The Effect of Leaching on Iron Levels in Soil

By: Julianne Payne, Allie Barnes, Melissa Goldman and Emily McWilliams

Abstract:

An increase in the percentage of water in the soil should greatly but indirectly affect the iron levels. Increasing the ratio of water to soil causes the pH to increase and the amount of iron to decrease. We hypothesized that by manipulating the amount of water in the soil we could alter the iron levels by leeching. We took 6 samples a day; one from the plot in the floodplain, and 1 from each of the 5 plots on dry land. Each day we added water in increments of 2 liters after taking 15 centimeter by 2 ½ centimeter diameter soil samples. After calculating the percentage of water in each soil sample and conducting chemical tests for both iron and pH, our results showed that our hypothesis was valid because as we progressively added the respective amounts water the iron levels seemed to drop correspondingly. Additional research on leeching activity should be done at our research site to determine if the stream at the research site is the cause of the leeching.

Introduction:

Iron is a very significant and essential element in the environment and is identifiable in the soil by its rusty red or orange color (O'Reilly, 2002. While only about five percent remains on the Earth's outer layer, it is essential to almost every living thing for various reasons (Lenntech Water Purification and Air Treatment Holding BV, 2006) Its ferrous iron form is essential to plant growth because it is essential in the production of chlorophyll, which in turn is significant because it is necessary for photosynthesis. (K State Research, 2003). However, the most plentiful form of iron in the soil is ferric iron, and ferric iron compounds cannot be absorbed by the roots. The pH of soil determines which form of iron is present, with ferrous iron available in acidic soil and ferric iron available in basic soils. Hence as the soils pH rises, plants must struggle and generally do not succeed in using the iron as effectively. Zinc, pH, Phosphate, Copper and Manganese are also all very influential in dictating the various iron amounts (Plank and Lee, 1989). But pH is the dominant factor. As soil pH increases the ferrous iron becomes ferric iron.

One key factor that influences soil pH, and consequently iron levels is the process of leaching. Leaching is the process of washing away nutrients and other dissolvable substances from soil by adding large amounts of water to the soil. The factors that influence leaching are temperature, the setting, and the solvent. Temperature influences leaching because it allows for materials to dissolve at different rates. The setting influences leaching because the environment varies based on it's features. In nature, the features of an environment that vary when leaching are the soil texture and the plants. Based on how dense the soil, the water would absorb at a different rate. Depending on the types of plants and the amount of plants in an area, it could effect how fast the water is absorbed. The solvent that you use when leaching is an influence because different liquids and solids dissolve things at different rates. Water is usually the main solvent in the leaching of soil. Since water obviously influences the pH of the soil environment, leaching can alter soil pH, which in turn determines the amount of iron available. So as we increased water, the pH should increase, decreasing the amount of iron.

During the E.S.S.R.E. biota survey (E.S.S.R.E. 2007) we discovered that the relationship between iron and pH in Site 4 was inconsistent with what it should be. The pH levels were found to be neutral while the iron levels were extremely high. Therefore, we wondered why it was that this relationship could occur, and further research led us to the theory that it was the water from a surrounding stream that washed the excess iron into the site. We decided to test this hypothesis by deliberately leaching soil plots where the correct pH and iron relationship was being observed.

Methods:

6 soil core samples 15cm deep with a diameter of 2.5cm were taken from 6 different ½ m² plots located in E.S.S.R.E. Microclimate Site 2 (N 39.35740; W 076.63893) and 4 (N 39.35733; W 076.63840). These plots were square-shaped and on flat ground, with equal amounts of shade, common plants and life. Five of these plots

were conjoined and located in Site 2; one plot was in Site 4 and served as a positive control because of its known high iron levels (E.S.S.R.E. Microclimate Databases 2007). The first plot in Site 2 served as the negative control and was left unaltered. The next four plots in Site 2 had water from a nearby creek progressively added in increments of two liters (2L, 4L, 6L and 8L respectively). Over the course of five days, these plots were re-visited daily to take additional soil core samples before adding the assigned amounts of water to the respective plots.

