
WATER QUALITY ASSESSMENT: THE EFFECTS OF LAND USE AND LAND COVER IN URBAN AND AGRICULTURAL LAND

Natural Resources and Environmental Sciences (NRES)

Kansas State University

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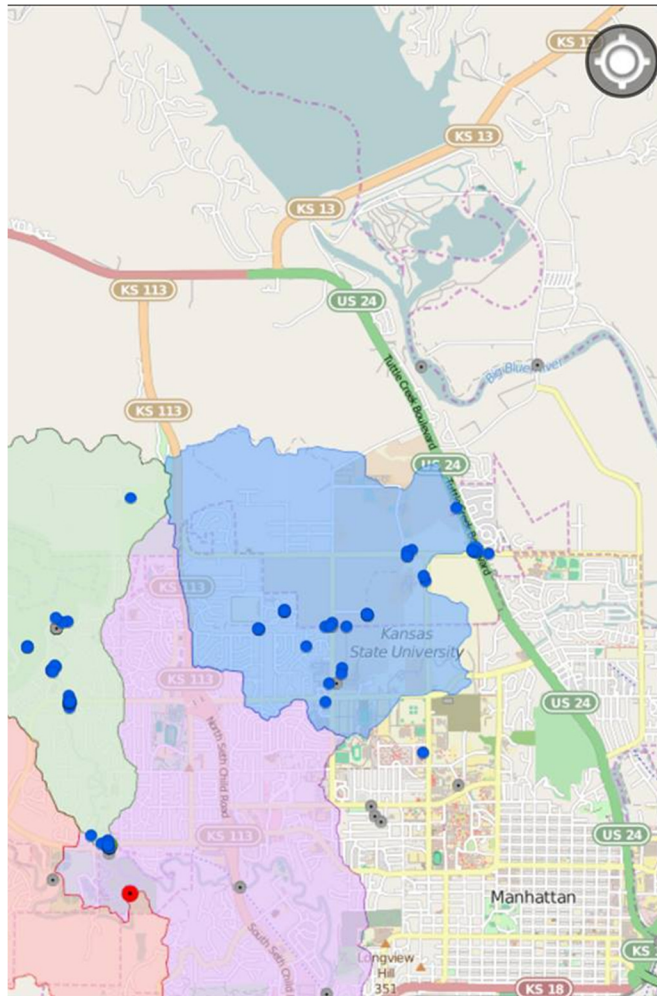
Abstract

Collectively, our natural resources and environmental sciences capstone course group chose to complete research over water quality. More specifically, the purpose of this project was to compare the quality of surface waters, using a citizen science approach, based on land use and land cover type. The objectives of our research are to: compare and contrast nutrient values of urban and agricultural land, determine agricultural and urban areas, and finally to analyze our results. After selecting our watershed location and determining the land use types within the Marlatt Watershed our group got to work researching topics related to our study area.

Our results found that there were no significant differences between urban and agricultural land uses, supporting our hypothesis. Future research on water quality in the Manhattan area should have an increased time period of collection, more standardized techniques for collecting water, and should concentrate on the amount of pollutants that are released by each household.

Introduction

Water is one of the most precious resources available to us and consequently, it is very important for us to understand the importance of preserving it. Water has a major impact on the environments it comes into contact with, and can greatly alter a landscape. A correlation is often found when examining the changes made to an area of land for human needs and the effects that these modified landscapes have on water quality within a watershed. By sampling and quantifying the effects that land use and land cover have on water quality, we can develop recommendations for better watershed management to ensure the quality of our surface waters.



(Figure 1.1 - Map of study area)

The area we focused on in figure 1.1 is the northern stretch of land north of Kansas State University (the blue highlighted area), the Marlatt Watershed. This area is subdivided between agricultural land use and urban land use.

Members of the group took water quality samples using a HACH® Test Kit, a relatively simple kit allowing tests to be performed by non-expert citizens. The group collected water samples within the Marlatt Watershed using the citizen science method and recorded the data into the ArcGIS mapping system. Then, by statistical analysis of water quality indicators, the group determined the differences in nutrient loads between the agricultural land and urban land. The

citizen science water sampling approach is the use of non-expert citizens in the collection of data for scientific analysis.

