Journal of Geography and Geology; Vol. 7, No. 2; 2015
ISSN 1916-9779 E-ISSN 1916-9787
Published by Canadian Center of Science and Education

Long-term Land Use and Land Cover Changes Affected by the Conservation Reserve Program in the Minnesota River Valley

F. Yuan[1], M. Mitchell[1], B. Bohks[1], K. Mullen[1] & C. Smith[1]

[1] Geography Department, Minnesota State University, Mankato, MN 56001, USA

Correspondence: F. Yuan, Geography Department, Minnesota State University, Mankato, MN 56001, USA. Tel: 507-389-2376. E-Mail: fei.yuan@mnsu.edu

Received: March 28, 2015 Accepted: April 18, 2015 Online Published: May 18, 2015
doi:10.5539/jgg.v7n2p105 URL: http://dx.doi.org/10.5539/jgg.v7n2p105

Abstract

The *Conservation Reserve Program* (CRP) is a cost-share and rental payment program signed into law by President Reagan in 1985 and administered by the Farm Service Agency (FSA) under the United State Department of Agriculture (USDA). CRP aims to counteract erosion and protect the environment by encouraging agricultural landowners to convert highly erodible cropland and other environmentally sensitive lands to native or alternative permanent vegetative cover through the implementation of 10-year contracts paying annual rents. CRP has been actively implemented since the enactment of the *Food Security Act of 1985*. Re-authorized by Congress in 1996 with major modifications, the CRP has been renewed with minor alterations several times. In 1998, the joint state/federal *Conservation Reserve Enhancement Program* (CREP) targeted the long-term retirement of an additional 40,469 ha (100,000 acres) of agricultural land in the Minnesota River basin to enhance water quality and wildlife habitat through permanent conservation easements.

This research examines land use change from 1985 to 2013 in the Minnesota River Valley beginning with an era of no long-term set-asides to the current era with two active long-term set-aside conservation reserve programs. Multi-temporal remote sensing images from 1985, 1995, 2005 and 2013 were analyzed to map the land use changes in response to the CRP policy alterations. The results revealed more than 36,000 ha (89,000 acres) cropland have been converted to grassland or forest during this 28-year span. A persistent drop in cropland occurred in spite of rising corn and soybean prices since 2002 associated with Minnesota's biofuel industry and increased foreign demand for these commodities, which indicates that the long-term nature of the CRP and CREP contracts are critical for maintaining the conversions of cropland to grassland or forest cover while providing stable farm income.

Keywords: land use change, multi-temporal remote sensing, Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP), the Minnesota River Valley

1. Introduction

1.1 History of Agricultural Set-Aside Programs

Agricultural set-aside programs originated with the *Agricultural Adjustment Act of 1933*, which intended to reduce agricultural production by paying farmers subsidies and taking land out of production to decrease supply and increase commodity prices. Declared unconstitutional in 1936 by the U.S. Supreme Court in *Butler v. United States* (297 U.S. 1 1936) because the regulation of agriculture was deemed a state power pursuant to the Tenth Amendment of the U.S. Constitution, subsequent federal agricultural bills sustained the constitutional test by: (1) reinforcing the national need of conserving soil, and (2) funding the programs through means other than taxing agricultural processors. In addition, President Roosevelt threatened to pack the Court with enough new justices to insure the New Deal programs received favorable judicial review.

Persistent drought conditions denoted by winter and growing season precipitation failures caused widespread crop failures on the Great Plains during the early 1930s. The implementation of farming techniques common to areas with persistent water balance surpluses exposed the region's soil to blowing wind, resulting in intense and frequent dust storms (Worster 2004). Consequently in 1935, President Roosevelt signed the *Soil Conservation Act*, which required landowners to plant grasses or legumes to conserve the soil (49 Stats. 163 1935). In the context of the Dust Bowl, this environmental mitigation was deemed constitutional and set the legislative precedent that agricultural set-aside programs need to contain environmental justifications even if economic factors are the main driving force.

After World War II, the *Agricultural Act of 1956* (52 Stats. 31 1956) created the *Soil Bank Program*, which authorized short- and long-term removal of land from production with annual rental payments to participants of the Acreage Reserve or the Conservation Reserve. The Conservation Reserve portion, whereby landowners placed acreage in grass or legume cover for 3-10 years, set the contemporary basis for long-term set-aside programs with one unintentional benefit: enhanced wildlife habitat for upland game birds in the US Midwest (Laingen 2011; MnDNR 2000).

Later, the *Food Security Act of 1985* enacted the long-term 10-year Conservation Reserve Program (CRP), aimed at taking highly erodible lands out of production (99 Stat 1504, 1985). The CRP has provided stability to farm incomes, mitigated soil erosion, and enhanced wildlife habitat in farmland areas (Mitchell and Kimmel 2009). The CRP was reauthorized in subsequent farm bills to include a scoring system for rating highly erodible land and various adjustments to the national cap of aggregate CRP acreage (12.9-16.2 million ha or 32-40 million acres). CRP enrollments in Minnesota of 780,262 ha (1.9 million acres), 576,698 ha (1.4 million acres), and 447,194 ha (1.1 million acres) occurred in 1993, 2005, and 2014, respectively, with acreage concentrated mainly in the Red River Valley and the Minnesota River basin.

