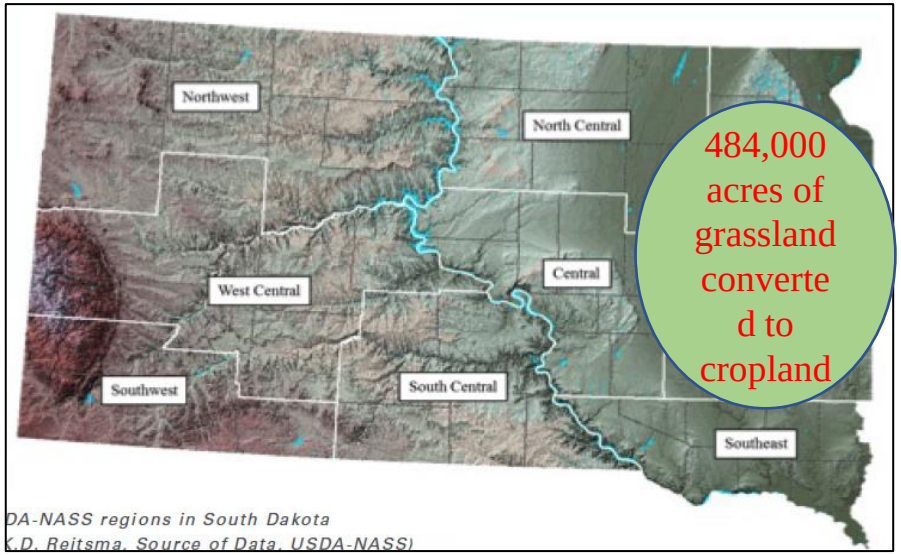
Impacts of Land Use and Land Cover Change on Water Quality in the Big Sioux River Basin: 2007-2016

49th South Dakota State Geography Convention, SDSU
Dinesh Shrestha, Dr. Darrell Napton
Department of Geography, SDSU

Outline

Introduction

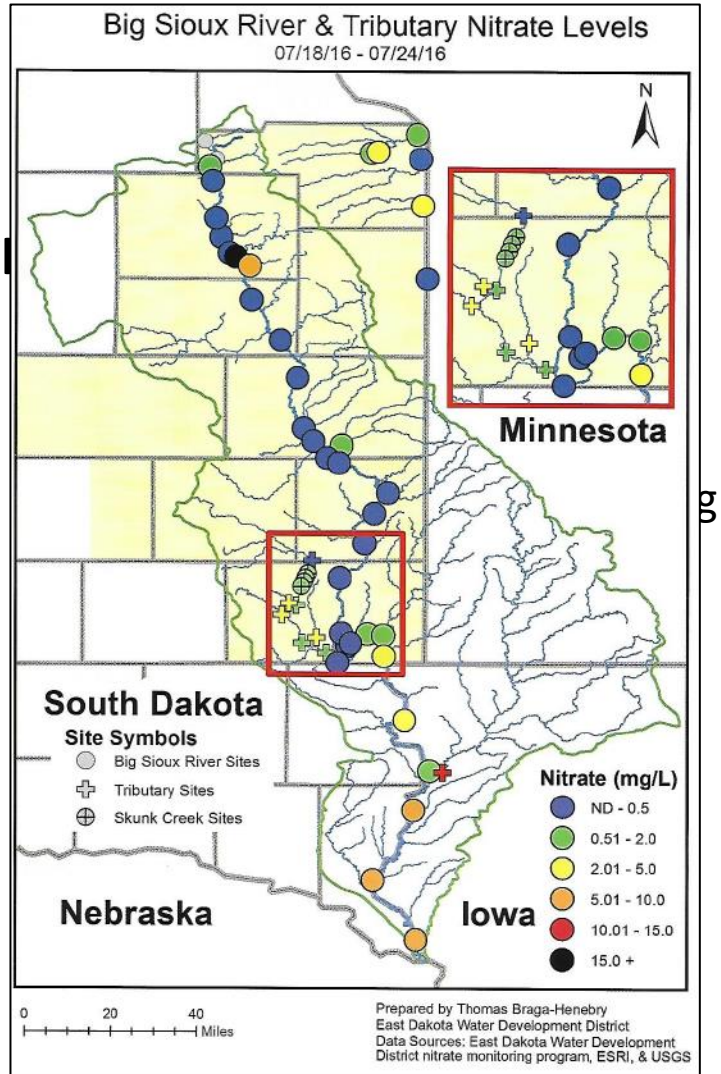
Why Land Use and Land Cover Change?



DA-NASS regions in South Dakota
K.D. Reitsma, Source of Data, USDA-NASS)

Wl

- g
-



The objectives of this research are to determine:

(1) Land Use and Land Cover (LULC) change in the Big Sioux River (BSR) watershed,

(2) spatial and temporal trends of nitrogen levels in the BSR, and

(3) determine whether there is a correlation between LULC change and changes in nitrogen levels in the river.

Additional questions:

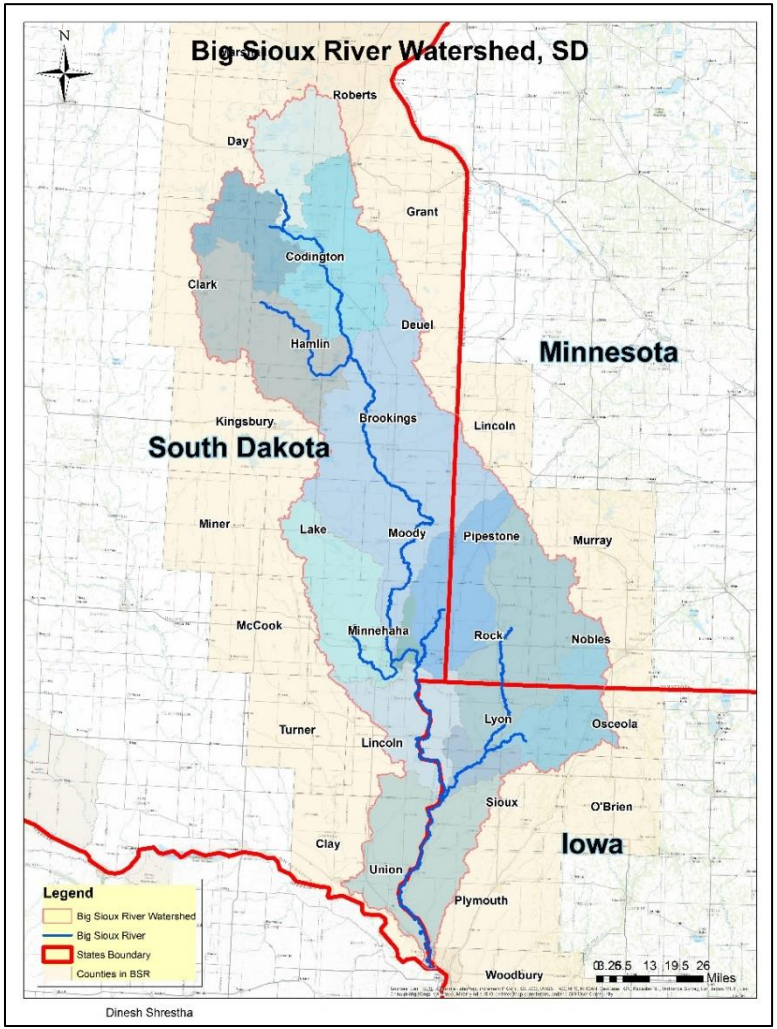
- What was the acreage of corn/soybeans and grassland in 2007, and how did it change between then and 2015? What are the rates of grassland conversion to corn/soy?
- What was the nitrogen level in water in the BSR in 2007 and how did it change between then and 2015? What is the nitrate trend in the river water? How did it change during the study period?

Methodology

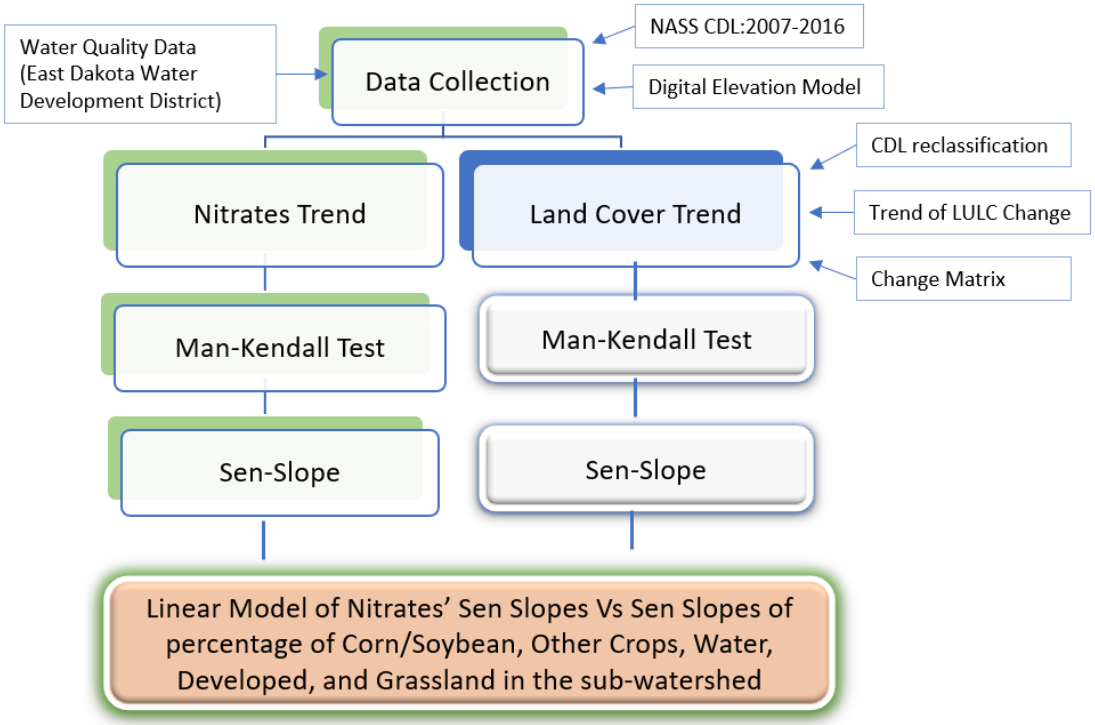
- **Study Area:**

The Big Sioux River Watershed

  - Location: Lies mostly (6,000 sq. miles) in Eastern SD, (1,500 sq. miles) in Minnesota, and (1,500 sq. miles) in Iowa
  - 420 miles long river that begins in Roberts County, SD and flows south to Missouri River in Sioux City, Iowa



