Hillside Assessment Report

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S3G4, Plot CP5

1. Abstract

The ecological health of a plot of land involves several different parameters that factor into the overall health of the land. Research was conducted on the ISAT Hillside Meadow between 12 different plots of land to study the effects of plots either treated with compost or left natural and how different ecological parameters were impacted to discern differences between the treatment type of a plot. The different parameters of study were soil analysis, plant identification, above ground biomass, microBIOMETER® readings, invertebrate communities, and spatial position. Soil analysis determined pH level, bulk density, soil texture, vegetation growth, organic matter, and moisture holding capacity of the different plots and treatments. Results showed that the treatment type made little difference in the health of the soil; both types of treatment had similar readings with pH level, bulk density, and vegetation growth. Spatial position revealed differences based on topography as soils further up the slope had higher silt concentrations but less organic matter. The ecological health of the plots of land were also investigated through plant identification and invertebrate analysis. The dataset supports that the invertebrates were also affected by spatial position and there was lower species diversity and richness in the innermost plots of the Hillside. However, the treatment type had no discernable pattern in invertebrate richness and diversity. Throughout our research we also took into consideration the natural effects that impacted the Hillside - data was collected during a drought which affected our soil content and results due to the very dry conditions in the area. Through our data we determined that the treatment type had minimal effect on the ecological health of the Hillside, however recommendations to further increase

the ecological health would be to introduce a new treatment type, minimize mowing on the lawn, and covering bare soil with vegetation.

2. Introduction

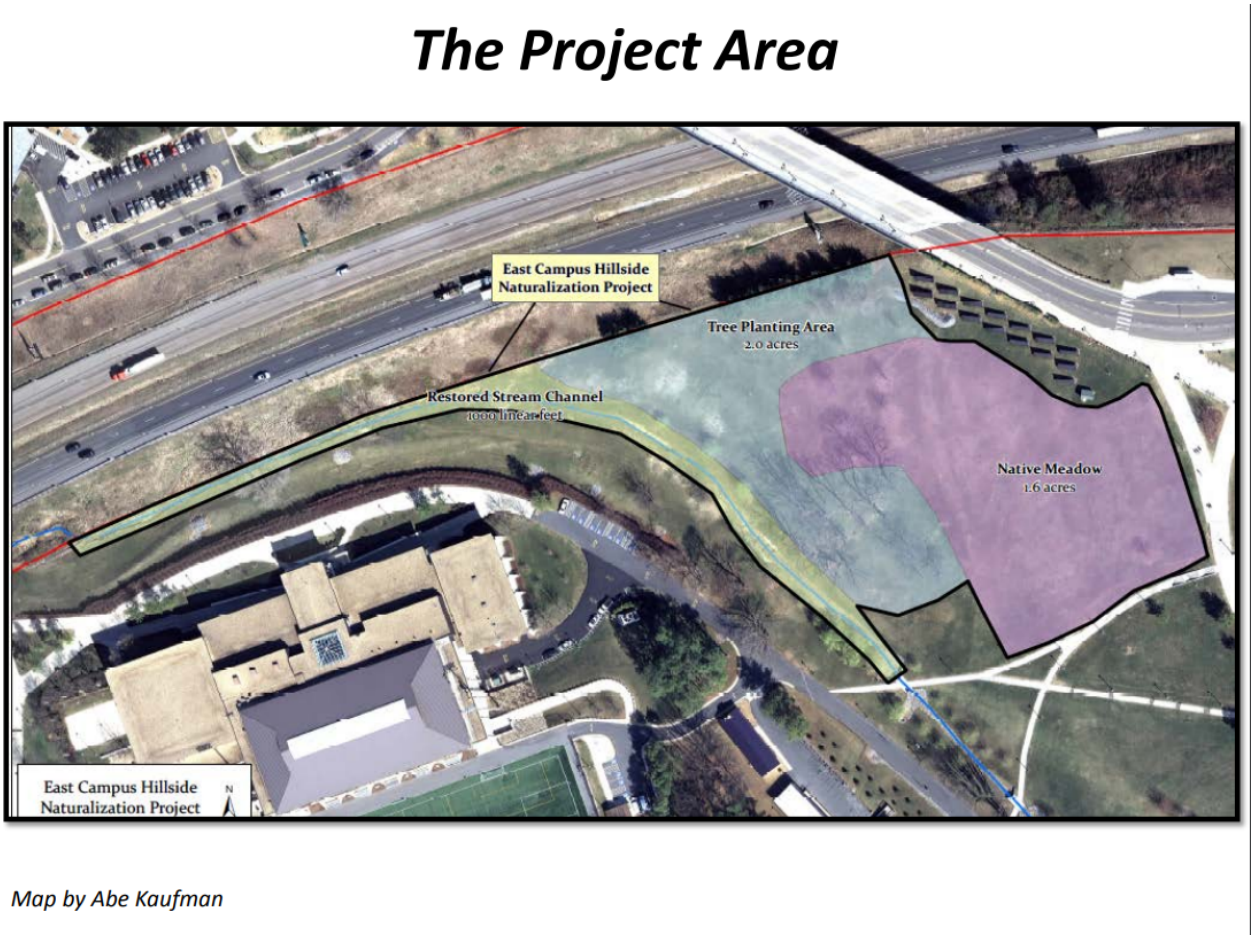


Figure 2.1: Proposed Project Area of East Campus Hillside Naturalization Project

The Hillside Meadow Project was first envisioned by a James Madison University(JMU) Integrated Science and Technology (ISAT) faculty member in 2002 as a means to investigate the Hillside's ecological qualities. From there, the first formal draft of a proposal was submitted in 2006, and by 2010, a few ISAT and Geography faculty at JMU had a vision for the meadow, which is shown in Figure 1 above. They were able to start the process in 2011 when JMU received a grant for stream channel restoration. Also in 2011, JMU faculty and students began contracted planting(19), and in 2012, they began class tree planting and stream restoration. From 2013 to present there has been ongoing

maintenance and development of the meadow, as well as experiments performed through faculty curriculum development in courses such as GEOG 210, ISAT 112, and ISAT 320.

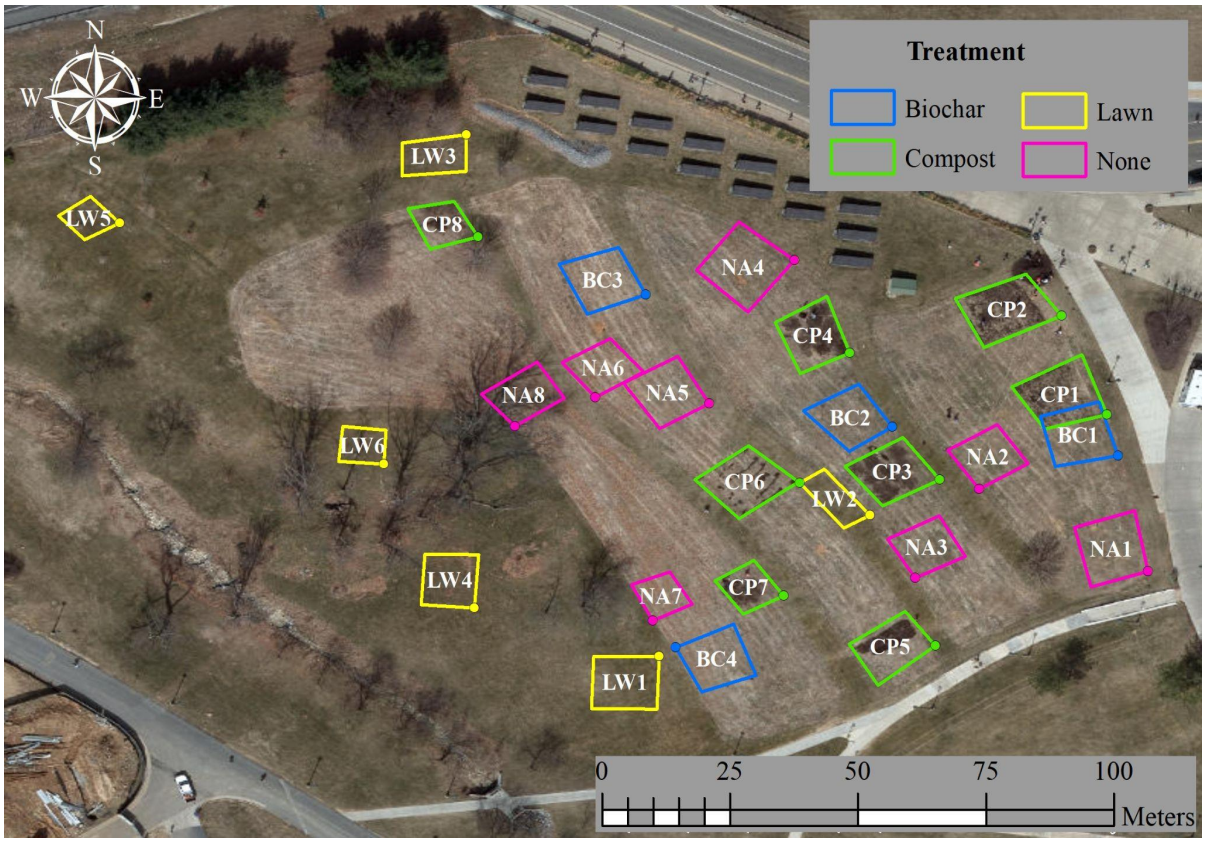


Figure 2.2: Plots of land on the Hillside Meadow sorted by treatment

The overall objective of this lab report is to summarize the general ecological health of the Hillside Meadow ecosystem and the specific parameters of a plot of land on the Hillside, such as soil analysis, plant identification, above ground biomass measurements, microBIOMETER® readings, and invertebrate communities, based on the treatment type of the plot. Our plot of land was CP5, a compost plot, meaning organic matter was buried there previously. We conducted soil analysis to determine the overall health of the soil and the penetrometer results, pH level, bulk density, soil texture, vegetation growth, and moisture holding capacity in the soil compared to a natural plot. We also studied other factors, such as spatial position on the Hillside, to determine how it influenced our soil parameters. We identified the current plants in our plot and compared them to the plants originally planted on the Hillside. We did this to determine if any invasive species out-competed the original species in order to gain a better understanding of how various plant species are spread across the Hillside, and to better understand how compost soil impacts plant life on the Hillside compared to natural soil in terms of

species richness and diversity. We calculated the total above ground biomass to compare how the Hillside's natural (NA) and compost added(CP) plots differ in terms of above ground biomass, showing the difference in the levels of organic material. We also recorded microBIOMETER® readings to study the %fungus and %bacteria as well as their concentrations and the overall microbial biomass (μg C/g) to determine the microbial community abundance and how that differs between the natural(NA) and compost added (CP) plots. Lastly we focused on the species richness and diversity of the invertebrates in our plot and how that compared to other plots on the Hillside. We further studied how this differed between the natural and compost plots and the spatial patterns in the distribution of insect types between the different plots.

Our plot on the Hillside was only one part of a much larger system that is the entire Meadow. In other words, our plot was its own nested system inside a bigger system. Seeing our study through this lens allows us to see each plot as its own open system that gives and takes away from the overall meadow. This Topography has a significant role in determining what is given and taken away, as the plots further up the slope of the meadow can affect the plots towards the bottom of the meadow through runoff and erosion which has an impact on soil formation and texture.

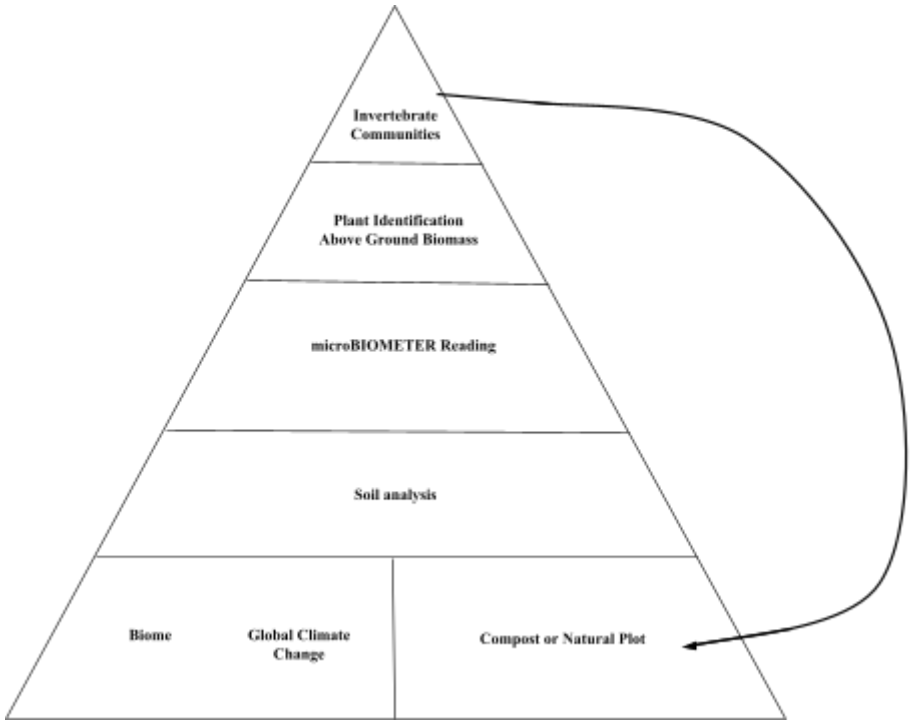


Figure 2.3: Pyramid Representation of Relationships Between Parameters

Above is a pyramid representation showing the different relations between our parameters and how they all affect each other, with the bottom of the pyramid being the base that affects the rest of the parameters. The base of the pyramid was split into two sections with one being a plot type of either compost or natural. The compost or natural plot will affect soil analysis because of the difference in decayed organic matter, leading to changes in the nutrient content, vegetation growth, and soil makeup. The other section on the base of the pyramid was biome, specifically, the biome that the Hillside Meadow is a part of, and how that affects average rainfall, temperature, and soil type. We also factored climate change into this section to acknowledge how this plays a role in increased occurrence and intensity of droughts; among other weather phenomena. Harrisonburg Virginia, and consequently the Hillside Meadow, is in a “temperate forest biome”(20) which are “characterized by warm summers, cool winters, and significant rainfall which lead to fertile soils and diverse plant and animal species”(27).

