THESIS

VALUING ECOSYSTEM AND ECONOMIC SERVICES ACROSS LAND-USE SCENARIOS IN THE PRAIRIE POTHOLE REGION OF THE DAKOTAS

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY WILLIAM R. GASCOIGNE ENTITLED VALUING ECOSYSTEM AND ECONOMIC SERVICES ACROSS LAND-USE SCENARIOS IN THE PRAIRIE POTHOLE REGION OF THE DAKOTAS BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

VALUING ECOSYSTEM AND ECONOMIC SERVICES ACROSS LAND-USE SCENARIOS IN THE PRAIRIE POTHOLE REGION OF THE DAKOTAS

This thesis uses biophysical values derived for the Prairie Pothole Region (PPR) of North and South Dakota, in conjunction with value transfer methods, to assess the environmental and economic tradeoffs under different policy-relevant land use scenarios over a 20-yr. time period. The ecosystem service valuation is carried out by comparing the biophysical and economic values of three focal services (carbon sequestration, reduction in sedimentation, and waterfowl production) across three focal land uses in the region (i.e. native prairie grasslands, lands enrolled in the Conservation Reserve and Wetlands Reserve Programs (CRP/WRP), and cropland). This study finds that CRP/WRP lands cannot mitigate (1 for 1) the loss of native prairie from a social welfare standpoint. Furthermore, land use scenarios in which native prairie loss was minimized and CRP/WRP lands were increased provided the most societal benefit. The scenario modeling projected native prairie conversion results in a social welfare loss valued at over $2.5 billion over the policy period, when considering the study's three ecosystem services, and a net loss of $1,888,237,567 when reductions in commodity production is accounted for. By quantifying ecosystem and economic tradeoffs of future land use scenarios, this thesis aims to help policy makers and natural resource managers make more knowledgeable, efficient, and defensible decisions.

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DEDICATION

I would like to dedicate this thesis to my parents, Dick and Susie, who have devoted so much to my education and have always supported my academic interests.

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I. INTRODUCTION

Increases in domestic and international demands for food, fiber, and now fuel, have led to increases in land conversion for agricultural production across regions of the U.S. In the last few decades, conservation previsions have been introduced into U.S. agricultural policy to combat such conversion and restore native habitats and the respective ecosystem services they provide. Two of most prominent conservation programs within the U.S. Farm Bill are the Conservation Reserve Program (CRP) and its subset, the Wetlands Reserve Program (WRP). These programs work primarily to restore, enhance, and protect ecosystems located on typically marginal farmlands, and have restored more than 30 million acres nationwide each year since 1990 (Hart, 2006).

Ecosystem services have been described as the direct and indirect benefits people obtain from ecological systems (Millennium Ecosystem Assessment, 2003). This altruistic viewpoint has led to increased efforts to identify, quantify, and value these services. This type of science continues to garner worth, as more people recognize the critical link between human welfare and healthy ecosystems. The inner workings of programs such as the CRP and WRP are geared towards increasing the provision of ecosystem services through public investment. To foster this venture even further, the U.S. Department of Agriculture (USDA) has announced the establishment of a new Office of Ecosystem Services and Markets (USDA, 2008; New Release No. 0307.08), now called "Office of Environmental Markets." By estimating and accounting for the economic value of ecosystem services, social benefits (or costs) can be included in policy assessments, that otherwise would have remained hidden due to their non-market characteristics and/or public good attributes. However, to reach such values there must be collaborative efforts across multiple disciplines (Georgantzís and Tarrazona, 2000).

To date, numerous studies have been conducted to estimate the value of a wide range of ecosystem services using both stated and revealed preference techniques, as well as benefit transfer methodology. However, the integration of both biophysical and ecosystem service valuation data is a relatively new phenomenon (Troy and Wilson, 2006; National Research Council, 2005). The integrated research that has been done usually incorporates a descriptive spatial component [ex. Geographic Information System (GIS)] within the models used (Troy and Wilson, 2006; Bockstael et al., 1995; Kreuter et al., 2001; Zhao et al. 2003; Eade and Moran, 1996; Lant et al., 2004). By doing so, one can compare the changes in ecosystem services and relative economic valuation across various land use[1] treatments and spatial patterns. However, few of these studies attempt to model future land-cover predictions, and subsequent changes in ecosystem service values produced (see Nelson et al. (2009) for uncommon example).

Due to the complexity of both the ecological and economic valuation processes, most of the integrated research has been either broad-scale assessments of multiple services (Costanza et al., 1997; Troy and Wilson, 2006), or highly detailed functional analysis of single ecosystem services at small geographical scales (Polasky et al., 2008; Smith, 2007). The broader approach is often criticized for its generality across habitat types, while the other is noted for lacking both the scope and scale for it to be relevant and applicable to policy scenarios (Nelson et al., 2009). Furthermore, few authors go on to compare the ecosystem service values generated to the opportunity costs of alternative

[1] The terms "land use," "land cover," and "land treatment" are used interchangeably.

land uses, such as agricultural production and/or urban development (see Nelson et al., 2009, Polasky et al., 2008, and Jenkins et al., 2010 for initial attempts) .

In this study, I model changes to ecosystem and economic services across policy-relevant land-use change scenarios over the next twenty years within the Prairie Pothole Region (PPR) of North and South Dakota. This is accomplished by way of linking sound ecological field data and economic valuation within an accounting model. The 20-year time period was chosen to allow the dynamics of the ecological impacts from land use change to play out and be captured, while at the same time not straining some of the linear assumptions built into the model. The study area was selected based on available scientific data, its unique and critical ecological makeup (ex. migratory bird nesting habitat), as well as its vulnerability to land use change in the near future. Within the study, I focus on services across three land covers: (1) native prairie grasslands, (2) prairie lands enrolled in CRP and WRP (CRP/WRP), and (3) cropland.

The PPR produces a magnitude of ecosystem services for each land use. Such examples include partial stabilization of climate, erosion control, translocation of nutrients, floodwater mitigation, and preservation of plant and animal biodiversity.[2] Ultimately, I selected three services based on the availability and accuracy of the biological and economic data. These services are: (1) carbon sequestration (as it pertains to global climate regulation), (2) reduction in sedimentation (relative to water quality), and (3) waterfowl production (in relation to the derived benefits associated with increases in duck populations). I recognize that many other ecosystem services in the region have unique, real, and possibly significant value to human welfare, yet find the three services

[2] Reference Appendix A for list of ecosystem goods and services

chosen for this study to maintain market-oriented properties and have large, ubiquitous effects.

The objectives of this thesis are to (1) model and analyze the primary ecosystem and economic services across prominent land uses within the PPR of North and South Dakota, (2) to illustrate and compare the societal values of agricultural products and ecosystem services produced under policy-relevant land-use change scenarios, and (3) explore the effectiveness of mitigating native prairie loss with conservation program lands. Currently, conservation and natural resource managers have been criticized for using approaches that focus on a single economic sector, while trying to maximize a narrow set of objectives (Tallis and Polasky, 2009). By quantifying both the ecosystem and economic services, and analyzing the tradeoffs between them, natural resource managers and policy makers can make more efficient, knowledgeable, and defensible decisions. This study's findings also provide valuable insight into the impacts of CRP/WRP and other conservation provisions that are in existence or up for consideration within the U.S. Farm Bill.

This paper first reviews the region of study and its importance environmentally and economically. Second, it explains how each of the three ecosystem service stocks and flows were calculated across land uses. Third, the paper describes the valuation process used for both the ecosystem services and agricultural profits. Fourth, it describes the development and integration of various land-use change scenarios. The study's results are then presented and discussed, noting plausible limitations and future directions.

II. METHODOLOGY

2.1 The Study Area

The Prairie Pothole Region is found within the Northern Great Plains, covering approximately 900,000 km^2 (347,490 mi^2). The region extends all the way from north-central United States, incorporating parts of Iowa, Minnesota, North Dakota, South Dakota, and Montana, to the south-central part of Canada (Figure 1) (Euliss et al., 2006). In this study, I focus specifically on the PPR of North and South Dakota that is roughly defined by the area and state boundaries north and east of the Missouri River, covering approximately 86,500 square miles (reference Figure 1&2).

Figure 1. The Prairie Pothole Region of North America; Adopted form Euliss et al. 2006

The historical landscape of this region was composed primarily of short-, mixed-, and tall-grass prairie, interspersed with extensive wetland ecosystems of all catchment types (permanent, semipermanent, seasonal, and temporary). This biological combination of grasslands and wetlands produces a highly valued bundle of ecosystem services. For example, the PPR has been referred to as the "Duck Factory," as it serves as the most important breeding ground for North American waterfowl, producing 50-80 percent of the continent's entire dabbling duck population on only 10 percent of the available nesting habitat (Batt et al., 1989, as cited by Kinnell et al., 2002; Ducks Unlimited, 2008a).

However, this same landscape provides necessary inputs for valuable agricultural production. Agriculture is the predominant land use in the PPR, with cattle-production operations most common in the western part of the region, and small-grain and row-crop production generally increasingly dominant from west to east (Reynolds, 2006). It is noted that North and South Dakota are more economically dependent on the agricultural sector than any other states in the country. In 2007, both of these states' (annual) agricultural products were valued at around $6.5 billion (USDA-NASS, 2007).

Increasing demand for biofuel production has further fueled the agricultural sector in this region, while threatening remaining tracts of native prairie and expiring CRP and WRP contracts. While only a quarter (South Dakota) of the original grasslands remain, elevated conversion rates persist (Reynolds, 2006; Stubbs, 2007; Stephens et al., 2006). From 2005 to 2007 alone, more than 3.2 million acres of prairie potholes were plowed under across portions of Iowa, Minnesota, North Dakota, and South Dakota (Streater, 2010). Similarly, previous estimates indicate more than 50 percent of PPR wetlands in the U.S. have been drained or altered for agricultural production (Tiner, 1984). Adding to the direness of the situation is the fact that altered native prairie grasslands are almost irretrievable; as they take thousands of years to establish themselves (Terry Shaffer, personal communication, September 2, 2008). In turn, the PPR has been identified as North America's most endangered ecosystem (Samson and Knopf, 1996).