Methodology



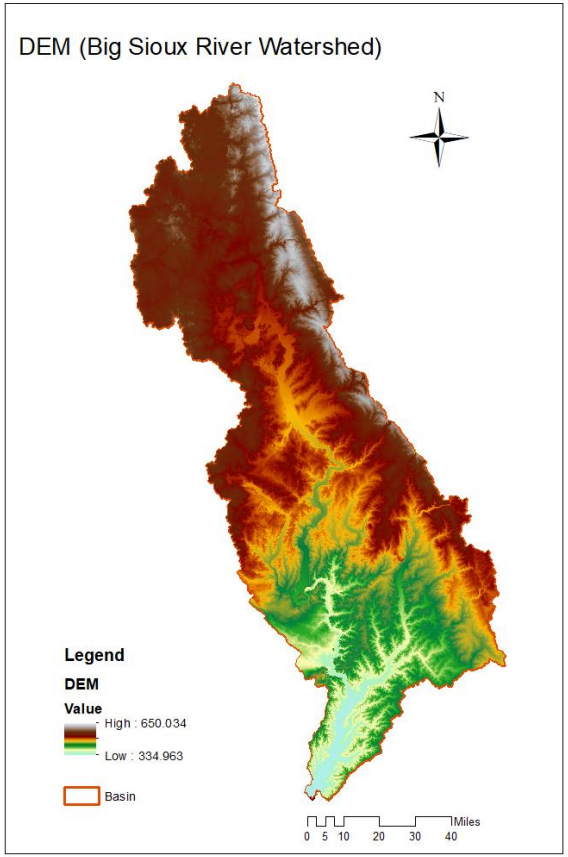
Methodology

Data Collection

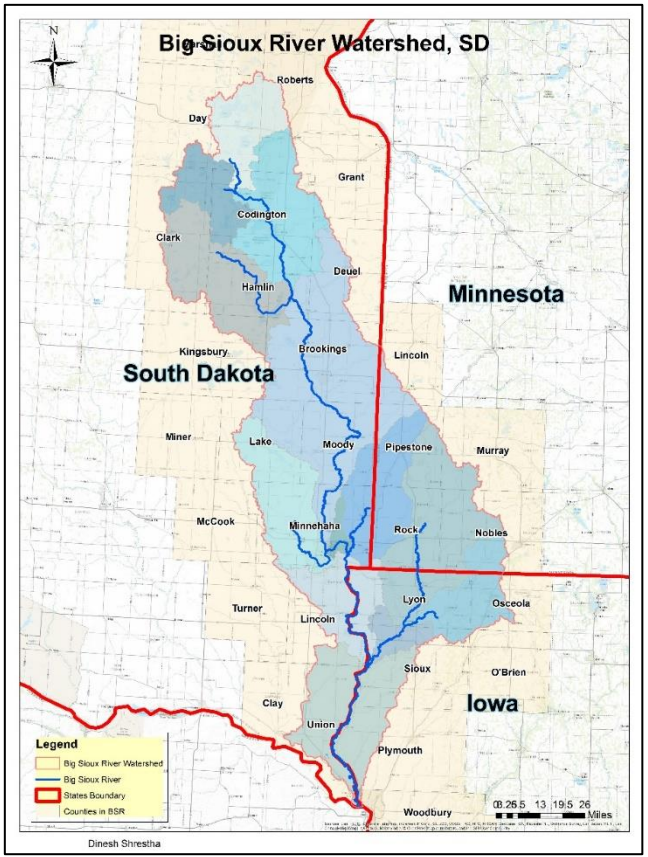
- **Land Use Data**
  - National Agricultural Statistics Service (NASS) CropScape-Cropland Data Layer (CDL): 2007-2016 [www.nass.usda.gov]
- **Water quality data**
  - East Dakota Water Development District, SD
  - Department of Environment and Natural REsources
- **Others**
  - Arc Grid representing a Digital Elevation Model for the Big Sioux River
  - Climate data [NCEI Map Viewer gis.ncdc.noaa.gov/map/viewer]
  - Streamflow (discharge) data [US EPA- Surf your Watershed]

Data

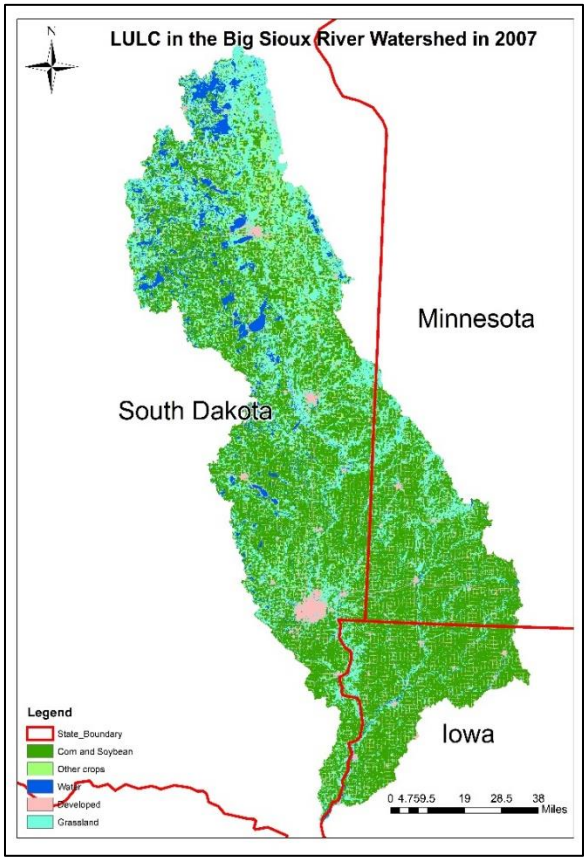
Digital Elevation Model (DEM)



