Relationships of Soil Nutrients with Slope and Land Usage in Dairy Pastures

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Hypothesis: The lower slope areas will show higher amounts of nutrient pooling, higher CEC and a lower pH, as well as the areas that have had animals grazing on them, opposed to the fields that have just been used for harvesting.

Photo 1: This picture shows the entire layout of the dairy farm. The three pastures were labeled and the plots were marked on the map. This shows the distance from the dairy farm located just in front of Pasture 1. This picture also shows some cows in pasture 1 as usual and the harvesting lines from the harvester in pastures 2 and 3.

Introduction: Hillside Farms has been a dairy farm for the past few decades, it has supported cows on and off for the past several decades as it has changed ownership. It has also been come a host for chickens and a mobile chicken tractor as they are free range chickens. There have been three fields that have been used mostly by the livestock. The one closest to the barn has seen the most action as a grazing pasture over the past several decades. The second field has been used mostly for hay and now for the mobile chicken coop on the lower third of the field. The third field has been solely used for hay harvesting. We are looking to see the spread of nutrients on the fields and how the slope and previous history of the lands has contributed to the soil quality.

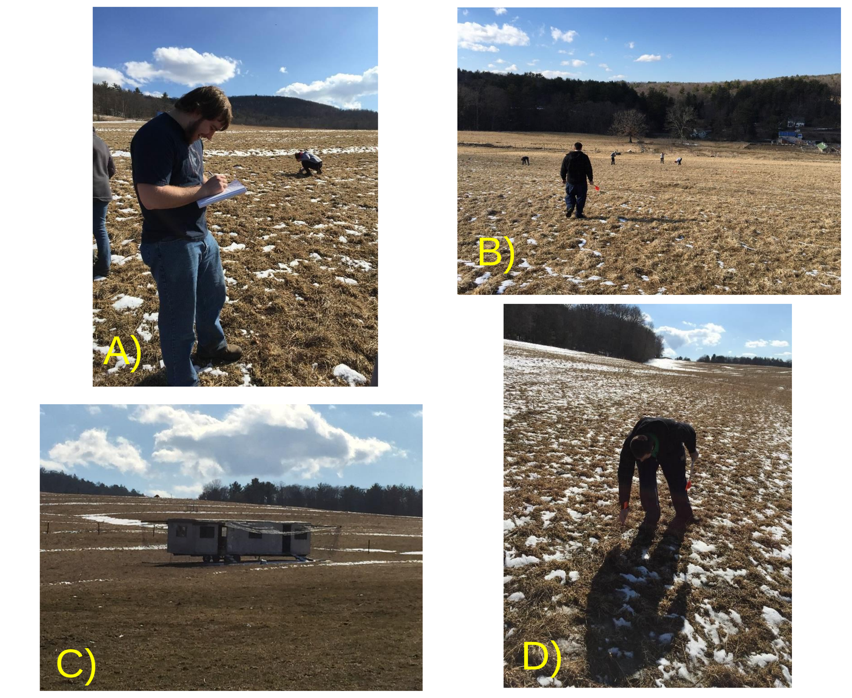
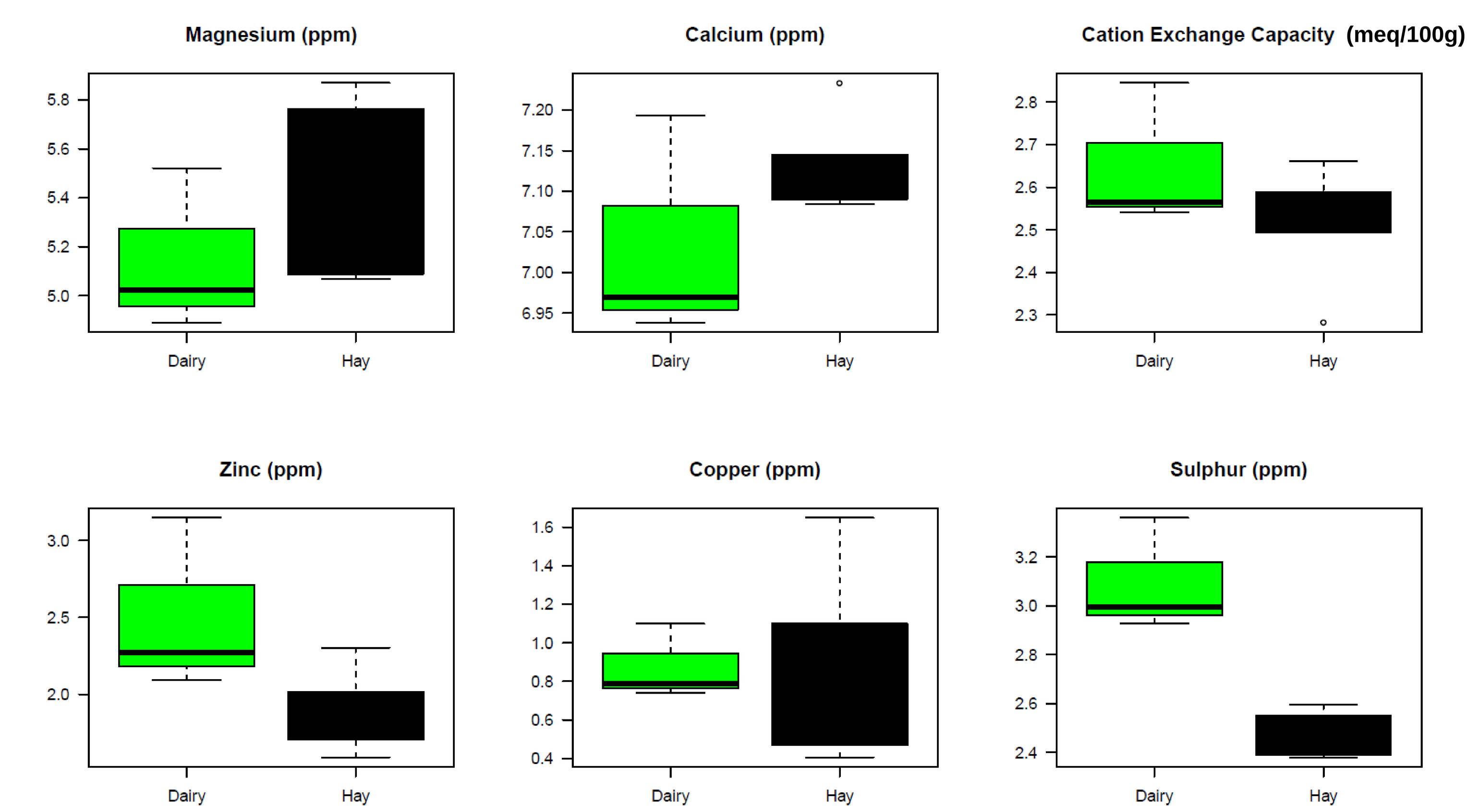