Each sample was first tested for its iron levels in ppm and pH levels using the LaMotte STH-14 Series soil test kit. Then each sample was massed, baked at 232.22˚C for a minimum of 1 hour, and then the dehydrated soil was massed again. The percent change in mass of the soil was determined to find the proportionate amount of water in each soil sample.

Results:

Figure 1: this graph shows the average change in iron levels for each of the plots

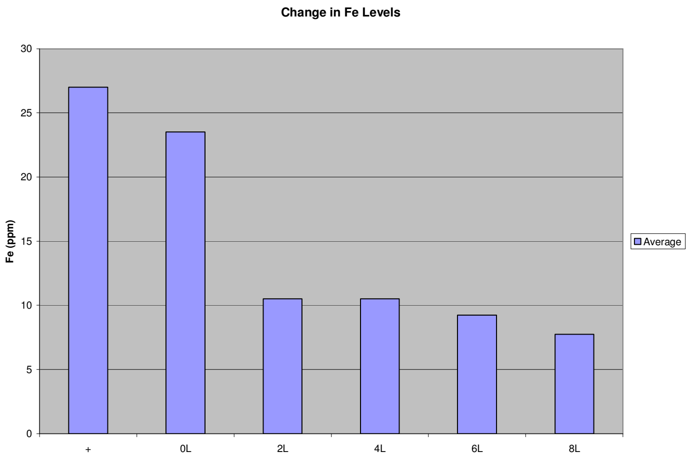


Figure 2: this graph shows the amount of water in the soil samples taken at each plot for each of the five days

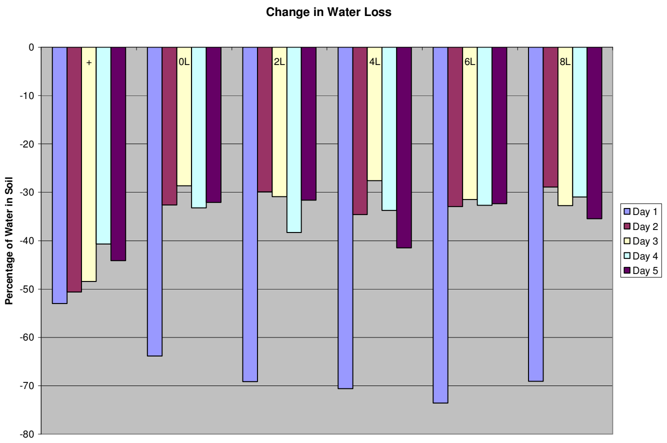


Figure 3: this graph shows the average amount of water in the soil samples for each of the plots

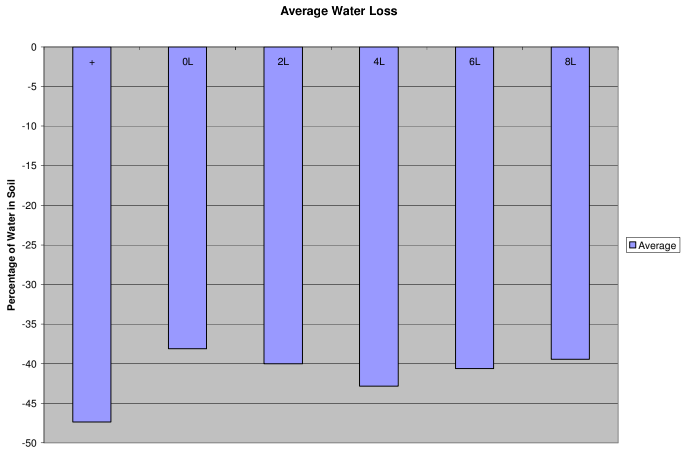


Figure 4: This scatter plot shows the relationship between the percentage of water in the soil samples to the iron levels found in those same samples before our experiment was begun (r-squared = 0.41363)

