how much wind is received by the soil. Given that the green roof is aligned with the predominant southeast wind direction in Houston it is easy to predict the effects. Understanding that soil pH increases in eroded areas, we were able to predict that the southeast plot would be the most alkaline with plots trending more acidic as you move away.

Methods

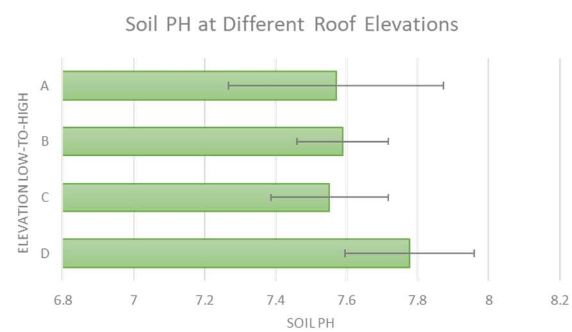
The study required the use of soil that was collected from the University of Houston's green roof located on top of the Burdette Keeland, Jr. Design Exploration Center. Specifically, soil samples were collected from 8.9 cm deep in depth across seven plots along four different elevation intervals from each plot. Each soil sample was collected into a pre-labeled plastic bag with a total of 28 samples collected. After collecting the soil samples, milli-Q water was added to the samples in a one-to-one weight ratio; that is, for every gram of soil, one mL of milli-Q water was added to the soil sample. After the addition of the water, the soil was allowed to sit for one hour. A pH probe was used in order to measure the pH values of each soil and water mixture using Sparkvue, an application that allows access to the PASCO pH meter. After collecting the pH measure for each soil and water mixture, distilled water was used to rinse the tip of the probe, which was then placed back into a pH buffer of 4. An analysis was done in order to understand whether or not there was a true mean difference among the elevation of the green roof.

Statistical Analysis

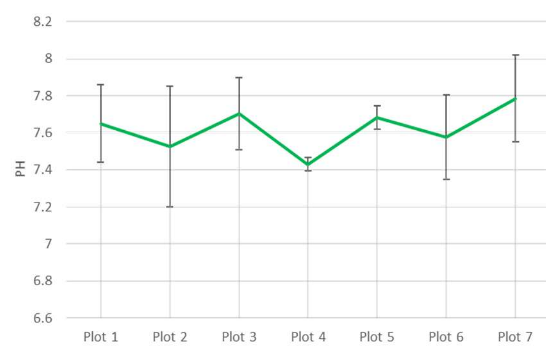
A paired t-test was used in order to determine the degree of significance for the study as this study is interested in whether or not there is a mean change significantly different from zero. Two paired t-tests were performed: the first test was used to examine the difference between the pH and the elevation, and the second test was used to examine the difference between the pH across the green roof. An alpha level of 0.05 was used to determine the baseline of significance

Results

Graph 1 of the soil pH in comparison to the different roof elevations showed that there seems to be no noticeable difference. The data showed that all pH measurements along the elevations were within 1 pH of each other with a high standard error and low variation. The graph of the soil pH across the plots of the green roof showed that there was no observable trend in pH with low variation in pH across the plots, though all data points were still within one pH. A paired t-test was performed in order to understand whether or not there was a difference in group means between the elevations and between the plots of the green roof.



Graph 1. Soil pH at four different roof elevations, labeled A, B, C, and D, with pH on the x-axis. Elevation D recorded the highest pH and elevation C recorded the lowest.



Graph 2. Soil pH across the green roof, labeled plots 1 through 7 with pH on the y-axis. Plot 7 is the highest pH, and plot 4 is the lowest

DIFFERENCE ACROSS	p must be <0.05
Plot 1 compared to Plot 2	p = .2714
Plot 1 compared to Plot 3	p = .5278
Plot 1 compared to Plot 4	p = .1112
Plot 1 compared to Plot 5	p = .7878
Plot 1 compared to Plot 6	p = .6974
Plot 1 compared to Plot 7	p = .3831

ELEVATION	p must be <0.05
Elevation A compared to Elevation D	p = 0.1469
Elevation A compared to Elevation B	p= 0.8838
Elevation A compared to Elevation C	p= 0.8891

