TRENDS OF LAND USE LAND AND COVER CHANGE IN THE BIG SIOUX RIVER WATERSHED: 2007-2015

Report (SDView Student Mini Grant 2017)

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Contents

Abstract

The increased demands on ethanol and rises in the price of corn led to increment of corn acreage in South Dakota. 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 such as wheat to corn. The grassland conversion was mostly concentrated in North Dakota and South Dakota, east of the Missouri River. The northeastern, east central and southeastern regions of South Dakota totaled 484,000 acres of grassland converted to cropland. Government payments, such as crop insurance subsidies and disaster payments, grain demand, biofuel demands, and climate change were the driving forces that encouraged farmers not only to convert grassland to cropland but also to shift from other crops to corn and soybeans. My research used NASS Cropland Data to characterize and determine the rates of land use land cover (LULC) change from 2007 to 2015. First, the 225 classes in CDL data layer were reclassified in 5 broad classes (Corn and Soybean, Other crops, Water, Developed, and Grassland), then the change on those classes were determined. I used Geographic Information System (GIS) for this purpose. After reclassification, I selected 3 sample blocks (Sample Block 8, 26, and 46) using stratified random method and went for a field visit to determine if my classifications were correct. I used Global Positioning System (GPS) to locate the locations in the field. Out of 450 sample points, 437 points were placed in the expected classes, whereas 13 were misclassified. This gave the total accuracy of 97.11%. The user's and producer's accuracy for the five reclassified classes Corn/Soy, Other Plants, Water, Developed, and Grassland, were: 98%, 97%, 98%, 100%, and 93% and, 94%, 99%, 100%, 100%, and 93% respectively.

Keywords: Land Use Land Cover change, Western Corn Belt Plains Ecoregion, South Dakota, Big Sioux River Watershed, GIS, GPS, NASS Cropland Data

Introduction

High corn and soybean prices accelerated the conversion of grassland to cropland in the Western Corn Belt Plains Ecoregion; the conversion mainly being to corn and soybean croplands. Grassland conversion from 2006 to 2012 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). 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 rotation between corn and soybean to meet the corn demands (United States Department of Agriculture 2017; Wright and Wimberly 2013).

South Dakota on the edge of the WCB and was influenced by ethanol demands. Farmers were interested in converting grassland into cropland and shifting other crops to corn. They adjusted crop rotation between corn and soybeans to meet the corn demands (United States Department of Agriculture 2017; Wright and Wimberly 2013). There was a conversion of 1.8 million acres of grassland to cropland, from 2006 to 2012 in South Dakota (Reitsma et.al 2014, 1). With most of the conversion taking place in northeastern, east-central and southeastern regions of the state, the gain in corn acreage totaled 585,000 acres (Retiesma et. al 2014).

Research Question and Objectives

The objective of project is to **determine Land Use and Land Cover change in the Big Sioux River watershed.** I used National Agricultural Statistics Service's (NASS) CropScape-Cropland Data Layer from 2006-2015 to characterize the LULC and to determine the rates of LULC change.

In addition, the project expect to answer the following research questions:

- What was acreage of corn and soybeans in 2007 how did it change between then and 2015?
- What was acreage of grassland in 2007 how did it change between then and 2015?
- What acreage of grassland has converted to corn and soybeans?
- What are the trends and patterns of LULC change? Where are the rates of grassland conversion to corn/soy agriculture highest in the BSR?

More importantly,

- The project estimated the accuracy of the acreage estimation of broadly reclassified five classes of CDL dataset.

Methodology

Study Area

Eastern South Dakota is lower in elevation and higher in precipitation than the western part of the state (Gries 1996). It is largely drained by the Big Sioux River, a tributary of the Missouri. South Dakota's early economy relied heavily on the soil, especially in agriculture. Agriculture has historically been a key component of the South Dakota economy (Reitsma et al. 2015, 2364). The five most valuable agricultural products in South Dakota are cattle, corn (maize), soybeans, wheat, and hogs (Reitsma et al. 2015, 2363). Farmers rely upon the Big Sioux River for irrigation. My study area covers approximately 5,799 sq. miles of the Big Sioux River basin that lie in east South Dakota. The Big Sioux River is a 420-mile-long river that begins in Robert County, SD and flows south until it confluences with the Missouri River in Sioux City, Iowa (eastdakota.org 2016).

Data Collection and Analysis

Cropscape-Cropland Data Layer

For the purpose of LULC, National Agricultural Statistics Service's (NASS) CropScape-Cropland Data Layer from 2006-2015 was used. The data is available online (https://nassgeodata.gmu.edu/CropScape/). The CDL is a raster, geo-referenced, crop-specific land cover data layer created annually for the continental United States using moderate resolution satellite imagery and extensive agricultural ground truth. All historical CDL products are available for use and are free for download through CropScape. The CDL Data Layer has 225 different classes including corn, soybeans, wheat, developed area, water and wetlands, grassland/pasture, and so forth.

Reclassification:

These classes were reclassified into 5 major groups: (1) Corn and Soybean, (2) Other Crops, (3) Water, (4) Developed, and (5) Grassland. A glimpse of the reclassification is given in table 1. Reclassification of CDL layers were done using modeling procedure in ArcGIS.