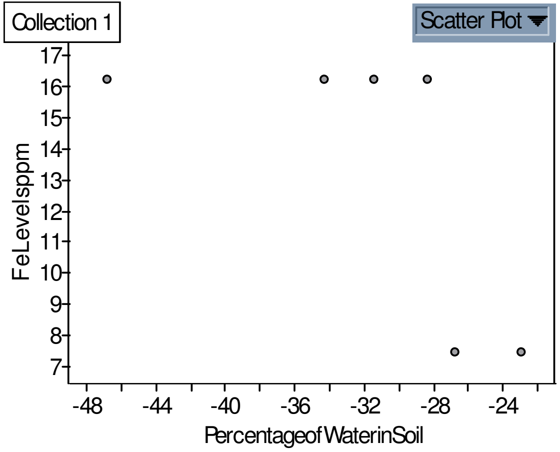


Figure 5: this scatter plot shows the relationship between the percentage of water in the soil sampled to the iron levels in those same samples after our experiment was completed (r-squared = 0.014862)

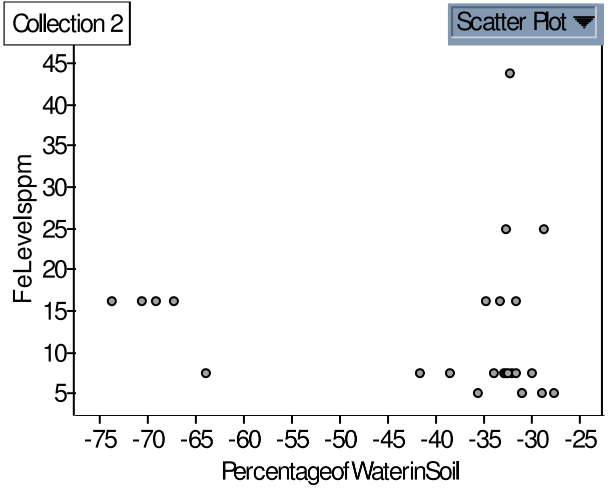


Figure 6: this graph shows the changes in pH levels at each plot for each of the five days

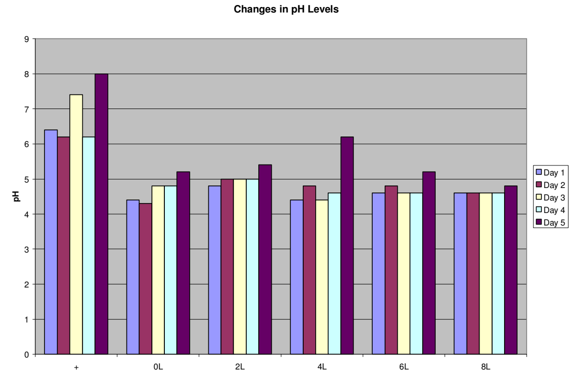
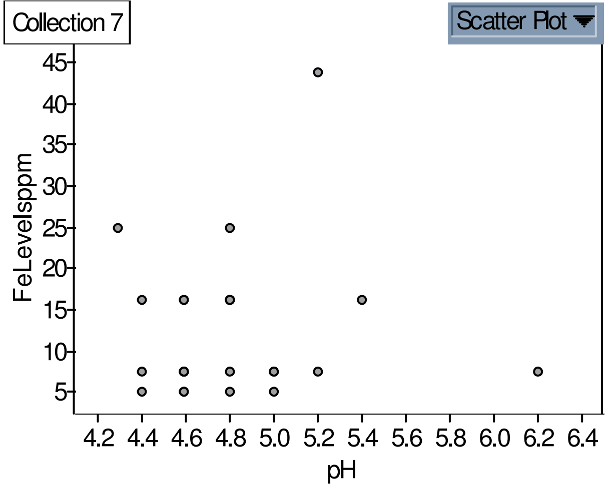


Figure 7: this scatter plot shows the relationship between pH and iron after our experiment was completed (r-squared = 0.0034493)



Discussion:

We hypothesized that by leaching iron rich soil with water we could decrease the amount of iron in the soil. What we found was that the iron levels did in fact decrease as additional amounts of water were added (see figure 1), thereby supporting the validity of our hypothesis. However, other data (see figure 2) seems to indicate that we did not successfully alter the percentage of water in the soil in the first place, thus potentially disproving our hypothesis and suggesting that perhaps there was another factor influencing the iron levels. After t-testing the date from the water plots against the negative control data, we were able to discount the trend this data implies since the lack of statistical significance neither supports nor refutes our hypothesis one way or the other. Instead, a careful analysis of the daily water data (see figure 3), shows that the percentage of water remaining in the soil increased as expected on trial day 1 and that after day 1 any further additional water on the plots resulted in a consistent level of saturation. This reasonably consistent range of saturation implies that after the water was added on the first day, the soil had reached its maximum capacity for retaining water, and as a consequence any additional water simply leached the soil columns more and more.

