COVER SHEET
SIGMA XI GRADUATE STUDENT
RESEARCH AWARD CONTEST

Due 5:00pm, March 9th (Friday) to Michael.Gonda@sdstate.edu

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DEGREE BEING PURSUED: ✓ M.S. __Ph.D.

✓ Proposal or ___Paper

The paper is Published__ Unpublished ✓

The Impacts of Land Use and Land Cover Change on Water Quality in the Big Sioux River basin: 2007-2016

Introduction

Between 2006 and 2011, increased demands for ethanol production resulted in high corn prices that accelerated the conversion of grassland to corn cropland and led to increased corn acreage in the Western Corn Belt (WCB) Plains Ecoregion. The conversion was mostly concentrated in North Dakota and South Dakota, east of the Missouri River—resulting in the westward expansion of the WCB (Wright and Wimberly 2013; Olimb 2013). Other driving forces such as crop insurance subsidies and disaster payments encouraged farmers to (1) convert pasture, fallow, and grassland to corn acreage, and (2) shift from other crops to corn. In many cases, farmers adjusted crop rotations between corn and soybeans to meet the demands of corn (United States Department of Agriculture 2017).

The increase in corn acreage is associated with the elevated use of industrial fertilizers that results in the nutrient-rich soils and leads to an increased amount of nitrate runoff (Assimakopoulos 2003). High concentration of nitrates in water leads to occurring of methemoglobinemia (blue baby syndrome) in babies, and thyroid and bladder cancer in adults (Iowa Environmental Council 2016; Arnold 2012; World Health Organization 2015), eutrophication of rivers, and formation of hypoxic zones in the coastal regions (Alexander et al. 2000; Strauss et al. 2012, Scavia and Donnelly 2007).

High concentration of nitrates in the river water is one of the major concerns of public and federal water authorities (Kreiling 2016). The Des Moines Water Works, for example, spends approximately $4,000-$7,000 per day to remove excess nitrates from the water (D.M. Water Works lawsuit questions 2016, 12). Alarmed with the lawsuit in Iowa, South Dakota public water authorities including East Dakota Water Development District (EDWDD) became concerned about the possible consequences of elevated nitrate levels on the water in the Big Sioux River (BSR). Most water experts think that this case, when resolved by the US Supreme Court will impact federal water laws/acts.

Thesis

Nitrate increases in the BSR may be associated with increased areas and intensities of agriculture in the watershed. High concentrations (10ppm) are associated with human health issues and regulated by EPA. The study determines LULC change in the watershed and analyze the temporal and spatial trend of nitrogen levels in the river and determines whether there is a correlation between LULC change and changes in nitrogen levels in the BSR.

Research Questions / Aims / Hypothesis

The LULC change and elevated use of nitrogen fertilizer are associated with diminished water quality in the river (Arnold 2012) which is associated with human health (Alexander et al. 2000; Strauss et al. 2011). The study focuses on determining (1) LULC change in the BSR watershed, (2) spatial and temporal trends of nitrogen concentration in the river water, and (3) a correlation between LULC change and changes in nitrogen levels in the river.

In addition, the study answers following research questions:

1. What was acreage of corn/soybeans and grassland in 2007 how did it change between then and 2015?
2. What are the trends and patterns of LULC change? Where are the rates of grassland conversion to corn/soy agriculture the highest in the BSR?
3. What was the nitrogen level in water in the BSR in 2007 and how did it change between then and 2015? What is the nitrate trend in the river water? How has it changed during the study period?

I hypothesize that industrialized fertilizer used in corn cropland is the primary contributor to increased nitrogen levels in the Big Sioux River and there is a significant correlation between an increase in corn cropland and an increase in nitrogen levels.

Alternative Hypothesis 1: There is a significant correlation between an increase in converted croplands and increased nitrogen levels in the Big Sioux River.

Alternative Hypothesis 2: There is a significant correlation in the increase in cropland conversion and an increase in fertilizer usage in the study area.

Methods

This study uses the National Agricultural Statistic Service (NASS) Cropland Data Layer (CDL) to characterize and determine the rates of LULC change, and the Mann-Kendall (MK) test to analyze upward and downward trends of land-cover change and nitrogen levels in the BSR. Then the Sen slope estimator is used to determine