Table 1: Reclassification table

Classes	Categories
Corn and Soybean	Corn and soybeans
Other Crops	Wheat, Alfalfa, Sorghum, Oats, Millet, Pumpkin, Flaxseed, Potatoes, and other crops.
Water /Wetland	Water, Perennial Ice/Snow, and Wetlands
Developed	Open space, low/medium/high density
Grassland	Forest, Switchgrass, Grass/Pasture, Fruit Trees, Shrub land, Barren, and others

Accuracy Assessment (Field Verification):

The total study area was divided into 52 sample blocks 22X22 km. At a sampling intensity of 5%, I selected 3 sample blocks randomly (5% of 52 = 2.6 blocks). Each sample block should have at least 30 training sample points for each class. There are 5 classes, which means I should have 150 training samples (5X30 = 150) per sample block. Altogether, I had 450 training samples.

Basically, the sample training for the classes such as Water and Developed was done using Google earth and ArcGIS online whereas the training samples for classes such as Corn and Soybeans, Other crops, and Grassland were verified by the field verification. For this purpose, I used Global Positioning System (GPS) to geo-locate the training points and verify the classes.

Results

A. Land Use and Land Cover Change Estimate

In my project, I demostrated recent changes in land use and land cover in the BSR. The "change" here refers to which land cover, for example grassland, had been converted to corn and soybeans or other class types and vice versa. This analysis explored the rates at which land use and land cover had changed from 2007 to 2015.

I used a modeling procedure in ArcGIS to reclassify the NASS CDL layer for all the years from 2007 to 2015. The reclassification was made based on the reclassification guidelines in Table 1. My research illustrated an increase of 1.37 million acres of corn/soybean cropland; decrease of 378,000 acres of other crops; and decrease of 1.5 million acres of grassland in the same study period from 2007 to 2015 (Table 2). The corn/soybean cropland showed an increment by 62% whereas grassland was decreased by 18% (Figure 4).

Table 2: NASS CDL Data Reclassification into 5 major class types, area in 1000 of acres, from 20107 to 2015.

	Acreage in 2007		Acreage in 2015		Acreage Change
	Acreage	%	Acreage	%	
Corn/Soybean	10,185,100	55%	11,559,200	62%	**1,374,100**
Other Crops	836,478	5%	1,214,840	7%	**378,362**
Water	1,029,580	6%	1,225,250	7%	**195,670**
Developed Area	1,445,020	8%	1,127,710	6%	**(317,310)**
Grassland	4,948,420	27%	3,422,500	18%	**(1,525,920)**
Total	**18,444,598**	**100**	**18,549,500**	**100**	

Corn/soy cropland shows an increasing trend from 2007 to 2015, whereas area devoted to the grassland decreased. Other crops and water area didn't change significantly (Figure 5). The acreage of corn/soy increased from 10.18 million acres to 11.59 million acres. The acreage of grassland decreased from 4.94 million acres to 3.42 million acres.

Interestingly the table shows that the developed area has decreased from 8% to 6%. This can be because the in CDL non-crop areas identified but with less specificity and concern over accuracy. The purpose of the Cropland Data Layer Program is to use satellite imagery to (1) provide planted acreage estimates to the Agricultural Statistics Board for the state's major commodities and (2) produce digital, crop-specific, categorized geo-referenced output products. Most analyses focus on agricultural applications (Lark et.al. 2017)

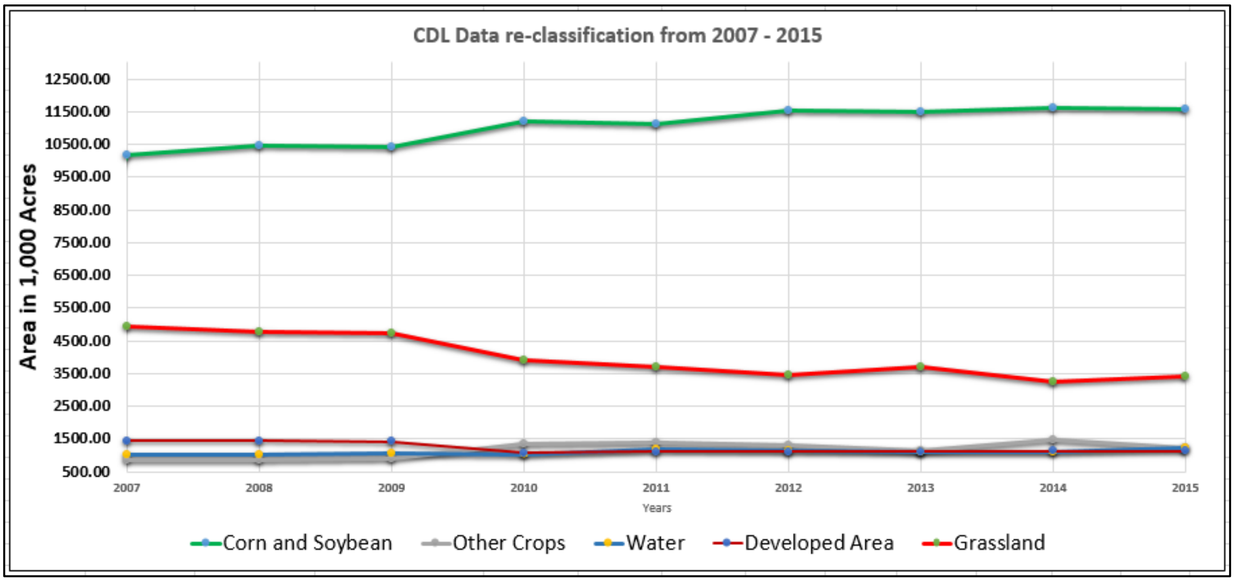


Figure 5: Trend of land cover land use change in the Big Sioux River from 2007-20115.