Photo 3: (A) Me recording the coordinates of the various plots. (B) The class that helped collect the samples in the pasture. (C) The chicken tractor used in pasture 2. (D) Marking out the plots where the samples were taken.

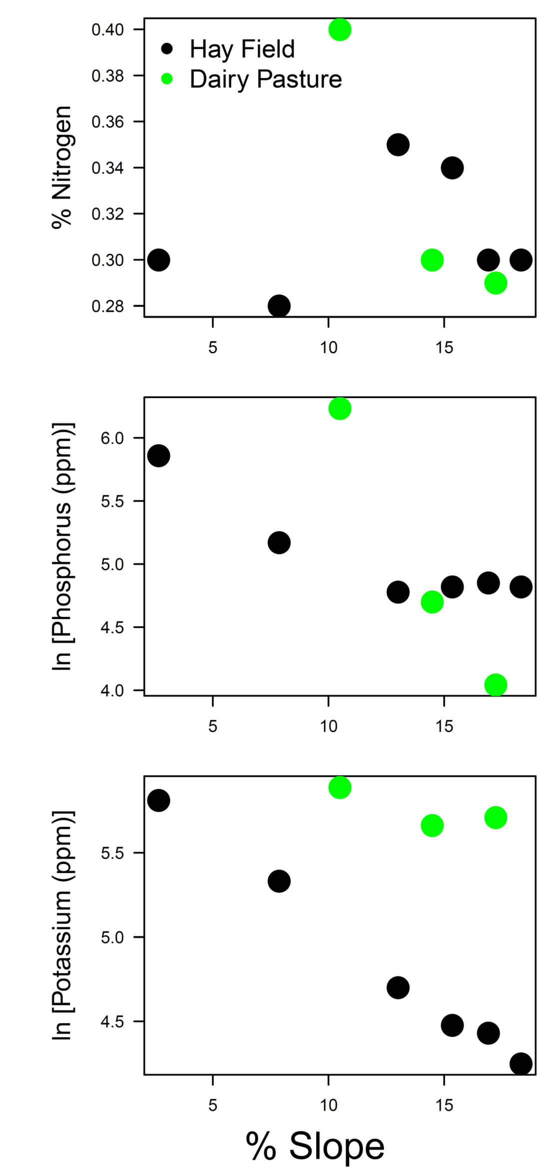
Pastures	1			2			3		
Sample #	1	2	3	4	5	6	7	8	9
p H	5.6	5.8	5.8	6.5	6.9	6.5	6.1	6	5.9
P (ppm)	510	110	57	351	176	124	119	128	124
K (ppm)	361	288	302	334	207	70	110	84	88
N (%)	0.4	0.3	0.29	0.3	0.28	0.3	0.35	0.3	0.34
Mg (ppm)	250	152	133	318	354	306	180	162	159
Ca (ppm)	1331	1064	1031	1385	1268	1204	1246	1193	1200
CEC (meq/100g)	17.2	13	12.7	14.3	9.8	12.1	12.5	12.6	13.3
Organic matter %	5.5	4.4	4.6	5	4.5	4.8	5.1	4.9	5.2
Zn (ppm)	23.3	8.1	9.7	10	5.5	4.9	7.5	5.7	5.9
Cu (ppm)	3	2.1	2.2	2.8	1.6	1.5	5.2	3	2.1
S (ppm)	28.8	20	18.7	13.4	11.6	10.9	12.8	10.8	12.4
Slope (%)	10.5	14.49	17.24	2.66	7.87	18.33	13.01	16.92	15.36
Animals or Hay	A	A	A	H	H	H	H	H	H

