Background Report

The world's ecosystem is filled with numerous organisms that all play a major role within it. Microbes are just one type of these organisms that contribute to the ecosystem, however they are one of the most important types of organism. They live deep within the soil and aren't visible to the human eye. Millions of these tiny microbes inhabit just a little bit of soil, living, reproducing, surviving, and dying. Along with all of these functions, microbes do many things to keep the ecosystem healthy.

A microbe is defined as "any organism that spends its life at a size too tiny to be seen with the naked eye"[1] Microbes have great but sometimes hidden power, and perform many tasks in the ecosystem. Among other things, microbes obtain and cycle carbon, sulfur, nitrogen, and phosphorus. Carbon is important because, according to Campbell, Williamson, and Heyden (2004) carbon makes sugar molecules through photosynthesis, which "are the building blocks for the other organic molecules…that make up the plant's tissues." (p. 461) Thus, carbon is the building block of organic life. Sulfur is important because, according to Jack Baird (1991), it activates enzyme systems that keep the plant alive by performing the tasks necessary for survival. Nitrogen is important because according to Campbell, Williamson, and Heyden (2004) it is used to "produce proteins, nucleic acids, and hormones". (p. 462) According to Campbell, Williamson, and Heyden (2004), bacteria play a large role in the nitrogen cycle because they transfer the unusable form of atmospheric nitrogen into a form useable by plants. (p. 462) Phosphorus is important to plants because, according to "What is Fertilizer and Why do Plants Need It" (n.d.) phosphorus is in the molecules of ATP and cell membranes, and without

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[1] http://216.239.53.104/search?q=cache:XKVTw1YlomEJ:www.visitmonmouth.com/03230planboard/EnvirGenReports/StreamCorridorEcoTims/StrCorrEcoTipsPage4.pdf+ways+to+prevent+erosion&hl=en&ie=UTF-8

phosphorus the cell can not transform energy. This cycling helps other organisms live and use resources that we take for granted. Many of these resources are available because of the microbes, hard at work in the soil.

Microbes are an ancient life form, and we have fossils of them dating back 3.5 billion years. Although microbes do not rely on humans for survival, we rely upon them for healthy soil. They are found in all different environments, atmospheres, and temperatures. Some, but not all, need oxygen to survive. Others can learn to adapt to an oxygen-free environment. A healthy microbe population makes soil healthier, and healthy soil helps plants to thrive. Healthy soil is made up of microbes, nutrients, and water. Microbes contribute to healthy soil because they produce secretions that hold soil together, thus decreasing run-off. When soil is held together by these secretions, the soil can hold more water, thus decreasing runoff and soil erosion. There are four major types of microbes that contribute to this healthy soil: bacteria, viruses, fungi, and protozoa.

Bacteria are an important element in healthy soil. According to the article “Seafriends: Soil Ecology” (1997), bacteria make soil more fertile, and are numerous: one kilogram of soil can be home to as many as 50 billion bacteria.(Soil,” n.d.) Bacteria adjust to their environments well, and can learn to survive without oxygen. According to the article “Seafriends: Soil Ecology” (1997) heir small size allows them to reproduce quickly, which also helps them to react to their environment. The adaptability of the bacteria shows that if they possibly can, they will continue to live in the soil, despite changing conditions. Thus when the bacteria population drastically changes, there must be a serious external factor, such as erosion. Healthier soil has more bacteria, because they decompose and fix nitrogen levels in the soil. (“Seafriends: Soil Ecology,” 1997)

Their major role in the nitrate cycle (which greatly affects how healthy the soil is) verifies that testing for bacteria is a way to test the health of the soil. Bacteria have several other jobs within the soil. They decompose dead matter, clean out the soil, ("Soil," n.d.) and, according to the article "Seafriends: Soil Ecology" (1997.), they fix the nitrogen levels on leguminous plants (plants with their seeds in pods). Bacteria also have a great effect on soil structure.

