A Comparative Study of Soil Nutrients in Drainage Ditches

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Abstract

Roadsides ditches contribute 30,000 miles to Ohio's watershed and are one of the leading conduits of nutrient pollution entering the Lake Erie watershed. This research focuses on analyzing soil nutrient levels of roadside ditches that align both an agricultural field and a municipal road. This is achieved by sampling both the agricultural and municipal slopes of a drainage ditch and analyzing the nutrient levels of the resulting soil samples. This analysis seeks to evaluate if elevated levels of nitrates and phosphates are present in the soil on either side of a drainage ditch and to determine which side is at fault for contributing more nutrient run-off. This research indicates significant relationships between the width of a slope and the soil pH levels, as well as between pH and phosphorus levels within a drainage ditch. Results conclude two-thirds of the sample sites demonstrate increased nitrate-nitrite levels on the agricultural slope when compared to the municipal slope. Research also indicates the variance in nutrient levels across a wide range of sites. This study is significant in the recent discussions of nutrient run-off, erosion of drainage ditch banks, and their role in nutrient run-off mitigation. Upon further inquiry, this research will also indicate where nutrient run-off is occurring, and if nutrient levels are within range to support buffer zones and rain gardens. The need for more information on this topic will become ever more apparent as excess nutrient run-off continues to cause environmental and economic distress in the Lake Erie region.

Introduction

Are farmers the only entities making sizable contributions to the excess nutrient runoff currently occurring in the Lake Erie watershed? The Western Lake Erie Basin spans across almost six million acres of ditches, streams, and rivers. Of the reported 77,500 miles of drainage ditches throughout Ohio, Indiana, Michigan, and Minnesota, 30,000 are within Ohio itself. Forty percent of the drainage ditches in the North Central Region of the United States are contained within Ohio and of that forty percent; ten percent encompasses Wood County (Ohio State University, n.d.). "Ohio has a higher percentage of land that needs or benefits from drainage than any other state [but] … nowhere is drainage more important than in the flatter glaciated parts of western and northwestern Ohio" ("Rural Drainage", 2008). Northwest Ohio was once home to the Great Black Swamp and largely unsettled. When settlers finally came to the area, the swamp was drained in efforts to create land for industrialization. "Drainage systems were originally designed for the efficient and economical removal of excess water [in cropland and roadways]; they were not installed as water quality management tools. As a result, drainage systems also efficiently deliver sediment, nutrients, and other pollutants downstream" ("Ohio Drainage Manual", 2009). Due to these drainage systems having been designed before environmental impact was considered, they have little to no precautions in place to mitigate erosion and nutrient leaching. In most cases, the standard drainage ditch is established with turf-grass along the sides to prevent the complete erosion of the bank. In this effort to mitigate soil erosion, the limited root zone of turf-grass does little to terminate the effects of soil erosion and nutrient leaching. When soil erodes from cropland or the banks of a drainage ditch, the nutrients attached to the soil particles are carried into the water. This transfer of nutrients leads to water quality degradation downstream.

Nitrogen (N) and phosphorus (P) are two fundamental nutrients commonly lost in runoff. Since each nutrient interacts with the environment differently, N and P enter the watershed in different ways. Nitrate, a form of nitrogen, is an extremely water soluble and negatively charged nutrient. Its negative charge causes it to repel the negatively charged organic and mineral particles that soil consists of. This results in nitrates remaining in the soil solution until they are lost through water leaching from the soil (Burg, Meehan, & Scherer, 2017). Phosphorus, however, attaches itself to soil particles. Although phosphorous can attach to most particles, "fine soil particles have a greater capacity to hold phosphorus than coarse particles. Unfortunately, soil erosion transports more fine particles, causing the eroded sediment to be "enriched" with phosphorus" (Berg, Meehan, & Thomas Scherer, 2018).

Nitrogen and phosphorus enter the watershed through various sources. Farmers apply nitrogen and phosphorus to soil from pre-planting until late season because crops require large amounts of these macronutrients (Burg, Meehan, & Scherer, 2017). However, "… 80 percent [of nitrogen] used to grow plant-based foods, is lost to the environment. It contaminates streams, lakes and oceans as well as drinking water, and fuels the growth of algae and other organisms that can suffocate fish and kill plants" (Moran, 2018). Municipalities also play a role in nitrogen and phosphorus pollution in a multitude of ways. Beet juice, frequently added to road brine to lower the freezing temperature, contains high levels of nitrogen and phosphorus (Dysard, n.d.). After brine is applied and washed off roadways by snow and rain events, it releases N and P into the entire watershed (Dysard, n.d.). Municipalities also contribute to excess N and P nutrient runoff through inadequate wastewater treatment processes and individual failing septic tanks. In the case of Northwestern Ohio, these pollutants flow downstream and eventually enter Lake Erie.

