Impacts of Land Use and Land Cover Change on Water Quality in the Big Sioux River Watershed: 2007 – 2016

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Background

Introduction:

Reitsma et al. (2015) estimated that 485,000 acres of grassland were converted to cropland throughout eastern South Dakota between 2006 and 2012. Most of the region is drained by the Big Sioux River (BSR) watershed. During this time, the East Dakota Water Development District (EDWDD) reported increasing nitrate levels in the BSR. In 2012, the *Rapid City Journal* published an Associated Press article ranking the BSR as one of the “dirtiest” rivers in the U.S (The Associated Press 2012).

Studies associate that the nitrogen leaching stimulated by the increased grassland-to-cropland conversion and application of synthetic fertilizers could pollute the river (Wright and Wimberly 2013). Therefore, it is important to identify Land Cover Change (LCC) trends in the BSR watershed, and to determine whether a causal relationship exists for the observed trend in BSR nitrate levels. In addition, elevated nitrate levels in the BSR are of great concern, especially since the BSR flows through Sioux Falls and other communities in the region where a significant percentage of the state’s population is concentrated.

The objectives of this research are to:

i) identify and characterize spatial and temporal changes in the land cover types within the BSR watershed,
ii) identify and characterize the temporal and spatial trends of BSR nitrate levels, and
iii) identify whether any relationship identified between LCC and changes in BSR nitrate levels is causal.

Data and Methods

- Cropland Data Layer (CDL) is used to characterize and determine rates of LCC.
- Then non-parametric Mann-Kendall test is used to identify statistically significant increasing and decreasing LCC trends within the BSR watershed.
- Similarly, nitrate data collected from 11 gauging stations operating in the BSR watershed were analyzed using the Mann-Kendall test to identify any trends.
- Sen’s Slope estimates were used to estimate the magnitudes of statistically significant LCC and nitrate trends.

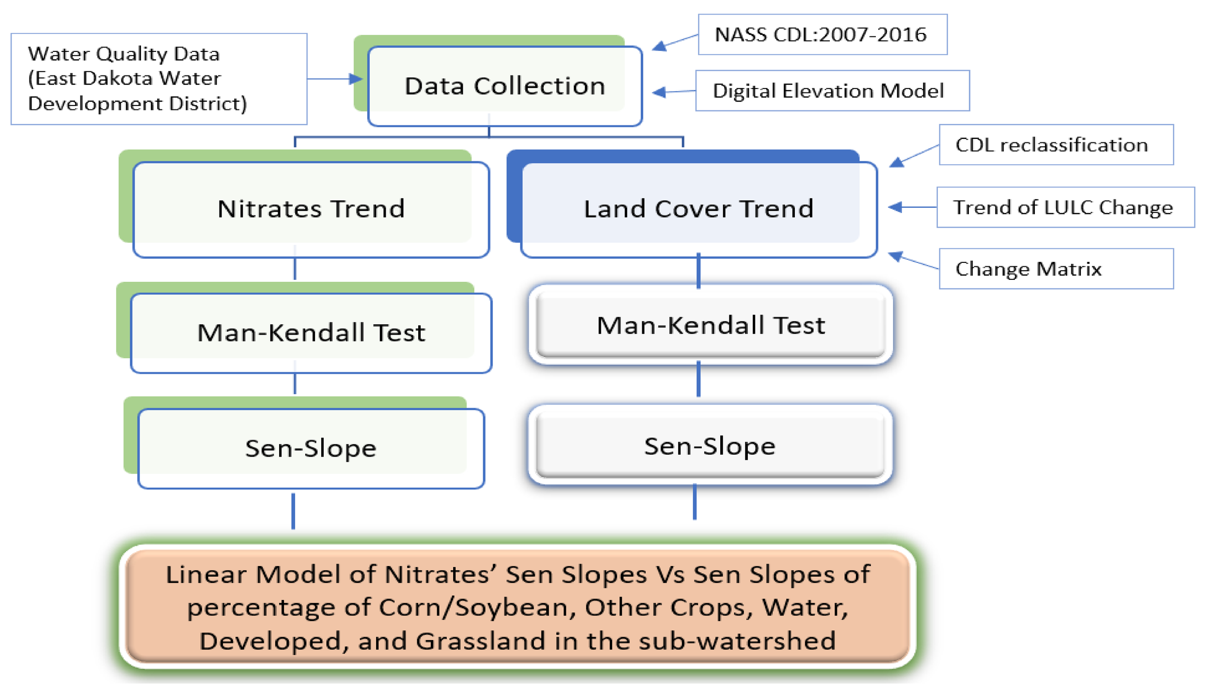


Figure 1: Data Collection and Analysis Process Flow

Data Sources

Land Use Data
- National Agricultural Statistics Service (NASS) CropScape-Cropland Data Layer (CDL): 2007-2016 [www.nass.usda.gov]

