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Assessing Vulnerability Mapping of Nitrate Contamination Among the Private Well Owners of Black Hawk County, IA

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ASSESSING VULNERABILITY MAPPING OF NITRATE CONTAMINATION AMONG THE PRIVATE WELL OWNERS OF BLACK HAWK COUNTY, IOWA

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ABSTRACT

Nitrate fertilizers have been extensively used in agricultural practices providing farmers an inexpensive way of applying nutrients to plants. These fertilizers applied in agricultural fields make their way to ground water and surface water systems by leaching and runoff. The safe limit for nitrate as nitrogen (NO_3-N) recommended by EPA is 10 mg/L in drinking water. The main objective of this study was to find potential sites that are vulnerable to nitrate contamination in the ground water of Black Hawk County through a weighted overlay analysis using ArcGIS 10.2.2 Software. Well locations (N=911) with nitrate concentration measurements from 2003 to 2014 were retrieved from the "Grants to County" database provided by the Iowa Department of Natural Resources (IDNR). The nitrate concentrations ranged from 0 to 85.5 mg/L with an average value of 6.91 ± 0.291 mg/L. The depth of wells ranged from 10 feet to 320 feet with an average value of 109 ± 2.17 feet. The linear regression analysis showed that an increase of 1 foot of depth, lowered the nitrate concentrations by 0.044 mg/L ($R = -0.334$, $p < 0.05$). In the weighted overlay, spatial data on land use, depth to water table, hydraulic conductivity, net recharge, topography, and impact to vadose zone were correlated. Each parameter was reclassified to a standard vulnerability score ranging from 1 to 5, from less to more vulnerable, for ground water contamination. The weighted overlay analysis indicated that the north and south eastern part of the county were the most vulnerable areas for nitrate contamination. The vulnerable areas were then correlated with existing private well nitrate concentrations, and the correlation was significant indicating that the relationship was not due to chance.

Keywords: Nitrate concentration, Vulnerability, Private wells, Black Hawk County

INTRODUCTION

Nitrates in ground water are a problematic and widespread contaminant (Canter, L.W, 1997) that occurs due to natural and anthropogenic sources. Increased nitrate concentrations in ground water of Iowa are mainly due to various agricultural practices such as nitrogen fertilizers and intensive animal farming (Weyer et al, 2001). Populations drinking private well water on or near agricultural land are at a higher risk of nitrate contamination exposure. Approximately 67% of Iowa residents depend on ground water from private and public wells to meet daily water needs. Federal and state laws only require that public water supplies be tested regularly for quality, so there is no mandatory requirement for water testing of private wells. Therefore these private well owners could be consuming water that is of uncertain safety, and a significant percentage of individuals may be drinking water that is not safe to drink (CHEEC, 2009). Measuring ground water vulnerability is important because it helps estimate possible contaminated areas and raises public awareness.
This study adopted the DRASTIC model to assess groundwater vulnerability in Black Hawk County. This model is a standardized technique for evaluating ground water vulnerability to pollution by using various hydrologic settings (Aller et al, 1987).

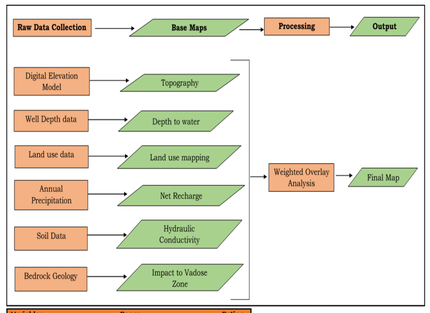
OBJECTIVES

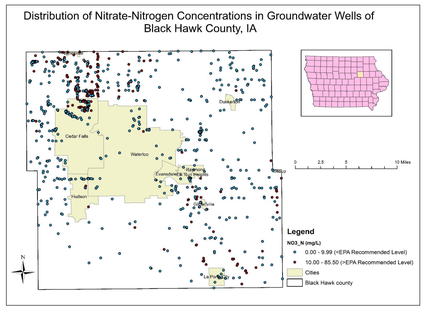
- To assess vulnerability to potential nitrate contamination in Black Hawk County, Iowa.
- Correlate existing ground water nitrate concentration with vulnerability map areas.

HYPOTHESIS

- H_0: There is no statistically significant relationship between mapped vulnerability and the level of nitrate contamination measured in wells.
- H_1: There is a relationship between vulnerability mapping sites of potential nitrate contamination and existing nitrate contamination points.

METHODOLOGY





Variables	Range	Rating
Land Cover 2005	Agriculture	5
	Grass	4
	Forest	3
	Water/Wetland	2
	Urban	1
Depth (Feet)	0-50	5
	51-75	4
	76-100	3
	101-150	2
	150-356	1
Net Recharge (Inch)	8.90291471 - 9.143705725	5
	8.602798371 - 8.902914709	4
	8.414353228 - 8.60279837	3
	8.264250558 - 8.414353227	2
	8.253825883 - 8.264295057	1
Hydraulic Conductivity (um/sec)	>141.14	5
	42.34-141.14	4
	14.11-42.34	3
	4.23-14.11	2
	1.41-4.23	1
Slope (%)	0 - 2	5
	2 - 6	4
	6 - 12	3
	12 - 18	2
	18+	1
Impact to Vadose Zone	Hopkinton	5
	LaPorte City Formation & Wapsipinicon Group	4
	Cedar Valley Group	3
	Maquoketa Formation	2
	Lime Creek Formation	1

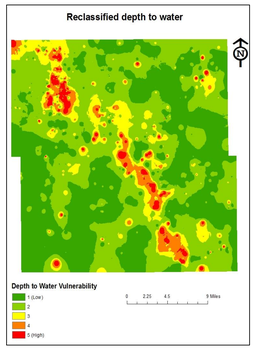
Data Sources

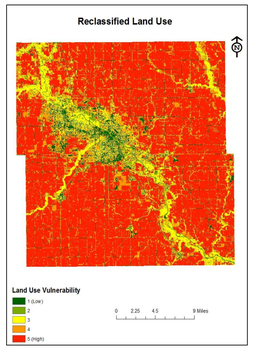
1. 10 m Digital Elevation Model from Iowa Department of Natural Resources GIS Library.
2. 2009 Land use map from Iowa Department of Natural Resources GIS Library.
3. Soil data of Black Hawk County from ArcGIS SSURGO.
4. Private wells nitrate contamination from Iowa Department of Natural Resources.
5. Bed Rock Geology from Iowa Department of Natural Resources GIS Library.