B. Accuracy Assessment

Total Accuracy is the number of correct plots divided by total number of plots. Diagonals represent sites classified correctly according to reference data. Off-diagonals represent the mis-

Table 3: Table showing the total number of the sample points that were correctly placed, and misplaced. Diagonals represent sites classified correctly according to reference data. Off-diagonals represent the mis-classified data.

		Class Types determined from reference source					
	#Plots	Corn/Soy	Others	Water	Developed	Grassland	Totals
Class Types determined from classified map	Corn/Soy	88	0	0	0	2	90
	Others	1	87	0	0	2	90
	Water	0	0	88	0	2	90
	Developed	0	0	0	90	0	90
	Grassland	5	1	0	0	84	90
	Totals	94	88	88	90	90	450

classified data. Out of 450 sample points, 437 points were correctly classified, whereas 13 were misclassified (Table 3). This gives the total accuracy of 97.11% (Equation 1).

$$\textbf{Accuracy}_{\textbf{Total}} = \frac{(88+87+88+90+84)}{450} * 100 = \mathbf{97.11\%} \qquad \textit{(Equation 1)}$$

In the total accuracy, the summary value is an average. It doesn't reveal if error was evenly distributed between classes or if some classes were really bad and some really good. Therefore, it is better to determine User accuracy and Producer accuracy. User accuracy corresponds to error of commission (inclusion) whereas Producer's accuracy corresponds to error of omission (exclusion).

User accuracy is calculated as ratio of number of points correctly identified in a given map class to number claimed to be in that map class. From the perspective of the user of the classified map, the user accuracy gives how many points on the map are actually what they are.

Producer's accuracy is calculated as the ratio of number correctly identified in reference plots of a given class to number actually in that reference class. From the perspective of the maker of the classified map, the producer's accuracy gives the number of points in the map that are labeled correctly (for a given class in reference plots).

For the five reclassified classes: Corn/Soy, Other Plants, Water, Developed, and Grassland, the user's accuracies were 98%, 97%, 98%, 100%, and 93% and the producer's accuracies were 94%, 99%, 100%, 100%, and 93% respectively (Table 4).

Table 4: User's and Producer's Accuracy for the five reclassified classes: Corn/Soy, Other Plants, Water, Developed, and Grassland

		Class Types determined from reference source						User's Accuracy
	#Plots	Corn/Soy	Others	Water	Developed	Grassland	Totals	
Class Types determined from classified map	Corn/Soy	88	0	0	0	2	90	98%
	Others	1	87	0	0	2	90	97%
	Water	0	0	88	0	2	90	98%
	Developed	0	0	0	90	0	90	100%
	Grassland	5	1	0	0	84	90	93%
	Totals	94	88	88	90	90	450	
Producer's Accuracy		94%	99%	100%	100%	93%		Total = 97.11%

Discussion

The contingency table (table 5) shows the conversion of land form to/from other class types between the years 2007 and 2015. 1.25% of corn/soy cropland were converted to grassland whereas 7.08% of grassland was converted to corn, resulting in an increase of corn/soy cropland by 62% (approx. 1.37 million acres). The table also shows the gain (from grassland to corn/soybeans) was greater than the loss (from corn/soy to grassland) (Table 3). The net conversion of grassland to corn/soy was concentrated on the north-eastern part of the BSR watershed (Figure 6).

The LULC change in the BSR can be associated with California's authorization that ethanol be used as a bio-fuel (Gruchow 2007) which increased the demand for ethanol. The number of ethanol plants were increased rapidly. Few years after that, Energy Independence and Security Act 2007 was formulated (EPA 2008) that demanded only the locally produced resources be used for ethanol production.

Table 5: The contingency table shows the conversion of land form to/from other class types between the years 2007 and 2015.

		2015	2015	2015	2015	2015	
		Corn and Soybean	**Other Crops**	**Water**	**Developed**	**Grassland**	**Total**
2007	**Corn and Soybean**	**49.80**	**2.88**	**0.44**	**0.84**	**1.25**	**55.22**
2007	**Other Crops**	**3.12**	**1.04**	**0.06**	**0.07**	**0.25**	**4.53**
2007	**Water**	**0.51**	**0.28**	**4.22**	**0.07**	**0.52**	**5.58**
2007	**Developed**	**1.98**	**0.23**	**0.21**	**4.31**	**1.11**	**7.83**
2007	**Grassland**	**7.08**	**2.13**	**1.63**	**0.82**	**15.16**	**26.83**
	Total	**62.50**	**6.55**	**6.56**	**6.11**	**18.29**	**100.00**

Corn being one of the best sources for ethanol—but not necessarily the only source, the demands on corn increased (Graesser 2008, 28). Besides, South Dakota uses a high percentage of its corn production for ethanol and has a very large ethanol industry (Graesser 2008). 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 such as wheat to corn. Grain storage capacities were increased (Graesser 2008).

