# EXPLORING LAND CONSERVATION USING ECONOMIC AND GEOSPATIAL MODELS

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**DOCTOR OF PHILOSOPHY**

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**ABSTRACT**

Three different, but related studies on conservation in North Dakota were completed. Expansion of Devil's Lake over the past 20 years has flooded farmland, towns, and roads, causing economic damage and distress. Retirement of private land into conservation could play a role in ameliorating damages to citizens, while simultaneously improving and protecting wildlife habitat. The objective of the first study is to investigate the supply of agricultural land that might be available for conservation use at various purchase prices. It was expected that increasingly frequent flooding over the past decades would have increased the supply of land available for conservation. This was verified to be the case for the most vulnerable lands in Devil's Lake Basin—areas below 1,460 ft. elevation and within 300 ft. of surface waters.

The Conservation Reserve Program is comprised of lands that were previously farmed and have been converted into grassland. The landowners are compensated by the US government for retiring this farmland because it provides environmental benefits. Current commodity prices are giving farmers less incentive to renew their CRP contracts and many are deciding to instead farm those lands. The second study aims to identify and quantify the factors that affect a landowner's decision to renew an expiring CRP contract or not in the Sheyenne River basin. The economic factors examined were crop prices and CRP payments. The ecological factors were slope of the land, distance to the nearest stream, and soil texture.

The purpose of the final study is to estimate the increase in sediment loading due to changes in CRP enrollment, and then value the cost to society of the increased sedimentation. This will be accomplished by creating a SWAT model of the Sheyenne River. Future and hypothetical land use datasets will be substituted into the model. Every ton of sediment entering the river costs society an estimated $2.40. The model estimated 1,218.36 tons of sediment

entered the river from the study area in 2005. Using the landcover conditions present in 2014, an estimated 1,661.4 tons of sediment would have entered the river across the study area, an increase of 36%.

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## LIST OF ABBREVIATIONS

ACEP .................................................Agricultural Conservation Easement Program

ARS...................................................Agricultural Research Service

CDL...................................................Cropland Data Layer

COE...................................................Nash-Sutcliffe Coefficient

CREP.................................................Conservation Reserve Enhancement Program

CRP ...................................................Conservation Reserve Program

DEM..................................................Digital Elevation Map

EBI ....................................................Environmental Benefits Index

ERS ...................................................Economic Research Service

FSA ...................................................Farm Service Agency

GIS ....................................................Geographic Information System

HRU ..................................................Hydrologic Response Unit

HUC ..................................................Hydrologic Unit Code

NAAAC .............................................Natural Areas Acquisition Advisory Committee

NASS .................................................National Agricultural Statistics

NDGIS ...............................................North Dakota Geographic Information System

NDSU.................................................North Dakota State University

NGO..................................................Non-Governmental Organization

NPS ...................................................Non-point Source

NPV...................................................Net Present Value

NRCS .................................................Natural Resources Conservation Service

NWI...................................................National Wetlands Inventory

NWIS ................................................National Water Information System

SAS ...................................................Statistical Analysis System

SRB ...................................................Sheyenne River Basin

SSURGO...........................................Soil Survey Geographic Database

STATSGO.........................................State Soil Geographic Dataset

SWAT ...............................................Soil and Water Assessment Tool

USACE .............................................US Army Corps of Engineers

USDA................................................United States Department of Agriculture

USFWS .............................................US Fish and Wildlife Service

USGS ................................................US Geological Survey

# CHAPTER 1. INTRODUCTION

Conservation and restoration of native habitat provide many ecological benefits which compete with the development of land for residential, commercial, or agricultural purposes. Land enrolled in the Conservation Reserve Program, or CRP land, is the main focus of this dissertation. However, there are many other federal and state land conservation programs that accomplish similar goals. The CRP was created as part of the 1985 Farm Bill. Its original purpose was to conserve soil resources and support agricultural commodity prices by taking cropland out of production and replacing it with native vegetation for 10 to 15 years. It has been renewed in every Farm Bill since then. The CRP is comprised of lands that were previously farmed and have been converted into native grassland or savannahs. The landowners are compensated by the US government for retiring this farmland because it provides wildlife habitat, reduces soil erosion, and improves water quality (USDA, FSA, 2011).

CRP fields are great nesting habitats for wildlife. Best et al. 1997, found abundance of birds was from 1.4 to 10.5 times greater in CRP fields than row crop fields. CRP fields supported 3 times more nesting species, 13.5 times the total number of nests, and produced greater than or equal to 14 times more young birds than row crops (Best et al. 1997). This study was completed over five years and throughout six Midwestern states. These results over a wide region and time highlight how crucial CRP is to recovery and continuation of avian populations. One year later Best et al. studied the same CRP and row crop lands, but over winter seasons. Widespread use of CRP fields by birds in the winter was documented and attributed to the presence of taller grasses and woody cover providing protection from the cold temperatures and providing easier access to food compared to row crop fields with a thick layer of snow covering them. CRP fields also showed a higher abundance of species undergoing a long term population decline (Best et al.

1998). Thus CRP fields can be useful in conserving and increasing biodiversity. In landscapes dominated by agriculture, CRP can offer habitat for fawn-rearing, bedding, and foraging on alfalfa and sweet clover for white-tailed deer (Gould and Jenkins, 1993). White-tailed deer are a valuable game species, so promoting CRP can yield economic benefits. These benefits increase the return on investment the government makes through the CRP.

In the Midwest, perennial C4 grasses have been shown to reduce runoff and thus reduce soil erosion and nutrient and sediment loading in streams (Wilson et al. 2011). These grasses were more difficult to establish due to “seed dormancy, weed pressure, and moisture and sunlight availability” (Wilson et al. 2011). Enrollment in the CRP is not a temporary endeavor and thus these lands are perfect candidates for planting of more effort- intensive plants that can improve water quality. In another study, five years after reestablishing grass on plots of sandy loam soil that had been cultivated for 60+ years, total organic C and N, and potential net mineralized C and N in the top 10 cm had increased to levels equal to or greater than those observed in a nearby native range (Reeder et al. 1998). CRP lands, in addition to reducing soil erosion (which can take mineralized carbon and nitrogen with it) also acts as a source of organic carbon though plant litter that accumulates every year. Soil organic matter is important because it provides soil structure, increases infiltration, and increases the nutrient holding capacity of the soil (Reeder et al. 1998).

While conservation has been shown to provide great ecological benefits, it must compete with the personal financial gain of harvesting our natural resources. In the Midwest this usually takes the form of agriculture. Studies into the economic relationships between markets, landowners, and their choices are necessary when exploring conservation efforts. Different government programs have different goals, such as promoting conservation or promoting crop production, depending on their structure. Feng et al. 2012, explored the effect of government crop insurance subsidies on the conversion of grassland, native or CRP, into cropland. Higher subsidies led to a reduction in CRP, which promotes a reduction in CRP and lowers net benefits to society. Whereas increasing CRP funding (or a similar program) still provides economic support to farmers, but at a much higher net societal benefit. Looking at North Dakota, Bangsund et al. 2004, found recreation almost completely offset lost agricutural revenue in counties in the western and central regions of the state. They believe this is because these counties produce less valuable crops and have more opportunities for hunting pheasants and waterfowl. Thus, CRP is best implemented when it targets low productivity land and allows for increased recreational opportunities for local economies to capitalize on. The benefits of CRP are often public and the costs are often private. Thus it is important for government bodies to internalize some of the benefits (such as increased CRP payments) and share the costs with the public (through taxes or fees).

Geographic Information Systems, or GIS, have become vital tools in the study of land use changes. GIS, in conjunction with remotely sensed data, can be used to track changes between land covers from year to year (Egbert et al. 2002). Due to its flexible nature economic and ecological parameters can be paired with the GIS to create multifaceted models. This technology and the knowledge it can uncover is widely beneficial across society. One effective use of GIS is to target lands for conservation. When funding is limited, it becomes important to conserve the "best" possible environments for the available money. Depending on the circumstances "best" can mean highest quality waterfowl habitat, most mature forest land, etc. GIS has been used by Kerchner et al. (2010), Naidoo and Adamowicz (2006), and Qiu (2009), among others, to target land with highest ecological benefits, that is cheapest cost to purchase, or has the highest risk for increased runoff. A GIS with landcover, soil, elevation, and other data can be a powerful tool when utilized for conservation programs.

Local, state, and federal governments interact with landowners in many different ways. They tax landowners, facilitate programs for different landowners, enact policies at the landowner level, and more. The scope is very wide and thus there are many land cover topics related to government that can be studied using GIS including urbanization, pollution, demographic shifts, natural resources management, etc. Governments can use an economic and GIS analysis to increase the cost-effectiveness of their conservation-based programs, such as the CRP.

In addition, non-governmental organizations will also be interested in using GIS to aid in the identification of potential conservation lands. Organizations who promote land conservation, such as Ducks Unlimited or The Nature Conservancy, have limited funds and want to maximize the ecological benefit of each dollar. This study will show how economic and GIS models can help them conserve the largest area of high quality land.

This dissertation consists of three individual, but related, papers each using GIS to facilitate an economic analysis of a different conservation issue. More specifically, to analyze land cover changes in an effort to target cost effective conservation lands, uncover economic and ecological forces behind land use change, and quantify the costs to society of land use change.

First, land cover datasets were combined with crop data to target areas for cost-effective land conservation in the Devil's Lake watershed in North Dakota. Due to climatic conditions, Devil's Lake has been rising for over 20 years (Larson, 2012). This inundation should offer opportunities for increased cropland retirement into conservation areas. Supply curves were used to show the feasibility of using public programs to retire inundated land. This benefits landowners by allowing them an option to escape their current situation while providing land/water for wildlife conservation.

Next, in the Sheyenne River basin in North Dakota, land cover datasets were used to locate parcels of land that have registered as conservation type lands (grassland, wetland, etc.) for an extended period of time and recently switched to any type of cropland. A logit model was used to identify and quantify the economic and environmental factors that may affect the landowner’s decision to crop existing grasslands. The economic factors examined were crop prices and CRP rental payments. The ecological factors were slope of the land, distance to the nearest stream, and soil texture.

Finally, increases in sedimentation due to land cover changes in the upper half of the Sheyenne River basin were estimated using a Soil and Water Assessment Tool, or SWAT model. Economic costs to society values, gathered by the US Department of Agriculture, or USDA were then used to assign a dollar value to the damages caused by soil erosion.

# CHAPTER 2. EFFECTS OF INUNDATION AND FLOOD RISK ON THE VALUE OF AGRICULTURAL LANDS IN THE DEVIL'S LAKE BASIN OF NORTH DAKOTA, AND THEIR POTENTIAL AVAILABILITY FOR CONSERVATION PURPOSES[1]

## Abstract

Over the past 20 years, Devil's Lake of North Dakota has been rising slowly. Expansion of the lake flooded farmland, towns, and roads, among other land use types, causing economic damage and distress for nearby individuals and communities. Retirement of private land into conservation through long term easements or purchases by the state or non-governmental organizations could play a role in ameliorating economic damages to private citizens while simultaneously improving and protecting wildlife habitat. The objective of this study is to investigate the supply of agricultural land that might be available for conservation use at various purchase prices. Supply curves are developed based on valuation of each parcel's land use history from 2000 to 2012. A parcel's minimum purchase price is assumed to be the expectation of its net present value of benefits in agriculture. Calculations of net present value were made for each parcel based on publicly available datasets, including land use data from the Cropland Data Layer and the Quick Stats 2.0 database—both produced by the National Agricultural Statistics Service—and crop production costs from the North Dakota State University Extension Service's annual crop budgets. It was expected that increasingly frequent flooding over the past decades would have reduced the NPV of agricultural parcels. This was verified to be the case for the most vulnerable lands in Devil's Lake Basin—areas below 1,460 ft. elevation and within 300 ft. of

[1] The material in this chapter was co-authored by Daniel Margarit and David Roberts. Daniel Margarit had primary responsibility for collecting, and analyzing data. Daniel Margarit was the primary developer of the conclusions that are advanced here. Daniel Margarit also drafted and revised all versions of this chapter. David Roberts served as proofreader of the work conducted by Daniel Margarit.

surface waters. The analysis indicates that the state government and/or non-governmental organizations could potentially purchase as many as 250,702 acres of such land at an offer price of \$100 $ac^{-1}$ if funding were made available.

## Introduction

Devil's Lake in North Dakota can be characterized as "having a mind of its own." It is located in a large watershed without a natural outlet. Thus, during the current wet climatic cycle, which started over 20 years ago, the lake has steadily risen. It has consumed farmland, forests, houses, roads, Native American tribal lands, and cities in its path (Larson, 2012). The small town of Minnewaukan, previously 13 kilometers west of the lake, is now partially underwater, forcing many residents to abandon their homes (Larson, 2012). Thus, Devil's Lake has caused economic damage since its dramatic rise. One possible solution to this considerable problem would be retiring private land into conservation use through long term easements or land purchases by the state or non-governmental organizations. This allows for economic relief to landowners whose land is inundated by the lake, and simultaneously increases wildlife habitat.

Land could be prioritized to achieve the most social, economic, and ecological benefits per dollar spent. An effective way to do this is to include the opportunity costs of conservation in the model. This has been shown to produce more cost-effective conservation programs (Naidoo and Adamowicz, 2006). Opportunity costs in the present Devil's Lake study were in the form of the net present value of the parcel. The marginal cost for one more acre of land will be the slightly higher opportunity cost associated with that acre. This is another way to look at the supply curve because the supply curve is an inverse function of marginal cost (McAfee and Lewis, 2009). Opportunity costs of conservation should be decreasing over time due to the increasing flooding. This should cause land supply curves based on the average opportunity cost of the past three years to occur to the right of land supply curves based on the average opportunity cost of the past 12 years. Secchi et al. (2009) also used a supply curve to show the effect of corn prices on how much cropland would be supplied for the Conservation Reserve Program, CRP. They then created 4 more supply curves showing the effect of higher CRP payments moving the curves leftward. However their research shows that, “[f]or higher corn prices, even doubling the payment becomes a relatively ineffective policy.” The high price of corn can cause landowners to raise their minimum accepted payment for land, making conservation more expensive. Thus targeting of land, to maintain an acceptable cost/benefit ratio of the CRP, becomes important. Geospatial criteria could be used to target lands with high ecological value. For example, Coleman (2007) and DeCecco and Brittingham (2011) both recommend riparian buffers of at least 300 feet to create suitable wildlife habitat. The present research produces supply curves for land within such a buffer.

Yang et al. (2003) studied pollution abatement costs in an Illinois watershed using the net present value as the opportunity cost similar to the methods presented here. Kerchner et al. (2010) designed a model to prioritize land based on its potential for cost-effective conservation of thrush breeding habitat in Hispaniola. Tools like these can easily be adapted to conservation goals worldwide. Rashford and Adams (2007) note that “[f]ailure to recognize differences in marginal cost across landscapes can result in a prescription of conservation activities that are efficient for one landscape type, and not for another,” and that, “[w]hen multiple landscape types are available, differences in marginal costs can be exploited to improve overall cost-effectiveness.” Landscape heterogeneity, in addition to requiring tailored conservation practices, offers an opportunity to maximize land retired into conservation (given a fixed budget) due to different opportunity costs (in this case money made from agriculture).

One common pillar in all the aforementioned studies is the use of a Geographic Information System (GIS) to target optimal locations for conservation. Optimal in this case can mean cheapest, providing the most ecological benefits, or the land exhibiting the most of some other characteristic, depending on the goals of the conservation program.

Brown et al. (2009) propose using GIS to target lands for retirement programs such as the Conservation Reserve Program (CRP). One of their recommendations is that states create layers showing areas of land with high conservation value based on ecological surveys, and use that layer to prioritize land for conservation use. Such “priority zone” maps would be beneficial to private organizations who buy land such as The Nature Conservancy, as well as to the federal government, which is facing declining funding and acreage caps for the CRP, and must make every conservation dollar as productive as possible.

A study by Ma and Swinton (2011) illustrates different factors that could be examined using a GIS to target prime conservation land. They valued ecosystem services using agricultural land prices to put a dollar value on benefits that do not have an explicit market, such as water quality, soil erosion prevention, biodiversity, pest predators, and many others. This research helps conservation efforts by illustrating private landowners’ preferences. It shows which ecosystem services and land cover types landowners would be willing to conserve for various payment levels.

Flooding in the Devil’s Lake Basin is a pressing problem, and potential solutions are of great interest and importance to the residents of the basin and the government officials charged with helping them. While the flooding problem and associated issues are complex, studies such as this one can help citizens and their representatives in local and state governments to begin to create comprehensive solutions. This research can also serve as a framework for using supply analysis to determine whether publicly-funded conservation programs can address reduced land use values attributable to climate variation.

## Study Area

The Devil's Lake watershed—Hydrologic Unit Code (HUC) 09020201—comprises 2,455,652 acres in northeast North Dakota (USGS and NRCS, 2012). The entire watershed lies within the Northern Glaciated Plains level III Ecoregion. Glacial processes left behind gently rolling hills, flat prairies, and many potholes which contain temporary and seasonal wetlands. The climatic conditions generate a transitional grassland between the tall and shortgrass prairie (Omernik and Griffith, 2008). Agriculture and game hunting are a central aspect of culture here due to the fertile soil and wildlife habitat.

While traditionally an agricultural state, North Dakota has seen a shift in demographics due to the oil boom in the Bakken Formation in the west and the growth in Fargo in the east. As of the most recent census in 2010, the State of North Dakota has almost 673,000 people. Median household income is $53,741 and the percentage of the population 65 years of age and older is 14.2% (US Census Bureau, 2010). Ramsey, Benson, and Nelson are the three counties with the highest proportion of land inside the Devil's Lake watershed. In Ramsey County, 18.2% of the population is 65 years or older. For Benson and Nelson Counties, the proportions are 12.2% and 27.6%, respectively. This is relevant because, relative to young landowners, older landowners may be more willing to retire from agricultural use, especially for payment, as they approach retirement themselves. The median household income in these three heavily affected counties ranges from $39,500 to $49,800, which is lower than the state average. Another relevant statistic is the percent of the county population of Native American descent. Benson County is 54% Native American, Ramsey is 9%, and Nelson is 1.7% (US Census Bureau, 2010). The Spirit

Lake Indian Reservation borders the southern edge of Devil's Lake and falls within Benson County. While Native American cultures place high reverence on the value of nature and conservation of nature, it is possible they would be wary of US government programs dealing with their land, due to the history of the US government and the Native American nations.

As of 2012, average (mean) farm size in North Dakota was 1,268 acres, with a median size of 480 acres (USDA, 2012). The average market value of agricultural products sold in 2012 per farm was $353,693. In Ramsey County, the mean and median farm sizes were 1,219 and 480 acres, respectively. The county average market value of agricultural products sold per farm in 2012 was $412,005. Benson County had mean and median farm sizes of 1,425 and 600 acres, respectively, and average market value of agricultural products sold per farm was $427,404. For Nelson County, mean and median farm sizes were 929 and 320 acres, respectively, with average market value of agricultural products sold per farm at $241,725. On average, farms in Nelson County are about half as valuable as those of Ramsey and Benson Counties. They are also about 24% to 27% smaller on an average. It can be assumed, *ceteris paribus*, that farmers in counties producing less valuable output would be more likely to enroll land in conservation programs than counties with more productive land.