Our research focused on finding out how human land use interactions affect water quality in urban and agricultural developments. The land cover was divided into two sections, urban and agricultural areas. Comparing and contrasting the nutrient loads was the main focus in our research. We thought it would be very beneficial to know which land use had the higher nutrient load. The group hypothesized there to be no significant difference between urban and agricultural developments. This led us to look at how different land cover and land uses such as urban and agricultural developments can affect water quality, as well as both land and ecosystem health.

Land cover and land use are very important elements in relation to water quality. Different types of land use and land cover affect the quality of water. Agricultural and household fertilizers have different chemicals within them, such as nitrogen and phosphorus. These chemicals can potentially run off into nearby water sources such as groundwater, streams and larger bodies of water. In turn, this could damage the nutrient content within that water supply, affecting the overall water quality itself.

Water pollution occurs when a body of water is adversely affected due to the addition of large amounts of materials to the water. The sources of water pollution are categorized as being a point source or a non-point source of pollution. Point sources of pollution occur when the polluting substance is put directly into the waterway. A factory along a river that is dumping toxic chemicals directly into a river is an example. A non-point source occurs when there is runoff of pollutants into a waterway, for example when fertilizer from a field is carried into a

stream by surface runoff. Nutrients can run off of land in urban areas where lawn fertilizers are used, especially if excessive amounts are added and the nutrients can't be absorbed by the soil. Gathering all of our ideas and information on our study gave us a better understanding of how we were to take action in analyzing our study on water quality. Literature review analysis has given us a better background on how to analyze our results and further understand the cause of water quality due to land use and land cover.

Literature Reviews

Citizen Science:

Citizen science is the conduct of research by people who do not consider themselves scientists, but are driven to do their part for the environment. Citizen scientists volunteer to perform scientific field experiments to help real scientists collect data. With the reduction of government funding, continuous research in the environment has fallen to these citizen groups. Some will spend time outside observing nature while others will become involved in cleanup projects or projects that create new wildlife habitats. By the use of the Internet and social media, these citizen scientists can easily share their data and experiences with real scientists.

GIS Analysis:

GIS (Geographic Information System) is a software that allows for mapping of physical objects in the environment. While at the same time, connecting the objects to numeric values that further describe their properties. This ability to map and interact with these variables on such a large scale has allowed for development of tools within the system that simulate actual environmental conditions. Which becomes very useful for agriculture and conservation management of resources. This process is called Precision conservation.

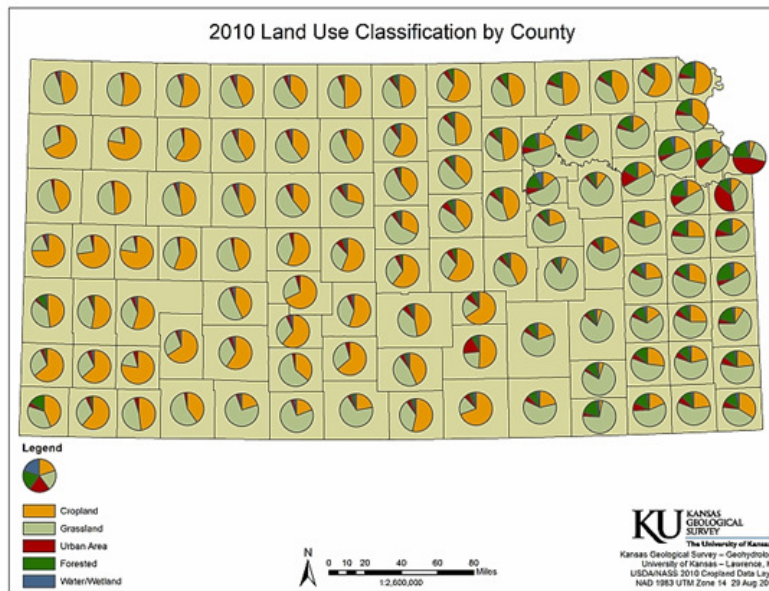
Precision conservation, although related to the field of precision agriculture, has a broader scope and scale. Precision agriculture applications focus on spatial coincidence among map layers to maximize crop production. Precision conservation focuses on interconnected cycles and flows of energy, material, chemicals, and water to reduce environmental impacts, off-site transport, and water pollution. For example, precision conservation may consider variability to increase carbon sequestration at landscape positions that may have a higher sink capacity. Precision conservation's geographic extent encompasses agricultural fields and their surrounding physical features (e.g., terrain, soil, water bodies, etc.), natural conditions (e.g., vegetation, wildlife, aquatic organisms, etc.) and system influences (e.g., climatic regimes, human infrastructure, management practices, etc.). (Berry, J. K., Delgado, J. A., Pierce, F. J., & Khosla, R. (2005))