Watershed and Sub-Watersheds

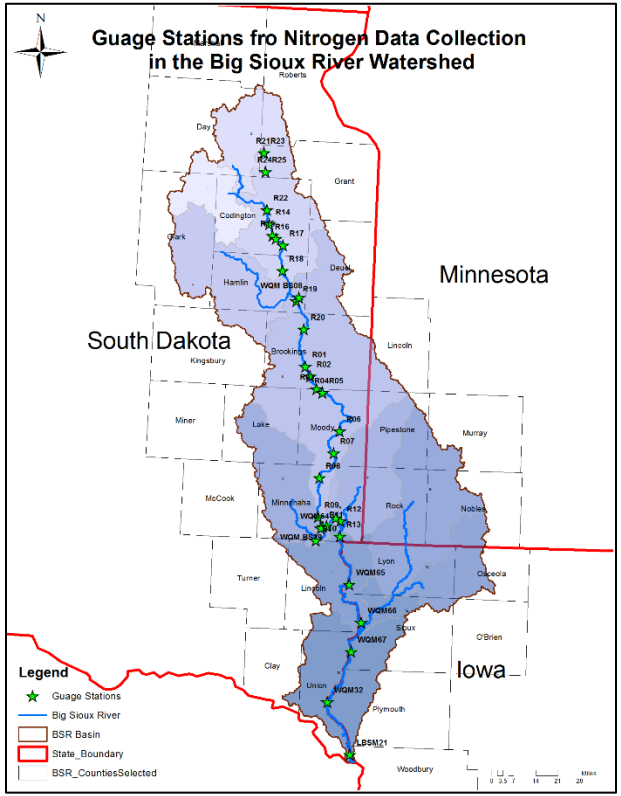


Cropland Data Layer 2007

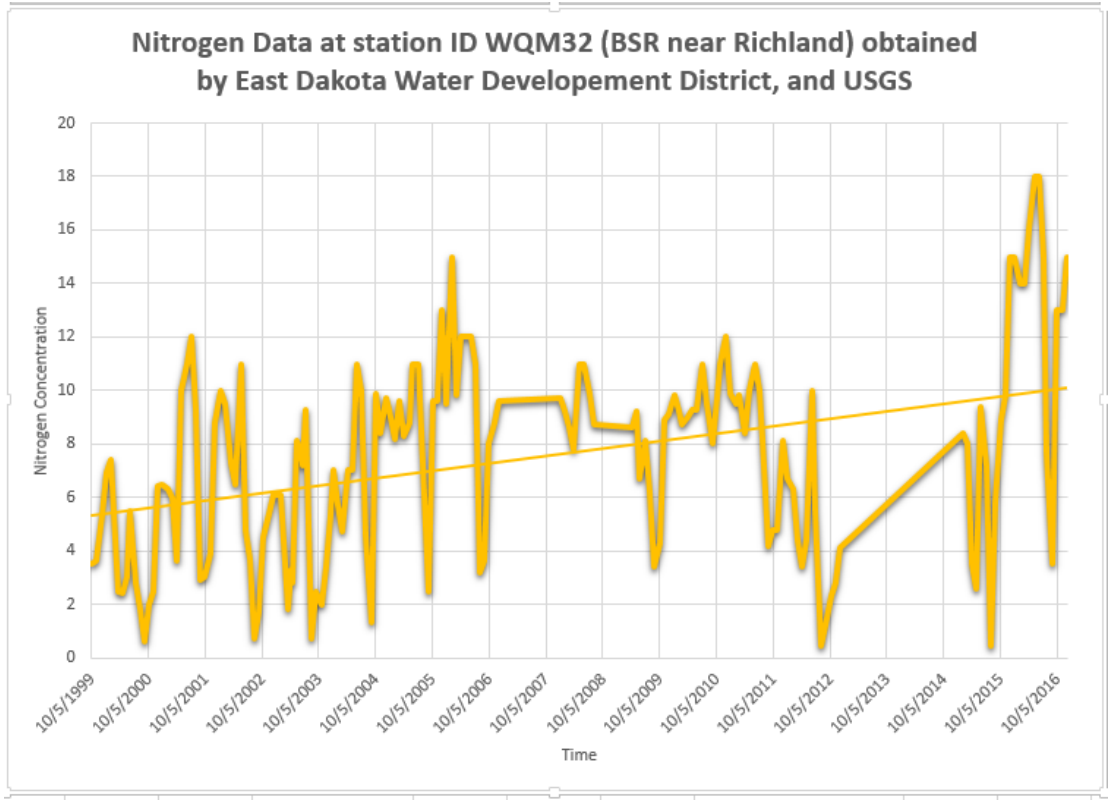


Data

Gauge Stations at BSR



Nitrogen Data

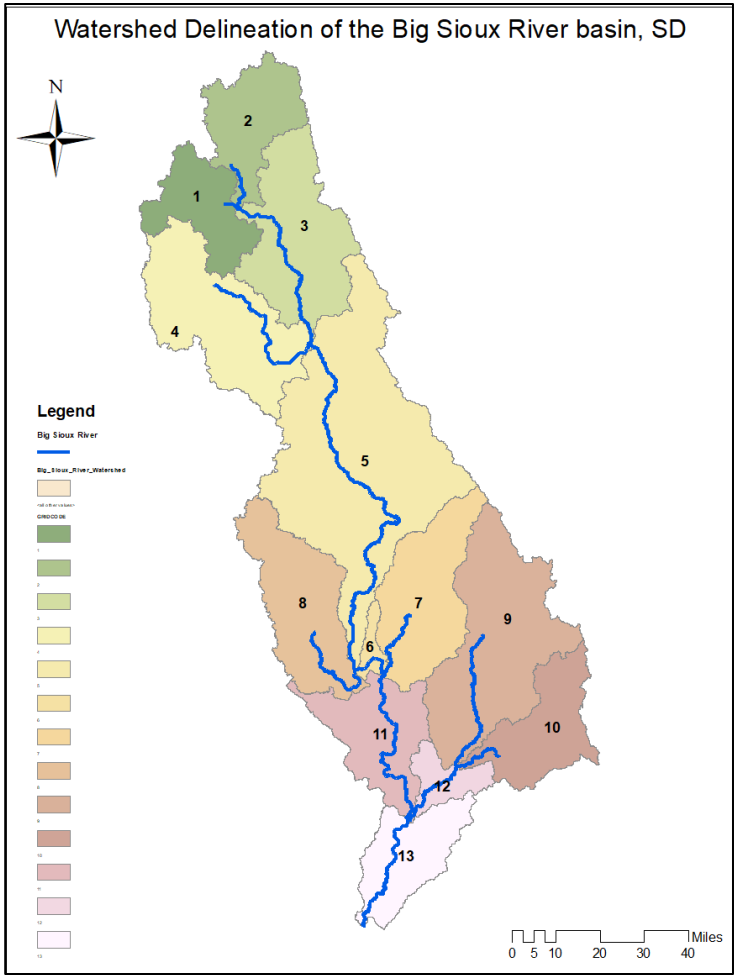


Land Cover Change

- Watershed Delineation
- Preparation of CDL Dataset
- Calculation of area for five major classes: Corn/Soybean, Other plants, Water, Developed, Grassland
- Man-Kendall test for land cover trend

Land Cover Change

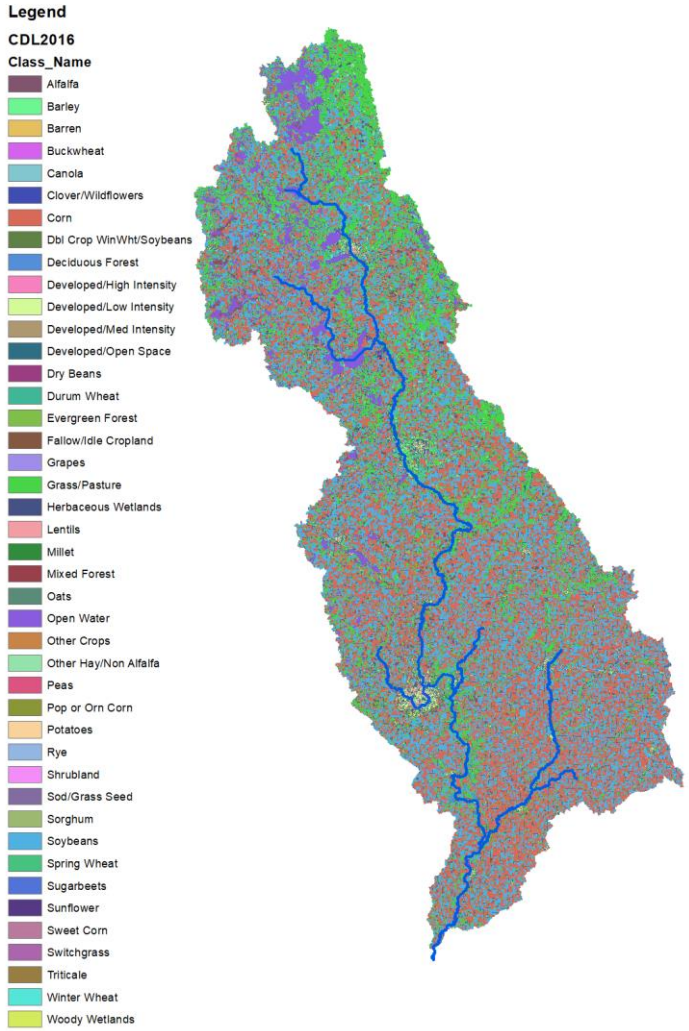
- Watershed Delineation
  - The total area = 8,364 square miles.
  - Then, the watershed is sub-divided into 13 sub-watersheds
  - WQM 32-gauge station near Richland (Latitude: 42.7616 ° N, Longitude: 96.632 ° W) as a pour point.



Land Cover Change

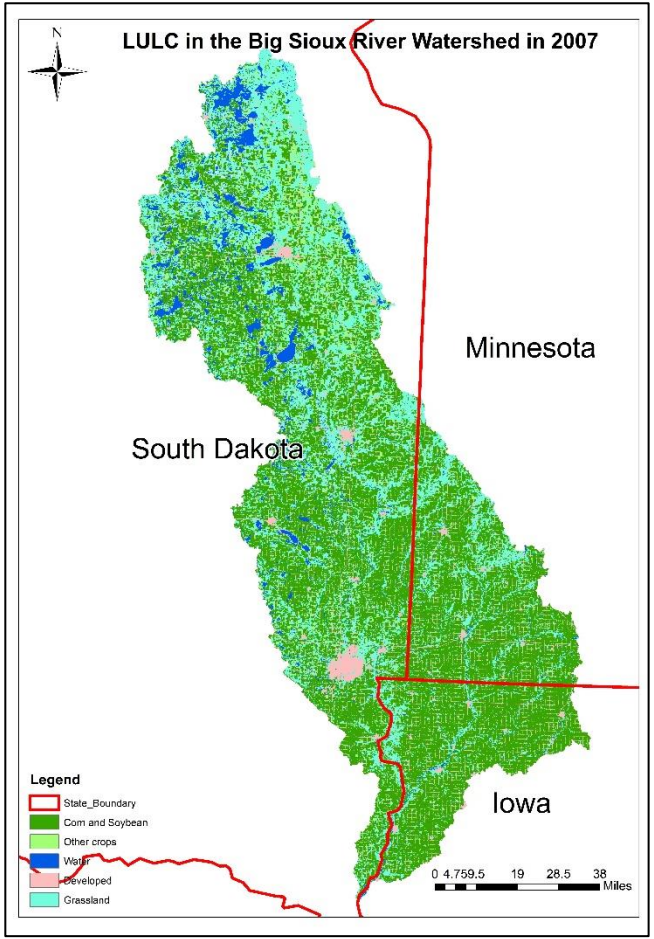
- Preparation of CDL Dataset
  - Reclassification
  - Trend of LULC change
  - Change Matrix

