The Effect of Land Use on Nutrient Levels

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Field Research 101

Abstract

Our streams are vital to our way of life. We use them for everything from transportation to recreation. Algal blooms can disrupt the beauty and life of a stream or lake, and occur as a result of high nutrient levels in a process called eutrophication. But what causes these nutrient levels to become so high? A combination of factors, surely, but perhaps the most important one is the land use of a watershed. The goal of this research was to find the effect different land use types had on nutrient levels. Water samples were collected from two sites in the Beaver Creek subwatershed and analyzed for their nitrate and phosphate levels. Analysis of the watershed's land use was also done using computer software. Statistical analysis was unable to determine a difference between phosphate levels at the two sites or in the land use between the two sites, however a difference in nitrate levels was found.

Introduction

Water has always played an important role in our lives. We drink it, bathe in it, and use it for recreation and scenery. In order to serve these important functions, it is imperative that our water be unpolluted and healthy. Concrete ways to assess the health of our water include measuring turbidity, pH, temperature, dissolved oxygen, and nutrient levels. The health of Beaver Creek, which feeds the Eau Claire river, is vital to the surrounding area, and by measuring chiefly its nutrient levels in comparison with one of its tributaries, the effect land use has on water quality can be seen clearly.

An important nutrient to consider when observing water quality is phosphorus. All living things, big and small, need phosphorus to survive (Mitchell p. 54). Because of its great demand, phosphorus levels in streams are usually low and serve as a "growth-limiting" factor for plants and animals (Murphy, S. *General Information on Phosphorus* n. pag.).

Phosphate levels greatly affect plants (Mitchell p. 55). If levels are too high, algae, which uses only a little phosphorus, can grow out of control (Murphy, S. *General Information on Phosphorus* n. pag.). This process is known as eutrophication, and can oftentimes be noticed in lakes around the Chippewa valley including lake Altoona and lake Eau Claire. The excess algae can, in effect, starve off other plants both from the phosphorus they need as well as block out light (Mitchell p. 55).

High phosphate levels affect animals as well as plants. Because animals are so highly dependant on plants in the first place for food or shelter, when plants die as a result of eutrophication, animals like fish as well as macroinvertebrates die as well (WDNR *Runoff Management Water Quality* n. pag.). But what makes high phosphate levels doubly dangerous for animals is the dissolved oxygen level. When algae and cyanobacteria grow out of control due to too much Phosphate, they also take up almost all of the oxygen in the water (Mitchell p. 55). This kills fish and other wildlife (WDNR *Runoff Management Water Quality* n. pag.). High phosphate levels can hurt animals directly; it can cause digestive problems in humans and animals. (Murphy, S. *General Information on Phosphorus* n. pag.).

Because phosphorus is so crucial, the effects of low phosphorus levels are easy to predict. Put quite simply, since phosphorus is a limiting factor on growth, low phosphorus levels leads to low growth, which can be just as devastating as high levels to animals and plants (Murphy, S. *General Information on Phosphorus* n. pag.).

Human, animal, and industrial wastes all contribute to higher levels of phosphorus (Mitchell pp. 54-55). Also, soil erosion whether from sandy soils or from a lack of trees can also increase phosphorus levels(Mitchell p. 55). Pavement also increases phosphorus because there is no soil or plant life to soak up runoff (Murphy, S. *General Information on Phosphorus* n. pag.). Phosphorus is also found in abundance in fertilizers and detergents, so having those in the area affects levels as well (Murphy, S. *General Information on Phosphorus* n. pag.). Therefore, watersheds which drain commercial or industrial areas will have higher levels than normal (Murphy, S. *General Information on Phosphorus* n. pag.).

Generally, 0.2 mg/L constitutes the upper range of phosphate values. The EPA says 0.5 mg/L is the highest limit (Community Clean Water Institute n. pag.).