The corn demands could be fulfilled by importing the corn (rejected—because it didn't support energy independence), intensification of corn cropland, and forming new cropland (Napton

2017). The use of new technology such as tile drainage and best management practices bolstered the corn production and yield (Reitsma et.al. 2015)

The purpose of the Cropland Data Layer Program is to use satellite imagery to provide acreage estimates to the Agricultural Statistics Board for the state's major commodities and to produce digital, crop-specific, categorized geo-referenced output products. Comparing the sample points from NASS CDL data layer to the ground points, the total accuracy gained was 97.11%. The user's and producer's accuracy for the five reclassified classes: Corn/Soy, Other Plants, Water, Developed, and Grassland, were 98%, 97%, 98%, 100%, and 93% and, 94%, 99%, 100%, 100%, and 93% respectively. I used the 2015 resampled CDL data layer for this purpose. It is likely that no houses were built or no constructions were done, and therefore both the user's and producer's accuracy for "developed" is 100%. The accuracy for grassland is 93%. Sampling area which was grassland in 2015 might have turned to cropland or the pixels in the grassland data layer were mis-classified.

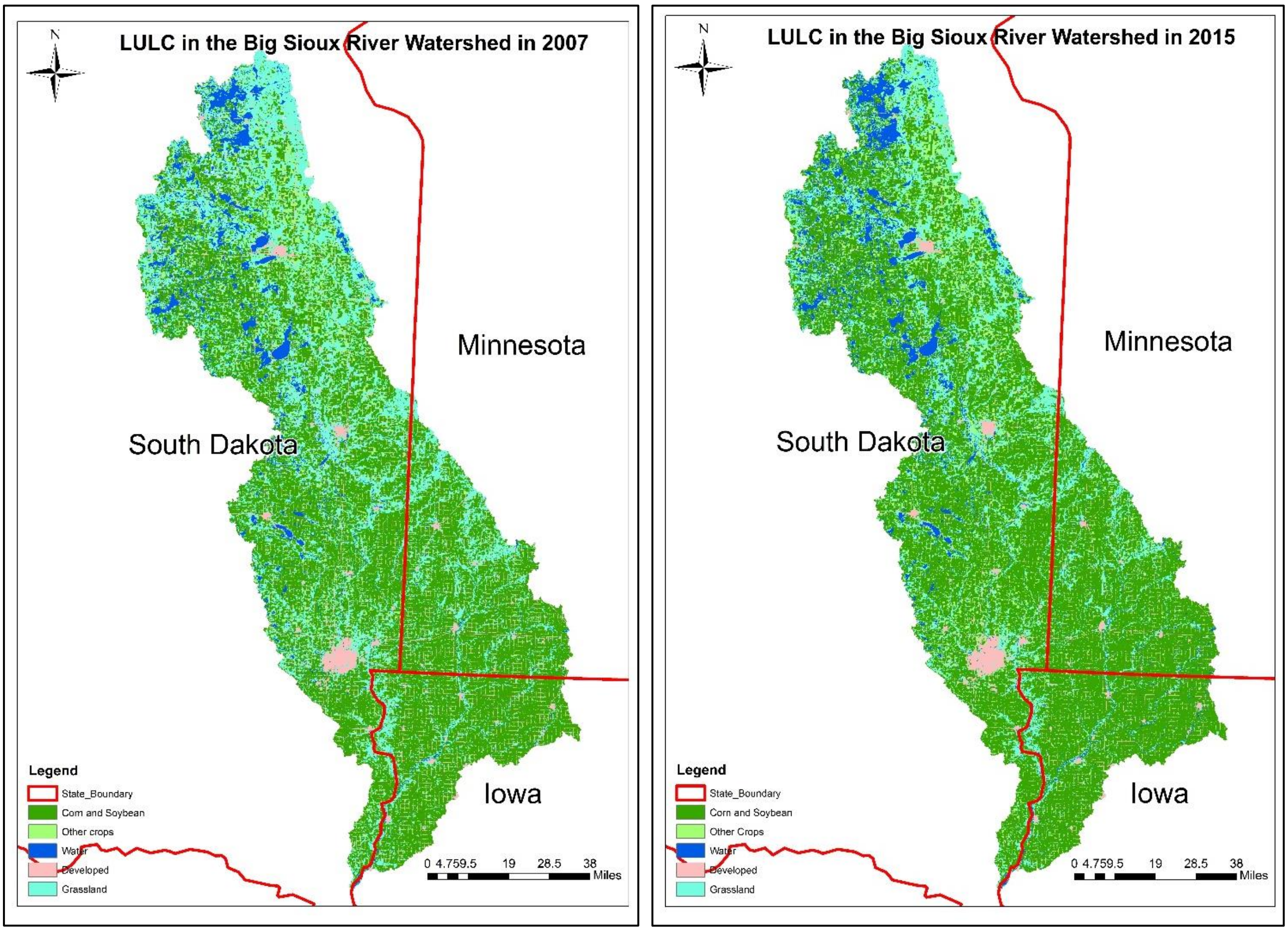


Figure 6: Maps showing the compariion of the land use land cover change in the Big Sioux River Watershed in 2007 (left) and in 2015 (right).

