Spring 5-2019

Nitrate Accumulation in the Vadose Zone of Waverly's Wellhead Protection Area

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Disclaimer: The following thesis was produced in the Environmental Studies Program as a student senior capstone project.

Nitrate Accumulation in the Vadose Zone of Waverly's Wellhead Protection Area

An Undergraduate Thesis Proposal

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Presented to
The Environmental Studies Program at the University of Nebraska-Lincoln

In Partial Fulfillment of Requirements
For the Degree of Bachelor of Science

Major: Environmental Studies
Minor: Fisheries and Wildlife

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ABSTRACT

Agriculturally intensive areas such as Nebraska are faced with a growing threat: groundwater nitrate pollution caused by years of applying nitrogen based fertilizer. Nitrate pollution can be attributed to several factors such as manure from cattle ranching and wastewater plants, but Nebraska's main threat is derived from years of leached nitrogen fertilizer. When nitrogen fertilizer is applied it has one of several fates: plant uptake, volatilization, leaching or run-off. When nitrates leach beyond the plant root system, they are unable to be absorbed by the plant and ultimately move slowly towards the regional ground water table. While nitrate accumulation in the vadose zone is a complex issue with localized contributing factors, understanding nitrate accumulation in the vadose zone helps communities to plan for potential water quality issues in the future. In 2017, staff from the Lower Platte South Natural Resources District (LPSNRD) sampled 8 public water supply wells in Waverly, NE and found that 50% of those wells had nitrate concentrations above 5 mg/L, indicating that the Waverly WHPA exceeded the Phase II ground water quality trigger for the LPSNRD (Ehrman, et al., 2017). A Drinking Water Protection Plan calling for vadose zone soil core testing was implemented and this study quantifies the nitrate concentrations at 7 vadose zone core locations in Waverly, Nebraska while exploring factors such as fertilizer application rates and land use that may attribute to vadose zone nitrate accumulation.

INTRODUCTION

Nitrogen is a macro nutrient essential for plant growth, and in many ecosystems, plant biomass and productivity are limited by nitrogen supply. Only two forms of nitrogen are available for plant uptake: nitrate (NO_3^-) and ammonium (NH_4^+). While both can be utilized by plants, the majority of nitrogen that plants consume is in the form of nitrate. Soil organic matter can be an abundant source of nitrogen in the natural world, but in agriculturally intensive areas such as Nebraska and much of the Midwest, nitrogen-based fertilizer is heavily relied upon in order to provide crops with sufficient amounts of nitrogen, thus optimizing crop yield and profitability.

Nitrogen fertilizer first became available in 1913 after the Haber-Bosch process was invented (Galloway & Cowling, 2002). The Haber-Bosch process allowed, for the first time, an unlimited supply of nitrogen that could be used to grow food. Nielson and Lee (1987) found that the use of inorganic fertilizers increased four-fold between 1960 and 1980. Inorganic fertilizer use has continued to increase and today, more than half of the food eaten by the global population is produced using nitrogen fertilizer from this process (Galloway & Cowling, 2002). Nitrogen use efficiency, or the ratio between the amount of fertilizer applied and the amount that is taken up by the crop, has increased over the last 40 years, but nearly half of N fertilizer input is not utilized by crops and a significant amount of N applied is lost to the environment via nitrification, denitrification, leaching, and ecological problems. (Cao, Lu, & Yu, 2018).

Nitrate is highly mobile in soil due to its negative charge repelling with the negatively charged soil. This mobility allows nitrate to easily become leached beyond plant root systems. Once leached beyond the plant root system, nitrate is no longer available for plant uptake, and instead, accumulates in the vadose zone. The vadose zone, also referred to as the unsaturated zone, is defined as the area between the Earth's terrestrial subsurface and the regional groundwater table. Once leached beyond the root zone, nitrate is essentially "lost" and slowly moves towards the water table, where it is ultimately deposited, and in time, infiltrates and contaminates the ground water supply. Few options for leached nitrate remediation have been explored with success, making the science of fertilizer application more and more important. Sebilo, Mayer, Nicolardot, & Mariotti (2013) stated,

> "Empirical correlations relating increased use of synthetic fertilizers, their application rates, land use change, and nitrate leaching suggest that the increased application of synthetic fertilizers is strongly connected with the increase of nitrate concentrations in ground and surface waters."

In Nebraska, increasing groundwater nitrate contamination coincides with extensive corn and soy production and in areas of the state with limited production of corn and soy there has been limited nitrate groundwater pollution (Juntakut, Snow, Haacker, & Ray, 2018). With about 80% of Nebraskans relying on groundwater for their drinking water (Skipton, Dvorak, & Woldt, 2005), vadose zone nitrate accumulation in areas of the state with intensive crop production is a relevant and critical issue to address in order to safeguard much of the state's public drinking water supply.

There are several concerns when it comes to nitrate contaminated water. One concern is Methemoglobinemia, also known as blue baby syndrome, which occurs in infants and causes cells to not receive enough oxygen, and often presents as cyanosis, giving the infant a blue-ish color (US Environmental Protection Agency, 2009). The relationship between cancer and nitrate intake has not been conclusively demonstrated (Bouchard, Williams, Surampalli, 1992), but evidence from some studies point to a possible linkage between nitrate intake and bladder and ovarian cancer (Weyer, et al., 2001).

In order to protect public health, the United States Environmental Protection Agency (EPA) set a maximum contaminant level (MCL) at 10 milligrams NO_3^- per liter (10 ppm) for drinking water in the United States (U.S. Environmental Protection Agency, 2009). In addition to a nitrate MCL, amendments to the Safe Drinking Water Act (SDWA) in 1986 required states to adopt a program to safeguard areas around wells that supply public drinking water systems from contamination that could have adverse effects on human health (Raucher, 1986). These safeguarded areas are known as Wellhead Protection Areas (WHPA). In the state of Nebraska WHPAs are delineated by the Nebraska Department of Environmental Quality and roughly correspond to the predicted 20-year-time-of-travel zone for the supply wells in those systems (Ehrman, et al, 2018).

A 1988 Nebraska study revealed that the effects of applying N at rates greater than 100 pounds per acre per year are more obvious [than that of fewer than 100 pounds per acre per year]. Average extractable NO3-N levels approximately doubled for each additional 100 lbs/acre/year (Spalding & Kitchen, 1988). Additionally, the data suggests that even in the finer textured soils of southeast Nebraska, significant loss of fertilizer via leaching may be the rule and not the exception. (Spalding & Kitchen, 1988). Regular sampling and testing of vadose zone soils can help map the movement of nitrate plumes and help communities plan for potential water quality problems. Soil testing also provides valuable information about the amount of nitrogen and other nutrients that are available for crop consumption and may save producers money on unnecessary fertilizer application and ultimately improve groundwater quality (Fleming, Adams, & Ervin, 1998).

While nitrate pollution occurs from sources other than N fertilizer, including livestock operations and wastewater reclamation processes, understanding optimal N fertilizer management and the expected N travel time to the water table in Nebraska is paramount to managing the ever-increasing nitrate problem and protecting the groundwater that so many Nebraskans rely on.