The effects of this pollution were exposed during the 2014 Toledo water crisis where an extremely large algal bloom proved detrimental to the city's water treatment processes. Algal blooms have been an annual occurrence in recent years ("Five Years Later", 2019). Although low levels nitrogen and phosphorus runoff is essential to the health of Lake Erie, they currently being introduced to the watershed in constant and extreme amounts. This leads to excess nutrients in the water causing algal blooms and effecting the long-term health of Lake Erie, its inhabitants, and the communities that rely on the resources it provides.

The purpose of this research is to analyze the soil nutrient levels of roadside ditches that align both an agricultural field and a municipal road. This analysis seeks to evaluate if elevated levels of nitrates and phosphates are present in the soil on either side of the ditch and to determine which side is at fault for contributing more nutrient run-off.

Hypothesis

If soil nutrient levels of the municipal slope show increased levels when compared to its agricultural counterpart then, municipal sources are larger contributors of nutrient loading and nutrient runoff in roadside drainage ditches.

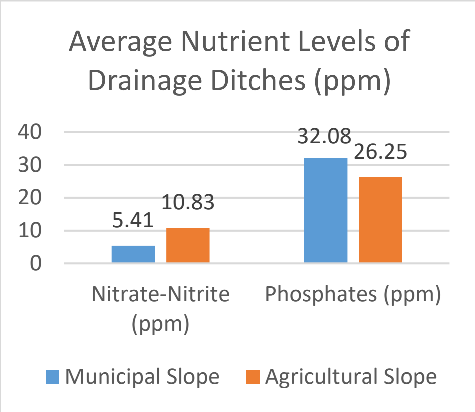
Methods and Materials

Beginning with the roadside slope of the ditch, determine where the gravel edge of the roadside ends, approximately twelve inches from the edge of the asphalt road. Remove all organic surface material from a fifteen-centimeter perimeter in this area including grass and twigs. A soil core is taken within this cleared area and the top fifteen centimeters of the core is placed into a metal airtight container and labeled “roadside slope”. A second core is then taken three centimeters to the left of the first core and stored in an airtight sample bag labeled “roadside slope.” The width of the ditch is then measured using a metric tape measure. This measurement begins at the point of the first core and stops five centimeters above the waterline of the ditch. If no water is present then the lowest elevation of the ditch is the endpoint. The middle point of the width is calculated and recorded along with the slope’s total width. Soil cores are collected from both the middle and bottom of the slope according to the procedure stated above. These samples are combined with each other in the containers to create a composite slope sample. This procedure is repeated on the agricultural slope of the ditch with the exception of the first soil core being taken approximately twelve inches from the edge of the agricultural field and the sample containers being labeled “agricultural slope.” After all soil samples are taken, the wet weight of each composite sample contained in the metal sampling can is determined using a digital scale.

In the lab, the lids are removed from the metal sampling cans and the cans are placed in the soil oven at 105 degrees Celsius for forty-eight hours. The samples contained in airtight bags are laid out on parchment paper to air dry for forty-eight hours. After the allotted time period, samples are removed from the soil oven and cooled until room temperature. Once they reach room temperature, the lids are placed back on the containers and they are weighed to determine the dry weight. The sample contained within the can is then disposed of and the mass of the empty can and lid is assessed. This weight is then subtracted from the wet and dry weight to determine the mass of the soil sample itself. The samples laid on parchment paper are sifted through a 2 mm mesh sieve and care is taken to thoroughly clean the sieve in between each sample. The soil that sifts through the sieve is stored in an airtight sample bag. This portion of the sample used for all chemical analysis. The pH, nitrate-nitrogen, and total phosphorus levels are analyzed according to the procedures listed in a LaMotte Combination Soil Outfit Kit.