Established in 1998 as a sub-program of the CRP, the Conservation Reserve Enhancement Program (CREP) was a joint federal (USDA) and state program aimed at retiring 40,469 ha (100,000 acres) in the Minnesota River basin using long-term (14-45 years) or permanent conservation easements with the USDA funding $163 million and the state of Minnesota $81.9 million (MN Board of Water and Soil Resources 2004). Achieved in 2002, the 100,000-acre target has reduced soil loss by 4.2 short-tons/acre/year and phosphorus by 5.3 lbs/acre/year (Allen 2005). In 2005, a second round of CREP was implemented with 120,000 acres (48,562 ha) targeted in the Red River, Mississippi River and Des Moines River watersheds. Based generally on Minnesota River basin performances, *CREP II* sought to pre-empt the loss of another 420,000 tons of sediment per year and 530,000 pounds of phosphorous per year (USDA 2005)

1.2 Study Site and Objectives

The Minnesota River basin's total drainage area comprises 44,000 km^2 (17,000 mi^2), with approximately 87% being located in Minnesota (Figure 1). Although the Minnesota River ultimately originates from a headwaters region in northeast South Dakota and Lake Traverse on the Minnesota-South Dakota border at Browns Valley, its official start begins as discharge from Big Stone Lake. It flows southeast to Mankato, and then turns 90° northeast and joins the Mississippi River near Fort Snelling in St. Paul. Possessing a total length of 534 km (355 mi) and a gradient of 24 cm/1.6 km (9.5 in/mi), the Minnesota River comprises a classic underfit stream. Formed by glacial River Warren, which breached a recessional moraine of the Des Moines Lobe bordering the southern end of glacial Lake Agassiz (a massive early Holocene freshwater lake encompassing over 100,000 mi^2) the Minnesota River Valley at Mankato measures about 2,470 m (9,000 ft) across and over 70 m (200 ft) deep (Ojakangas & Matsch 1982; Lepper et al. 2007). Downstream, its annual discharge into the Mississippi averages 141 m^3/sec (5,000 cfs), although it can range as high as 2,820 m^3/sec or 100,000 cfs (Waters 1987).

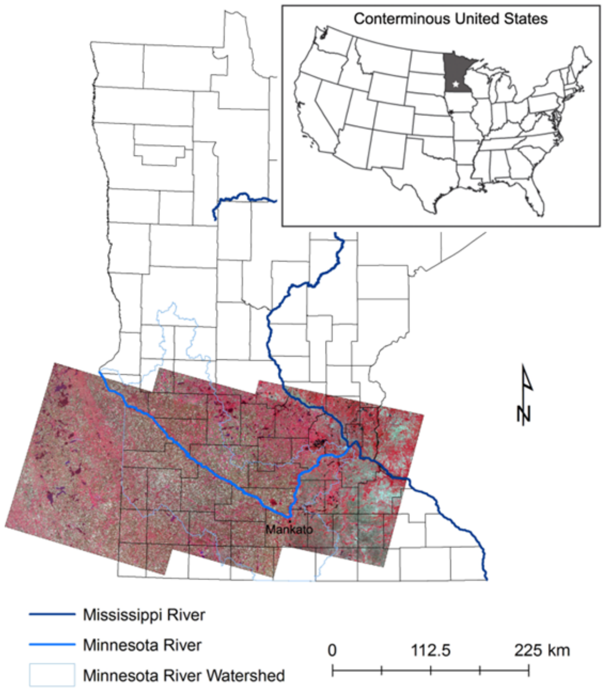

Figure 1. The Minnesota River Basin

The Minnesota River is bordered by floodplains with rich alluvial soil utilized for intensive cultivation of corn or soybeans. In addition, a series of terraces found about ¼ to ½ mile away (650 m) from the main channel are often used for livestock operations and grazing (Figure 2). Known for heavy sedimentation and movement of non-point runoff, state and federal officials, including former Governor Arne Carlson, sought to abate these problems in the 1990s utilizing agricultural set-aside programs (Minnesota State University 2009; Minnesota River Data Center 2005). Figure 3 depicts agricultural set-aside acreage on an alluvial floodplain about 4 km (2.5 mi) northeast of Mankato.

This study aims to measure the effects of CRP and CREP on land cover by utilizing remote sensing capabilities within the spatial context of the Minnesota River Valley proper, defined herein as the area between the upper banks of the former River Warren about 1.6 km (1 mi) from the main river's main channel. The specific objectives include: (1) documenting land use and land cover changes from 1985 to 2013 in the Minnesota River Valley, beginning with 1985 when no long-term set-aside programs were in place to the current era with two active long-term set-aside programs; and (2) analyzing and discussing land use changes in response to the CRP and CREP policy alterations.