Bacteria play a large role in holding soil together, or providing soil structure. They make a sticky substance that binds the soil together. According to Jim Bauder (1998), bacteria also improve the soil's water capacity. This means that the soil allows more penetration of air, water, and roots. Moister soil is healthier soil, assuming that it is not overly saturated. Moist soil is important because, according to "Soil Biology and Soil Management" (2002), bacteria can break down plant matter faster in moist conditions. According to Jim Bauder (1998), the broken down plant material is then converted into proteins and acids, which are converted to inorganic nitrogen. The bacteria then convert this inorganic nitrogen into nitrogen that can be used by the environment. Bacteria and plants are fully capable of carrying out this cycle undisturbed. Soil erosion, however, makes this process more difficult for both the bacteria and the plants.

The definition of soil erosion is, according to J. Collins (2001), "the washing away of soil." That is exactly what happens during soil erosion. Soil erosion occurs because of either or both of these two factors: wind and water. They carry soil into the closest river or stream. The amount of soil they carry away is influenced by two factors including the speed the water and wind is moving and the amount of plant cover in that area. If wind and water are both moving at a fast pace across the soil then they will end up eroding more soil than if they were moving slower. Since fast moving water also has a fast velocity it has the force to push more soil with it. The same is also true for wind, it has more force when it moves faster, which in turn will move more soil along with it. Plants also come into play here because the more plants there are in an area, the less erosion will take place. The plants act as barriers, not letting wind and water move as much soil. Having plants as barriers decreases wind erosion, because it is easier for the wind to move dirt on a flat surface. *Microbes indirectly decrease erosion because they make healthier soil on which more plants will grow, thus decreasing erosion.* On a surface with barriers, the dirt could hit plants and no longer be airborne, thus making wind erosion less effective. Again microbes are an important factor in preventing soil erosion. According to Tracy Gow and Michael Pidwirny (http://royal.okanagan.bc.ca/mpidwirn/agriculture/erosion.html), some microbes in the soil, bacteria mainly, decompose organic matter that used to be the plant, and produce polysaccharides. Polysaccharides are sticky and act to glue soil particles together and therefore resist erosion.

There are different factors that affect how much water erosion takes place. The first factor is rainfall intensity. The amount of soil that erodes is affected by the size of the raindrops and how hard they hit the soil. Also, harder rainfall is necessary to move larger particles of soil. The next factor is soil erodibility. According to G. Wall, C.S. Baldwin, and I.J. Shelton (1987), “soil erodibility is an estimate of the ability of soil to resist erosion, based on the physical characteristics of each soil.” Normally soils with high permeability have high infiltration, or penetration, rates. This reduces runoff and erosion potential. Higher levels of organic matter along with improved soil structure have a greater chance to resist erosion. This means that soil that has a high amount of decayed organic matter in it along with a good sturdy structure are not likely to have a high erosion rate. The decayed organic matter helps to hold the soil together, and is another factor adding onto why plants are helpful in preventing erosion, when they decay they help the soil structure. The number of past erosion also has an affect on the soil's erodibility. Normally if soil is on a surface that is eroded regularly, the soil will have a higher chance of eroding in the future. The soil is more likely to erode in the future because water, wind, or both have already broken it down. The constant wearing of these elements creates a poor soil structure and lower organic matter, whereas areas where erosion does not normally occur are more likely to have good soil structure along with high organic matter. Erosion causes soil structure to be of poorer quality because the soil loses valuable rich topsoil, exposes harder, more rocky sub soil, which therefore makes it hard for vegetation to grow back. The slope gradient, or rate of incline, and length is also a major factor in soil erosion. The steeper the slope, the greater amount of soil loss will occur, because the water will move at a faster velocity, pushing more soil along with it. Ultimately, one can only tell how much an area is in danger of soil erosion by water by examining all the different factors that change the erodibility of an area.