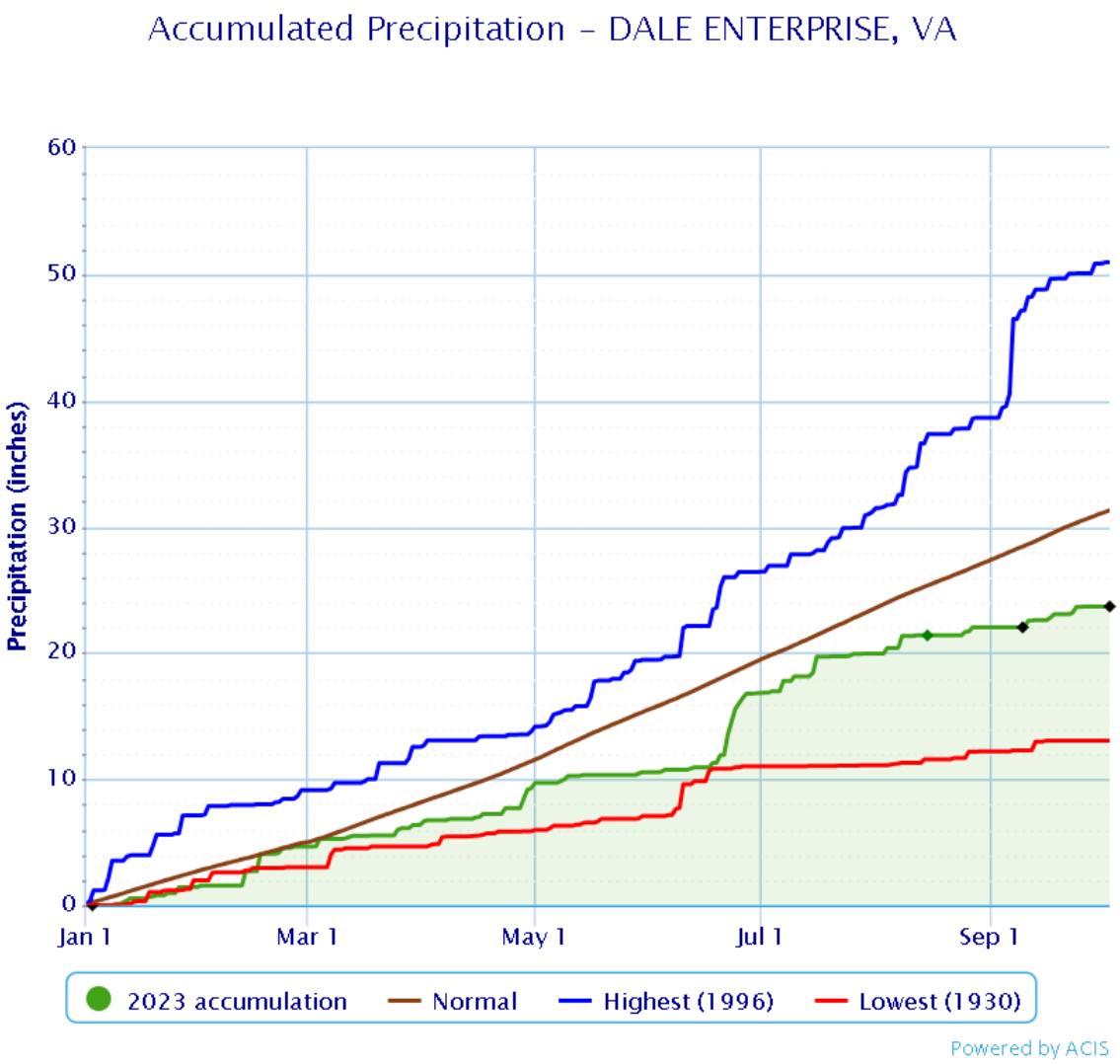


Figure 2.4: Accumulated Precipitation from 2023-Present Recorded from a Weather Station Nearby to Harrisonburg, VA

https://www.weather.gov/wrh/Climate?wfo=lwx

From Figure 4 and data it was built off, Harrisonburg has received 23.68 inches of rain from January 1st, 2023 to September 30th, 2023. The normal rainfall in this period is 30.99 inches, so Harrisonburg has received 7.31 inches less rain than average by this point in 2023. This constitutes a drought in our area which is defined as "an extended period of unusually low precipitation that produces a temporary shortage of water for people, other animals, and plants" (28). This drought and lack of water affects our soil analysis and parameters as drier soil affects vegetation growth, soil texture, bulk density, and overall moisture in the soil. Moving up the pyramid our soil affects the MicroBIOMETER readings due to our soil being very dry and low in moisture which led to higher

percentages of bacteria in the plots; fungus could not grow as steadily due to the lack of moisture. All of these factors previously mentioned will affect the plant identification and growth and the above ground biomass. The drought, soil, and high bacteria percentages will affect plant identification and growth as a collection of specific plants that thrive under drier conditions and high bacteria percentages are common in our plot and the Hillside. This also leads into above ground biomass, with the soil moisture and nutrients leading to a lower amount of above ground biomass, as well as organic matter in the soil which affects the overall above ground biomass. All of this goes into the invertebrate communities and with the collection of specific plants and biomass this will affect what and how much invertebrates can eat in the plot. The soil also plays a huge factor and that invertebrates who work well under drier conditions and need less moisture are less likely to be inhibited by the conditions. Finally the last stage of the pyramid representation is the living or dead invertebrates and plant material going back into the soil leading to increased organic matter in the soil (Chiras, Ch6, 29). Overall all parameters of the Hillside work into each other and affect one another, however the major factor in our analysis was the drought in Harrisonburg and how that was the root cause of differences in the parameters.

The Hillside Meadow Project has had ongoing maintenance since 2013, for 10 years now. This shows a longitudinal study for the Hillside. A longitudinal study is beneficial as there are repeated observations over a long period of time so we can analyze how the Hillside has changed over time and in different conditions. This year is a good example to study the effects of drought on the Hillside and how the results of this semester's study differ from years with no drought or with increased rainfall. There could be different plant species or invertebrates that are more common this semester than most others because of the dryness and lack of rainfall.

The Hillside Meadow will continue undergoing maintenance for the years to come, with that new changes will also continue. In the coming years Harrisonburg should hopefully be getting out of a drought and the Hillside will be wetter and hopefully have a wider range and plants and animal species. Along with that new procedures could help the Hillside become healthier, for example if compost posts are an improvement to a lot of the parameters then more compost could be added, or another type of plot that could benefit the Hillside.

3. Materials and Methods

Intro

Overall, the goal of this series of labs was to determine the physical properties of soils on the ISAT Hillside in order to determine its ecological health in a representative and unbiased manner. To achieve this goal, we collected data on plant species (to determine species richness and diversity), above

ground biomass, soil samples, and invertebrates. Soil data collected included compaction samples, moisture, bulk density, texture, and microBIOMETER readings.

To begin, each plot for Hillside, including our own, CP5, was created using *stratified random sampling*. Our class used this technique to "...ensure that the exact location of each sample is random and unbiased"(9). Each plot was classified as either "1) 'Natural,' which refers to naturalizing Hillside without additional direct treatments, 2) 'Compost,' which refers to naturalizing Hillside that received compost amendments, 3) 'Lawn,' which refers to the managed lawn between and around the Hillside naturalization areas, and 4) 'Biochar,' which refers to the naturalizing Hillside that received biochar compost amendments"(9). Our plot was a compost plot.

To aid us in finding our plot for Lab #1 we used a portable 'TerraSync' GPS. Once our assigned plot was located we created two subplots within it, one being 10ft. X 10ft., and the second at 3ft. X 3ft. When creating these subplots, we used a random number generator (www.random.org) to make sure we placed the first corner marker for each in a completely unbiased location within the main plot. Once a corner marker had been established we measured out a 10ft. X 10ft. area from the point and repeated the process for the 3ft. X 3ft.

Image 1: Plot CP5 Plants before Lab 2 Plant Identification

3.1 - Plant Identification

We began Lab #2 by collecting a representative sample of each plant species within our 10ft. X 10ft. Subplot. To gather samples safely and effectively, we used a hori-hori tool (gardening knife) and gloves to cut plants which possessed a stem, leaf, and flower. Following this, each sample was temporarily labeled with tape and a pen to prevent confusion and disorganization during the identification process. Each temporary label was marked with a 'Sample ID' which included pictures and names for plants "...commonly found on the Hillside since 2011." Whenever a match was found, we entered the "...sample on the datasheet with the Sample ID, description, and identified species"(8). Once we had identified as many species as we could, we confirmed them with Dr. Coffman and received help with samples that were challenging to associate. For samples that we could not identify in time we filled out a Chain of Custody form and submitted it to Dr. Coffman with the corresponding unknown species in a container. Then, for the samples that were deemed correct, we removed all tags and returned the plants to the subplot where they could decompose. Finally, we determined the species richness for our 10ft. X 10ft. subplot by counting the total number of successfully identified plant species.

3.2 - Above Ground Biomass Measurement

In order to measure the above ground biomass, we placed a hula hoop in three randomly selected locations within our 10ft. X 10ft. subplot. For each location we used a hori-hori tool to cut all the above ground biomass within the hula hoop perimeter. After successfully collecting all of the above ground plant matter from a hula hoop sample, we would weigh it using mesh netting and a scale. However, before weighing any of the samples we made sure to balance the scale by hanging the empty netting

from the scale hook. Once the scale was balanced, we would record the weight of the biomass on our data sheet. This process was then repeated for the two remaining hula hoop locations. Next, we used a paper bag to collect a subsample of biomass from the hula hoop samples. We made sure that it was representative of each hula hoop sample by contributing an equal amount of plant matter from each of the three to the bag. The bag was then weighed and placed in a drying oven for a week by Lab Manager Kyle Snow in order to determine its dry weight biomass. Finally, we found the wet-weight above ground biomass by calculating the average weight of the above ground biomass for our plot and recording the final answer in kg/m^2.

3.3 - Collecting Soil Sample

In Lab #3 we conducted two different types of soil sampling. Composite sampling was "...used for most chemical, texture, and organic matter studies"(7). While soil core sampling was "...used specifically for obtaining information on the bulk density, porosity,
and moisture content of the soil"(7). We collected composite samples first by using a random number generator to determine how many feet to move into our 10ft. X 10ft. subplot (from the corner marker) for three different sample locations. Then, for each spot, we recorded its location within the subplot using a tape measure, along with the date, time, weather, and any notable visual observations. Following this, we used a hand auger to "...collect the soil to a depth of at least six inches"(7), while also making sure we were "...retrieving approximately 1/4 liter (about 1 cup) of soil at each location"(7). Second, we placed each soil sample into a plastic bag and marked it with the date, time, and our group ID before thoroughly mixing its contents. Finally, we randomly picked one of the holes created in this process and used it for invertebrates testing which will be detailed in subsequent sections. Upon our return to the lab room, we poured the soil into a '#10 sieve' and removed any vegetation and rocks before sieving the entire sample into a pan. From there, we prepared a portion of the soil to be sent to "Waypoint Analytical Virginia (www.waypointanalytical.com), a Richmond-based environmental laboratory"(7). At this facility, tests were conducted to determine the soils "...organic matter, pH, phosphorus, potassium, calcium, magnesium, sodium, sulfate-sulfur, boron, zinc, manganese, iron, and copper"(7). Next we labeled a Waypoint sample bag and poured the sieved soil up to the fill line. Then, about 200 grams of soil was returned to the labeled plastic bag and placed in a refrigerator by lab manager Kyle Snow for microBIOMETER testing in Lab #4. The remaining soil was placed in a separate plastic container to be air dried for texture tests in lab five.