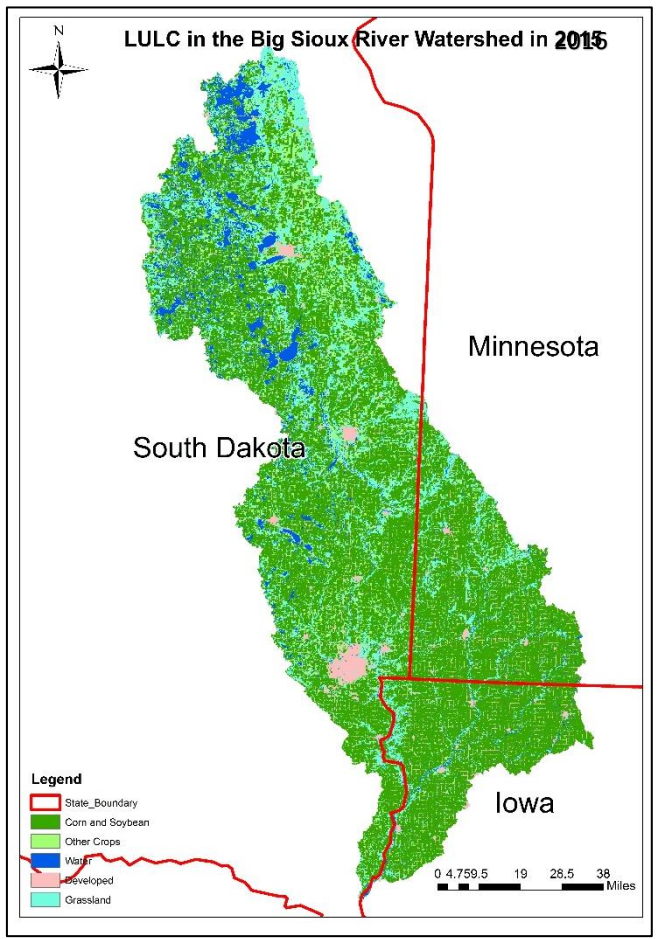
Reclassification Table	
Classes	Categories
Corn/Soy	Corn and Soybeans
Other Crops	Wheat, Alfalfa, Sorghum,Pumpkin, Flaxseed, Potatoes, and other crops.
Water	Water, Wetlands
Developed	Open space, low/medium/high density
Grassland	Switchgrass, Grass/Pasture, Fruit Trees, Shrub land



Corn/Soybean increased by **1.09 million** acres

Grassland decreased by **917,000** acres





Land Cover Change

- Calculation of area for five major classes: Corn/Soybean, Other plants, Water, Developed, Grassland

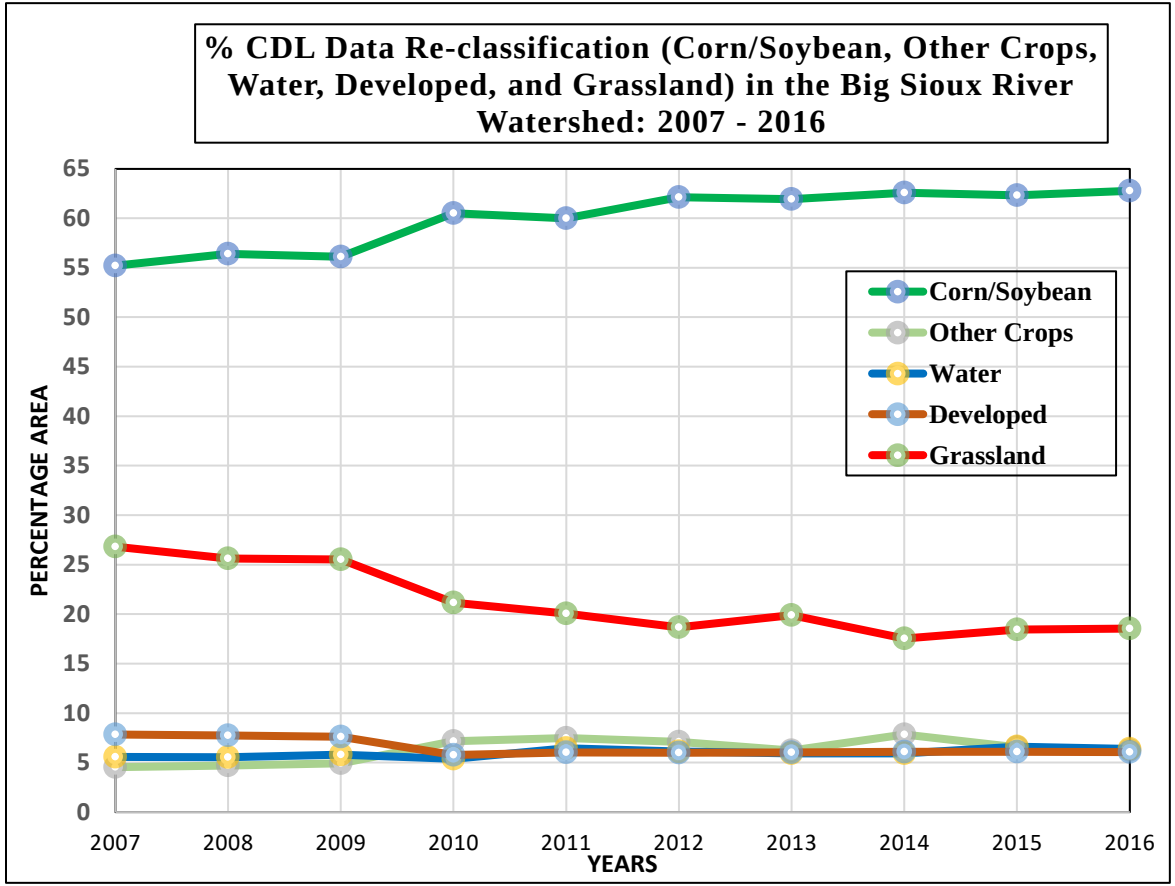


Table: CDL Data Reclassification into 5 major class types, area in 1,000 of acres, from 2007 to 2016.

		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**

Man-Kendell – Trend Analysis

Land Cover Trend

- Delineate watershed into sub-watersheds (13)
- Trend of percentage of each class types from 2007 to 2015, in each watershed.
- Derives tau and level of significance
- Determine +ve, -ve or not significant trend

Nitrates Trend

- Estimate the number of stations with increasing and decreasing NO3-N trends
- Derives tau and level of significance
- Determine +ve, -ve or not significant trend

Results

Man-Kendell – Trend Analysis

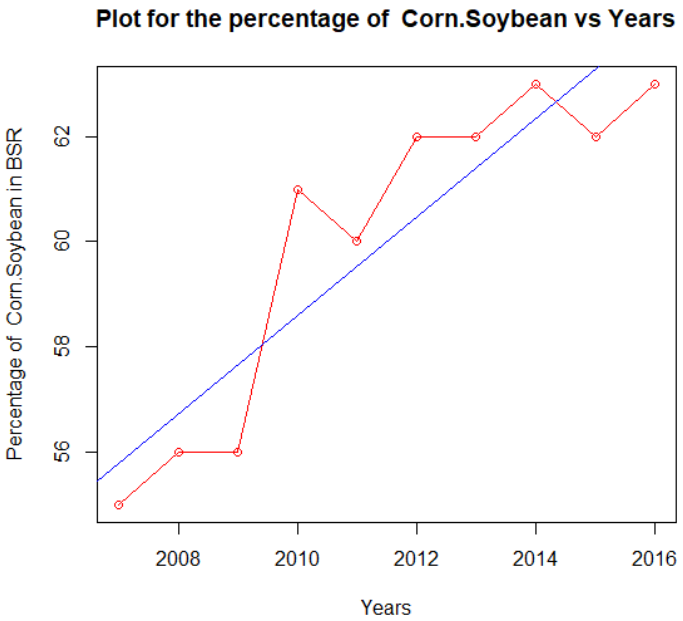
Land Cover Trend

- The corn/soybean class in all the sub-basins showed upward trend

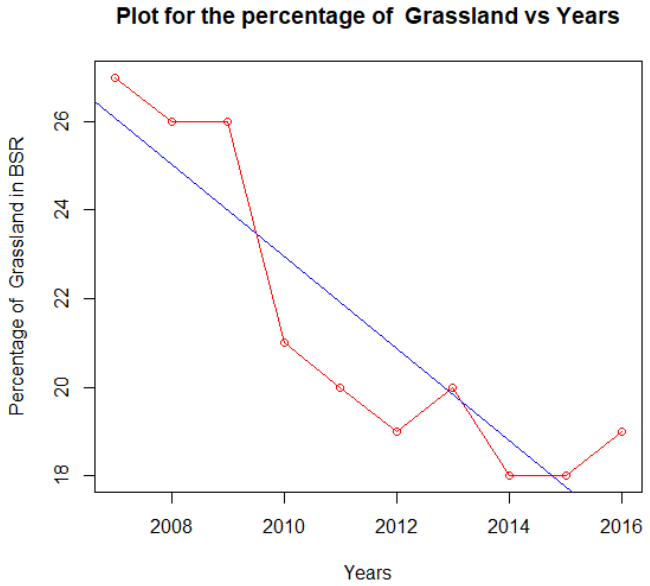
Nitrates Trend

- 6 out of 10 stations showed upward trend, 2 downward and 2 neutral.