Furthermore, upon examining and comparing figures 4 and 5, we can see that in figure 4 the relationship between the water and iron follow their natural correlation while in figure 5, (post experiment), the normal trend is absent. This means that although after day 1 we no longer changed the amount of water in the soil, we did continue to effectively alter the natural relationship between water and iron. One possible explanation for the changed relationship could be that the water is affecting the pH and thereby altering the iron levels. However, as seen in figures 6 and 7, the pH levels were not changing during the experiment and the usual relationship between pH and iron were not observed at all. Therefore, our original supposition that it was the water causing the changes in iron levels remains the only possible explanation supported by our data.

The next logical step would be to test the iron levels at various points along the stream to see if there is a pattern to the locations where leaching is occurring. In addition, research done by another team in the E.S.S.R.E. 2007 Program (E.S.S.R.E. 2007) showed a relationship between mold and iron levels in the soil. Since water is known to cause high mold levels, we should look at that relationship as well as a possible cause for the decreasing iron levels.

Acknowledgements:

We'd like to especially thank our sponsors, SeaWorld Busch Gardens Fuji Film Environmental Excellence Award Program, and Human Capital Development, Inc. Without their generous funding, our experiment would not have been possible. Also, we would like to thank Roland Park Country School; thank you so much for allowing us to use your Backwoods and classroom lab. This was a great learning experience and we will treasure it forever!

References:

1. E.S.S.R.E. Microclimate Databases. August 2006. "Environmental Science Summer Research Experience for Young Women". <https://faculty.rpcs.org/essre/2007/ESSRE%202007%20Files/2007%20Entire%20site%204%20Data.htm>
2. E.S.S.R.E. Microclimate Databases. July 2007. "Environmental Science Summer Research Experience for Young Women." <https://faculty.rpcs.org/essre/2007>
3. Guernot, M and Robinson, N. "Researchers Isolate Gene That Helps Plants Take Iron From Soil". Dartmouth News, February 1999. [Available Online] <http://www.dartmouth.edu/~news/releases/1999/feb99/iron.html>
4. Kluepfel, Marjan and Lippert, Bob. "Changing the pH of Your Soil". <http://hgic.clemson.edu/factsheets/HGIC1650.htm>

5. Lenntech Water Purification and Air Treatment Holding BV. "Iron-FE". Lenntech Water Purification and Air Treatment Holding B.V.,2006. [Available Online]<http://www.lenntech.com/Periodic-chart-elements/Fe-en.htm>
6. Murray R. and Tedrow J. September 5, 2001. "Secrets Hidden In Soil" <http://soil.gsfc.nasa.gov/forengeo/secret.htm>
7. O'Reilly, S. "Iron-rich Soil can Help Remove Lead; Manganese Also Important". Virginia Tech, April 2002. [Available Online]<http://www.scienceblog.com/community/older/2002/A/20027034.html>
8. Plank, C and Lee, D. "Possible Causes for Plant Nutrient Levels Below or Above the Sufficient Range". College of Agricultural and Environmental Science , 1989. [Available Online]<http://www.cropsoil.uga.edu/~oplank/diagnostics70/Causes/causes.html >
9. The University of Georgia College of Agriculture and Environmental Sciences. "Possible causes for plant nutrient levels below or above the sufficiency range". <http://www.cropsoil.uga.edu/~oplank/diagnostics70/Causes/causes.html>
10. Trulove, S. "Iron-rich Soil Can Help Remove Lead; Manganese Also Important". Science from Virginia Tech, August 2002. [Available Online] <http://www.research.vt.edu/resmag/sciencecol/iron.html>
11. Winter. "Iron Deficiency". 2004, [Available Online] <http://web.missouri.edu/~umcsnrsoilwww/313_W2004/fe1_2004.htm>