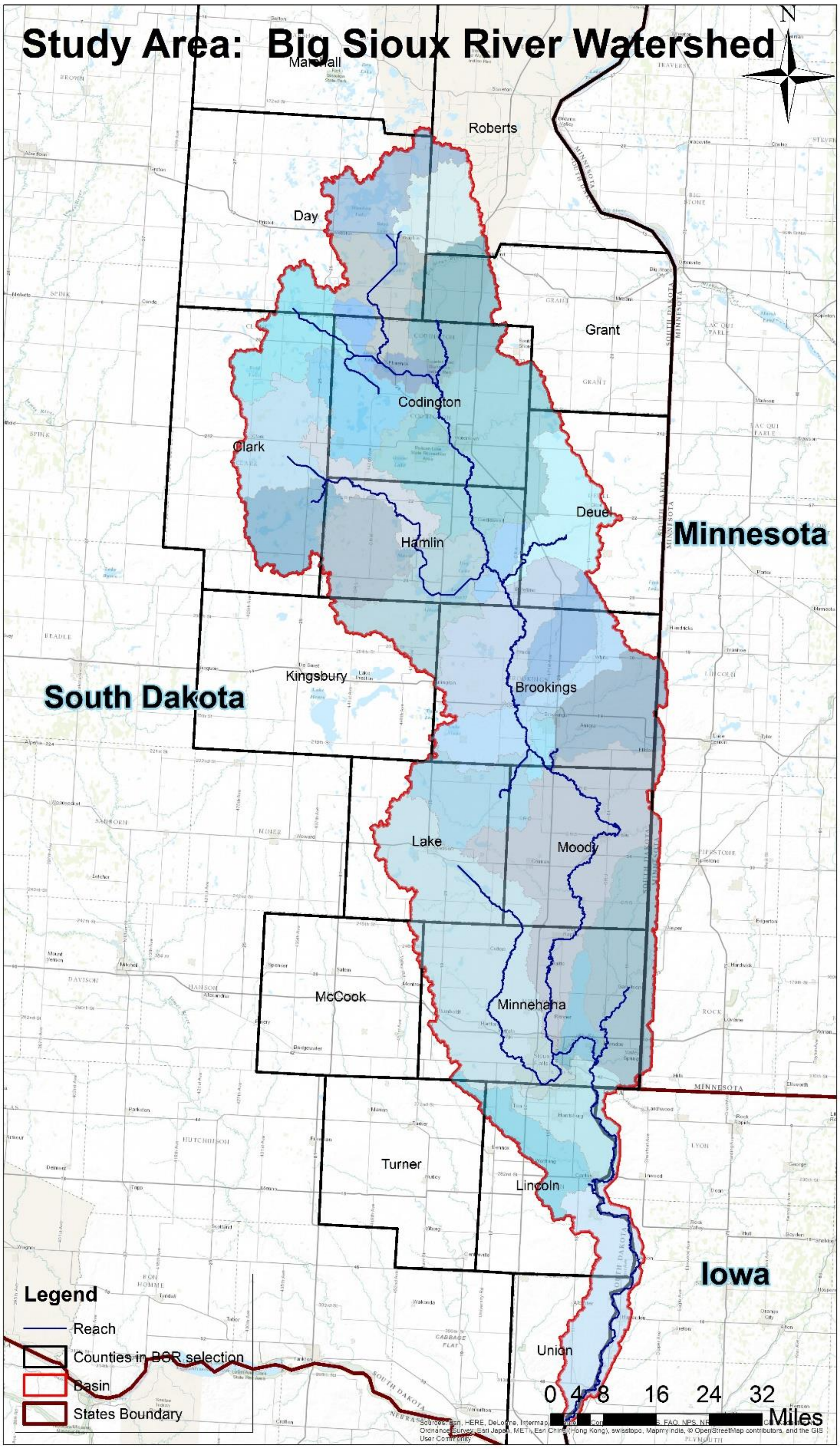
Summary, Conclusion, and Contribution

Overall, both the user and producer accuracy for the five classes of CDL data layers are greater than 90%. I think the CDL can be used to look at cropland change for the major crops like corn and soybean, and grassland conversion.

The grant received from SD View helped me a lot in completion of this project. The grant money was used in purchasing the GPS, and travelling to the sites. Thanks a lot to SDView for the grant, and Mary O’Neill for assisting me in the process of reimbursing the grant money.