Policy and education are arguably the best way to reduce the amount of nitrate entering the watershed (Schepers, Moravek, Alberts, & Frank, 1991), but there is little literature that addresses both fertilizer application rates and N travel time through the vadose zone. Nkonya and Featherstone (2000), claimed,

> "the transport of leached nitrate from the root zone to groundwater takes approximately 30 to 60 years."

But, because factors such as soil type, climate, precipitation and land use influence the transport of N, there are location-specific attributes that influence optimal fertilizer application rates for every different location. Regular sampling and testing of vadose zone soils can help map the movement of nitrate plumes and help communities plan for potential water quality problems. Soil testing also provides valuable information about the amount of nitrogen and other nutrients that are available for crop consumption and may save producers money on unnecessary fertilizer application and ultimately improve groundwater quality (Fleming, Adams, & Ervin, 1998).

In an effort to extend the body of knowledge related to optimal fertilizer application rates (specifically in Lancaster County, NE), better understand the factors that influence nitrate accumulation in the vadose zone, and to outline best management practices for Lancaster County, this study closely examines 15 sites near Waverly, Nebraska.

Waverly is a small agricultural town located approximately 20 miles east of Lincoln in Lancaster county, and depends upon groundwater for the community's drinking water. This location was chosen because in 2017, staff from the Lower Platte South Natural Resources District (LPSNRD) sampled eight public water supply wells in Waverly and found 50% of those wells had nitrate concentrations above 5mg/L, indicating that the Waverly WHPA exceeded the Phase II ground water quality trigger for the LPSNRD (Ehrman, et al., 2017).

This study will follow a mixed research design, incorporating both qualitative and quantitative data by examining the relationship between local N fertilizer rates and vadose zone nitrate accumulation near Waverly. The study will specifically follow an explanatory sequential design, in which soil cores will be collected and processed, yielding quantitative nitrate concentration data. Data including crop type and soil classification from the corresponding site will then be used to explain, qualitatively, why the nitrate concentrations may be so.

METHODS

RESEARCH DESIGN

The research for this project involves vadose zone soil core collection, processing, and instrumental measurement of nitrate concentrations. In addition to data collection from the cores themselves, an endeavor to obtain fertilizer application rates from landowners near core sites was attempted, but ultimately unsuccessful. Landowner fertilizer application rates were pursued through a survey that was delivered to the homes of nearby landowners on 21 March 2019. The following week several of the landowners were called in an effort to conduct the survey, but many were not reached. Doug Althouse, of Althouse Acres LLC, provided information related to his crop management practices while standard N fertilizer application rates for the Waverly area were provided by The Midwest Farmers Coop in Waverly. Specifics from Althouse Acres and Midwest Farmers Coop can be found in the Results section of the paper.

Fifteen locations in the Waverly area were chosen for soil core extraction. This project only examines at 7 of the 15 locations, as the data from the remaining locations was not processed at the time of the writing of this paper. Land use in these 7 locations include urban landscaped and un-landscaped, rural converting to urban, right of way next to cropland, and cropland. The locations were strategically chosen in accordance to the Waverly Wellhead Protection Area. At the core site, a description of the location, weather, and any other unique aspect(s) were noted. Due to the unique geographical location and not being able to replicate plots, the results from this study are a case study, but and may be used to extrapolate themes across the agricultural industry. Geographical coordinates of the locations and additional pertinent information can be found in Table 1. A map outlining the WHPA with coring locations is provided in Figure 1.

Table 1: Core Names and Identifying Characteristics

Core Name	Date Extracted	Latitude	Longitude	Core Depth (ft)	Location Notes
Wa-Lots-18	1-31-18	40.906342	-96.521972	50	Rural, converting to urban (new construction site)
Wa-Math-18	1-30-18	40.909651	-96.531688	30	Urban, unlandscaped
Wa-Church-18	1-30-18	40.913878	-96.526273	30	Urban, taken from Methodist church
Wa-Well-18	1-31-18	40.911294	-96.536857	20	City property, Waverly Well #5
Wa-Fletcher-18	2-2-18	40.870738	-96.521505	50	Right of way, next to cropland
Wa-AlvoW-18	2-2-18	40.885669	-96.534893	70	Cropland
Wa-AlvoE-18	2-2-18	40.886128	-96.529001	30	Cropland

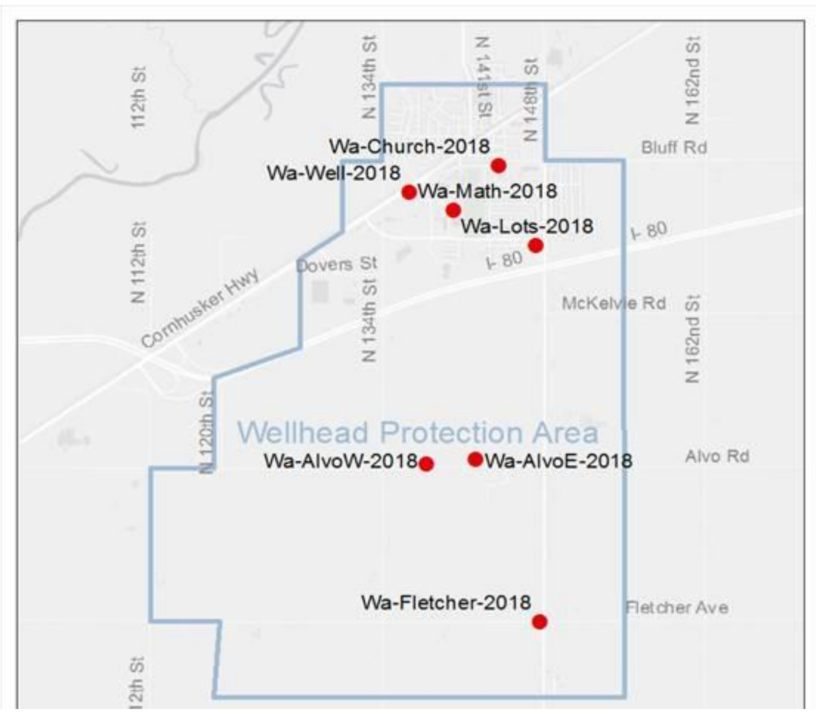


Figure 1: Waverly WHPA and Coring Locations

CORE RETRIEVAL

All samples were collected via a hollow stem auger drill rig or a Geoprobe Model 66DT direct push coring system depending on the suspected parent material and depth to the water table. An American Society for Testing Materials SOP was followed at the core site in order to ensure the capture of undisturbed soils and minimize sample loss (American Society for Testing and Materials, 1991).

The rigs allowed augers to be drilled from the surface to the water table or refusal (point at which drilling cannot continue) in five foot intervals. Each five-foot auger interval was lined with two 2.5 foot Plexiglas tubes which encompassed the soil cores in sequential depth. The Plexiglas liners were then retrieved and physical changes in soil properties were noted in the field book. The site location as well as the depth was labeled on each end of the tube before it was capped and frozen for further processing.

CORE PROCESSING

In the lab, a detailed Standard Operating Procedure (SOP) modeled after the United States Department of Agriculture's second version of the Soil Survey Field and Laboratory Methods Manual (Soil Survey Staff, 2014) was followed for soil core processing. Further adoption of methods was derived from the book, "Laboratory Guide for Conducting Soil Tests and Plant Analysis" (Jones, 2001).