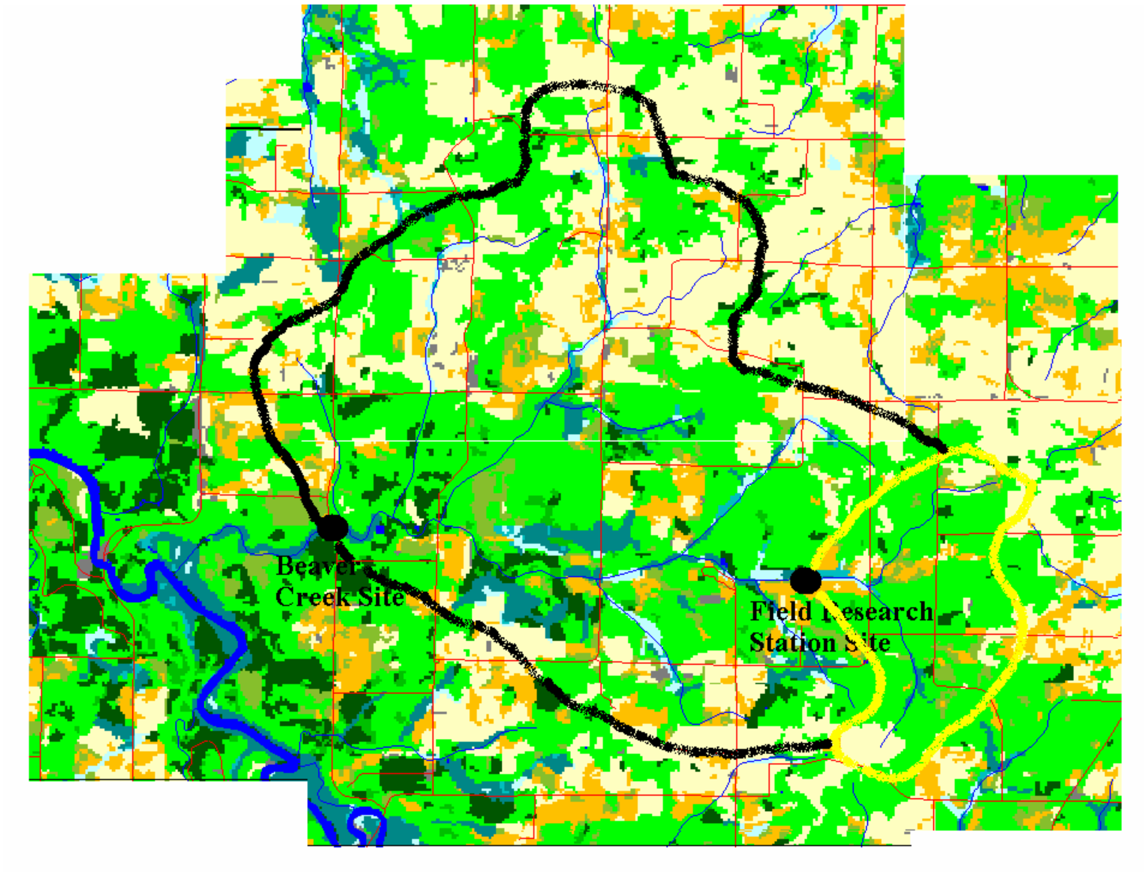
Nitrogen is another nutrient important to water quality. Nitrogen is essential for building amino acids in animals and other proteins for plants (Mitchell p. 60). It is also very abundant- 79% of the air we breath is nitrogen (Mitchell p. 60). A handful of organisms convert gaseous nitrogen to ammonia or nitrates which other organisms use (Mitchell p. 60). Since plants are also dependant on nitrogen for growth, high levels can cause eutrophication, but since it is found abundantly, it has less of an immediate impact on water life (Mitchell p. 60).

Sewage has a large impact on nitrate levels, as does runoff from cattle farms and fertilizers (Murphy, *Basin: General Information on Nitrogen* n. pag.). Sometimes the burning of fossil fuels can produce acid rain which raises nitrate levels. (Murphy, *Basin: General Information on Nitrogen* n. pag.).

High levels of nitrogen contribute to eutrophication, and low levels can limit plant growth. Nitrate levels above 2 mg/L are considered unusually high. The EPA has set a limit of 10 mg/L ((Murphy, *Basin: General Information on Nitrogen* n. pag.).

Nitrates and phosphates generally enter the stream through runoff events (Mitchell p. 60). These events don't just affect nutrient levels, however. They can also change water temperature or turbidity (Mitchell pp. 51, 66). But the amount of nutrients that enter the stream is largely governed by the land use of that stream's watershed (WDNR *Runoff Management Water Quality* n. pag.). Farmland, with its large amounts of manure and fertilizers, raises nutrient levels (Mitchell pp. 62-63). The type of soil- wether the soil is sandy or clay- also raises levels if the soil is sandy because more will erode (Mitchell p. 63).

As can be seen from the diagram, Beaver Creek drains a much larger watershed, with higher proportions of land devoted to general agriculture than the smaller portion of the watershed that drains into the field research station site. Still, the predominant use for both sites is deciduous forest. One would expect higher nutrient levels at the Beaver Creek site because of its higher use of farmland. However, out of all of the creeks feeding the Eau Claire river, Beaver Creek would be expected to have lower levels of nutrients because of the lack of residential areas. All of the maps and land use information were obtained through the Wisconsin Department of Natural Resources (*Land Cover Data WISCLAND*).



The farm site was chosen for a few reasons. First and foremost were its practicality and proximity. It is located right at the field research station, and has a range of land uses, even though most of the area it drains is deciduous forest. The nutrient levels also had never previously been observed with as much regularity or purpose before. The farm site is important because it feeds Beaver Creek and eventually the Eau Claire River.