For soil core sampling, we had to use a different collection method compared to composite sampling because "Using an auger can loosen soil considerably…"(7). To begin, we cleared a small spot of above ground biomass near our augured samples in the 10ft. X 10ft. subplot. Then, we used a mallet to drive a 15 cm long hollow pipe (Diameter of 5.2cm) five centimeters into the ground. Additionally, to make the process more efficient, we held a small wooden block to the top of the

Image 2 & 3: Will Sizemore (left) and Alex Chizmadia (right) using a Hand Auger to dig soil samples for Lab 3

pipe to make hammering easier given the increased surface area. After this step we used a ruler to "...measure the distance inside the pipe from the top of the pipe to the soil surface to subtract this from the total length to make sure there is at least 5 cm of soil within"(7). Next, we used our hori-hori tool to both loosen the soil around the pipe to make removal easier, and then to drive it under the pipe so we could lift it up without losing any soil. Afterwards, we cut away any soil sticking to the outside of the end of the pipe, before using the mallet once again to gently push the soil into a small tin can (Before doing this we had recorded the weight of the empty tin can). We would have measured the length and diameter of the resulting soil plug, however this was not possible because our soil was very brittle due to recent drought. After this, we took some observational notes of the sample before using a scale to record its weight in the tin can. Finally, this sample was placed in an oven for over 24 hours by Lab Manager Kyle Snow to find soil moisture and bulk density calculations later on in lab five.

3.4 - Soil Compaction Measurement

Lab #3 also involved completion of soil compaction tests using a penetrometer. We used the same random number generating method as we did for the composite samples to determine five different locations within the 10ft. X 10ft. subplot for compaction testing. To actually conduct the test, we carefully pushed the conical end of the tester into the ground while making sure not to exceed the red pressure limit line on the dial. Once we reached a point where we could not push any harder, we recorded the maximum pressure on our datasheet. In addition, we also recorded "...the depth of penetration by allowing the wing nut collar on the metal shaft to drop to the soil surface and then tightening the wing nut to mark the shaft"(7) before repeating the process for four different locations.

3.5 - Soil Moisture and Bulk Density

To calculate soil moisture and bulk density in Lab #5, we used our soil core sample from Lab #3 which had been placed in a drying oven for at least 24 hours by this point. First, we weighed the sample and subtracted the mass of the tin can to find its dry weight. Then to calculate the soil moisture percentage, we subtracted the dry weight from the wet weight of the sample recorded in Lab #3, multiplied the result by one-hundred, and divided the final answer by the dry weight.

For bulk density we began by calculating the total volume of our core sample. For this we plugged the dimensions of the pipe that was used to collect the sample into $\pi r^2 h$ (Volume of a Cylinder Equation), wherein 'h' was the distance the pipe was driven into the ground (5cm), and 'r' was the pipe radius. Finally, bulk density was calculated by dividing the dry weight of the core sample by its volume.

3.6 - Soil MicroBIOMETER® Readings

Microbiometer testing was conducted in Lab #4 to determine the level of microbial biomass in our plot as its considered "...the leading indicator of soil health"(10). To begin, we used a microBIOMETER IPAD app provided by JMU, which ran us through the steps required to complete the test. First, we filled an 'extraction tube' with water before emptying a packet of 'extraction powder' inside and whisking it for a few seconds to mix the contents. Then, we filled a syringe with 1mL of the sieved composite soil which had been refrigerated since Lab #3. We compressed the soil to the 0.5mL mark on the syringe to provide a more precise measure of the volume of soil we would add to the extraction tube. After adding the soil to the extraction tube we mixed the solution with an electric stirring tool for

five minutes. Then, we let the tube settle for five minutes, tapped it against the lab table a few times to settle the floating debris, and let it settle for an additional fifteen minutes. After this, we used a pipette to draw solution from about one inch below the surface in order to avoid debris. Then, we applied three drops to a paper sample window, allowing each drop to absorb completely before applying the next. Next, after allowing two minutes for the sample to sit, we used the microBIOMETER app to scan it in order to provide readings on "...microbial biomass (μg C/g), % fungus, fungal concentration (μg C/g), % bacteria, and bacterial concentration (μg C/g) for your sample"(10).

3.7 - Soil Texture Analysis

Determining the soil texture is an important aspect in learning where a particular soil sample lies on the USDA texture triangle, allowing us to classify a sample according to its relative composition of sand, silt, and clay. Our group completed two different tests to determine the texture of the soil. One was completed in the field during Lab #3 while the second was performed in Lab #5.
For the field test, we had one group member gather about a fistfull of soil from our composite sampling site and remove any plant matter and gravel before adding some water to it. Then, they rolled the wet soil into a ball with their hands and the rest of the group recorded how well it held together, the noticeable organic matter, and took a photo for the datasheet submission. Finally, we formed the ball into a ribbon, recorded our observations on how well it held together, how long we were able to make it, and how it felt before taking a second photo for the datasheet.

Completing a chemical determination of soil texture using a hydrometer accounts for the downfalls of the sieve method, which "...works well for separating the gravel, pebbles and larger sand fractions, but does not separate the very fine sand, silt, and clay"(11). We began this test in Lab #5 by adding about 60 grams of soil to a 1,000mL beaker. This soil had been air dried since we took our composite samples in Lab #3. However, before adding the sample, we made sure to tare the balance of the beakers empty weight on the scale. Next, we added about 700mL of deionized water, as well as about 50mL of 0.1 N sodium hexametaphosphate. Moving on, we placed the beaker on an electronic stirring plate and dropped a magnetic bar inside the solution to help mix the contents. We slowly increased the stirring speed until there was a steady whirlpool and let it mix for thirty minutes. After mixing, we added the solution to a 1,000mL graduated cylinder and filled it up to the 1,000mL mark with more deionized water. Next, we used a plunger to slowly mix the suspension before adding a hydrometer setting a forty second timer to record the measurement. After this we removed the hydrometer and recorded the temperature of the solution in Celcius. Then, we repeated this process for two more hydrometer/ temperature readings. Finally, we marked our graduated cylinder with our group name so that Lab Manager Kyle Snow could repeat the mixing and density measurement procedures to measure the density and temperature of the solution after two hours of settling because "Silt takes a full two hours to settle out of solution…"(11).

3.8 - Soil pH

Measuring soil pH is important because most plants have adapted to specific pH ranges. Thus, "The pH is one of many indicators of factors that influence which plants thrive and which plants slowly disappear from what was planted in 2011"(11). To determine the pH of our subplots soil, we weighing out ten grams of field moist soil that had been sieved in lab #3 and adding it to a centrifuge tube. Next, we added 0.01 M $CaCl_2$ solution up to the 45mL mark because "..The calcium ions in this dilute

solution neutralize the negative surface charges on clay particles and release the hydrogen ions"(11). Then, we stirred the mixture for about fifteen seconds and secured a cap before shaking it vigorously for two minutes. Next, we placed the sample in a centrifuge at 1,700RPM for five mins. After this, we used a pipette to draw twenty milliliters of solution to a clean centrifuge tube. Finally, we measured this sample with a pH meter to record the final result.

3.9 - Invertebrate Traps

For the purpose of the Hillside study, collecting invertebrates measurements is important because they are another biological indicator of ecosystem health. As stated in the manual for Lab #3, "Insects are also monitored for ecosystem health reasons when a landscape has been disturbed. In areas where hazardous waste is present, insects often display the first signs of ecological effects"(7). Further, the Hillside is undoubtedly a disturbed environment as it was created from the dumping of dirt involved in the construction of the ISAT building; making this statement ever-relevant to the investigation.

Image 4: Invertebrate trap constructed from Lab 3

To conduct an invertebrates test, we used simple pitfall traps because they are "...especially good tools for arthropods that crawl along the surface of the soil during the day and night"(7). A pitfall trap is essentially a container placed in the Earth so that its opening is level with the ground. To begin, we started by using a hand trowel to modify one of the holes we had created for our composite soil samples to fit an average sized red solo cup. After this, we placed one solo cup into the ground with premade holes in the bottom first before placing a fully intact cup inside of it. Then, we filled the cup with about two inches of the provided preservation solution (propylene glycol, ethyl alcohol, or a soap-water solution) in order to make it challenging for the captured insects to escape. Finally, we placed a plastic cover above the trap to prevent rain from filling up the trap, as well as a rock on top of the cover to prevent the wind from blowing it off.

Image 5: Round 2 Invertebrate Trap Collection

Subsequently, one week later in Lab #4, we removed the trap from the Hillside plot to begin a count of the trapped invertebrates. First, we separated the specimens from the cup by pouring the solution through a sieve. Then, using tweezers, we moved the invertebrates to a paper towel, grouping individuals that were perceived to be of the same species together. With this, we recorded the number of each presumed species, in addition to the total number of captured invertebrates. Using this data, we calculated the Simpson Index of Diversity in order to determine the relative diversity of invertebrate species on our plot. The equation for this is: $D = 1 - \Sigma(\frac{n_i}{N})^2$,

where “n_i” is the total number of individual species, “N" is total number of invertebrates recorded, and “D” is the diversity index.

4. Result and Discussions

- 4.1 - Soil Analysis

4.1.1 - Analysis of Compost Treatment

Compost is a mixture of certain ingredients that are used as plant fertilizers and improves the soil's physical, chemical, and biological properties through natural decomposition through leaves, food waste or manure. The natural plots were untouched and no manure or any sort of fertilizer that could influence any sort of soil parameters or other factors. When analyzing data Table 1, we are looking at various soil characteristic parameters and how they could have been influenced in any sort of way due to the specific compost treated plots and how they contained organic decaying matter or any other possible manure or fertilizer in the soil compared to the natural plots that were not given any special treatment. It becomes apparent that there was no difference between the majority of the soil parameters. When looking at the averages it proves the point even further that there was not that much of an affect for the compost plots then the natural plots, seeing that the averages for Bulk Density was exactly the same at 1.16g/cm^3 for both compost and natural plot samples along with Soil Moisture % averaging out to 8.7% for natural plots and 8.6% for compost plots with only slight differences in sand, clay, and silt percentages throughout the data.

We conducted a T TEST between the one parameter in which the standard deviations and averages were not remotely similar, Average Penetrometer Reading Depth (cm) for natural and compost plots. We then conducted the T TEST for the parameter and got the p value of 0.17. Since it is not less than 0.05, the parameter is not significant enough to be mentioned as evidence that there was a difference between compost and natural plots and their effect on the average Penetrometer Reading Depth (cm). This specific parameter was chosen for the T TEST because the results between compost and natural plots were more different than any other other parameter and had the potential to show how the treatments may differ from each other, but after conducting the T TEST, the p value was closer to significance (<0.05) then expected but was not enough to prove that the treatments for the natural and compost plots had any impact on the soil and the experimented parameter of Penetrometer Reading Depth (cm).

T.TEST

From Excel Formula

=T.TEST((Y21:Y26,Y28:Y33,2,3) on the 2023 Hillside Data 0923 Files

$P\ value\ =\ 0.1716 > 0.05$

Table 1: (4.1.1) The Data from both 320 Sections Comparing Soil Characteristics between Natural and Compost Plots

Instructor	Section/ Group	Plot ID	Treatment type	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %	Soil texture type (refer to the soil texture triangle, Lab #4 and in PPT)
Brent	S1G1	NA1	Natural/None	300	6.0	8.6	0.90	27.3	17.7	55.0	silt loam
Brent	S1G2	NA3	Natural/None	300	5.2	9.6	1.15	27.8	19.3	52.8	silt loam
Brent	S1G3	NA7	Natural/None	170	8.0	8.9	1.11	39.9	17.7	42.5	loam
Brent	S1G4	CP5	Compost	300	5.7	3.3	1.20	29.7	21.0	49.3	loam
Brent	S1G5	CP6	Compost	314	7.8	5.5	1.65	23.6	22.7	53.8	silt loam
Brent	S1G6	CP7	Compost	323	9.4	16.4	0.96	37.5	21.0	41.5	loam
Coffman	S3G1	NA1	Natural/None	300	4.5	7.9	1.57	28.5	22.7	48.8	loam
Coffman	S3G2	NA3	Natural/None	300	3.5	7.8	0.74	27.3	17.7	55.0	silt loam
Coffman	S3G3	NA7	Natural/None	300	4.3	8.5	0.58	37.3	12.7	50.0	loam/silt loam
Coffman	S3G4	CP5	Compost	300	4.6	9.8	0.99	37.8	20.2	42.1	loam
Coffman	S3G5	CP6	Compost	300	5.9	7.8	1.70	29.9	14.3	55.8	silt loam
Coffman	S3G6	CP7	Compost	300	6.4	9.8	1.40	29.8	12.7	57.5	silt loam

HUMAN ERROR

I wanted to point out that there ws human error when conducting this lab and the certain parameters that were affected by the error were bolded in red in Table 1: (4.1.1). They were either above or below the value of 300 psi which affected the parameter of Penetrometer Reading Depth. The evidence of this means that there was also a high possibility that there were other human errors that were prevalent in this lab assessment report.