Once cores were thawed, they were separated by depth and color and/or textural differences. After initial separation, the subsamples were given 24 hours to air dry before being finely ground (2mm) in a Thomas-Wiley mill. Once ground, 10 grams of the subsample was placed in an Erlenmeyer flask with 100mL of 1M potassium chloride solution. The flask was then capped and placed on a Wrist Action Shaker for one hour in order to ensure homogenization of the solution.

After ensuring homogenization of the subsample, the subsample was filtered through a Buchner vacuum filtering assembly. The Buchner vacuum assembly was lined with a 7cm Whatman #42 filter paper and wetted with a 1M KCl solution in order to remove any potential contaminates on the filter paper. Once the filter paper was rinsed, the Buchner assembly was set up and the soil subsamples were slowly poured into the Buchner assembly and filtered, yielding a clear liquid potassium chloride solution containing the same nutrient content as the soil it was derived from.

If the solution produced was not clear, the filtration process was repeated. This final, clear liquid KCl solution is what will be analyzed on the LACHAT. The subsample solution was then placed in clean 125 mL Nalgene bottles, labeled accordingly, preserved with 1 drop of HCl and frozen until a sufficient number of samples were ready for LACHAT analysis.

MEASUREMENT OF NITRATE-N

The LACHAT uses flow injection analysis, which is a continuous flow method for rapidly processing instruments (Lachat Instruments, 2012). The instrument operates on the basis photometry in order to analyze concentrations of ammonia and nitrate, but only nitrate concentrations will be utilized for this study. The LACHAT requires users to make a set of standards in order for it to create a calibration curve. The calibration curve provides a set of known standards in which the instrument has reference to. The calibration curve was required to have an accuracy of 99.9% or greater in order to move forward with analyzing samples. Concentrations are read in milligrams per liter. A full SOP for LACHAT operation can be found in the appendix.

In order to validate sample results, several quality assurance and quality control (QA/QC) samples were included. Quality assurance samples were treated the same as the rest of the samples, which involved putting them in the wrist-action-shaker and filtering them in the Buchner assembly. For each run on the LACHAT, three different QA/QC methods were utilized: a laboratory duplicate (LD2), a laboratory fortified blank (LFB), and a laboratory reagent blank (LRB).

Laboratory duplicates are two identical subsamples that come from the same container. They are processed and treated as if they were individual samples. The results from LD2 analysis are used to evaluate analytical precision and include variability associated with sub-sampling and the matrix (KCl), but not the precision of field sampling, preservation or storage (EPA Publication, SW-846). The laboratory reagent blank is analyzed to assess background interference or contamination that exists in the LACHAT, which could lead to reporting of elevated concentrations or false positives (US EPA, Sw-846). In the case of this study, the LRB’s consisted only of the matrix, KCl. Finally, the LFB, is an aliquot of KCl with a specified concentration of the analyte (NO_3-) added. The LFB is processed and analyzed exactly like a sample, with the purpose of determining whether methodology is in control and whether the user is capable of making accurate and precise measurements (EPA Publication, SW-846).

DETERMINING LAND USE AND ITS CORRELATION TO VADOSE ZONE N-LOAD

ArcMap 10.6, a program for geospatial information system (GIS), was utilized to create a map of Lancaster County that featured nitrate contaminated wells (5 mg NO_3-N/L or greater) and land use. A raster, thematic data layer produced by CALMIT and the Nebraska Department of Natural Resources (NDNR) provided Nebraska land use data. It was created using Landsat 5 Thematic Mapper satellite imagery between 06/13/2005 and 09/20/2005 and featured 25 different classifications of land use. Data for nitrate contaminated wells was obtained through the NDNR website. The data from this shapefile included all well types and all detected levels of N.

In ArcMap 10.6, the land use data which originally featured 25 classes of crops and whether they were dryland or irrigated, was simplified into 5 classes: irrigated crops, dryland crops, range/pasture/grassland, urban land/roads, and open water/riparian areas/wetlands. The NDNR well data was reconfigured to only show wells that tested at 5 mg NO_3/L or greater.

RESULTS

Table 1 outlines the date the soil cores were collected, processed, as well as the depth to the water table and the total depth of the soil core, both in feet. The water table was not intercepted at Wa-AlvoW-2018. Average measurements for bulk density, gravimetric water content, pH, NO3-N, pore water NO3-N and soil NO3-N in pounds per acre can be found in table 2.