Beaver Creek was chosen also for its practicality and proximity and also because, like the farm site, its nutrient levels hadn't been observed with as much regularity or purpose. Since the field research station's watershed differs in its land use from the Beaver Creek site's, if the research station and the Beaver Creek site have different nutrient levels, by measuring the nutrient and land use changes between the two sampling sites, the change in nutrients can be associated directly with the change between the land use types. Beaver Creek is important by itself because it provides recreation for patrons of Beaver Creek Reserve as well as opportunities for studies like my own, and because it feeds the Eau Claire River.

Method

Equipment:

In order to take water samples, I used two collection methods. The first, and least used, was an acid-washed dissolved oxygen bottle. It proved to be a hassle to use and clean, which is why I switched to using Ziploc bags. Sterile, small, convenient, and cheap, I found them to work a lot better than the glass dissolved oxygen bottles.

To analyze the water samples, a Hach 2010 Spectrophotometer along with AccuVac Ampuls for Nitrate and Phosphate was used. After analyzing the sample, data was entered into Microsoft Excel and its self-contained data analysis tools were used to run T-Tests on the data. These T-Tests were designed to tell if a significant difference in the mean values of the nutrient levels at both sites occured.

For manipulating land use data, all of which I got from the DNR as part of their GIS services, I used the popular mapping program, ArcView.

Procedure:

I picked two sites along Beaver Creek. One was near the headwaters of Beaver Creek at the Field Research station at the bridge. Because it was near the Henke farm, I labeled this site the Farm site. The other site was a little more than a mile west, closer to Beaver Creek Reserve. I called this site, the Beaver Creek site.

Approximately twice a week from mid-November to early May, I would collect water samples in bottles or Ziploc plastic bags for further analysis back at the lab. I calculated phosphate and nitrate levels based on the directions given in the Hach Lab book (1997).

To calculate land use, I pulled in watershed data from the DNR, as well as elevation maps from the DNR. Using the elevation maps as a guide, I cut out the sub-watershed I was interested in, as well as the sub-sub-watershed within that. Next, I overlaid the watersheds with a picture of their land use from the DNR. To get this picture to be something I could work with, I hand-digitized the land use pictures from the DNR into the following types: forest, agriculture, grassland, and wetland. Because I hand-digitized the images, there was a fair amount of left over area, which I labeled Other in my data.

Data:

Table 1. Nutrient Levels at Farm Site (levels in mg/L)

Farm					
Totals	PO_4^{3-}	P	P_2O_5	NO_3^--N	NO_3^-
11/11/02	0.25	0.09	0.18		
11/20/02	0.15	0.05	0.11	0.6	3.1
12/3/02	0.13	0.05	0.09		
1/7/03	0.15	0.05	0.11	0.8	3.9
1/14/03	0.2	0.07	0.15	1.1	5.2
1/21/03	1.98	0.65	1.47	1.1	5.3
1/22/03	Over	Over	Over		
1/28/03	0.24	0.08	0.17	1	4.8
2/4/03	0.22	0.08	0.16	1.3	6
2/10/03	0.34	0.11	0.25	1.1	5.3
2/12/03	0.23	0.08	0.17	1	4.7
2/17/03	0.35	0.12	0.25	1.2	5.5
2/24/03	0.38	0.13	0.28	1.2	5.4
3/3/03	2.18	0.71	1.62	1.2	5.5
3/10/03	0.3	0.1	0.22		
3/18/03	0.22	0.08	0.16	0.7	3.1
3/20/03	0.21	0.07	0.16	0.9	4
4/1/03	0.13	0.05	0.09	0.9	4.2
4/7/03	0.09	0.03	0.07	0.9	4.2
4/10/03	0.11	0.04	0.08	0.7	3.4
4/15/03	0.2	0.07	0.14	0.8	3.8
4/16/03	0.16	0.05	0.11	1.1	5.1
4/29/03				0.8	3.6

Table 2. Nutrient Levels at Beaver Creek Site (levels in mg/L)

Beaver					
Total	PO_4^{3-}	P	P_2O_5	NO_3^--N	NO_3^-
12/6/02	0.14	0.05	0.11		
12/20/02	Over	Over	Over	1.4	6.2
1/9/03	1.94	0.64	1.44	1.3	5.8
1/30/03	0.24	0.08	0.17	0.8	3.7
2/6/03	0.24	0.08	0.17	1.7	7.8
2/27/03	0.22	0.08	0.16	1.6	7.5
3/5/03	0.18	0.05	0.13	1.8	8.2
3/13/03	1.05	0.35	0.78		
3/20/03	2.19	0.72	1.63	1.1	4.5
4/8/03	2.72	0.89	2.03	1.4	5.8
4/10/03	0.7	0.23	0.52	1.3	5.3
4/25/03	0.15	0.05	0.1	1.2	4.7
5/5/03	0.98	0.32	0.73	1.2	4.7