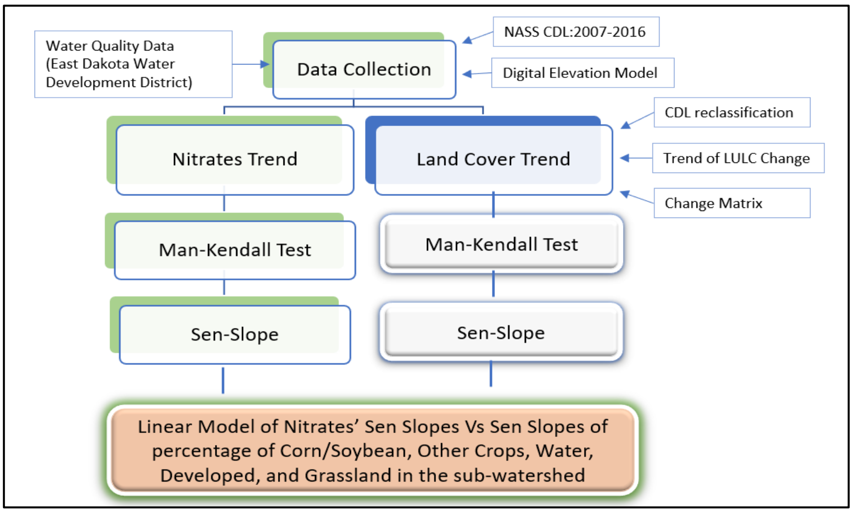

Figure 1: Methodology adopted to conduct the research

how these parameters are related. Land-cover change trends and nitrogen trends are determined separately and simultaneously. Then, Sen slopes of the percentage of land cover types and nitrates are calculated. Finally, a linear model of nitrates' slopes versus the slopes of the percentage of land cover classes is built to see how closely these parameters are co-related (Figure 1).

Primary outcomes

Land-cover change

The comparison of one class type to another (over the period 2007 to 2016) was done by using the 2007 NASS CDL as a baseline and comparing it with the 2016 NASS CDL on a per-pixel basis. For example, the reclassified 2007 NASS CDL was overlaid with reclassified 2016 NASS CDL to identify pixels that changed from grassland in 2007 to corn/soy in 2016. In doing so, all the pixels from one class type that changed to other class type were identified. The total area covered by those pixels were calculated and contingency table was produced.

The contingency table suggests that the conversion of grassland to corn/soybean is much higher than the conversion of corn/soybean to grassland suggesting that corn/soybean cropland is increasing every year (Table 1). The percentage of corn/soybean cropland that was converted to grassland was 1.28% whereas the percentage of grassland were converted to corn/soybeans was 7.29%, resulting in an increase of corn/soybean land. Also, 2.75% of corn/soybean cropland was converted to other crops whereas 3.17% of other crops were converted to corn/soybean, resulting in an increase of corn/soybean land.

Table 1: Contingency table for land use/land cover change from 2007 to 2016. The table shows the proportion of land converting to/from other class types.

		2016	2016	2016	2016	2016	
		Corn/ Soybean	**Other Crops**	**Water**	**Developed**	**Grassland**	**Total**
2007	**Corn/Soybean**	**49.96**	**2.75**	**0.39**	**0.84**	**1.28**	**55.22**
2007	**Other Crops**	**3.17**	**0.99**	**0.06**	**0.07**	**0.25**	**4.53**
2007	**Water**	**0.51**	**0.32**	**4.17**	**0.07**	**0.51**	**5.58**
2007	**Developed**	**2.00**	**0.21**	**0.19**	**4.30**	**1.13**	**7.83**
2007	**Grassland**	**7.29**	**1.98**	**1.51**	**0.82**	**15.22**	**26.83**
	Total	**62.93**	**6.26**	**6.32**	**6.10**	**18.39**	**100.00**

The initial Man Kendall test shows that the percentage of corn/soybean cropland in the entire Big Sioux River watershed had a positive trend with a tau value of 0.228 (2-sided) and the p-value of 1.8835e-05. The percentage of corn/soybean coverage was 55% (2,900,000 acres) in 2007 that increased to 63% (3,300,000 acres) in 2016. Conversely, the percentage of grassland showed the negative trend—it decreased from 27% (1,400,000 acres) to 19% (986,000 acres) from 2007 through 2016. Other classes did not show any significant changes.

Then, the watershed was divided into 13 sub-watersheds. The corn/soybean cropland for all 13 sub-watersheds had positive trends. Sub-watershed 1 that covers Day, Clerk, and Codington counties had the highest conversion rate. The corn/soybean acreage jumped from 33% (80,000 acres) to 46% (114,000 acres). Sub-watershed 11 that covers most parts of Union County and some part of Minnehaha County had the lowest conversion rate. The corn/soybean acreage jumped from 64% (205,000 acres) to 68% (219,000 acres).

The Sen slope estimator shows an upward trend for percentage corn/soybean class type, a downward trend for percentage grassland class type, and no specific trend for percentage other crops, percentage water, and percentage developed class types.