## Conceptual Framework

In concept, current land owners make decisions about future land use and land ownership based on the expected *net present value* (NPV) of each parcel in each mutually exclusive use. For example, a farmer who currently employs a parcel in agriculture may observe changing commodity prices and agricultural policy over a number of years, while simultaneously observing many other factors such as urban/suburban growth, changing flood risk, etc., and use the information to choose, from amongst all alternative uses, the use which brings the highest expected NPV. In other words land owners make decisions based on opportunity cost, implying that farmers will move land from agricultural production into conservation use if the NPV of compensation for doing so exceeds the expected NPV from other mutually exclusive uses, such as continued agricultural use or sale to a residential or commercial developer. Thus, the supply of agricultural land for conversion to conservation use is a function of the expected NPV of land in agriculture and other uses, as determined by expected agricultural commodity prices and expected agricultural productivity. Land that is frequently unproductive due to flood risk or soil salinization—both common problems in the Devil's Lake Basin—may be available for conservation use at relatively low cost, especially when farmers are not optimistic about future commodity prices. Thus, a farmer's land use choice for a particular parcel could be modeled as follows:

$$\max_{k \in K} E[\,NPV_{ik}] = \max_{k \in K}\left[\frac{E(R_{ik} - C_{ik})}{e^{\delta} - 1}\right], \qquad (1)$$

where $NPV_{ik}$ is the per acre NPV of land use *k* on parcel *i*, $R_{ik}$ is the per acre revenue from land use *k* on parcel *i*, $C_{ik}$ is the operating cost per acre for land use *k* in parcel *i*, $\delta$ is the discount rate, and *K* is the set of all possible land use alternatives for parcel *i*. If a parcel is currently in agricultural use, and is located in a rural area with high flood risk, the landowner may have only two basic land use alternatives from which to choose: 1) continued agricultural use—cropping only when sufficiently dry—or 2) abandonment. Offering a third option, such as a long-term conservation easement, could increase producer welfare by defraying the economic losses from flooding while simultaneously providing public benefits in the form of wildlife habitat. In theory, any parcel for which the NPV in agricultural use is less than or equal to the purchase (or easement) price offered by a conservation program should be available for conservation use. The law of supply indicates that, *ceteris paribus*, the quantity of agricultural land supplied for conservation use is an increasing function of the easement (or purchase) price offered by the conservation program (Just and Zilberman, 1986). The other determinant of supply of land for conservation purposes is the expected agricultural use NPV on each parcel, so that the supply function can be represented as:

$$Q_S = \sum_{i=1}^{N} d_i(P, E[NPV_i])q_i, \tag{2}$$

where $Q_S$ is the total acreage acquired for conservation use, $d_i$ is a binary function of the conservation offer price ($P$) and the expected net present value of parcel *i* in agricultural use ($E[NPV_i]$) that takes on a value of 1 if $P \geq E[NPV_i]$ and 0 otherwise, and $q_i$ is the acreage of parcel *i*. In effect, increasing flood risk over time in the Devil's Lake Basin should have reduced the value of the land in continued agricultural use, *ceteris paribus*, increasing the availability of land for conservation use.

However, it might not be cost-effective to target agricultural parcels for acquisition based solely on their (low) values in continued agricultural use. Cost-effectiveness requires maximization of the total social benefits per program dollar spent; thus, agricultural land should be prioritized for acquisition based on the environmental or ecological benefits it can provide in conservation use. Parcels can be indexed and prioritized for enrollment based on a number of characteristics—as with the US EPA's Environmental Benefits Index (EBI)—or they might be prioritized based on a single factor, such as potential sediment load reduction to surface water, suitability as habitat for a targeted species, or protection from economic losses from flood damage.

## Data

Several publicly available data sources were used in this research including the National Agricultural Statistics Service's (NASS) Cropland Data Layers (CDL) (Han et al., 2014), NASS's Quick Stats 2.0 database (USDA, 2012), USGS's Hydrologic Unit Code (HUC) dataset (USGS and NRCS 2012), The National Wetlands Inventory (NWI) dataset (USFWS, 2006), the Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO) (Soil Survey Staff, NRCS, 2007), and the Shuttle Radar Topography Mission (SRTM1) dataset from USGS, NASA, & NGA, (2009).

The CDL for each year from 2000 to 2012 provided land cover raster data for all of North Dakota (Han et al, 2014). These datasets were created by the USDA using medium resolution satellite imagery to detect different types of land cover. The accuracy values vary from year to year but in 2014, the CDL for North Dakota had an estimated accuracy of 83.2% (USDA, 2014). These data were used in the present study to identify land in the Devil's Lake Basin that has been in agricultural use during the study period, and also to identify the specific crop (or other land cover) on each parcel each year.

Variables downloaded from the Quick Stats 2.0 database included county-level crop yields and the statewide average price received for each crop. The information for NASS surveys was gathered by NASS from farmers and ranchers in a variety of ways: mail surveys, telephone interviews, face-to-face interviews, and field observations (USDA, 2012). NASS statisticians then used the raw data to make estimates for crop prices, yields, etc. NDSU Extension Service's annual crop budgets provided production cost estimates for each crop in the region, for the year 2012. The costs were estimated by the Extension Service based on regional environmental conditions and historical agricultural trends (NDSU Extension Service, 2011). Crop prices were adjusted to constant 2012 U.S. dollars using a crop price index, and, along with the estimated production costs, were used to estimate a profit for each crop in each year in 2012 dollars.

## Methods

Annual profit values for each parcel were calculated using yield and price data downloaded from the USDA's NASS Quick Stats 2.0 database (USDA, 2012) and input costs from crop budgets created by the NDSU Extension Service (NDSU Extension Service, 2011). The annual per acre profit values for each land use were joined to the polygon shapefile based on each polygon's annual land use in the CDL (Han et al., 2014). The *Field Calculator* tool was used to estimate expected profit for each polygon using a trailing average, and the expected profits for each parcel were then converted to expected net present value, assuming the expected profit would be received annually in perpetuity. Equations used to find the expected NPV for each parcel were as follows:

$$E[\pi_i]_{TYMA} = \left(\sum_{t=0}^{T-1} \pi_{i,2012-t}\right)/T \tag{3}$$

$$E[NPV_i]_{TYMA} = (E[\pi_i]_{TYMA})/\left(e^{\delta} - 1\right) \tag{4}$$

where $E[\pi_i]_{TYMA}$ is the expected profit from parcel *i* based on a *T*-year trailing average, $\pi_{i,2012-t}$ is profit on parcel *i t* years before 2012, $E[NPV_i]_{TYMA}$ is the expected NPV of parcel *i* in continued agricultural use in perpetuity based on a $\underline{T}$-year moving average, *e* is the base of the natural logarithm, and $\delta$ is the long-term discount rate. These calculations were performed for each parcel using $T$ = 3, 6, 9, and 12. The discount rate ($\delta$) was set at 0.05 to reflect the long-term rate of return to farmland in the US (Nickerson et al., 2012).

The spatial analyst tool *Zonal Statistics as Table* was used to calculate the mean elevation of each polygon (parcel). One hundred sixty (160) elevation raster files were merged together for full coverage the area of the Devil's Lake watershed. The *buffer* tool was used to create a 300 ft. buffer around all water bodies within the watershed, which was then *unioned* to the master layer, along with the soil data layer. Finally a column was created, named "Acres," and the *calculate* *geometry* tool was used to calculate the area of each parcel, in acres. Federally-owned, state-owned, tribal-owned, and developed lands were removed from consideration. The frequency of annual flooding for each parcel was calculated based on land cover data—i.e. for any year in which the CDL classified a parcel as "water" or "wetlands", the parcel was considered flooded. These data are presented graphically for a small portion of the Devil's Lake Basin in Figure 1.

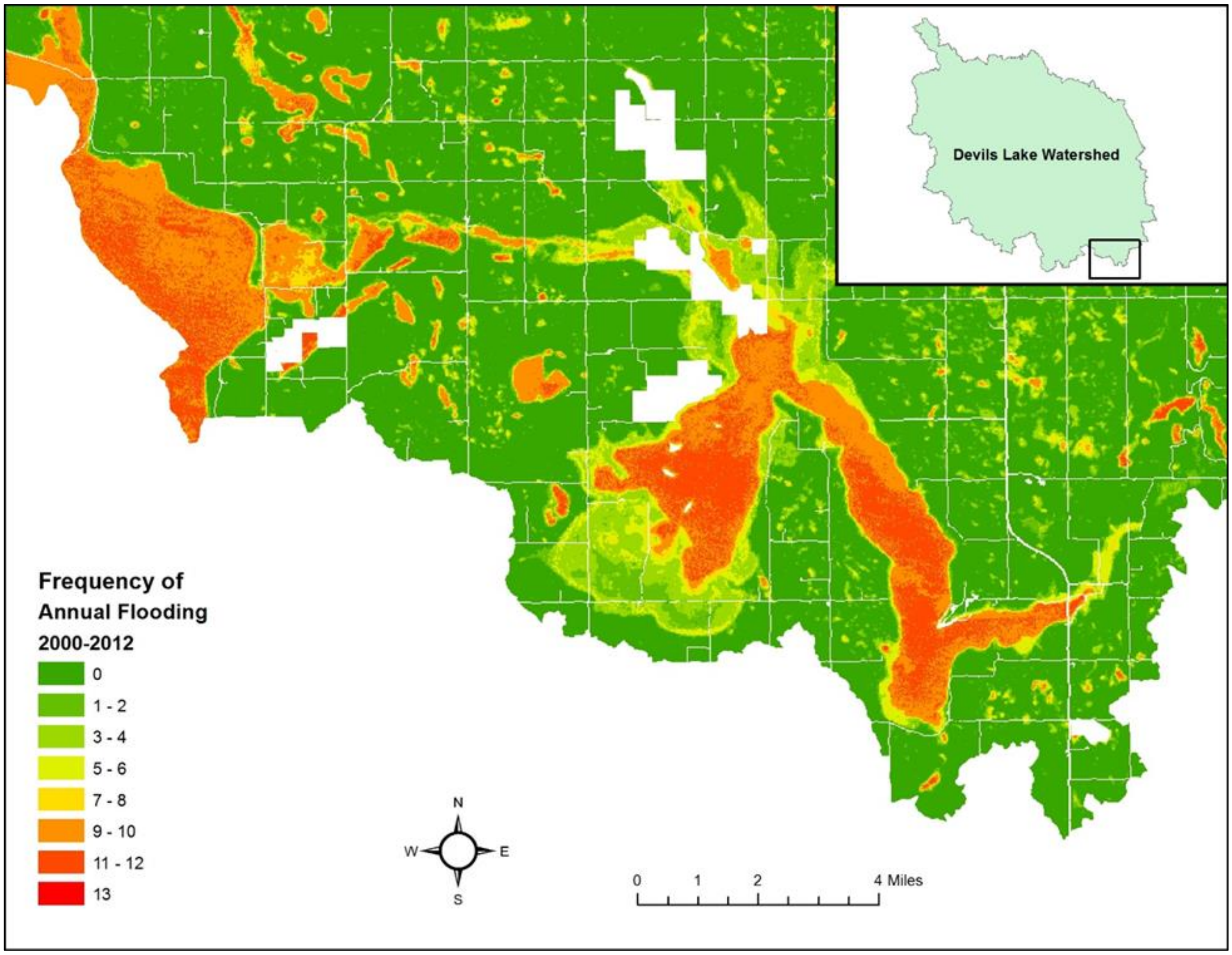


**Figure 1.** Frequency of annual flooding in Devil's Lake Basin from 2000 to 2012

Figure 2 shows the expected NPV of each parcel based on the average net return from 2006 to 2012, in 2012 US dollars. Note that the frequency of annual flooding is a major driver of expected NPV. The quantity of land that would be supplied for conservation at each offer price

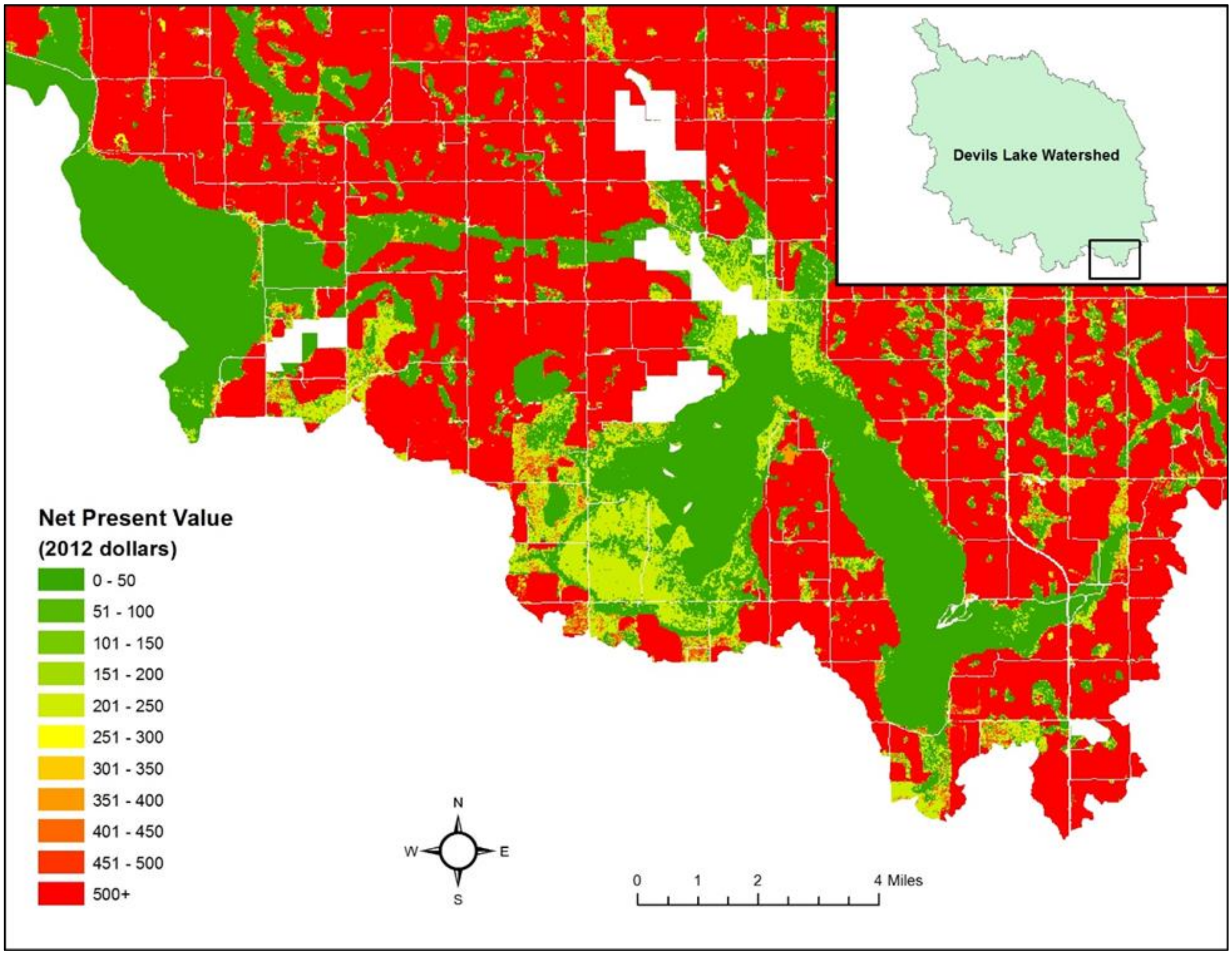


**Figure 2.** Net present value in agriculture for land in the Devil's Lake Basin based on average net return from 2007 to 2012 (2012 USD per acre)

was calculated using the *select by attributes* tool from the attribute table of the master layer. For example, the expected NPV based on the three-year trailing average is a column called "NPV_3yr," so the parcels were selected by the code "NPV_3yr ≤ 'price'". Once the selection was complete the *statistics* tool was run on the "Acres" column of the selected parcels and the "sum" value was entered into a table. For each estimator of expected NPV (i.e., 3-, 6-, 9-, and 12-year trailing averages) the selection procedure was iterated with offer prices increasing from $0 to $500 per acre in increments of $50 to create a land supply schedule. This was completed for (1) the entire watershed, (2) land at or below 1,460 feet elevation, and (3) land at or below 1,460 feet elevation within 300 ft. of a water body. The elevation of 1,460 ft. was selected because Devil's Lake flows through Tolna Coulee into the Sheyenne River if the lake rises this high, making land above 1,460 ft. less prone to flooding. The final step was to illustrate the supply schedules graphically. Supply schedules are illustrated in Figures 3, 4, and 5 for lands that meet different sets of criteria.

## Results and Discussion

The supply curves based on 3-, 6-, 9- and 12-year trailing average NPV for the entire watershed are illustrated in Figure 3.

This set of supply curves indicates that, if farmers expect average input and output prices and flood risks for 2010 to 2012 to continue for the foreseeable future, they will be willing to sell more land at any given offer price below $150 per acre than they would if they expect future conditions to reflect price and flood risk conditions of a longer historical period, such as 2001 to 2012. Large portions of the supply curves based on smaller trailing averages occur to the right of the supply curves based on larger trailing averages. However, because flood risk has not uniformly increased on all agricultural land in the Devil's Lake Basin, many parcels that are relatively (or entirely) unaffected by flood risk have higher expected NPV in agriculture based on 3-year (2010 to 2012) average market conditions than based on the 12-year (2001 to 2012) average. Thus, some portions of the supply curve have shifted left, rather than right. The graph indicates that 251,870 acres—i.e. the horizontal intercept of the 12-year trailing average supply curve—have an expected NPV equal to zero based on profitability over the last 12 years, presumably because these acres have been flooded consistently for the duration of the study period. If farmers' expectations about flood risk are based on only the most recent three years—

2010 to 2012—the expected NPV will be equal to zero for the 456,178 acres that were flooded consistently throughout those years, which is the horizontal intercept of the three-year trailing average supply curve. The supply curves in Figure 3 indicate that 310,310 to 456,256 acres would be available at a purchase price of \$100 $ac^{-1}$, for a total cost of \$31 million to \$45.6 million.

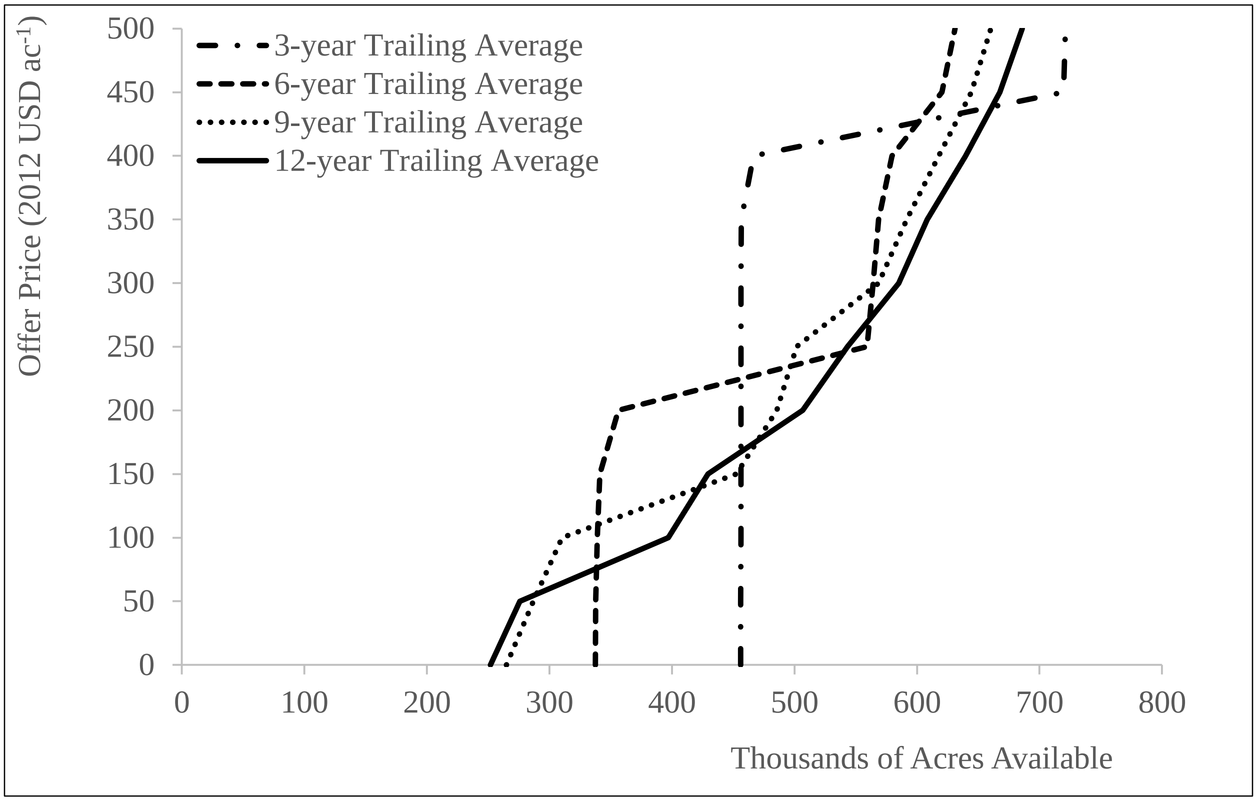


**Figure 3**. Supply of land available for conservation purchase within the entirety of Devil's Lake Basin based on 3-year, 6-year, 9-year, and 12-year trailing average net returns

The supply curves based on 3-, 6-, 9- and 12-year trailing average NPV for only land below 1,460 ft. elevation are shown in Figure 4. This set of supply curves indicates that farmers will be willing to sell more land at offer prices below \$200 per acre if they expect average prices and flood risks for 2010 to 2012 to continue for the foreseeable future than they would if they expect future conditions to reflect price and flood risk for the entire 2001 to 2012 period. At a price of $100 per acre, farmers ought to be willing to sell between 216,129 and 294,632 acres, at a total program cost of $21.6 million to $29.5 million. It should be further noted that 187,260 acres in this target area have been consistently flooded for the past 12 years, while 294,620 have been flooded consistently for the past 3 years, indicating that most of the acreage that is regularly flooded in Devil's Lake Basin as a whole (65% to 75%) is below 1,460 ft. elevation.