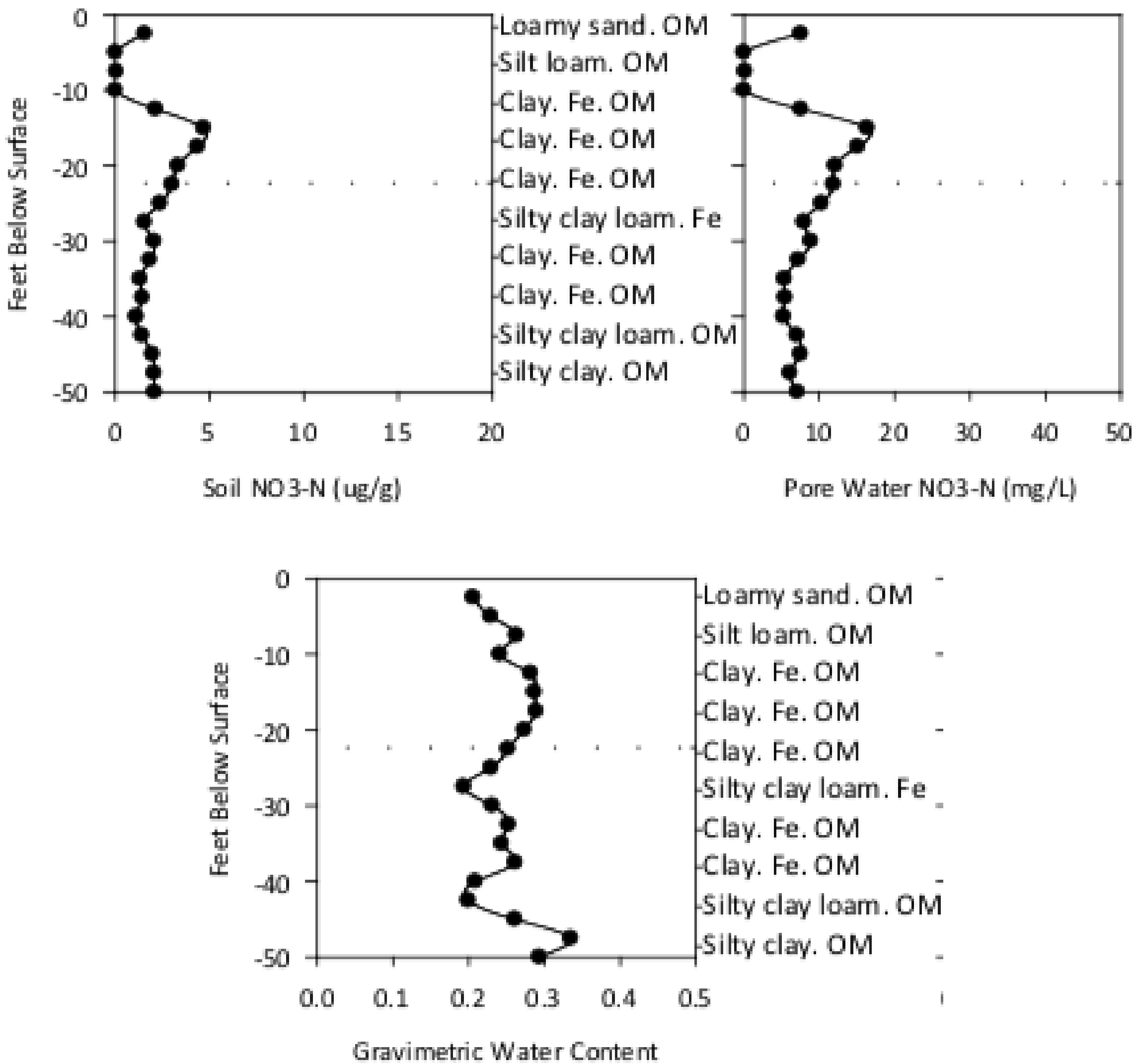
Table 1

Site	**Sampled**	**Processed**	**Water Table (ft)**	**Total Depth (ft)**
Wa-Lots-2018	1-31-2018	2-16-2018	22.3	50
Wa-Church-2018	1-30-2018	2-21-2018	14.8	30
Wa-Math-2018	1-30-2018	3-16-2018	14.1	30
Wa-Well-2018	1-31-2018	3-22-2018	12.2	20
Wa-Fletcher-2018	2-2-2018	5-7-2018	48	50
Wa-AlvoW-2018	2-2-2018	6-20-2018	Refusal	70
Wa-AlvoE-2018	2-2-2018	6-27-2018	30	30

Table 2

Site	**Bulk Density (g/mL)**	**Gravimetric Water (g)**	**pH**	**NO3-N (ug/g)**	**Pore Water NO3-N (mg/L)**	**Soil NO3-N (lbs-N/acre)**
Wa-Lots-2018	1.97	0.25	7.03	1.91	7.45	10.3
Wa-Church-2018	1.91	0.27	7.32	0.92	3.60	4.78
Wa-Math-2018	1.90	0.25	6.66	0.75	3.57	3.96
Wa-Well-2018	1.81	0.24	6.87	1.78	8.42	8.04
Wa-Fletcher-2018	1.82	0.14	7.64	0.47	4.15	2.18
Wa-AlvoW-2018	2.11	0.22	7.67	0.62	2.68	3.31
Wa-AlvoE-2018	2.00	0.24	6.47	3.01	12.39	16.26
Average	1.96	0.22	7.25	1.19	5.43	6.20

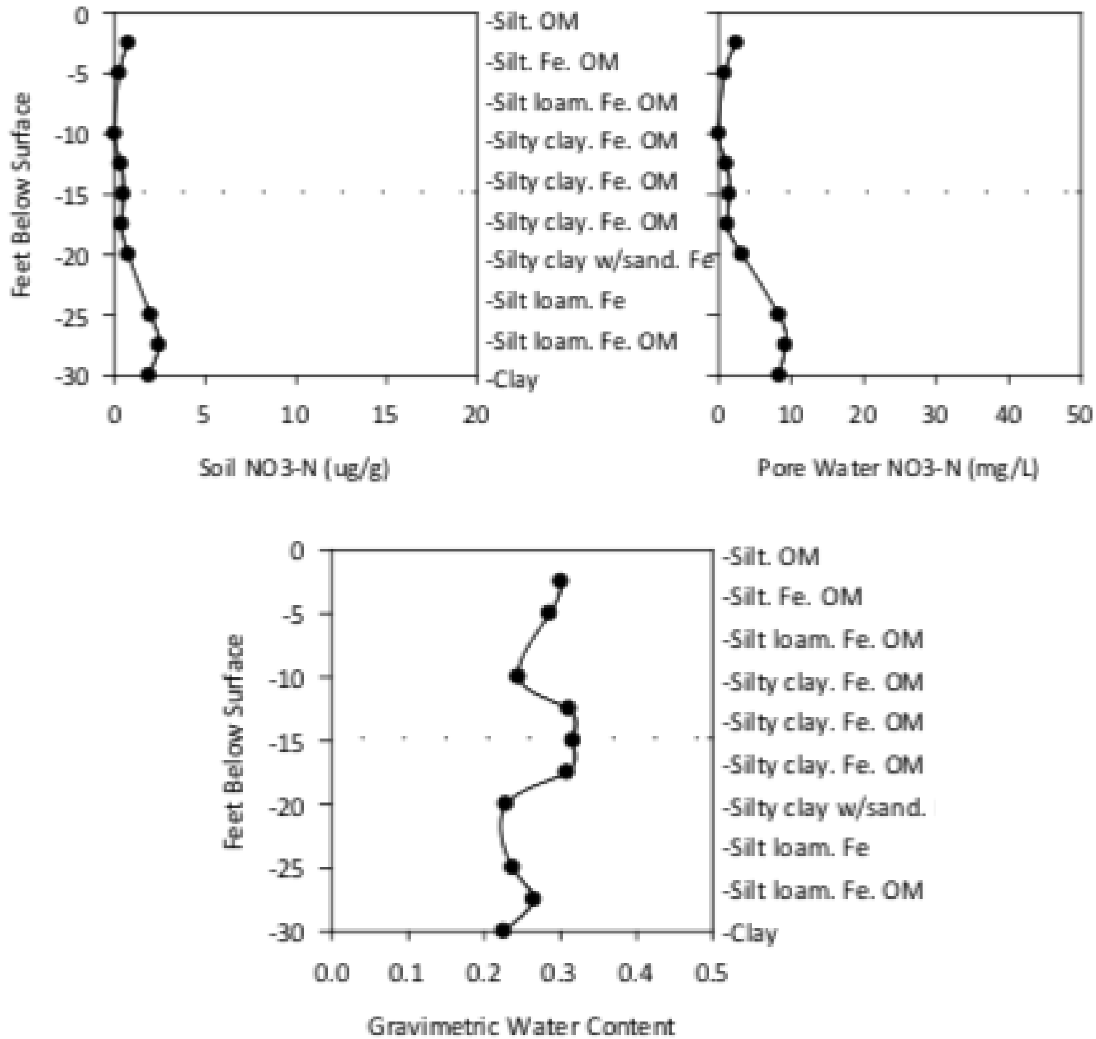
Wa-Lots-2018



Discussion

The urban location with the highest soil concentrations of NO_3-N was Wa-Lots-2018. The location was a new construction site and the depth to the water table was 22.3 feet. This core had an average of 10.3 lbs-NO_3-N/acre. The site is unique because its top five feet of soil was comprised of loamy sand, while the top five feet of soil in other locations was comprised of mostly silt or silty clay. The loamy sand at this location likely allowed for a greater amount of leaching when compared to a site with a high clay content at the surface. The top 10 feet of soil had very little NO_3-N accumulation, but when the soil lithology changed from loamy sand to clay, the amount of NO_3-N increased significantly, suggesting that the sandier soil allowed NO_3-N to leach, but was being held up by the clay around 10 feet. Another contributing factor to the soil NO_3-N load for Wa-Lots-2018 could be the amount of soil organic matter that was noted throughout the depth of the core. Organic matter (OM) was noted in all but one subsample from this core.