Land Use and Land Cover (LULC):

Land use and land cover comprises of urban development, agriculture, and natural habitat. These three aspects together all play both positive and negative roles on the water quality within an ecosystem. Urban development mostly has a negative effect on water quality. Urban development reduces the uptake of water, which causes water in urban areas to collect chemicals and pollutants. This takes the chemical pollutants to larger bodies of water, such as streams or ponds, and damages the water quality.

Nonpoint source runoff from agricultural lands has also been identified as a major source of water quality impairment in many streams and rivers of the United States (USEPA, 2000). Anthropogenic inputs of nitrogen (N) and phosphorus (P) to agricultural watersheds in the United States have increased markedly since the early 20th century (Alexander and Smith, 1990; Vitousek et al., 1997; Galloway et al., 2004; Ruddy et al., 2006), in large part because of an increase in cultivated acreage and an increase in the aerial application rate of fertilizers.

Natural habitat aids in erosion reduction as well as prevents runoff of water. An example of how natural habitats do this is by plants absorption. Without plant absorption, all water and chemical content will runoff into water sources such as streams and lakes. This results in decreasing water quality for that particular ecosystem.



(Figure 1.2 Land Use Classification in Kansas)

Impacts on Water Quality:

Water quality is becoming increasingly important as we move into the future. There are many factors that have an impact on water quality. Some of the main ones are geogenic and anthropogenic factors. Geogenic factors are naturally caused, such as wind erosion and weathering. Anthropogenic factors are human produced causes. For example, fossil fuels, fertilizer, and waste disposal are anthropogenic factors. Wind erosion causes damage to water quality by increasing sedimentation, which causes one of the largest impacts to the quality of streams and other bodies of water. Weathering has a negative effect on water quality as well. It damages water quality by fragmenting the structure of aquatic ecosystems. Fragmentation

isolates habitats by destroying crucial corridors, increases costs for public service provision, decreases agricultural and forest productivity and reduces or eliminates culturally relevant open spaces and natural amenities.

Humans also have a very large impact on water quality. This anthropogenic factor can create damage for many living organisms, ecosystems, and other humans. The combustion of fossil fuels degrade water quality by making the water more toxic because of the increased chemical content that gets runoff into bodies of water. Waste disposal can hinder organism's ability to thrive by destroying their natural habitat and polluting their environment. Water quality, including water temperature and nutrient loadings, is affected by human influences, such as industrial and power plant use (NRC 2001).

Geogenic and anthropogenic factors are very broad terms for what can impact water quality. Water is a very important resource in the lives of all organisms, thus making it easy to have many factors impacting it. Chemicals such as nitrogen and phosphorus are two examples of both geogenic and anthropogenic factors. These chemicals can either hinder or benefit aquatic communities.

Methods

Study Sites

Observing differences in watershed analysis, the Marlatt Watershed was selected as a site of interest during the months of March and extending until the last part of April. The Marlatt Watershed was determined to find differences between urban and agricultural land. This site is located on the north end of Manhattan and is extending just outside the city's limits. This watershed was distributed into two different subwatersheds that included agricultural land east of College Avenue and south of Marlatt Avenue and urban land west of College Avenue.