Soil Erosion by Wind is the other way that soil can be eroded. Whether or not wind is successful in eroding soil is based upon the soil's texture. The smaller the particles of soil the farther the wind can carry it, because obviously smaller particles weigh less. Small particles can be suspended by the wind and carried great distances, medium particles can be lifted and deposited, and coarse particles can only be blown across the surface. The roughness of the soil is another issue. If a surface is not rough or ridged will offer very little resistance to the wind, meaning it could more easily be picked up and transported. According to G. Wall, C.S. Baldwin, and I.J. Shelton (1987), "the speed and duration of the wind has direct relationships to the extent of soil erosion." The faster and longer wind lasts the more soil is eroded. Also not having barriers in the way can help wind to carry soil particles farther. The more windbreaks the wind cannot put soil particles into motion for long distances. A lack of vegetative cover also makes it easier for wind to pick up soil. Soil that is loose and not covered by plants is the most susceptible.

Knowing how soil erosion is affected, we can find ways to limit and prevent it. Some major ways include maintaining vegetation, keeping the soil healthy by not dumping waste materials, and avoiding building or storing anything heavy. Building heavy structures can weaken stream banks that lead to excessive amounts of erosion. RPCS has this problem; the weight of the building adds pressure onto the hillside, which in turn eventually causes more erosion. Our school tries to help stop erosion by putting in cement walls trapping the soil in, putting woodchips on pathways, and by adding a hill underneath of the tennis courts. <u>Another way that a landowner can help to prevent erosion is to strengthen and stabilize eroding banks. One could go about doing this by inserting live willow stakes into the soil and installing secured bundles of branches along the stream banks.</u> Other methods include spreading mulch, building retaining walls, and building terraces.(Piemann, n.d.) Mulch is helpful because it stops water from carrying soil away.(Piemann, n.d.) Retaining walls are tall and therefore hold back large amounts of soil from eroding. Terracing, or building steps on a hillside, according to Piemann (n.d.), prevents soil from sliding down the hill. So, we can ultimately use these different erosion prevention techniques to help keep our streams and rivers clean, which is essential for ecosystems.

In our experiment we plan on testing samples of soil from different parts of the campus in order to determine what, if any, affect our school's erosion prevention methods have on the number of bacteria in the soil. To do this, we will compare bacteria levels in the soil affected by three different erosion prevention methods we have on campus. We will take soil samples from the ground below the stone wall on the playground, the backwoods trail, and the bottom of the hill on the playing field We will compare the number of bacteria in these soil samples with each other and with soil samples from above the first locations.

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Soil Erosion Prevention

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I. Problem: Which soil erosion prevention method at RPCS functions the best to prevent the least amount of bacteria loss in the soil?

II. Hypothesis: The playground wall will prevent the least amount of bacteria loss in the soil.

III. Procedure:

A. Variables

a. Independent: the location where soil samples are taken from

b. Dependent: density of bacteria in the soil at the base of a given soil erosion prevention site.

B. Controls:

a. Baseline Negative Control: density of bacteria in the soil taken from the flattest land on the highest point on campus and

b. Negative Control Two: the soil taken from above the erosion prevention sites.

c. Controlled Variable List:

  i. Amount of soil gathered

  ii. Same time of day when soil is collected

  iii. Depth in the ground from which soil was gathered

  iv. Same amount of time from when soil is taken from the ground to when tested for a given sample

  v. Room conditions

  vi. Amount of light and water soil receives while in bag

  vii. When collecting from each prevention site, collect from the exact same plot each time

viii. Different pipettes for each soil sample

ix. Same type of culture tubes (15 mL)

x. Same type of nutrient agar plates

xi. Same type of water (sterile)

xii. Same cabinet for storing bacteria plates

C. Step by Step:

1. Mark each soil erosion prevention site with a flag in the square meter area you are testing from.

2. The first site is the High Plot at N 39.35818° and W 76.63556°. The High Field site is at N 39.35864° and W 76.63615°, the Low Field site is at N 39.35864° and W 76.6368°, the High Playground site is located at N 39.35710° and W 76.63579°, the Low Playground site is at N 39.35702° and W 76.63580°, the High Trail site is at N 39.35740° and W 76.63718°, and the Low Trail site is located at N 39.35737° and W 76.63721°.