Table 2: (4.1.1) The Pooled data of both 320 Sections for Compost Plots with their Calculated Averages, Ranges, and Standard Deviation for all Parameters located in Table 1.

COMPOST AMENDED PLOTS	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %
Average	306.17	6.6	8.6	1.16	31.8	16.7	51.5
Range	23	4.8	2.0	0.16	10.5	10.0	15.4
Standard Deviation	9.97	1.70	0.97	0.46	4.58	4.17	5.74

Table 3: (4.1.1) The Pooled data of both 320 Sections for Natural Plots with their Calculated Averages, Ranges, and Standard Deviation for all Parameters located in Table 1.

NATURAL PLOTS	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %
Average	278.3	5.2	8.7	1.16	31.0	19.9	49.2
Range	130	4.5	13.1	0.75	16.3	5.0	13.5
Standard Deviation	53.07	1.58	4.46	0.27	6.35	2.01	5.86

Table 4: (4.1.1) The Soil Chemical data from Waypoint Analytical for Natural and Compost Plots

			WayPoint Results														
Instructor	Plot ID	Treatment Type	Organic Matter	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)	Sodium (Na)	Sulfur (S)	Zinc (Zn)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Boron (B)	Soil pH	Acidity	Cation Exchange Capacity
			%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	pH	meq/100g	meq/100g
Brent	NA1	Natural	6.2	48	221	176	1522	12	15	4.1	48	87	1.0	0.7	6.4	1.0	10.7
Brent	NA3	Natural	5.4	41	71	123	1351	12	21	4.4	66	107	1.2	0.4	6.1	1.3	9.3
Brent	NA7	Natural	7.2	40	100	164	3911	11	13	5.8	113	76	1.5	1.2	7.3	0.0	21.2
Coffman	NA1	Natural	4.1	33	139	136	1256	10	14	3.1	45	99	1.2	0.4	6.4	0.8	8.6
Coffman	NA3	Natural	4.1	34	119	139	1368	11	13	4.1	102	136	1.5	0.5	6.2	1.2	9.6
Coffman	NA7	Natural	5.8	18	77	173	3686	15	12	4.3	98	79	1.8	1.0	7.5	0.0	20.1
Brent	CP5	Compost	5.5	83	139	159	1894	9	13	4.5	75	129	1.5	0.7	6.8	0.3	11.5
Brent	CP6	Compost	6.8	71	141	148	1452	13	13	5.2	79	123	1.0	0.5	6.3	1.1	10.0
Brent	CP7	Compost	7.4	83	146	152	1651	10	14	6.6	87	111	0.8	0.6	6.5	0.8	10.7
Coffman	CP5	Compost	5.8	122	198	137	1683	12	15	4.4	59	129	1.1	0.6	6.5	0.8	10.9
Coffman	CP6	Compost	5.7	64	147	134	1303	10	12	5.9	63	110	1.0	0.4	6.2	1.1	9.2
Coffman	CP7	Compost	7.6	67	117	146	2404	13	18	5.0	102	108	0.9	0.9	7.1	0.0	13.6

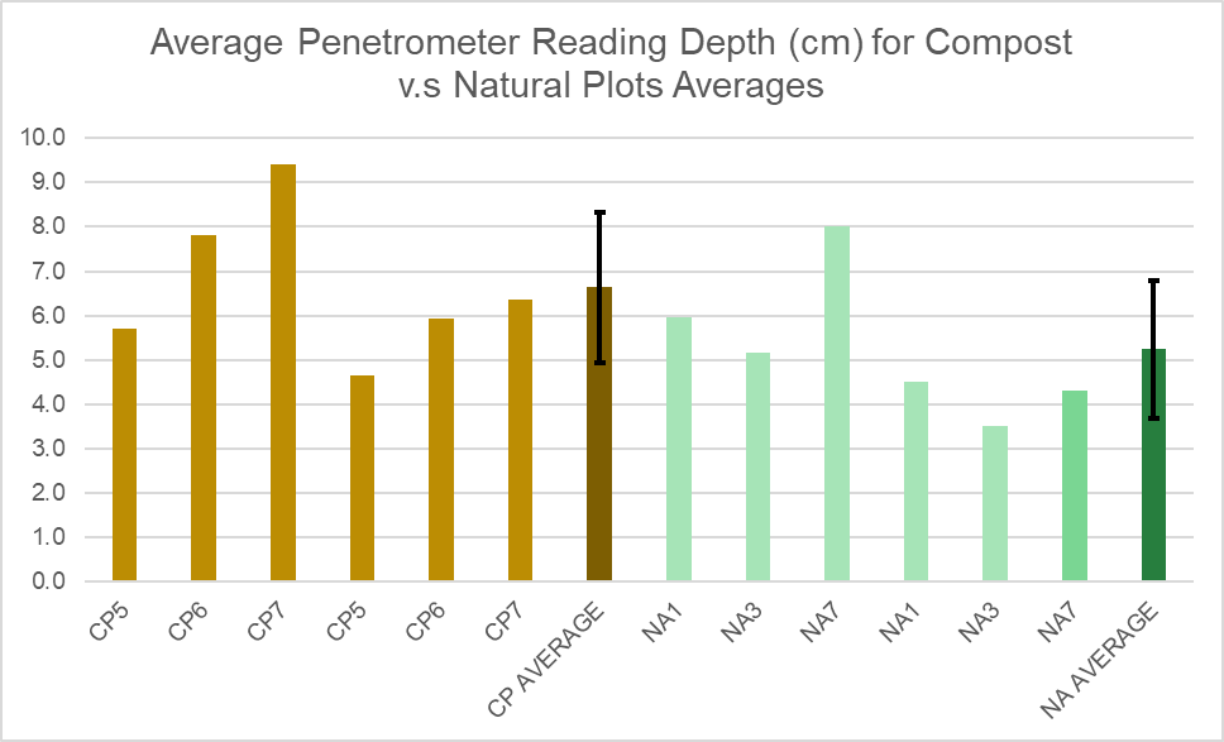
When observing table 4 (4.1.1) and analyzing through the waypoint analytical data on soil chemicals, you don't really pick up any significant difference in the results without deeper analysis of the data. So we must go through the process of calculating the averages, range, and standard deviations of all of the elements to get a better understanding of what elements/chemicals are clearly lopsided and deserve a proper T.TEST to indicate any significant differences between the natural and compost treated plots. When running the calculations of the averages, ranges and standard deviations for the WayPoint Analytical parameters, it became apparent that Phosphorus was definitely a worthy parameter to be evaluated through a T.Test as it had certainly raised the levels of Phosphorus. The average Phosphorus level for all natural plots was 36 ppm, while the compost treated plots average was 82 ppm. After running the T.TESTs, we were able to have one result in which the significance was less than 0.05. Phosphorus (P), scored a p-value of 0.0019 which is <0.05 and therefore meaning that the treatments between the natural and compost treated plots resulted in a difference in Phosphorus levels in ppm in the soil. Phosphorus is a major nutrient for the soil and is necessary for growth and development of plants and is prevalent in fertilizers and manure for enhancing the soil, which is a possible explanation of why there is a high level of Phosphorus in the compost treated plot.

T.TEST

From Excel Formula

=T.TEST=(AI24:AI29,AI30:AI35,2,3) on the 2023 Hillside data 0923 Files

$$P\ value\ =\ 0.0019\ <\ 0.05$$



Graph 1: (4.1.1) This Graph Represents the Data for Compost and Natural Plots for Average Penetrometer Reading Depths (cm) and the Average of all Compost and Natural Plot Data

This graph also has the error bars on the Compost and Natural Plot averages of all the data. Statistically, the T TEST for the Penetrometer Depth Parameter proved that Natural and Compost plots in regard of influence did not have an effect on each other, although relatively close as talked about on Page 13.

4.1.2- Spatial Analysis

When looking over the data for just the natural plots and keeping in mind their spatial position on the Hillside and whether or not it could have any impact on any soil parameters we start to notice slight correlations between spatial position and certain soil parameters, such as NA1 from group S1G1 recorded the highest percentage of silt at the top of the Hillside with 55%, while groups S1G3 and S3G3 recorded the two lowest percentages of silt at 41.5% and 42.5% respectively. Topography has a significant impact on soil formation due to water runoff and erosion is more effective on steeper, unvegetated grounds. The water runoff can strip the soil surface parent material and cause it to run downwards and over time, it has the potential to change the sand, clay, and silt percentages of the soil.

The topography does correlate to the amount of nutrients, organic matter or any weakly developed parent material will be located on the slope. The further down the slope, the better the accumulation of organic material and nutrients. This is all due to water runoff that carries the loose material down the steep slope, building momentum and carrying more sediment with its momentum and mini channels of water, this can also happen when

there are many other factors. For example, when the seasons change from winter to spring and buildup of snow and other soils accumulate with the snow from the snow plows into a mountain of snow on top of the hill, the snow will then melt into water and create water runoff with the newly ripped up dirt soil and would travel down the hillside from the snow mountain that was created from plowing.

Table 1: (4.1.2) Data Table that Compares Plot IDs Physical Soil Parameters by Hillside Position of Top, Middle, and Bottom.

Section/ Group	Plot ID	Spatial Position	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %	Soil texture type (refer to the soil texture triangle, Lab #4 and in PPT)
S1G1	NA1	Top	300	6.0	8.6	0.90	27.3	17.7	55.0	silt loam
S3G1	NA1	Top	300	5.2	9.6	1.15	27.8	19.3	52.8	silt loam
S1G2	NA3	Middle	170	8.0	8.9	1.11	39.9	17.7	42.5	loam
S3G2	NA3	Middle	300	4.5	3.3	1.20	29.7	21.0	49.3	loam
S1G3	NA7	Bottom	300	3.5	5.5	1.65	23.6	22.7	53.8	silt loam
S3G3	NA7	Bottom	300	4.3	16.4	0.96	37.5	21.0	41.5	loam

Table 2: (4.1.2) The Average, Range, Standard Deviation for the Natural Plots Located on the Top of Hillside.

Spatial Position: TOP	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %
Average	300	5.6	9.1	1.03	27.6	18.5	53.9
Range	0	0.79	1	0.25	0.50	1.60	2.20
Standard Deviation	0	0.56	0.71	0.18	0.35	1.13	1.56

Table 3: (4.1.2)The Average, Range, Standard Deviation for the Natural Plots Located in the Middle of Hillside.

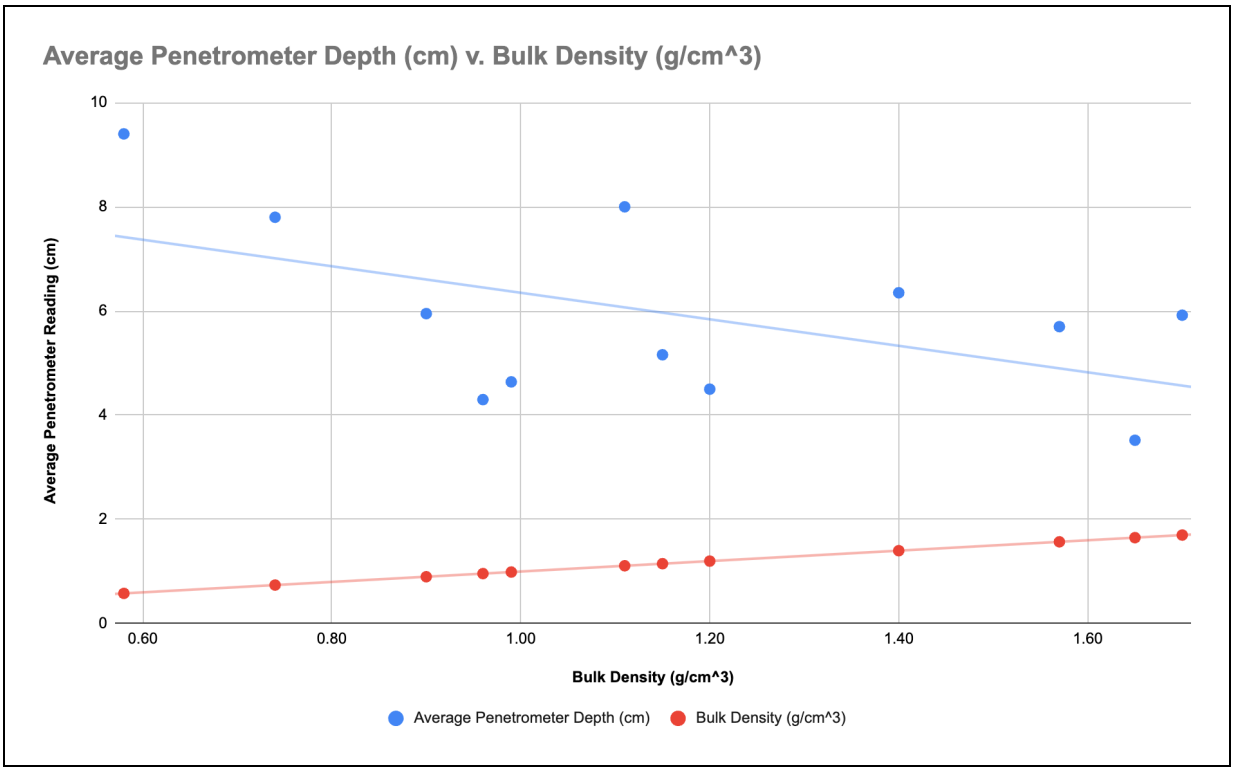
Spatial Position: MIDDLE	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %
Average	235	6.3	6.1	1.16	34.8	19.4	45.9
Range	130	3.5	5.6	0.09	10.2	3.3	6.8
Standard Deviation	91.92	2.47	3.96	0.06	7.21	2.33	4.81

Table 4: (4.1.2) The Average, Range, Standard Deviation for the Natural Plots Located on the Bottom of Hillside.