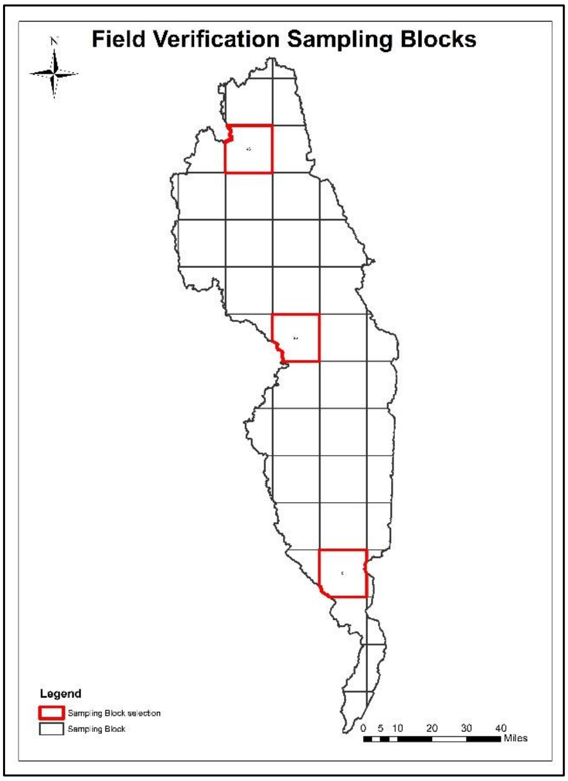
Appendix I: Map List

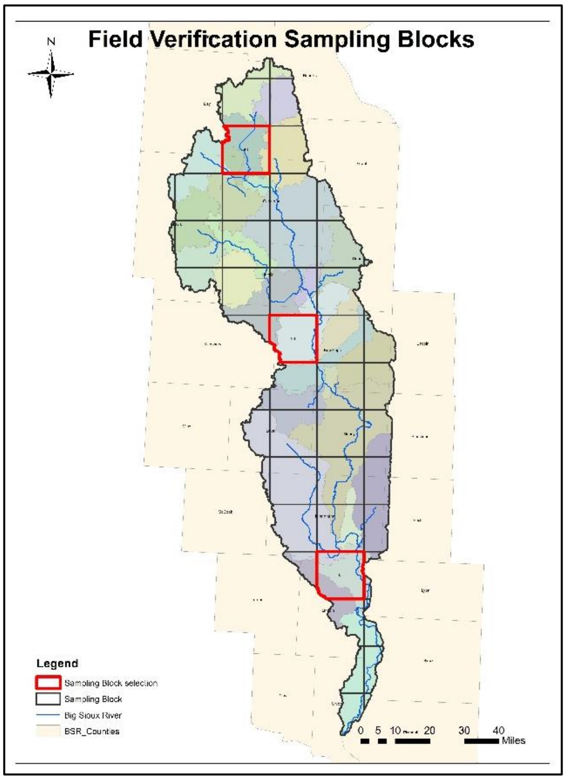
Map of the study area:



Dinesh Shrestha

Map of the study area with sampling blocks



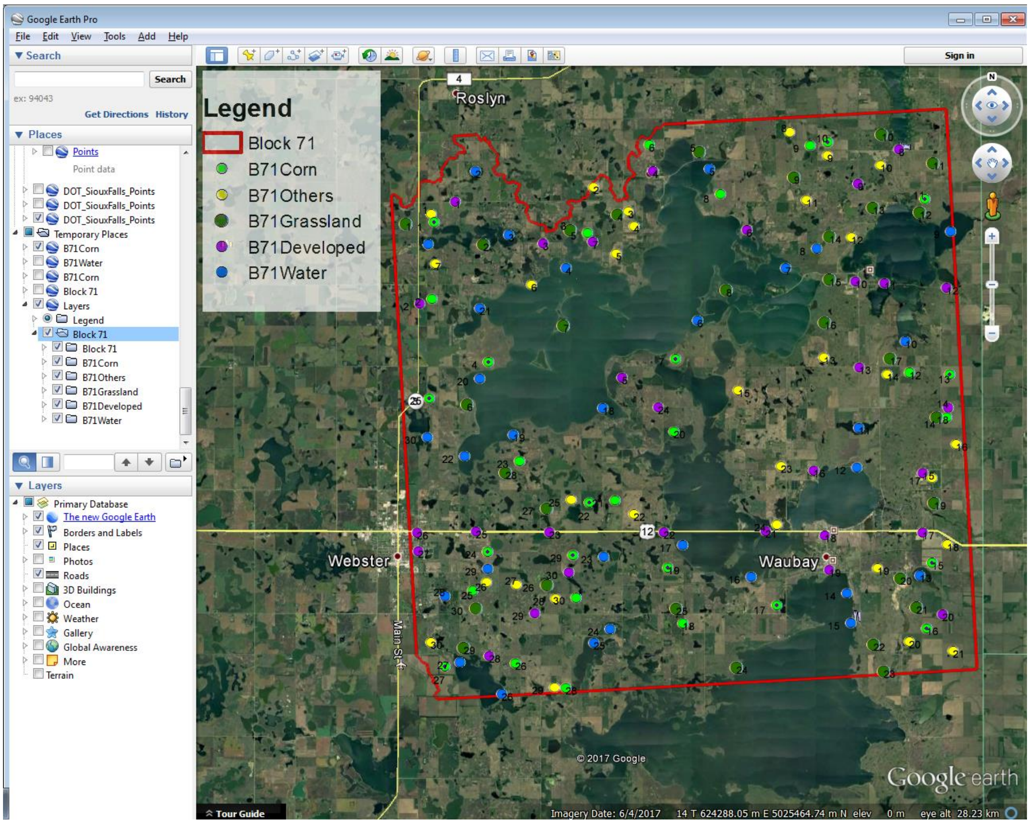


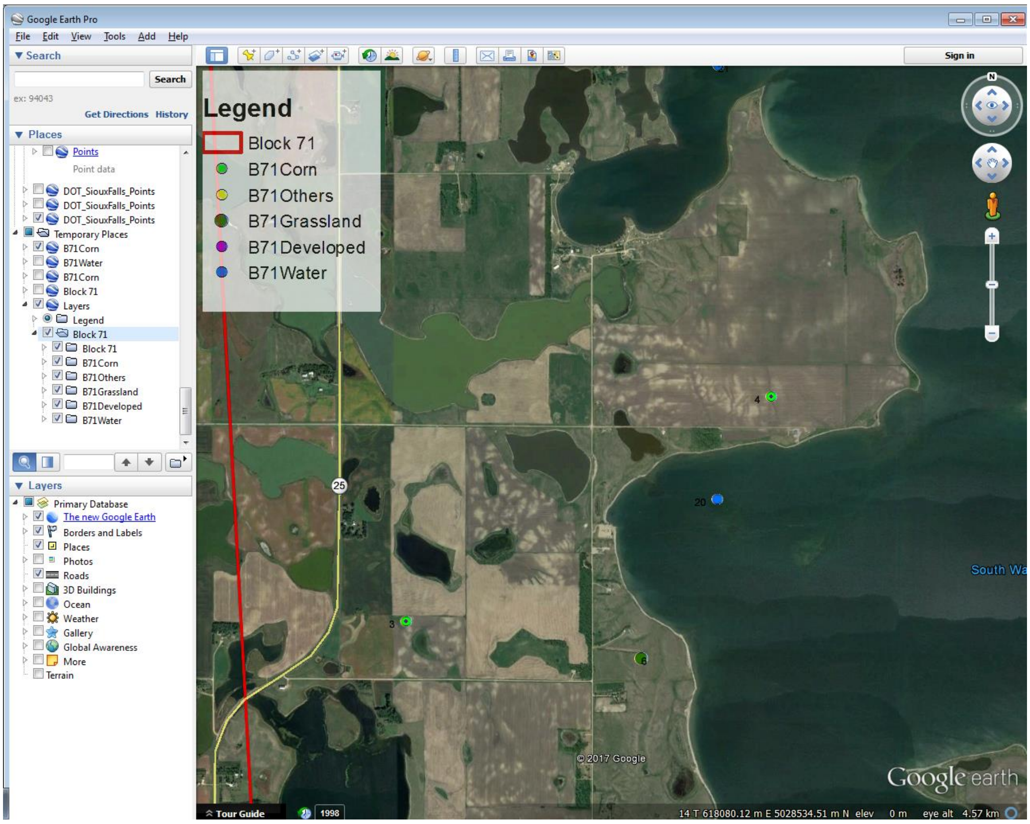
Appendix II: Schedule

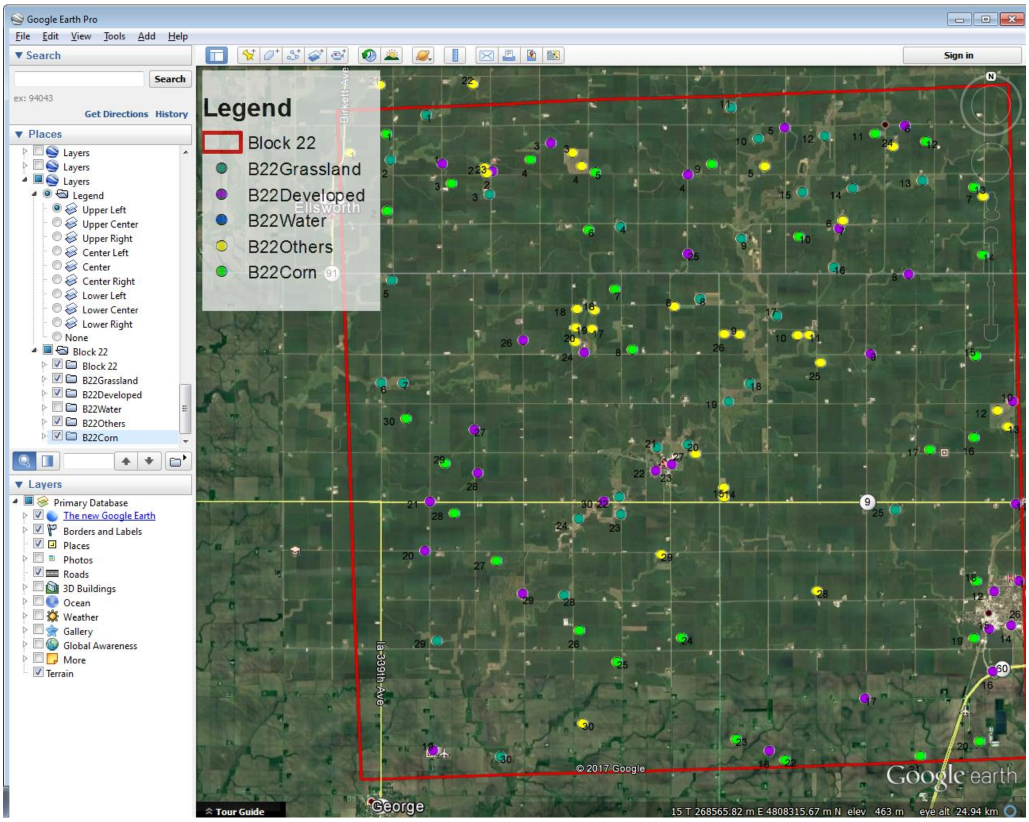
Schedule																
Events/ Date	May				June				July				August			
	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4	Week 1	Week 2	Week 3	Week 4
Data Collection (NASS CDL and Geopatial Data)																
Reclassification (GIS Model preparation)																
Analysis (Trend of LULC)																
Filed Visit (Sample Block 8)																
Analysis																
Filed Visit (Sample Block 26)																
Analysis																
Filed Visit (Sample Block 46)																
Analysis																
Report Preparation																
Final Report Submission																