Water quality data
- East Dakota Water Development District, SD

Others
- Arc Grid representing a Digital Elevation Model for the Big Sioux River [https://gdg.sc.egov.usda.gov/
- Streamflow (discharge) data [US EPA- Surf your Watershed https://gdg.sc.egov.usda.gov/GDGOrder.aspx

Results

CDL reclassification

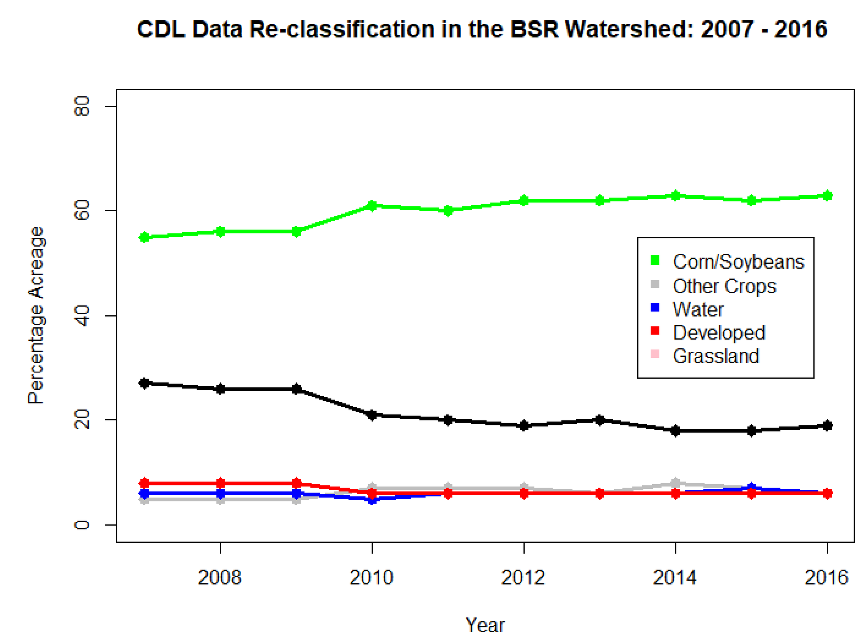


Figure 2: Graphical representation of change in percentage coverage of each class in each year (from 2007 through 2016).

The percentage of corn and soybean acreage increased from 56% (2,900,000 acres) in 2007 to 63% (3,300,000 acres) in 2016, whereas the percentage of grassland acreage decreased from 27% (1,400,000 acres) in 2007 to 19% (987,000 acres) in 2016.

During this period, the absolute amount of water-related and human-developed acreage varied somewhat (by about 500 to 1500 acres); however, the percentage of acreage in these cover classes remained constant.

The additional corn and soybean acreage was mainly gained from converted grassland and other crops

Land Cover Trends

Summary of the output from Mann-Kendall Test and Sen’s Slope Estimate for Reclassified CDL Classes for entire BSR Watershed

CDL Classes	Mann-Kendall Test			Sen's Slope Estimate		
	Tau	p-value	Trend	Z Score	Slope (Q)	Const (B)
Corn and Soybeans	0.85	0.001	Increasing	3.22	0.86	56.1
Grassland	-0.815	0.002	Decreasing	-3.22	1.03	26.4
Other Crops	0.428	0.13	No Trend	1.43	0.195	50.1
Water	0.325	0.3	No Trend	1.97	0.009	55.3
Developed	0.683	0.23	No Trend	-0.89	0.11	69

Nitrate Trends

Summary of the output from Mann-Kendall Test and Sen’s Slope Estimate for Nitrate Gauging Stations

Gauging Stations	Mann-Kendall Test			Sen's Slope Estimate	
	Tau	p-value	Trend	Slope (Q)	Const (B)
SD Grant SA1	0.422	0.107	No Trend	0.7	1
SD Codington K06	- 0.742	0.008	Decreasing	-0.233	2.4
SD Hamlin S08	- 0.067	0.858	No Trend	-0.013	1.84
SD Moody BSA	0.4	0.462	No Trend	0.194	0.22
MN Pipestone 094	0.524	0.033	Increasing	0.487	8.90
MN Pipestone 099	0.571	0.004	Increasing	0.722	2.49
MN Rock 528	0.167	0.602	No Trend	0.123	3.53
MN Rock 811	0.449	0.088	No Trend	0.242	4.99
R13 EDWDD	0.6	0.133	No Trend	0.158	2.79
IA Lyon 001	- 0.067	0.858	No Trend	-0.058	1.50
Iowa Hawarden	0.047	1	No Trend	-0.058	1.50