Table 1: All of the measured nutrients for all nine plots that were sampled. The green shows what nutrients were within the acceptable ranges. Red shows what nutrients were higher than normal. Blue showed what nutrients were below normal. Purple was used to show the nutrients that were off significantly higher than they should be. The data in black is not applicable. Phosphorus was high in most plots. Potassium was high in about half the plots. The CEC was high in almost all plots. Magnesium showed the most extremes in some and high in other plots.

Methods: The fields were mapped out using Google Earth to get areas with similar slope. When sampling we used three 75 ft. x 75 ft. plots at different slopes on the hill side pasture. Each was spaced out about 10 yards, There were 11 total samples for each of the nine plots, with three plots per pasture. The samples were put into individual small bags and collected in a larger bag labeled for each plot. After all were taken, they were dried in the lab, then packaged and shipped to Penn State University's Agriculture Analytical Service Lab to be tested for all macro- and micro nutrients, Cation exchange capacity, organic matter, and pH. For the macronutrients we used a General Linear Model to determine significance. While in the micronutrients and cation exchange capacity, we used a t-test and then plotted them on the bar graphs.



Graph 1: These bar graphs show the micro nutrients and Cation Exchange Capacity (CEC) in the soil between the hay and animal pastures. The only significant one is Sulphur, which had a p-value of 0.037. The other micronutrients and CEC were insignificant. The animal fields show a farther variation from the median due to the first plot and the possible pooling of nutrients.



Graph 2: The General Linear Model for the three macronutrients: Nitrogen (N), Phosphorus (P), and Potassium (K). The % N graph shows no clear fit which was expected due to the legumes in the pasture. The P and K graphs were loged to satisfy conditions of normality. The P graph showed no significance for either condition but in the hay fields it showed a stable relationship for pasture 2 and then leveled off for pasture 3 as shown above. The animal field showed an interesting linear relationship but there weren't enough data points. The K graph shows a clear relationship between slope, land usage, and K levels for the hay fields. The p-value for the interaction was 0.00468, and for the entire test it was 0.0000065. The R^2 value for the interaction was 0.99.