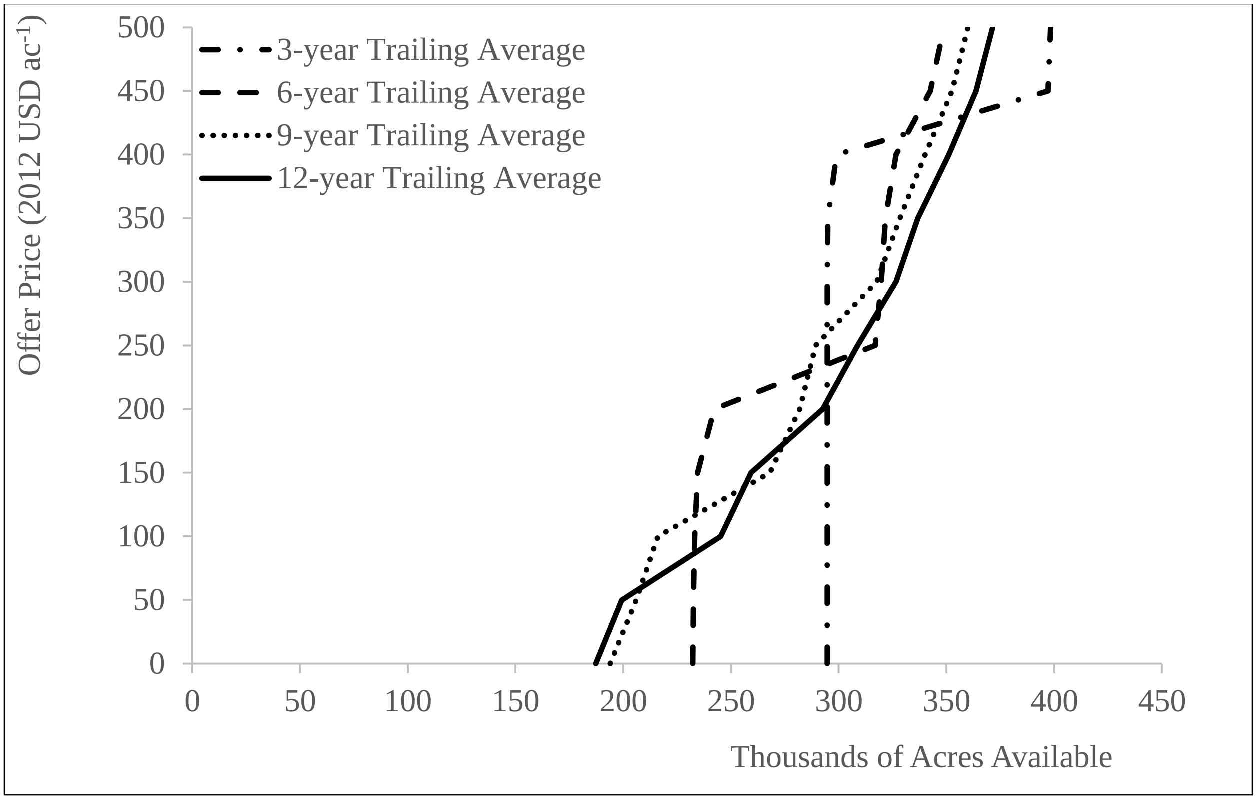


**Figure 4.** Supply of land available for conservation purchase below 1,460 ft. elevation in Devil's Lake Basin based on 3-year, 6-year, 9-year, and 12-year trailing average net returns

Figure 5 shows the supply curves for land below 1,460 ft. elevation and within 300 ft. of surface water features, including land that has been underwater for the entire study period. About 165,184 acres of land meeting these criteria have been flooded for the entire period, which accounts for approximately 65% of all the land in the basin that has been flooded for the entire

12 years. That is, most of the persistent flooding problems occur on this type of land. The supply curves show that between 186,647 acres and 250,702 acres within the 300 ft. buffer and below 1,460 ft. elevation could be acquired for $100 per acre, costing the purchasing organization a total of $18.7 million to $25.1 million.

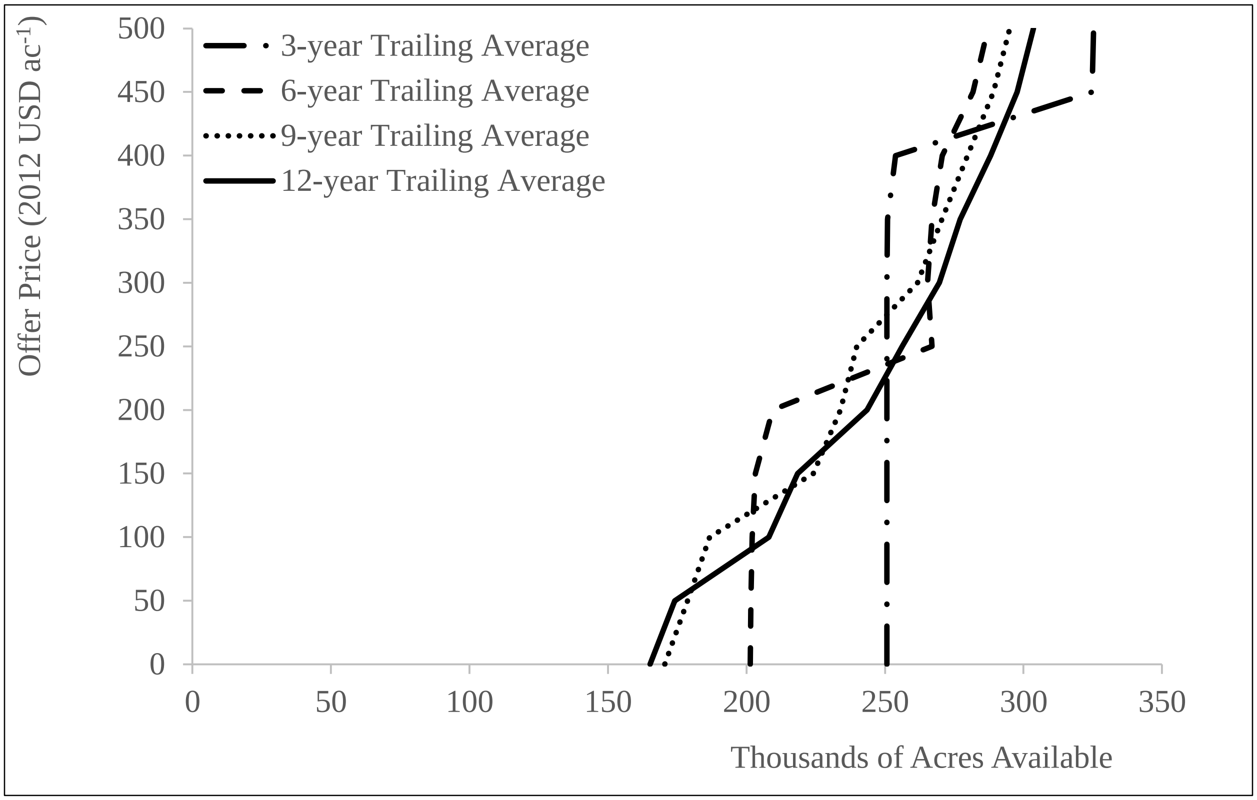


**Figure 5.** Supply of land available for conservation purchase below 1,460 ft. elevation and within 300 ft. of a water body in Devil's Lake Basin based on 3-year, 6-year, 9-year, and 12-year trailing average net returns

Land that is not flooded but is inaccessible due to flooded roads was not considered in this analysis. This land would register as "fallow," "grassland," or a similar non-agricultural land cover, depending on what is growing there. These land covers were given estimated profit values of 0, so these types of land will affect the supply curves as intended, if the land is located under 460m elevation. If the land is above 460m in elevation it may still be a good target for conservation, but was not included in the supply curve calculations. Thus the actual number of acres supplied may be slightly larger for a given price.

Among the many obstacles to such a conservation plan: the state of North Dakota places hefty restrictions on land purchases by the state, as well as by non-governmental organizations (NGOs). The NGO or state agency must present a purchase plan at a public hearing before the Natural Areas Acquisition Advisory Committee (NAAAC). That committee then gives a recommendation to the governor who can approve or deny it. Additionally, the NGO must make payments in lieu of taxes on the land (North Dakota Farmers Union, 2014). The NAAAC can be very particular about the land they allow to be purchased as evidenced by a recent decision (Dokken, 2014). Proposals brought before the committee must be very thorough and show clearly the benefits outweigh the costs. The North Dakota Clean Water, Wildlife & Parks Amendment was a ballot issue in the November 2014 election. It was estimated the amendment would have funding of up to $259 million between 2015-2017, which could potentially have been used to purchase land claimed or threatened by Devil’s Lake—considered a win-win scenario for landowners and the State government (Nowatzki, 2014). The amendment failed; however, this was the second time this amendment was put to a vote. Perhaps in the future a compromise can be reached, and a new amendment can be written that stands a better chance at passing and ultimately benefitting all North Dakota residents, especially those residing in the Devil’s Lake watershed. Currently the Outdoor Heritage Fund exists to promote protection of North Dakota’s Natural resources. However, this fund is capped at $30 million a year, and cannot be used to purchase land (Nowatzki, 2014).

## Conclusions

This research has demonstrated that hundreds of thousands of acres of privately-owned land in Devil’s Lake Basin, currently affected or threatened by flooding and soil salinization, could be purchased for conservation purposes for a total of about $25 million. This purchase would lead directly to immediate benefits for current landowners who are struggling due to a loss of productive assets to the floodwaters. But as floodwaters recede, these lands could provide large amounts of contiguous wildlife habitat, including wetland and grassland habitats, if they are protected from efforts to reclaim them for agriculture. These lands will likely be damaged and expensive to bring back onto agricultural production once the lake level diminishes, causing them to be a continuing burden for current landowners. While flooding is a temporary problem inundating the land, salinization of the land can persist much longer, removing the land from agricultural production (USDA, ARS, 2005). Devil’s Lake is large enough that salinity levels vary throughout the lake with the cleaner water in the west and the saltier water in the east. Therefore the length of time that flooded land is out of production after the floodwaters recede depends on the location of the land and the chemistry of the water flooding it.

Many of the lands that are relatively unaffected by flooding in Devil’s Lake Basin have substantially increased in value between 2001 and 2012 due to increasing commodity prices. High commodity prices have been a boon to many farmers in North Dakota, and for those struggling with inundated land around Devil’s Lake. However, commodity prices have decreased substantially since the study period, meaning that a larger quantity of land may be available at any given offer price, depending upon farmers’ expectations about commodity prices in future years. This paper gives the North Dakota government a starting point, showing how much it might cost to acquire flooded or soon to be flooded lands to remove them from agricultural production and reduce the strain that flooding has caused for the communities surrounding Devil's Lake. The purchase of private land by the state of North Dakota would be a long term solution and offer landowners a ticket out of a difficult situation. The issue of restoring native landscapes, or otherwise providing ecosystems services, on the acquired lands is an issue for further study, as it would potentially involve some major costs.

This research also has implications for NGOs that might be interested in conserving land for natural habitats in North Dakota. While it may be more difficult for NGOs to purchase the land in the first place, due to the NAAAC process, once purchased they may operate with less restrictions and bureaucratic red tape than governments, which could enable them to be more efficient at managing land that is flooded or in danger of flooding. These organizations, however, will most likely have less money to spend than governmental agencies with allocated funding. Future research on a much more specific scale, such as land within half a mile of the current lakeshore, may be beneficial in helping NGOs target their conservation efforts.Another future research topic could be the costs and benefits of restoring wetlands in the upper reaches of the basin. In addition to storing precipitation that would otherwise run off into the lake, Qiu (2009) found that such upland wetlands can be better at removing pollution than riparian buffers. Slowing the rise of the lake, which restored wetlands would do by storing precipitation, may also be more important than helping currently flooded landowners. Once the lake reaches the Tolna Coulee, it will spillover and flow into the Sheyenne River. The Sheyenne flows into the Red River which flows north to Canada. This is important because Devil's Lake has high concentrations of salts, especially sulfates. Canada does not want these salts polluting their waters. Also in the event of the Tolna Coulee being breached, the US Geological Survey has predicted the escaping lake water would erode the Coulee down to an elevation of 441 meters, allowing up to two million acre-feet of water to flow out of Devil’s Lake and into the Sheyenne (Larson, 2012). This gigantic rush of water could cause great damage to people and property downstream. This problem definitely merits more research.

# CHAPTER 3. EXPLORING THE FACTORS THAT AFFECT THE CONVERSION OF GRASSLAND INTO CROPLAND IN THE SHEYENNE RIVER BASIN[2]


## Abstract

The Conservation Reserve Program (CRP) was created as part of the 1985 Farm Bill. The Conservation Reserve Program is comprised of lands that were previously farmed and have been converted into native grassland or savannahs. The landowners are compensated by the US government for retiring this farmland because it provides wildlife habitat, reduces soil erosion, and improves water quality. Current commodity prices are giving farmers less incentive to renew their CRP contracts and many are deciding to instead farm those lands. This study aims to identify and quantify the economic and environmental factors that affect a landowner's decision to renew an expiring CRP contract or return the land to crop production in the Sheyenne River basin. The economic factors examined were crop prices and CRP rental payments. The ecological factors were slope of the land, distance to the nearest stream, and soil texture. The effect, positive or negative, and its magnitude on a landowner's decision to return grassland to production was modeled using a binary choice logit model Crop prices were shown to positively affect the probability of a parcel of grassland converting to cropland. The distance to streams variables showed that land that was located farther than 1/8 mile and closer than 5/8 mile was the most likely to return to production from conservation. Slope and soil texture variables carried inconsistent values throughout the watershed.


[2] The material in this chapter was co-authored by Daniel Margarit and David Roberts. Daniel Margarit had primary responsibility for collecting, and analyzing data. Daniel Margarit was the primary developer of the conclusions that are advanced here. Daniel Margarit also drafted and revised all versions of this chapter. David Roberts served as proofreader of the work conducted by Daniel Margarit.

## Introduction

The Conservation Reserve Program (CRP) was created as part of the 1985 Farm Bill. Its original purpose was to conserve soil resources and support agricultural commodity prices by taking cropland out of production and replacing it with native vegetation for 10 to 15 years. It has been renewed in every Farm Bill since then; however, its purpose has evolved over the years. The CRP is comprised of lands that were previously farmed and have been converted into native grassland, savannahs, or wooded land. The landowners are compensated by the US government for retiring this farmland because it provides wildlife habitat, reduces soil erosion, and improves water quality.

CRP fields are exceptional nesting habitats for wildlife. Best et al. (1997) found abundance of birds was from 1.4 to 10.5 times greater in CRP fields than row crop fields. CRP fields supported 3 times more nesting species, 13.5 times the total number of nests, and produced greater than or equal to 14 times more young birds than row crops (Best et al., 1997). This study was conducted over five years, and throughout six Midwestern states. These results over a wide region and time highlight how crucial CRP is to recovery and continuation of avian populations. The nesting rates were probably also underestimated due to the difficulty of locating nests in CRP lands (Best et al., 1997). One year later Best et al. (1998) published a paper looking at the same CRP and row crop lands, but over winter seasons. Widespread use of CRP fields by birds in the winter was documented and attributed to the presence of taller grasses and woody cover providing protection from the cold temperatures and providing easier access to food compared to row crop fields with a thick layer of snow covering them. Relative to row crops, CRP fields also showed a higher abundance of bird species historically experiencing long term population decline (Best et al., 1998). Thus, CRP lands are extra valuable in preserving avian biodiversity.

In agricultural landscapes, CRP can offer habitat for fawn-rearing, bedding, and foraging on alfalfa and sweet clover for white-tailed deer (Gould and Jenkins, 1993). White-tailed deer are a valuable game species, so promoting CRP can provide economic benefits. Hunting activities help fund wildlife agencies through deer tags, increase sales at outfitter stores, and promote the hospitality industry related to tourism. These benefits increase the return on investment the government makes through the CRP.

In the Midwest, perennial C4 grasses have been shown to reduce runoff, and thus reduce soil erosion, as well as nutrient and sediment loading in streams (Wilson et al., 2011). Five years after reestablishing grass on plots of sandy loam soil that had been cultivated for more than 60 years, total organic carbon and nitrogen, and potential net mineralized carbon and nitrogen in the top 10 cm of soil had increased to levels at least as high as those observed in a nearby native range (Reeder et al, 1998).

The 2014 farm bill cuts the maximum acres allowed in the program from 32 million to just 24 million over the next five years. This program cut has not been regarded as very detrimental, *per se*, because it is believed high agricultural commodity prices would have driven CRP enrollment down regardless (NSAC, 2014). Recently, high commodity prices increased farmers' short-term opportunity cost of renewing their CRP contracts, leading many to return those lands to agricultural use. Thus, the study of land use changes from grasslands to croplands is of special importance right now. From 2000 to 2012, prices of corn, soybeans, and wheat—the three most common crops in the Sheyenne River Basin (SRB)—have increased 232 to 305 %. Figure 6 shows annual average prices for these crops in North Dakota, in 2012 US dollars, from 2000 to 2014 (USDA, 2012). Commodity prices have declined substantially since 2012.

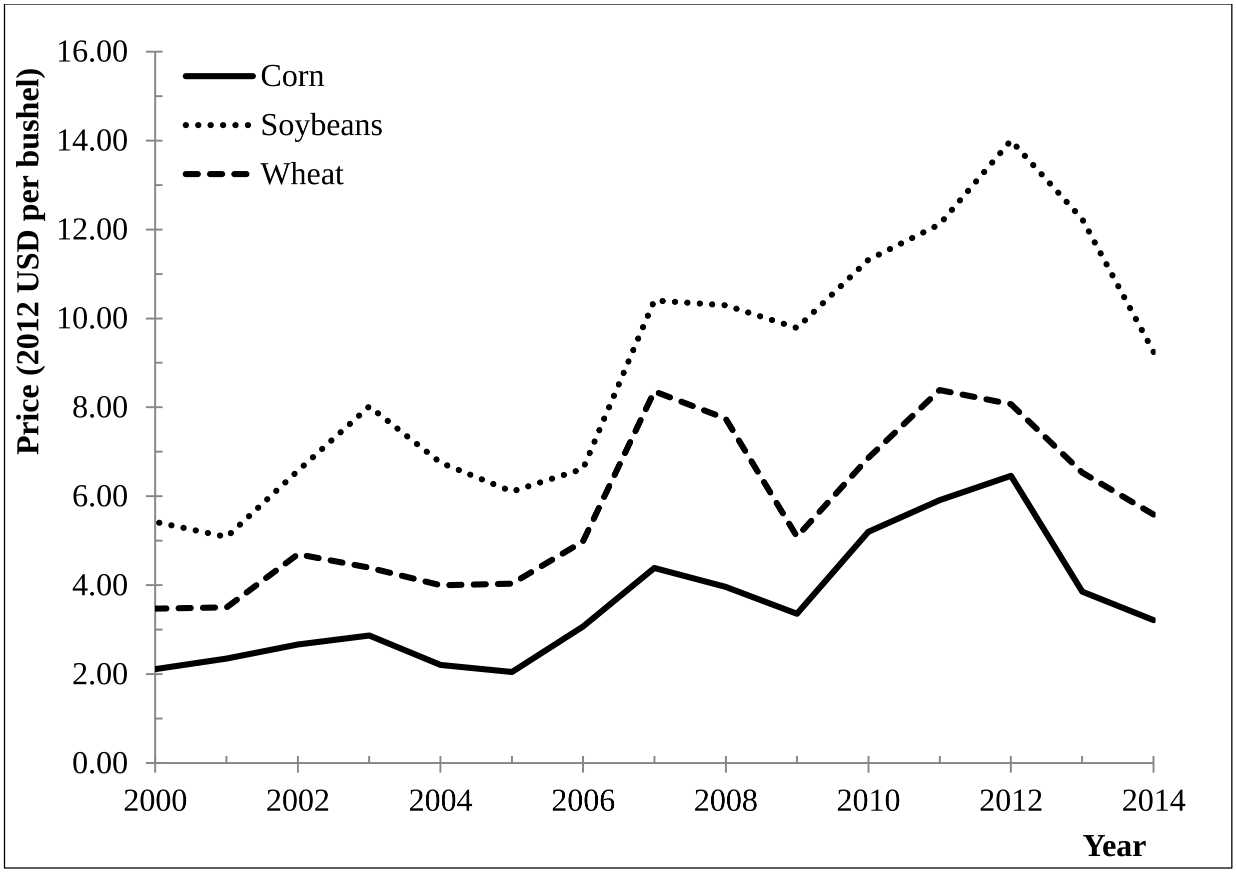


**Figure 6.** Annual average crop prices for corn, soybeans, and wheat in North Dakota from 2000 to 2014

Rising crop prices and higher farm subsidies may have similar impacts on farmers' land decisions, as both increase farm revenue. Feng et al. (2012) explored the effect of government crop insurance subsidies on the conversion of grassland—native or CRP—into cropland. Higher crop insurance subsidies, predictably, lead to a reduction in CRP enrollment. In a related study, Lant et al. (2005) argued for a different structure of government assistance, such as increased support for CRP-type programs. Crop insurance subsidies promote reduction in CRP and lower net benefits to society, whereas increasing CRP funding still provides economic support to farmers but a much higher net societal benefit (Lant et al., 2005). Hellerstein and Malcolm (2011) modeled the effects of rising crop prices on the quantity and quality of land accepted for enrollment in the CRP. They estimated that constant rental rates would cause enrolled acreage to greatly decrease. With moderate rental rate increases the program could still meet its goal of enrolling approximately 30 million acres; however, the remaining enrolled land will be less environmentally beneficial, as the government will have to accept lower quality land into the CRP. The process for enrolling land in the CRP entails the landowner presenting their land with a bid of how much they want to receive. Their land is rated on an Environmental Benefits Index, or EBI. With lower commodity prices the government is able to reject land bids for CRP with low EBIs and still accept enough bids with higher EBIs to meet their goal. With the drop in overall land bids however (due to high commodity prices), they will be forced to accept the lower quality land (land with lower EBI values) that they usually reject, to meet their goals. To keep environmentally beneficial land in retirement it may require almost doubling the rental rates (and, thus, current program costs) to compete with rising crop prices (Hellerstein and Malcolm, 2011).