(Figure 1.3 Sample Site in Marlatt Watershed, Urban Land Use)

The land cover categories that it consists of is woody wetlands, pasture/hay, open water, grassland/herbaceous, evergreen forest, low intensity developed land, open space developed land, medium intensity developed land, high intensity developed land, deciduous forest, and cultivated crops.



(Figure 1.4 Sample Site in Marlatt Watershed, Agricultural Land Use)

Kings Creek, located south of Manhattan off of McDowell Creek Road in the Konza Prairie Biological Station, was selected as the control site. The watershed in the Konza Prairie consists of 1581 hectares of land. Konza Prairie is a protected site that is used for biological research. Its land cover consists of grassland, herbaceous, developed open space, emergent herbaceous, mixed forest, deciduous forest, and woody wetlands.

Sampling

Six samples were collected from each of our test sites during our time period between the beginning of March to the of end of April. The HACH Surface water test kit was used to test samples on each of our sites. These tests included: air temperature, water temperature, dissolved oxygen (DO), nitrogen (N), phosphorus (P), pH, electrical conductivity (EC), and turbidity. After results were gathered, averages for each of our values were computed. Averages between urban and agricultural land were compared and contrasted. Testing was performed by inexperienced college students, which for many, was there first time taking water samples. These students had various different backgrounds and fields of study.



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(Figure 1.5 A Basic HACH Kit)

Statistical Analysis

All subwatersheds were delineated using ArcGIS software. A tool was created that determines the geographic region contributing to a given point by taking into account flow direction and the outflow of the selected watershed. While in the field gathering data, the Arc Collector app was used to record the variables in real time and record them on a cloud-server based interactive GIS web map. Microsoft Excel was used to gather all of our results to create tables of our data.

Program R was used to develop line graphs, bar graphs, and box and whisker plots for a clear view of our concluding results. These graphical representations compared dissolved oxygen, phosphorus, nitrogen, acidity (pH), and turbidity values between urban and agricultural land.

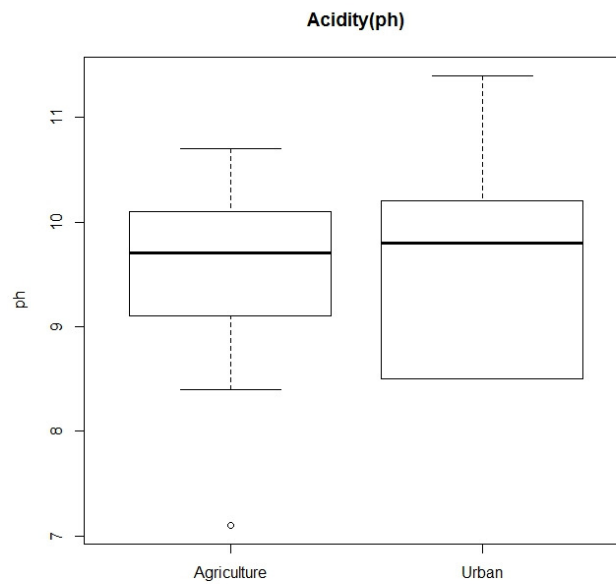
Results

Once all the data points had been collected, analysis of the data began to take place and the picture of the watershed unfolded with our results. Each land area type had noticeably higher mean values for the variables tested. Agriculture land use was higher in DO (30 mg/l), nitrogen

(1.6 mg/l), and EC (780 ppm). While the urban land area lead in pH (9.9), phosphorus (24 mg/l), and turbidity (32.1), while the mean averages were split evenly between the two land areas. The margins for several of the variables (pH and nitrogen) were fairly small between the two land classes. Nitrogen was particularly scarce throughout the entire watershed; throughout most of the testing period most data points had nitrogen levels of zero. Any noticeable nitrogen leakage into the water system didn't occur until later in the season when things started to warm and the fields began to be prepped for first plantings. Readings were minuscule and only noticeable after large rainfall events.