Figure 1. Digitized Land Use Map from ArcView

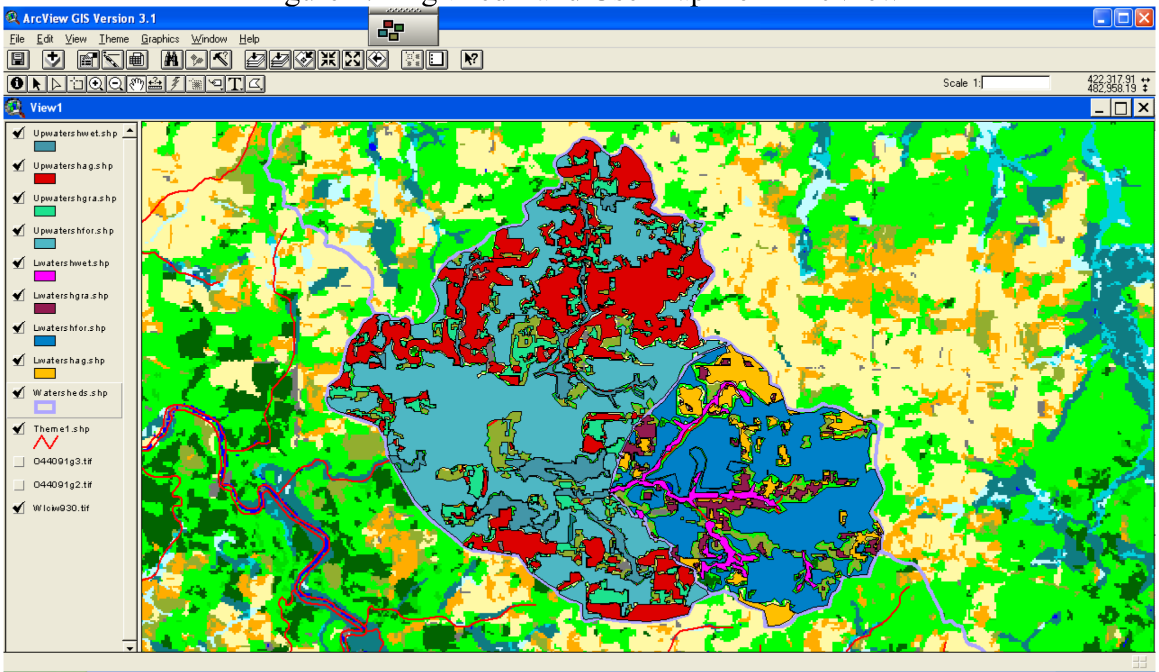


Table 3. Acreage of Land Uses in both Watersheds calculated from Figure 1

Land Use Type	Acres
Sub-Sub-Watershed Total	3459.353
Forest	1802.574
Grassland	219.252
Wetland	192.846
Agriculture	401.639
Other	843.042
Sub-Watershed Total	10794.670
Forest	5020.958
Grassland	764.806
Wetland	622.008
Agriculture	2351.819
Other	2035.084

Analysis of Data:

Figure 2. Graph of Nitrate Levels over Time at Farm Site

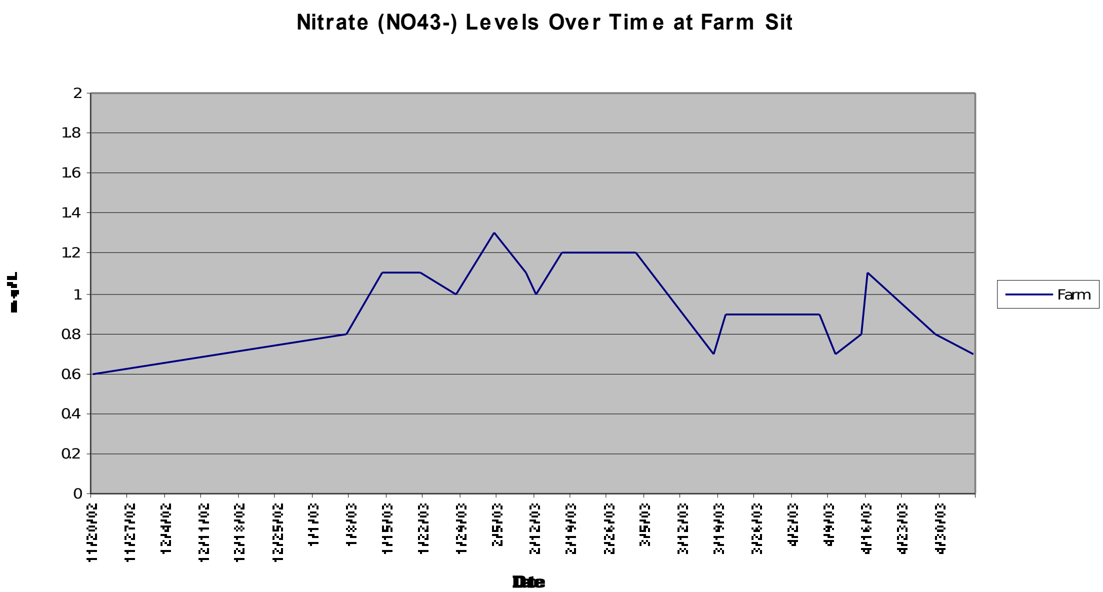


Figure 3. Graph of Nitrate Levels over Time at Beaver Creek Site

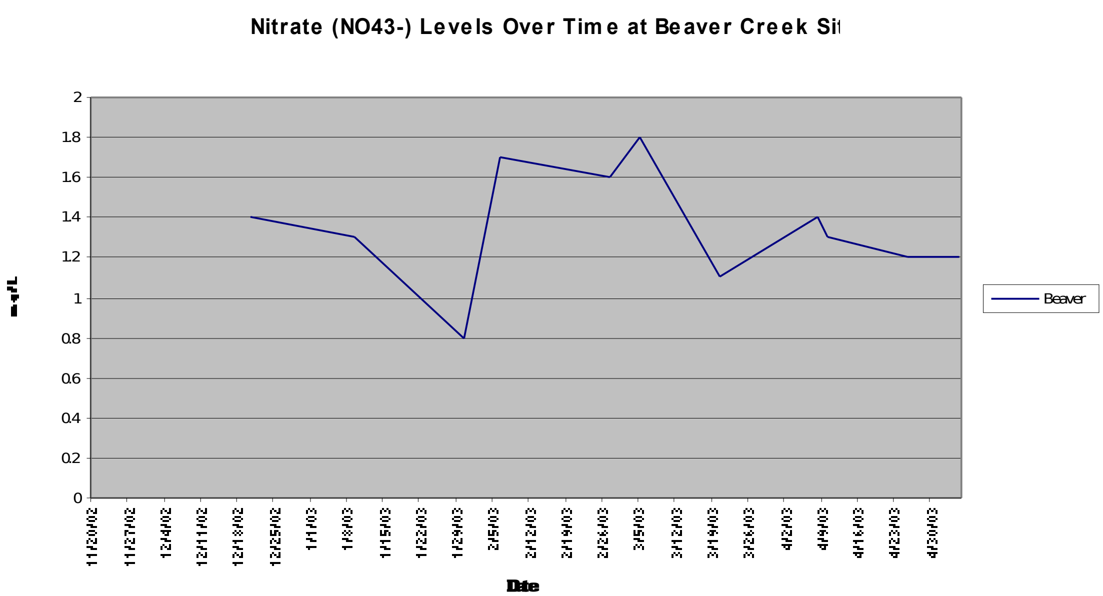


Figure 4. Graph of Phosphate Levels over Time at Farm Site
Note that according to field notes, there was a rain event on March 2 accounting for 2nd spike, but there was no rain event in mid-Jan. for the first spike

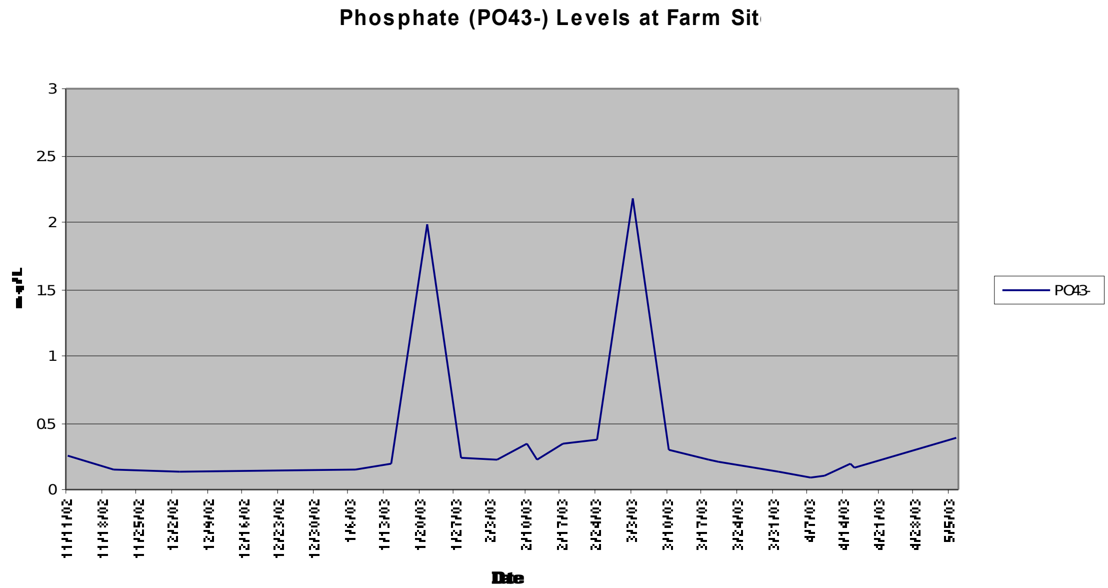


Figure 5. Graph of Phosphate Levels over Time at Beaver Creek Site
Note that according to field notes, there were rain events on Jan. 8 before 1st climb, and rain events March 19 and April 7 before second climb