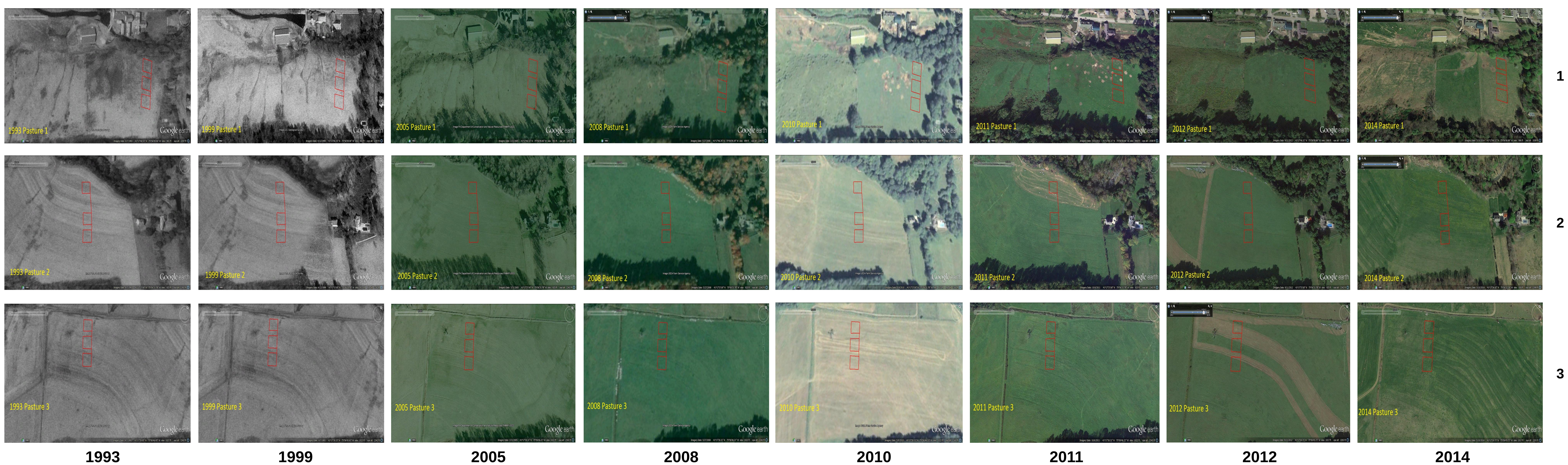


Photo 2: These pictures show the three pastures through time. It is clearly visible that pasture 1 has been heavily used by the dairy cows. Pastures 2 and 3 show that they have been steadily been used for harvesting hay for at least the past 20 years. In pasture 1 you can see the cows in the last picture and the heavy usage of the cows through the field, as well as the location of the round bales around the base of the hill (close to plot 1). Pastures 2 and 3 mostly show the harvesting lines and round bales. But the field do look healthier overall. Pasture 3 also had platforms of land with ridges which can be seen in the pictures, it was the only field with this configuration.

Conclusions: In conclusion, we saw that potassium levels showed a significant correlation with slope, land usage, and K ppm, where the hay fields showed that as the slope increased K ppm decreased. We also saw how the animals affected the amount of potassium in a plot as the plots with animals were significantly higher than the harvest pastures. Sulfur was the other significant nutrient that we saw, as it showed a relationship between the use of dairy cows and increased S ppm in the soils. Phosphorus showed a possible relationship between slope, land usage, and P ppm but the slope in plots 6, 7, 8, and 9 being so similar could have affected the results. Overall we saw that their was a significance to the slope of the farm and usage of the land, between dairy and harvest fields. The biggest reason I believe we are seeing such significant amounts of Sulphur in plot 1 is due to the application of too much manure, combined with the runoff from the top of the hill pooling in the lower slope area, as this is the pasture that the cows are always grazing on. The other extreme amounts could be also from applications of manure, specifically for phosphorus and potassium.

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Soil Sampling at Hillside Farms

Abstract: For this project we were looking to see if there was a relationship between slope, previous land usage, and soil nutrient levels. For this experiment we used Hillside Farms in Shavertown, PA. The farm has three pastures for their dairy cows, one for grazing, and the two others mostly for hay harvesting. We began testing by looking for the most ideal locations away from any nutrient sinks (drains, manure piles, etc…), and areas with similar slopes. We marked out three plots at different slopes per pasture. We took 11 samples per plot and coagulated the samples for each plot before sending them to Penn State University's Agricultural Analytical Service Laboratory. Using a General Linear Model on the macro nutrients we determined that Potassium was the only significant macronutrient, showing a relationship with slope and land usage. In the hay fields, as the slope decreased, potassium increased. Phosphorus showed us some interesting results, but we didn't have enough samples to show any significance. For the micronutrients we used a t-test for each nutrient in each type of field and compared them to find that Sulphur was the only significant macronutrient with a relationship to the type of pasture it was in, as it was higher in the animal pastures. With these results we saw that there was a relationship between slope and previous land usage on the nutrient levels in the soils.