The vast network of agricultural operations interspersed among critical habitats has made the PPR an attractive area for farm conservation investment. At the end of 2008, both North and South Dakota ranked in the top ten for acreage enrolled in the CRP, with a combined enrollment of over 4.2 million acres (USDA-FSA). However, in a time of rising commodity prices, biofuel mandates, and tightening federal allowances, along with the timing of CRP contract expirations, many experts fear that enrollment acres are on a steep decline. In a recent Congressional report, North and South Dakota were noted as having the largest decreases in CRP acreage in the country over the last few years (CRS Report, 2009). In 2007 alone, enrolled CRP acreage in South Dakota decreased by 17 percent (Janssen et al., 2008). In response to these land use changes, many are seeking public policy amendments that might slow, halt, or even reverse these trends.

2.2 Valuation Process

The valuation sequence of modeling projected land use scenarios is composed of four essential steps; (1) identify the ecosystem services by land use, (2) quantify the biological values associated with those services (down to annualized per-acreage values), (3) monetize those values using economic methods, and (4) track and sum the flux in those values as the acreage of each land use changes (Murray et al., 2009). Biological values are obtained from field observations and entered into a dynamic accounting model to estimate changes in annual flows. For this analysis, these measurements are standardized into per-hectare values, allowing for comparison across ecosystem services and other land incomes at the regional scale. Once economic values are added, ecosystem service values can be summed and cross-tabulated by service and land use for each scenario. As noted by Troy and Wilson (2006), the total (or net) ecosystem service value of a given land use can be calculated by adding up the individual service values associated with that cover type and multiplying by the overall area as given below.

$$V(ES_i) = \sum_{k=1}^{n} A(LU_i) \times V(ES_{ki})$$

Where $V(ES_i)$ = total (or net) ecosystem service value by land use/cover type (i), $A(LU_i)$ = area of land use/cover type (i) and $V(ES_{ki})$ = annual value per unit area for ecosystem service type (k) generated by land use/cover type (i) (adopted from Troy and Wilson, 2006).

In order to model and analyze the land-use change scenarios, current land cover estimates are needed to act as a baseline. The biophysical values derived from Gleason et al. (2008) were individualized for counties, physiographic regions, Major Land Resource Areas (MLRA's) (only for soil loss estimates), catchment zones (wetland and upland), and the three land uses in the study (reference geographical breakdown in Figure 2). The geographical breakdown of the biological data is maintained in the accounting model in order to produce as accurate estimates as possible. To derive acreage figures for each level of specificity, I relied on geospatial data-extracting software (ESRI ArcMap 9.2). Regional boundaries for the Prairie Potholes were overlaid to produce the exact acreage (and percentages) within the study area (i.e. some counties do not have 100 percent of their lands within the boundaries of the PPR). Cultivated cropland and native prairie vegetation estimates were extracted from the most recent U.S. Fish and Wildlife Service (USFWS) HAPET land cover dataset (2002). CRP/WRP acreages were calculated using fiscal year (FY) 2007 USDA-FSA CRP and USDA-NRCS WRP cumulative enrollment acres by county.[3]

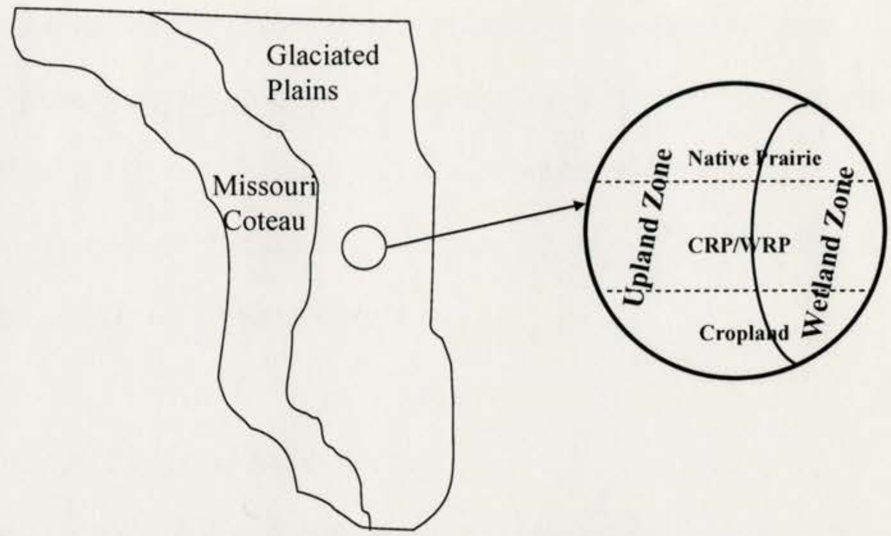

Figure 2; Geographical breakdown of biophysical values. Figure notes the major physiographic regions within PPR of the Dakotas, and breakdown of the catchments. Note: Figure not exact replica of geographical boundaries and scale.[4]

Land cover estimates were further refined down to catchment zones (i.e. upland and wetland), due to the specificity of the biophysical data. Using data from the 1997 National Resources Inventory (NRI) (USDA, 2000), I estimate the percentage of wetlands on cultivated croplands within the region. Since data on individual wetlands across other land uses were not available at the time of this report, I prescribe the same average percentages of wetland zones to lands in CRP/WRP, along with native prairie.[5] Average wetland percentages are multiplied by the total area of each land use to estimate total wetland acreage, with the remaining acreage deemed as the "upland" zone.

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[3] CRP estimates include acreage for general signup, continuous CREP, continuous non-CREP, and Farmable Wetland. County estimates for CRP and WRP enrollment acres were multiplied by the percentage of the county in the PPR to achieve a more representative estimate.

[4] The Prairie Coteau in the PPR is not displayed in Figure 2 as the biological estimates for that region were simply assigned (and averaged) to those in the Missouri coteau, given their similar ecological makeup.

[5] Gleason et al. (2008) follow the same procedure in their CEAP analysis.

Once calculated, ecosystem service flow values are coupled with percentages of each land cover (in terms of acreage) in order to aggregate up to regional estimates for each land-use change scenario. Since no information was available about how hypothetical land use changes would be distributed, ecosystem service estimates were made proportional to land use changes. That is, a 25 percent increase in CRP acreage would increase carbon proportionally to the increase in carbon sequestration that CRP provides as compared to the cropland it replaces.

2.3 Measurement of Ecosystem Service Flows

For the majority of this study's biophysical measurements, I relied on the work presented in Robert Gleason et al.'s professional paper, "Ecosystem Services Derived from Wetland Conservation Practices in the United States Prairie Pothole Region with an Emphasis on the U.S. Department of Agriculture Conservation Reserve and Wetland Reserve Programs (2008)," as well as personal communication with these authors. Their study was a joint collaboration between the United States Geological Survey (USGS), the United States Department of Agriculture Farm Service Agency (USDA-FSA), and the Natural Resources Conservation Service (NRCS) as part of the Conservation Effects Assessment Project (CEAP). Initiated in 2003, CEAP is a multi-agency effort to verify and ultimately quantify the ecosystem service benefits provided by private lands enrolled in selected USDA conservation programs (i.e. CRP and WRP) (Gleason et al. 2008, USDA-NRCS).

Sampling design and data collection for the CEAP study in the PPR was carried out by scientists within the USGS Northern Prairie Wildlife Research Center (NPWRC).

Their two-stage study consisted of a comprehensive, stratified survey of 204 catchments (wetland and surrounding uplands contributing runoff to the wetland) in 1997 and 270 catchments in 2004 (sites displayed in Figure 3).

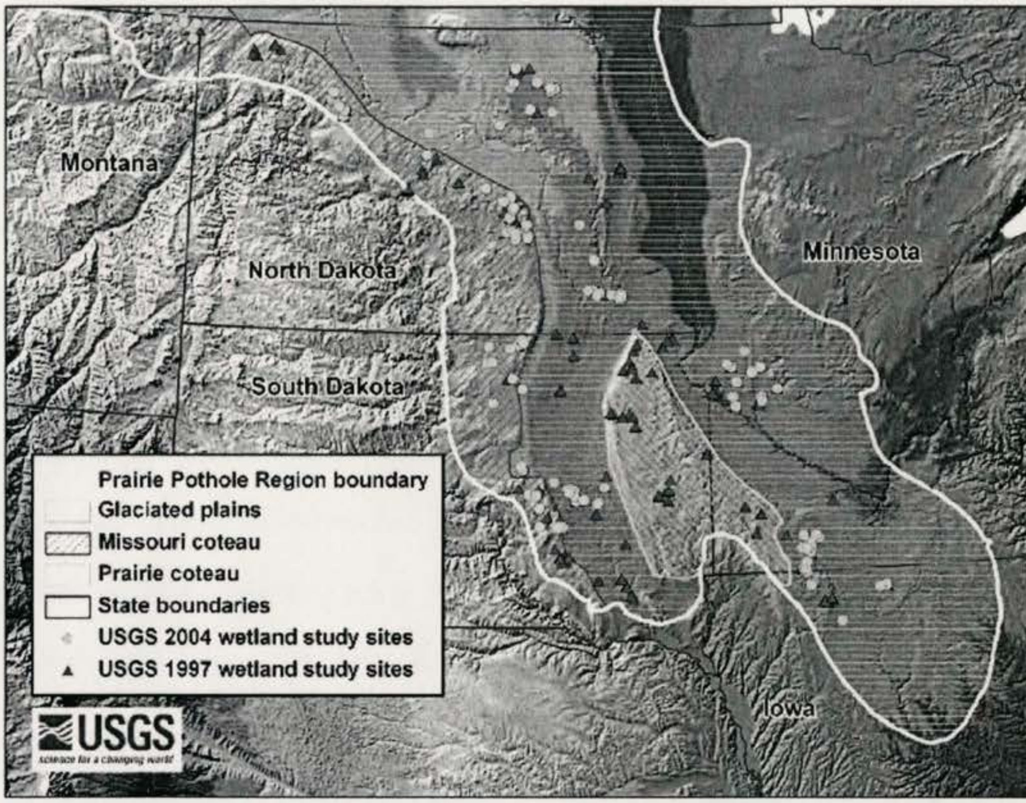

Figure 3. Extent of the Prairie Pothole Region in the United States, and locations of wetland sampled by the U.S. Geological Survey (USGS) during 1997 and 2004; Adopted from Gleason et al. 2008.

