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:
Historically farmers applied more nitrogen than plants could use. This resulted in nitrate runoff or leaching that fed the Big Sioux River. Additionally, the increased demands on ethanol and rises in the price of corn led to an increase of corn acreage in South Dakota. The increase on corn acreage and adjustments in crop rotations between corn and soybeans resulted in increased applications of industrial fertilizers per acre of cropland. **There is a significant correlation between an increase in converted croplands and increased nitrogen levels in the Big Sioux River**.

The **objectives** of my research are:
(1) to determine Land Use and Land Cover (LULC) change in the Big Sioux River (BSR) watershed,
(2) to determine spatial and temporal trends of nitrogen levels in the BSR, and
(3) to determine whether there is a correlation between LULC change and changes in nitrogen levels in the river.

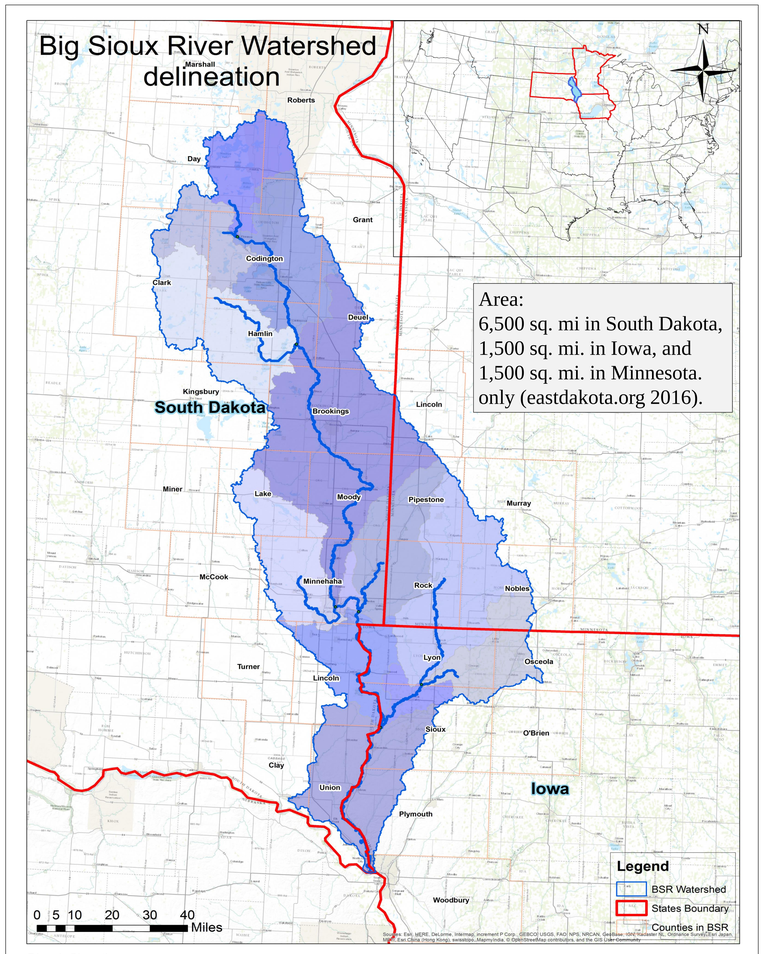


Figure 1: The Big Sioux River Watershed that lies in Eastern South Dakota, Southwestern Minnesota, and Northwestern Iowa.

METHODS / RESULTS

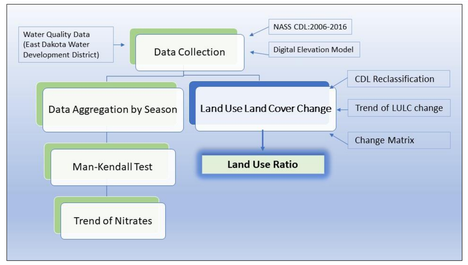


Figure 2: Methods applied to determine (1) Land use and Land Cover Change, (2) spatial and temporal trends of nitrogen levels, and (3) correlation between LULC and nitrogen levels in the BSR.

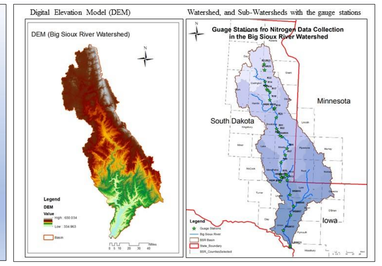


Figure 3: **(Left):** Digital Elevation Model 30x30m resolution for BSR watershed that was used to delineate the watershed **(Right)** 13 sub-watersheds obtained by watershed delineation.

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.*

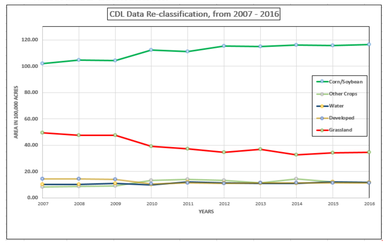
		2016 Corn/ Soybean	2016 Other Crops	2016 Water	2016 Developed	2016 Grassland	Total
2007	**Corn/Soybean**	**49.96**	**2.75**	**0.39**	**0.84**	**1.28**	**55.22**
2007	**Other Crops**	**3.17**	**0.99**	**0.06**	**0.07**	**0.25**	**4.53**
2007	**Water**	**0.51**	**0.32**	**4.17**	**0.07**	**0.51**	**5.58**
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 contingency table shows the conversion of land to/from other class types between the years 2007 and 2016. The percentage of corn/soybean cropland that was converted to grassland was 1.28% whereas 7.29% of grassland were converted to corn/soybeans, resulting an increase of corn/soybean land. Also, 2.75% of corn/soybean cropland was converted to other crops whereas 3.17% of other crops was converted to corn/soybean, resulting an increase of corn/soybean land.