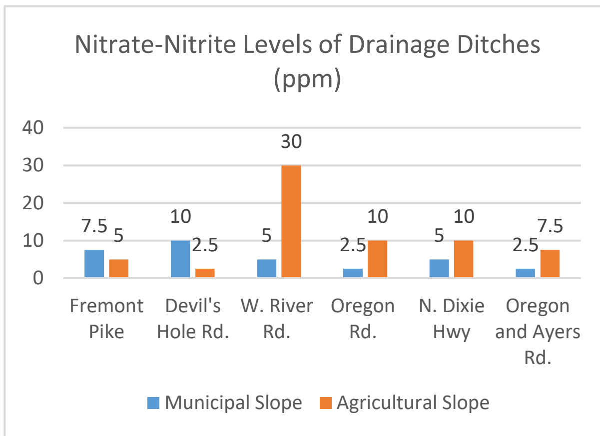
Results

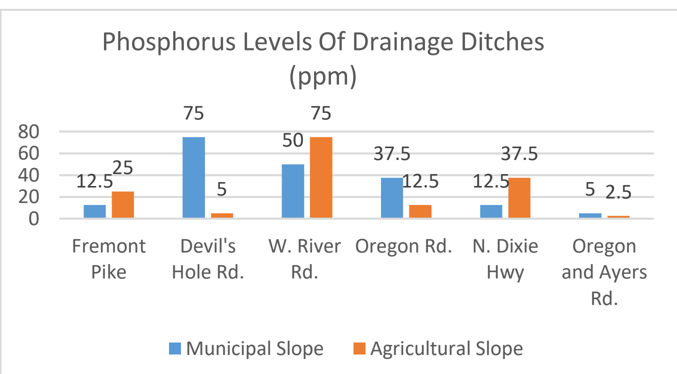
The data was first evaluated by calculating the averages of each parameter for both the municipal and



agricultural slopes of a site. These initial findings indicate the average nitrate-nitrite levels across all sites of both the municipal and agricultural slopes rank in the “low” range of 0-15 parts per million (ppm) . While the average phosphorus levels rank both groups in the “medium” range of 0-25 ppm. Although the average nitrate-nitrite levels of both slopes ranked “low”, the agricultural slopes’ levels were twice the amount of the municipal slope. When comparing the average phosphate levels, the municipal slope contains more parts per million than the agricultural slope. This indicates the presence of, on average, more phosphorus in municipal soils. This gives evidence to support that municipalities are also a large contributor to soil nutrient loading.

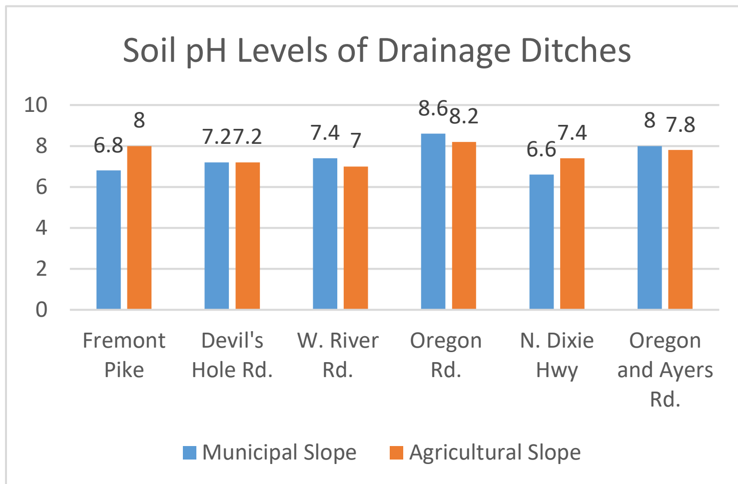
Nitrate-nitrite levels were analyzed in detail by comparing individual sites’ municipal and agricultural slopes. This revealed that 1/3 of the sites showed elevated nitrate-nitrite levels in the municipal slope over the agricultural slope of the same site. While 2/3 of the sites indicated higher nitrate-nitrite levels in their agricultural counterpart. The highest levels were found in samples taken from W. River Rd.’s agricultural slope. This gives evidence to support the theory of agricultural land contributing more nutrient runoff into drainage ditch soils than municipal sources.