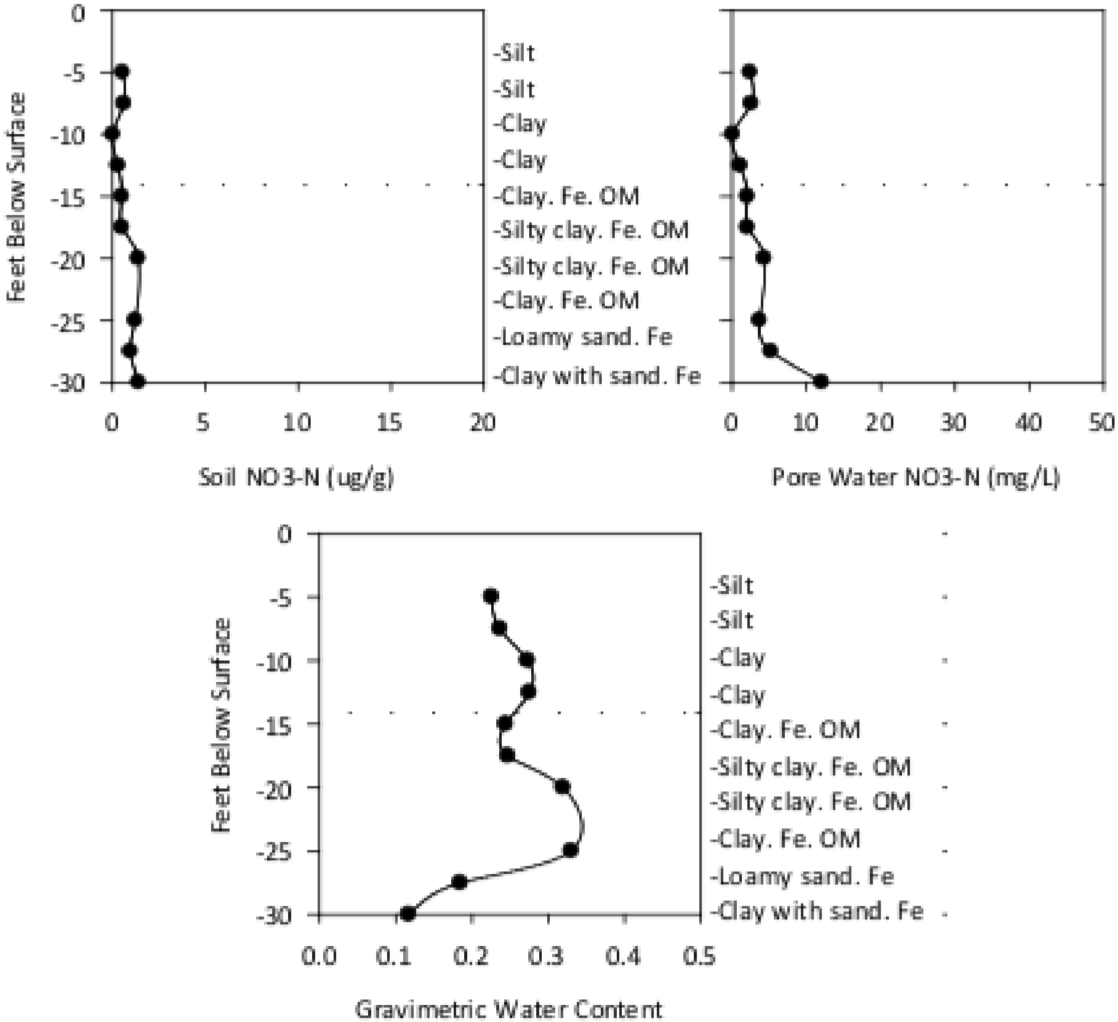
Wa-Church-2018



DISCUSSION

Wa-Church-2018, an urban site, was taken from the Methodist Church and had an average 4.78 lbs- NO_3-N/acre. The water table was intercepted at 14.8 feet. The majority of the soil from this core was silt loam and silty clay, with the very last subsample entirely clay. The greatest amount of NO_3-N is stored between 22 and 30 feet below the surface.

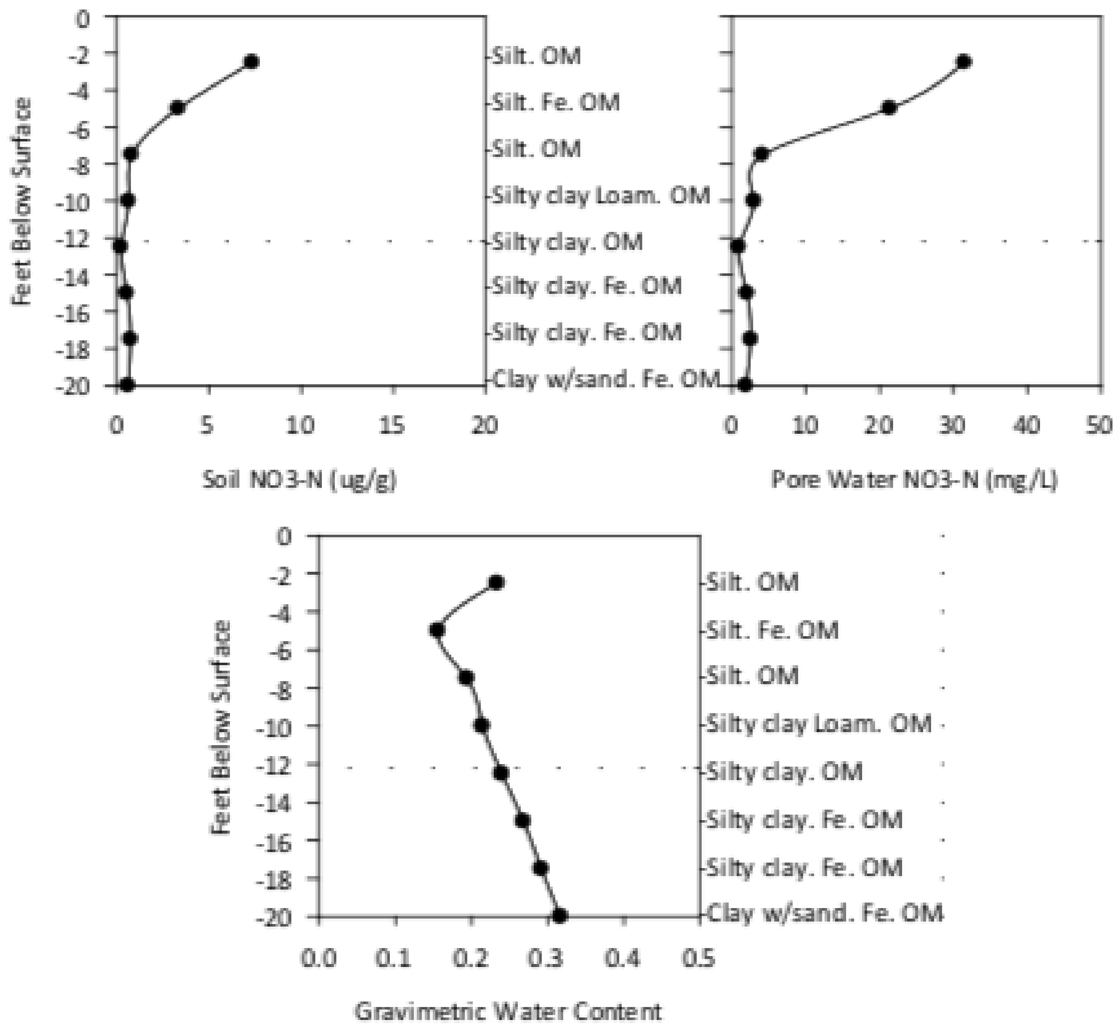
Wa-Math-2018



DISCUSSION

Wa-Math-2018 is an urban, landscaped site. The water table was intercepted at 14.1 feet below the surface and its average soil NO_3-N was 3.96 lbs/acre. The majority of the soil was composed of silt and clay. The greatest amount of NO_3-N is stored between 20 and 30 feet below the surface.