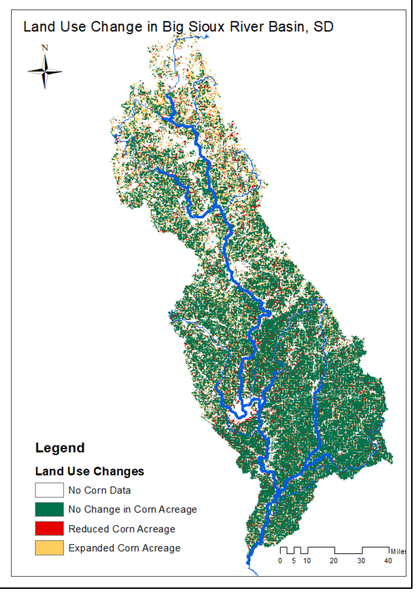
Land Use Change Ratio

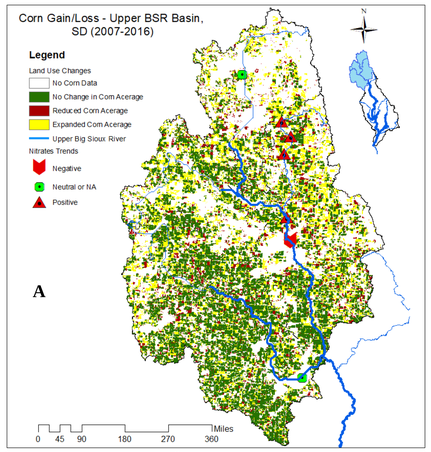
The change ratio of each land use category = area of each land use category in 2016 / the area of relevant land use in 2007.
- If the calculated ratio > 1.0, the land use was considered to have expanded since 2007.
- If the ratio < 1.0, the land use was reduced in relation to conversion to a different land use category.

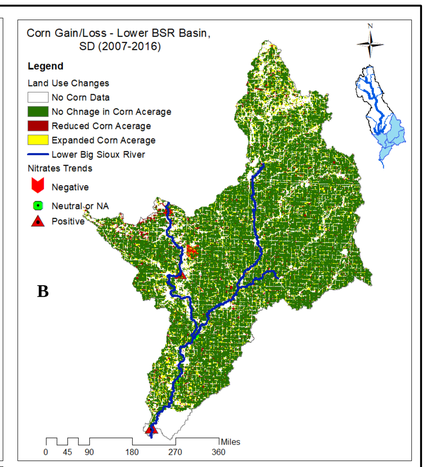
Figure 4: The land use change ratio (corn/soybean) class type from 2007-2016. The total acreage that remained unhanged (corn/soybean) from 2007 to 2016 was 2.6 million acre. The acreage that was corn/soybean in 2007 and was converted to other classes in 2016 was 278,000 acres. Similarly, the acreage that was gained from other classes to corn/soybean from 2007 to 2016 was 686,000 acres.



Graph 1: The CDL data was reclassified in 5 major groups: (1) Corn/Soybean, (2) Other Crops, (3) Water, (5) Developed, and (6) Grassland.







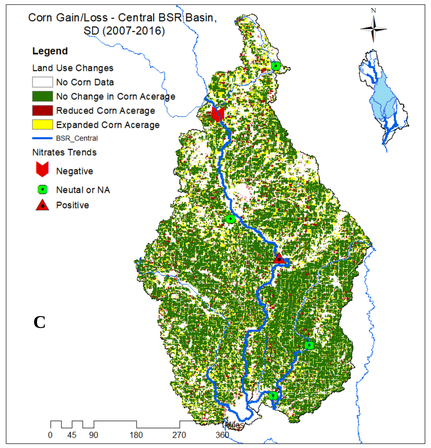


Figure 5: The land use change ratio (corn/soybean) class type from 2007-2016 for 3 sub-basins: Upper BSR, Central BSR, and Lower BSR along with the increasing and decreasing nitrates trends.
(A) The Upper Basin has 4 stations that show increasing nitrates trends, 1 station that shows the decreasing trend, and 2 stations with no trends.
(B) The Central Basin has 3 stations that show increasing nitrates trends, 1 station that shows the decreasing trend, and 2 stations with no trends.
(C)The Lower Basin has 1 station that show increasing nitrates trends, 1 station that shows the decreasing trend, and 3 stations with no trends.

DISCUSSIONS AND CONCLUSION

The increased demands for ethanol and rises in the price of corn led to increases in corn acreage in South Dakota. Other driving forces such as crop insurance subsidies and disaster payments encouraged farmers to (1) convert pasture and grassland to corn acreage, and (2) shift from other crops such as wheat to corn.
The study shows that the land change ratio for corn/soybean category is greater than 1, which suggests that the area devoted to corn/soybean has expanded since 2007. The gain of corn/soybean cropland was from grassland and other crops. Similarly, the tau value from Mann-Kendall test equal to 0.228 suggests a statistically significance upward trend in the nitrates time series. This suggests that there is a correlation between land use and land cover change and the nitrogen levels in the BSR from 2007 to 2016.
The findings are likely to provide a better understanding of the role of LULC change to BSR water quality, and be important to water supply organizations and farmers in developing improved land management strategies and to ensure clean and affordable public water.

DATA SOURCES

- Land Use Data
  - National Agricultural Statistics Service (NASS) CropScape-Cropland Data Layer (CDL): 2006-2016 [www.nass.usda.gov]
- Water quality data
  - East Dakota Water Development District, SD
  - US EPA- Surf your Watershed
- 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

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