At the end of their contract, CRP enrollees are faced with the decision of whether to leave their land in a grassland landscape providing ecological benefits, or to convert their land to agricultural production. This study aims to identify and quantify the economic and environmental factors that affect a landowner's decision to renew an expiring CRP contract or return the land to crop production in the SRB. The revealed ecological implications and economic determinants of the CRP will benefit policy makers who are debating the funding and structure of the CRP and other conservation programs in light of rising crop prices and current environmental conditions. The methods developed in this research, while directly applicable to the SRB, may be easily extended to any subbasin containing CRP lands or other privately owned grasslands, provided similar data are available for the specific locations.

## Conceptual Framework

It is important to consider the landowner's process of deciding whether to re-enroll land in the CRP. One primary consideration in the farmer's decision is the irreversible nature of program enrollment. The CRP uses multi-year contracts and severe financial penalties for early withdrawal to ensure that farmers remain enrolled long enough to establish adequate land cover, as land cannot not quickly be converted from field crops to ecologically active grassland and back again. Conceptually, data used by landowners making decisions about CRP enrollment include expected crop prices, CRP rental rates, land characteristics, and personal preferences, as illustrated in Figure 7. Past crop prices (combined with an opinion of where the market is heading) give the farmer an expectation of the revenue they could gain from planting crops. Because the CRP operates by assessing and selecting bids for land, given by landowners, the landowners know about how much they would bid for the land and thus have a good expectation of the revenue they could make in the CRP. Poor land characteristics may decrease yields and/or increase the effort and inputs required to achieve sufficient yields, thus decreasing expected profitability in agriculture, making CRP enrollment relatively more attractive. A farmer's land use choice for a particular parcel could be modeled as follows:

$$\max_{k \in K} E[\,NPV_{ik}] = \max_{k \in K} \left[\frac{E(R_{ik} - C_{ik})}{e^{\delta} - 1}\right] \quad (5)$$

where $\boldsymbol{NPV_{ik}}$ is the per acre NPV of land use *k* on parcel *i*, $\boldsymbol{R_{ik}}$ is the per acre revenue from land use *k* on parcel *i*, $\boldsymbol{C_{ik}}$ is the operating cost per acre for land use *k* in parcel *i*, $\boldsymbol{\delta}$ is the discount rate, and *K* is the set of all possible land use alternatives for parcel *i*. $\boldsymbol{R_{ik}}$ and $\boldsymbol{C_{ik}}$ are both functions of the characteristics of parcel *i*—frequency of flooding, soil salinity, soil type,

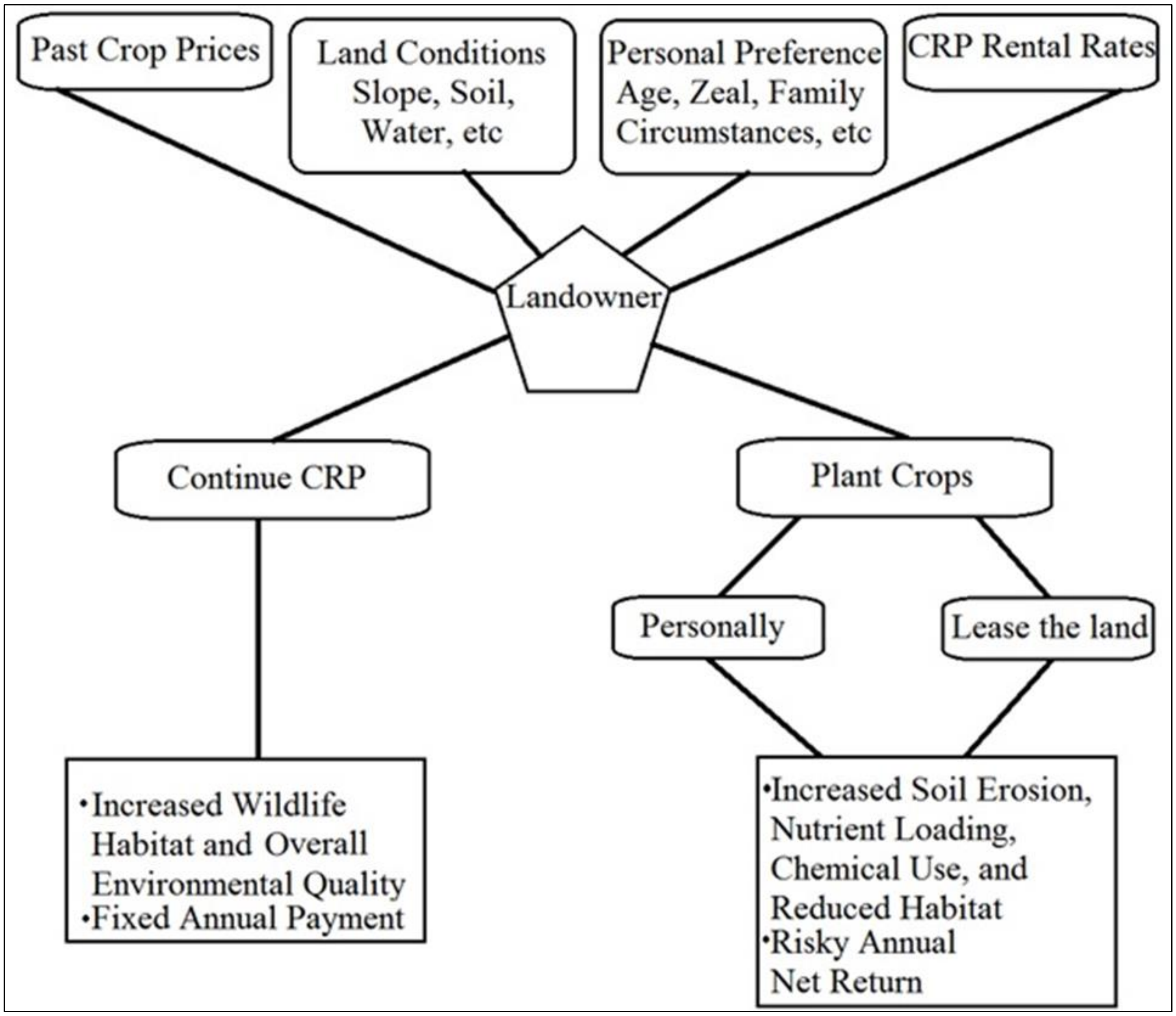


**Figure 7.** Schematic of a Landowner's CRP Reenrollment Decision Process and Outcomes

climate, etc.—as well as market variables like input and output prices. Another factor, which was not included in this research due to lack of data, is the personal preferences of the landowner. A farmer's age, passion for farming, non-farm income level, and desire to retire/relax all play an important role in the choice between agricultural use and conservation use. Information about farmer's preferences and personal characteristics can be difficult and expensive to procure through survey methods. The data sources used for the present research are publicly available free of charge. Ultimately, a landowner's decision results in one of two outcomes: (1) enrollment in CRP after a successful bid or (2) non-enrollment, either because the owner made no bid or made an unsuccessful bid.

## Study Area

The majority of the SRB is located within the Northern Glaciated Plains Level III Omernik Ecoregions, shown in figure 8 (Omernik and Griffith, 2008). Glacial processes left behind gently rolling hills, flat prairies, and many potholes which contain temporary and seasonal wetlands. The climatic conditions generate a transitional grassland between the tall and shortgrass prairie (Omernik and Griffith, 2008). Agriculture and game hunting are a central aspect of culture here due to the fertile soil and wildlife habitat. The Northwestern Glaciated Plains ecoregion is only present in the headwaters of the Sheyenne River. It is the westernmost boundary of glaciation and thus is composed of similar landscape heterogeneity with a high concentration of wetlands (Omernik and Griffith, 2008). It is a dryer climate but agriculture is still practical in this ecoregion. Conversely, on the eastern edge of the SRB, the Lake Agassiz Plain ecoregion begins about halfway across the Lower SRB. The region is very flat, as it was once the lakebed of the glacial Lake Agassiz. Thus, there are very few lakes and pothole wetlands (Omernik and Griffith, 2008). Before settlement it consisted of wide ranges of tall grass prairie, which is now mostly farmed.

In the year 2013, cropland comprised 51.2% of the basin’s area, and developed land covered only 0.4%. Water and fallow land was 3.8% and 6.3% of the total basin, respectively. The remaining land—considered conservation-type land for this research—entails forest land, wetland, grassland, etc., claimed the remaining 38.3% of the SRB (USDA, 2014).

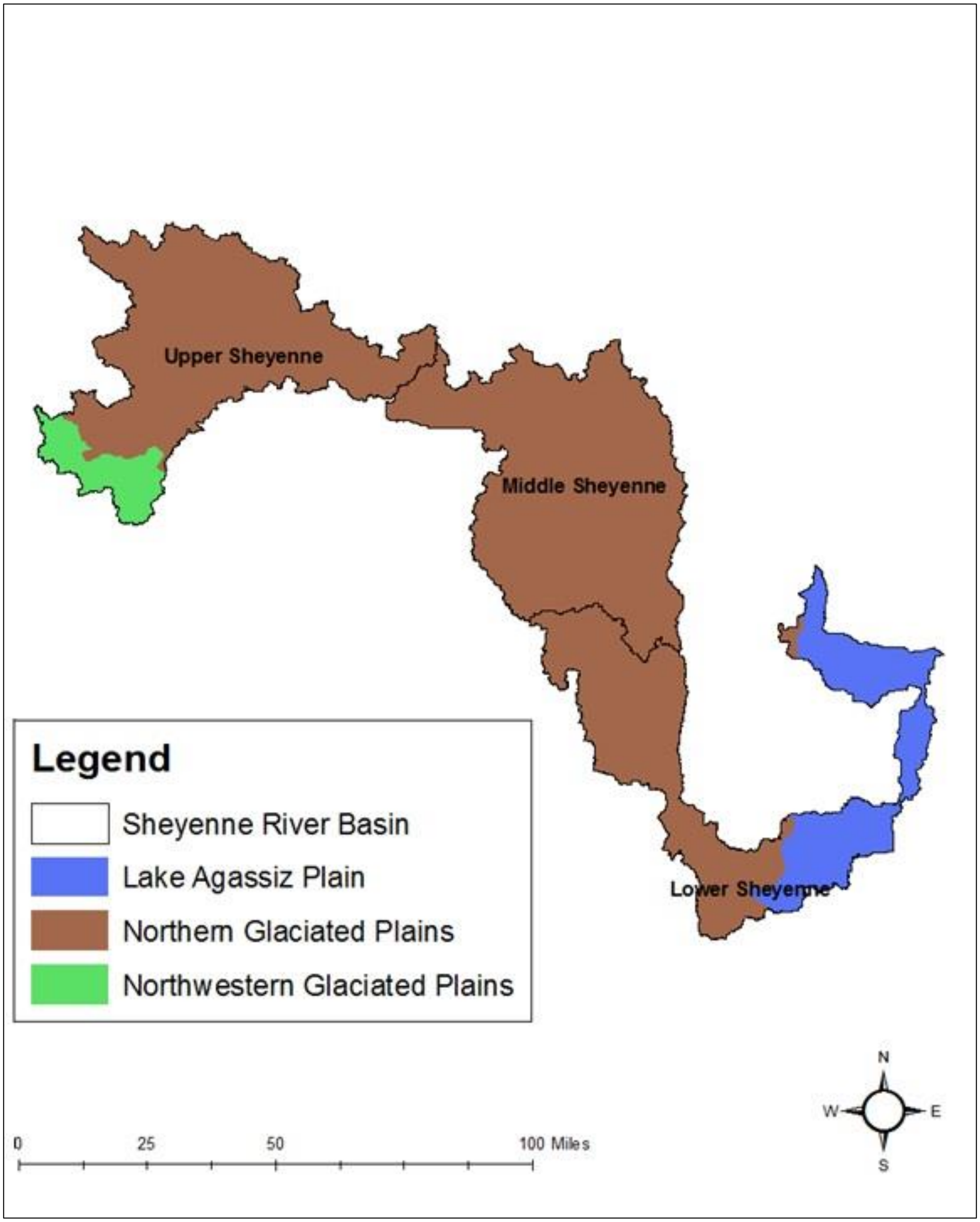


**Figure 8.** Level III Omernik Ecoregions of the Sheyenne River Basin

Though traditionally an agricultural state, North Dakota has seen a shift in demographics due to the oil boom in the west, and the growth in Fargo in the east. Overall demographics of North Dakota were compared to three counties in the SRB: Sheridan in the Upper Sheyenne, Griggs in the Middle Sheyenne, and Ransom in the Lower Sheyenne. As of the most recent census in 2010, the State of North Dakota has almost 673,000 people. Median household income is $53,741 and the percentage of the population 65 years of age and older is 14.2% (US Census Bureau, 2010). In Sheridan county, 30.2% of the population is 65 years or older. For Griggs, the proportion is 28.7% and Ransom is 20.4%. This is important because the CRP might be more attractive to an aging population young people who could be potential farmers. Median household income in the three counties is slightly lower than the state average; anywhere from around $43,000 to $49,000.

In 2012, the mean farm size in North Dakota was 1,268 acres, median farm size was 480 acres (USDA, 2012). The average market value of agricultural products sold per North Dakota farm in 2012 was $353,693 (USDA, 2012). In Griggs County, the mean and median farm sizes were 977 and 437 acres, respectively, and the average market value of agricultural products sold was $280,324 (USDA, 2012). Ransom County had a mean farm size of 915 acres, and median size of 269 acres (USDA, 2012). The average market value of agricultural products sold per farm in Ransom County in 2012 was $327,127 (USDA, 2012). Finally, in Sheridan County during 2012, mean farm size was 1,388 acres, median farm size was 565 acres, and average market value of agricultural products sold per farm was $291,294 (USDA, 2012). Sheridan County was the only one with farms larger than the state average, and Ransom County had the smallest farms. Yet, Ransom County also produced the highest mean value of output for the three counties discussed, despite being less than the state average. It can be assumed, all else constant, that farmers in counties producing less valuable output would be more likely to enroll land in the CRP than counties with more productive land.

## Data

First, the land use data for years 2003 to 2013 was downloaded from Agricultural Statistics Service's (NASS) Cropland Data Layers (CDL) (Han et al, 2014) through the USDA's *Cropscape* portal. This raster data was clipped to a polygon of the SRB, which was downloaded from the North Dakota GIS website. The SRB is found in the Devil's Lake-Sheyenne Basin (HUC 090202) and comprised of three subbasins: the Upper Sheyenne (HUC 09020202), Middle Sheyenne (HUC 09020203), and Lower Sheyenne (HUC 09020204) (USGS and NRCS 2012). Table 1 shows the top five land covers of the SRB by area.

A shapefile that contained all the streams in the SRB was downloaded from the NDGIS hub data portal (USGS, 2008), and used to create the "distance to streams dummy variables." Dummy variables were used to allow for comparison between different distances. The dummy variables also allowed for a non-linear relationship between odds of a grassland parcel entering production and distance of that parcel to the nearest stream.

**Table 1**. Top Five Land Use Classifications in the Sheyenne River Basin by Year, Rank, and Proportion of Total Area within the Basin

| | Ranked Cropland Data Layer Land Use Classifications | | | | |
|---|---|---|---|---|---|
| Year | First | Second | Third | Fourth | Fifth |
| 2013 | Soybeans (0.245) | Grass/Pasture (0.243) | Corn (0.134) | Spring Wheat (0.097) | Herbaceous Wetlands (0.084) |
| 2012 | Grassland Herbaceous (0.257) | Soybeans (0.228) | Corn (0.125) | Spring Wheat (0.107) | Herbaceous Wetlands (0.083) |
| 2011 | Grassland Herbaceous (0.254) | Soybeans (0.228) | Spring Wheat (0.141) | Wetlands (0.117) | Corn (0.06) |
| 2010 | Soybeans (0.210) | Pasture/Hay (0.144) | Spring Wheat (0.139) | Grassland Herbaceous (0.119) | Pasture/Grass (0.094) |
| 2009 | Soybeans (0.203) | Pasture/Hay (0.176) | Spring Wheat (0.143) | Grassland Herbaceous (0.125) | Wetlands (0.077) |
| 2008 | Pasture/Hay (0.208) | Soybeans (0.189) | Spring Wheat (0.145) | Grassland Herbaceous (0.131) | Corn (0.081) |
| 2007 | Grassland Herbaceous (0.301) | Spring Wheat (0.146) | Soybeans (0.145) | Wetlands (0.120) | Corn (0.088) |
| 2006 | Pasture/Grass (0.342) | Soybeans (0.195) | Spring Wheat (0.180) | Wetlands (0.072) | Corn (0.045) |
| 2005 | Pasture/Grass (0.295) | Spring Wheat (0.183) | Soybeans (0.152) | Fallow/Idle Cropland (0.103) | Corn (0.054) |

Note: Numbers in parentheses indicate the proportion of the watershed in the land use classifications above them.

The Natural Resources Conservation Service's (NRCS) Soil Survey Geographic Database (SSURGO) (Soil Survey Staff, NRCS, 2007) was downloaded from the USDA's Web Soil Survey with only the "map unit" as an attribute. The accompanying Microsoft access file was used to match soil textures to each map unit. The soil map units were generalized down to nine different classifications based on texture. The colorized soil textural triangle in Figure 9 shows which soil textures were merged with each other (Shirazi & Boeersma, 1984). The triangle shows seven categories; the other two were "very stony" and "complex." Complex is a combination of two or more soil types.