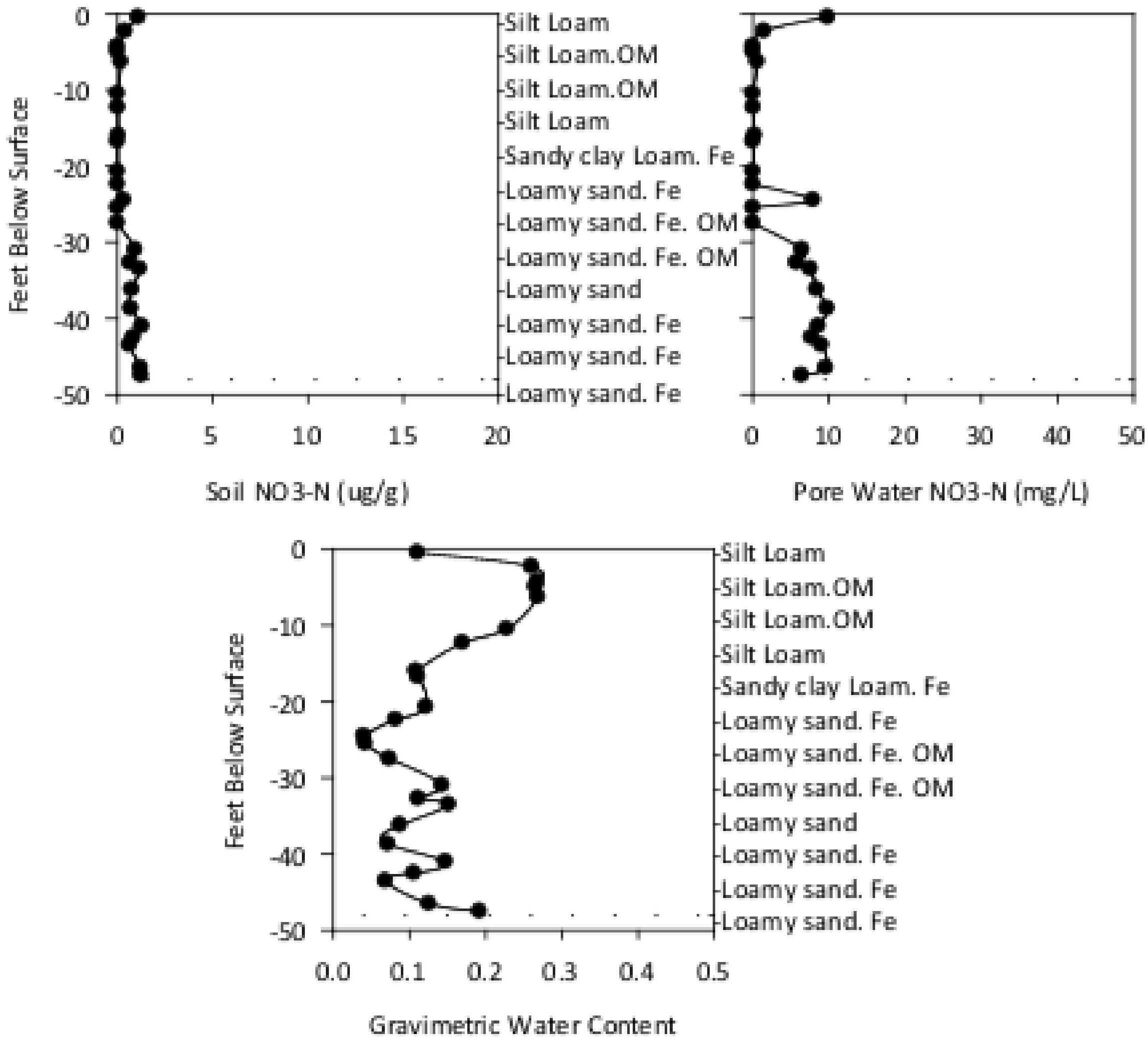
Wa-Well-2018



DISCUSSION

Wa-Well-2018 was sampled from Waverly Well #5, an urban location. The water table was intercepted 12.2 feet below the surface, but the core was collected down to 20 feet. The greatest amount of NO_3-N is being stored in the top 8 feet, and the average soil NO_3-N is 8.04 lbs/acre. The first 8 feet are comprised of silt and OM was noted throughout the depth of the core.