A key element in their sample design was to have catchments within their study area span an alteration gradient ranging from highly altered, such as cropland, to minimally altered, such as native prairie. In turn, their evaluation on restoration programs compared changes across three land uses: native prairie, CRP/WRP, and cropland. Information collected during both surveys on soil, vegetation, and morphological variables were used to estimate the following five ecosystem services: plant community quality and richness, carbon sequestration, floodwater storage, reduction of sedimentation and nutrient loading, and potential wildlife habitat suitability. Due to various limitations embedded in my study, I chose to focus explicitly on carbon sequestration, reduced sedimentation, and habitat suitability with respect to waterfowl.

2.3i Carbon Sequestration

The CEAP assessment team within the NPWRC calculated soil organic carbon (SOC) and vegetation organic carbon (VOC) content separately for upland and wetland zones in each of the 270 catchments surveyed. Biophysical data was collected for each of the three land uses, and was documented in metric tons of carbon per hectare (see Appendix 2). They used analysis of variance (ANOVA) to test for differences in SOC and VOC among land treatments and cross-examined their results for SOC with restoration age through simple linear regression.[6]

Site SOC data collected for the upper 15 cm of the soil is used in estimating the soil carbon sequestration flow value. Previous work (Euliss and others, 2006; as cited by Gleason et al., 2008) has demonstrated that most differences in SOC among the land covers found in this study occur within this particular soil depth. Net fluxes of SOC are calculated using data for each specific physiographic region (Missouri coteau and Glaciated plains), catchment zone (upland and wetland), and land use (native prairie, CRP/WRP, and cropland).[7] To derive estimates for the entire study region (i.e. not just lands in wetland catchments), I apply values generated for the upland zone in the

[6] For a detailed description of ANOVA and the assessment team's methodology reference Gleason et al. (2008).

[7] Due to limited data, PPR lands in the Prairie Coteau were handled the same as lands in the Missouri Coteau, as they were formed from similar glacial processes (Tangen, personal communication, 2009). Also, mean estimates and land-use scenarios assume conventional tillage on all "cropland".

catchment to acreage outside the catchment boundary. The potential bias from this application is expected to be minimal given the glaciated nature of the pothole region.

In order to estimate potential carbon gains/losses from changing land cover, mean estimates supplied by the CEAP Assessment Team are coupled with historic sequestration/leaching rates found in the biological literature. By using mean estimates (i.e. sample averages), I am assuming these values indicate each land use in a representative biological equilibrium. Sequestration/leaching rates are necessary for estimating changes in stock and flow values, as carbon sequestration/leaching is a dynamic process that only occurs for a certain amount of time. When calculated (net) differences in carbon (among land uses) are fixed with cited sequestration/leaching rates, a relative timeline is produced (reference Table 1; a-c). For instance, if the estimated net difference in SOC between CRP/WRP and cropland is 12 Mg, and a linear sequestration rate of 0.75 Mg/ha/yr is applied, then I assume the maximum restoration potential of 12 Mg (from restoring cropland) will be met uniformly in its entirety over the course of sixteen years (i.e. $12 \div 0.75 = 16$). This concept garners greater importance later in the monetization process, as interest and discount rates are utilized when aggregating up to the 20-yr. study period.[8]

Due to the nature of each land use within the study, three specific land cover changes are in need of consideration; (1) native prairie being converted to cropland, (2) CRP/WRP converted back to cropland, and (3) cropland becoming enrolled in CRP/WRP. In calculating the carbon sequestration "benefit" of restoring cropland to CRP/WRP, I first calculate the sequestration potential of restored lands. It is common

[8] Sequestration timelines produced using mean estimates were rounded down to the nearest year within the model (Ref. Table 1).

within the biological field to use mean estimates for native prairie as the maximum potential level for restored CRP/WRP lands (Euliss et al., 2006; Gleason et al., 2005; Gleason et al., 2008; Gleason and Tangen, personal discussion, July 28, 2009). In turn, I subtract the mean estimates for cropland from those of native prairie to arrive at the potential net gain from restoration (see Table 1-b). The sequestration itself, however, is a dynamic process. Again relying on the literature, I employ a very conservative sequestration rate of 0.5 Mg/ha/yr to the carbon flow measurements (listed in Table 1-a) (Follet et al., 2001; Lewandrowski et al, 2004).

For converting native prairie to cropland, I again subtract steady state averages for cropland from those of native prairie. A study by Davidson and Ackerman (1993) reports that cultivation of previously untilled soils results (on average) in a 30 percent decrease in SOC, usually occurring entirely within the first five years. The net differences in mean estimates from Gleason et al.'s 2008 study are on par with those of Davidson and Ackerman. In turn, I calculate individual leaching rates for both catchment zones in each physiographic region by dividing the net difference between native prairie and cropland by five. For example, in one catchment the mean SOC estimates for native prairie and cropland were 64.76 Mg and 44.57 Mg, respectively, resulting in a net difference of 20.19 Mg (or 31 percent) (Table 1-b). I then divide this difference by five (as I assume it is entirely lost in the first five years) to arrive at an annual leaching rate of 4.04 Mg/ha (Table 1-a). This estimation process produces SOC leaching rates ranging from 1.22 Mg/ha/yr (upland zone in the Missouri coteau) to 4.04 Mg/ha/yr (upper zone in the Glaciated Plains) when native prairie is converted to cropland.

Table 1. Sequestration and leaching rates of SOC, calculated net differences for SOC and VOC, and relative time span for sequestration/leaching for possible land-use changes.

a.) SOC		Sequestration/Leaching Rates ($Mg \cdot ha^{-1} \cdot yr^{-1}$)		
Region	Zone	CROP to CRP	CRP to CROP	NP to CROP
GP	UPL	0.50	1.00	4.04
	WET	0.50	1.00	1.47
MC/PC	UPL	0.50	1.00	1.22
	WET	0.50	1.00	2.63

b.) SOC		Mean Net Differences in SOC ($Mg \cdot ha^{-1}$)		
Region	Zone	CROP & CRP	(-) CRP & CROP	(-) NP & CROP
GP	UPL	20.19	5.00	20.19
	WET	7.36	5.00	7.36
MC/PC	UPL	6.12	5.00	6.12
	WET	13.16	5.00	13.16

c.) SOC		Time Period for sequestration/leaching (yrs.)		
Region	Zone	CROP to CRP	CRP to CROP	NP to CROP
GP	UPL	40.39	5.00	5.00
	WET	14.73	5.00	5.00
MC/PC	UPL	12.24	5.00	5.00
	WET	26.32	5.00	5.00

d.) VOC		Mean Net Differences in VOC ($Mg \cdot ha^{-1}$)		
Region	Zone	(+/-) CRP & CROP	(-) NP & CROP	(+/-) CRP & NP
GP	UPL	1.57	1.32	0.25
	WET	1.40	0.80	0.60
MC/PC	UPL	1.91	1.83	0.08
	WET	1.84	1.49	0.35

* "GP" stands for Glaciated Plains; "MC/PC" stands for the Missouri and Prairie Coteau; "UPL" stands for the upland zone of the catchment; "WET" stands for the wetland zone of the catchment

To calculate the flow value of SOC lost from converting CRP/WRP lands back into cropland, I first calculate the baseline (mean) estimates for CRP/WRP from which I can subtract mean estimates for cropland. The CRP/WRP SOC estimates from Gleason et al.'s (2008) study were deemed unusable, as values were inconsistently affected by the study site's restoration age, farming history, climate variations, soil type, etc (Gleason and Tangen, personal communication, July 28, 2009). That is, SOC levels found by the USGS study show where the carbon is on a path of change that is dependent on when and where it was converted. Their estimates do not show how or where CRP carbon values will ultimately end up. Therefore, I take the mean estimates for cropland and apply the well-cited sequestration rate of 0.5 Mg/ha/yr (Follet et al., 2001).[9] Given the fact that CRP/WRP contracts are 10 to 15 years in duration, I assume that any restored lands that might be re-cultivated in the future have been in a conservation program for the minimum of 10 years (USDA-FSA). In turn, I estimate CRP/WRP lands to have (on average) five more Mg/ha of SOC (i.e. 10×0.5) than cropland. Furthermore, I assume this difference in SOC will leach out in the first five years, as was the case when native prairie was converted. This results in a transferable leaching rate of 1.0 Mg/ha/yr.

VOC in standing crops (live and dead) was also calculated for each land treatment across physiographic regions and catchment zones by the assessment team. Unlike with SOC, the biomass (and relative carbon) is often higher on restored CRP/WRP lands than native prairie because of differing plant communities (Gleason et al., 2008). Due to the relatively fast establishment (and cultivation) of crops and planted CRP/WRP vegetation, a static VOC gain/loss is calculated for each land-use scenario from each land treatment's mean VOC estimates (Table 1-d).

Once total carbon fluxes (SOC plus VOC) have been determined, I then convert them into units of carbon dioxide equivalents (CO_2e) by multiplying by the conversion factor of 3.67 (Murray et al., 2009). Converting the service flows into units of CO_2e provides the currency for which the carbon service flow values are monetized.

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9 Mean estimates for cropland were used as the starting point for estimating CRP/WRP SOC because restored program lands are essentially cropland at the beginning timeperiod.