Man-Kendall (Land Cover Trend)



tau = 0.849, 2-sided, pvalue =0.001355

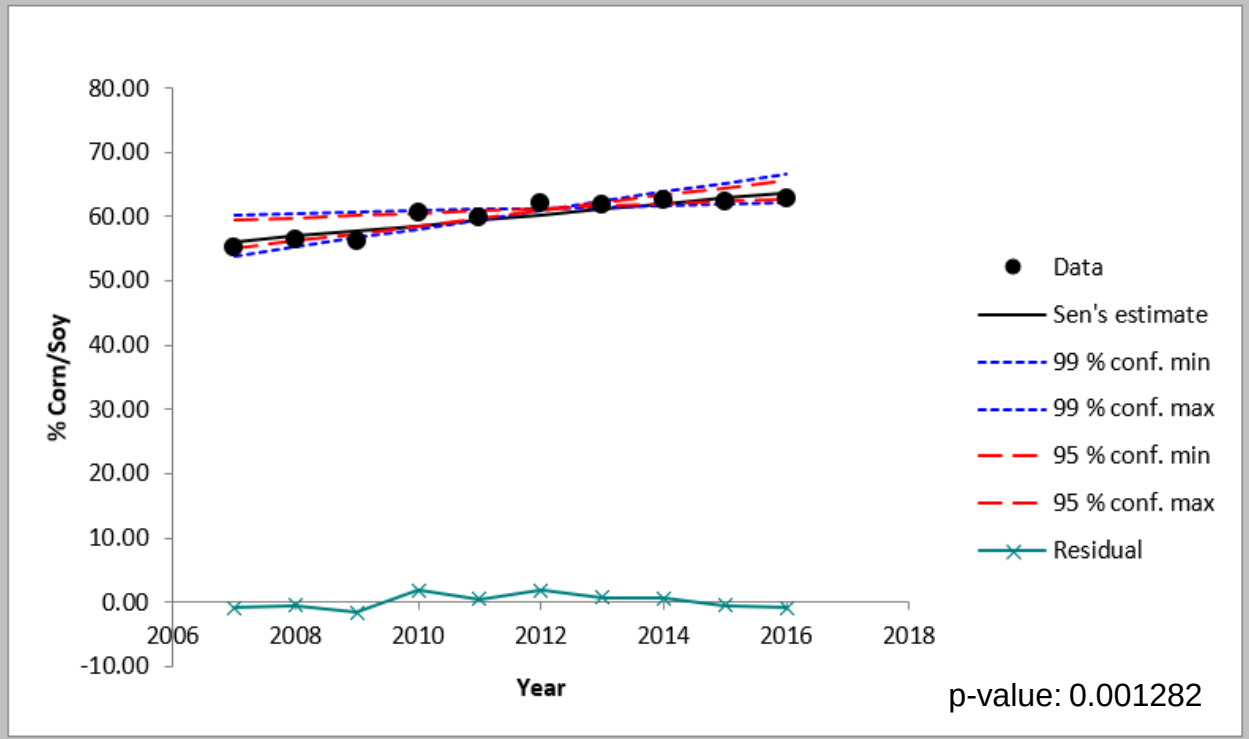


tau = -0.815, 2-sided, pvalue =0.0019954

Sen Slopes (Land Cover Trend)

Land Cover Change (BSR) 2007 - 2016

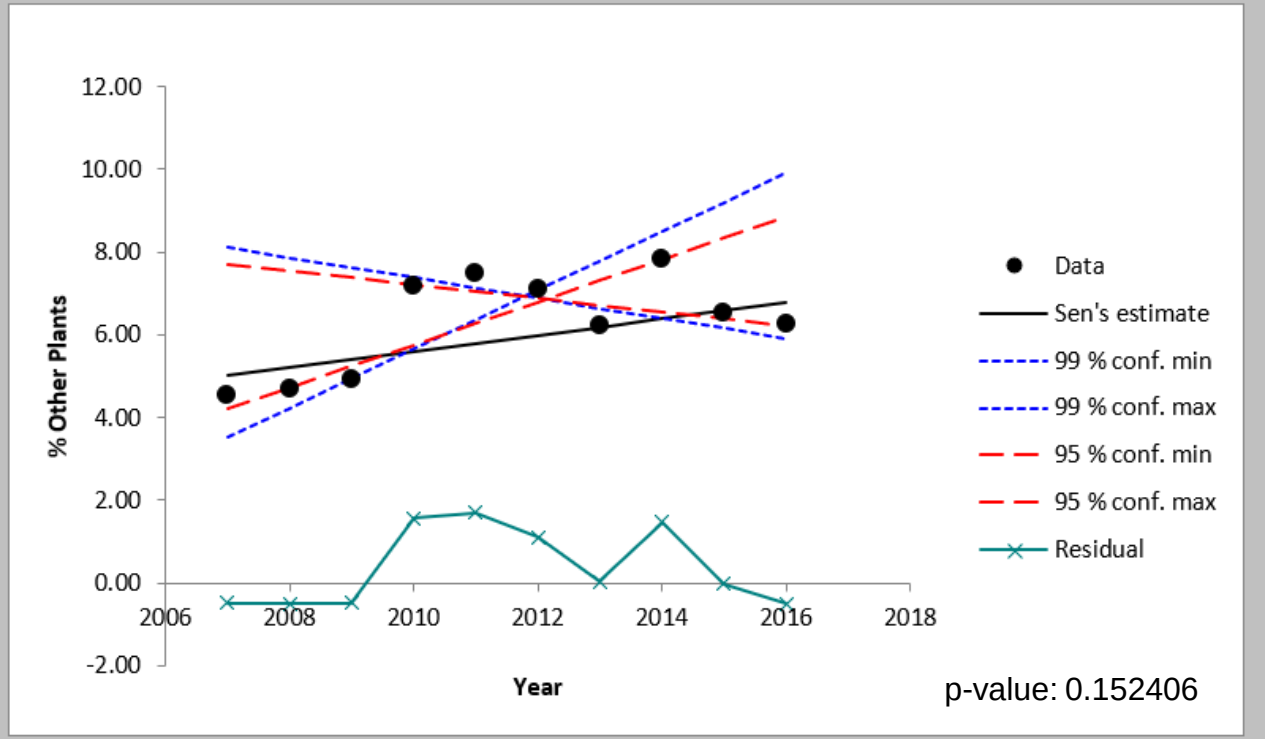
TsNumber	1
Name	% Corn/Soy
Years	2007 - 2016
n	10
Test S	
Test Z	3.22
Signific.	**
Q	8.45E-01
Qmin99	1.94E-01
Qmax99	1.43E+00
Qmin95	3.69E-01
Qmax95	1.19E+00
B	5.61E+01
Bmin99	6.03E+01
Bmax99	5.38E+01
Bmin95	5.94E+01
Bmax95	5.50E+01



Sen Slopes (Land Cover Trend)

Land Cover Change (BSR) 2007 - 2016

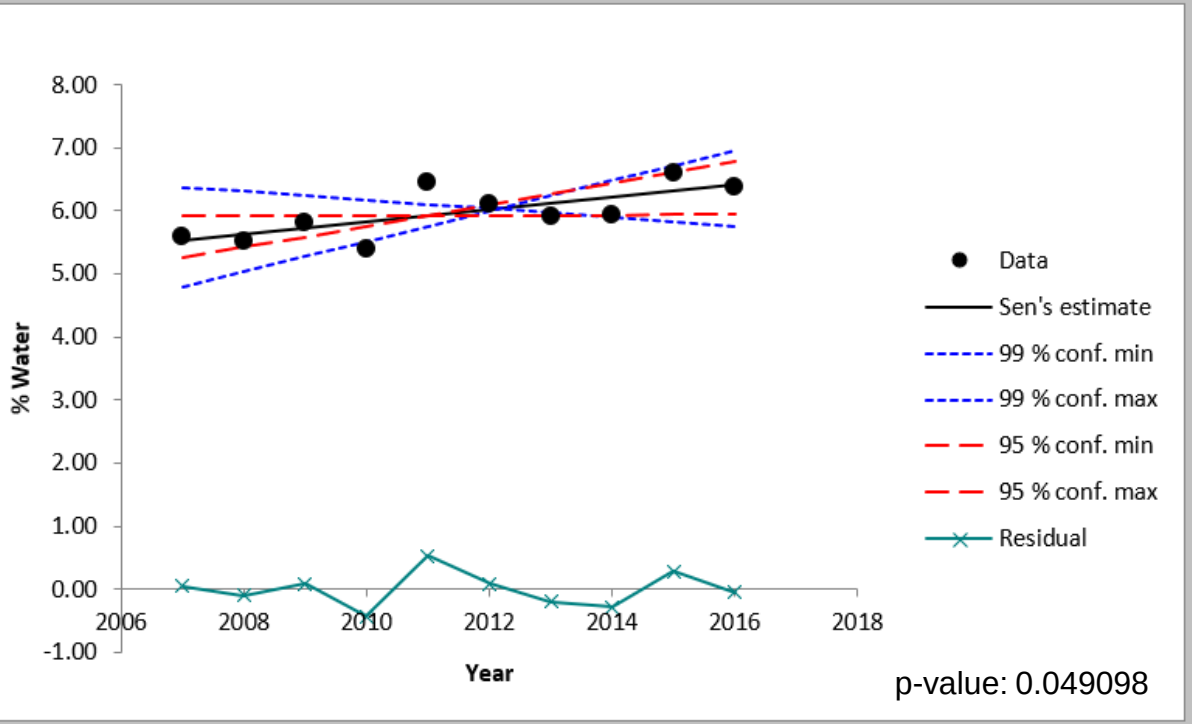
TsNumber	2
Name	% Other Plants
Years	2007 - 2016
n	10
Test S	
Test Z	1.43
Signific.	
Q	1.95E-01
Qmin99	-2.45E-01
Qmax99	7.10E-01
Qmin95	-1.65E-01
Qmax95	5.17E-01
B	5.01E+00
Bmin99	8.11E+00
Bmax99	3.52E+00
Bmin95	7.71E+00
Bmax95	4.20E+00