3. Using a cylinder soil sample with a diameter of 2 cm and 15 cm high collect three soil samples from each site.

4. Place the soil samples in plastic bags and carry them back to lab.

5. Remember to label all of your bags with your soil samples as you collect them.

6. Place 1 cc of your 1st trial from one of the erosion prevention sites into a culture tube containing 10 mL of sterile water; cap the tube and shake vigorously.

7. Using a serological pipette, remove 1 ml of the soil/water mixture and place into a fresh culture tube.

8. Add 9 ml of fresh sterile water to this second tube; cap and shake vigorously.

9. Repeat steps 7 and 8 using the second diluted tube and then repeat the steps with a third tube.

10. Continue steps 7 and 8 with additional tubes until you have diluted the original soil/water mixture a minimum of four times (a 10-4 dilution). You should now have a total of five culture tubes.

11. Place 100 ml samples from the 4th and 5th tubes (dilutions 10-3 & 10-4) onto their own nutrient agar plates and allow them to incubate at room temperature for a week.

12. Examine each of the plates for individual bacteria colonies and choose the plate with the fewest colonies (first look at the 10-4 plate, and if there are at least 5 bacteria colonies then use that plate for your research) to make your estimates of the number of bacteria in the original 1 cc soil sample (# colonies on plate · 102 = # of bacteria in dilution tube; # of bacteria in dilution tube · 10 [# of dilutions] = # of bacteria in original sample tube).

a. Equation for finding bacteria when using dilution 10-4: X · 102 · 10 – 4 = n

b. Equation for finding bacteria when using dilution 10–3: X · 102 · 10-3 = n

13. Count the number of bacteria colonies on the plate and plug it into one of the above formulas to figure out how many bacteria were in the original soil sample.

14. Repeat steps 6-13 with the soil samples from the other trials from the erosion sites collected on the 1st day. After you have finished testing for all of the trials on the 1st day, repeat steps6-13 for a 2nd day.

15. After you have finished using all of your soil samples from each day, then take all of the soil samples for one given plot (including all the trials and all the different days) and combine it into one bag. Repeat this for all of the plots.

16. Fill 1⁄4 of a flat bottom cylindrical container with soil from one of the test sites.

17. Fill the rest of the container with water and then add a few drops of detergent solution to the mixture.

18. Close the lid and shake vigorously for 30 seconds. Immediately afterwards place the container on the flat surface on which you can observe them. After placing the containers down you cannot move them until after you have observed them. Let containers sit for 24 hours or more.

19. Measure the height of the entire soil column, and record. Measure the height of the individual soil layers: soil, silt, and sand. Then find the percentage each layer is of the soil column.