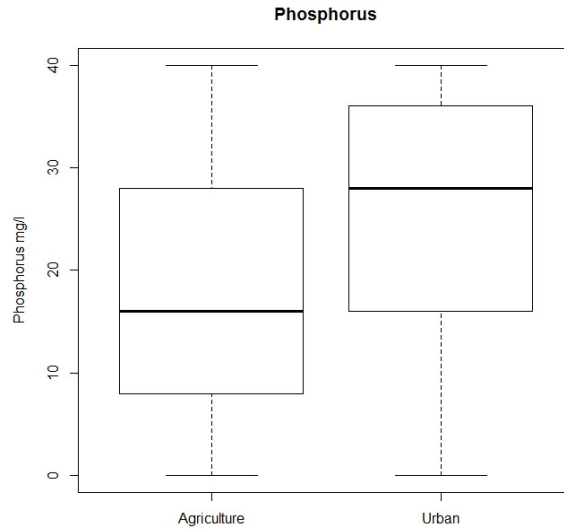
After all the values were gathered and analyzed, each variable was separated based on land use and was tested to find any statistical difference using T-Tests. While the average mean values may have been different for each variable in both land areas, after testing the values, it appeared that there was no statistical difference for any of the variables tested for.

1. Acidity (pH)



$t = -0.52105$, $df = 27.451$, $p\text{-value} = 0.6065$
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
-0.8547860, 0.5083574
sample estimates:
mean of x mean of y
9.512500, 9.685714
pH levels were not statistically different

2. Phosphorus



$t = -1.3144, df = 28.467, p\text{-value} = 0.1992$

alternative hypothesis: true difference in means is not equal to 0

95 percent confidence interval:

-17.084353, 3.723008

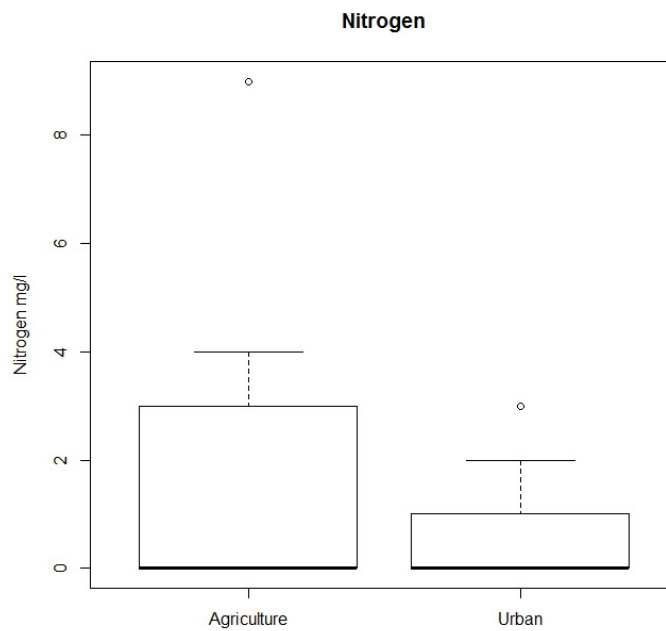
sample estimates:

mean of x mean of y

18.17647, 24.85714

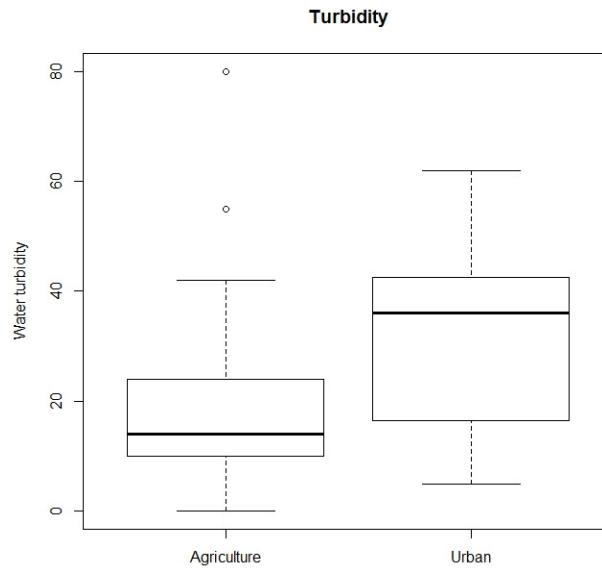
Phosphorus levels were not statistically different.