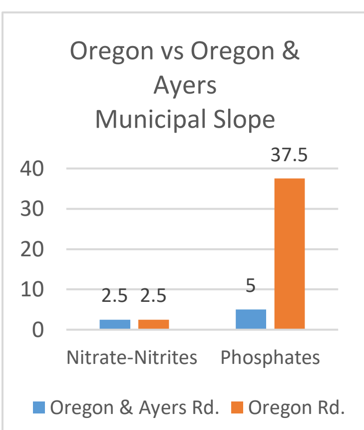


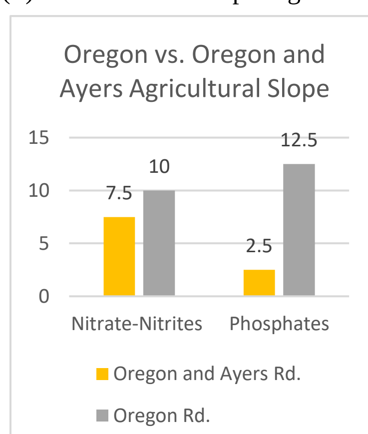
Phosphorus levels were evaluated similarly to the nitrate-nitrite levels. The phosphorus levels of the municipal slope were placed alongside its agricultural counterpart. Through this comparison, several results were identified. In 3/6 trials, the municipal slope showed elevated P levels over its agricultural counterpart. Within this, all of the elevated P levels were at least double the amount of the agricultural slope from that same site. The most elevated phosphorus levels are found at both the municipal slope of Devil's Hole Rd. and the agricultural slope of W. River Rd. Overall, the phosphorus levels are relatively even between the municipal and agricultural slopes, leading to an inconclusive result from this data.

While nitrate-nitrogen and phosphates were the main parameters analyzed, soil pH was also considered. The pH average of both the municipal and agricultural slope indicate the soil is slightly alkaline. However, when the data is broken down into individual sites, separated between municipal and agricultural slopes, a large range of pH values are discovered. When interpreting only the municipal slope data, 1/3 of the sites indicated slightly acidic soil, while 2/3 indicated slightly alkaline to alkaline soil. In contrast, when interpreting only the agricultural data, 1/6 of the sites identified as having a neutral pH and 5/6 as slightly alkaline to alkaline. When comparing the pH levels of the municipal slopes to that of the agricultural slopes, 1/2 of the municipal sites had more alkaline soils than the agricultural slopes indicating the possibility of increased nutrient loading on the municipal slopes.



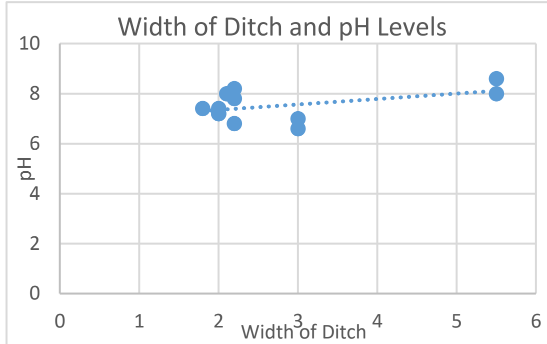
To determine the variability of nutrient levels on a single stretch of road, two sites, located on the same road, 0.3 miles from each other and on opposite sides of the road were analyzed. These two sites, Oregon Rd. and Oregon and Ayers Rd., showed variations in the nitrate-nitrogen and phosphorus (P) levels. When comparing the municipal slopes of each site, the nitrate-nitrite levels remained constant at 2.5 ppm, but the P levels increased by 7.5 times between the two sites. Oregon and Ayers Rd. indicated phosphorus levels of 5 ppm while the Oregon Rd. site indicated levels of 37.5 ppm. When analyzing the agricultural slopes of these sites, the nitrate-nitrite levels demonstrated an increase of 2.5 ppm between Oregon and



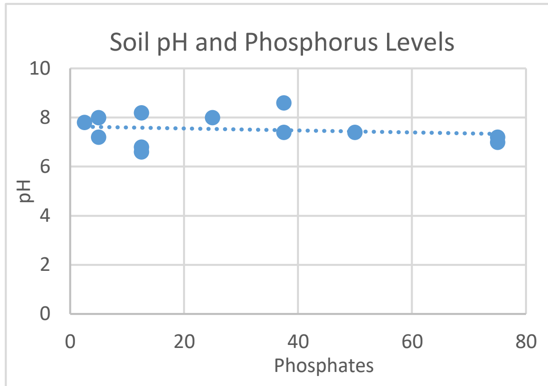


Ayers Rd. and the Oregon Rd. site. There was also an increase of 10 ppm of phosphorus between Oregon and Ayers Rd. and Oregon Rd. These significantly large increases indicate the possible inconsistency of nutrient levels even within a small range and the impact both municipal and agricultural sources can have on the soil.

Despite the relatively small limited data set, statistical analysis in the form of a paired t-test was performed on the data. This resulted in statistical significance of a correlation between the width of both the municipal and agricultural slope and their respective pH levels. This analysis indicates a linear relationship between the width of a ditch and the soil pH levels. As the width increases, so does the soil pH.



Statistical significance was also found within the combined results of the municipal pH and phosphorus levels. Which demonstrated the trend of lower phosphate levels when pH levels are more acidic.