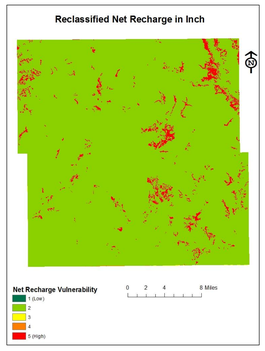
The input parameters were overlaid in an Weighted Overlay operation based on the ground water vulnerability model "DRASTIC". Our model extended DRASTIC to take into account land use. The resulting output is a measure of vulnerability to nitrate contamination.

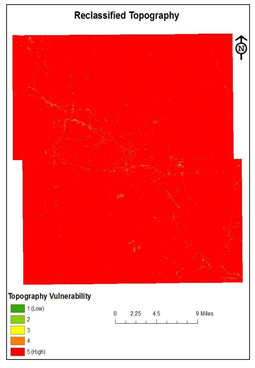
D=Depth to water, **R**=Net Recharge, **A**=Aquifer media, **S**= Soils, **T**=Topography, **I**=Impact to Vadose Zone, **C**= Hydraulic Conductivity

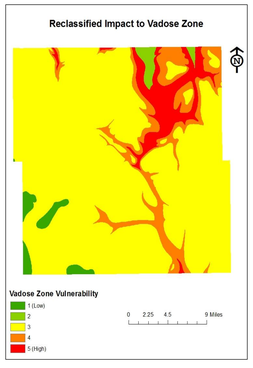
RESULTS

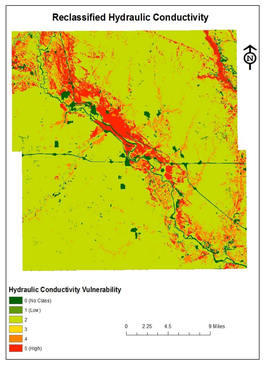






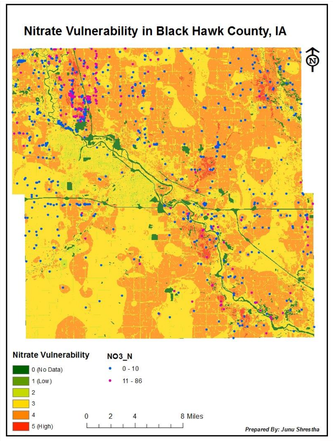


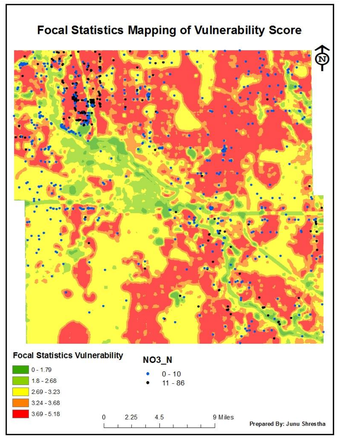




Weighted Overlay Analysis; Land use (30%), Depth to water (20%), Impact to Vadose Zone (20%), Net recharge (15%). Hydraulic Conductivity (10%), Topography (5%)

RESULTS (cont..)





ANOVA
NO3-N (Weighted Overlay Analysis)

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	2215.05	4	553.76	7.54	.000
Within Groups	6654.10	906	73.44		
Total	68756.15	910			

NO3-N			
Score	Mean	N	Std. Deviation
0	8.533	43	17.4046
2	4.278	101	6.6812
3	6.115	546	7.5383
4	9.173	211	9.2494
5	7.180	10	6.8184
Total	6.745	911	8.6923

ANOVA
NO3-N (Focal Statistics)

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	24306.99	218	111.50	1.73	.000
Within Groups	44427.63	692	64.20		
Total	68734.62	910			

Variable	Min	Max	Mean ± SE
NO3-N (mg/L)	0	85.5	6.91 ± 0.291
Depth (feet)	10	320	109.17± 2.17

Linear Regression			
Variables	Slope	P-Value	Stat. Sig
Depth	-0.044	0.000	Significant
R	-0.334		

Focal Statistics tool was used to investigate vulnerability within a 500 m neighborhood with the assumption that neighboring areas could influence groundwater contamination at a given point.

CONCLUSIONS

The Final Weighted Overlay map produced by considering six parameters indicated that there are many areas (represented by score 5 & 4) that might be vulnerable to potential nitrate leaching to ground water. To confirm the hypothesis, existing nitrate concentrations were used and assigned a respective raster cell value using the Extract Values to Points tool. Statistical analysis, one way ANOVA, showed that differences between the mean nitrate concentrations were statistically significant among the vulnerability scores including relatively high nitrate concentrations found coincident with high vulnerability score sites i.e. 5 and 4. Therefore, we reject the null hypothesis and conclude that nitrate concentrations are related to modeled vulnerability scores. Although this study tried to consider six parameters, there might be other parameters that also contribute to groundwater contamination. Therefore further investigation with more parameters should be considered.

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