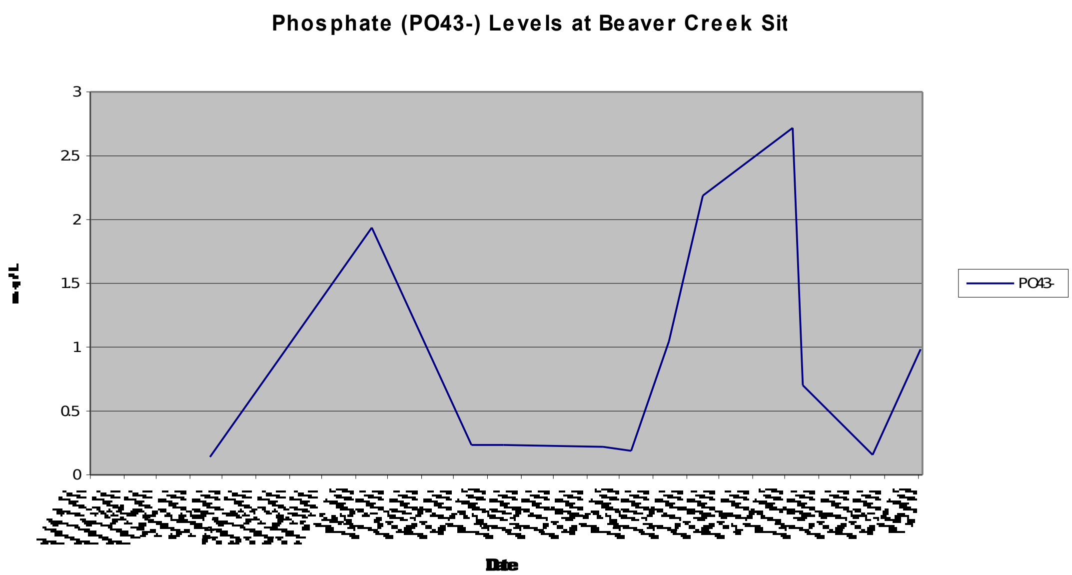


Figure 6. Land Use as a Percentage of Total Acreage of Sub-Sub-Watershed (Key: Forest: Blue (52%) Grassland: Red(6%) Wetland: Yellow(6%) Agriculture: Teal(12%) Other: Purple(24%)

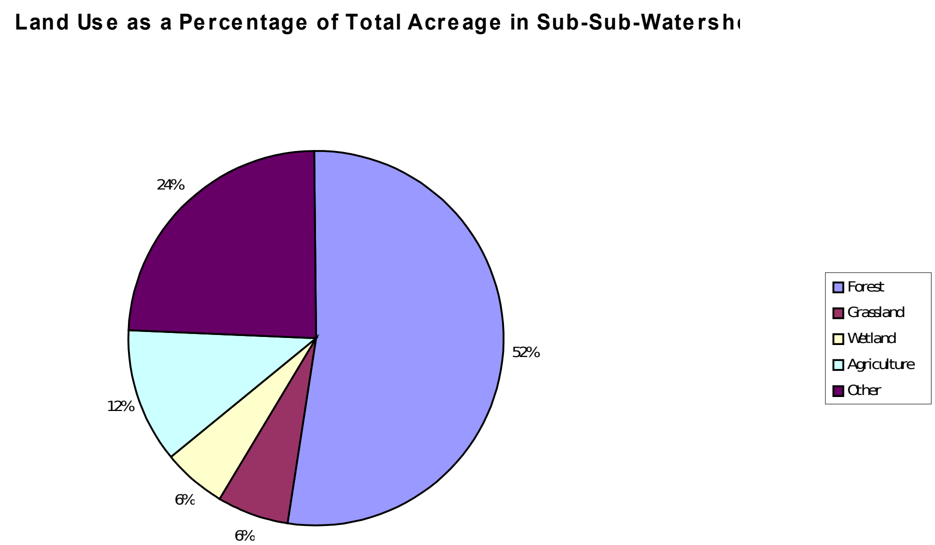


Figure 7. Land Use as a Percentage of Total Acreage of Sub-Watershed (Key: Forest: Blue (46%) Grassland: Red(7%) Wetland: Yellow(6%) Agriculture: Teal(22%) Other: Purple(19%)