Introduction: Good soil health is a necessity for all types of farming, whether it is vegetables or cattle. The soil contains the basic media, nutrients, flora (bacteria, fungi, etc..), and process that all plants and animals need to grow (Wagenet & Hutson, 1997). It is important to understand how everything we do with our soils can have long lasting effects, such as plowing, pesticide spraying, erosion, etc… This is important since once we abuse a particular patch of soil too much it can take decades or even longer to repair the damages (Wagenet & Hutson, 1997). Hillside farms has used three main pastures on and off for several decades. The main pasture behind the barn is the most common of grazing sites for the dairy cows. This pasture, like the others are on the side of a mountain. The only difference is that the other pastures were used more as hay fields, they have been used to feed the cows when the main pasture was not being used and when the winter months rolled around. The second pasture has also seen the "chicken tractor", a mobile chicken coop that allowed the chickens to be outside but not allowed to run away. This was favorable for the pasture as it was able to use the chicken manure for nutrients and to help the pastures grow (Antonious *et al.*, 2009). The only problem being that only the lower third of the field is flat enough to use the chicken tractor so only the flatter portions received any poultry manure. Poultry manure is a viable source of nutrients but can have a heavy impact on the soil and its make-up. Poultry manure can be too strong for most soils if applied in large amounts directly due to its extremely high nutrient levels (Antonious *et al.*, 2009,). This isn't the only source of manure used on the fields as the cow manure is collected and spread on the fields as well, to help boost the field's nutrients, like in many other farms (Jokela *et al.*, 2012). There can be a problem in this use of nutrients as they can be over applied and runoff and/or pool in the lower slope areas (Kleinman & Sharpley, 2003, Jokela *et al.*, 2012). Through the history we also know that the pastures were used heavily, we also know that recently the implication of broadcast manure spreading has been used on the pastures to help replenish the soils. This history can play into the whole picture as well because of the heavy usage of the first pasture there could already be an abundance of nutrients in that ground and possibly negative effects to the soil from all of the manure (Jokela *et al.*, 2012). Nutrient runoff is a huge ecological problem, especially in the location of the farm as it lies around a stream that leads to the Susquehanna, which ultimately leads to the Chesapeake Bay. This can be a big contribution to the huge problem that occurs in the Chesapeake Bay every year with major dead zones forming due to too many nutrients in the water (Ramakrishna *et al.*, 2007). With the way the pastures are placed, on the side of a mountain and near a water source it is important to pay attention to how much and what kinds of nutrients are put on the field compared to what it actually needs. As well as the abundance of the abuse to the soil from all of the cows, this can be detrimental to the soil structure in itself by hurting the legume's ability to fix nitrogen into the soil (Menneer et al., 2005). The first pasture especially shows signs of compaction in the soil as there are areas where no grass is growing and we know from the history that the round hay bales have been sitting for many years. The cows keep abusing the soil with their hooves as well as the possible formation of cow pies. This can allow for some nutrients to just roll over the soil as it has nothing to grab the nutrients because it is just compacted dirt. This means that the soils aren't getting the nutrients they need and but the streams are collecting all of these nutrients and bringing them down the river (Jokela *et al.*, 2012 , Kuykendall *et al.*, 1999). The Cows can have a strong effect on the land that they use, similar to chickens as their manure can be harmful to the soil due to its high nutrient content and the possible leaching of the excess nutrients (Antonious *et al.*, 2009). To better understand better what is going on at Hillside farms, we want to see how the relationship between slope of the pasture and the history of the usage of the pastures affects the nutrient levels in the soil. We will be sampling the soils to get a better idea of what is actually going on in the pastures at different slopes of each pasture. Then we'll compare them to each other and the normal values from Penn State to see how healthy they are.

Materials and Methods:

Planning of Sampling: First we had to start looking for the ideal spots to sample in each of the three pastures. The three pastures were all different sizes and we decided to sample in 25 yard x 25 yard sampling plots. Each pasture would have three plots, one at the bottom or flattest part of the pasture. One at the middle part of the pasture and one at the top of the pasture. To ensure our samples were ideal representations of each plot I made sure that the three areas that we were sampling had the same or very similar slopes. This was done to make sure that the nutrient run off/ build up, if there was any, was accurate for all three areas of each pasture. This part was done using Google Earth, by measuring the distance between two areas totaling around ~315 yards, and using the slope equation for the different heights to find areas with similar slopes. This was done to give us rough areas where the slope was the same, as when we got to the actual pastures we would be making sure to avoid any possible problem areas like drains in the pastures, the chicken tractor, and any other objects that would be in the way or that could affect the results in a way that would give us skewed results.

Sampling of Pastures: The actual sampling was conducted off of the general coordinates that were found using Google Earth. To avoid any objects that could affect the samples, we would go off of one coordinate and walk out the rest of the square by walking 25 yards in each direction marking the edges of the square with road marker flags. After the bottom square was done, I would walk up 10 yards from the top corner and repeat the process walking out the square and marking it. Then I would walk up another 10 yards from the top of the middle plot and start marking out the next square. When I got to the top corner I would double check my coordinates and make sure I was within the area of my predetermined slope. If the coordinates were close then we would be cleared for sampling. The sampling was done by taking 11 random samples throughout the marked squares to ensure a random mixture of the soils for each plot would be sent out for sampling. To collect the samples we would take a steel trowel and remove the grass and root cover to get down to the actual soil. We had to ensure most organic matter was clear of the soil and take a sample that would give us a good representation of the soil. After each of the 11 samples were taken in each plot they would be put inside a sandwich bag and placed in a larger collection bag for that actual plot. This whole process was repeated for all plots on all pastures.

Prepping of Samples: The samples were then taken to the lab where they had to be dried due to the high amount of water in the soil for all the samples. Each plot had a designated area to be laid out on the lab table to allow them to dry for a week to ensure that they weren't muddy when trying to sort the samples. The samples were placed and separated so that there would be no mixing or contamination between plots. When the samples were dry enough they were inspected to remove any organic matter and/or rocks that could affect the testing of the samples. About a cup of dirt was taken for each sample and put into a sample bag that was labeled with the serial number for that individual plot. The samples were then packaged and sent out to the Penn State University Agricultural Analytical Services Laboratory. We had the soil samples tested for organic matter, total nitrogen content, and a standard fertility test. The standard fertility test showed the Potassium (K), Phosphorous (P), Magnesium (Mg), soil pH, Cation exchange (CEC), Calcium (Ca), as well as Zinc (Zn), Copper (Cu), and Sulfur (S). The results were then used to compare the differences between the various plots in a pasture and the plots of the other pastures as well as how they fared to the normal values.