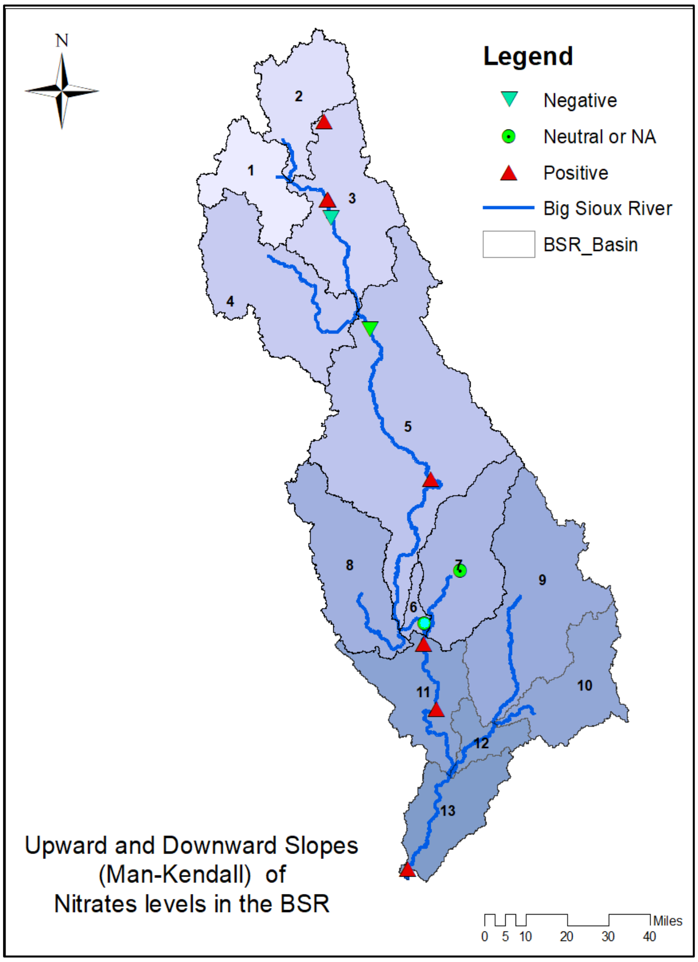

Figure 2: The upward and downward slopes (Man-Kendall) of Nitrates levels in the BSR.

Nitrogen Trends

For the nitrate trend, out of 10 stations, 6 stations showed an upward trend, 2 showed a downward trend, and 2 showed a neutral trend (Figure 2). The positive trends of percentage growth of corn/soybean cropland and positive trends of nitrates in the river in the same watershed can hence be correlated. However, there are 2 stations that show negative trends and 2 stations neutral trends. The station R23 near Summit, SD, and R22 at Codington, SD have positive trends, while the station Iowa_Ambient which is just below R22 has a negative trend. It is likely that the station below the same river should have the same trends. As our hypotheses state that the increase in corn/soybean cropland is associated with the increase in nitrates level in the river. But, as we look closer, the stations R23 and R22 are at the different stream which are tributaries of the Big Sioux River. The high nitrogen concentration in the tributary water is diluted in the water of Big Sioux River and shows a negative trend. Similarly, the station at MN_Rock shows a neutral trend because it is also a tributary of the BSR. The station R12 at Brandon, SD has fewer data, so it also shows a neutral trend.

The Relationship between land cover change and nitrogen trends

The linear model of Sen slope of percentage corn/soybean, percentage other crops, percentage water, percentage developed, and percentage grassland was produced. The linear model of the Sen slopes of nitrates versus the Sen slopes of percentage corn/soybean and other classes had lower R^2 and p-values. The R^2 and the p-values were -0.1863 and 0.6554, suggesting that the relation between land-cover change and nitrates level were not statistically significant (Table 2).

Table 2: R^2 and p-values of a liner model of the Sen's slopes of nitrates versus the Sen slopes of percentage of each class type.

Nitrates_Slope Vs	**R^2**	**P-Values**
%Corn/Soybean_Slope	-0.0844	0.6488
%Other Crops_Slope	-0.1025	0.7974
%Water_Slope	0.01206	0.3171
%Developed_Slope	-0.1091	0.9
%Grassland_Slope	-0.0759	0.6007
Overall	**-0.1863**	**0.6554**

Conclusion / Significance of the study

The results show that there was an upward trend of corn/soybean and the downward trend of grassland in the Big Sioux River basin from 2007 to 2016. The consistency table shows that higher percentage of grassland was converted to corn/soybean in the same study period. Similarly, there was an upward trend of nitrogen increase in the basin in the same period. Form this we can refer that the conversion of grassland to corn/soybean in the basin is associated with the increase in nitrogen level in the river. However, the linear model didn't give us a strong correlation between the land use and land cover change. The linear model of the Sen's slopes of nitrates versus the Sen's slopes of percentage corn/soybean and other classes had lower R^2 and p-values. The R^2 and the p-values were -0.1863 and 0.6554 which are not statistically significant.

The findings of my research will help water authorities to make decisions to resolve to water quality related issues. The findings are also important because results of a pending court case may alter the Corn Belt Farmland management and Water Acts which could have an impact on EDWDD and other water districts. The findings of my research provide a better understanding of the role of LULC change to BSR water quality which can be important to water supply organizations and farmers in developing improved land management strategies.

It could be interesting to incorporate the soil type, slopes, terrain, temperature, precipitation, application of nitrogen fertilizer versus nitrogen level in the river and build a regression model to see which factor strongly contribute to increasing in nitrogen level in the river basin.

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