2.3ii Reduction of Sedimentation

Gleason et al. (2008) quantified the potential of the CRP and the WRP to reduce upland soil losses and sedimentation of wetland basins in the PPR. They used the Revised Universal Soil Loss Equation[10] (RUSLE) to estimate the change in soil erosion rates on upland zones of catchments when tillage was replaced with perennial cover as part of the CRP and WRP. Input data for RUSLE was obtained from the 1997 National Resources Inventory (NRI) database (USDA-NRI, 2000) for soil series common to both cultivated croplands and conservation program lands within each MLRA. Their study provides mean annual soil-loss estimates ($Mg \cdot ha^{-1} \cdot yr^{-1}$) for cropland and CRP/WRP within each MLRA in North and South Dakota (Figure 4;Table 2).

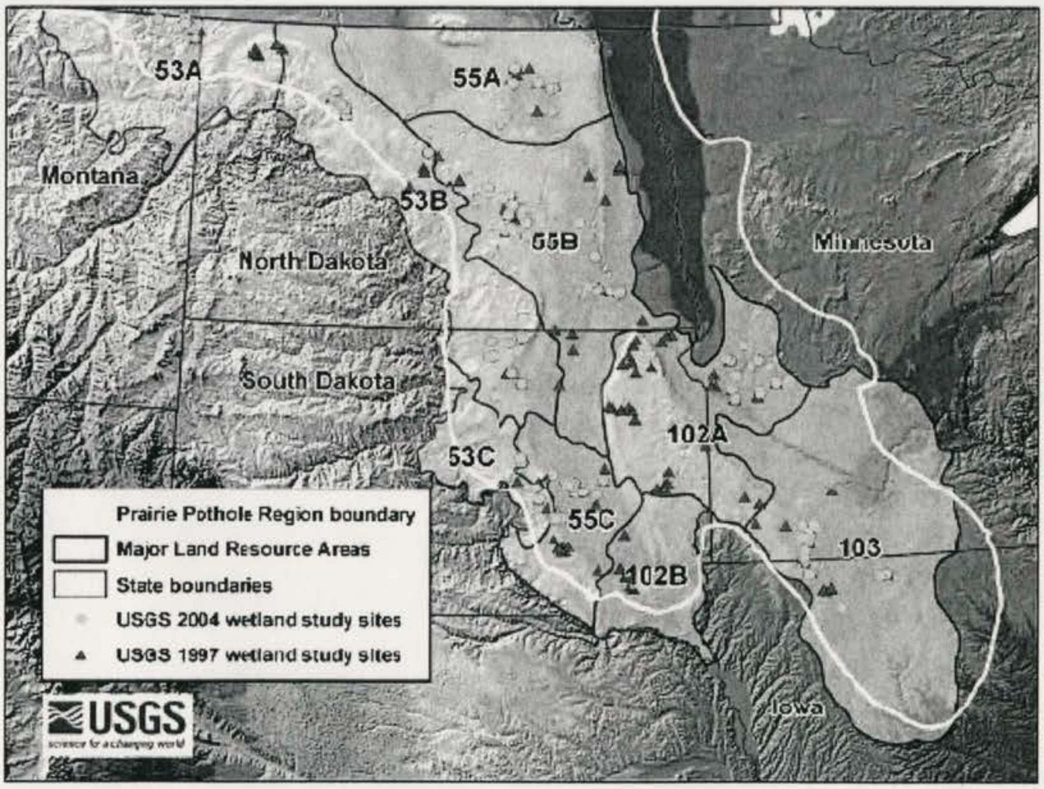

Figure 4. Major Land Resource Areas defined by the U.S. Department of Agriculture in the Prairie Pothole Region of the United States. Symbols represent locations of wetland sampled by the U.S. Geological Survey (USGS) during 1997 and 2004. Adopted from: Gleason et al., 2008.

[10] Reference Gleason et al. 2008 CEAP report for specific description of RUSLE.

Mean soil loss estimates for respective land covers are used in the ecosystem service analysis, with estimates for restored CRP/WRP lands conservatively assigned to native prairie acreage. The multiple estimates within each physiographic region (displayed in Table 2) are averaged to provide a single multiplier. Because the study is focused on the changes to ecosystem services occurring under land use scenarios, net differences are then calculated from the mean estimates. These values are then used in the processing model to track changes in soil-loss tonnage as one land use changes to another.

Table 2. Mean soil-loss values by MLRA.

[Mg, megagrams; ha, hectares; CRP, Conservation Reserve Program; MLRA, Major Land Resource Area; WRP, Wetlands Reserve Program]. Source: Gleason et al., 2008; Adopted from Table E-2.

		Mean soil loss $Mg \cdot ha^{-1} \cdot yr^{-1}$ ($tons \cdot acre^{-1} \cdot yr^{-1}$)		Mean Reduction in soil loss	
MLRA	Region	Croplands	CRP/WRP	$Mg \cdot ha^{-1} \cdot yr^{-1}$ ($ton \cdot acre^{-1} \cdot yr^{-1}$)	Percent
102A	Prairie Coteau	5.26 (2.35)	0.31 (0.14)	4.95 (2.21)	94.11
102B	Glaciated Plains	8.04 (3.59)	0.4 (0.18)	7.64 (3.41)	95.02
53A	Missouri Coteau	10.76 (4.80)	0.51 (0.23)	10.17 (4.54)	95.31
53B	Missouri Coteau	8.2 (3.66)	0.71 (0.32)	7.48 (3.34)	91.22
53C	Missouri Coteau	2.29 (1.02)	0.13 (0.06)	2.16 (0.96)	94.32
55A	Glaciated Plains	2.37 (1.06)	0.23 (0.10)	2.15 (0.96)	90.72
55B	Glaciated Plains	7.24 (3.23)	-0.44 (0.20)	6.8 (3.03)	93.92
55C	Glaciated Plains	6.11 (2.73)	0.25 (0.11)	5.86 (2.61)	95.91

Net Difference (of average)		$Mg.ha^{-1}.yr^{-1}$	$tons.acre^{-1}.yr^{-1}$
GP	CROP - CRP	5.61	2.503
MC/PC	CROP - CRP	6.19	2.761

* "GP" stands for Glaciated Plains, "MC/PC" stands for the combined MLRA's of the Missouri Coteau and Prairie Coteau.

2.3iii Waterfowl Habitat Suitability

The Gleason et al. (2008) CEAP report attempts to assess the potential wildlife habitat suitability of different land covers. However, due to limitations within their study with respect to waterfowl, I relied on a waterfowl production model developed by Terry Shaffer within NPWRC and Ron Reynolds from the Habitat and Population Evaluation Team within the USFWS.[11]

To produce their original model, these authors relied primarily on duck population and wetland habitat data collected on 335 10.4-km^2 sample blocks in the PPR of North and South Dakota during 1987-1998.[12] They then used models presented by Cowardin et al. (1995; Equations 3-7) and Krapu et al. (2000) to estimate production parameters for 5 upland nesting duck species [mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), blue-winged teal (*Ana discors*), northern shoveler (*Anas clypeata*) and northern pintail (*Anas acuta*)] for years 1992-2004. The principle production parameters include (1) overall nest success, (2) recruitment rate (number of females fledged/adult females in the breeding populations), and (3) recruits (total males and females fledged). Shaffer and Reynolds' model also relies on NPWRC's Waterfowl Nest file—a repository of waterfowl nest records submitted yearly by numerous researchers and land managers within the study area—to determine duck preference (probability that a female will select a particular habitat for nesting, given all habitats are equally available) and daily survival rate (DSR). These additional inputs are added to the production model and calibrated to different nesting habitats using methods outlined in Klett et al. (1988).

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11 For a full description of the waterfowl production model reference Reynolds et al. (2007)

12 Additional input data for the production model was obtained from Krapu et al. (2000) and Reynolds et al. (2001)

With the necessary parameters in place, Shaffer and Reynolds' model is able to estimate duck production under current and potential land configurations. Using 2007 breeding pair densities, wetland conditions, and available upland habitat as the baseline, Shaffer altered percentages of native prairie, CRP/WRP, and cropland (i.e. the available nesting habitat) congruent to the percent changes in this study's land use scenarios. In doing so, I am able to estimate the additional number of young ducks fledged to the fall population, referred to as "Recruits," from the PPR of North and South Dokata (Terry Shaffer, personal communication, February 17, 2010).[13] Wetland habitat conditions in 2007 in the U.S. prairies were highly variable throughout the region, generally ranging from good to poor. However, the overall pond estimate (2.0 ± 0.1 million) was 29 percent above the long-term average (1.5 ± 0.02 million from 1955—2005), coupled with favorable conditions in the Canadian prairies (U.S. Fish and Wildlife Service, 2007). All in all, I anticipate the model's estimates to be generally unbiased over the study period, while providing a reasonable basis for the analysis.

In addition to using 2007 wetland and habitat conditions as the baseline in the model, these additional assumptions apply:

1. Wetness conditions and distribution in 2007 are representative of the 20-year period
2. Spatial distribution of breeding pairs in 2007 is representative of the 20-year period
3. Brood survival rates are constant (0.74)
4. Female annual survival rates are constant (0.67) and are the same for adults and juveniles.
5. Nest survival in all habitats is positively related to percent perennial cover in the landscape
6. Density-independent population growth
7. No wetlands are lost due to conversion of grasslands to croplands
8. The ND and SD duck breeding populations are closed (no immigration or emigration)

[13] The model initially produces a number for additional female recruits (see Appendix C). This number was multiplied by two to estimate the total (male and female) number of recruits.