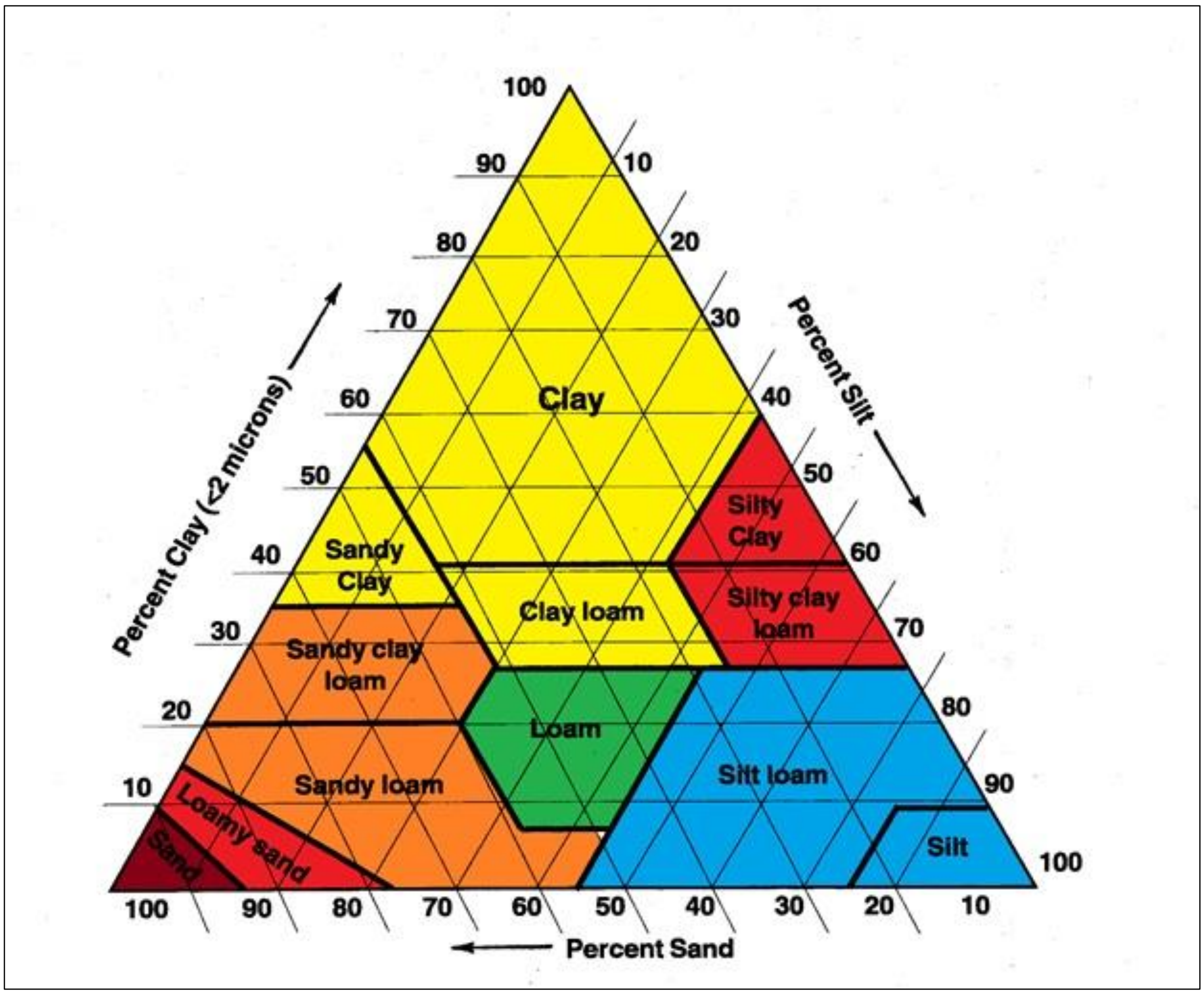


**Figure 9.** Soil Textural Triangle (Shirazi & Boersma, 1984)

A shapefile of the counties of North Dakota, downloaded from the NDGIS hub data portal to give each parcel an attribute showing what county it falls in (US Census Bureau, 1994). The 30m, 1 arc-sec Shuttle Radar Topography Mission (SRTM1) elevation dataset was downloaded from webgis.com and used to calculate the average slope, in degrees, for each parcel (USGS, NASA, & NGA, 2009).

The effect of crop prices on land use change was included in the model in the form of a crop price index. Crop price and yield data was downloaded from USDA's NASS's Quick Stats 2.0 database (USDA, 2012) and a crop revenue index was created for each county. The revenues (price times yield), of the most common crops in the SRB, were weighted by their respective acreage in the SRB, and then summed together to create a basket of crop revenues. This basket was indexed to the year 2012. The average of all the counties is shown in Figure 10.

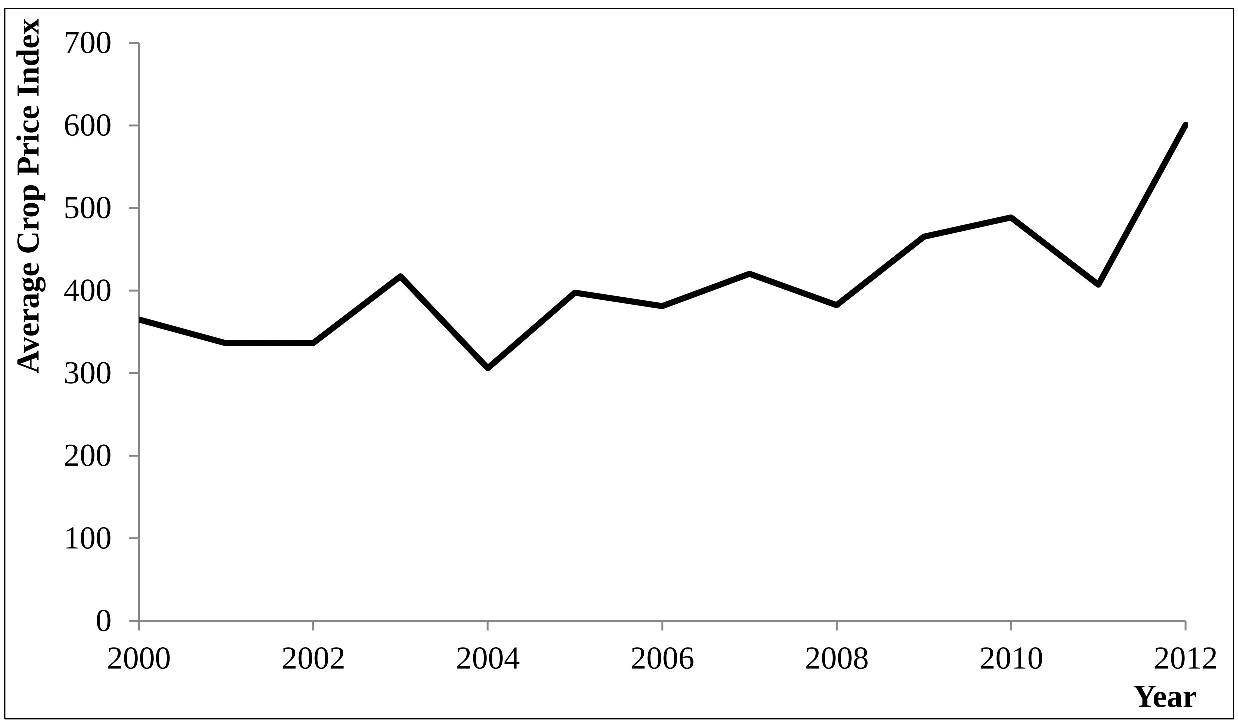


**Figure 10.** Average Crop Price Index across the Sheyenne River Basin, 2001-2012

## Methods

Economic factors examined included crop price level and CRP rental payments, while ecological factors were slope of the land, distance to the nearest stream, and soil texture. The effect, positive or negative, and its magnitude on a landowner's decision to return grassland to production was modeled using a binary choice logit model. The basin was separated into three subbasins, the Upper, Middle, and Lower Sheyenne River subbasins. This was to decrease the computational requirements of the logit models as each subbasin had large panel datasets.

A panel dataset was created that contained, for each cross-sectional unit, 11 years of data including; county name, average slope, soil texture, distance to the nearest stream, and land use data. A "distance to streams" variable was created by using the *multi-ring buffer* tool on a shapefile that contained all the streams in the SRB (this shapefile was downloaded from the NDGIS hub data portal). Eight buffers were created, one for every 1/8 of a mile away from the stream. A shapefile of the counties of North Dakota, downloaded from the NDGIS hub data portal, was intersected to the master layer giving each parcel an attribute showing what county it falls in. The spatial analyst tool *slope* was used to convert the elevation raster into a raster where each pixel value was the average slope, in degrees, inside that pixel.

To run the models a binary variable was created to specify whether the land went out of grassland and into cropland (1) or not (0). Columns summarizing landuse were created for each year. For example a parcel's attribute in column LU00 would be "1" for grassland, wetland, forest, or other non-crop vegetation in the year 2000. It would be a "2" if the landcover was cropland in 2000 and "0" if the landcover was developed, water, barren, or no-data, in the year 2000. Thus the binary variables were calculated based on the generalized landuse columns. A parcel that registered a "1" for five years and then registered a "2" on the sixth and seventh year was given a 1 in the “outofgrass” binary variable column; otherwise it registered a “0”. In order to more effectively target CRP lands, the parcels had to be in grassland for at least five years prior to the year in question. Parcels also must have switched to cropland for at least two years. This was to decrease the probability of false positives due to remote sensing/classification errors.

Once the data was compiled in Arcmap, it was imported into SAS to run a logit model on the probability of conversion from grassland of at least five years to cropland of at least two years. The data, which contained 11 years of landuse data for each parcel, was converted into panel data. Each cross-sectional unit, the parcel, had 11 entries in the database, one for each year. Once the data was organized in SAS a Binary Logit model was run. The explanatory variables, were lagged crop price index values, lagged CRP rental price index values, average slope of the parcel (in degrees), soil texture dummies, and distance to the nearest stream dummies.

A binary logit model is preferable to any linear probability model for three reasons. The linear probability model; has a heteroskedastic error term, the error term is not normally distributed, and the predicted probabilities can be greater than one and less than zero (it is not bounded by zero and one like a logistic regression) (A.S.U., nd). This study deals with a binary output Y (into grass = 1 or 0). The logit model allows us to model the conditional probability P(Y=1|X=x) as a function of x; all parameters of the function (in this case crop prices, slope, soil types, etc). These parameters are estimated by maximum likelihood estimation. For each training data point we have a vector of features $x_i$ and an observed class $y_i$. The probability of that class was either “P” if $y_i$=1 or “1-P” if $y_i$=0. Then by differentiating the likelihood function with respect to the parameters a maximum can be found and the associated parameters will be appropriate for the model (Faraway, 2006). This was conducted for all three subbasins in SAS and the results are compared below.

## Results and Discussion

The Logit model was estimated for the entire SRB, and also separately for each of the subbasins—the Upper Sheyenne (HUC 09020202), Middle Sheyenne (HUC 09020203), and Lower Sheyenne (HUC 09020204). The results are shown below in Table 2.

Crop covers were also summarized for the parcels that converted from grassland to cropland to find what crops were most common on land that had previously been grassland. These values for the years 2005-2012 are shown below in Table 3.

As expected, crop prices positively affect the probability of a parcel of grassland converting to cropland. Lagged crop prices and CRP rental rates were used because landowners generally plan ahead when deciding what to do with their land. They do not know what the prices of crops or CRP payments will be when they decide what to do. They only know the past prices, so lagged crop price levels and CRP rental payments were relevant as proxies for farmers' expectations. The structure of the CRP enrollment could offer an explanation for the unexpected signs on the CRP rental rate variables. The enrollment is a competitive bidding process among landowners. In their application they analyze the environmental quality of their land, calculating an environmental benefits index or EBI, score and bid how much they would be willing to accept as a rental payment. Thus the rental payments are not equal across the board for all landowners as is the case with the crop prices. The site specific variables may actually describe the relationship between CRP rental rates and renew better. Slope of the land, soil type, and distance to nearest stream are factors that affect the EBI score directly and indirectly. An increase in erosion potential increases the EBI score for a given parcel of land (USDA, Farm Service Agency, 2011). The closer the land is to water the higher its EBI score is ceteris paribus (USDA, Farm Service Agency, 2011).

**Table 2.** Binary Logistic Regression Models for the Upper, Middle, and Lower Subbasins and for the Entire Sheyenne River Basin of the Sheyenne River Basin, Probability of Converting from Grassland to Cropland

| Parameter | Entire Basin | Subbasin | | |
|---|---|---|---|---|
| | | Upper Sheyenne | Middle Sheyenne | Lower Sheyenne |
| Intercept | -5.972 (0.013) | -6.227 (0.034) | -5.566 (0.043) | -4.551 (0.046) |
| Crop Index Lag1 | 0.002 (0.000) | 0.002 (0.000) | 0.003 (0.000) | 0.002 (0.000) |
| Crop Index Lag2 | 0.001 (0.000) | 0.0005 (0.000) | 0.001 (0.000) | 0.001 (0.000) |
| CRP Rate Lag1 | 0.010 (0.000) | 0.007 (0.000) | 0.021 (0.000) | -0.003 (0.000) |
| CRP Rate Lag2 | -0.008 (0.000) | 0.002 (0.000) | -0.016 (0.000) | -0.004 (0.000) |
| Average Slope | -0.128 (0.000) | 0.020 (0.003) | -0.166 (0.002) | -0.296 (0.003) |
| Loam | 0.333 (0.005) | 0.379 (0.010) | 0.109 (0.008) | 0.593 (0010) |
| Loamy Sand | 0.258 (0.008) | 0.289 (0.014) | 0.111 (0.015) | 0.580 (0.016) |
| Sand | -1.376 (0.026) | -1.301 (0.035) | -1.586 (0.082) | -1.125 (0.044) |
| Sandy Loam | 0.314 (0.008) | 0.414 (0.014) | 0.287 (0.011) | 0.312 (0.016) |
| Clay Loam | -1.490 (0.278) | -1.289 (0.278) | Not Present | Not Present |
| Silt Loam | 0.027 (0.013)* | -0.419 (0.035) | -0.022 (0.018)† | 0.101 (0.021) |
| Silty Clay Loam | -0.353 (0.012) | -0.218 (0.028) | -0.834 (0.021) | -0.162 (0.018) |
| Very Stony | -1.423 (0.087) | -1.282 (0.102) | -1.381 (0.167) | Not Present |
| Stream 1 | -0.353 (0.008) | -0.621 (0.016) | -0.391 (0.011) | -0.012 (0.014)† |
| Stream 2 | 0.096 (0.007) | -0.125 (0.014) | 0.015 (0.011)† | 0.442 (0.014) |
| Stream 3 | 0.282 (0.007) | 0.201 (0.014) | 0.113 (0.011) | 0.650 (0.014) |
| Stream 4 | 0.328 (0.008) | 0.336 (0.015) | 0.106 (0.011) | 0.672 (0.015) |
| Stream 5 | 0.331 (0.008) | 0.440 (0.015) | 0.061 (0.012) | 0.610 (0.016) |
| Stream 6 | 0.244 (0.009) | 0.370 (0.017) | -0.063 (0.014) | 0.503 (0.018) |
| Stream 7 | 0.090 (0.010) | 0.266 (0.019) | -0.271 (0.016) | 0.334 (0.020) |

Notes: Numbers in parentheses are standard errors. An asterisk (*) indicates statistical significance at α-level 0.05, while the dagger (†) indicates statistical insignificance. All other parameter estimates are statistically significant at α-level 0.01 or better.

**Table 3.** Top Five Crops Replacing Grassland in Each Subbasin Each Year from 2005 to 2012

| | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rank | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | 2006 | 2005 |
| Upper Sheyenne River Subbasin | | | | | | | | |
| 1 | Soybeans | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Other small grains |
| 2 | Corn | Soybeans | Soybeans | Soybeans | Soybeans | Corn | Soybeans | Spring wheat |
| 3 | Spring wheat | Alfalfa | Alfalfa | Corn | Sunflower | Alfalfa | Sunflower | Alfalfa |
| 4 | Alfalfa | Corn | Corn | Oats | Corn | Sunflower | Barley | Canola |
| 5 | Flaxseed | Sunflower | Canola | Alfalfa | Barley | Winter wheat | Corn | Sunflower |
| Middle Sheyenne River Subbasin | | | | | | | | |
| 1 | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Other small grains |
| 2 | Corn | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Alfalfa |
| 3 | Spring wheat | Alfalfa | Corn | Corn | Corn | Corn | Alfalfa | Spring wheat |
| 4 | Alfalfa | Corn | Alfalfa | Winter wheat | Winter wheat | Alfalfa | Corn | Soybeans |
| 5 | Sunflower | Winter wheat | Canola | Dry beans | Sunflower | Winter wheat | Barley | Corn |
| Lower Sheyenne River Subbasin | | | | | | | | |
| 1 | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans | Soybeans |
| 2 | Corn | Corn | Corn | Corn | Corn | Corn | Spring wheat | Corn |
| 3 | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Spring wheat | Alfalfa | Alfalfa |
| 4 | Alfalfa | Alfalfa | Alfalfa | Alfalfa | Alfalfa | Alfalfa | Corn | Spring wheat |
| 5 | Winter wheat | Winter wheat | Dry beans | Winter wheat | Winter wheat | Winter wheat | Barley | Other small grains |

Soil type also affects the type and success of vegetative cover, which is the biggest factor in determining the EBI (USDA, Farm Service Agency, 2011). Finally land closer to streams is considered better habitat and more likely to be included in "Wildlife Priority Zones" which increases the land's EBI score (Coleman (2007), DeCecco & Brittingham (2011), and USDA, Farm Service Agency, 2011).

The coefficient for the average slope of the parcel is positive for the Upper subbasin, but is negative for the Middle and Lower subbasins, and for the overall SRB. Thus, in the Upper subbasin, the steeper the average slope of the parcel, the higher chance it converts to crop production. A negative coefficient, as was found in the middle, and lower subbasins, and in the overall SRB, was expected because it was assumed that farmers would rather bring back more level land to farm, as opposed to sloping land which is less preferable to farm. The positive coefficient in the Upper subbasin might be attributable to the fact that the average slope of the land in the Upper subbasin is less than the overall SRB (2.05 degrees in the Upper subbasin vs 2.30 degrees in the SRB as a whole). Of the Upper subbasin, the more steeply sloping land would be marginal farmland that was previously put into the CRP or left fallow due to low yields, but now is being converted to agricultural use in response to increased commodity prices.

The magnitudes of the effects of soil texture variables were found to differ slightly from subbasin to subbasin, but every soil texture indicator had the same sign (positive/negative) across the three subbasins, except the silt loam indicator. When compared to the "complex" soil texture, loam, sandy loam, and loamy sand were always positively correlated with a return to production. Sandy, clay loam, silty clay loam, and very stony were negatively correlated with a return to production in all four models. These variables can be explained by soil agricultural properties. Sandy soils retain less moisture and plant available nutrients, so they are less desirable for agriculture (DuPont & Beegle, 2012). The loamy soils have more silt and clay, which can hold more vital nutrients and drain slower (DuPont & Beegle, 2012). Clay loam, and silty clay loam, although loams, would tend to contain more silt and clay than the other loams (DuPont & Beegle, 2012). Thus although they may have a higher capacity to store plant nutrients, they may drain too slowly. Clayey soils can also be difficult for plant roots to penetrate, reducing their potential for agriculture (DuPont & Beegle, 2012). “Very stony” soils are soils containing rocks with a diameter of 10 or more inches that interfere with or prevent tillage (USDA, NRCS, 2014). These would not be soils suitable for conversion to agricultural production. The effects of the silt loam variable differed amongst subbasins and the overall watershed. In the Upper and Middle subbasins it was a positive effect (however the variable was insignificant in the middle subbasin logit model with a p-value of 0.2122) and in the lower subbasin and overall watershed, the variable had a negative effect.

In general, the distance to streams variables showed that grasslands located between 1/8 mile and 5/8 mile were the most likely to return to production in the SRB overall. Grasslands between 1/4 mile and 5/8 mile from surface water were consistently most likely to convert from grassland to cropland across the individual subbasin models. It is important to note that land less than 1/8 of a mile (660 ft.) from surface water is not converting to cropland at a high rate. This could be because flood risk on these lands is high enough that the risk-adjusted cost/benefit ratio doesn’t support cropping it. Another possible explanation for the negative coefficient for land within 1/8 of a mile of streams is that many streams run through wetlands. These wetland areas are protected and it is difficult and sometimes impossible to farm them. The Wetland Conservation Compliance provision was added to the 1985 Farm Bill to remove incentives to convert wetlands to agricultural production (USDA, NRCS, n.d.). Thus there is a smaller chance these wetland areas would be converted to farmland, providing more support for the negative coefficient. This result is also noteworthy because perennial grasses on the land closest to surface water reduces soil erosion and improves water quality. In addition, Coleman (2007) and DeCecco & Brittingham (2011) both recommend at least a 300 ft. buffer for wildlife habitat purposes around streams.

The most common crops replacing grassland were spring wheat, soybeans, corn, and alfalfa, as shown in Table 3. Soybeans were more common in the Middle and Lower subbasins, while spring wheat was the most common six out of eight years in the Upper subbasin. Corn was less likely to replace grassland in the Middle subbasin compared to the Lower subbasin and even less in the Upper subbasin.

The biofuel use mandate, set forth by President Bush in 2005, and the Renewable Fuel Standard in the Energy Independence and Security Act of 2007, have greatly increased the production of US ethanol and demand for corn (Jekanowski and Vocke, 2013). Meanwhile China's increasing demand for meat products has also positively affected the market for US soybeans (Jekanowski and Vocke, 2013). China has become the world's biggest importer of soybeans for livestock feed purposes. This has helped increase the price of soybeans here in the US and globally (Jekanowski and Vocke, 2013). Wheat prices have also grown over the last decade; however, that growth may slow in the coming years as many other countries have begun to export wheat globally, including Argentina, Australia, Canada, Ukraine, Russia, and Kazakhstan (Jekanowski and Vocke, 2013). This does not prove that landowners are bringing land out of retirement because of the rising demand for these crops, but it is an interesting correlation. The remaining alfalfa could be increasing due to the global increase in demand for meat, led by developing nations such as China and India. There is also the possibility that, due to its similar vegetative structure to prairie grasses, it could be mis-classified in the CDL when the land cover maps are created and processed.

## Conclusions

This study has quantified the effects of market variables and land characteristics on a landowner's decision to bring retired cropland back into production in the SRB. Higher crop prices and low CRP rental rates are inducing landowners to crop even some marginally productive lands that were previously in long-term grass cover. This is a pressing issue due to the wildlife, soil quality, and water quality benefits lost as a result of this land use change.