Results:

The data received from the Penn State showed us all of the Micro- and Macronutrients in the soil, as well as the cation exchange capacity, pH, and organic matter (see Table 2). This was done for each plot. With the data we can see relatively high amounts of phosphorus in all of the plots, excluding plot 3. We can also see that potassium was higher in the animal pastures compared to the hay pastures. The cation exchange capacity was also found to be elevated in the soils that we sampled. We saw some extreme values in plots 1 and 4 in regards to phosphorus levels, which were way above the norm, and at possibly harmful levels for the animals and environment. We also saw high amounts of magnesium in pasture 2. The last extreme number we found was the zinc level in plot 1. Besides this most of the data was well within the accepted ranges for the soil type that we were sampling (*The Agronomy Guide 2014 – 2015*, 2014). Nitrogen was tested for but not considered seeing as it was a leguminous pasture and the fact that it doesn't stay in soils long, especially with the heavy amount of animal travel over the first pasture, which can affect the nitrogen rate (Menneer *et al.*, 2005).

Our results were compared to the accepted values from Penn State's Agricultural Analytical Service Laboratory (AASL). These are the recommended values for the soils in Pennsylvania (See Table 1 below). We used their normal ranges as they run the extension offices around the state and their agricultural base is centered on Pennsylvanian farming (*The Agronomy Guide 2014 – 2015*, 2014) . The only range not found on PSU's reference guide was cation exchange capacity, which was found in another soil reference manual (*"Fundamentals of Soil Cation Exchange Capacity (CEC)."*, 2012).

Normal Ranges	
pH	6.0 – 7.0
P (ppm)	30 – 50
K (ppm)	100 - 200
N (%)	N/A
Mg (ppm)	120
Ca (ppm)	700-5000
CEC (meq/100g)	5-10
Organic Matter (%)	1.7 – 9.9
Zn (ppm)	1.1 – 9.4
Cu (ppm)	1.2 – 5.5
S (ppm)	10 – 25

Table 1: These are the normal ranges given to us by the Penn State AASL. Nitrogen was not applicable due to the legumes in the crop.

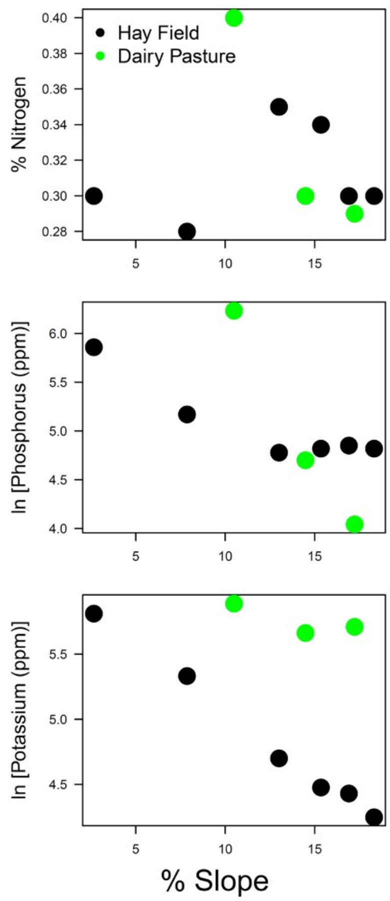
Table 2: All of the measured nutrients for all nine plots that were sampled. The green shows what nutrients were within the acceptable ranges. Red shows what nutrients were higher than normal. Blue showed what nutrients were below normal. Purple was used to show the nutrients that were off significantly higher than the normal ranges. The data in black in not applicable.

Sample #	1	2	3	4	5	6	7	8	9
p H	5.6	5.8	5.8	6.5	6.9	6.5	6.1	6	5.9
P (ppm)	510	110	57	351	176	124	119	128	124
K (ppm)	361	288	302	334	207	70	110	84	88
N (%)	0.4	0.3	0.29	0.3	0.28	0.3	0.35	0.3	0.34
Mg (ppm)	250	152	133	318	354	306	180	162	159
Ca (ppm)	1331	1064	1031	1385	1268	1204	1246	1193	1200
CEC (meq/100g)	17.2	13	12.7	14.3	9.8	12.1	12.5	12.6	13.3
Organic matter %	5.5	4.4	4.6	5	4.5	4.8	5.1	4.9	5.2
Zn (ppm)	23.3	8.1	9.7	10	5.5	4.9	7.5	5.7	5.9
Cu (ppm)	3	2.1	2.2	2.8	1.6	1.5	5.2	3	2.1
S (ppm)	28.8	20	18.7	13.4	11.6	10.9	12.8	10.8	12.4
Slope (%)	10.5	14.49	17.24	2.66	7.87	18.33	13.01	16.92	15.36
Animals or Hay	A	A	A	H	H	H	H	H	H

The data showed us that in pasture 1 we had signs of heavy manure usage. Specifically plot 1 where we had the most high/extreme values. Phosphorus was high in just about all plots. Potassium was high in any pasture that had an animal, while in the hay fields it was normal or slightly low. Sulphur was higher in the animal pastures, while magnesium was surprisingly higher in pasture 2.