LCC Trends and Nitrate Trends at HUC12 Sub- watersheds

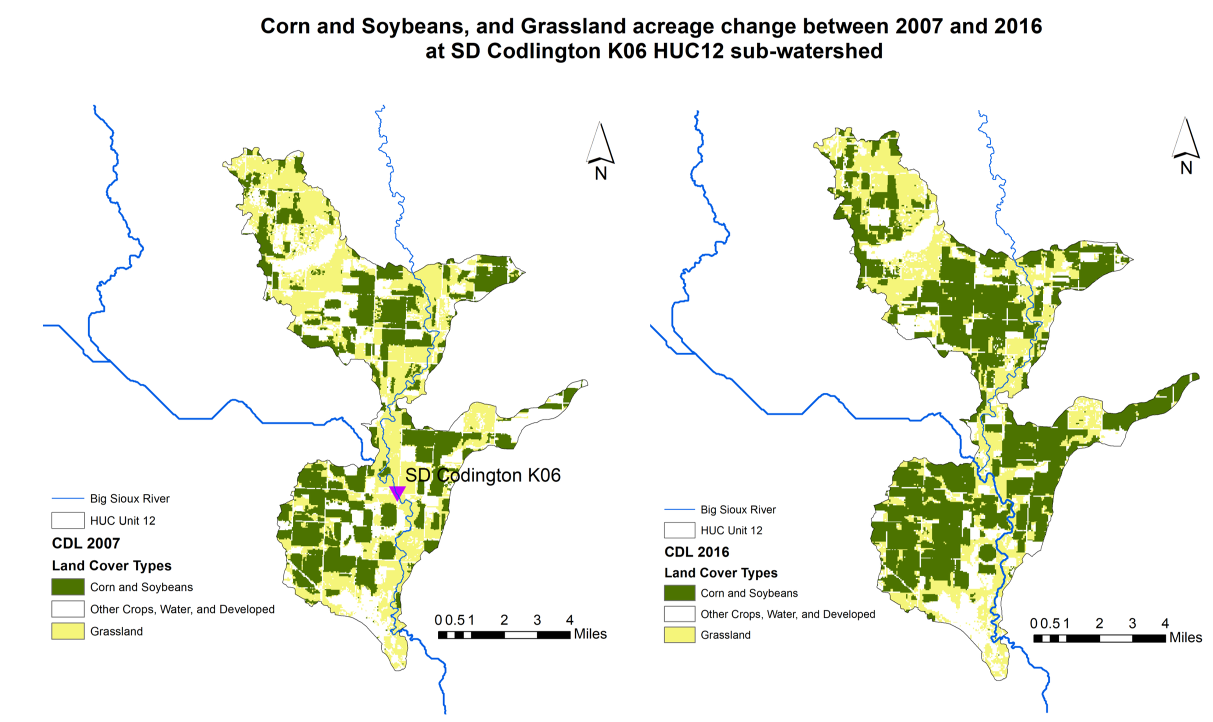
Results from Mann-Kendall Test and Sen's Slope estimates at HUC12 sub-watershed

Gauging Stations / HUCs	Nitrates / LCC Trends	Mann-Kendall Test			Sen's Slope Estimate	
		Tau	*p-value*	*Trend*	*Slope (Q)*	*Const (B)*
SD Codington K06	Nitrate	-0.743	0.008	Decreasing	-0.23	2.40
	Corn/Soybeans	0.689	0.007	Increasing	1.65	35.68
	Grassland	-0.644	0.012	Decreasing	-1.29	39.75
MN Pipestone 094	Nitrate	0.524	0.033	Increasing	0.49	8.90
	Corn/Soybeans	0.067	0.858	***No Trend***	0.07	76.33
	Grassland	-0.733	0.004	Decreasing	0.46	17.63
MN Pipestone 099	Nitrate	0.571	0.034	Increasing	0.72	2.49
	Corn/Soybeans	0.733	0.004	Increasing	0.34	76.19
	Grassland	-0.511	0.049	Decreasing	-0.46	16.16

Map 1: LCC Trends and Nitrate Trends in HUC12 sub-watershed in BSR watershed.