The results show site-specific variables (soil type, average slope, and distance to streams) have greater effects, positive or negative, on the probability of grassland returning to production, than market conditions (crop prices and CRP rental rates). This highlights the importance of targeted conservation efforts. Even during market conditions that are not conducive for retiring land from agriculture production, targeted-type programs can concentrate funds on only conserving a limited area or land type. This will maximize the environmental benefits received, given budgetary constraints or caps on total enrollment. An example of a targeted conservation program is the Conservation Reserve Enhancement Program (CREP). CREP is voluntary program, administered by the same organization that oversees the CRP, the Farm Service Agency (FSA). For different CREP initiatives, the FSA partners with different local governments, tribal governments, or non-governmental organizations to address a specific conservation issue (USDA, FSA, nd). CREP offers contracts from 10-15 years for land that meets certain criteria set by these partnerships. These contracts are not bid on; as long as the land falls within the targeted characteristics it is automatically accepted for enrollment. The landowner is paid a federal annual rental rate, including an FSA state committee-determined maintenance incentive payment, plus cost-share of up to 50% of the eligible costs to install the practice (USDA, FSA, nd ). Programs such as CREP, which target specific lands, may be more efficient than the CRP at achieving specific conservation goals.

State and local governments will be interested in these results because they will most likely want to promote private conservation. Conservation will benefit local economies by increasing hunting opportunities and associated revenue (Bangsund et al., 2004). It will also improve the local surface water supply which is healthier for the citizens and reduces the cost of filtering it for consumption (Wilson et al, 2011). The federal government will be concerned with the implications of this research for the CRP, which is a federal program. Legislators and other policy makers may wish to account for crop price volatility when debating how to fund the CRP to promote stable enrollment of lands that provide environmental benefits targeted to local conditions. For example, in the 2014 Farm Bill there was increased support for more directed conservation efforts—particularly towards wetlands, natural areas threatened by urban development, and lands under soon-to-expire CRP contracts—under the new Agricultural Conservation Easement Program (ACEP) (NSAC,2014). ACEP is one solution to the decreasing supply and quality of land being put into conservation use. The program is cost-effective because it targets conservation on the lands that will provide the most ecological benefits per dollar, such as wetlands and established restored prairies. Results from studies like this one support the continued financial support for conservation programs such as the CRP and ACEP.

This research would be useful to non-governmental organizations who are in favor of conservation, such as Ducks Unlimited or The Nature Conservancy. It helps to highlight the importance of educating the public on the benefits of conservation. While money is tough to argue against, some landowners might consider the ecological benefits if they were more educated about the ecological benefits of grasslands. This could partially mitigate the effect of rising crop prices on rates of grassland to cropland conversion.

Examining which crops are more likely to replace grassland helps policy makers track agricultural trends that affect grassland conversion. By analyzing these trends they can make more informed decisions knowing what other factors are causing this conversion and how best to work with these exogenous factors.

This model did not take into account any social factors such as age of landowners, occurrence of non-farm income, whether landowner farms or rents the land to farmers, social attitudes towards farming, etc. These social factors would make a much more complete model, and would be a great opportunity for future research. Again tying in all the costs and benefits of the CRP in a comprehensive study would be a great topic for additional research.

Another avenue to continue the analysis of grassland changing into cropland would be to examine water quality before and after land use change. Previously cited authors have outlined the positive effects of conservation on water quality but quantitative information, specific to the SRB would be beneficial to state and local North Dakota governments.

# CHAPTER 4. ECONOMIC COSTS OF INCREASED SEDIMENTATION DUE TO LAND USE CHANGE IN THE SHEYENNE RIVER BASIN[3]


## Abstract

The Conservation Reserve Program (CRP) was created as part of the 1985 Farm Bill. The landowners are compensated by the US government for retiring this farmland because it provides wildlife habitat, reduces soil erosion, and improves water quality. Current commodity prices are giving farmers less incentive to renew their CRP contracts and many are deciding to instead farm those lands. Thus the study of land use changes from grasslands to croplands is of special importance right now. Corn, Soybean, and Wheat prices, three of the most common crops in the Sheyenne River basin, have increased 300 to 400%. The purpose of this study is to estimate the increase in sediment loading due to changes in CRP enrollment, and then value the cost to society of the increased sedimentation. This will be accomplished by creating a SWAT model of the Sheyenne River, upstream of the Baldhill dam and Lake Ashtabula in North Dakota. After a sufficient model is formed, future and hypothetical land use datasets will be substituted into the model. By holding all other inputs and parameters equal, it will be possible to isolate the effect of changing land use on sediment loading. Every ton of sediment entering the Sheyenne River costs society an estimated $2.40. The model estimated 1,218.36 tons of sediment entered the river from the study area in 2005. Given the same climatic conditions, and using the landcover conditions present in 2014, an estimated 1,661.4 tons of sediment would have entered the Sheyenne River across the study area. There was a 36% increase in sedimentation while the


[3] The material in this chapter was co-authored by Daniel Margarit and David Roberts. Daniel Margarit had primary responsibility for collecting, and analyzing data. Daniel Margarit was the primary developer of the conclusions that are advanced here. Daniel Margarit also drafted and revised all versions of this chapter. David Roberts served as proofreader of the work conducted by Daniel Margarit.

net conversion of grassland to cropland from 2005 to 2014 was 3%. Increases were smaller for the hypothetical scenarios, most likely due to ignoring urbanization in the hypothetical scenarios.

## Introduction

The Conservation Reserve Program (CRP) was created as part of the 1985 Farm Bill. Its original purpose was to conserve soil resources and reduce agricultural surpluses by contracting with farmers to convert productive cropland to native vegetation for 10 to 15 years. It has been renewed in every Farm Bill since then, though the program's objectives have evolved over time to heavily target lands that can provide environmental benefits. Landowners are compensated by the US government for retiring this farmland because it provides wildlife habitat, reduces soil erosion, and improves water quality. CRP fields are excellent nesting habitats for birds. In the Midwest, perennial C4 grasses have been shown to reduce runoff and, thereby, reduce soil erosion and sediment loading in streams (Wilson et al, 2011). This is accomplished by increasing the interception of precipitation and providing a permanent, deep root structure to help hold soil in place.

The 2014 farm bill cuts the maximum acres allowed in the program from 32 million to 24 million over the next five years. However, this cut is not regarded as that detrimental to program goals because it is believed high agriculture prices would have driven enrollment down regardless (NSAC, 2014). Commodity prices were strong from 2009 to 2012, giving farmers less incentive to renew CRP contracts due to high expected returns in agriculture. CRP contract acres have been trending downward in ND as a whole since 2007, Figure 11 (USDA, FSA, 2015). Thus, the study of land use conversion from grasslands to crop production is of special importance right now. Nationally, corn, soybean, and wheat prices—the three most common crops in the SRB—have increased 300-400%, Fig. 12 (Jekanowski & Vocke, 2013).

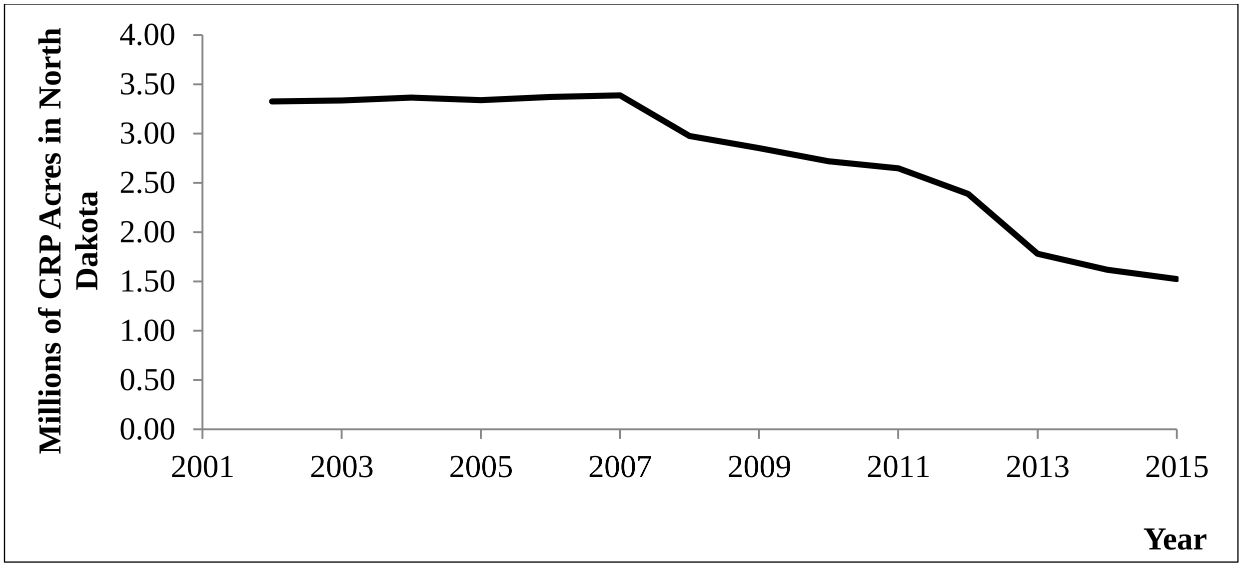


**Figure 11.** Millions Conservation Reserve Program Acres in North Dakota

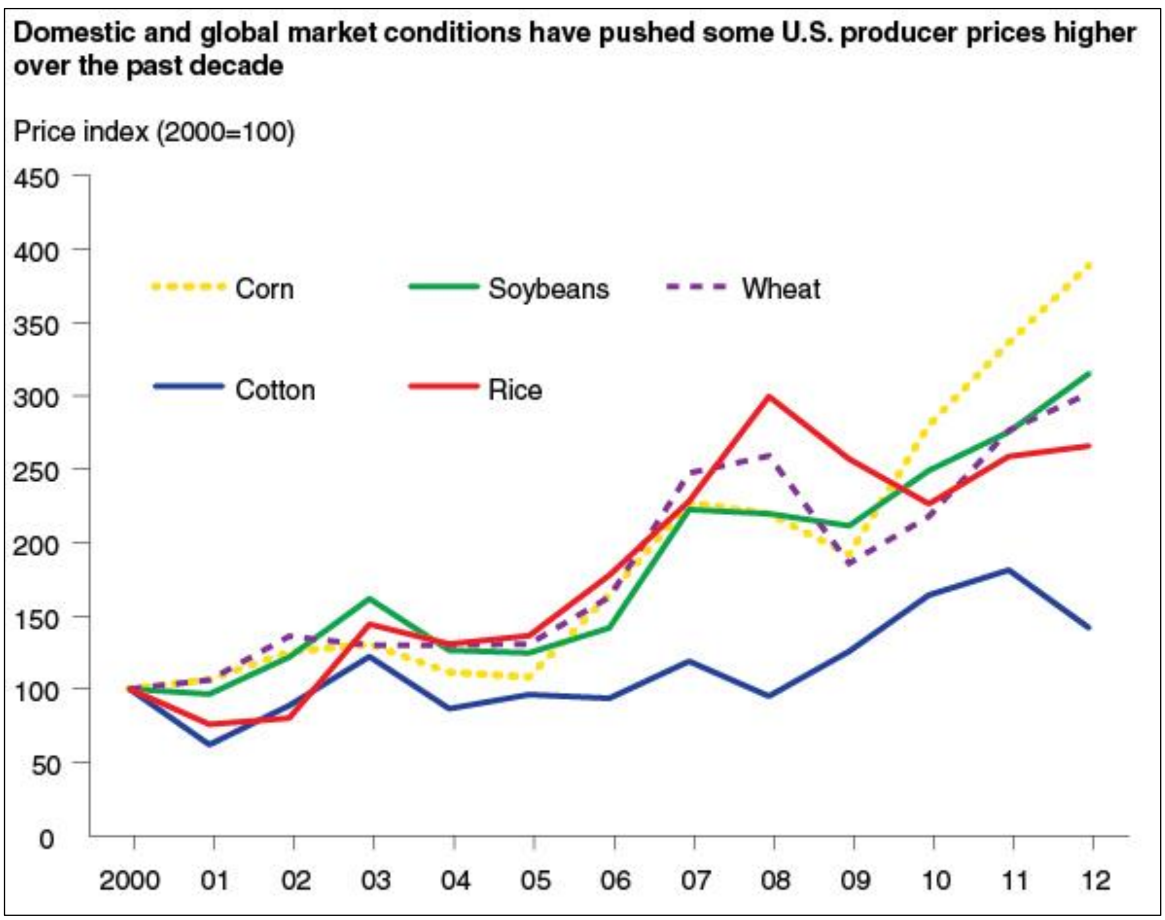


**Figure 12.** Price Indices for Corn, Soybeans, Wheat, Cotton, and Rice (Jekanowski & Vocke, 2013)

The purpose of this study was to estimate the increase in sediment loading attributable to grassland conversion into cropping systems, and then to value the cost to society of the increased sedimentation. This was accomplished by creating a Soil and Water Assessment Tool (SWAT) model of the Sheyenne River, upstream of the Baldhill dam and Lake Ashtabula in North Dakota (Figure 13). The Baldhill dam is located 12 miles northwest of Valley City, ND (USACE, 2015). The dam is located on the Sheyenne River, separating the middle and lower subbasins and forming Lake Ashtabula (USACE, 2015). The model was calibrated to the weather and land use conditions of 2005. After a sufficient model was defined and validated, future and hypothetical land use datasets were substituted into the model. By holding all other inputs and parameters equal, it was possible to isolate the effect of changing land use on sediment loading in the Middle and Upper Sheyenne River Subbasins. The Economic Research Service of the US Department of Agriculture, or ERS, has published estimates on the costs to society of sediment loading for watersheds across the US (Hansen and Ribaudo, 2008). These values were used in the calculations.


**Figure 13.** Sheyenne River Basin Upstream of Baldhill Dam

This information is valuable to government officials who are dealing with CRP funding policy, and also to researchers who are studying the costs and benefits of policies, such as the CRP, that affect land use. Policy makers and other researchers may know the effects of land use changes, but that is not as useful as knowing quantitatively how much change in land use affects change in soil erosion. This numerical information is needed to inform the creation of efficient policy, to modify current policy for efficiency's sake, and to protect current government policies that foster efficient use of natural resources for both public and private benefit. This research also provides a framework for other studies investigating the costs of decreasing CRP and grasslands elsewhere in the US.

### *USDA ERS Soil Benefit Values*

Hansen and Ribaudo (2008) compiled a list of 14 studies that analyzed the economic effects of sediment loading (Table 4). These values were calculated at the 8 digit Hydrologic Unit Code (HUC) scale for the entire United States. These are non-market costs of sediment loading into streams, lakes, and coastal areas. Non-market goods are goods that are not traded in the market place and thus do not innately have a dollar value attached to them. There are 12 benefits related to reduced soil erosion from water, one related to reduced soil erosion from wind, and one related to soil productivity, which is indifferent to what type of erosion is causing the soil loss. The water of the Sheyenne River is used in a variety of different ways enabling these values to be used as relevant costs to society in the Sheyenne River basin. First there are plenty of water-based recreation opportunities available including three swimming areas and seven boat launches in Lake Ashtabula alone (USACE, 2015). A variety of fish are stocked and present upstream of the Baldhill Dam including Fathead Minnow, Northern Pike, Walleye, and Yellow Perch (Lake-Link, Inc. 2015). Reduced sediment in the river provides cleaner water for

**Table 4.** Soil Conservation Benefit Categories (Hansen & Ribaudo, 2008).

| Category | Consumer/Producer Surplus Gain due to | Level of Aggregation | Range of Values ($/ton) | Year Estimated |
|---|---|---|---|---|
| Reservoir services | Less Sediment in Reservoirs | HUC | 0 to 1.38 | 2007 |
| Navigation | Shipping Industry Avoidance of Damage from Groundings | HUC | 0 to 5.00 | 2002 |
| Water based recreation | Cleaner fresh water for recreation | HUC | 0 to 8.81 | 1997 |
| Irrigation ditches and channels | Reduced cost of removing sediment and aquatic plants from irrigation channels | FPR | 0.01 to 1.02 | 2007 |
| Road drainage ditches | Less damage to and flooding of roads | FPR | 0.20 | 1986 |
| Municipal water treatment | Lower sediment-removal costs for water treatment plants | FPR | .04 to 1.45 | 1989 |
| Flood damages | Reduced flooding and damage from flooding | FPR | 0.1 to 0.77 | 1986 |
| Freshwater fisheries | Improved catch rates for freshwater commercial fisheries | FPR | 0 to 0.12 | 1986 |
| Municipal and industrial water use | Reduced damages from salts and minerals dissolved from sediment | FPR | 0.07 to 1.47 | 1986 |
| Steam power plants | Reduced plant growth on hear exchangers | FPR | 0.04 to 1.05 | 1986 |
| Soil productivity | Reduced losses in soil productivity | FPR | 0.37 to 1.21 | 1990 |

swimming/boating and improved catch rates for fishing (Hansen and Ribaudo, 2008). Five entities hold permits for water stored in Lake Ashtubula and two of those, Valley City and Fargo, currently utilize Sheyenne River surface water directly for municipal water supply (Burian, 2011). Sediment suspended in the water causes increased maintenance costs of water treatment plants (Hansen and Ribaudo, 2008). Values for soil productivity and road drainage ditch maintenance are relevant due to the presence of widespread agriculture. Soil is an input to agriculture and when it is lost to erosion, production will either fall or inputs must be increased to maintain production (Hansen and Ribaudo, 2008). Some sediment eroded from farmland will find its way to road drainage ditches, increasing maintenance costs of keeping the ditches free of sediment and vegetation that can impede flow (Hansen and Ribaudo, 2008). In 2009 Valley City, and other cities along the Sheyenne River, experienced historic flooding (Kolpack, 2009). Suspended sediment can increase the flow of flood waters and cause damages when deposited after the flood recedes (Hansen and Ribaudo, 2008). Although no records of dredging the Sheyenne River, or Lake Ashtubula were found, sedimentation has led to a need to dredge channels for navigation and reservoirs to remove built up sediment (Hansen and Ribaudo, 2008). Thus these values could be relevant in the future.

There are some limitations to these estimates which should be noted. First, these estimates do not include *all* costs of increased sedimentation. Thus, they are a good lower bound estimate. The level of aggregation for many of the studies reviewed by Hansen and Ribaudo (2008) was farm production regions, which are multistate regions. Meaning they studied large areas for each sample, so their estimates may not fully account for variation amongst HUCs (except for the three studies conducted at HUC level). Additionally, some of the studies were completed a long time ago. So even though the dollar amounts are adjusted for inflation to 2015 dollars, circumstances have changed in the past 20 plus years. Advanced technology, increasing population, and changing public preferences will have affected people's willingness to pay for decreased sediment loading in their lakes, streams, and coastal areas.

Hansen and Ribaudo (2008) reviewed studies that used varied methods to estimate the public's willingness to pay for decreased sediment loading—(1) the travel cost, (2) the damage function method, (3) replacement cost method, and (4) avoided costs method. The travel cost method uses expenditure and trip data to estimate demand for a recreational activity that is dependent on environmental quality, such as swimming or fishing (Flemming et al., 2008). The damage function method values environmental quality, in this case reduced sediment loading, by looking at the reduction in revenue (or increase in cost) it causes to a firm that is dependent on that natural resource for producing a market good (Crow et al., 2000). The third method used is the replacement cost method. This method assumes the loss in welfare due to a change in environmental quality is approximately equal to the expenditures made to replace, repair, or restore goods and capital assets (Hansen and Ribaudo, 2008). Both this and the damage function methods are considered to be conservative estimates. This is because they do not account for damages that require no expenditures, and do not account for remedial actions. The final method is the avoided costs method. This method uses the costs voluntarily incurred to avoid damages from lost environmental services to represent a basis of the worth of those services/ environmental goods (Hajkowicz, 2006). In other words, it is measuring the costs of protecting the benefits instead of measuring the benefits directly. Some examples of the costs avoided if water quality improves include purchase of bottled water, personal and municipal water filtration, rainwater tanks, and more.

### *Study Area*

The majority of the Sheyenne River Basin is located within the Northern Glaciated Plains Level III Omernik Ecoregions (Omernik and Griffith, 2008). Glacial processes left behind gently rolling hills, flat prairies, and many potholes which contain temporary and seasonal wetlands. The climatic conditions generate a transitional grassland between the tall and shortgrass prairie (Omernik and Griffith, 2008). Agriculture and game hunting are a central aspect of culture here due to the fertile soil and wildlife habitat. The Northwestern Glaciated Plains ecoregion is only present in the headwaters of the Sheyenne River. It is the westernmost boundary of glaciation and thus is composed of similar landscape heterogeneity with a high concentration of wetlands

(Omernik and Griffith, 2008). It is a dryer climate but agriculture is still practical in this ecoregion (Figure 8).