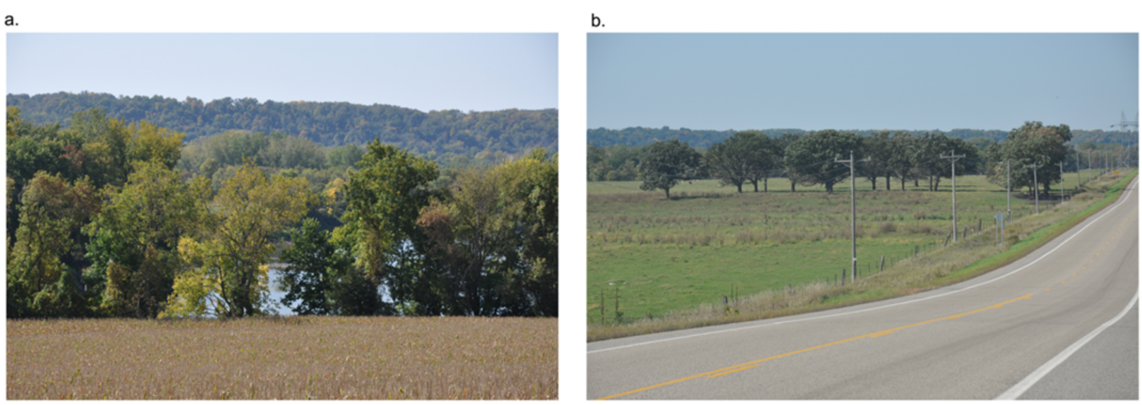

Figure 2. (a) Corn field along the Minnesota River and, (b) cattle pastures near the River

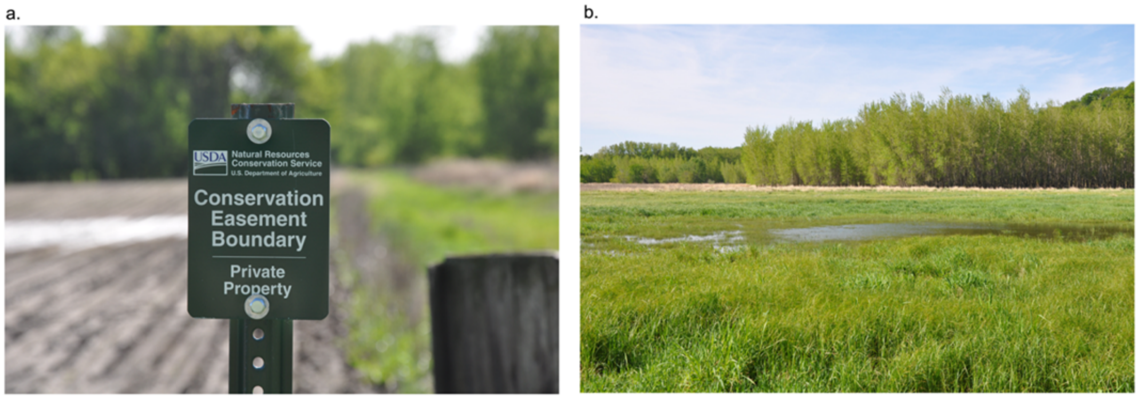

Figure 3. (a) CREP easement boundary and, (b) CREP land on floodplain near Mankato

2. Data and Methods

2.1 Remote Sensing Data and Preprocessing

Multiple Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) images from the growing seasons of 1985, 1995, 2005, and 2013 were obtained from the United States Geological Survey (USGS) EROS data center. Three tiles of Landsat imagery located in Paths 27-29 and Row 29 from each year were obtained to cover the major Minnesota River Basin (Figure 1). Since the year of 2013 lacked cloud-free OLI images for the location of Path 27 and Row 29, a TM image from 2011 was used instead. Likewise, a 1986 TM image was used to represent the year of 1985 for the location of Path 29 and Row 29, and a 1996 TM image was used to represent the year of 1995 for the scene of Path 27 and Row 29. The exact acquisition information is summarized in Table 1.

Table 1. Acquisition information pertaining to the Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) imagery

Year	**Acquisition Date of Path 27, Row 29**	**Acquisition Date of Path 28, Row 29**	**Acquisition Date of Path 29, Row 29**	Sensor
1985	June 2, 1986	June 22, 1985	June 16, 1986	TM
1995	June 13, 1996	June 18, 1995	June 27, 1995	TM
2005	June 22, 2005	Sept. 1, 2005	Aug. 7, 2005	TM
2013	June 7, 2011	Oct. 9, 2013	Oct. 16, 2013	TM & OLI

All the images were already geo-rectified with residuals less than half-pixel size. They were all in UTM map projection and WGS 84 Datum while some of them were in Zone 15 and others were in Zone 14. Most of the multi-temporal images lined up well with each other except for the ones from 1985 or 1986, which were rectified once more using the 2013 images as the references. Next, the three tiles of images from each year were mosaicked with the color balancing function in ERDAS/Imagine 2014. All images in UTM zone 14 were re-projected to zone 15 before the mosaic. Lastly, the mosaicked image was clipped using the 1.6 km (1 mi) buffer file of the Minnesota River to encompass the valley's 2,470 m (9,000 ft) width.

In addition, multi-year digital aerial photography, including 2013 and 2006 color National Agriculture Imagery Program (NAIP) ortho-images along with 1991 Black & White USGS digital ortho-photos were obtained from the Minnesota Geospatial Information Office (MNGEO). These one-meter resolution images were used as the reference data for training and accuracy assessment purposes.