Sen Slopes (Land Cover Trend)

Land Cover Change (BSR) 2007 - 2016

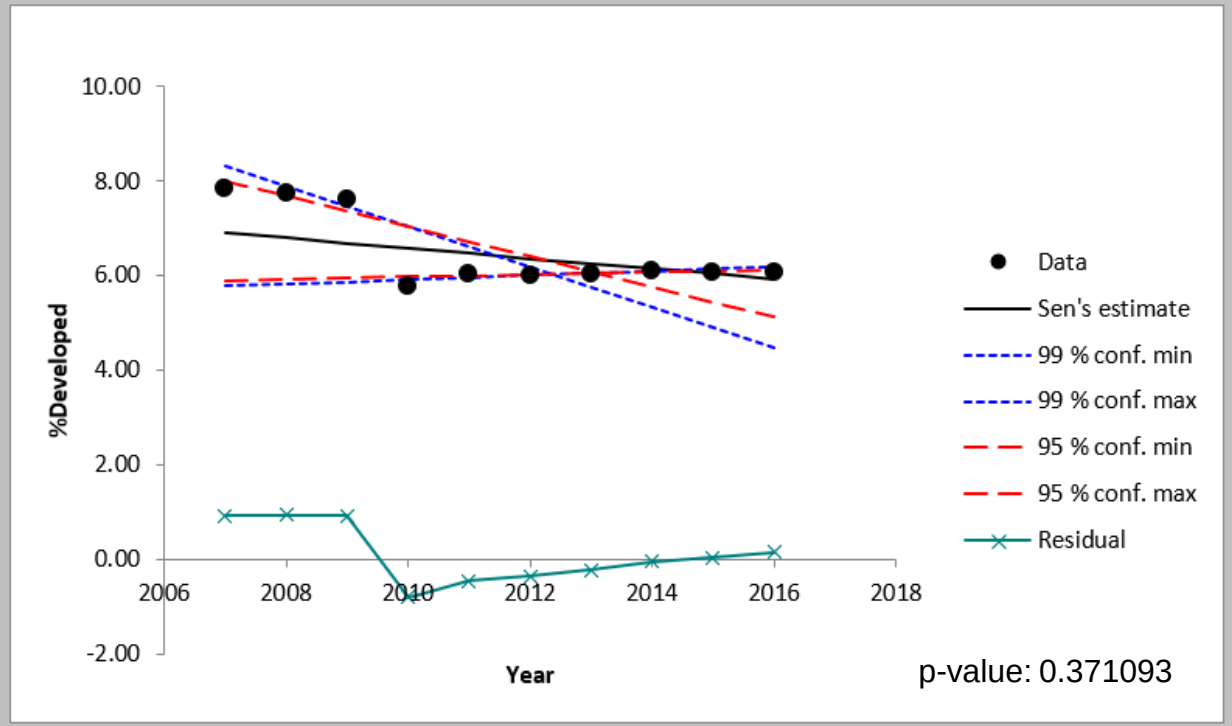
TsNumber	3
Name	% Water
Years	2007 - 2016
n	10
Test S	
Test Z	1.97
Signific.	*
Q	9.95E-02
Qmin99	-6.84E-02
Qmax99	2.40E-01
Qmin95	2.89E-03
Qmax95	1.71E-01
B	5.53E+00
Bmin99	6.38E+00
Bmax99	4.80E+00
Bmin95	5.91E+00
Bmax95	5.25E+00



Sen Slopes (Land Cover Trend)

Land Cover Change (BSR) 2007 - 2016

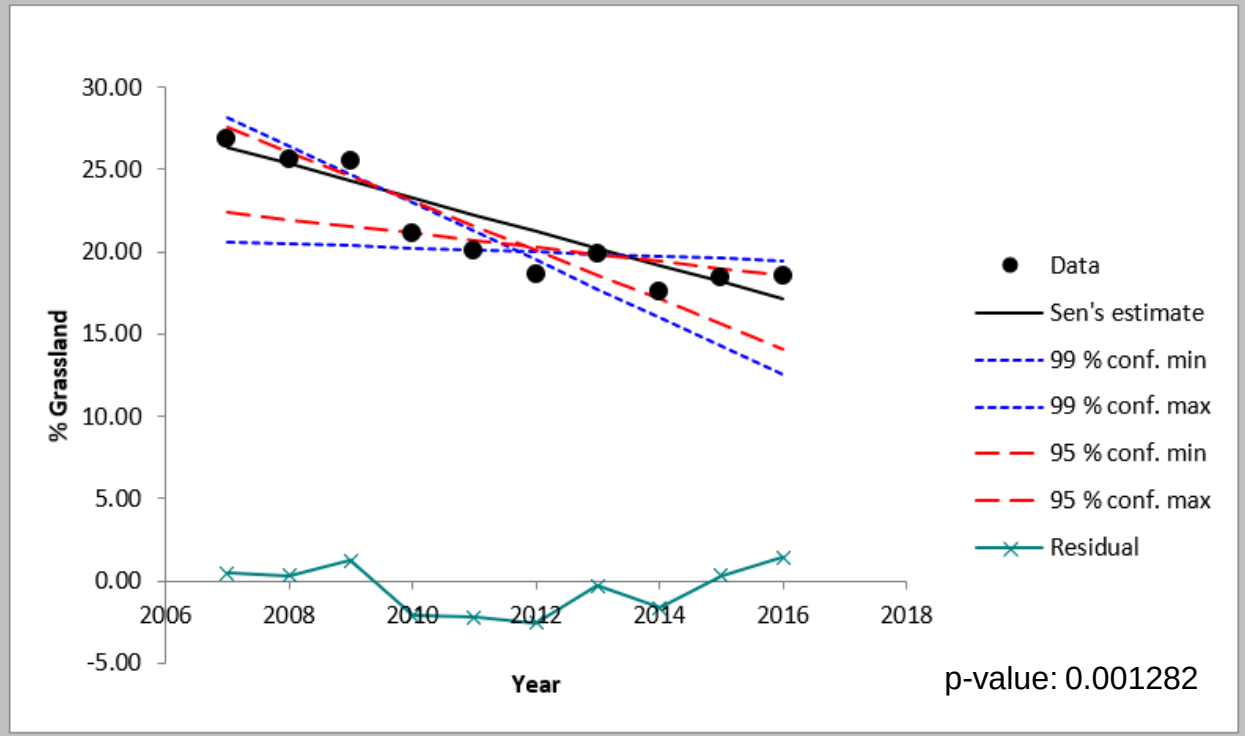
TsNumber	4
Name	%Developed
Years	2007 - 2016
n	10
Test S	
Test Z	-0.89
Signific.	
Q	-1.09E-01
Qmin99	-4.28E-01
Qmax99	4.65E-02
Qmin95	-3.20E-01
Qmax95	2.47E-02
B	6.90E+00
Bmin99	8.32E+00
Bmax99	5.77E+00
Bmin95	8.00E+00
Bmax95	5.90E+00



Sen Slopes (Land Cover Trend)

Land Cover Change (BSR) 2007 - 2016

TsNumber	5
Name	% Grassland
Years	2007 - 2016
n	10
Test S	
Test Z	-3.22
Signific.	**
Q	-1.03E+00
Qmin99	-1.74E+00
Qmax99	-1.31E-01
Qmin95	-1.49E+00
Qmax95	-4.26E-01
B	2.64E+01
Bmin99	2.82E+01
Bmax99	2.06E+01
Bmin95	2.76E+01
Bmax95	2.24E+01



Man-Kendall (Nitrogen Trend)

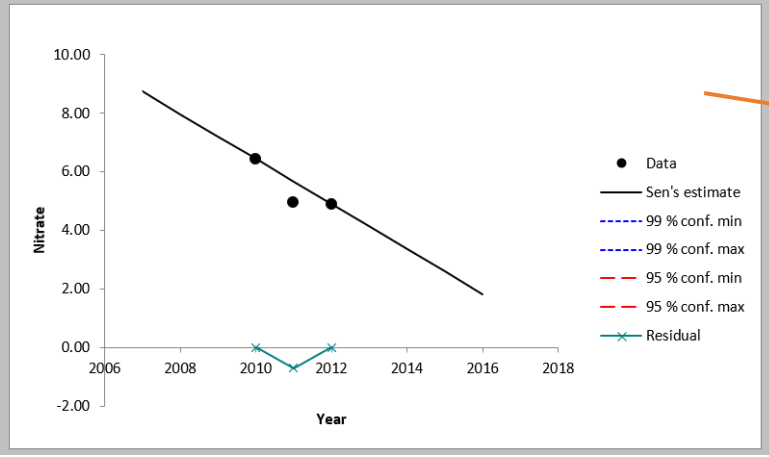
6 out of 10 stations showed upward trend,

2 downward and

2 neutral.