2.4 Ecosystem Service Valuation

An economic perspective on ecosystems portrays them as natural assets providing a flow of goods and services (Daily et al., 2000, Turner, 2008). Once these goods and services are identified and quantified, they can be monetized to complete the valuation process (Murray et al., 2009). Complicating this last step is the fact that most of these goods and services are public and non-market. However, identifying the economic relevance of these services is essential in revealing their societal value because it provides a common metric that allows for comparisons across attributes and differing ecological scenarios (National Research Council, 2005). There are both direct and indirect pathways in which ecosystem services can provide utility to humans. For the monetization process, I attempt to value ecosystem services from a social welfare standpoint. However, the natural goods and services provided can have distinct beneficiaries. For instance, climate stabilization associated with carbon sequestration is provided on a global scale, while the benefits derived from reductions in sedimentation are certainly more localized. These distinctions need to be made in policy discussions and when providing economic assessments.

Given various limitations within the study, benefit transfer methods (as outlined in Rosenberger and Loomis, 2001) are used to monetize the non-market ecosystem services within the analysis. Benefit transfer relies on previous economic studies to make inferences about the economic values of non-market goods and services at an alternative policy site (in place and/or in time). While primary research is the "first-best" strategy to collect information on specific goods, services, or actions, benefit transfer is seen as an important "second-best" strategy to evaluate management and policy actions when primary research is not possible or plausible. Given the financial and time commitments of non-market valuation, benefit transfer has gained momentum within environmental economics research. However, the reliability of the benefit transfer estimates is solely dependent on both the applicability of the study sites and the quality of the original benefit estimation (Wilson and Hoen, 2006). While benefit transfer is likely better than no valuation at all (which assumes the ecological services provided have zero value), caution should be use, especially when the costs of being wrong are high.

The two broad approaches within benefit transfer methodology are (1) value transfer and (2) function transfer. In this study, I use value transfer as it encompasses the transfer of a single (point) benefit estimate. In conjunction with the ecological flow data, I look to monetize three services within the region: carbon sequestration, reduction of sedimentation, and waterfowl production. Previous research done in other wetland dominated landscapes (Jenkins et al., 2010), along with the biological makeup of the PPR, suggests that the services included in the valuation are among the top in terms of economic value.

2.4i Carbon Sequestration

Currently there is a market for carbon trading, however the price is a function of government limits on carbon; not of its true value. Consequently, carbon can be seen as both a market and non-market good. This study uses estimates of the marginal *social cost* (or benefit) *of carbon*, or SCC. This value embodies the damages avoided by mitigating the risk of climate change, and in turn, is expressed in units of carbon dioxide (CO_2). However, due to the complexity and uncertainty surrounding this scientific issue, there continues to be a wide range of published monetary values. In this study, I prescribe a value of \$12/MgCO_2, which is consistent with mean estimates reported by the Intergovernmental Panel on Climate Change's (IPCC) 2007 assessment and Tol's (2004) meta-analysis.[14] A sensitivity analysis in the results explores the implications of pricing carbon at its market price rather than its non-market value.

Total carbon fluxes (converted into CO_2) are tracked for each land type in each scenario for a twenty-year time horizon. The amount of CO_2 sequestered/leached is multiplied by the social value price for each year, and then discounted back to the present with a 4% real discount rate to generate a net present value (NPV) for each land use scenario.[15] The NPV of carbon services provided by each scenario is the sum over land types.

2.4ii Reduction in Sedimentation

Per-ton benefit values for reduced soil erosion are derived from Hansen and Ribaudo's 2008 USDA-Economic Research Service (ERS) study and referenced database.[16] Their study is a progression of work done by the ERS since the 1980s, and is believed to be the best available data for larger analyses on soil conservation benefits. These values incorporate fourteen different categories of soil conservation benefits with respect to farmland erosion. The authors rely on reduced-form models, incorporating complex physical processes that ultimately link soil erosion to environmental quality, and the economic values that both the public and private sector place on these fluxes.

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[14] Tol's (2004) meta-analysis reports a standard deviation of \$22/MgCO_2.

[15] The 4% discount rate has been observed in similar ecosystem service valuations (e.g. Jenkins et al., 2010) and a sensitivity analysis using different rates was deemed unnecessary as it was determined the overall trends forecasted by the model were not highly sensitive.

[16] Per-ton values in Hanson and Ribuado's (2008) database were adjusted to 2007 dollars.

Given the study area, I focus exclusively on changes to water (sheet and rill) erosion. Soil erosion values are summed from ten applicable categories pertaining to sediment in reservoirs, damage to navigation passages, irrigation channels, and road drainages, water-based recreation, and freshwater fisheries, flood mitigation, municipal water treatment and use, and effects to steam-powered powerplants.[17] The applied values can viewed as prices that people, businesses, and government agencies would be willing to pay for a 1-ton reduction in soil erosion. These marginal values are provided for each county within the study region, and are noted to increase in accuracy when aggregated up to regional scales.

With the per-ton (benefit) values being conventionally similar to market prices, total benefits ($) equate to the economic soil-loss values multiplied by the changes in erosion (summed across all changes). In specific, I multiply the changes to upland zone acreage of specific land uses (relative to each scenario) by the net difference in sedimentation estimates (see *2.3ii*) of cropland, CRP/WRP, and native prairie. Calculated values are then summed over the 20-yr. time period and simplified down to NPV using a 4% real discount rate.

2.4iii Waterfowl Habitat Suitability

Within the analysis, I chose to value waterfowl as an input to satisfying recreation hunting demand.[18] Because the PPR serves as the essential breeding habitat to North American waterfowl, the valuation is done at the margin of additional ducks added to the

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17 For a complete list and description of the categories and potential biases within the models used please reference Hansen and Ribaudo (2008).

18 Non-consumptive recreational activities (eg. birdwatching) associated with waterfowl were ignored since the marginal changes in population numbers were thought to have little impact on such activities (Barbier et al., 1997; Laughland et al., 2005).

fall (autumn) flight. Greater population numbers can result in additional waterfowl hunter days (a quantity effect) as well as increased harvest rates for hunters (a quality effect) (Murray et al., 2009).

After a review of the recreation economics literature, I chose to value the quality effects of an additional waterfowl 'kill' beyond people's current harvest. In this light, I conclude that harvest figures are part of a hunter's individual utility function and add to the net economic value they derive from the hunting experience (Laughland et al., 2005).[19] For this type of benefit transfer estimate, I relied on a previous study done by Hammack and Brown (1974).[20] To derive such a value, the following assumptions are made in their valuation: (1) Waterfowl are homogeneous to the hunter, i.e. the value of a bird is not influenced by its species, age, or sex; (2) the kill probabilities are constant for each hunter on each hunting site during the season, and each hunter is aware of the probabilities; (3) each hunter hunts waterfowl at but one site during the season; (4) and all relevant costs are known to each hunter at the beginning of the season. From the given assumptions, a representative hunter will consider any waterfowl shot to be equal in value to any other they might have shot. Results from their contingent valuation survey indicate the marginal value of additional duck bagged to be between $14.72 (2008 prices; $2.38 in 1968) and $32.23 ($5.21 in 1968), for a mean value of $23.45 (Bureau of Labor Statistics, 2009).

However, it would be a mistake to assume that an additional duck bred in the PPR and added to the fall flight unequivocally resulted in an additional duck harvested. In turn, I calculated the average take of waterfowl as a percentage of the total population

[19] Refer to Laughland et al. (2005) for the mathematical model behind the waterfowl hunter's utility function.

[20] This study was chosen because of its application to the Prairie Pothole Region.

and annual harvest figures. This resulted in a U.S. harvest percentage of nearly 35 percent (in 2007) (Flyway.us in conjunction with USFWS).[21] I then multiplied the marginal value of a bagged duck (as revealed in Hammock and Brown, 1974) by the estimated harvest rate, resulting in a range of \$5.15 to \$11.28, and a mean of \$8.21.[22] This value is used as the shadow price for an additional duck produced in the study region and added to the fall flight. As is the case with the other two ecosystem services, I calculate the NPV of additional ducks over the twenty-year study horizon using a 4% real discount rate.

2.5 Agriculture Production and Government-related Payments

While the ecosystem services produced on different land covers provide societal benefits, one must also look into the production of marketed commodities in considering the land's true economic contribution. Cash rent values (Mg/ha) for general cropland (individualized by county) are taken from USDA-NASS 2008 data and are assigned to the deemed acreage. Cash rents were chosen for the study because they are relatively unbiased towards crop type. Additional government payments/subsidies related to cropland were not considered as I assume they are intuitively built in to the cash rent values.

Average annual CRP/WRP county-level payments are derived by dividing 2007 USDA Census data for total government payments (\$) made for CRP/WRP by the

[21] Population estimates for the 10 most common duck species in the traditional survey area was 41.2 million in 2007. Duck harvest numbers for the 2007-2008 season were estimated at 14.5 million.
[22] These estimates assume that waterfowl harvest rates remain constant over the studied time period.

estimated CRP/WRP acreage in each county.[23] These figures are converted into per hectare values and are assigned to the associated acreage within the model. Revenues generated by managed or emergency grazing and haying on CRP/WRP lands were initially considered, yet the operating constraints for these practices seemed to counter any potential gains. Grasslands deemed as native prairie, are assigned no additional market value. These are very conservative estimates, as some managed grazing and/or recreational activities (i.e. hunting, fishing, and wildlife viewing) often co-exist with these land uses (Allan and Witter, 2008).

2.6 Land use Scenarios

Four land-use change scenarios were developed for the ecosystem and economic service tradeoff analysis. The hypothetical scenarios were engineered to represent large, institutional/structural changes. These changes represent foreseeable trends in social and/or private thinking and management that could occur within the next 20 years, such as increased vigilance to preserve remaining native prairies or economic circumstances that lead to continued conversion of these native lands. I do not directly consider the causes or nuances of where the changes might occur, since the scope of interest is on how a major land use change would impact the overall ecosystem services provided. The 20-year time period was chosen to allow for the dynamics of the ecological impacts of land use change to play out and be captured (ex. carbon sequestration potential), while at the same time trying not to abuse some of the linear assumptions built into the accounting model by forecasting far off into the future.