In the year 2013, cropland comprised 51.2% of the entire Sheyenne River basin and developed land was only 0.4% by area. Water and fallow land represented 3.8% and 6.3% of the basin, respectively. Conservation-type land (which entails forest land, wetland, grassland, etc.) claimed the remaining 38.3% of the Sheyenne River basin.

North Dakota, while traditionally an agricultural state, has seen a shift in demographics due to the oil boom in the west and the growth in Fargo in the east. Overall demographics of North Dakota were compared to two counties in the Sheyenne River basin; Sheridan, representative of the Upper Sheyenne and Griggs, representative of the middle Sheyenne. As of the most recent census in 2010, the State of North Dakota has almost 673,000 people. Median household income is $53,741 and the percentage of the population 65 years of age and older is 14.2% (US Census Bureau, 2010). In Sheridan county, 30.2% of the population is 65 years or older. For Griggs, the proportion is 28.7%. This is important because the CRP might be more attractive to an aging population than young people who could be potential farmers. Median household income in the two counties is slightly lower than the state average; from $43,250 in Sheridan, to $45,542 in Griggs.

In 2012, North Dakota farms had an average size 1,268 acres with a median size of 480 acres (USDA, 2012). The average market value of agricultural products sold in 2012 per farm was $353,693. In Griggs County, the average and median farm size, in acres, was 977 and 437, respectively. The average market value of agricultural products sold in 2012 per farm was $280,324. Finally in Sheridan, the average farm size was 1,388 acres and the median farm size was 565 acres. The average market value of agricultural products sold in 2012 per farm was

$291,294. Sheridan had larger than average farms. It can be assumed, everything else constant, that counties producing less valuable output would be more likely to enroll land in the CRP than counties with more productive land.

### *The SWAT Model and Economics*

The Soil and Water Assessment Tool, (SWAT) is a very powerful and customizable model that can be used to model the hydrology and water quality outputs of a watershed (Neitsch et al., 2002). SWAT can model and calibrate sediment, nutrient, pesticide, and bacteria loading. SWAT is very comprehensive in the processes that it simulates, including biological, chemical, and physical processes; instream, in the subsurface, in and on the vegetation, snow fall and snow melt, etc. This extreme level of detail in the modeling process produces better models of what is actually happening. However with that much potential, there are some limitations. Being very complex, with a large number of inputs and outputs, SWAT requires training before use. If one wants to properly use the model to achieve a high degree of detail and accuracy, it takes time to learn how to use the program. Luckily there is much literature published on the creation and calibration of SWAT models. There are also several informational videos available online, along with other educational materials, at http://swat.tamu.edu/. SWAT also is data-intensive. Data on soil, land cover, elevation, precipitation, temperature, and more must be acquired and preprocessed to be used in the SWAT model. Thus, the accuracy of the model depends on the accuracy of the data the user can acquire.

The SWAT model has been used countless times to analyze and predict water quality aspects in watersheds across the nation (e.g. Shao et al. 2013; Whittaker et al., 2015; Bhattarai et al., 2008; others). This study has built on the previous work of others by combining water quality modeling with economic analysis to provide a framework to value water quality changes due to government programs that influence land use change.

Shao et al. (2013), used GIS and SWAT to model sediment yield in four Great Lakes watersheds. Then they created hypothetical land use layers and assessed the possible sediment yields from these scenarios. They believe increased corn production will continue into the future and this may cause many negative environmental consequences. Integrating land cover change and watershed modeling is a powerful analytical tool to assess the environmental consequences of this change. They built a SWAT model and calibrated it using the $R^2$ value of .7 or greater for a target. They also used the Nash and Sutcliffe model efficiency coefficient (E) for validation (Nash and Sutcliffe, 1970). Their hypothetical land cover data sets are very unlikely but they provide a boundary of extreme conditions. Climatic conditions were kept constant throughout the simulations. Their model was very similar to the model used in this research, but this work builds on theirs by using slightly more detailed and realistic hypothetical land use datasets and it also adds the economic valuation component to the sedimentation results.

Zimmerman et al. (2003) observed cool water and warm water streams and analyzed the effects of agricultural practices on fish communities of these streams. They created four scenarios with varying degrees of intensity of agriculture. In general, the cool water fish were more affected by increased sediment. This is an example of one of the benefits assigned an economic value by Hansen and Ribaudo (2008). Zimmermann et al. (2003) conclude that "[a]griculture has altered stream ecosystems by increasing temperatures, increasing nutrients, and altering hydrologic regime."

Whittaker et al. (2015) created a SWAT model to study the cost of reducing the size of the Gulf of Mexico Hypoxia dead zone to a task force recommended target. They found converting cropland to CRP could reduce hypoxia most effectively, but it was very expensive in terms of CRP payments and higher agricultural commodity prices. Another important fact is that nutrient loading is very weather dependent. Thus even in the face of reduced farmland, heavy precipitation can still cause high levels of runoff and erosion and, thus, nutrient loading. Their research was concerned with nutrient loading, as opposed to sedimentation, but still shows how hard it can be for conservation programs to compete with high crop prices. By completing these economic studies we can help policy makers make informed decisions about conservation programs.

In another public policy minded study, Polasky et al. (2011) used a spatially explicit integrated modeling tool (InVEST) to quantify the changes in ecosystem services, habitat for biodiversity, and returns to landowners from land-use change in Minnesota from 1992-2001. It is difficult to predict the change in ecosystem services as a function of the ecosystem conditions. These conditions are affected by land use change. They modeled actual land use change along with five other scenarios to show limits of ecosystem services. One service they modeled was phosphorus (P) loading as a proxy for overall water quality. They used Mathews et al. (2002) to estimate the economic value of P loading. P is also greatly affected by urban land use, not just agricultural. Their "agricultural expansion" scenario generated the highest private returns to landowner and lowest net social benefit. They conclude that "[t]he divergence of private and net social benefits demonstrates need to institute policies that encourage choices that enhance the provision of non-market ecosystem services." Finally they note that "economic and ecological uncertainty make evaluation of the net present value of long-term flow of ecosystem services difficult." Depending on the values society attributes to ecosystem services, conservation measures can be seen as valuable or not.

Mathews et al. (2002) used a contingent valuation technique that combined revealed and stated preferences models to value to willingness to pay for a 40% reduction of P in the Minnesota River. This method uses a survey technique to estimate willingness to pay for reduced P loading by users and non-users of the river. Sources of P include wastewater treatment plants, septic systems, and runoff from fields and feedlots. They estimated a total annual willingness to pay of $140 in 1997 dollars per household in two metro counties. This study is a good complement to the current project. By aggregating different valuations for different water quality parameters, we can provide an estimate for the value for the cost to society of decreased water quality. These different parts can also be combined in future research to model and find a complete list of water quality non-market values.

Basnyat et al. (2000) comment on one important motivation for the present study in noting that "[i]dentification of candidate lands [for retirement] is based on spatial and biophysical considerations, whereas the decision to retire candidate lands is an economic one [for the landowner]." It is important to recognize the decision making process for landowners, as they have one of the biggest impacts on water quality. Basnyat et al. (2000) used opportunity costs of agriculture on forested buffers to value the minimum cost to improve water quality in an Alabama watershed. Agriculture is the biggest source of nonpoint source (NPS) pollutants, and forested stream buffers are one way to mitigate that. They calculated the discounted present values of a stream of agricultural returns and spatially displayed the costs. They created a framework to identify potential program costs of reaching defined water quality objectives through land retirement.

## Data

Several publicly available data sources were used in this research including the National Agricultural Statistics Service's (NASS) Cropland Data Layers (CDL) (Han et al, 2014), USGS's Hydrologic Unit Code (HUC) dataset (USGS and NRCS 2012), the Natural Resources Conservation Service's (NRCS) State Soil Geographic dataset (STATSGO) (NRCS, 2014), the Agricultural Research Service's SWAT format climate data (USDA, 2011), the USGS's National Water Information System (NWIS) dataset (USGS, nd), and the Shuttle Radar Topography Mission (SRTM1) Digital Elevation Map (DEM) from USGS, NASA, & NGA (2009).

As the SWAT database for the NRCS's Soil Survey Geographic Database (SSURGO) is incomplete, and there were too many missing to be added manually, the less detailed STATSGO soil data that is included in the SWAT program files was used (Detail of soil map shown in figure 14). The USDA Agricultural Research Service, or ARS, supplies SWAT-ready precipitation and temperature data, which was used for this study. Finally observed streamflow data for the Sheyenne River near Cooperstown, ND was downloaded from the US Geological Survey's National Water Information System portal. Observed sediment data was not available, this will be addressed below. The DEM was compiled at a resolution of 30m.

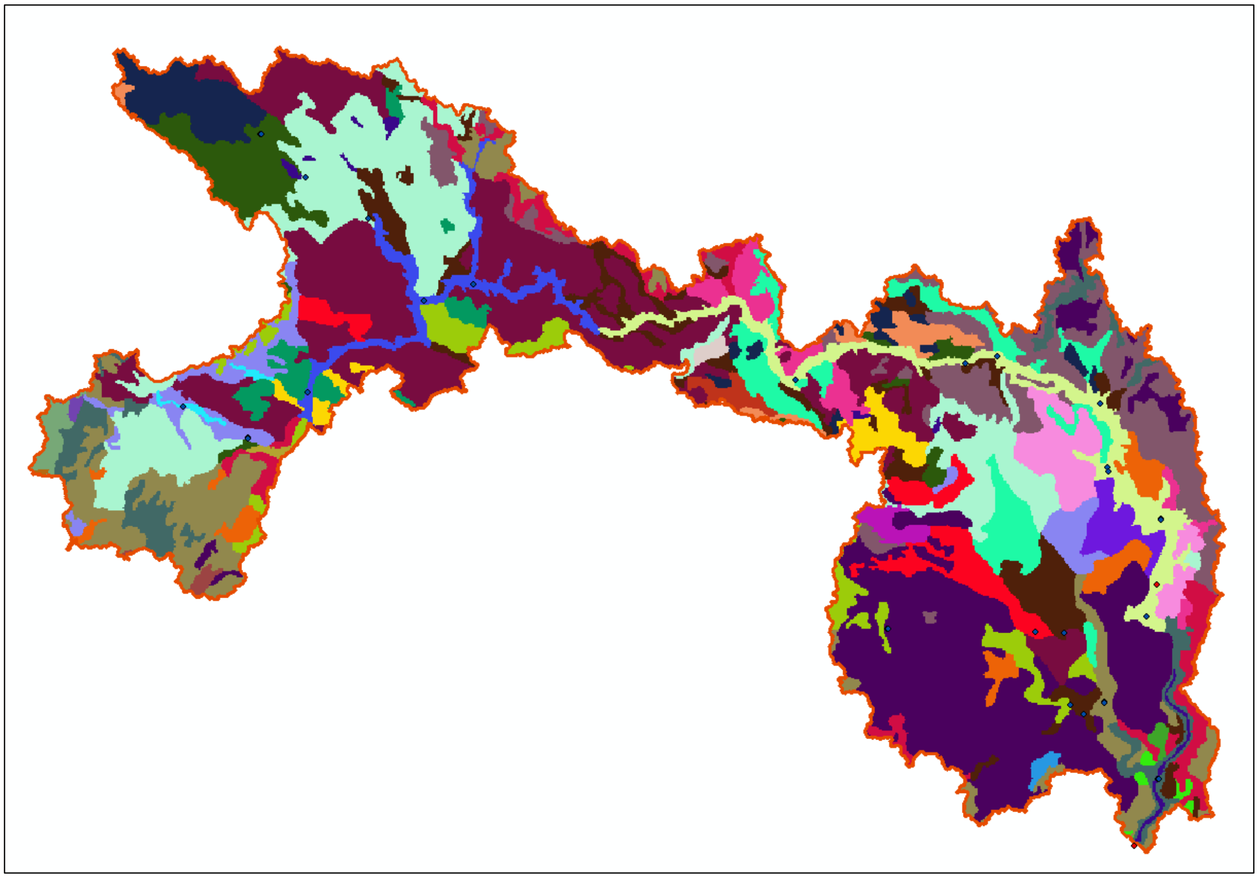

**Figure 14.** Sheyenne River Basin Soil Map Detail

## Methods

Some preprocessing of the input data was necessary before loading it into ArcSWAT (the SWAT model developed for ArcGIS). Several DEMs were merged together to cover the middle and upper Sheyenne River basin area being studied. ArcSWAT does not recognize the CropScape "Gridcodes" so a lookup table was created to match the CropScape land cover gridcodes, to SWAT's four letter land cover codes. SWAT did not contain values for every type of crop and land cover so for some the closest vegetative crop/land cover was estimated and used as a substitute. Codes for these "closest vegetative crops" were chosen subjectively based on plant characteristics such as entire plant size, leaf size, type of harvestable plant feature. This table was then loaded into the SWAT model. Figure 15 shows the reclassification of land use.

ArcSWAT has an “Automatic Delineation” dialog box that takes the user through delineation step by step. Stream threshold was set to 12,000 ha. Figure 16 shows the stream network. An outlet was manually placed at the location of the streamflow monitoring site of the observed streamflow data. This way simulated outflow could be compared with observed data from this monitoring point to calibrate the model.

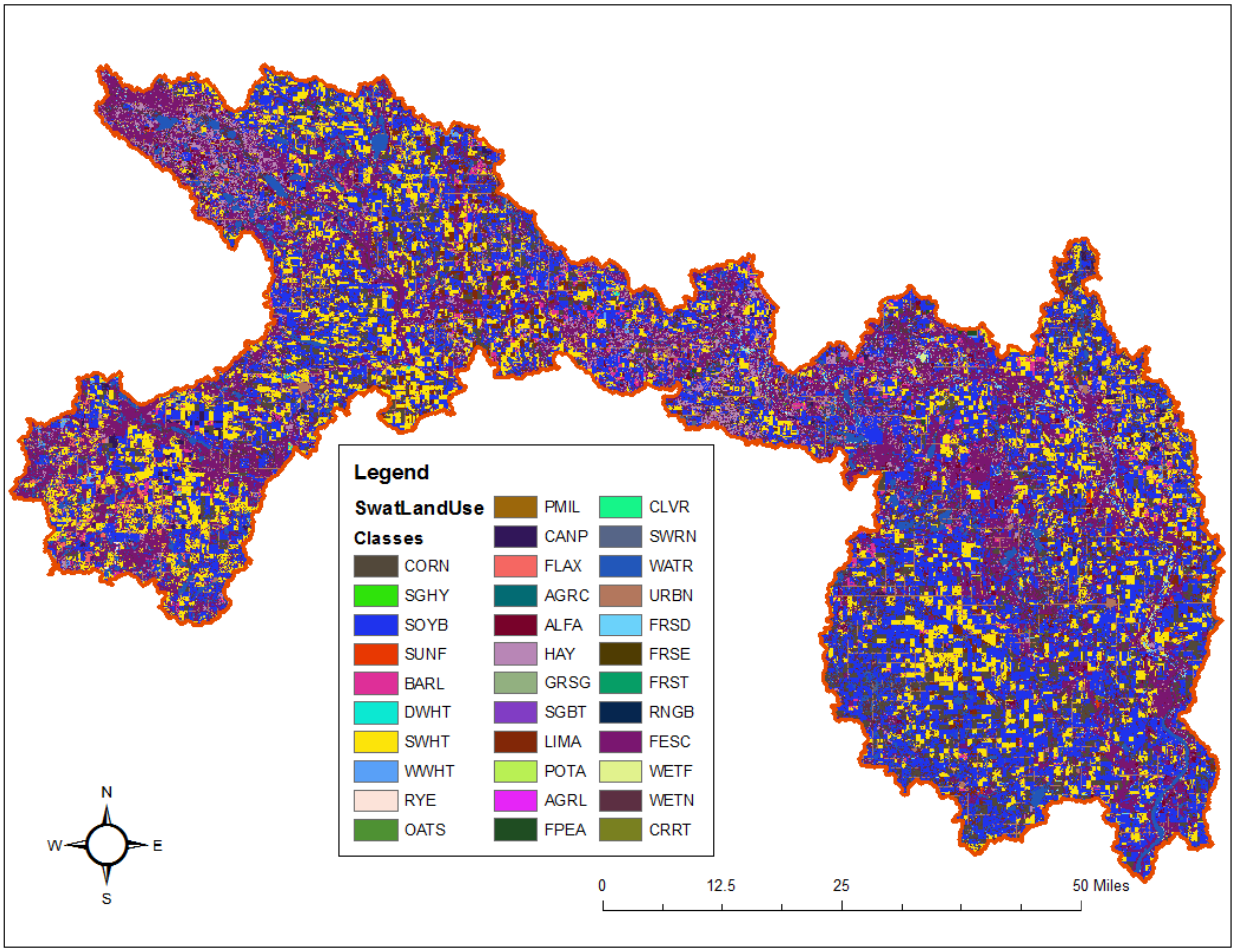


**Figure 15.** Land Use Classifications in SWAT Model of Sheyenne River Basin

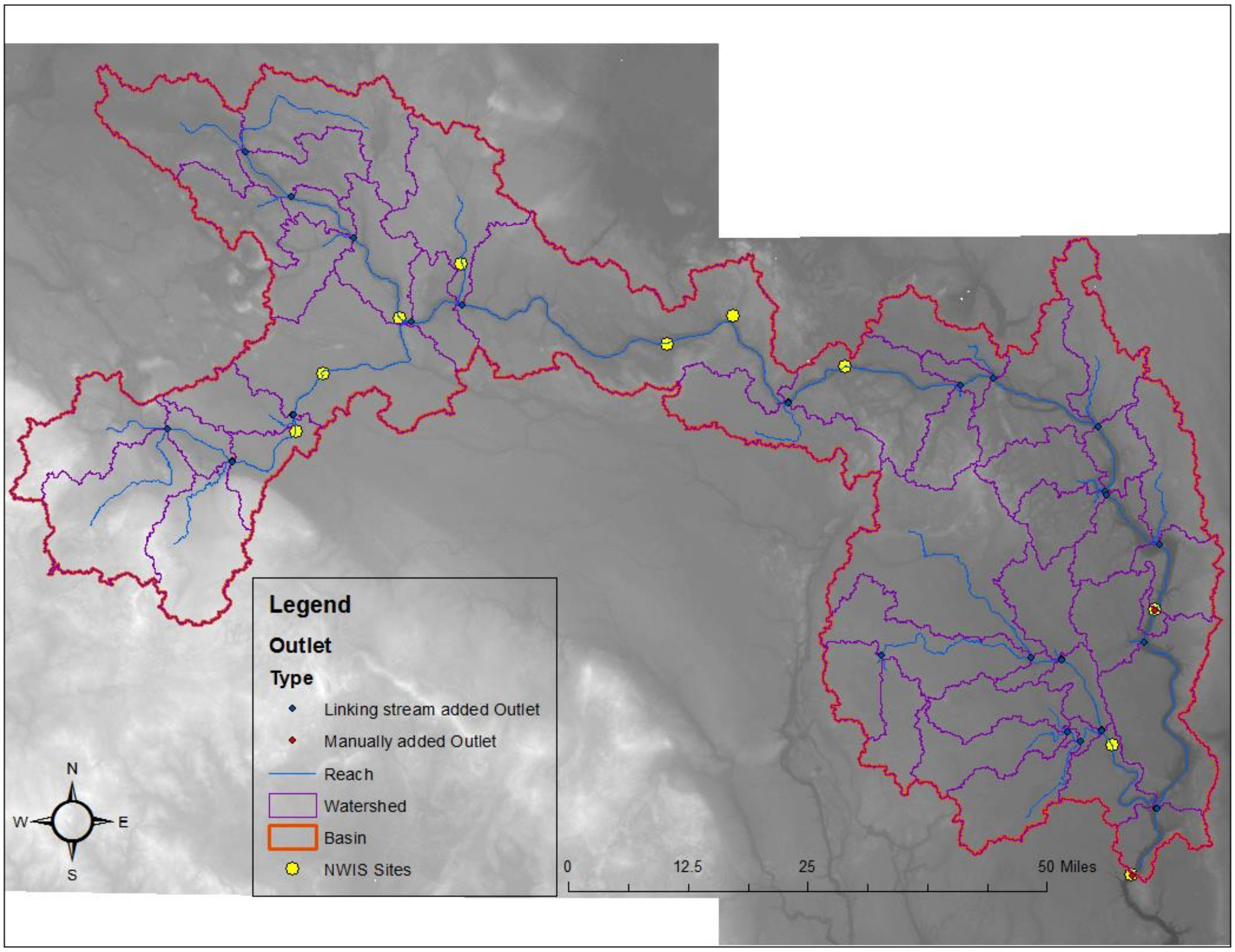


**Figure 16.** Stream Network for Sheyenne River Basin SWAT Model

The Hydrologic Response Units (HRUs) were defined with thresholds of 1% landuse, 10% soil type, and 10% slope class. This means that an every land use that consisted of at least one percent of the total area would be in its own HRU. And of each of those HRU's for every soil type that was at least 10% of that area another HRU was created. And finally for each remaining HRU, for any slope class that contained 10% or more of the land in that Land use and soil type HRU, another HRU was created. The lower the threshold values, the more detailed the HRUs are and the more HRUs are created. The higher the threshold values, the more generalized the HRUs become and thus less are created. The final input needed by ArcSWAT is the climate data and then the model is ready to run. Using a warm-up period of four years (2001-2004), flow was simulated at Cooperstown, ND for a whole year (1/1/2005-12/31/05). A warm-up period is used to normalize certain values such as water available in the soil at the beginning of the simulation year, and beginning flow in the streams.