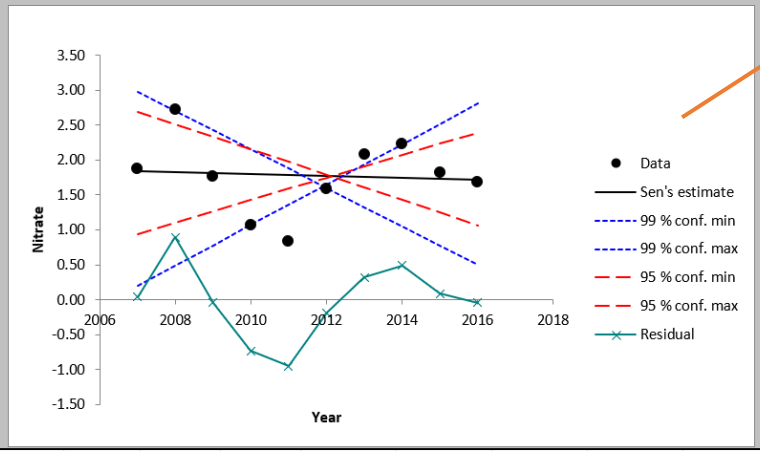
Sen's Estimate for Nitrates at IowaAmbient Station

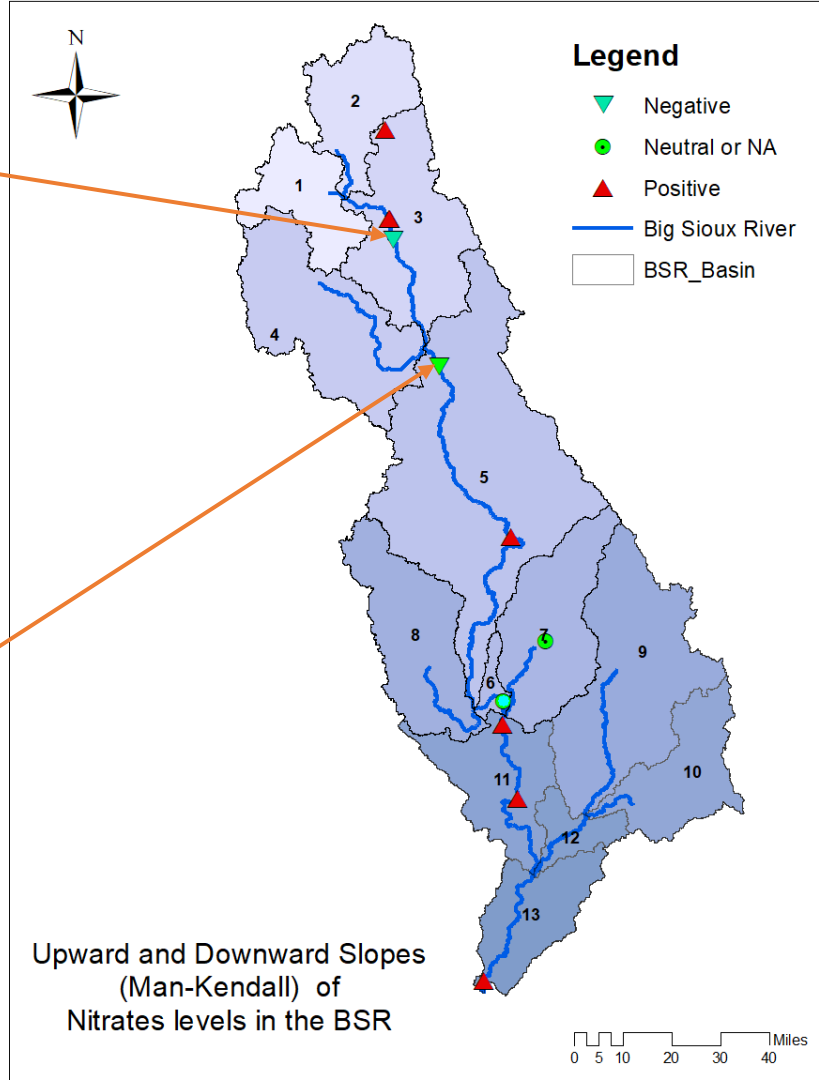
TsNumber	1
Name	Nitrate
Years	2007 - 2016
n	3
Test S	-3
Test Z	
Signific.	
Q	-7.67E-01
Qmin99	
Qmax99	
Qmin95	
Qmax95	
B	8.73E+00
Bmin99	
Bmax99	
Bmin95	
Bmax95	



Sen's Estimates at Station SD_Hamlin

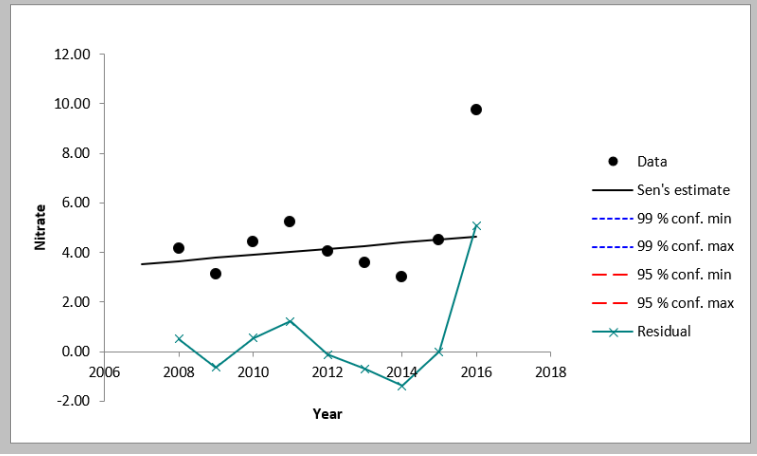
TsNumber	1
Name	Nitrate
Years	2007 - 2016
n	10
Test S	
Test Z	-0.18
Signific.	
Q	-1.31E-02
Qmin99	-2.76E-01
Qmax99	2.89E-01
Qmin95	-1.81E-01
Qmax95	1.61E-01
B	1.84E+00
Bmin99	2.98E+00
Bmax99	2.02E-01
Bmin95	2.70E+00
Bmax95	9.44E-01





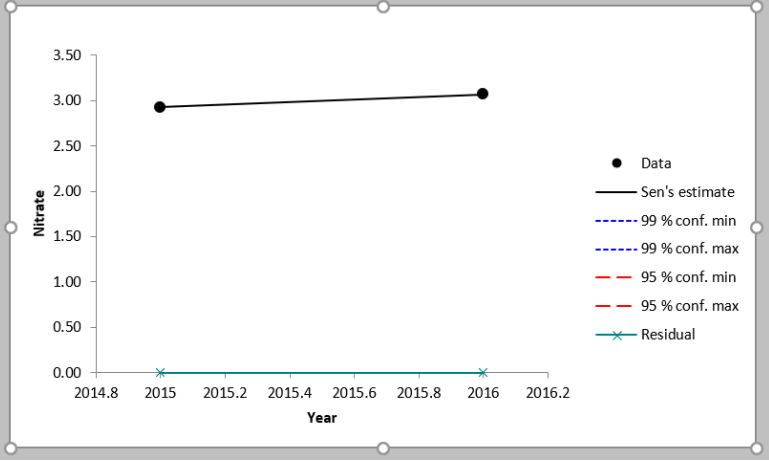
Nitrate Trend at Station MN_Rock

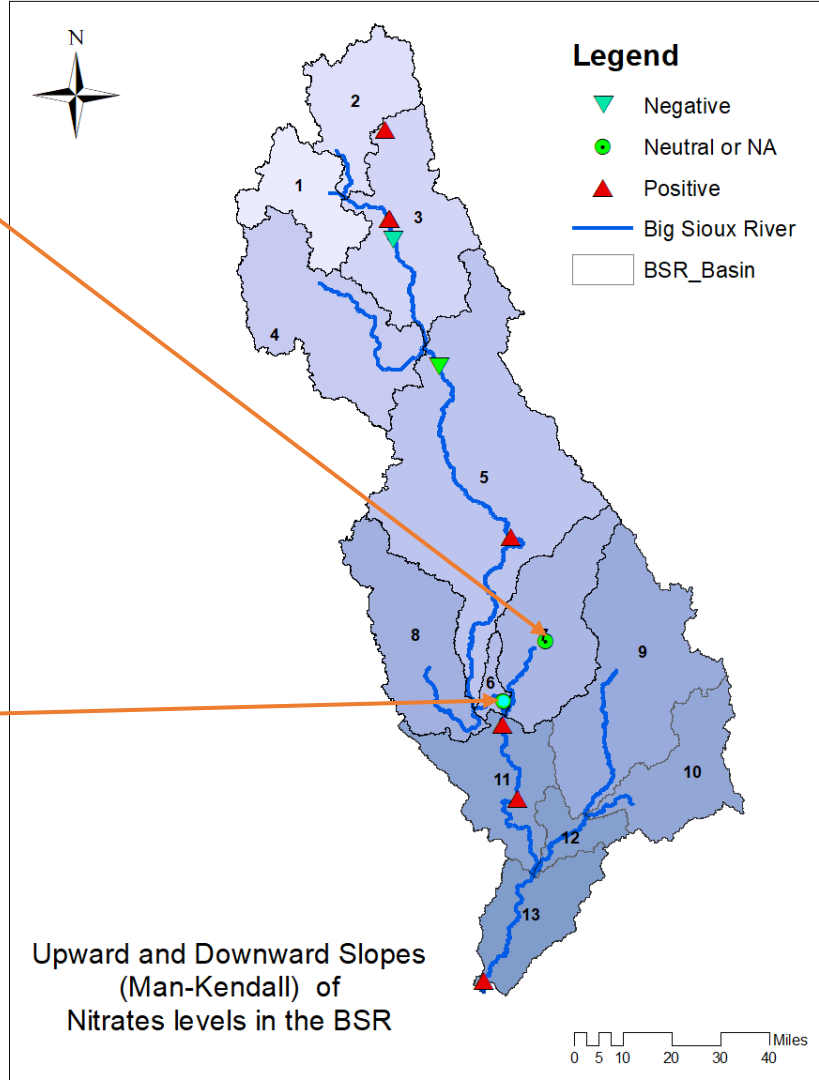
TsNumber	1
Name	Nitrate
Years	2007 - 2016
n	9
Test S	6
Test Z	
Signific.	
Q	1.23E-01
Qmin99	
Qmax99	
Qmin95	
Qmax95	
B	3.53E+00
Bmin99	
Bmax99	
Bmin95	
Bmax95	