Spatial Position: BOTTOM	Average Penetrometer Reading Pressure (psi)	Average Penetrometer Reading cm (depth)	Soil Moisture %	Bulk Density g/cm^3	SAND %	CLAY %	SILT %
Average	300	3.9	11.0	1.31	30.6	21.9	47.7
Range	0	0.8	10.9	0.69	13.9	1.7	12.3
Standard Deviation	0	0.55	7.71	0.49	9.83	1.20	8.70

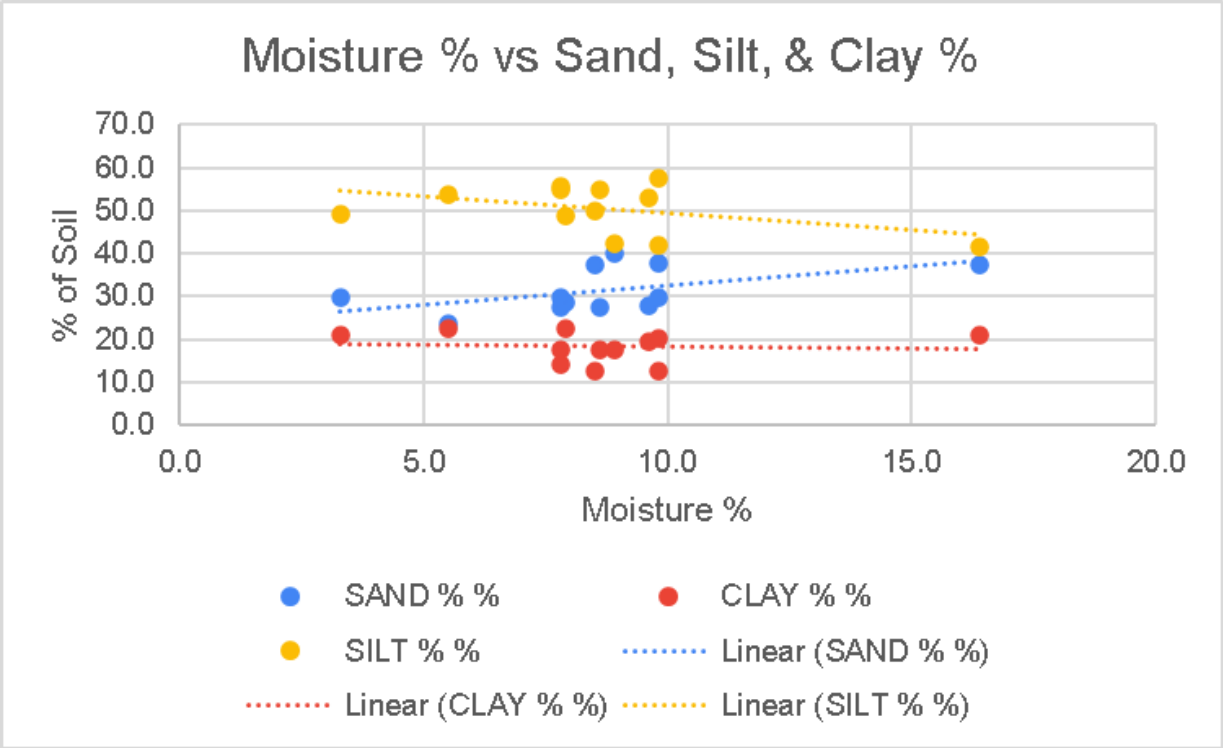
4.1.3 - Parameter Relationships

We hypothesized that the soils with higher percentages of silt would possess a higher moisture percentage because silt has the highest moisture holding capacity out of the three smaller particles of soil (10). That said, clay dominated soils would have the lowest moisture percentage since it has the lowest water holding capacity. We also hypothesized that there would be an inverse relationship between bulk density and average penetrometer reading. Consequently, we predicted groups that have a higher bulk density would have a lower penetrometer reading because the higher the soil compactness is, the more challenging it is to penetrate it, and vice versa.



Graph 1 (4.3): Average Penetrometer Depth (cm) v. Bulk Density (g/cm^3)

Based on our analysis of the relationship between bulk density and the average penetrometer reading, we concluded that there was a slight relationship between the two parameters. In Graph 1 (4.1.3), it demonstrates there being a gradual decrease in the average penetrometer readings as the bulk density slowly increases. It's also notable to mention there was a significant amount of human error within this experiment because on multiple occasions, some groups made mistakes when pressing the penetrometer into the group. For example, groups S1G3, S1G5, and S1G6 had average penetrometer reading in psi of 170 psi, 314 psi, and 323 psi, respectively.



Graph 2 (4.3) : Moisture % vs. Sand, Silt, & Clay %

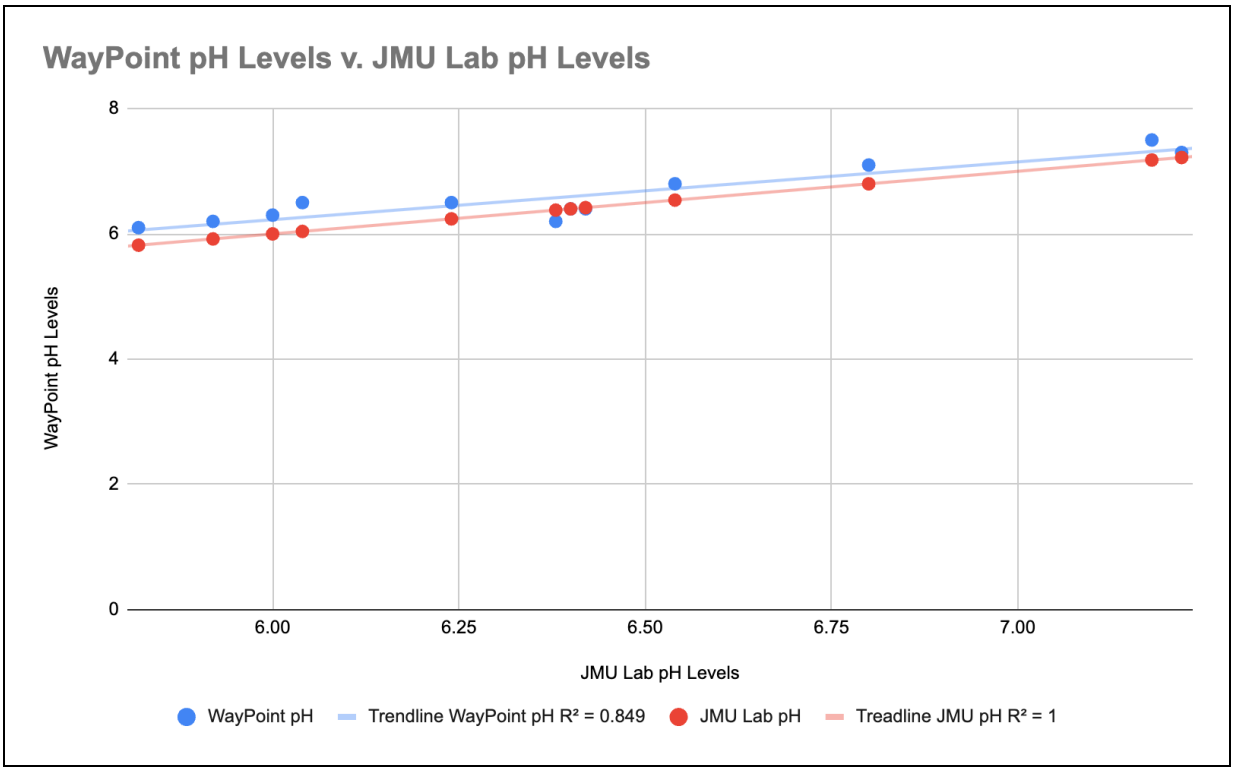
After analyzing the relationship between the moisture, silt, sand, and clay percentages, we determined that as the moisture percentage increased, the sand percentage of the soil increased, while the silt percentage decreased. Overall, this finding contradicts our hypothesis that there would be a higher water and silt percentage, leading us to believe the data to be misleading. We've come to this conclusion because silt possesses a higher water holding capacity than sand according to Lab 3 (7). Overall, we attribute this information to human errors which led to miscalculations when measuring the moisture percentage within the soil.

4.1.4 - Measurement Variability

Table 1: (4.1.4) Soil pH Measurement Variability

Group ID	Plot ID	Treatment type	Soil pH (Section 1) (Brent)	Soil pH (Section 3) (Coffman)	Mean	Standard Deviation	Coefficient of Variation
G1	NA1	Natural/ None	6.40	6.42	6.41	0.0	0.0022
G2	NA3	Natural/ None	5.82	6.38	6.1	0.4	0.0649
G3	NA7	Natural/ None	7.22	7.18	7.2	0.0	0.0039
G4	CP5	Compost	6.54	6.24	6.39	0.2	0.0332
G5	CP6	Compost	6.00	5.92	5.96	0.1	0.0095
G6	CP7	Compost	6.04	6.80	6.42	0.5	0.0837

From this data, we can see there was low variability in plots NA1, NA7, and CP6 while plots CP 7, CP5, and NA3 had high variability. That being said, we attribute this variability to the random samples of the soil within each plot and that our soil does not have uniform pH levels. We discern no reasonable pattern between the treatment type of the plot and the variability of the pH levels.



Graph 1 (4.1.4): WayPoint pH Levels v. JMU Lab pH Levels

From this graph, we see the soil pH testing conducted in the JMU lab had a R value of 1 while the WayPoint soil tests had a R value of .849. To our surprise, this means that the testing done in our lab was indicative of perfect measurements while the WayPoint demonstrated variations within their tests; we expected the WayPoint tests to demonstrate perfect measurements since they possess more advanced measuring equipment enabling them to make more accurate examinations. We believe the methodology of examining the soil contents would be an attributable source of variation, which then leads to varying results.

- 4.2 - Plant Identification and Above Ground Biomass

Determining the number of species present and the number of individuals in those species can prove useful when observing a community such as the Hillside. To that end, Table 1 lists the plant species collected on August 30th, 2023 in Lab 2.

Table 1: (4.2) S3G4 Hillside Species Identified

Sample ID	Common Name
S3G4_SP1	Black Eyed Susan
S3G4_SP2	Brown Eyed Susan
S3G4_SP3	Switchgrass
S3G4_SP4	Sweet Goldenrod
S3G4_SP5	Blackberry
S3G4_SP6	Wild Bergamot
S3G4_SP7	Curly Dock
S3G4_SP8	Burdock
S3G4_SP9	Tall Goldenrod
S3G4_SP10	Aster
S3G4_SP11	Young Mulberry

In order to understand how the Hillside CP5 plot has changed over time, it is useful to compare which species were collected as part of the procedure of Lab 2 and the total species originally planted on the Hillside. The original Hillside species are listed in Tables 4 and 5 in Lab 2, and in Table 2 in this report.