2.2 Land Cover Classification

The object-based classifier, Feature Analyst, classified the clipped Landsat images into water, cropland, other natural areas, and impervious surface classes. In particular, the cropland class includes both vegetated cropland and fallow fields, whereas, the other natural areas include forest, grassland, and a small amount of riverine wetland. Impervious surface class includes urban, transportation roads, and compacted soils.

Compared to traditional per-pixel classifiers, the object-based Feature Analyst uses both spectral and spatial context information. Therefore, object-based methods can produce more accurate classification maps, especially with studies lacking multi-seasonal or multi-source images (Benz et al. 2004; Al-Khudhairy et al. 2005; Hay et al. 2005; Budreski et al. 2007; Bhaskaran, et al. 2010; Whiteside et al. 2011; Nagel et al., 2014). Further, its contextual classifier allows more flexibility in the types of objects that can be identified (Opitz and Bain 1999). The foveal input representation allows the classifier to give more importance to pixels nearer to the pixel being processed for each class being defined. Compared to simple local windows (e.g. 3 by 3 pixels or 5 by 5 pixels etc.), foveal representation makes the integration of contextual information in a classification process more efficient (Opitz and Bain 1999; Nagel, 2014).

Training samples for the four classes representing the spectral, size, shape, pattern, texture, and neighborhood information were digitized carefully on the screen. The classifier divided the individual pixels into objects using the training samples in the image segmentation process, and then assigned classes to these new objects instead of single pixels in the subsequent analysis and classification process. Each land cover class was extracted individually as a vector shapefile. The study site stretched more than 500 km (312 mi) long and possessed large variations in spectral characteristics within a single land cover type such as cropland. Therefore, to improve the classification accuracy, we divided the study site into three sections (west, middle, and east) based on the boundaries of the three tiles of Landsat images. Individual classification was then performed on each of the three sections. In addition, post-classification refinement was accomplished by means of removing misclassified clutters and adding missing clutters with the hierarchical approach in Feature Analyst, which has machine learning capabilities to revise initial errors. The refined individual classes and the results from the three sections were then combined and converted into one image for each year. Finally, single, isolated pixels in the classified images were removed by the aggregation function.

2.3 Accuracy Assessment and Change Detection

The accuracy assessment was conducted using a set of 60 random samples for each year. The sample unit is a single 30 m Landsat pixel. Reference values were assigned to these points based on visual inspection of the multi-year's 1 m digital aerial photography and the original Landsat imagery. An error matrix was generated accordingly for each year's classification map.

The post-classification change analysis was performed based on the classification maps. Consequently, change maps and cropland conversion statistics from 1985 to 2013 were generated. Visual assessment was performed for focused areas of change, such as upstream Mankato, downstream Mankato, and the areas between Renville and Redwood Counties, using the 1 m resolution multi-year aerial photographs as the reference. In addition, ground truth field data were obtained in September 2014 to verify the land use and land cover of certain parcels. This process involved on-site visitation, photography and interviews with local residents familiar with the properties in question (Figure 4). Once confirmed on the ground, these data were then used to ascertain accuracy of the change analysis.

Figure 4. An example of cropland to grassland conversion validated through field checking

3. Results and Discussion

3.1 Classification Statistics

Our classification results revealed cropland decreased consistently over the 28-year span, while other natural areas increased steadily along the Minnesota River Valley (Figure 5). Specifically, from 1985 to 2013, cropland dropped 44,706 ha (110,000 acres), or more than 60% from 1986. In the meantime, other natural areas, mostly forest and grassland, increased 36,699 ha (90,685 acres) or 88%. The discrepancy between cropland reduced and increased natural cover can be attributed to a stipulation in the CRP that allows for occasional cutting for hay.

The largest amount of cropland decrease of 29,134 ha (72,000 acres), was found from the ten-year span of 1995 to 2005. This drop in agricultural acreage and increase in natural cover corresponds to the implementation of the CREP and its achievement of obtaining 40,470 ha (100,000 acres) in long-term set-asides throughout the Minnesota River basin. The ability to stabilize one's income and minimize year-to-year price risks associated with volatile commodities markets was another factor that likely influenced enrollments in traditional CRP or CREP. For example, corn priced in nominal dollars at $3.51/bushel in 1995 dropped by almost 50% to $1.80/bushel in 1999-2001, while soybeans dropped nearly 40% from $7.18/bushel in 1996 to $4.50/bushel in 1999-2001 (Iowa State University 2015). Indeed, when CREP was implemented in 1998, rental payments averaged $111.35/acre versus gross revenue of $234/acre for corn assuming an average yield of 130 bushels/acre during 1999-2001 (Allen 2005 and USDA 2002). While taking a decrease in gross revenue, the landowner nevertheless avoided all the costs associated with planting, growing, harvesting and marketing the corn crop.