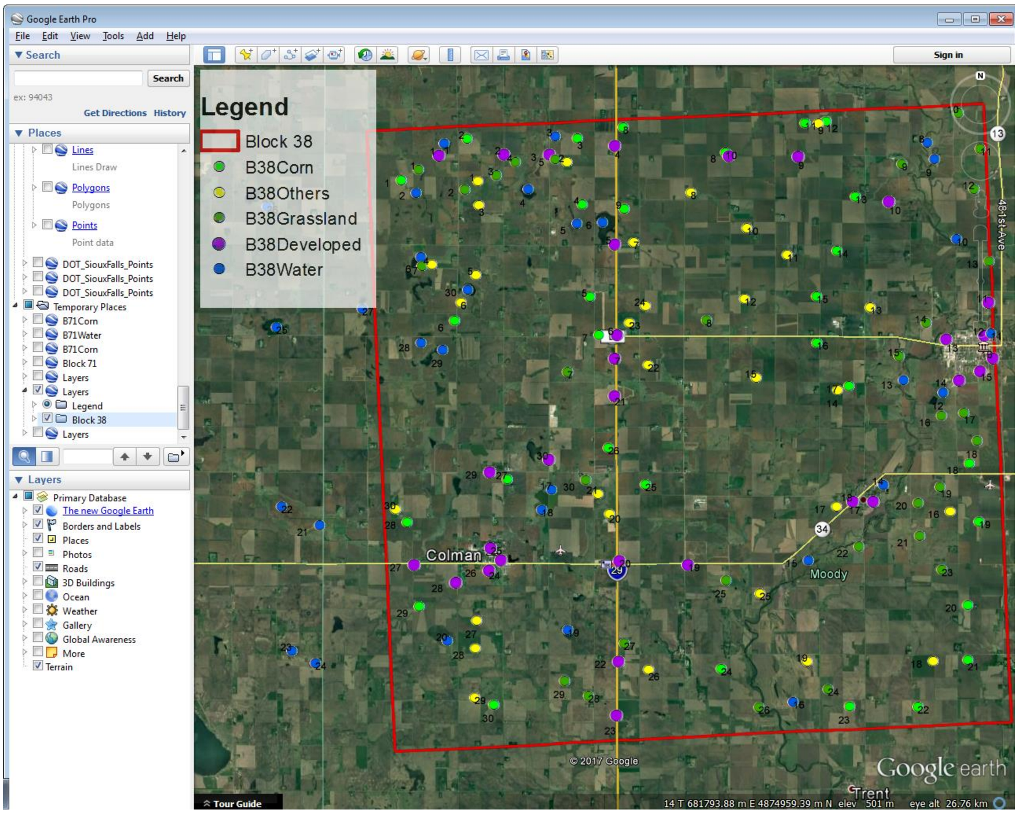
Appendix IV: Google Earth Maps

Google Earth maps for different sites






Google Earth Pro
Legend
Block 22
B22Grassland
B22Developed
B22Water
B22Others
B22Corn
George
© 2017 Google
Google earth
15 T 268565.82 m E 4808315.67 m N elev 463 m eye alt 24.94 km


Google Earth Pro
Legend
Block 38
B38Corn
B38Others
B38Grassland
B38Developed
B38Water
Colman
Moody
Trent
© 2017 Google
Google earth
14 T 681793.88 m E 4874959.39 m N elev 501 m eye alt 26.76 km

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 Riverr.* 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.

Graesser, Jordon. 2008. "The Impacts of Ethanol on Land Use in the Northwestern Corn Belt." Department of Geography: South Dakota State University. 28.

Gries, John Paul. 1996. *Roadside Geology of South Dakota.* Mountain Press.

Gruchow, Matthew. 2007. Ethanlo Industry Basks in Big Profits. *Sioux Falls Argus Leader* 1-3.

Iowa Environmental Council. 2016. NITRATE IN DRINKING WATER: A Public Health Concern For All Iowans. Execcutive Summary, Iowa. doi:11/20/2016.

Lark, Tyler J, Richard M. Mueller, David M. Johnson, and Holly Gibbs. 2017. Measuring land-use and land-cover change using the U.S. department of agriculture’s cropland data layer: Cautions and recommendations. *International Journal of Applied Earth Observations and Geoinformation.*

Napton, Darrell, and Jordan Graesser. 2011. Agricultural land change in the Northwestern Corn Belt, USA: 1972–2007. *GeoCarpathica 11* 65-81.

National Water Quality Monitoring Council, NWQMC. 2007. Glossary of water-quality monitoring terms: Advisory Committee on Water Information. Accessed April 3, 2016.

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.

Reitsma, K. D., R. Gelderman, P. Skiles, K. Alverson, J. Hemenway, H. J. Woodard, T. E. Schumacher, D. Malo, and D. E. Clay. 2008. Nitrogen best management practices for corn in South Dakota.

Resources, Iowa Department of Natural Resources and South Dakota Department of Environment and Natural. 2007. Total Maximum Daily Loads for Pathogen Indicators: Big Sioux River, Iowa and South Dakota. 1-142.

2012. *The Associated Press.* May 7. Accessed May 22, 2016. http://rapidcityjournal.com/news/south-dakota- s-big- sioux-among- dirtiest-rivers- in-nation/article_26094a6e-984c- 11e1-a46d-001a4bcf887a.html.

World Health Organization, WHO. 2015. *Hazards in drinking-water supply and waste management.* Accessed 05 22, 2016. http://www.who.int/water_sanitation_health/hygiene/plumbing3.pdf.

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.