Table 2: (4.2) Originally Planted Hillside Species

Common Name	Botanical Name
Common milkweed	Asclepias syriaca
Butterfly weed	Asclepias tuberosa
Columbine	Aquelegia canadensis

New England aster	Aster nova-angliae
Aromatic aster	Aster oblongifolius
Heath aster	Aster pilosus
Wild blue indigo	Baptisia australis
Partridge pea	Chamaecrista fasciculata
Woodland sunflower	Helianthus divaricatus
Oxeye sunflower	Helianthus helianthoides
Shaggy blazing star	Liatrus pilosa
Blazing star	Liatrus spicata
Wild bergamot	Monarda fistulosa
Bee balm	Monarda punctata
Appalachian beardtongue	Penstemon canescens
Black-eyed Susan	Rudbeckia hirta
Brown-eyed Susan	Rudbeckia triloba
Wild senna	Senna hebecarpa
Early goldenrod	Solidago juncea
Grey goldenrod	Solidago nemoralis
New York ironweed	Vernonia noveboracensis
Slender mountain mint	Pycnanthemum tenufolium
Big bluestem	Andropogon gerardii
Broomsedge bluestem	Andropogon virginicus

Sideoats grama	Bouteloua curtipendula
Switchgrass	Panicum virgatum
Little bluestem	Schizachyrium scoparium
Indiangrass	Sorghastrum nutans

There are 28 species listed in Table XX, compared to 11 listed in Table X. However, four of the eleven species appearing in Table X were not originally planted on the Hillside. During the procedure of Lab 2, a botanical taxonomy book was consulted that gave slightly different names as the Lab 2 tables Table XX is sourced from. As a result, the "sweet" and "tall" goldenrod listed in Table X will both be respectively considered of the same species as the original "early" and "grey" goldenrods planted. Counting in this way gives a percentage of

$$\frac{7\ species}{28\ species} = 0.25,\ 25\%, \frac{11\ species}{28\ species} = 0.39,\ 39\%$$

Only 25% of the original species planted on the Hillside were identified by S3G4. Counting only the number of species with no concern for matching identified to original species, S3G4 counted about 39% of 28 total species. The Blackberry, Burdock, Curly dock, and Young mulberry species were all new arrivals to the Hillside, not being intentionally planted.

The missing 21 species that were originally planted were most likely out-competed for resources by the species that were identified in the CP5 Hillside plot. The combination of mowing requiring frequent, costly energy expenditures for regrowth and poor soil nutrition caused by years of lawn grass being planted on the Hillside prior to the start of the Hillside planting also likely played a part in determining which species would thrive on the Hillside and which would be out-competed. For example, Switchgrass grows best in full sun and with moist soil, but is highly adaptable to other soil conditions, and can grow back relatively quickly. This makes it an ideal candidate for the Hillside especially when compared to a plant such as the Slender mountain mint, which is more limited in its soil moisture requirements and regrowth capability. The Switchgrass's most important property is shared across many of the identified plants in Table X; they are adaptable to disturbances ("Virginia Native Plant Guides").

Due to the treatment the Hillside received prior to its first planting, some plots are fertilized and some are natural soil. It is useful to compare the species richness, Simpson Diversity Index (S.D.I), and

total aboveground biomass across these natural and composted plots so as to gain understanding of how the various plant species, and the total amount of life present aboveground, are spread across the Hillside, and how the compost and natural soil each impacted the life on the Hillside. Table 3 displays the average species richness and S.D.I. for each plot (NA1, 3, and 7, and CP5, 6, and 7) from both class sections that took measurements for those plots, as well as the total average of all 6 measurements taken from both the natural and compost plots.

Table 3: (4.2) Plots' Species Richness & Diversity Index Averages

Plot ID	Plant Species Richness	Plant Diversity Index	Above Ground Biomass ($\frac{kg}{m^2}$)
NA1 (S1&3 G1 avg.)	11.5	0.625	0.660
NA3 (S1&3 G2 avg.)	14.0	0.745	0.935
NA7 (S1&3 G3 avg.)	8.50	0.09	0.440
CP5 (S1&3 G4 avg.)	6.50	0.725	0.490
CP6 (S1&3 G5 avg.)	12.0	0.65	1.155
CP7 (S1&3 G6 avg.)	8.50	0.615	0.625
All Natural Plots Average	9.67	0.49	0.678
All Treated Plots Average	9.00	0.66	0.756

The natural plots have a higher average Species Richness, while the compost plots have a higher Diversity Index and biomass. The Diversity Index accounts for the number of individuals present in each species, and so the compost plots having the greater D.I. but lower Richness shows that while there were a greater number of species on the natural plots, there were more individuals of the species present on the compost plots. The compost plots also displayed a higher above ground biomass which also backs this interpretation up. One possible reason for this phenomenon has to do with the species that weren't originally planted on the Hillside being part of the samples collected. Perhaps the purposely-planted species are better suited to the natural plots while the species that migrated onto the Hillside grew better in the compost plots. Invasive species sometimes excel at overtaking native species in part because they can grow and spread quickly, and two of the four migratory plant species found (the Curly Dock and Mulberry) are invasive to Virginia ("Virginia Invasive Plant Species List"), which

could explain why there were more individuals in the species on the compost plots, as the added nutrients gave these invasive species more than enough energy to overtake the natural plots' plants that were adapted to the natural soil of the Hillside.

Comparing the different sections' natural and treated plots values reveals some interesting data trends that deserve a t-test to determine their statistical significance. The species richness of two of the three natural and compost plots increased, with the NA1 and CP6 plots making especially large gains. Using a t-test, we can investigate the significance of the natural and compost plots datas' behavior.

Starting with the natural plots, we'll assign Section 1's data for $mean_1$ and Section 3's data for $mean_2$ (this same data-grouping structure will be applied to every t-test, with Section 1 always being $mean_1$ and Section 3 always being $mean_2$).

$$mean_1 = \frac{8+8+9}{3} = 8.333, mean_2 = \frac{15+10+8}{3} = 11$$

$$s(diff) = 4.041$$

$$t = \frac{mean_1 - mean_2}{\frac{s(diff)}{\sqrt{n}}} = \frac{8.333-11}{\frac{4.041}{\sqrt{3}}} = -1.143$$

From Excel Formula =T.TEST(E4:E6,E10:E12,2,1) on the 2023 Hillside Data 0923 File,

$$P\ value = 0.3715$$

A P value greater than 0.05 means we fail to reject the null hypothesis for this data set, or in less statistical terms, the data points hold no statistical significance from Section 1 to Section 3's data for species richness of natural plots.

We'll perform the same test on the species richness values for the compost plots.

$$mean_1 = \frac{9+10+10}{3} = 9.667, mean_2 = \frac{4+14+7}{3} = 8.333$$

$$s(diff) = 4.726$$

$$t = \frac{mean_1 - mean_2}{\frac{s(diff)}{\sqrt{n}}} = \frac{9.667-8.333}{\frac{4.726}{\sqrt{3}}} = 0.489$$

From Excel Formula =T.TEST(E7:E9,E13:E15,2,1) on the 2023 Hillside Data 0923 File,

$$P\ value = 0.6734$$

Once again, a P value greater than 0.05 means we fail to reject the null hypothesis for this data set; the data points also hold no statistical significance from Section 1 to Section 3's data for species richness of compost plots.

While the Plant Diversity Index values do not show any immediately intriguing behavior, the Above Ground Biomass values certainly do, with wide variance from section to section across both types of plots. Keeping the same sections for data sets 1 and 2,

$$mean_1 = \frac{0.92+1.24+0.37}{3} = 0.8433, mean_2 = \frac{0.40+0.63+0.51}{3} = 0.5133$$

$$s(diff) = 0.4104$$

$$t = \frac{mean_1 - mean_2}{\frac{s(diff)}{\sqrt{n}}} = \frac{0.8433-0.5133}{\frac{4.104}{\sqrt{3}}} = 0.139$$

From Excel Formula =T.TEST(E4:E6,E10:E12,2,1) on the 2023 Hillside Data 0923 File,

$$P\ value = 0.2969$$

This P value represents yet another statistically insignificant data set for the Diversity Index of natural plots. Finally, we'll put the compost plots values through a t-test.

$$mean_1 = \frac{0.49+0.7I\,9+0.73}{3} = 0.57, mean_2 = \frac{0.49+1.52+0.82}{3} = 0.94$$

$$s(diff) = 0.36529$$

$$t = \frac{mean_1 - mean_2}{\frac{s(diff)}{\sqrt{n}}} = \frac{0.57-0.94}{\frac{0.36529}{\sqrt{3}}} = -1.75438$$

From Excel Formula =T.TEST(I7:I9,I13:I15,2,1) on the 2023 Hillside Data 0923 File,

$$P\ value = 0.2187$$

This P value completes our set of four statistically insignificant comparisons, between the natural and compost plots' species richness and above ground biomass. The largest probable contributor to none of these relationships bearing significance is human error. The fact that the labs were the first time many students were exposed to the measuring tools and techniques necessary to gather data, combined with the Hillside lab area itself which, especially on hot and dry days deep into drought such as the ones our data were collected on, is likely to produce a number of measuring errors, leads to a high likelihood the data collected is not of the highest possible quality.

Biomass is defined as the weight or the total quantity of one species of animal or plant, or the weight/quantity of all the species in a community or otherwise defined area ("Biomass | Definition, Types, & Facts"). It can be measured as wet weight, with the moisture content of the biomass included in the measurement, or dry weight, once the sample material has completely dried out (often with the assistance of a heating process). In terrestrial environments, biomass is typically measured in $\frac{g}{m^2}$.

Above ground dry weight biomass data were collected on the ISAT Hillside as part of the procedure of

Lab 2. Table 4 displays both our and section one's above ground biomass data and soil parameters, as well as the soil moisture percentage for each section.

Table 4: (4.2) Above Ground Biomass, Soil Moisture, & Soil Parameters

Dry Weight Above Ground Biomass per area	Soil Moisture	Section/ Group	Plot ID	Treatment type	Organic Matter	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)	Sodium (Na)	Sulfur (S)	Zinc (Zn)	Manganese (Mn)	Iron (Fe)	Copper (Cu)	Boron (B)	Soil pH	Acidity	Cation Exchange Capacity
kg/m^2	%				%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm		meq/100g	meq/100g
0.92	8.6	S1G1	NA1	Natural/None	6.2	48	221	176	1522	12	15	4.1	48	87	1.0	0.7	6.4	1.0	10.7
1.24	9.6	S1G2	NA3	Natural/None	5.4	41	71	123	1351	12	21	4.4	66	107	1.2	0.4	6.1	1.3	9.3
0.37	8.9	S1G3	NA7	Natural/None	7.2	40	100	164	3911	11	13	5.8	113	76	1.5	1.2	7.3	0.0	21.2
0.49	7.9	S1G4	CP5	Compost	5.5	83	139	159	1894	9	13	4.5	75	129	1.5	0.7	6.8	0.3	11.5
0.79	7.8	S1G5	CP6	Compost	6.8	71	141	148	1452	13	13	5.2	79	123	1.0	0.5	6.3	1.1	10.0
0.43	8.5	S1G6	CP7	Compost	7.4	83	146	152	1651	10	14	6.6	87	111	0.8	0.6	6.5	0.8	10.7
0.40	3.3	S3G1	NA1	Natural/None	4.1	33	139	136	1256	10	14	3.1	45	99	1.2	0.4	6.4	0.8	8.6
0.63	5.5	S3G2	NA3	Natural/None	4.1	34	119	139	1368	11	13	4.1	102	136	1.5	0.5	6.2	1.2	9.6
0.51	16.4	S3G3	NA7	Natural/None	5.8	18	77	173	3686	15	12	4.3	98	79	1.8	1.0	7.5	0.0	20.1
0.49	9.8	S3G4	CP5	Compost	5.8	122	198	137	1683	12	15	4.4	59	129	1.1	0.6	6.5	0.8	10.9
1.52	7.8	S3G5	CP6	Compost	5.7	64	147	134	1303	10	12	5.9	63	110	1.0	0.4	6.2	1.1	9.2
0.82	9.8	S3G6	CP7	Compost	7.6	67	117	146	2404	13	18	5.0	102	108	0.9	0.9	7.1	0.0	13.6

Section one's natural plots average biomass was 0.84, and their compost plots' average was 0.57. Compared to our section's natural plots average of 0.51 and compost plots' average of 0.94, the natural plots biomass decreased by about a third, while the compost plots' biomass almost doubled (with every biomass measurement sharing units of $\frac{kg}{m^2}$). The different plots' soil organic matter (OM) levels could explain this trend. Two of the three compost plots' OM levels increased from section to section, while all of the natural plots' OM levels decreased. This speaks to the natural plots' soil quality decreasing, as OM levels are one of the telltale signifiers of healthy, nutrient-rich soil. Of course, a decrease in nutrients in the soil on the natural plots would explain why the overall biomass on the natural plots decreased, as they would not be able to support as much life as was previously possible due to a decrease in nutrient cycling and other benefits OM typically brings to soil. The two compost plots that showed an increase in OM levels, CP5 and CP7, also show this relationship: CP5's biomass remained the same and CP7's almost doubled from Section 1 to Section 3's measurements. This behavior also suggests OM levels could be a major influencer on the above ground biomass measured for each plot. Due to the weeks of drought the Hillside experienced prior to our soil sampling, and disregarding the 16.4% outlier collected by S3G3, the natural plots' moisture levels were much lower than the compost plots', which could also contribute to the biomass relationship described above.