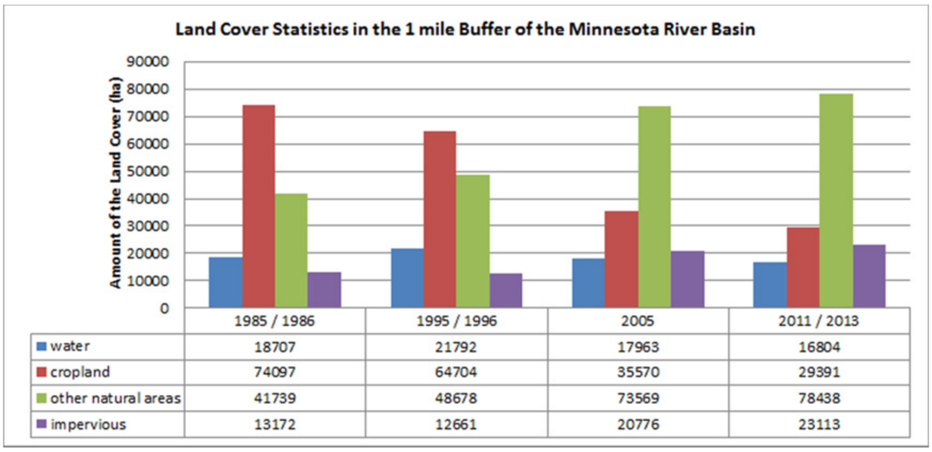

Figure 5. Land cover statistics in the 1.6 km (1 mi) buffer of the Minnesota River for the four years

This interannual variability continued through the study period with corn prices of $1.90/bushel in 2005, increasing to $4.78/bushel in 2008 only to decline to $3.81/bushel in 2009. Another spike in prices associated with the summer drought of 2012 resulted in corn peaking at $6.94/bushel, while two years later the price dropped 25% to $3.64/bushel (Iowa State University 2015). Although corn-based ethanol production in Minnesota increased from 204 million gallons in 2000 to over 1.1 billion gallons in 2012 and exports remained steady with a slight increase as measured by volume rather than dollar value, corn prices and their inter-annual fluctuations and price volatility generally reflect or track crude oil futures (Minnesota Dept. Agriculture 2013; Mitchell 2013). For instance, oil rose steadily from roughly $55/barrel in 2005 to a peak of $148/barrel during June 2008 and then plunged to $37/barrel in early 2009 before rebounding to a $85-$110/barrel range that held until late 2014 when oil again plunged by 50% to $45/barrel (Figure 6). The general rise in corn and oil prices corresponds with the 2005-2013 period having the lowest percentages of decrease in cropland and increases in other natural areas.

Impervious surface areas increased from 9% to 15.6% from 1985-2013 in association with urbanization in Mankato, St. Peter and Belle Plaine. The water classification fluctuated slightly over the study period, a situation most likely stemming from precipitation variability as Minnesota's summer rainfall regime is driven by the presence of unstable maritime tropical air masses advecting north from the Gulf of Mexico.

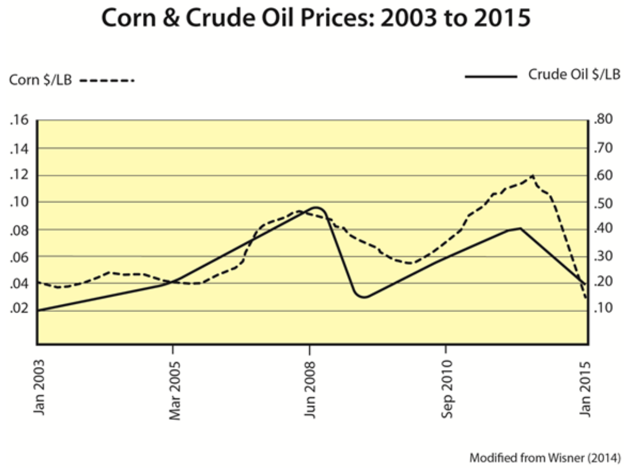

Figure 6. Corn and crude oil prices from 2003 to 2015

3.2 Accuracy Assessment and Change Detection Results

The overall accuracies ranged from 81.7% to 91.7% for the four classification maps. Table 2 provides the error matrices with detailed information for producer's and user's accuracies of each class. The 2013 classification had the highest overall accuracy of 91.7%, which was attributed to the two OLI images acquired from October of 2013 when natural areas such as forest and grassland are more easily differentiated from cultivated cropland relative to the summer when their spectral reflectances are more closely aligned. Also, classification variations could have resulted from different classification analysts. The water class had the perfect 100% accuracy for all the four classifications due to its unique spectral and spatial characteristics. Cropland and other natural areas had comparable moderate accuracies.

Table 2. Error matrices of the four land cover classifications

(a)

1985 Classification	water	cropland	other natural	impervious	Producer's Accuracy (%)
water	8	0	0	0	100.0
cropland	0	23	6	1	76.7
other natural areas	0	1	16	0	94.1
impervious	0	0	1	4	80.0
User's Accuracy (%)	100.0	95.8	69.6	80.0	
Overall Accuracy = 85%		Overall Kappa Statistics = 0.78			

(b)

1995 Classification	water	cropland	other natural	impervious	Producer's Accuracy (%)
water	9	0	0	0	100.0
cropland	0	23	5	1	79.3
other natural areas	0	1	19	0	95.0
impervious	0	0	0	2	100.0
User's Accuracy (%)	100.0	95.8	79.2	66.7	
Overall Accuracy = = 88.3%		Overall Kappa Statistics = 0.82			

(c)