The most significant findings of this study include that the average nitrate-nitrite levels of both the municipal and agricultural slopes of a site are in the "low" range, while the average phosphorus levels for both groups are in the "medium" range. As well as, 2/3 of the sites demonstrated increased nitrate-nitrite levels on the agricultural slope when compared to the municipal slope. Statistical significance was found between the width of the slope and soil pH levels, as well as significance between the pH and amount of phosphorus in the soil.

Discussion and Conclusion

Due to this study being preliminary in nature and using a small number of collection sites over a short period of time, the results concluded from this study may not accurately define the groups being compared. One source of error may be in the analysis of the samples. Samples were analyzed using a LaMotte Combination Soil Outfit, which consisted of a general extraction procedure for soil samples that is not guaranteed to extract all of the nitrate-nitrogen and phosphorus from the sample. The procedures also consisted of colorimetric analysis that used color-coded cards to identify the amount of a nutrient in the sample. This method is not the current industry standard. It uses a more generalized range to measure nutrient levels resulting in a moderate margin of error. Along with these largely unavoidable errors, the limited number of samples collected may have led to incomplete results. Another consideration to be made when assessing the accuracy of these results is that nutrient levels concluded are considered to be residual amounts. This is due to the fact that soil samples were collected after harvesting time and before road salt or brine was applied to roads. If samples were to be collected during the growing season, or the winter months, increased levels may be seen on either side. The nitrate-nitrite and phosphorus levels that were determined are amounts that are left after growing season had ended and before excess salt or brine has been applied to municipal roads. Despite these limitations and sources of error, relevant information can be concluded from the results.

Due to soil quality in drainage ditches emerging as a recent focus in the scientific community, there is little relevant research available to compare the results of this study with. However, it is important to recognize all possible correlations found within a study. This allows all probable relationships to be made known and compared to relevant studies when they are available. This study concluded several results that have been analyzed and identified as statistically significant. When a paired t-test was conducted on the pH and phosphorus levels of both the municipal and agricultural slopes, a statistical significance was determined. This infers that phosphorus availability in soil is correlated with soil pH. This is supported by the United States Department of Agriculture (USDA), which stated, “soils with inherent pH values between 6 and 7.5 are ideal for P-availability, while pH values below 5.5 and between 7.5 and 8.5 limits P-availability”, supports this finding (“Soil Phosphorus”, n.d.). The correlation of soil pH and width of the slope was an unexpected discovery within this study. However, it is significant in determining how the physical aspects of a drainage ditch such as width, depth, and angle of the slope contribute to the amount of nutrients within the soil. It is hypothesized that with further testing, this correlation will be strengthened. The fluctuation found in the nitrate-nitrogen and phosphorus levels of the Oregon and Ayers Rd. and Oregon Rd. sites are significant because the variance in the nutrient levels of the sites, located only 0.3 miles from each other, demonstrates how individual practices influence the surrounding environment.

Although the data yields inconclusive results due to the limited amount of data, it is reasonable to infer that upon further sampling, data will confirm the trend inferring the agricultural slope contains higher levels of nitrate-nitrites. Due to the phosphate levels being equally divided between the municipal and agricultural slopes it is recommended that further testing be completing before trends are inferred. To expand upon this study in the future, sampling of several more drainage ditches during various seasons is essential to determining long-term trends in the soil nutrient levels. With the addition of samples, the need of a more advanced extraction procedure and analysis method increases. With more advanced extractions, the nutrient levels determined by the test procedure will be more accurate because more of the nutrients will be released into the test sample. With improved procedures and increased samples, the data collected through this study will prove invaluable to research being conducted on the role drainage ditches and nutrient pollution, and offer solutions to mitigate pollution at its source. This research will also indicate where nutrient run-off is occurring, and if nutrient levels are within range to support buffer zones and rain gardens.

While this study is limited in the amount of data and quality of test kits, the results concluded from the research are still relevant in the scientific community. This study is significant in the recent discussions of nutrient run-off, erosion of drainage ditch banks, and their role in nutrient run-off mitigation. This research concludes the likelihood of significant relationships between the width of a slope and the soil pH levels, as well as between pH and phosphorus levels within a drainage ditch. The variance in nutrient levels is demonstrated across a wide range of sites, as well as those in close proximity of one another. While the main research question is largely unanswered, this study provides preliminary data that can be expanded on in the future. The need for more information on this topic will become ever more apparent as excess nutrient run-off continues to cause environmental and economic distress.

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