Calibration and validation are two very important steps when modeling anything, including watershed hydrology and water quality. By comparing the observed stream flow hydrograph to the simulated hydrograph, the peaks can be visually matched up by adjusting parameters. Statistical measures of goodness of fit including the coefficient of determination ($R^2$) and the Nash-Sutcliffe coefficient of model efficiency were also calculated to give objective analysis on the model. Some of the most influential parameters included Manning's n, which is a measure of streambed roughness (CH_N), the surface runoff lag coefficient which affects how fast runoff enters the stream from overland flow (SURLAG), the soil evaporation compensation factor which affects how much water may be taken up through evapotranspiration (ESCO), and the curve number, which affects the ratio of infiltration to runoff (CN2). In addition there were several ground water and snow related parameters that were adjusted. The groundwater parameter that had the biggest impact on the hydrograph was the baseflow alpha factor (Alpha_BF). This determines how much stream baseflow can come from sub-surface sources. The threshold depth for return flow (GWQMN) sets the amount of water required in the shallow aquifer before return flow to the stream may occur. Two parameters were changed that affect the ability of plants to withdraw subsurface water for evapotranspiration purposes. Those were the groundwater "revap" coefficient (GW_REVAP) and the threshold depth for "Revap" (REVAPMN). Finally snowfall and snowmelt are two present and important factors when modeling a watershed in North Dakota and the Sheyenne River is no exception. The first hydrograph peak, due to snow melting, required extra calibration. The temperature at which precipitation was considered snowfall (SFTMP), the temperature where snow began to melt (SMTMP), the maximum and minimum snow melt rate (SMFMX and SMFMN), and the snow pack temperature lag factor (TIMP) all required adjustment.

The land use data used for calibration was then switched out with landcover data from 2014, and the sediment loading was compared from 2005-2014. Then eight hypothetical land use datasets were created. 5% of all CRP-type land covers ("grassland," "wetland," etc.) were randomly selected from the 2014 landcover dataset and replaced with corn. Then 10% of the CRP-type land covers were replaced with corn. This procedure was continued with soybeans and wheat. Finally two more land cover scenarios were created. 5% of the CRP-type land was replaced with a mix of corn, soybeans, and wheat. The mix consisted of 60% soybeans, 20% corn, and 20% wheat. These proportions were derived from the most current land use trends, those seen in the 2014 land cover dataset. This mix again replaced first 5%, then 10% of the CRP-type land covers in 2014.

The net conversion of grassland to cropland from 2005 to 2014 was 3% (Table 5). Five and ten percent were chosen arbitrarily to explore increasing levels of grassland conversion. SWAT outputs sediment yields in metric tons/ha/year. A simple spreadsheet was created to convert that value into annual tons of sediment for the whole basin. The sediment yields were recorded for each simulated land cover.

**Table 5.** Transitional Probabilities from 2005 to 2014

| | | 2005 | | | |
|---|---|---|---|---|---|
| | | Grass | Crop | Other | |
| 2014 | Grass | - | 0.075 | 0.014 | 0.320 |
| | Crop | 0.105 | - | 0.004 | 0.602 |
| | Other | 0.026 | 0.025 | - | 0.078 |
| | | 0.362 | 0.592 | 0.046 | 1.000 |

After the total sediment yields for each land cover were calculated, they were inputted into a spreadsheet which calculated the cost in 2015 dollars of sedimentation in the study area, using the dollar values compiled by Hansen and Ribaudo (2008). The values provided by Hansen and Ribaudo were in “year 2000 dollars.” They were adjusted to “year 2015 dollars” using the inflation calculator provided by Bureau of Labor Statistics (Bureau of Labor Statistics, nd).

## Results and Discussion

Calibration was performed iteratively until a set of parameter adjustments was found that delivered the highest $R^2$ and Nash-Sutcliffe scores, 0.68 and 0.58 respectively (Figure 17).

The model was then validated using observed data from the year 2006. The model actually matched better in 2006 with an $R^2$ value of 0.79 and Nash-Sutcliffe coefficient (COE) of 0.69 (Figure 18). These results are similar to results reported by Shao et al. (2013) in their study of Great lakes basins ($R^2$= 0.67-0.83; COE= 0.41-0.82) and Kirsch et al. (2002) in their study of

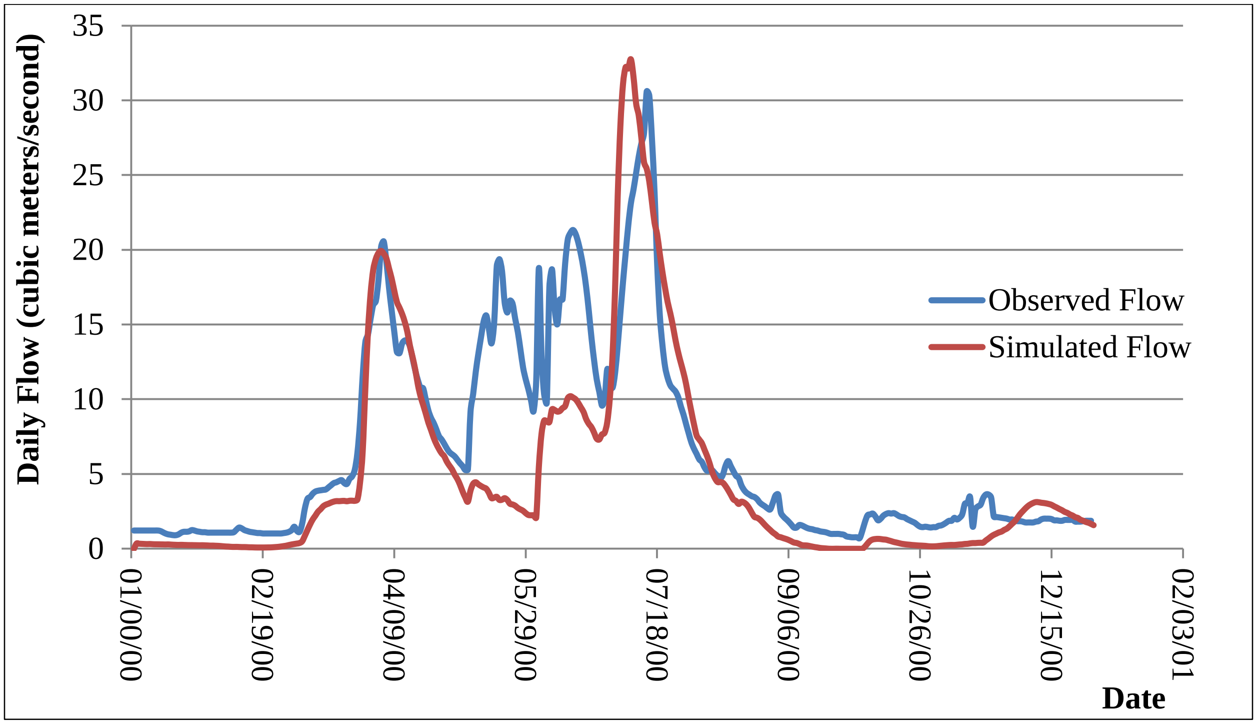


**Figure 17.** Calibration Model Results

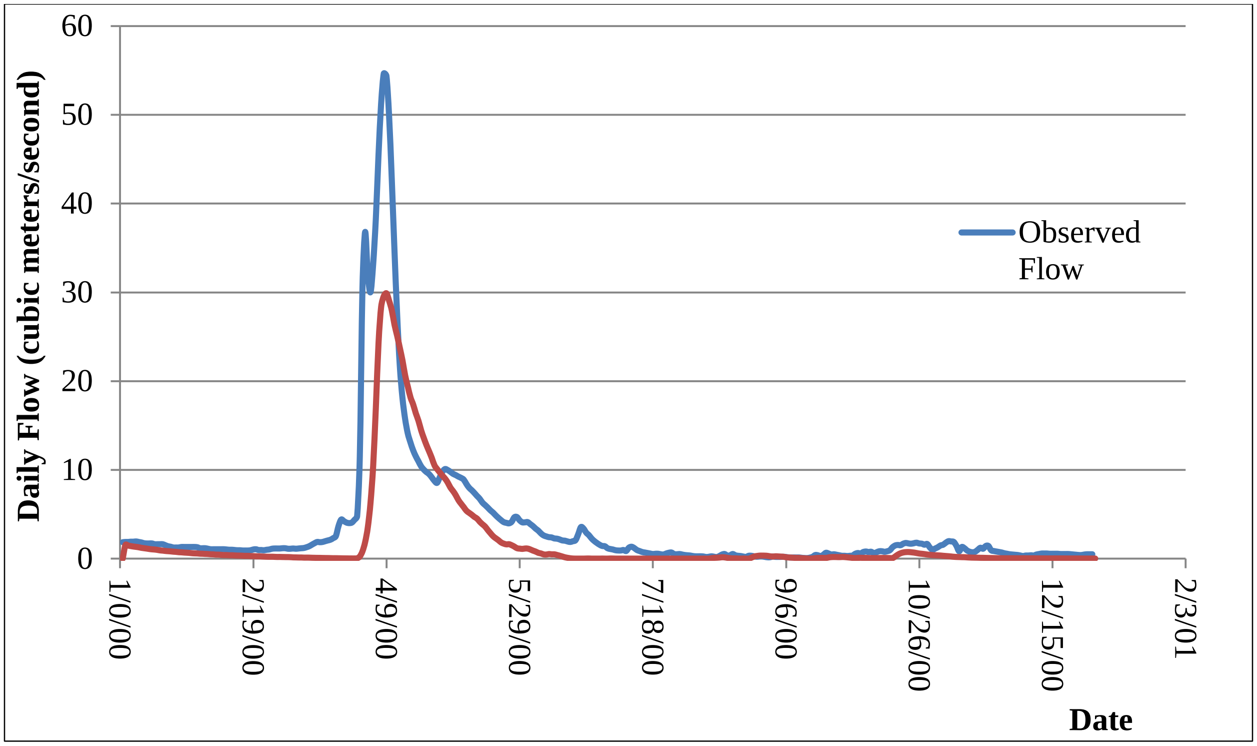


**Figure 18.** Validation Model Results

the Rock River basin in Wisconsin ($R^2$= 0.74; COE= 0.61), and were above the general threshold value (COE > .5) suggested for SWAT model calibration (Nair, 2010). Thus, the model developed in the present study is sufficient for use in estimating sedimentation. There is a small dam in the upper reaches of the basin which would affect hydrology, but given the scale of the model, its affects were minimal. The late spring, early summer time period was very difficult to get right as the model consistently underestimated flow during this time. The default model drastically overestimated stream flow. The peaks were reduced by increasing the coefficient for Manning's *n* to 0.12, decreasing the surface runoff lag coefficient to 0.1, increasing the groundwater revap coefficient to 0.2, and making other adjustments. Table 6 shows all of the calibrations made to the model.

There was no observed sediment data to calibrate sedimentation so the default sediment parameters were used. Hydrology is the driving force in soil erosion and the model was calibrated for streamflow, but the sediment loading estimates may not be as exact as they could be because sedimentation was not calibrated *per se*. Thus using the best estimates with the available data, the annual sediment yields in tons/ha were converted into tons of sediment loaded in the entire watershed, for the year.

**Table 6.** Parameters of the Calibrated SWAT Model

| SWAT Parameter | Default | Final Value |
|---|---|---|
| SMTMP | 0.500 | 1.500 |
| SMFMX | 4.500 | 2.000 |
| SMFMN | 4.500 | 5.000 |
| TIMP | 1.000 | 0.200 |
| SNOCOVMX | 1.000 | 20.000 |
| CH_N | 0.014 | 0.120 |
| ESCO | 0.950 | 0.400 |
| SURLAG | 2.00 | 0.100 |
| Alpha_BF | 0.048 | 0.120 |
| GWQMIN | 1000.000 | 300.000 |
| GWREVAP | 0.020 | 0.200 |
| REVAPMN | 750.00 | 0.000 |
| CN2 | | Inc. 8% |

Every ton of sediment entering the Sheyenne River costs society an estimated $2.40. The model estimated 1,218.36 tons of sediment entered the river from the study area in 2005. Given the same climatic conditions, and using the landcover conditions present in 2014, an estimated 1,661.4 tons of sediment would have entered the Sheyenne River across the study area. This is a 36% increase in sedimentation. Increases were smaller for the hypothetical scenarios, compared to the 2014 values. Changing 5% of grasslands to wheat crops didn't change the sediment yields at all while changing 10% increased sedimentation by 13%. Soybean crops contribute the most towards sedimentation among corn, wheat, and soybeans. Changing 10% of the grasslands to soybeans increased sedimentation by 20%. Converting to corn produced values in between wheat and soybeans. The most interesting and probably relevant data however are the values for the mixed hypothetical land use scenarios, as they model current trends in agriculture. Changing 5% of the grasslands to a mix consisting of 60% soybeans, 20% corn, and 20% wheat increased sedimentation by 13%. Converting 10% of the grasslands to that mix increased sedimentation by the exact same amount. This is probably due to the way SWAT outputs sedimentation data. The values reported in the output are in metric tons per hectare, per year. This ends up being a small value and SWAT only reports to the second decimal. For example the values for 2005, 2014, and light/heavy mix were 0.11, 0.15, and 0.17, respectively. Thus the small differences between crop types are made even smaller when aggregating them in the mixed scenario, and SWAT does not report sedimentation values detailed enough (for this study area) to differentiate between the two scenarios. However the important result is still evident; increasing cropland, at the expense of grasslands, will increase sediment loading into the Sheyenne River.

The increase in sedimentation from 2005-2014 was greater than the increase from 2014 to any of the hypothetical scenarios (Tables 7 and 8). This could be because there was no accounting for increasing urbanization in the hypothetical scenarios. Increasing impervious surfaces increases runoff and reduces infiltration, both contribute to sediment loading. Again, Table 5 shows the transitional probabilities of land types from 2005 to 2014. From 2005 to 2014 a net increase of grassland conversion to cropland of 3% was found. Using this change as a baseline, eight hypothetical land use datasets were created exhibiting an increase in land use change from grassland to cropland.

Tables 7 and 8 show the contribution to the cost of sedimentation, from each soil conservation benefit category. In addition, the total costs are shown on bottom line. Costs of sedimentation rose from $2,920.94 to $3,983.10 from 2005 to 2014. As for components of the valuation, reduced efficiency at steam power plants, lost soil productivity, and impaired water-based recreation were the biggest sources of reduced welfare due to sediment loading. Water-based recreation, navigation, and reservoir services were the only three values calculated at the 8 digit HUC level. Thus there is a possibility that the other values could be skewed by other watersheds in the Northern Plains farm production region (farm production region was the scale of calculation for the other values). This was mentioned previously and must be noted when using these values and analyzing the results of this study.

**Table 7.** Sediment-related Costs in 2005 and 2014

| Soil Conservation Benefit | Cost ($/ton) | Total Annual Cost 2005 | Total Annual Cost 2014 |
|---|---|---|---|
| Irrigation ditches/canals | 0.163 | 198.84 | 271.14 |
| Freshwater fisheries | 0.002 | 1.90 | 2.59 |
| Flood damages | 0.175 | 213.40 | 290.99 |
| Road drainage ditches | 0.272 | 331.39 | 451.90 |
| Muni. and indust. water use | 0.096 | 117.54 | 160.28 |
| Municiple water treatment | 0.306 | 372.50 | 507.96 |
| Steam power plants | 0.448 | 545.31 | 743.60 |
| Soil productivity | 0.562 | 684.33 | 933.18 |
| Water-based recreation | 0.346 | 421.44 | 574.69 |
| Navigation | 0.014 | 16.57 | 22.60 |
| Reservoir services | 0.015 | 17.72 | 24.17 |
| Total Cost (2015 dollars) | 2.40 | 2920.94 | 3983.10 |
| Total Tons | - | 1218.36 | 1661.40 |

**Table 8.** Sediment Costs under Eight Land Use Change Scenarios

| | Land use change scenario | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Soil Conservation Benefit | Light corn | Heavy corn | Light wheat | Heavy wheat | Light soy | Heavy soy | Light mix | Heavy mix |
| Irrigation ditches/canals | 289.22 | 307.29 | 271.14 | 307.29 | 307.29 | 325.37 | 307.29 | 307.29 |
| Freshwater fisheries | 2.77 | 2.94 | 2.59 | 2.94 | 2.94 | 3.11 | 2.94 | 2.94 |
| Flood damages | 310.39 | 329.79 | 291.00 | 329.79 | 329.79 | 349.19 | 329.79 | 329.79 |
| Road drainage ditches | 482.03 | 512.15 | 451.90 | 512.16 | 512.16 | 542.28 | 512.15 | 512.15 |
| Muni. and indust. water use | 170.97 | 181.65 | 160.28 | 181.65 | 181.65 | 192.34 | 181.65 | 181.65 |
| Municiple water treatment | 541.82 | 575.68 | 507.96 | 575.68 | 575.68 | 609.55 | 575.68 | 575.68 |
| Steam power plants | 793.18 | 842.75 | 743.60 | 842.75 | 842.75 | 892.32 | 842.75 | 842.75 |
| Soil productivity | 995.39 | 1057.60 | 933.18 | 1057.60 | 1057.60 | 1119.81 | 1057.60 | 1057.60 |
| Water-based recreation | 613.00 | 651.31 | 574.69 | 651.31 | 651.31 | 689.63 | 651.31 | 651.31 |
| Navigation | 24.10 | 25.61 | 22.60 | 25.61 | 25.61 | 27.11 | 25.61 | 25.61 |
| Reservoir services | 25.78 | 27.39 | 24.17 | 27.39 | 27.39 | 29.00 | 27.39 | 27.39 |
| Total (2015 dollars) | 4248.63 | 4514.17 | 3983.10 | 4514.17 | 4514.17 | 4779.71 | 4514.17 | 4514.17 |
| Total Tons | 1772.16 | 1882.92 | 1661.40 | 1882.92 | 1882.92 | 1993.68 | 1882.92 | 1882.92 |

## Conclusions

Net increases in conversion of CRP and private grasslands into croplands, though a sound economic decision for landowners, will continue to impose external costs on the public, and may reduce overall social welfare. These results only consider increased social costs attributable to higher sedimentation from land use change. Nutrient loading, pesticide loading, reduced land-based recreational activities (including hunting), reduced wildlife habitat, and others should also be considered to form a more complete picture of the costs to society of converting CRP and other private grassland into cropland. One important aspect to note is that the locations of CRP lands are not available to the public. In fact, this data is exempt from even a Freedom of Information Act request. Thus CRP land cannot be targeted with certainty, but instead a best guess can be made, given the land cover data available. Farmers often put their least productive land into the CRP. Thus, when this land is not reenrolled, and instead farmed, it is often some of the most susceptible to soil erosion (Lant et al., 2005). The hypothetical land use scenarios therefore should be considered conservative estimates of the increase in sedimentation. Grassland plots were selected at random when in reality landowners/farmers will be converting CRP land that is located on soil with higher than average erodibility. This has been confirmed by T. Kemp, lifetime farmer in the Red River Valley, (personal communication, December 10, 2012), who said, “5 years ago CRP would make more money than a crop on poor land because of low yield and low price, but now they could possibly make more farming it, even with low yield, because of high prices.” Farmers generally put poor quality land into CRP.

Knowing, or at least estimating, the costs and benefits of public policies, is very important to lawmakers and special interest groups lobbying for their causes. This study expands the literature on the costs, in dollars, of sedimentation due to land use change. Policy makers need to know the value of the CRP to justify spending money on it, especially given how rising crop prices have been competing with the CRP rental rates.

Finally, although it is beyond the scope and resources of this study, future research should attempt to value all the costs of CRP-related land use change. Government agencies can also access current CRP land data, which would allow researchers a much more exact estimate of how much CRP land is actually being brought back into production and what the consequences are in terms of habitat loss, nutrient loading, and sedimentation. A comprehensive study of the costs to society of reduced CRP lands, using actual CRP land data would be very beneficial to policy makers debating the CRP and other conservation minded government programs.

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