2005 Classification	water	cropland	other natural	impervious	Producer's Accuracy (%)
water	7	0	0	0	100.0
cropland	0	10	5	0	66.7
other natural areas	0	4	26	0	86.7
impervious	0	1	1	6	75.0
User's Accuracy (%)	100.0	66.7	81.3	100.0	
Overall Accuracy = 81.7%		Overall Kappa Statistics = 0.72			

(d)

2013 Classification	water	cropland	other natural	impervious	Producer's Accuracy (%)
water	7	0	0	0	100.0
cropland	0	11	0	1	91.7
other natural areas	0	2	30	0	93.8
impervious	0	0	2	7	77.8
User's Accuracy (%)	100.0	84.6	93.8	87.5	
Overall Accuracy = 91.7%	Overall Kappa Statistics = 0.87				

Our change analysis results indicated that from 1985 to 2013, approximately 36,000 ha (89,000 acres) cropland have been converted to other natural areas, mainly grassland or forest. Most of the conversions were concentrated directly near the river bank. This practice makes sense in light of the Minnesota River's weak banks that are prone to failure during high precipitation events when the weight of wet soils combined with increased pore pressures overcome the soil's cohesion properties (Gupta et. al 2011). Indeed, precipitation has increased in southern Minnesota with Waseca (located about 25 miles east of Mankato) experiencing a statistically significant gain of nearly 30% in annual precipitation when comparing 1981-2010 to 1920-1949 (Yuan and Mitchell 2014). During the study period, land by the river was inundated by floodwaters several times (1986, 1993, 1997, 2001, 2010, and 2011). Moreover, the Minnesota River is dynamic with its meanders constantly exerting incisive pressure on its cutbanks that eventually result in new oxbows and yet another set of dynamic meanders (Figure 7). This situation becomes readily apparent when examining USGS 7.5' topographic maps surveyed in 1974 between Mankato and St. Peter and subsequently comparing them to aerial photographs taken in 1992. From a landowner's perspective, maintaining permanent natural cover and keeping heavy equipment away from wet areas prone to stream bank failure fits with the objectives and outcomes of CREP.

Figure 7. An example of a cutbank along the Minnesota River

The land cover change map from 1985 to 2013 is shown in Figure 8. Our visual assessment for focused areas based on image interpretation and field visits indicated that most of the identified changed areas were correctly interpreted (Figure 9). We still encountered some minor uncertainties that were addressed through interviewing local residents familiar with the subject parcels.