3. Nitrogen



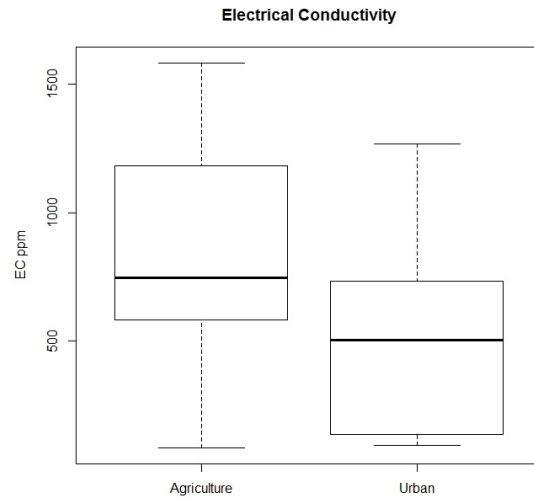
$t = 1.5618$, $df = 22.908$, $p\text{-value} = 0.1321$
 alternative hypothesis: true difference in means is not equal to 0
 95 percent confidence interval:
 -0.3264524, 2.3362563
 sample estimates:
 mean of x mean of y
 1.5882353, 0.5833333
Nitrogen levels were not statistically different.

5. Turbidity



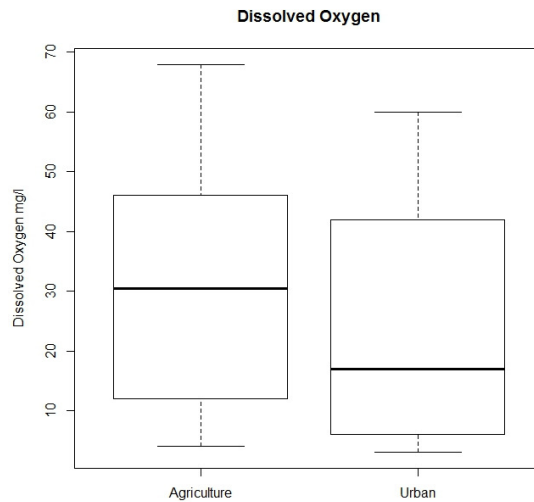
$t = -1.4023$, $df = 23.11$, $p\text{-value} = 0.1741$
 alternative hypothesis: true difference in means is not equal to 0
 95 percent confidence interval:
 -26.82951, 5.14769
 sample estimates:
 mean of x mean of y
 21.25000, 32.09091
Turbidity levels were not statistically different.

6. Electrical Conductivity



$t = 1.7653$, $df = 27.764$, $p\text{-value} = 0.08851$
 alternative hypothesis: true difference in means is not equal to 0
 95 percent confidence interval:
 -41.07214, 551.87571
 sample estimates:
 mean of x mean of y
 780.1875, 524.7857
Electrical Conductivity levels were not statistically different.