20. Repeat steps 16-19 for each of the other test sites.

V. Data Tables and Graphs

Bacteria Density (per cubic cm) Day 1

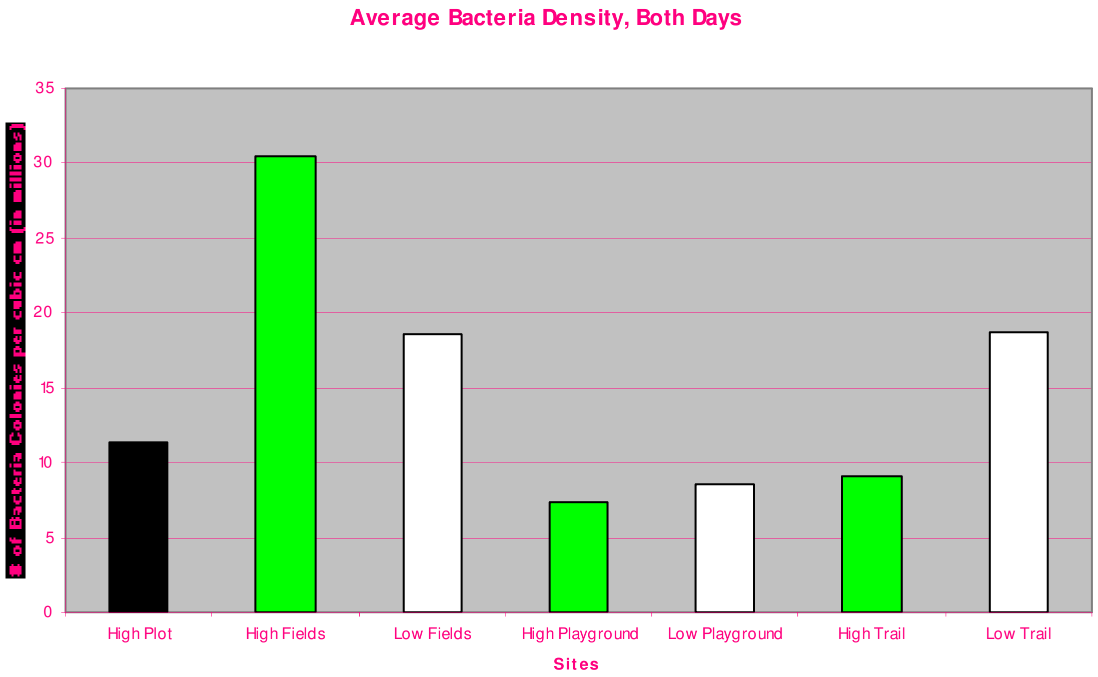
	High Plot	High Fields	Low Fields	High Playground	Low Playground	High Trail	Low Trail
A	$2.4\bullet10^{7}$	$2\bullet10^{7}$	$1.8\bullet10^{7}$	$1.1\bullet10^{7}$	$1\bullet10^{7}$	$2.4\bullet10^{6}$	$5\bullet10^{6}$
B	$2.7\bullet10^{6}$	$5\bullet10^{6}$	$1.8\bullet10^{6}$	$9\bullet10^{5}$	$6\bullet10^{6}$	$8\bullet10^{6}$	$9\bullet10^{6}$
C	$9\bullet10^{6}$	$8\bullet10^{7}$	$7\bullet10^{6}$	$5\bullet10^{6}$	$8\bullet10^{6}$	$1.3\bullet10^{7}$	$1.2\bullet10^{7}$

Bacteria Density (per cubic cm) Day 2

	High Plot	High Fields	Low Fields	High Playground	Low Playground	High Trail	Low Trail
A	$5\bullet10^{6}$	$4.2\bullet10^{7}$	$1.2\bullet10^{7}$	$1.6\bullet10^{7}$	$9\bullet10^{6}$	$1.9\bullet10^{7}$	$2.4\bullet10^{6}$
B	$1\bullet10^{7}$	$1\bullet10^{7}$	$2.3\bullet10^{7}$	$1.1\bullet10^{6}$	$1.3\bullet10^{7}$	$7\bullet10^{6}$	$9\bullet10^{6}$
C	$1.7\bullet10^{7}$	$2.6\bullet10^{7}$	$5\bullet10^{7}$	$8\bullet10^{6}$	$5\bullet10^{6}$	$5\bullet10^{6}$	$7.5\bullet10^{7}$

Bacteria Density (per cubic cm) Averages (for both days)