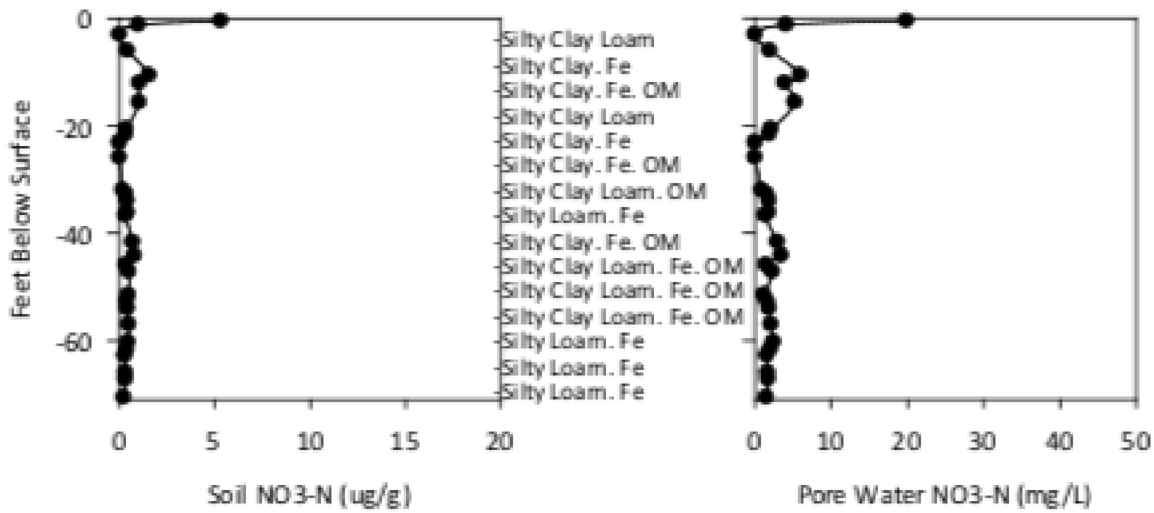
Wa-Fletcher-2018

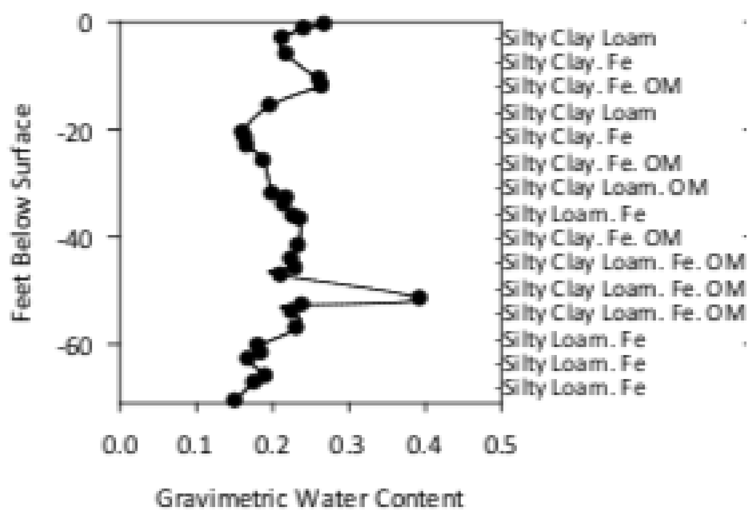


DISCUSSION

Wa-Fletcher-2018 is a rural location, next to cropland and was taken from the right of way off of Fletcher Avenue. The water table was intercepted at 48 feet and the average soil NO_3-N load is 2.18 lbs- NO_3-N/acre, the lowest amount of all 7 samples.

Wa-AlvoW-2018

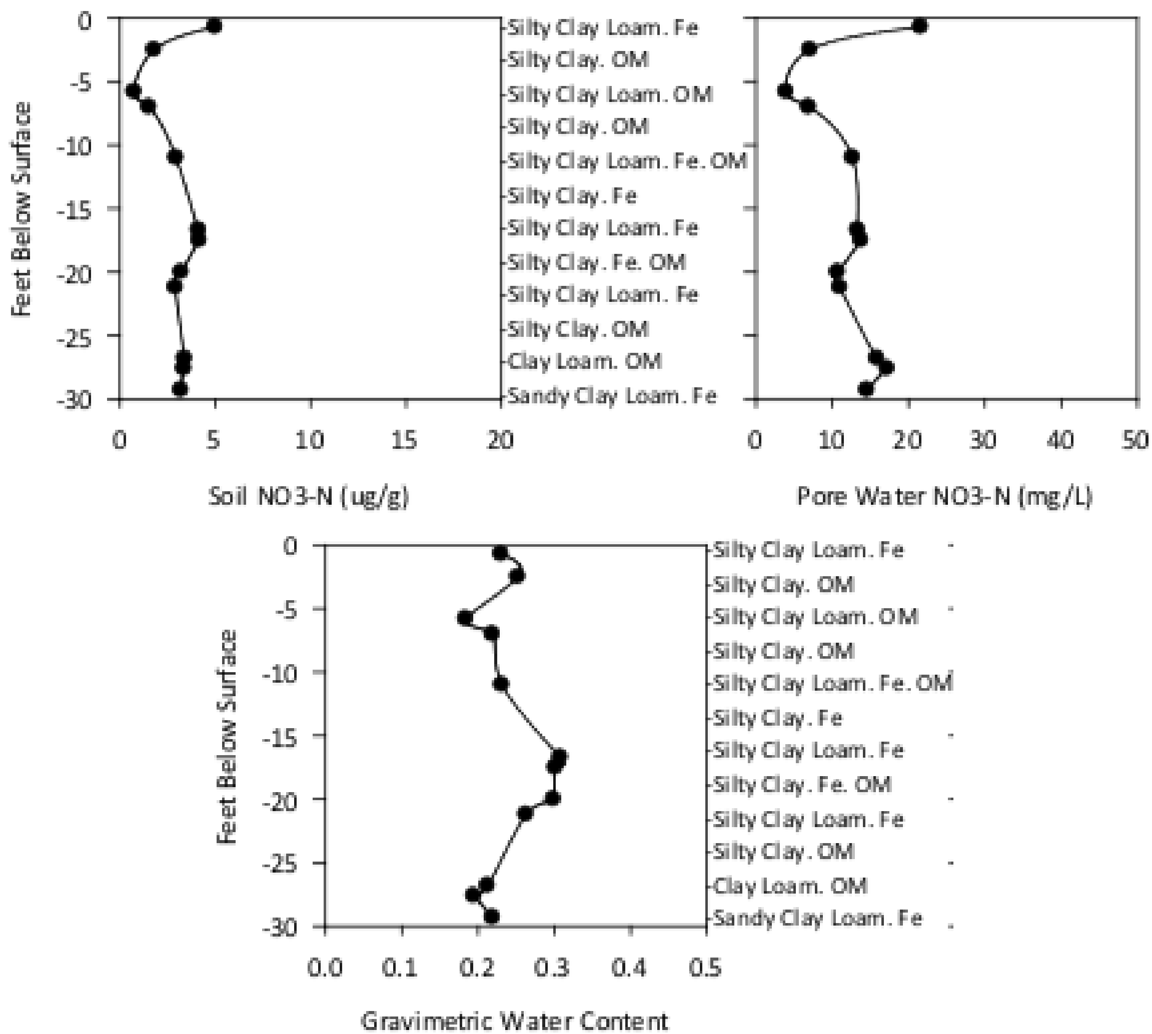




DISCUSSION

Wa-AlvoW-2018 is a rural location, sampled from a cornfield. The core was collected to 60 feet in depth, but the water table was not intercepted. The majority of the soil is classified as silty clay (from the surface level to approximately 30 feet), silty clay loam occurs between 40 and 50 feet, while the final 10 feet are silty loam. A lot of iron and some OM were observed in this core. AlvoW also had relatively low average NO_3-N storage at 3.31 lbs- NO_3-N/acre.

Wa-AlvoE-2018



Discussion

Wa-AlvoE-2018 was collected not far from AlvoW, and was also located in a corn field. The water table was intercepted 30 feet below the surface. This location had the greatest average amount of soil NO_3-N, at 16.26 lbs/acre.

SURVEY RESULTS

The Midwest Farmers Coop in Waverly was contacted on 29th March 2019 via telephone. They reported that 145 lbs-N/acre/year is typical N application dryland corn. Irrigated corn was reported to receive about 195 lbs-N/acre/year of fertilizer, but it was noted that there are only a few farmers who irrigate. A majority of farmers do a split application, with approximately 75% of the application done in the fall as anhydrous ammonia. The remaining amount is applied as dry urea when the corn is V4-V6 growth stage. The Coop reported that some cover crops are being utilized through the Natural Resource Conservation Service's Conservation Stewardship Program (CSP). Bean stubble is commonly used for CSP and the Coop reported that it reaches about 6 inches in height before being terminated to plant corn. To terminate, herbicide is applied. The Coop reported that only about ten growers in the area till the land.

Doug Althouse, of Althouse Acres, was contacted in late March via telephone. Althouse Acres operates north of the Wa-AlvoW-2018 and Wa-AlvoE-2018 coring locations. Althouse was asked the same questions as the Midwest Farmers Coop. He reported he does not till and is currently in his fourth year trying a few cover crops with the NRCS CSP. Althouse typically applies anhydrous in the fall with an inhibitor. The amount that of Nitrogen fertilizer he applies is variable and based off yield potential. He typically bases his application on the recommendation from the University of Nebraska-Lincoln.