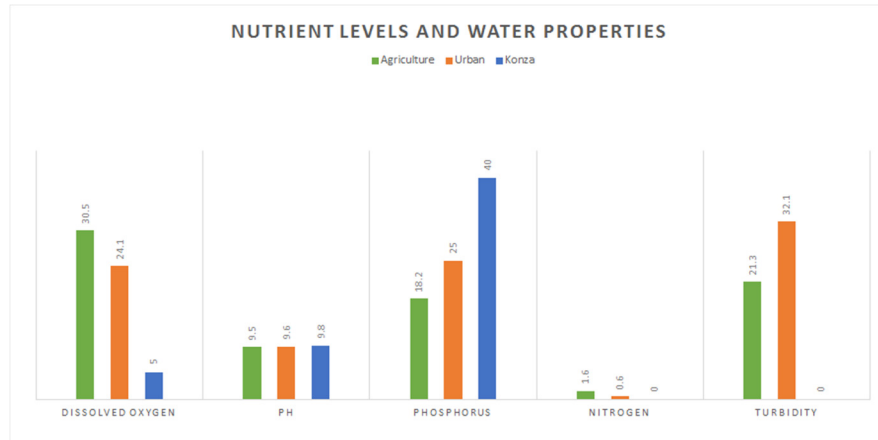
7. Dissolved Oxygen



$t = 0.80058$, $df = 24.651$, $p\text{-value} = 0.431$
 alternative hypothesis: true difference in means is not equal to 0
 95 percent confidence interval:
 -10.11259 22.95875

sample estimates:
mean of x mean of y
30.50000 24.07692

Dissolved Oxygen levels were not statistically different.



(Figure 1.6 Nutrient Levels and Water Properties of Samples)

Discussion

Overall, this research is conducted to reveal the elements within the system. With a better understanding of what is going on within the watershed, we can now lead to more effective management strategies for all land managers and homeowners. Better management of our water systems is also beneficial for cleaner water and a healthier ecosystem. We can improve overall water quality by targeting issue areas within the watershed. Areas that may be releasing too many nutrients into the water supply can be identified. With this information we can advise landowners to change their management strategy due to their negative influence on the system. Many homeowners put excess amounts of fertilizer and chemicals on their lawns, which then run off directly into, nearby streams. Educating the public on how to better manage their yard could help greatly in reducing nutrient loads in urban areas. This information can be used to help delineate areas for restoration into riparian or ecological buffer areas between nutrient leakage and the water supply.

Nutrients are more rich in certain areas due to different land uses that take place. An agricultural example of this is a farmer applying fertilizer onto a field next to a stream right before it rains, the fertilizer will then run off into the nearby stream, making the stream much more nutrient rich. An urban example of this is when a whole community applies fertilizer to their yard at the same time with an excess amount, leading to runoff, making the stream more nutrient rich. This leads to problems such as eutrophication.

While the data was relatively similar, it did shed light on a common issue within many water bodies in the world, eutrophication. Eutrophication can become a common issue within a watershed if it goes unmanaged. Nutrient matter such as Phosphorus or Nitrogen can leak within the water supply. This, in turn promotes prosperity and growth for algae within the water. When algae rates increase, they can lower levels of dissolved oxygen can even cover the surface of the water, blocking sunlight from entering the water and allowing photosynthetic growth for underwater plants. Eutrophication causes serious biological disturbances and can dramatically affect the water if not carefully managed. Both subwatersheds showed signs of a eutrophic event. While small, urban and agricultural data points indicated high dissolved oxygen and phosphorus levels, creating a prime environment for eutrophication to take place. This anomaly would be an interesting issue to look into in further research. The rates occur in fairly similar intervals between the urban and agricultural areas. However the urban rates occur slightly higher than the agricultural rates. Further investigation into the possible explanation behind this event could result in some promising research.

Turbidity was much higher in the urban areas due to the times that the samples were taken. The samples were taken during or right after rainfall events in the surrounding area due to lack of

water being present. The higher amounts of runoff created a higher sediment load, which contributed to the higher turbidity numbers.

Future research for this project should consist of more of a citizen science approach in urban areas. Focusing on what homeowners are doing to their lawn (ex: fertilizer and other chemical applications). This would give a more accurate idea of why the water tests are showing what they are. Kansas State University farms keep in depth paperwork of what and when they apply certain chemicals and fertilizers. Future research could obtain data from the surrounding farms and correlate that data with the nutrient loads for the given time frames. More points should be collected over a larger time frame consisting of diversified areas to give us a more accurate idea of exactly what is going on within the watershed. These research ideas will give us a better understanding of how we can better manage our land to improve water quality.

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