No Difference Found

No statistically significant trends in soil pH were found on the green roof. Data was based on high external validity

Table 1. Statistical result of pH across the plots and statistical result of pH along the elevations

Discussion

Though the statistical analysis of the study suggested that there is no difference in pH along the elevations and across the plots, it can be suggested that due to the functionality of the University of Houston's green roof, the probability of soil erosion is minimal. Thus, it can be said that due to the improbability of soil erosion on the green roof, this is a potential explaining factor as to why there was no difference in pH across the plots. In terms of the elevation of the green roof, water that gets rained down from the top to the bottom gets distributed into the runoff channels, leading the water off of the green roof. As a result, there is no accumulation of soil and nutrients at the bottom end of the elevation, potentially explaining the no difference of means in the green roof elevation.

Limitations

Some limitations of the study included small area, which resulted in the pH being buffered by natural systems in addition to the soil containing small rocks for certain areas; measuring equipment, which may have resulted in inaccurate data collection as low precision equipment causes an unlikelihood to detect trends in a green roof; time, as only approximately two weeks were given for data collection; and low internal validity, but high external validity, which prevented the use of measuring the different factors that could have affected and influenced pH readings. Furthermore, a low sample size could have significantly impacted our t-test which may have prevented our p-values to have an actual significance factor as a sample of size of 30 or above ensures adequate assumptions that our sample size is infinitely large, which serves as a factor for determining level and degree of significance.

Future Implications

Some suggestions for future studies include doing a longitudinal study to examine the influences in pH across different seasons and doing experimental studies in a laboratory setting in order to examine the effects of pH along the elevation and across the plot more accurately and precisely. More precisely, experiments that attempt to explain the differences in pH should be done in a mutually exclusive manner. That is, examining the difference in pH along the elevation should be done separate from that of the horizontal difference in pH. In terms of elevation, water can be used as a way to imitate rainfall, and using a fan or some other source that imitates wind can be used as a way to examine the difference in pH due to potential wind erosion of soil. Additionally, examining multiple green roofs provides a baseline as to the potential of a difference in pH. Lastly, having a higher sample size from each green roof allows for a better understanding of degree of significance. Having a larger surface area of a roof allows for an adequate understanding of how general field factors influence pH change. Perhaps, examining the soil pH of an elevation and a horizontal roof also allows for an understanding of the baseline of pH differences as well.

Acknowledgments
Soil was collected and examined from the Burdette Keeland, Jr. Design Exploration Center from the Architecture Department at the University of Houston. The probes to measure the pH of the mixture and the software used to connect to the pH probe was from PASCO scientific equipment.

Literature Cited

Ferrarezi, R. S., X. Lin, A. C. Gonzalez Neira, F. Tabay Zambon, H. Hu, X. Wang, J.-H. Huang, and G. Fan. 2022, April 4. Substrate ph influences the nutrient absorption and rhizosphere microbiome of huanglongbing-affected grapefruit plants. Frontiers in Plant Science: Section Plant nutrition 13: 1-7https://www.frontiersin.org/articles/10.3389/fpls.2022.856937/full.

Lake, B. 2000. Understanding pH. https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/167187/soil-ph.pdf. NSW Agriculture: Acid Soil Action 2:1-4

Neina, D. 2019, November 3. The role of soil pH in plant nutrition and soil remediation. Hindawi: Review Article 2 https://www.hindawi.com/journals/aess/2019/5794869/. 2019:2-9

Sullivan, T. 2017. Soil Acidity Impacts Beneficial Soil Microorganisms. WSU Extension: Pullman, Washington. http://pubs.cahnrs.wsu.edu/publications/wpcontent/uploads/sites/2/publications/FS247E.pdf (2/1/2023)

Zhao, H., Yi, X., Zhou, R., Zhao, X., Zhang, T., and Drake, S. 2005, Wind erosion and sand accumulation effects on soil properties in Horqin Sandy Farmland, Inner Mongolia. ScienceDirect [doi:10.1016/j.catena.2005.10.001]