Nitrate Trend at Station R12

TsNumber	1
Name	Nitrate
Years	2015 - 2016
n	2
Test S	1
Test Z	
Signific.	
Q	1.44E-01
Qmin99	
Qmax99	
Qmin95	
Qmax95	
B	1.77E+00
Bmin99	
Bmax99	
Bmin95	
Bmax95	





Summary/ Discussion

Summary

(1) What is Land Cover Trend in the Big Sioux River Watershed?

- Corn/Soybean – positive (upward)
- Grassland – negative (downward)

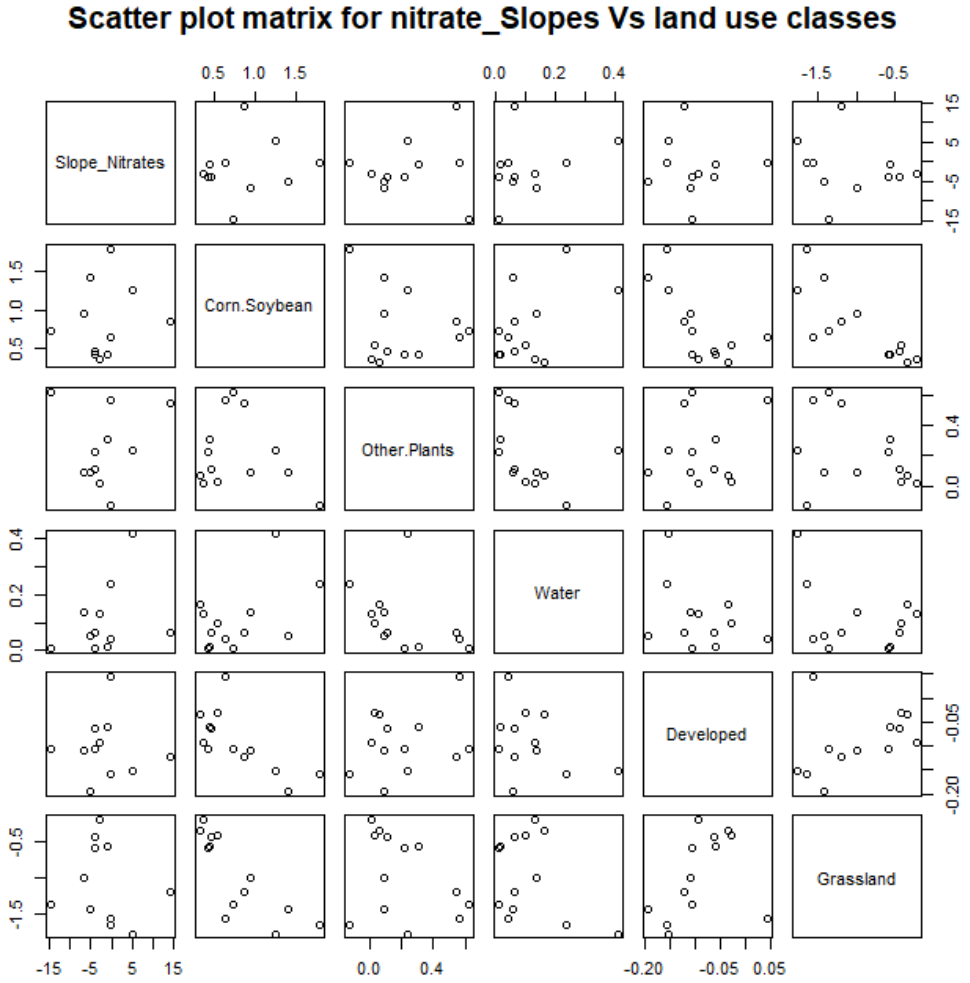
(2) What is the Nitrogen trend the Big Sioux River Watershed?

- 6 out of 10 gauge stations – positive
- 2 negative, and
- 2 neutral

(3) Is there a correlation between LULC change and changes in nitrogen levels in the river?

- Yes, but not strongly correlated

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

- The liner model showed that the nitrates and other variables don’t have strong correlation.
- However, the Man-Kendall and Sen’s estimator gave the upward and downward relationship between these variables.

Contribution

- Results are important:
  - likely to provide a better understanding of the role of LULC change to BSR water quality,
  - be important to water supply organizations and farmers in developing improved land management strategies and to ensure clean and affordable public water,
  - the results of the pending court case may alter the Corn Belt Farmland management and Water Acts and could have an impact on EDWDD and other water districts

References

- 2016. *D.M. Water Works lawsuit questions.* 01 11. Accessed 04 29, 2016. https://www.scribd.com/doc/295174322/D-M-Water-Works-lawsuit-questions#fullscreen.
- eastdakota.org. 2016. *...more about the Big Sioux River.* April 20. Accessed April 25, 2016. http://eastdakota.org/bsrwatershed/More%20About%20Watersheds.html.
- EPA, United States Environmental Protection Agency. 2008. *EPA's 2008 Report on the Environment.* US EPA.
- Napton, Darrell, and Jordan Graesser. 2011. "Agricultural land change in the Northwestern Corn Belt, USA: 1972–2007." *GeoCarpathica 11* 65-81.
- Reitsma, K. D., B. H. Dunn, U. Mishra, S. A. Clay, T. DeSutter, and D. E. Clay. 2015. Land-use change impact on soil sustainability in a climate and vegetation transition zone. Agronomy Journal 107 (6): 2263-2372.
- Wright, Christopher K., and Michael C. Wimberly. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences 110 (10): 4134-4139.

	Other Crops	Water	Developed
Entire BSR	tau = 0.428, 2-sided pvalue =0.13	tau = 0.325, 2-sided pvalue =0.30035	tau = -0.683, 2-sided pvalue =0.022654
WS1	tau = -0.145, 2-sided pvalue =0.64343	tau = 0.545, 2-sided pvalue =0.05392	tau = -0.683, 2-sided pvalue =0.022654
WS2	tau = 0.242, 2-sided pvalue =0.40201	tau = 0.76, 2-sided pvalue =0.0050213	tau = -0.683, 2-sided pvalue =0.022654
WS3	tau = 0.0233, 2-sided pvalue =1	tau = 0.298, 2-sided pvalue =0.36077	tau = -0.715, 2-sided pvalue =0.013708
WS4	tau = 0.199, 2-sided pvalue =0.50959	tau = 0.441, 2-sided pvalue =0.12539	tau = -0.683, 2-sided pvalue =0.022654
WS5	tau = 0.358, 2-sided pvalue =0.1981	tau = 0.526, 2-sided pvalue =0.071387	tau = -0.683, 2-sided pvalue =0.022654
WS6	tau = 0.471, 2-sided pvalue =0.081983	tau = 0.487, 2-sided pvalue =0.10982	tau = 0.526, 2-sided pvalue =0.071387
WS7	tau = 0.63, 2-sided pvalue =0.023137	tau = 0.373, 2-sided pvalue =0.23998	tau = -0.683, 2-sided pvalue =0.022654
WS8	tau = 0.442, 2-sided pvalue =0.10082	tau = -0.0497, 2-sided pvalue =1	tau = -0.43, 2-sided pvalue =0.14658
WS9	tau = 0.653, 2-sided pvalue =0.025043	tau = 0.596, 2-sided pvalue =0.050186	tau = -0.715, 2-sided pvalue =0.013708
WS10	tau = -0.0298, 2-sided pvalue =1	tau = 0.542, 2-sided pvalue =0.069919	tau = -0.402, 2-sided pvalue =0.16913
WS11	tau = 0.479, 2-sided pvalue =0.088498	tau = 0.268, 2-sided pvalue =0.4034	tau = -0.234, 2-sided pvalue =0.44352
WS12	tau = 0.488, 2-sided pvalue =0.11061	tau = 0.562, 2-sided pvalue =0.049494	tau = -0.234, 2-sided pvalue =0.44352
WS13	tau = 0.0325, 2-sided pvalue =1	tau = 0.316, 2-sided pvalue =0.29976	tau = -0.683, 2-sided pvalue =0.022654