	High Plot	High Fields	Low Fields	High Playground	Low Playground	High Trail	Low Trail
Day 1	$1.19\bullet10^{7}$	$3.5\bullet10^{7}$	$8.933\bullet10^{6}$	$5.633\bullet10^{6}$	$8\bullet10^{6}$	$7.8\bullet10^{6}$	$8.66\bullet10^{6}$
Day 2	$1.06\bullet10^{7}$	$2.6\bullet10^{7}$	$2.833\bullet10^{7}$	$9\bullet10^{6}$	$9\bullet10^{6}$	$1.033\bullet10^{7}$	$2.88\bullet10^{7}$
Overall	$1.13\bullet10^{7}$	$3.05\bullet10^{7}$	$1.8633\bullet10^{7}$	$7.3166\bullet10^{6}$	$8.5\bullet10^{6}$	$9.066\bullet10^{6}$	$1.873\bullet10^{7}$



VI. Analysis

On average, our base negative control (the High Plot) had 11.5 million bacteria colonies per cubic cm. The soil structure of the high plot is 68% silt, 28% sand and 4% clay. The high fields had significantly higher bacteria density of 30.5 million bacteria per cubic cm (bpccm). The high fields also had a drastically higher bacteria density then the low fields, which had only about 18.5 million bpccm. The high fields' soil structure contains 47% silt, 33% sand and 20% clay. Similarly, the low fields contain 50% silt, 35% sand and 15% clay. With different results from the fields, the playground area had a lower bacteria density at the high area then the low area. The high playground had about 7 million bpccm, while the low playground had about 8.5 million bpccm. However, the soil structures of the high and low playground are also drastically different. The high playground produced a problem because it was predominantly composed of woodchips. So the soil structure turned out to be 23% silt and 77% detritus. The low playground on the other hand is composed of 61% sand and 39% clay, and no silt. The high and low trail also produced similar results to the playground; the high area had a lower bacteria density then the low area. The high trail had around 8.5 million bpccm, while the low trail had about 19 bpccm. The soil structures of these two areas are also similar. The high trail is composed of 48% sand, 35% silt and 17% clay. The low trail is composed of 65% sand, 25% silt and 10% clay. Overall the high plot was the median of the data bacteria density wise, the high fields had a higher bacteria density then the low fields, the high playground had a lower bacteria density then the low playground, and the high trail had a lower bacteria density then the low trail. The high plot is mostly silt, some sand and a little clay, the high and low fields are almost identical in soil structure with mostly silt, some sand and partially clay. The high and low playground sites have radically different soil structures: the high playground is about 1⁄4 silt and mostly detritus, while the low playground is mostly sand and almost half clay with no silt at all. The high and low trails are very similar with about half composed of sand, followed by about 1/3 silt and the rest clay.

VI. Conclusion

Our hypothesis is incorrect because the playground's retaining wall is not the most effective soil erosion prevention method, the woodchips on the trail are. On average, the number of bacteria in the soil increased by about 9 million from the High Trail site to the Low Trail site. The playground was the second best erosion prevention site; there was an average increase of 1.2 million bacteria colonies. The grassy hill on the field was the worst site; there was a decrease of about 12 million from the Low Field site to the High Field site. The success of the erosion prevention is based on two factors – what type of soil the site contains and what method is implemented to prevent erosion. Based on our data regarding the soil structure we can conclude that it was a combination of both that makes the trail the most effective site. The grass on the slope between the high and low fields obviously was the worst at preventing soil erosion because of drastic difference between bacteria densities at the top of the field and at the bottom. We know that this could only be the result of the grass' lack of soil erosion prevention because the soil structure itself was well equip to blocking erosion. The fields had the most equal distribution of sand, silt and clay. An equal distribution of sand, silt and clay makes the soil less easy to erode. The playground wall and the woodchips on the trail both were affective in blocking erosion, but the trail showed a greater success than the playground wall. Also, the trail soil has a more even distribution of sand silt and clay then the playground. The fields overall had good soil structure, but the grass was not effective in preventing erosion, the playground had poor soil structure, but was effective in blocking erosion. However, the trail is different than both of these areas because the trail was composed of good soil for decreasing erosion and had a successful erosion prevention method. It can then be concluded that the trail is the most successful area in the prevention of soil erosion.