- 4.3 Microbial and Invertebrate Communities

Microbial

Table 1 (4.3): microBIOMETER Reading for both ISAT 320 Sections

Instructor	Section/ Group	Plot ID	Treatment type	Microbial Biomass Concentration (MBC in $\mu g\ C/g$	Fungal to Bacterial Ratio (F:B)	Fungi %	Fungal Biomass Concentration ($\mu g\ C/$) (column 1 x column 3)	Bacteria %	Bacterial Biomass Concentration ($\mu g\ C/$) (column 1 x column 5)
Brent	S1G1	NA1	Natural/None	118.0	0:1	3.0	3.5	97.0	114.5
Brent	S1G2	NA3	Natural/None	67.0	0:1	3.0	2.0	97.0	65.0
Brent	S1G3	NA7	Natural/None	136.0	0.1:1	8.0	10.9	92.0	125.1
Brent	S1G4	CP5	Compost	32.0	0:1	1.0	0.3	99.0	31.7
Brent	S1G5	CP6	Compost	105.0	0.1:1	6.0	6.3	94.0	98.7
Brent	S1G6	CP7	Compost	202.0	0.3:1	22.0	44.4	78.0	157.6
Coffman	S3G1	NA1	Natural/None	66.0	0:1	3.0	2.0	97.0	64.0
Coffman	S3G2	NA3	Natural/None	72.0	0:1	3.0	2.2	97.0	69.8
Coffman	S3G3	NA7	Natural/None	53.0	0:1	1.0	0.5	99.0	52.5
Coffman	S3G4	CP5	Compost	56.0	0:1	0.0	0.0	100.0	56.0
Coffman	S3G5	CP6	Compost	113.0	0.1:1	8.0	9.0	92.0	104.0
Coffman	S3G6	CP7	Compost	147.0	0.1:1	11.0	16.2	89.0	130.8
Average				97.3		5.8	8.1	94.3	89.1
Ranges				170		22.0	44.4	22.0	125.9
Standard Deviation				48.74		6.11	12.47	6.11	38.14

Our hypothesis when analyzing the data was that the Hillside was in poor/suboptimal condition given the lack of rainfall in the weeks leading up to the Hillside experiments. After reviewing the microBIOMETER readings, it supports our hypothesis because it demonstrates zero fungal growth within our soil, which is a key indicator of soil health (Coffman, 2023).

Based on the data provided in Table 1, it's clear that bacteria dominates the microbial biomass concentration within the soil samples of both the compost and natural plots. As previously stated, we attribute this imbalance of microbial biomass to the weather conditions (as demonstrated by our pyramid in Introduction). We believe the lack of rainfall from the weeks leading up to the soil testing has had the greatest impact in regards to the microbial populations within the soil; even more significant than pH levels, organism matter percentages, and nutrients within the soil. According to the National

Library of Medicine, fungi require a significant amount of moisture (roughly 70% humidity for longer than three days) and little to no airflow within the soil to survive (Cordereo, 2013). According to our data, the average moisture percentage of the soil across both sections was approximately 8.7% with average bulk density of 1.16. That being said, the moisture percentage alone demonstrated the soil's inability to sustain fungal growth, which constitutes poor overall soil. In addition with a low bulk density, that means our porosity would be higher (because they have an inverse relationship), which means greater airflow within the soil and consequently little to no fungal growth.

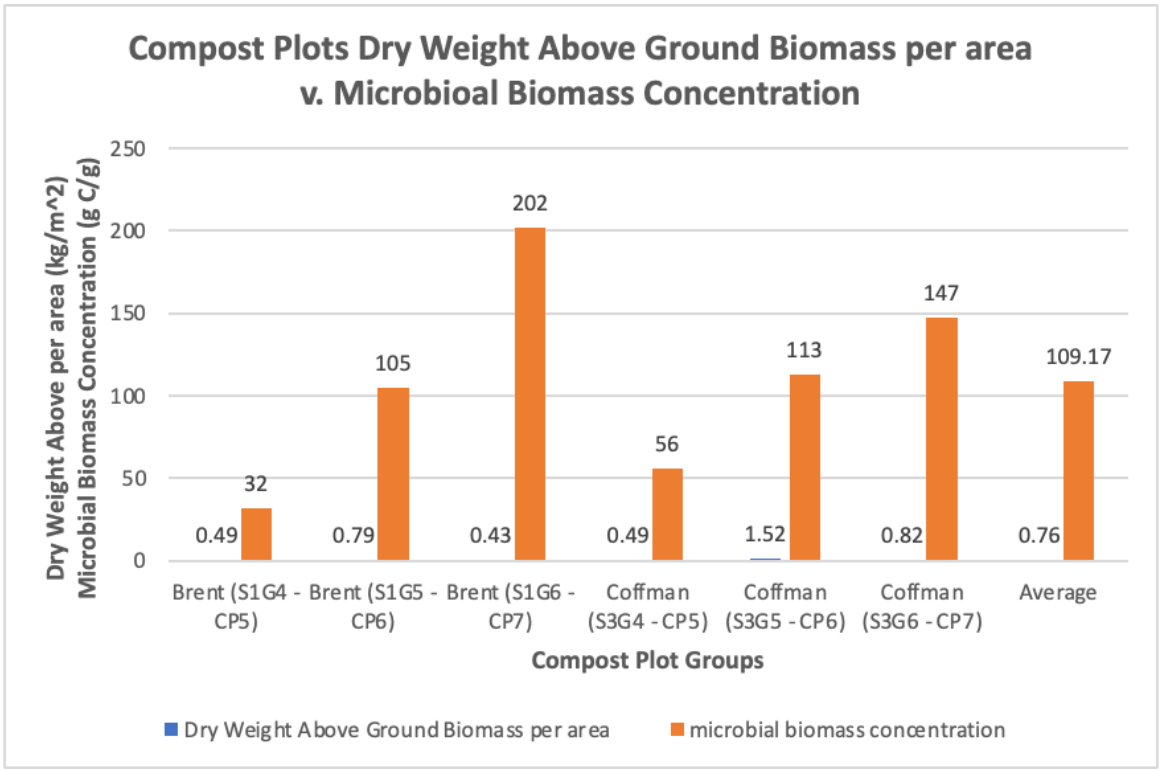
However, a couple groups demonstrated relatively high fungal amounts compared to the average of both sections. S3G6 - CP7 had 11% fungus, S1G6 - CP7 had 22% fungus, and S1G3 - NA7 and S3G5 - CP6 had 8% fungus. We attributed these high - above average amounts of fungal growth to the geographical location of the plots within the Hillside. Since those plots are located at the lowest points of the Hillside, runoff from higher plots could've washed downhill into those plots, thus increasing the fungal growth within them. In addition, with char plots located directly above and in a linear runoff path to NA7, CP6, and CP7, it's reasonable to assume vital nutrients from the biochar like organic carbon, magnesium, potassium, and calcium would have an impact on overall fungal growth. Especially with plot CP7 with its proximity to BC4, a biochar plot, and its position in the runoff path, its extremely high 22% and 11% fungal growth is reasonable.

Above Ground Biomass per area

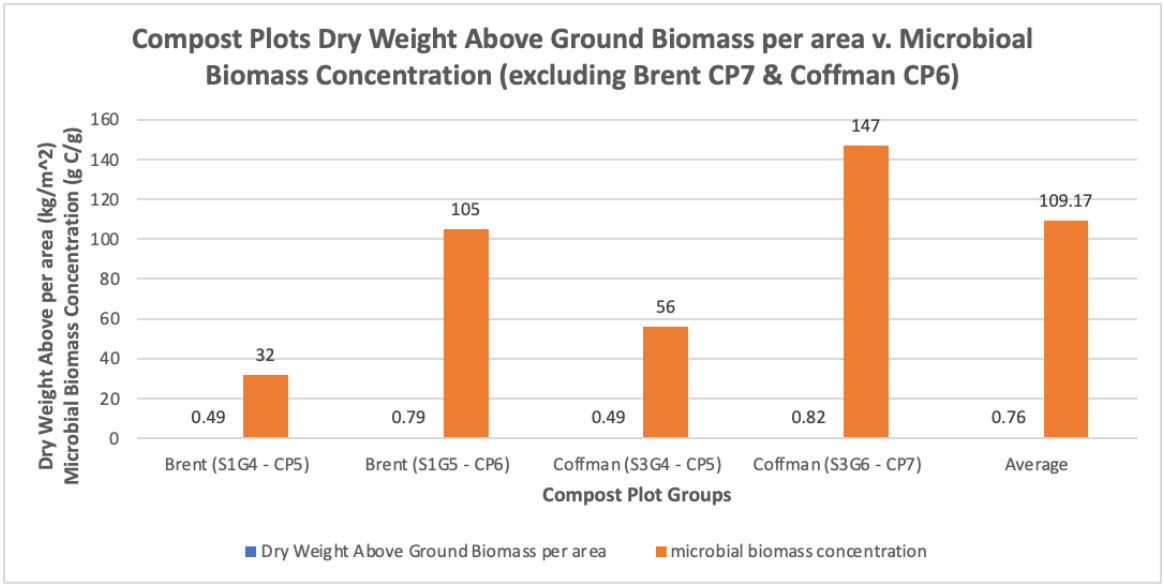
After analyzing the data and observing the trends regarding the above group biomass per area, then relating the values to their respective compost or natural plot averages, the compost plot demonstrated a slight pattern that supports our hypothesis, as depicted in Graph 1, with some outliers while the natural plots in Graph 3 demonstrated no evidence between the microbial biomass and dry weight of biomass to support our hypothesis.

In Graph 1, it compared the values of the compost dry plots dry weight above ground biomass per area with the microbial biomass concentration, where we concluded there were two outliers that demonstrated unusual trends, those being Brent (S1G6 - CP7) and Coffman (S3G4 - CP5). This trend is better represented in Graph 2 where it shows the same data excluding the two outliers. As you can see, there is a loose correlation between the amount of microbial biomass and the amount of dry weight biomass accumulated from the soils. Though the relationship between the microbial and dry weight biomass isn't specific, it demonstrates a general positive correlation where if one value rises (the

microbial biomass) so does the other (the dry weight biomass). Therefore, partly supporting our hypothesis.

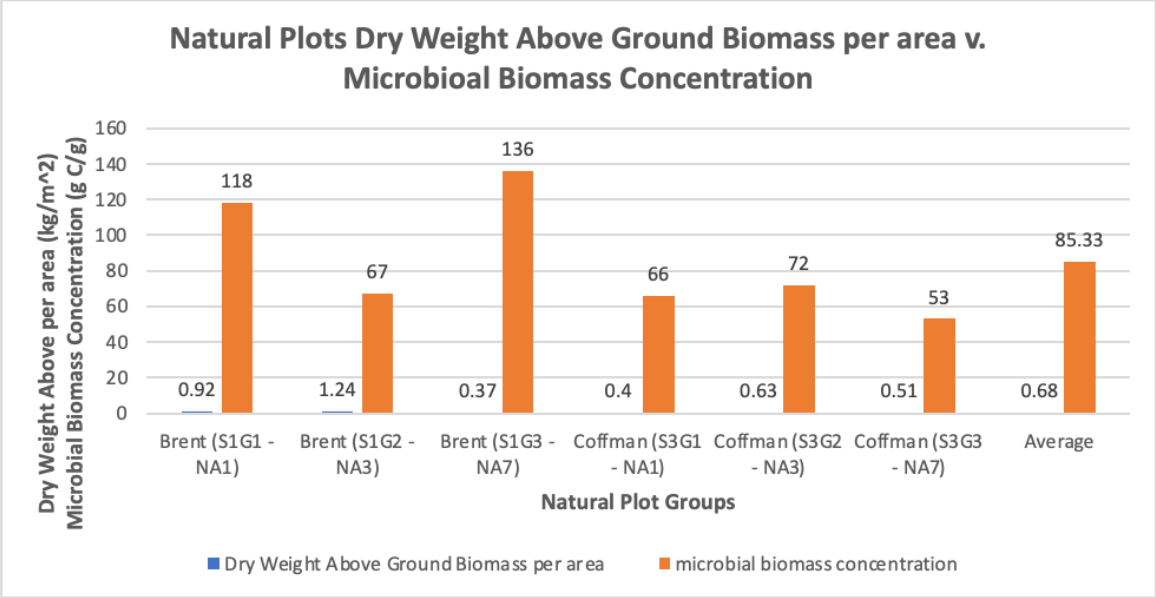


Graph 1(4.3): Compost Plots Dry Weight Above Ground Biomass per area v. Microbial Biomass Concentration



Graph 2(4.3): Compost Plots Dry Weight Above Ground Biomass per area v. Microbial Biomass Concentration (excluding Brent CP7 & Coffman CP6)

In regards to the natural plots, there seems to be no correlation/relationship with the microbial biomass and dry weight biomass with the data between both sections demonstrating extreme variability and inconsistency. For example, in plot NA1, S1G1 obtained a microbial biomass concentration of 118 $\mu g\ C/g$ with a dry weight biomass of .92 kg/m^2 while S3G1 (also in NA1) obtained a microbial biomass of 66 $\mu g\ C/g$ with a dry weight biomass of .4 kg/m^2. Another example was plot NA7 with S3G3 presenting .51 kg/m^2 dry weight biomass with a microbial biomass of 72 $\mu g\ C/g$ while S1G3 presented .37 kg/m^2 dry weight biomass with a microbial biomass of 136 $\mu g\ C/g$.