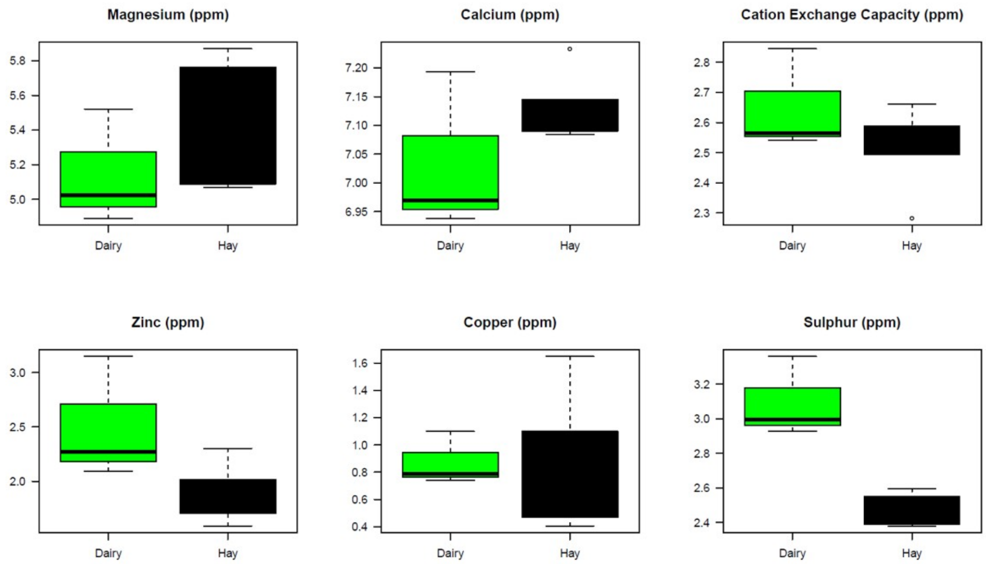
With the data we wanted to look at the relationship between the slope and previous land usage and how it affected the soil nutrients. To do this we used a General Linear Model (GLM), using a two-variable linear model. This allows us to look at two variables, a numerical value (slope) and a categorical value (land usage). The GLM was used to graph the data to show if there is any significance to the data. This is done by using a line of best fit through the data, it gives us a way to see if the data is linear and significant, or if it is just a bunch of scattered points with no significance. To tell how accurate the line is we look at the R^2 value to see how the rightness of fit is of the line. Too low of an R^2 value shows that even though there is a line, the line may not be significant. We did this when looking at the Macronutrients, with Phosphorus and Potassium we had to log them to satisfy conditions of normality. When looking at the data we saw that Potassium was significant when looking at the interaction of slope and previous land usage (Graph 1). When looking at the variables individually we saw no significance. With potassium we saw that as the slope increases the amount of potassium increases, only in the fields used to harvest hay. The animal field data that was plotted showed no linear significance. The p-value for the interaction between slope, the hay fields and potassium was 0.00468, with an R^2 value of 0.99. The p-value for the entire test was 0.0000065.

The test for phosphorus showed no significance for either the interaction or for a single variable. The graph showed possible linear relationships in pasture 1 and 2 but they were not conclusive as there were not enough points to conclude any findings. But the graph did raise some possible questions (see Graph 1 below). Nitrogen was the last of the macronutrients we looked at, and the data showed no significance at all as the points were just scattered randomly. There was no significance for either the interaction or independent variables (see Graph 1 below).



Graph 1: This graph shows each of the macronutrients. The data points are color coded by land usage, green for animals and black for hay. The graphs show that the only significant results were those of potassium. Phosphorus showed some interesting results, but nothing significant due to the small sample size.

The micronutrients were examined using a t-test for each field and each nutrient, and then plotted on a bar graph. This showed us how the two compared statistically. The only significant results we found from the micronutrients was Sulphur, it was found to be higher in the animal soils compared to the hay soils. Although when looking at the data we can see that there were some other high and low amounts in the micronutrients, Sulphur was the only one to show a significant difference (see Graph 2 below). The p-value for the Sulphur test was 0.037.