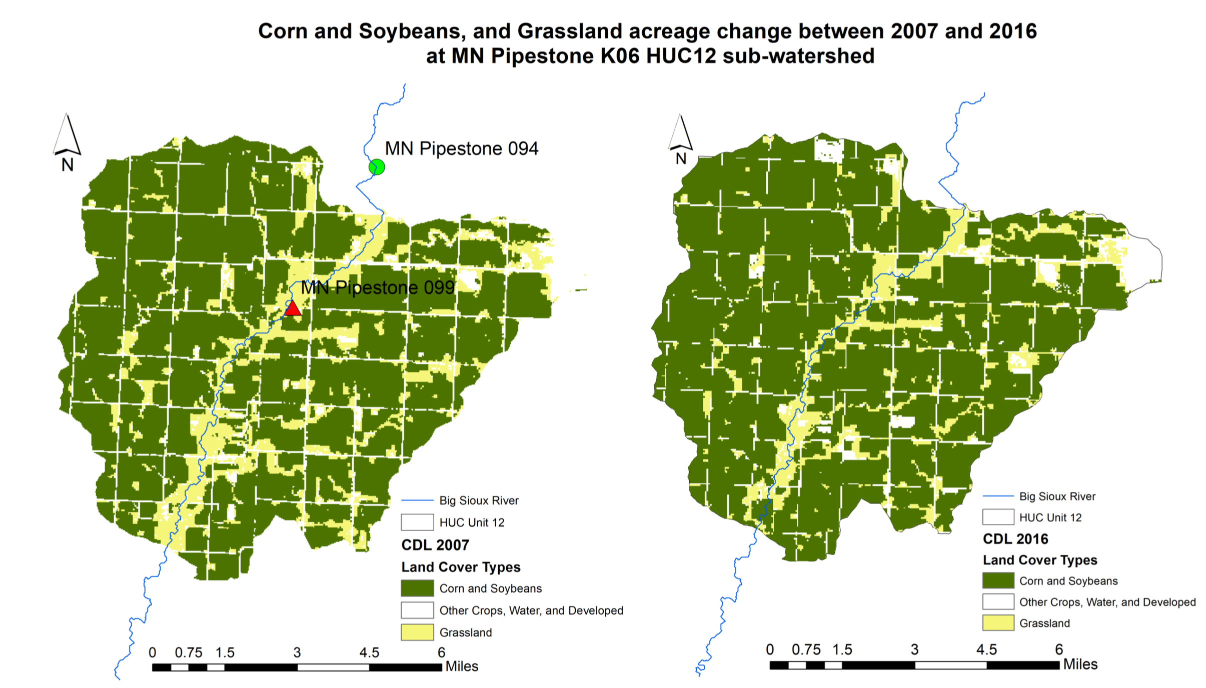
- The percentage of corn and soybean acreage increased in all of the HUC12 sub-watersheds at the expense of grassland acreage.
- Most of the conversion occurred near or along the banks of the BSR itself.
- **SD Codington K06**, South Dakota and **MN Pipestone 099**, Minnesota showed ***Decreasing*** and ***Increasing*** Trends, respectively.

Discussions



Map 2: Corn and Soybeans, and Grassland acreage change between 2007 and 2016 at SD Codington K06 HUC12 sub-watershed

- Within the SD Codington K06 sub-watershed, corn and soybeans increased from 35% in 2007 to 49% in 2016.
- Grassland and other crops decreased (from 40% and 16% in 2007 to 29% and 12% in 2016, respectively).



Map 3: Corn and Soybeans, and Grassland acreage change between 2007 and 2016 at MN Pipestone 099 HUC12 sub-watershed

- Within the MN Pipestone 099 sub-watershed, corn and soybean acreage increased from 75% in 2007 to 79% in 2016.
- Grassland acreage appeared to be consistently decreasing (from 16% in 2007 to 12% in 2016).

Summary / Conclusion

- While significant trends in corn/soybean and grassland acreage were identified, significant opposing trends in nitrate levels were identified at only 2 gauging stations.
- The decreasing trend in SD Codington K06 station in South Dakota could be because farmers in South Dakota adopted various conservational approaches to limit nitrogen/nitrate flow into its waterways.
- The increasing trend in MN Pipestone 099 station in Minnesota could be because Minnesota was in the early stages of mandating and enforcing use of such approaches (Pfankuch 2018).
- In general, there was insufficient evidence to conclusively link changes in corn/soybean LCC to changes in nitrate levels.

Selected References

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