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[23] As noted earlier, CRP and WRP acreage estimates were made from (FY) 2007 USDA-FSA and USDA-NRCS cumulative enrollment data.

The central theme of the scenarios is the role native and planted grasslands play in ecosystem services provided in the future. They are carried out by varying the percentages of native prairie, CRP/WRP lands, and cropland (across counties within the study region) in relation to baseline (2007) figures.[24] Their formulation was aided by existing literature, along with consultation with USDA economists and USFWS habitat specialists (Skip Hyberg and Ron Reynolds, personal communication, September 18, 2009). The variation in the four scenarios can be viewed in the description provided in Table 3.

Table 3. Land use Scenarios

Land-use Change Scenario	Native Prairie		CRP/WRP		Cropland	
	ha (acres)	% gained or (-) lost	ha (acres)	% gained or (-) lost	ha (acres)	% gained or (-) lost
Scenario 1 ("Aggressive Conservation")	0	0	738,685 (1,825,291)	+50	-738,685 (-1,825,291)	-8.21
Scenario 2 ("CRP Mitigation")	-399,491 (-987,131)	-10	399,491 (987,131)	+27.04	0	0
Scenario 3 ("Market Forces")	-399,491 (-987,131)	-10	0	0	399,491 (987,131)	+4.4
Scenario 4 ("Ultimate Conversion")	-399,491 (-987,131)	-10	-369,342 (-912,633)	-25	768,834 (1,899,790)	+8.54

The first scenario, dubbed "Aggressive Conservation," forecasts the land use makeup following the utmost investment in conservation/preservation. I assume all remaining native prairie in the PPR [1,477,371 ha (3,650,533 acres)] is preserved along with a 50 percent increase in CRP/WRP lands that are substituted away from overall

[24] Given various limitations and general aim of the study, I assume any changes in land-use to be uniform across all counties within the study region.

cropland acreage (a decrease of roughly 8.2%). Given future political and financial considerations, a 50 percent increase in CRP/WRP was determined to be at the height of possibilities. This future increase in conservation lands pertains to the specific PPR and does not necessarily have to occur at the national level (i.e. CRP/WRP lands can simply substitute away from other regions). The land use changes within this scenario are certainly plausible if policy makers continue to seek greater market structure for the allocation of ecosystem services. Federal investment in CRP-related programs could also gain momentum if enrolled acreage was used to replace/strengthen more traditional commodity price or (farm) income support programs.[25] Similarly, if traditional farm subsidy programs are simply lessoned or the price of farm inputs, such as fuel, continue to increase faster than commodity prices, we could easily see more individuals willing to place their cultivated lands into restoration programs.

The other three scenarios included in the study all look into the effects (environmental and economic) of projected native prairie loss, coupled with varying degrees of conservation investment. Since 1984, the overall average rate of native prairie conversion to cropland has been 0.5% a year (Stephens, 2008). While many note that this conversion rate has been increasing in recent years, especially in the Dakotas, I conservatively maintain the 0.5% average over the time span of the analysis, resulting in a 10 percent reduction in existing native prairie in 20 years that is assumingly transferred into cropland.

The second scenario, titled "CRP Mitigation," estimates the effects of mitigating projected native prairie loss with additional CRP/WRP lands. Given current estimates,

[25] Overall acreage in production is often managed within farm policy to maintain commodity prices at certain levels.

nullifying a 10 percent reduction in native prairie would require roughly a 27 percent increase in conservation program lands within the region. The third land-use change scenario, "Market Forces," examines the environmental and economic consequences of projected native prairie loss with CRP/WRP lands remaining at current levels. The fourth and final scenario in the analysis, titled "Ultimate Conversion," investigates the effects of projected native prairie loss with a compounded 25 percent reduction in conservation program lands. This group of scenarios is certainly relevant if high commodity prices are maintained, demand for biofuels (and subsequent cropland acreage) continues to increase, and additional funds for conservation programs such as CRP/WRP are not granted due to constraining federal and state budgets.

III. RESULTS

3.1 Scenario Results

Table 4 provides the overall results for the land-use change scenario analysis. Total stock values for the 20-year time period were calculated, as well as amortized annual flow values. The table reveals the overall monetary changes to the three ecosystem services, land income (i.e. cropland cash rent value, CRP/WRP payment value, and net difference), and an overall net value for each land cover configuration. Per/hectare (and per/acre) values were then calculated from the overall net values and acreage figures for the PPR. Estimated biophysical values associated with each land-use change scenario can be viewed in Table 5.

Table 4. Net present value ($) of annual flow and total stock by ecosystem service and land use scenario

Values from Land-use Change (Over 20 yr. time period)		Scenario 1 $	Scenario 2 $	Scenario 3 $	Scenario 4 $
Annual Flow Value	Carbon (SOC+VOC)	33,938,140	-118,518,706	-154,991,620	-179,922,124
	Soil Loss	6,854,726	0	-3,806,021	-7,233,384
	Waterfowl	25,305,070	-15,740,267	-30,007,273	-37,324,622
	CRP/WRP Market Value	66,285,552	35,393,139	0	-33,142,776
	Cropland Market Value	-91,980,124	0	49,865,178	95,855,240
	Net Ecosystem Service Value	66,097,936	-134,258,973	-188,804,914	-224,480,129
	Net Commodity Value	-25,694,572	35,393,139	49,865,178	62,712,464
	Overall (Net) Value of Scenario	40,403,364	-98,865,834	-138,939,736	-161,767,666
	Overall Value/Hectare (acre)	0.85 (0.35)	2.09 (0.85)	2.94 (1.19)	3.42 (1.38)
Total Stock Value	Carbon (SOC+VOC)	461,230,393	-1,610,707,887	-2,106,386,696	-2,445,200,380
	Soil Loss	93,157,783	0	-51,724,965	-98,303,857
	Waterfowl	343,904,160	-213,915,368	-407,808,633	-507,253,789
	CRP/WRP Market Value	900,840,540	481,003,380	0	-450,420,270
	Cropland Market Value	-1,250,037,481	0	677,682,726	1,302,701,467
	Net Ecosystem Service Value	898,292,336	-1,824,623,255	-2,565,920,294	-3,050,758,026
	Net Commodity Value	-349,196,941	481,003,380	677,682,726	852,281,197
	Overall (Net) Value of Scenario	549,095,395	-1,343,619,876	-1,888,237,567	-2,198,476,829
	Overall Value/Hectare (acre)	11.60 (4.70)	28.39 (11.49)	39.90 (16.15)	46.45 (18.80)

In the first scenario, *Aggressive Conservation*, I estimate a 50 percent increase in CRP/WRP lands in the region would generate an ecosystem service value equal to \$898,292,336 over the 20-year policy period, or an annual flow value of \$66,097,935. Large decreases in commodity production value are curbed by conservation program payments, resulting in an overall net benefit to society estimated at \$549,095,395, or \$40,403,363 per year. To provide a more comprehensible figure, these values translate into \$4.70/ha (\$11.60/acre) in stock value, or \$0.35/ha (\$0.85) in flow value, when divided by the study region's general acreage.

The second scenario, *CRP Mitigation*, explores the mitigating potential of conservation program lands to the loss of native prairie. While estimated VOC values actually increase (due to the large biomass of differing plant communities), the overall ecosystem service stock value decreased by \$1,824,623,255 (\$-98,865,833.61/yr.). This estimate is largely driven by the high cost associated with losing roughly 34.6 million Mg (381.2 million tons) of carbon (addressed further with a sensitivity analysis). Additional landowner revenues from CRP/WRP payments curtailed the overall social welfare loss associated with this scenario to \$1,343,619,875 (\$-98,865,833/yr.). This translates into a stock value of \$-11.49/ha (\$-28.39/acre) and \$-0.85/ha (\$-2.09/acre) annual flow value.

While conservation program lands have certainly increased the overall provision of ecosystem services in cropland-dominated regions, these results suggest they cannot provide the same magnitude of environmental benefit as native prairie. Additionally, there are certainly more native prairie-endemic species than the five nesting duck species included in this initial analysis (discussed further later in chapter). Furthermore, the reduction in duck recruits estimated for this scenario (see Table 4; section *2.3iii*) is thought to be very conservative, as wetland conditions in the baseline year of 2007 were much greater in the eastern part of the region where there is prominent CRP acreage, versus the middle portion where native prairie is more common (Terry Shaffer, personal communication, February 26, 2010).

Table 5. Total biophysical values of each ecosystem service or 20-yr. study period.

Ecosystem Service	Total Biophysical Values over 20-yr Study Period			
	Scenario 1	*Scenario 2*	*Scenario 3*	*Scenario 4*
Soil Organic Carbon (Mg)	12,551,454	-34,525,992	-49,299,699	-56,686,552
Veg. Organic Carbon (Mg)	1,242,467	-68,642	-630,013	-1,251,247
Soil Lost (-) or Retained (Mg)	80,595,677	0.00	-44,971,047	-85,268,886
Waterfowl (Additional/Lost Fledgings)	76,284,125	-48,670,082	-92,165,626	-113,876,648

The third scenario, *Market Forces*, estimates the effects of converting the projected 10 percent of overall native prairie to cropland. The model estimates this conversion results in a social welfare loss equal to \$2,565,920,293 over the policy period (\$-188,804,913/yr.), when considering the study's three ecosystem services. The additional commodity value generated reduces this loss to \$1,888,237,567 (\$-138,939,735/yr.), or \$-16.15/ha (\$-39.90/acre) stock value and \$-1.19/ha (\$-2.94/acre) flow value. These negative trends are furthered in the fourth and final scenario, *Ultimate Conversion*. Enormous losses of carbon, soil, and waterfowl due to conversion come at an estimated cost to society of over \$3 billion. Increases in cropland revenue do little to negate these losses, resulting in an estimated net social welfare loss of \$2,198,476,829 stock value and \$161,767,665.59 flow value, or \$(-) 18.80/ha (\$-46.45/acre) and \$(-) 1.38/ha (\$-3.42), respectively. These developments are visual in Figure 5 and Figure 6.