Graph 2: This graph shows the animal (green) vs hay (black) nutrient levels for the micronutrients. The only significant finding was that Sulphur was higher in the animal soils compared to the hay soils with a p-value of 0.037.

Discussion:

With the results we saw that the Potassium levels were significant when looking at the interaction between slope and previous land usage. With this we saw that in the pastures that were used as hay fields, the amount of potassium increased as the slope decreased. While in the animal soils there was no linear relationship at all, nor were there enough points. But the hay fields did show the possible effects of nutrient runoff and pooling in the lower slope areas (Kuykendall *et al.*, 1999). This is visible where in plot 6 with the highest slope had a lower than normal potassium level compared with plot 4 which had the lowest slope and the highest amount of potassium in the hay soils. This was the only significant macronutrient that we tested, phosphorus was still interesting to look at though. As we only had so many points to test and had to test the three pastures each, the last three plots, in pasture 3, had relatively similar slopes. This could have affected the data as there weren't any real flat areas in the pasture due to its position on the hillside. So although the data showed there was no significance, it would be interesting to see testing done in higher slope areas of the pasture, as well as possibly finding lower slope areas on pasture 3. This would give us a better idea of what the actual relationship between phosphorus in the hay fields and slope. For these pastures we had a feeling that nitrogen would not be a problem due to the fact that it is a leguminous pasture, and the fact that they apply heavy amounts of manure on each pasture. We were looking though for any extremes that could be hints of an underlying problem, but there was no problem in the soils. We did notice that plot 1 was significantly higher than the rest, possibly pointing to a problem with nutrient runoff on the pasture, but we can't be 100% certain without looking into it farther. We thought the effects of all the animal movement and pugging of the soils would have a big effect on the soil nitrogen levels but we were surprised when we saw the data showed no significant difference between the two types of pasture (Menneer *et al.*, 2005).

When looking at the data for the micronutrients we found that the only significant difference between the two types of pastures was in Sulphur. Sulphur was seen to be higher in the animal pastures compared to the hay fields. Sulphur was also seen in the data to be at its highest levels in plot 1, and higher in general in pasture 1. This makes sense as Sulphur is known to leach out of soils and can move from the soil easily when water is added to the soil. When we were sampling, it was a sunny day following a descent snow storm. This meant that there was a lot of water running down the hill. This water could have carried all of the Sulphur from the higher points down and given us higher results. Another way this number could have been inflated was due to the high amounts of manure that were on the fields at the time. The manure was visible in piles and combined with the melting snow, the amount of Sulphur could have sky rocketed in the soils, before it drained into the nearby stream (Kuykendall *et al.*, 1999). This nutrient runoff from the soils and high manure application could have been a big reason for the really high ranges found in plot 1, as well as the high numbers in all of pasture 1. We also know that Pennsylvania has one of the highest amounts of acid rain, which contributed to the overall crops normal Sulphur levels, but this made it easier for the Sulphur levels in the animal plots to get out of hand. From our data we know that K, S, and possibly P are our most significant results (*The Agronomy Guide 2014 – 2015*, 2014). The others nutrients we tested showed no signs of significance between the two fields and/or slope. But any interesting note was that magnesium was higher in pasture 2 compared to the other two pasture significantly, it wasn’t significant but was just puzzling seeing as it was highest in plot 5 with the medium slope, where we would have thought that it would have been in the plot 4 where the slope was the lowest.

With our results we saw what we were expecting, as the lower slope soils showed a pooling in nutrients. As well as the fact that the hay fields showed a significant trend of potassium as it followed an expected run off pattern explained above. The phosphorus would have been interesting for both plots to see if we had more data because it is known to leach out of soils and could also be significant if we had more testing done. Sulphur, was seen as significantly higher in the first pasture, mostly due to the ability of it to leach out of the soil and extra manure all over the pasture. So although we didn’t see all the nutrients pooling in lower slopes as well as higher amounts in the dairy pasture, we did see significant data showing that there was a trend for what we were looking for in the soils.

Conclusion:

In conclusion, we did find that there was a relationship between slope and usage history of the land and the nutrients in the soil. This was evident in potassium levels, as mentioned above. As the slope decreased, the concentration of potassium increased. Phosphorus may have shown similar results but the slopes were too close together on the last three plots to give us a significant answer. Sulphur was found to be higher in the animal plots compared to the hay plots, this had to do more with the past land usage. But when looking at the data slope could play a big part in Sulphur levels as well due to nutrient runoff and pooling. With the results that we found I would say that I accept my hypothesis that there is a relationship between slope, field usage, and soil nutrients. Although I think a bigger study on the hillside would warrant better results we were limited in what we were able to do in this project. Some possible improvements would be to do this testing in the fall rather than the spring. Also to try and maybe test each field twice on both sides instead of only in one area, or to increase the area of the sampling plots as well as the amount of samples per plot.

Resources:

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