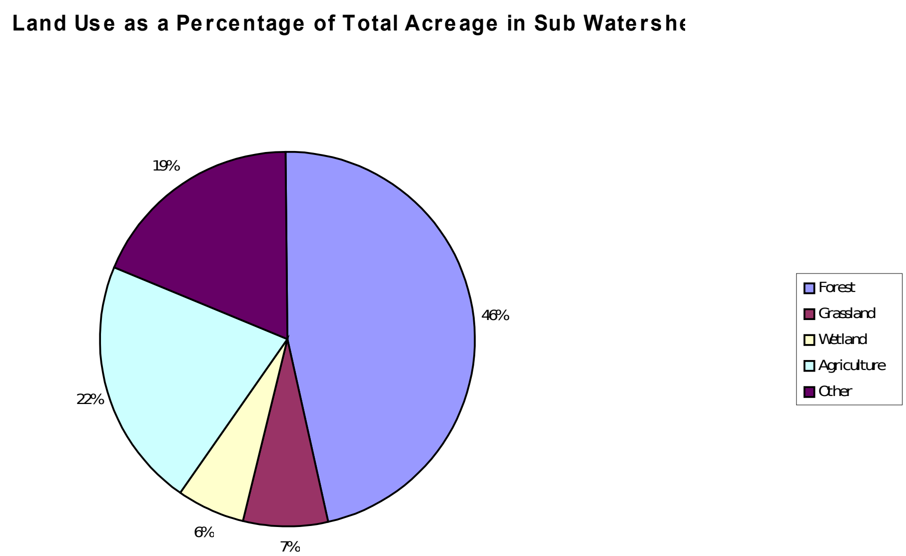


Table 4. Results of T-Test comparing PO_4^{3-} Levels between Farm site and Beaver Creek site

t-Test: Two-Sample Assuming Equal Variances

	Farm	*Beaver*
Mean	0.391364	0.895833
Variance	0.306965	0.82899
Observations	22	12
Pooled Variance	0.486411	
Hypothesized Mean Difference	0	
df	32	
t Stat	-2.01556	
P(T<=t) one-tail	0.026154	
t Critical one-tail	1.693888	
P(T<=t) two-tail	0.052309	
t Critical two-tail	2.036932	

Table 5. Results of T-Test comparing P Levels between Farm site and Beaver Creek site

t-Test: Two-Sample Assuming Equal Variances

	Farm	*Beaver*
Mean	0.131364	0.295
Variance	0.032412	0.089118
Observations	22	12
Pooled Variance	0.051905	
Hypothesized Mean Difference	0	
df	32	
t Stat	-2.00142	
P(T<=t) one-tail	0.026944	
t Critical one-tail	1.693888	
P(T<=t) two-tail	0.053888	
t Critical two-tail	2.036932	

Table 6. Results of T-Test comparing P_2O_5 Levels between Farm site and Beaver Creek site

t-Test: Two-Sample Assuming Equal Variances

	Farm	*Beaver*
Mean	0.287727	0.664167
Variance	0.170133	0.462917
Observations	22	12
Pooled Variance	0.270777	
Hypothesized Mean Difference	0	
df	32	
t Stat	-2.01582	
P(T<=t) one-tail	0.02614	
t Critical one-tail	1.693888	
P(T<=t) two-tail	0.052281	
t Critical two-tail	2.036932	

Table 7. Results of T-Test comparing NO_3^--N Levels between Farm site and Beaver Creek site

t-Test: Two-Sample Assuming Equal Variances

	Farm	*Beaver*
Mean	0.955	1.345455
Variance	0.041553	0.080727
Observations	20	11
Pooled Variance	0.055061	
Hypothesized Mean Difference	0	
df	29	
t Stat	-4.4328	
P(T<=t) one-tail	6.11E-05	
t Critical one-tail	1.699127	
P(T<=t) two-tail	0.000122	
t Critical two-tail	2.045231	

Table 8. Results of T-Test comparing NO_3^- Levels between Farm site and Beaver Creek site

t-Test: Two-Sample Assuming Equal Variances

	Farm	*Beaver*
Mean	4.475	5.836364
Variance	0.828289	2.156545
Observations	20	11
Pooled Variance	1.286309	
Hypothesized Mean Difference	0	
df	29	
t Stat	-3.19766	
P(T<=t) one-tail	0.001669	
t Critical one-tail	1.699127	
P(T<=t) two-tail	0.003338	
t Critical two-tail	2.045231	

Discussion:

To associate a connection between land use and nutrient levels, it is first important to calculate a difference in nutrient levels between sites. The phosphate levels at both sites, when entered into a spreadsheet and analyzed statistically using an unpaired T-test, actually came out to be close enough together that no significant difference was able to be detected. This could have happened for a few reasons. The first reason could be that the phosphate levels weren't all that different because the land uses in the two watersheds weren't all that different. To see a bigger difference, I would need to study a site much farther away from the other so that there would be a larger difference in total drainage area, land use, etc. One other way to explain the lack of a difference in phosphate levels is that if I had collected more samples, I would have had more degrees of freedom statistically as well as much more accurate numbers, and this could have pushed the statistics over the edge. To report a significant difference, I needed to be 95% confident there was a difference- I came out 94.7% confident. Maybe just taking a few more samples or having fewer 'flukes' would have made a difference of .3%. But even if the phosphate levels didn't differ significantly, the nitrate levels did. Still, one piece of evidence which seemed out of place with the nitrate was its lack of a spike brought about by spring rain events. This could possibly have happened because I switched testing supplies right about the start of spring. Even though I redid my calibrations for the new supplies, if I made one mistake on the calibrations, the entire rest of the data set would be off. Another reason for the lack of spikes in the spring could be my timing- usually, I would collect samples more than a dozen hours after it had begun raining. If I had collected my samples earlier, then maybe I would have seen the spikes I expected.