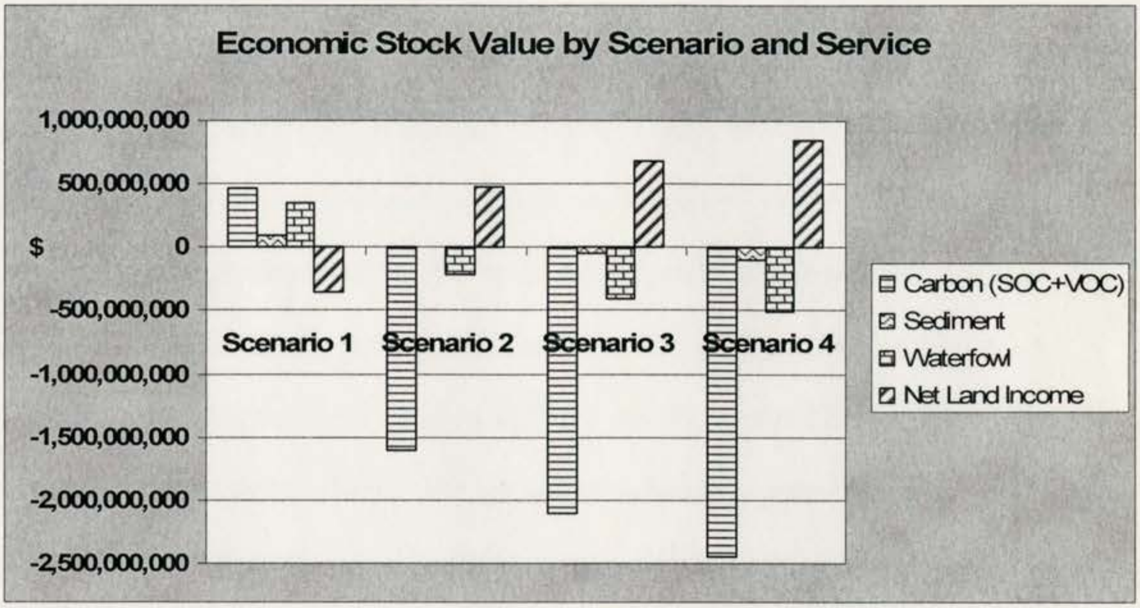

Figure 5. Economic stock value of 20-yr. period by scenario and ecosystem service.

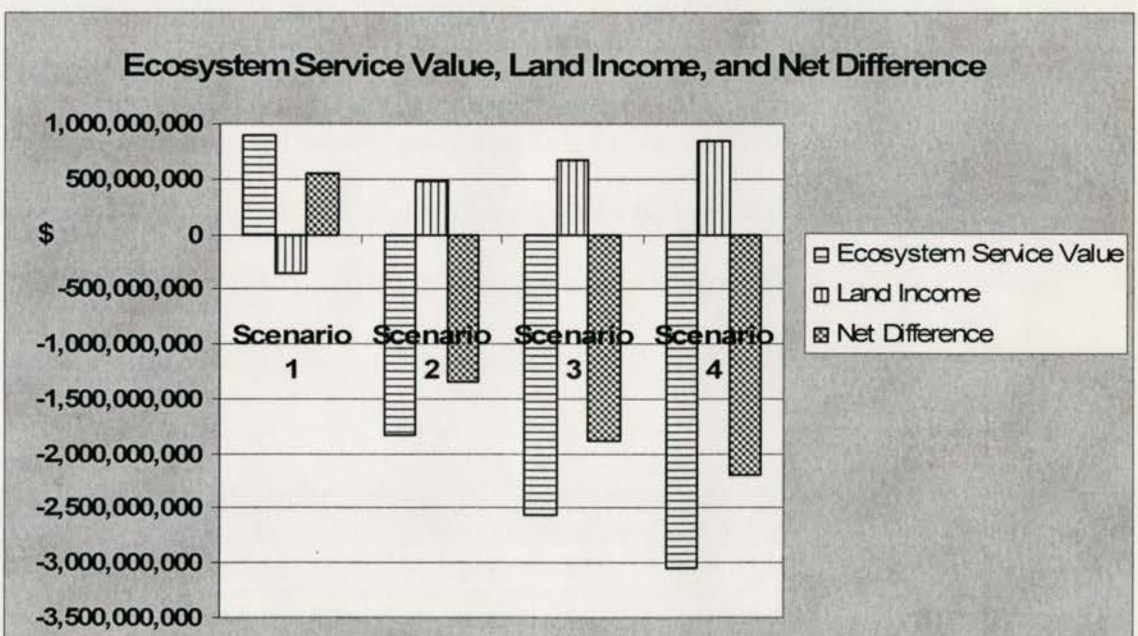

Figure 6. Ecosystem service (stock) value, land income, and net difference by scenario.

3.2 Sensitivity Analysis

The environmental and subsequent human effects from increases in CO_2 levels continue to be debated among scientists of many disciplines. In following, we observe a wide range of values for the social cost of carbon (SCC) within the environmental economics literature. The value used in this study (\$12/tCO_2e) was chosen as a representative mean for the SCC (see section *2.4i*), and was derived from the literature. Even this range of values, however, is often debated (reference Tol's (2004) meta-analysis in which there was a mean of \$12/tCO_2 with a standard deviation of \$22/tCO_2). Given the considerable influence the carbon value has on the model's results (reference Figure 5&6), I conducted a sensitivity analysis using the mean carbon market price and a lower bound value that was low enough to change the scenario trends..

Carbon is a unique ecosystem good in that there are markets in which it can be bought and sold, and in turn, a relative price revealed. Values were chosen from those observed in voluntary "Over-the-Counter (OTC)" markets. In 2008, the price for agricultural soil credits was \$4.43/tCO_2e on the Chicago Climate Exchange (CCX) (Hamilton, et al., 2009), and has ranged from over \$7 to under \$0.15 just in the last two years. Table 6 reveals the results after this price is substituted into the scenario model.

Table 6. NPV (\$) of each scenario with varying carbon price.

CO_2e Price	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
\$12.00	549,095,395	-1,343,619,875	-1,888,237,567	-2,198,476,829
\$4.43	258,135,889	-327,531,649	-559,458,626	-655,962,922
\$1.95	163,968,017	1,321,210	-129,404,676	-156,734,511

While there are decreases in the overall net benefit/cost to society, we still observe the same trends across land-use change scenarios as when the carbon price was set at \$12/tCO_2e. Proceeding with normative science, I wanted to determine at which price is there a trend reversal in the scenario analysis. It is not until the price reaches below the \$2 mark that we observe a significant change in the results. At \$1.98/tCO_2e, the estimated net value of Scenario 2 (*CRP Mitigation*) becomes positive. With carbon valued at this price, the mitigating power of conservation program lands starts to match the loss of native prairie from a social welfare standpoint (all else equal).

There are certainly limitations to these conclusions (discussed in proceeding section), however, these patterns are relevant as the U.S. attempts to implement new/strengthen existing markets for measurable ecosystem services. Surely, one can argue that the market prices included in the analysis are proportional to the amount of government policies in place and are indicative of current market failures that mask the true economic value of the good. For instance, the Congressional Budget Office (CBO) estimates that under the proposed cap and trade program (H.R. 2454) within the U.S., CO_2e allowances are estimated at starting around \$15 in the initial year the cap would take effect (2012), and would rise at an annual rate of 5.6 percent over the course of the policy, reaching \$23 in 2020 (CBO, 2009). If markets for carbon sequestration gain momentum in the near future and prices rise to estimated social welfare (or cost) values, this study's results will be further supported and arguments for conservation provisions and native prairie preservation will be strengthened.

3.3 Limitations

While the three ecosystem services in the analysis are perceived to be at the top in terms of economic value, there is a myriad of services not included in this study that have real and significant relations to human welfare, both direct and indirectly. For instance, Ahearn et al. (2006) reported a conservative non-use value of $33 million per year for increases in Central Plains grassland bird populations as a result from CRP. Other species, such as the white-tailed deer, also have benefited from the increased food provisions found on cropland. In addition, the three services included in the analysis do not capture the entire ecological impact of land conversion in the region. Certainly, there are native prairie-endemic species (ex. prairie grouse and grassland passerines) that experience greater impacts when native prairie is converted, than do the waterfowl species valued in this study (Terry Shaffer, personal communication, 2009).

While the limitations pointed out thus far do not change the direction of the results, there are certainly economic values left out of the analysis as well. Many industries within the region rely heavily on the inputs and outputs of agricultural operations, and could be affected by fluctuations in cropland acres. On the other hand, there are industries that rely on the valued bundle of ecosystem services, such as hunting operations and wastewater treatment plants. However, these values are beyond the scope of this ecosystem service analysis, as they are regional multipliers and only appropriate when doing a regional-scaled spillover assessment. To do so, ecosystem service values would have to be adjusted and/or calculated differently to represent regional benefits. Such an analysis could potentially be very meaningful as it could explore the affects on income distribution and other outputs of concern, such as any shifts in employment.

Overall, the services not included in the analysis were left out due to the lack of reliable biological and/or economic valuation data. It is important for future researchers to stay on top of the literature and to make sure to include all ecosystem and economic services available data allows. Furthermore, by using value transfer techniques I am employing point estimates and not accounting for confidence intervals entirely. This type of sensitivity analysis needs to be conducted in future research, as it can limit the strength of the model's conclusions and policy implications. This is of particular concern with carbon values as they are a dominant force within the model, as has been the case in other economic studies (see Kremen et al. (2000) and Naidoo et at. (2009) for examples). Similarly, there is a range of uncertainty around the biophysical values utilized in the accounting model. Assessing standard deviations associated with the field data would provide further insight.