Graph 3 (4.3): Natural Plots Dry Weight Above Ground Biomass per area v. Microbial Biomass Concentration

From these graphs, there isn't much data to present any impact microbial biomass may have on above ground biomass because it is extremely varied, however, we know there is a positive correlation between them. With that, we believe that if this experiment was elongated to cover the span of multiple months (for example, 6 months), then we could gather sufficient data that could show how there is a relationship between the microbial biomass abundance and above ground biomass abundance, therefore, make a better conclusion to determine if our hypothesis was correct or not.

Plant Identification

As stated previously, our plot only had 7 of the 28 (or roughly 25%) plant species originally planted on the Hillside. The following presents the names of each plant identified from the plot and

brief descriptions of their soil/climate preferences (from Table 1(4.2): S3G4 Hillside Species Identified):

- Black Eyed Susan: This plant prefers slightly acidic soils (less than 6.8 pH) that are moist to moderately dry with full sun exposure (United States Department of Agriculture).
- Brown Eyed Susan: This plant prefers full sun exposure in sandy, loamy soils with moderate moisture, but can tolerate drought (University of Wisconsin-Madison).
- Switchgrass: This plant prefers dry to poorly drained, sandy to clay loamy soils. It can't grow in very dense (or high bulk density) soils (United States Department of Agriculture Natural Resources Conservation Service)
- Sweet Goldenrod: This plant thrives in dry sandy or loamy drained soils with a pH less than 6.8 (acidic). It is able to grow in soils with little nutrients (Greenfield Community College).
- Blackberry: This plant prefers well-drained or loamy soils with a pH between 5.5 to 6.8 (acidic) with sufficient organic matter to improve aeration, drainage, and water holding capacity (Vossen).
- Wild Bergamot: This plant prefers dry, well drained soils (Jubenville & Kerr, 2023).
- Curly Dock: This plant prefers to be fully exposed to the sun in moist soil but can tolerate temporary drought, flooding, and mowing (Weld County Public Works Dept., Weed Division)
- Burdock: This plant can grow in most soils but prefers well drained soils with humus (Stephens, 2018)
- Tall Goldenrod: This plant prefers to grow in drier soils on open lands (Taylor
- Aster: This plant prefers to grow in well drained, loamy soils that are slightly acidic (5.8 - 6.5), but is tolerable of poor, dry soils (Gilmen, Klein, Hansen, 2021)(Adams Fairacre Farms, 2022)
- Young Mulberry: This plant prefers to grow in various soil types like sandy, loamy, and clay soils that are nutrient dense and slightly acidic to neutral (pH 6 to 7) (Pino, 2023).

[References to each plant's information is located in '4.3 References']

From this collection of data, the most common soil characteristics shared amongst this collection of plants is the ability to tolerate or prefer moderate to dry soils, preference to acidic soil (roughly around a pH of 5 - 6.8), and a preference to loamy soil. These characteristics indirectly correlate to the patterns within the microbial biomass concentration as it demonstrates the relationship that moisture percentage and climate has on both of them. The combination of drought and low moisture levels led to a significantly low to no amount of fungi within most of the groups' plots while also affecting the species of biomass present in them. For our plot, S3G4 - CP5, we had only plants that were tolerable of the micro drought and dry soil that came with it. That being said, this information

supports our hypothesis that the Hillside soil was poor/suboptimal because it demonstrated that only plants that are tolerable of dry, low moisture soil are present in the plot while other plants with different preferences weren't available. This means that there isn't a large enough biomass abundance and diversity representative of all of the originally planted plants in the Hillside.

It's important to note throughout the entire Hillside experiment that there are major sources of human error, so it's challenging to propose an accurate conclusion regarding the health of the Hillside as a whole. An example of this would be the immense variation between data points about the plots' dry weight biomass and microbial biomass between both sections, where the data followed no clear, evident patterns.

Invertebrates

Table 2 (4.3): Invertebrates for ISAT 320 Brent & Coffman lab groups

	ISAT 320 Hillside Invertebrates Results						
				Round 1 (Lab 4)		Round 2 (Lab 5)	
Instructor	Section /Group	Plot ID	Natural/None	Species Richness	Species Diversity	Species Richness	Species Diversity
Brent	S1G1	NA1	Natural/None	1	0.00	0	0.00
Brent	S1G2	NA3	Natural/None	4	0.46	2	0.56
Brent	S1G3	NA7	Natural/None	2	0.17	4	0.72
Brent	S1G4	CP5	Compost	4	0.65	4	0.61
Brent	S1G5	CP6	Compost	4	0.45	2	0.41
Brent	S1G6	CP7	Compost	4	0.71	3	0.56
Coffman	S3G1	NA1	Natural/None	6	0.82	6	0.76
Coffman	S3G2	NA3	Natural/None	3	0.53	0	0.00
Coffman	S3G3	NA7	Natural/None	4	0.55	6	0.78
Coffman	S3G4	CP5	Compost	5	0.66	5	0.69
Coffman	S3G5	CP6	Compost	4	0.23	2	0.44
Coffman	S3G6	CP7	Compost	5	0.48	2	0.45

For the first round of invertebrate testing, our group's plot, S3G4 - CP5, presented a species richness and species diversity of 5 and 0.66 respectively, and for the second round a species richness of 5 and species diversity of 0.69 respectively. These values, compared to other groups within both ISAT 320 lab sections, are above average in both respects. Attributable factors to our invertebrate trap results include the quality of the soil and the quality of the pitfall trap itself.

Our plot was labeled as a compost plot, meaning organic matter was buried there. Despite that, our organic matter percentage was within the average at 5.8%. That being said, with organic matter being composted within our soil, it meant there were going to be vital nutrients like phosphorus, nitrogen, potassium, calcium, magnesium, and sulfur present within our soil. The results from WayPoint Results solidify it with our nutrient values (in ppm) hovering near or above the average. Table 1.0 presents the nutrient values for our plot and of the average of both lab sections combined. In addition to the nutrients, our soil type was loam soil, meaning it had a distribution roughly equalling 20% clay, 40% silt, and 40% sand. Specifically, our soil was 20.2% clay, 42.1% silt, and 37.8% sand. The benefits associated with this soil type combined with a relatively low bulk density of 0.99 constitute a good moisture holding capacity (which was at 9.8% and above the total average within both sections), proper drainage, and good aeration within the soil so air can reach the roots of the plants. Additionally, with the pH level being slightly acidic (within the 6 -7 range) at 6.5 (according to WayPoint) or 6.24 (from the lab tests), it meant optimal plant uptake and consequently better growth. The combination of these factors contributed to the health of our soil, the amount of vegetation grown on it, and the abundance of invertebrates attracted to it.

Table 3 (4.3): S3G4 CP5 Nutrient Values v. ISAT 320 Brent & Coffman Average

	Nutrients										
	Phosphorus	**Potassium**	**Magnesium**	**Calcium**	**Sodium**	**Sulfur**	**Zinc**	**Manganese**	**Iron**	**Copper**	**Boron**
ISAT 320 Averages	59	135	149	1957	12	14	4.8	78	108	1.2	0.7
S3G4 - CP5	122	198	137	1683	12	15	4.4	59	129	1.1	0.6

The second attributable factor to our species richness and diversity values was the quality of our invertebrate pitfall trap. Compared to other groups within our lab section and others, our lab manager, Kyle Snow, rated ours very highly. Having said that, since our trap was constructed with a low enough leveled cup and roof to allow invertebrates of appropriate sizes to fall in with a sufficient amount of weight to hold it in place from the wind and heavy rainfall that occurred days after its installment, it allowed us to gather as many invertebrates from our plot as possible without the trap itself being a limiting factor. From it, we gathered a variety of insects like daddy long legs, beetles, rollie pollies, and more that we weren't able to fully identify. The combination of decent plot soil and a well constructed invertebrate pitfall trap allowed us to collect two accurate samples of the local invertebrate richness and diversity, giving us a better understanding of the life present in our plot.

Before analyzing the distribution of the species richness or diversity within the Hillside, it's important to note the quality of the invertebrate pitfall trap being a major source of human error with this experiment. Depending on the quality of the trap, it could've determined if a group collected accurate samples of the invertebrate population within their plot. One instance would be group S1G1's trap on plot NA1 who recorded only 1 species with 0 diversity from both rounds while the second group, S3G1, collected substantially more with an average richness of 6 and diversity of 0.79 (obtained from dividing 0.82 + 0.76 by 2). Based on the data, there appeared to be consistently lower species richness and diversity within the innermost plots of the Hillside, specifically CP6 and NA3, while plots NA1, CP5, CP7, and NA7 demonstrated higher amounts of richness and diversity. This could be attributed to the invertebrate predation from animals like birds and frogs who prefer to feed in the middle area of the Hillside and avoid the edges where they could encounter creatures larger than them, like humans. Also, those animals may prefer to build their homes in areas they encounter larger organisms less. Both of these possibilities could push invertebrates to the outermost regions of the Hillside to avoid being eaten and/or being near larger animals.

Table 4 (4.3): Intervetrabes Species Richness & Diversity S3G4 CP5 Round 1 (Lab 4)

Species	**Description**	**# of Individuals**	(n/N)	$(n/N)^2$	
1	Daddy Long Legs	1	1/28	.001	
2	Cricket	4	4/28	.026	
3	Spotted Orange Beetle	13	13/28	.215	
4	Rollie Pollie	1	1/28	.103	
5	Beetle	1	1/28	.001	
Total (N) =		28	Total =	0.34	**D**
			1 - Total =	1 - 0.34	0.66

Species Richness = 5 Species Diversity = 0.66

Table 5 (4.3): Invertebrates Species Richness & Diversity S3G4 CP5 Round 2 (Lab 5)

Species	**Description**	**# of Individuals**	n/N	$(n/N)^2$	
1	Cricket	5	5/13	.148	
2	Rollie Pollie	5	5/13	.148	
3	Beetle	1	1/13	0059	
4	Spotted Orange Bug	1	1/13	.0059	
5	Small Brown Bug	1	1/13	.0059	
Total (N) =		13	Total =	0.31	**D**
			1 - Total =	1 - 0.31	0.69

Species Richness = 13 Species Diversity = .69

5. Conclusions

The soils on the Hillside were analyzed based on treatment type, and if a natural or compost plot influenced the soil parameters measured, such as bulk density, soil moisture, and soil texture. Through, the evaluations we came to showed that there was no difference in the majority of the soil parameters based on treatment type. However, there was a correlation between the spatial positions and soil parameters, such as soil texture and organic matter. Topography had an impact on the texture of the soil as plots near the top of the Hillside were higher in silt concentrations than the plots at the bottom. Further, topography had an impact on organic matter due to runoff and erosion which caused better accumulation of organic matter and nutrients toward the base of the Hillside. Additionally, after analyzing our dataset, we found that the invertebrates were also affected by spatial position as they displayed lower species diversity and richness in the innermost plots of the Hillside.

The vast majority of data collected for plot CP5 was either the representative of the average for all sections or less conducive to supporting life than other plots where data was collected from. An outlier from this trend was the plant diversity index, which was the highest of all sections recorded at 0.78. Another notable exception is our bacterial content, which was 100%, meaning we had no fungus. However, both our microbial and bacterial biomass concentrations were low compared to most other groups. Our organic matter percentage was

higher than most of the natural plots, but nothing special when compared to the other compost plots. These somewhat lackluster conditions for supporting life are most likely explained by the drought the Hillside and greater Harrisonburg area experienced in the weeks leading up to and the weeks of data collection.

To improve the health of the Hillside, we recommend consistently covering the soil with vegetation, and to minimize the occurrence of mowing on the Hillside, and introducing a new treatment type to be tested. Since compost plots had a minimal effect on the ecological health of the Hillside, a new treatment type could be done to further test how different treatments can affect the health of the Hillside. By ensuring the soil is consistently covered with vegetation, it'll ensure the soil erodes less down the slope. Lastly, by minimizing the occurrences of mowing on the Hillside, the soil compaction will be reduced, thus lowering the bulk density and increasing porosity to allow plants to absorb necessary nutrients and grow. In regards to additional testing, we believe elongating the duration of the Hillside lab to cover several months rather than one to two months would be optimal. By elongating the lab, it allows us to conduct our tests multiple times over a larger time frame, which would provide us with an array of data to decipher trends and give us a better base to make conclusions off of.

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