Another point of interest I found in the data was the period of a few days in January in which the phosphate levels spiked wildly at the Farm site, going to 1.96 mg/L. Initially, I was inclined to chalk it up to a testing error- maybe the accuvac ampul was a fluke, or maybe the spectrophotometer was calibrated incorrectly. However, this seemed unlikely because not only was this ‘fluke’ repeated a few days later at the Farm, but it was *not* repeated at the Beaver Creek site. The fact that the nitrate levels didn’t spike can be interpreted a few ways. How could there be a spectrophographic error if the nitrate test turned out fine? But if the phosphate levels spiked, why wouldn’t the nitrate levels spike as well? What the cause of the spike was remains a mystery.

After mulling over all the different possibilities regarding the nutrient levels, I was ready to look at the differences in land use. This is where I ran into a bit more trouble- how do you tell if one watershed’s land use is any different from anothers by statistical means? Since the one watershed was so much larger than the other, I couldn’t accomplish this by just feeding in raw acreage into another T-Test. And percentages of the total land use wouldn’t work either- if the T-test looked at the average of the data, it would find the same average for both sites if both used percentages and both sites were broken into the same categories of use. Besides, just eyeballing the pie chart in figures 6 and 7 doesn’t show a very big or noticable difference at all. Adding to the confusion was the inaccuracy of the land use data itself. I had to hand digitize all of the little polygons that the DNR had made because I lacked the ArcView extension to create a theme from a grid. My maps weren’t nearly as accurate as I would have liked them to have been- nearly a quarter of the map was unaccounted for in its land use. Still, I counted on the fact that I had been indiscriminate and random in my inaccuracy- if I cut the forest pieces too small by a random margin, I should have cut the wetlands pieces too small by the same random margin so the two would offset one another.

But even if there had been a more objective way to tell the difference in land use types, and even if the data itself could be counted on to be accurate, that wouldn’t help me if the two watersheds were just naturally similar in their land use, which I think is the case here. To solve the problem, new sites that could isolate certain land use types could be chosen. For example, placing one site at the edge of some protected woods, and placing one site downriver after lots of urban development would eliminate the hassle of determining a difference. That way, if phosphate and nitrate levels rose dramatically between two points on a stream, and the only real use for the area between the points was one land use type, the two could be assosiated much more easily.

Conclusions:

I originally wanted to answer the question, what effect does land use have on nutrient levels in streams? The phosphate levels at the two sites I monitored didn’t show a difference between them, although the nitrate levels did. The land use of the two watersheds also didn’t turn out to be different. Therefore, my data tells me very little pertaining to my question, and I can neither accept nor reject the hypothesis.

If I were to change anything about my project, I would do the following. First, I would pick more appropriate testing sites. The sites I chose, I chose for convenience above all else- the farm site is at the only bridge across the stream at the Field Research Station, and the Beaver Creek site was at the only bridge across Beaver Creek proper that could be accessed in less than fifteen minutes. Because there are few sharp land use changes in the Lower Eau Claire Watershed as a whole, maybe an entirely different watershed could be studied. Aside from changing the testing sites, I would also change the testing methods a little. By taking a sample from one site, analyzing it the next day, then taking a sample from a different site, random fluctuations would appear more frequently, throwing off some of the data. Instead, I would like to collect data from both sites in the same day- that way there would be less chance of things being randomly off. I also would have collected a lot more data than I did. This would have solved some of the problems of my being pretty sure there was a difference in phosphate levels, but not having enough data points to statistically say for sure. Also, I would find someone that had the Spatial Analyst Extension for ArcView so that the land use maps would be as accurate as possible. Lastly, I'd like to split and verify some samples at more sophisticated labs just to check to see if I'm getting numbers that are close to right, as a QAQC test.

Because of the healthy (not too high or too low) levels of nutrients and the general consistency of the watershed as a whole, I found that Beaver Creek is a very protected creek. There aren't any huge nonpoint sources like large cities or urban areas making the nutrient levels go haywire, there's just mostly perserved forest and a few farms and grassland. Also, my data serves as excellect background research for any future students conducting research at the the Field Research Station. But the information is pertinent to anyone studying the Creek, not just students, and adds to the general knowledge we have of it. If water is so important, I'm glad I discovered a little more about the water of Beaver Creek, even if what I found wasn't what I was looking for.

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