AVERAGE NITRATE LOAD FOR RURAL AND URBAN SITES

Table 4 shows the calculation for average soil NO3-N within urban area of the Waverly WHPA.

Table 4

URBAN SITES	AVERAGE SOIL NO_3-N LBS/ACRE
Wa-Lots-18	10.3
Wa-Church-18	4.78
Wa-Math-18	3.96
Wa-Well-18	8.04
Total Average	**6.77**

Table 5 shows the calculation for average soil NO3-N within rural area of the Waverly WHPA.

Table 5

RURAL SITES	AVERAGE SOIL NO_3-N LBS/ACRE
Wa-Fletcher-18	2.18
Wa-AlvoW-18	3.31
Wa-AlvoE-18	16.26
Total Average	**7.25**

Table 2

LAND USE AND NITRATE CONTAMINATED WELLS IN LANCASTER COUNTY

A GIS map depicting land use type and nitrate contaminated wells is shown in Figure 3 below. Below figure 3 is a zoomed in view of the Waverly area (figure 4).

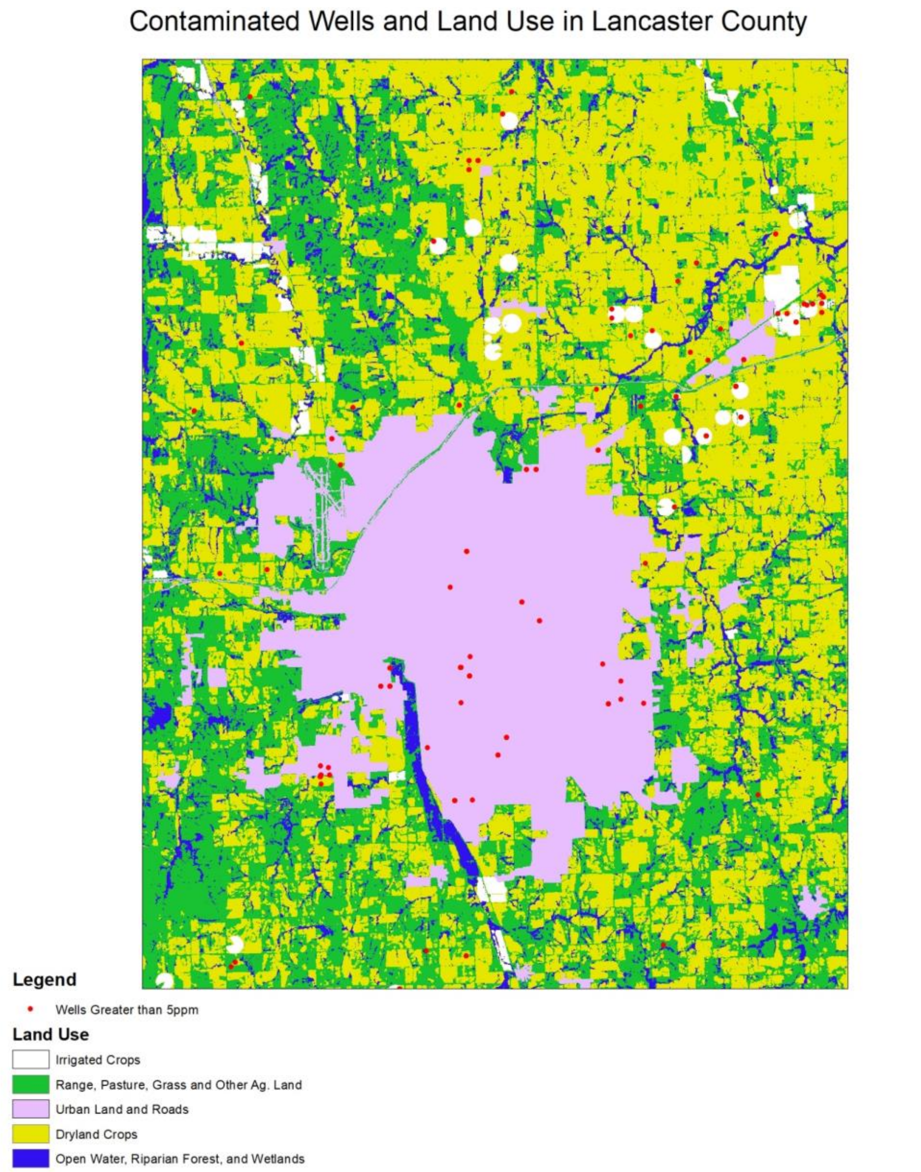


Figure 2

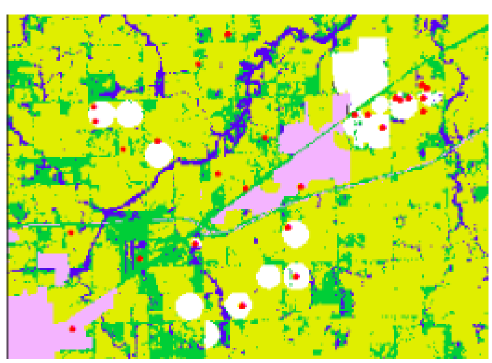


Figure 4 Close up of Waverly

Discussion

Survey

Survey results from the Waverly Farmers Coop (WFC) suggest crop management in the Waverly area is improving through the use of cover crops, no till practices, and responsible N application. An area for improvement in terms of fertilizer application is the time at which N is applied. WFC stated that a majority of farmers apply 75% of their total nitrogen fertilizer in the fall as anhydrous ammonia. Scharf, 2015, notes that corn is the only major crop that typically receives all of its nitrogen before planting. He goes on to emphasize that corn is the crop to receive the most nitrogen fertilizer and that applying in the fall makes the crop most vulnerable to nitrogen loss. While Waverly farmers may not be applying all of their N in the fall, applying 75% in the fall is significant and should be seen as a potentially large contributing factor to N loss and consequent groundwater contamination.

Land Use and N Load

Themes from the GIS map regarding land use and its relationship to groundwater contamination should be considered as a reference point, as the land use is limited to a single year (2005) and well contamination points span from the late 1980s to 2017. Limitations aside, visually, the map suggests that irrigated crops increase the risk of groundwater contamination. Previous studies from (Juntakut, Snow, Haacker, & Ray, 2018) suggest a positive correlation between irrigated crops and increased N contamination of groundwater.

Conclusion

Vadose zone nitrate accumulation within the WHPA varies significantly among locations. Among the most concentrated sites are Wa-Lots-2018 and Wa-AlvoE-2018. The high concentrations at Wa-Lots-2018 may be attributed to its sandy top soil, while high concentrations at Wa-AlvoE-2018 is likely attributed to the land use of the area and nitrogen fertilizer that has been applied over the years.

Differences in accumulation among all sites can be attributed to differing soil properties land management practices. The 2005 land use map and information from the Waverly Famers Coop can be used as a starting point for understanding the varying accumulation, but further research is necessary to draw well defined conclusions. Further areas for research may include elevation mapping and an in-depth survey for land owners.

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