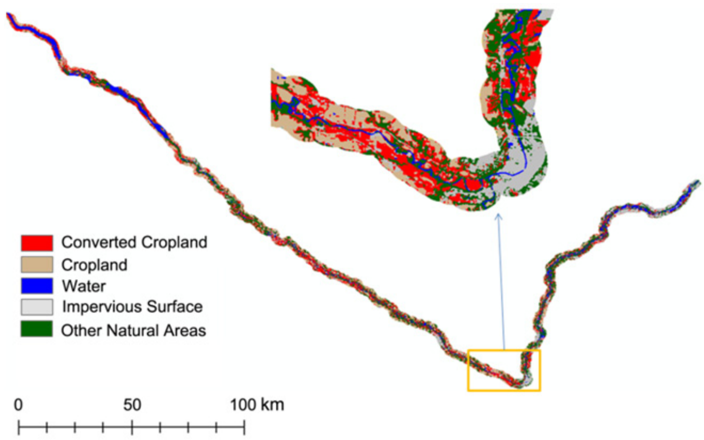

Figure 8. Land cover change from 1985 to 2013

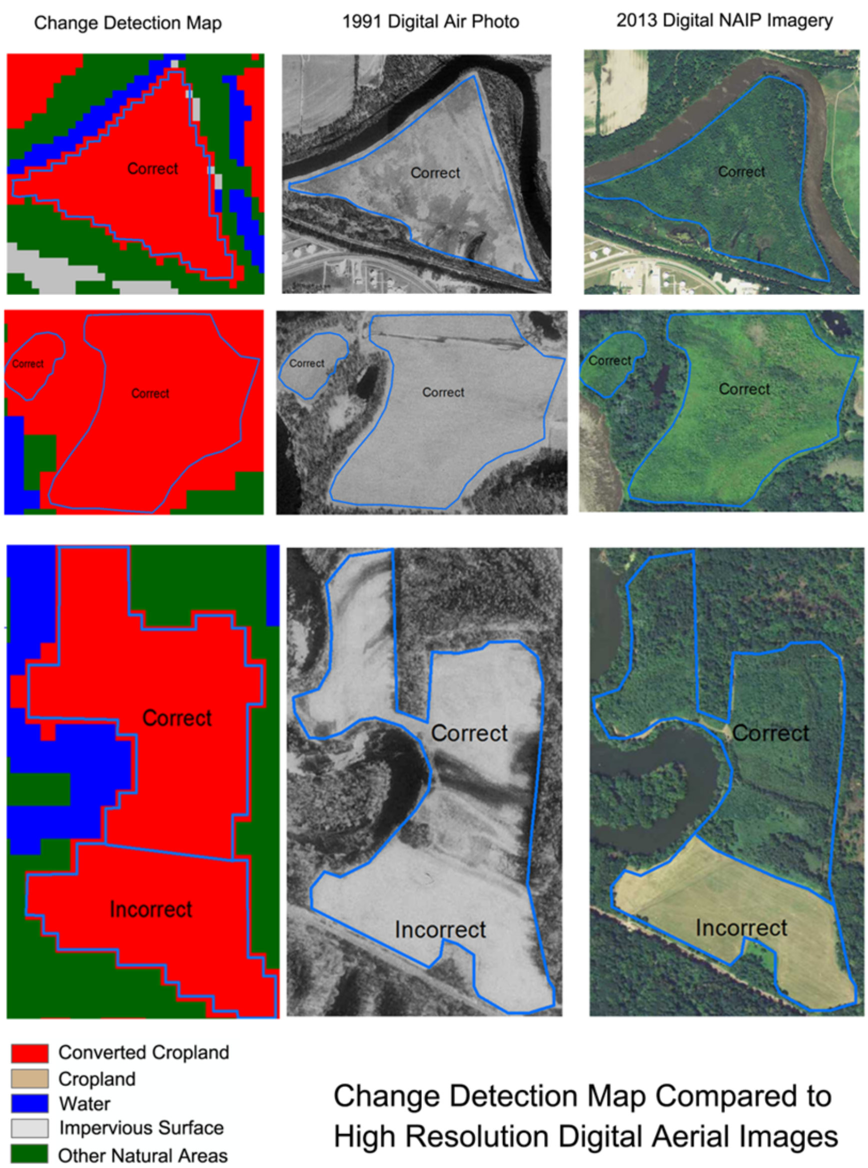

Figure 9. An example of change detection map from 1985 to 2013 compared to 1 m resolution digital aerial images of 1991 and 2013

4. Conclusions

The results demonstrated that the 30 m resolution Landsat images with large coverage and 16-day revisit interval are suitable for such regional study that involves multi-temporal classifications and change detection. Moderate to high overall classification accuracies were obtained based on the object-based classification technique.

A persistent drop in cropland occurred in spite of rising and volatile corn and soybean prices since 2005 associated with Minnesota's biofuel industry. This persistence derives from the implantation of CREP's long-term and/or permanent use of conservation easements with their stable income revenues during 1998-2002 when corn and soybean prices had decreased by 30-50% when compared to the prior three years (1995 through 1997). Such fortuitous circumstances comprise an important context for the present situation.

Based on Allen's (2005) citation of CREP reducing soil loss by 4.2 short-tons/acre/yr (9,415 kg/ha/yr) and phosphorous by 5.3 lbs/acre/yr (5.94 kg/ha/yr) within the Minnesota River basin, our finding of 36,000 ha (89,000 acres) of cropland being converted to natural cover from 1985-2013 suggests a reduced soil loss by over slightly over 373,800 short-tons/yr (339,000 metric tons/yr) and phosphorus loading by another 472,000 lbs/yr (214,000 kg/yr) from sources within the Minnesota River Valley proper. This situation keeps with former Governor Carlson's policy of using CRP and especially CREP to aid in cleaning up the Minnesota River.

Future research within the Minnesota River basin utilizing a combination of geo-spatial technologies and field work needs to focus more accurately on determining: (1) the reduced sedimentation and phosphorous loading into the Minnesota River and its downstream impacts pursuant to the Mississippi River; (2) the effect of natural cover in delaying or mitigating stream bank failure; and (3) the enhancement of wildlife habitat for species such as pheasants and wild turkeys that are hunted and generally respond well to a mixed landscape of agriculture and natural cover.

Acknowledgements

The authors thank Dean Barry Ries of the College of Graduate Studies and Research and Acting Dean Maria Bevacqua of the College of Social and Behavioral Sciences, at Minnesota State University, for funding the graduate assistants and the software used herein.

References

Agricultural Act of 1956. (1956). Statutes at Large, 52, 31.

Al-Khudhairy, D., Caravaggi, I., & Glada, S. (2005). Structural damage assessments from Ikonos data using change detection, object-oriented segmentation, and classification techniques. *Photogrammetric Engineering and Remote Sens., 71*(7), 825.

Allen, A. (2005). The Conservation Reserve Enhancement Program, U.S. Geological Survey, 191. Retrieved February 16, 2015, from http://www.nrcs.usda.gov/TECHNICAL/nri/ceap/fwbenefit.html

Benz, U. C., Hofmann, P., Willhauck, G., Lingenfelder, I., & Heynen, M. (2004). Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS J. of Photogrammetry and Remote Sens., 58*(3), 239-258. http://dx.doi.org/10.1016/j.isprsjprs.2003.10.002

Bhaskaran, S., Paramananda, S., & Ramnarayan, M. (2010). Per-pixel and object-oriented classification methods for mapping urban features using Ikonos satellite data. *Applied Geography, 30*(4), 650-665. http://dx.doi.org/10.1016/j.apgeog.2010.01.009

Budreski, K. A., Wynne, R. H., Browder, J. O., & Campbell, J. B. (2007). Comparison of segment and pixel-based non-parametric land cover classification in the Brazilian Amazon using multi-temporal Landsat TM/ETM+ imagery. *Photogrammetric Engineering and Remote Sens., 73*(7), 813. Food and Security Act of 1985. *Statutes at Large, 99*, 1504.

Butler vs. United States. (1936). U.S. Reports 297:1.

Gupta, S., Kessler, A., & Dolliver, H. (2011). Natural versus anthropogenic factors affecting sediment production and transport from the Minnesota River basin to Lake Pepin. Retrieved February 17, 2015, from at www.mncorn.org/sites/mncornorg/files/research/final-reports/201206/w3-Evaluation-of-stream-bank-erosion.pdf

Hay, G. J., Castilla, G., Wulder, M. A., & Ruiz, J. R. (2005). An automated object-based approach for the multiscale image segmentation of forest scenes. *International J. of Appl. Earth Observation and Geoinformation, 7*(4), 339-359. http://dx.doi.org/10.1016/j.jag.2005.06.005

Iowa State University. (2015). Average Iowa corn and soybean prices by marketing year 1925-2014. Retrieved

February18, 2015 from www.extension.iastate.edu/agdm

Laingen, C. (2011). Historical and Contemporary Trends of the Conservation Reserve Program and Ring-Necked Pheasants in South Dakota. *Great Plains Research, 21*, 95-103.

Lepper, K., Fisher, T., Hajdas, I., & Lowell, T. V. (2007). Ages for the Big Stone Moraine and the oldest beaches of glacial Lake Agassiz: Implications for deglaciation chronology. *Geology, 35*(7), 667-670. http://dx.doi.org/10.1130/G23665A.1

Minnesota Board of Soil and Water Resources. (2004). Minnesota River CREP factsheet. Retrieved February 15, 2015, from http://www.bwsr.state.mn.us/easements/rim/crep.pdf

Minnesota Department of Agriculture. (2013). Minnesota Agricultural Exports. Retrieved February 20, 2015 from http://www.mda.state.mn.us/food/business/economics/agexprtfile.pdf

Minnesota Department of Natural Resources. (2000). Ring-necked Pheasant Populations, 1-3. Retrieved February 16, 2015 from http://files.dnr.state.mn.us/eii/factsheets/pheasants.pdf

Minnesota River Data Center. (2005). Minnesota River Basin Conservation Reserve Program Enhancement program CREP. Retrieved February 17, 2015 from http://mrbdc.mnsu.edu

Minnesota State University, Mankato. Water Resources Center. (2009). Minnesota River Basin Trends. 40. Retrieved February 20, 2012 from http://mrbdc.mnsu.edu/minnesota-river-basin-trends-report

Mitchell, M. (2013). Southern Minnesota: An evolving alternate energy frontier. *Journal of Geography and Geology, 5*(3), 43-52. http://dx.doi.org/10.5539/jgg.v5n3p43

Mitchell, M., & Kimmel, R. (2009). Landowner attitudes and perceptions regarding wildlife benefits of the Conservation Reserve Program. *Rural Minnesota Journal, 4*, 93-106.

Nagel, P. (2014). Landscape and impervious surface mapping in the Twin Cities Metropolitan Area using Feature Recognition and Decision Tree techniques. Master's Thesis. Minnesota State University, Mankato.

Nagel, P., Cook, B., & Yuan, F. (2014). High spatial-resolution land cover classification and wetland mapping over large areas using integrated geospatial technologies. *International Journal of Remote Sensing Applications, 4*(2), 71-86. http://dx.doi.org/10.14355/ijrsa.2014.0402.01

Ojakangas, R., & Matsch, C. (1982). Minnesota's Geology (Minneapolis: University of Minnesota Press) 208, 223-224.

Opitz, D., & Bain, W. (1999). Experiments on learning to extract features from digital images. International Association of Science and Technology for Development: Signal and Image Processing Conference.

Soil Conservation Act. (1935). Statutes at Large, 49, 163.

U.S. Department of Agriculture (USDA). (2002). Census of Agriculture, Minnesota, Table 41. Retrieved February 16, 2015 from http://www.agcensus.usda.gov/publications/1997/vol_1_national_state_and_county_tables/Minnesota/mn23/mn1_41.pdf

U.S. Department of Agriculture (USDA). (2005). Conservation Reserve Enhancement Program—Minnesota II, Retrieved February 17, 2015, from http://www.fsa.usda.gov/internet/FSA_file/crepmn05.pdf

Waters, T. (1987). The streams and rivers of Minnesota, (Minneapolis: University of Minnesota Press) 304-314.

Whiteside, T. G., Boggs, G. S., & Maier, S. W. (2011). Comparing object-based and pixel-based classifications for mapping savannas. *International J. of Appl. Earth Observation and Geoinformation, 13*(6), 884-893. http://dx.doi.org/10.1016/j.jag.2011.06.008

Wisner, R. (2014). Ethanol, gasoline, crude oil and corn prices: are the relationships changing, Agricultural Marketing Resources Center. Retrieved March 4, 2015, from http://www.agmrc.org/renewable_energy/ethanol/ethanol-gasoline-crude-oil-and-corn-prices-are-the-relationships-changing/

Worster, Donald. (2004). The Dust Bowl: Southern Plains of the 1930s (New York: Oxford University Press) 69-72.

Yuan, F., & Mitchell, M. (2014). Long-term climate change at four rural stations in Minnesota, 1920-2010. Journal of Geography and Geology 6(3) 228-241. http://dx.doi.org/10.5539/jgg.v6n3p22