IV. CONCLUSION

Ecosystem services have been traditionally obscured by the modern way of life and lack of value in the marketplace. However, in recent decades we have begun to realize the essential links to human welfare and have relied on the government to invest in conservation programs such as CRP and WRP and attempt to provide market structure for greater allocation. With a foreseeable future of tightening fiscal budgets, it is imperative to have good information on the return of these investments. Subsequently, policy makers and natural resource managers need to know how their actions might affect the flow of these goods and services and the overall value they provide to society. It is the goal of this study to help address these issues.

The PPR of the Dakotas is a unique and rich ecosystem with a constantly changing landscape. With high ecological scores on native lands, along with significant economic dependence on the agricultural sector, it is important to measure how these land uses work with and against each other. This composition also makes the PPR a highly political area with management needs. In following, I chose to model the economic values of ecosystem services, commodity production/land income, and net differences across policy-relevant land-use change scenarios. Unlike most other ecosystem service studies, I was able to take a holistic approach to the entire ecological region and across various land covers.

This thesis's findings suggest that large investment in restoration programs, and more importantly, native prairie preservation, would provide a net benefit to society over the policy time-period. The largest benefits arise from increases in carbon sequestration, followed by additional waterfowl fledged to the fall flight. Furthermore, the data shows that CRP/WRP cannot mitigate the entire ecological loss of native prairie lands (1 for 1), when considering the three services within the study. The projected 10 percent conversion of native prairie to cropland in the next twenty years is estimated at having an ecosystem service cost to society of over $2.5 billion, present value.

This analysis reveals how economic valuation can be matched with site-specific biological data, which helps local researchers put their own specialized work into a broader framework. This was certainly the case within the PPR of North and South Dakota, as local scientists expressed the desire to expand the social and policy relevance of a detailed CEAP assessment. It is my hope that this information is valuable in directing future research. This type of work also increases efficiency at a more macro level, where various organizations and/or governing bodies can see where to focus their limited resources or to consider policy adjustments.

Given the value of ecosystem services in the scenario assessment, a system of payment for ecosystem services is in need to align farmers' decisions with social interests. The results of this thesis indicate that altering conservation programs such as CRP and WRP in size and criteria is one such policy method to increase the supply of ecosystem services. For instance, if global climate regulation is of significant concern, particular provisions could be written into CRP/WRP payment criteria for uplands in the Glaciated plains, where the highest concentrations of carbon sequestration potential were recorded. Similar provisions could be written into more general farm subsidy programs, as has been attempted with the Swampbuster and Sodsaver provisions implemented/proposed in past Farm Bill legislation.

Ultimately, this research contributes to an emerging literature that attempts to quantify the value of multiply ecosystem services at a regional scale by way of linking sound ecological field data, an accounting model, and economic valuation. This type of data is a necessary input into the decision making process for policies affecting land use and the management of organizations such as the USDA's Office of Environmental Markets. The results from this study provide the initial insight for ecosystem service valuation in the PPR, and a foundation to build upon.

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APPENDIX A

List of Ecosystem Goods and Services (Adopted from Brown et al., 2007)

Ecosystem Goods

- Nonrenewable
  - Rocks and minerals
  - Fossil fuels
- Renewable
  - Wildlife and fish (food, furs, viewing)
  - Plants (food, fiber, fuel, medicinal herbs)
  - Water
  - Air
  - Soil
  - Recreation, aesthetic (e.g., landscape beauty), and educational opportunities)

Ecosystem Services

- Purification of air and water (detoxification and decomposition of wastes)
- Translocation of nutrients
- Maintenance and renewal of soil and soil fertility
- Pollination of crops and natural vegetation
- Dispersal of seeds
- Maintenance of regional precipitation patterns
- Erosion control
- Maintenance of habitats for plants and animals
- Control of pests affecting plants or animals (including humans)
- Protection from the sun's harmful rays
- Partial stabilization of climate
- Moderation of temperature extremes and the force of winds and waves
- Mitigation of floods and droughts

APPENDIX B

Biophysical data used to estimate changes in carbon values.

VARIABLE	REGION	ZONE	TREATMENT	ESTIMATE	SE	LOWER	UPPER
SOC	GP	UPL	CROP	44.57	4.55	35.48	53.65
			CRP	45.65	4.00	37.66	53.64
			NATIVE	64.76	4.97	54.84	74.68
	MC		CROP	49.76	3.81	42.15	57.37
			CRP	39.94	3.46	33.02	46.86
			NATIVE	55.88	4.30	47.30	64.47
	GP	WET	CROP	49.11	4.55	40.02	58.20
			CRP	48.91	4.00	40.92	56.90
			NATIVE	56.47	4.97	46.56	66.39
	MC		CROP	56.56	3.81	48.95	64.16
			CRP	48.50	3.46	41.58	55.41
			NATIVE	69.72	4.30	61.13	78.30
VOC	GP	UPL	CROP	0.23	0.26	-0.29	0.74
			CRP	1.80	0.17	1.45	2.15
			NATIVE	1.55	0.33	0.90	2.21
	MC		CROP	0.00	0.21	-0.41	0.42
			CRP	1.91	0.15	1.61	2.21
			NATIVE	1.84	0.27	1.31	2.37
	GP	WET	CROP	0.40	0.26	-0.12	0.91
			CRP	1.80	0.17	1.45	2.14
			NATIVE	1.19	0.33	0.54	1.85
	MC		CROP	0.44	0.21	0.03	0.86
			CRP	2.29	0.15	1.98	2.59
			NATIVE	1.94	0.27	1.41	2.47

APPENDIX C

Shaffer and Reyolds' duck production (fall recruits) model results. Total females were multiplied by two to estimate total (male and female) production.

2007 Actual Landscape Configuration

	North Dakota				South Dakota				Total Females
Year	BPOP	R	S	Lamda	BPOP	R	S	Lamda	
1	1.84	0.5339	0.67	1.027713	1.72	0.84247	0.67	1.234455	3.56
2	1.890992	0.5339	0.67	1.027713	2.123262	0.84247	0.67	1.234455	4.014254
3	1.943397	0.5339	0.67	1.027713	2.621072	0.84247	0.67	1.234455	4.564469
4	1.997254	0.5339	0.67	1.027713	3.235595	0.84247	0.67	1.234455	5.232849
5	2.052604	0.5339	0.67	1.027713	3.994196	0.84247	0.67	1.234455	6.0468
6	2.109488	0.5339	0.67	1.027713	4.930655	0.84247	0.67	1.234455	7.040143
7	2.167948	0.5339	0.67	1.027713	6.086671	0.84247	0.67	1.234455	8.254619
8	2.228029	0.5339	0.67	1.027713	7.513721	0.84247	0.67	1.234455	9.741749
9	2.289774	0.5339	0.67	1.027713	9.275349	0.84247	0.67	1.234455	11.56512
10	2.353231	0.5339	0.67	1.027713	11.45	0.84247	0.67	1.234455	13.80323
11	2.418446	0.5339	0.67	1.027713	14.13451	0.84247	0.67	1.234455	16.55295
12	2.485468	0.5339	0.67	1.027713	17.44841	0.84247	0.67	1.234455	19.93388
13	2.554348	0.5339	0.67	1.027713	21.53928	0.84247	0.67	1.234455	24.09363
14	2.625136	0.5339	0.67	1.027713	26.58927	0.84247	0.67	1.234455	29.21441
15	2.697887	0.5339	0.67	1.027713	32.82325	0.84247	0.67	1.234455	35.52114
16	2.772653	0.5339	0.67	1.027713	40.51883	0.84247	0.67	1.234455	43.29148
17	2.849492	0.5339	0.67	1.027713	50.01866	0.84247	0.67	1.234455	52.86816
18	2.92846	0.5339	0.67	1.027713	61.74579	0.84247	0.67	1.234455	64.67425
19	3.009616	0.5339	0.67	1.027713	76.22239	0.84247	0.67	1.234455	79.232
20	3.093022	0.5339	0.67	1.027713	94.0931	0.84247	0.67	1.234455	97.18612
20-YEAR TOTAL (Millions of Female Ducks)									**536.3913**

Aggressive Conservation

	North Dakota				South Dakota				Total Females
Year	BPOP	R	S	Lamda	BPOP	R	S	Lamda	
1	1.84	0.55946	0.67	1.044838	1.72	0.8495	0.67	1.239165	3.56
2	1.922502	0.55946	0.67	1.044838	2.131364	0.8495	0.67	1.239165	4.053866
3	2.008704	0.55946	0.67	1.044838	2.641111	0.8495	0.67	1.239165	4.649815

4	2.09877	0.55946	0.67	1.044838	3.272773	0.8495	0.67	1.239165	5.371543
5	2.192876	0.55946	0.67	1.044838	4.055506	0.8495	0.67	1.239165	6.248381
6	2.2912	0.55946	0.67	1.044838	5.025441	0.8495	0.67	1.239165	7.316641
7	2.393933	0.55946	0.67	1.044838	6.22735	0.8495	0.67	1.239165	8.621283
8	2.501273	0.55946	0.67	1.044838	7.716714	0.8495	0.67	1.239165	10.21799
9	2.613426	0.55946	0.67	1.044838	9.562282	0.8495	0.67	1.239165	12.17571
10	2.730607	0.55946	0.67	1.044838	11.84925	0.8495	0.67	1.239165	14.57985
11	2.853043	0.55946	0.67	1.044838	14.68317	0.8495	0.67	1.239165	17.53621
12	2.980968	0.55946	0.67	1.044838	18.19487	0.8495	0.67	1.239165	21.17584
13	3.114629	0.55946	0.67	1.044838	22.54645	0.8495	0.67	1.239165	25.66108
14	3.254283	0.55946	0.67	1.044838	27.93877	0.8495	0.67	1.239165	31.19305
15	3.4002	0.55946	0.67	1.044838	34.62074	0.8495	0.67	1.239165	38.02094
16	3.552658	0.55946	0.67	1.044838	42.90081	0.8495	0.67	1.239165	46.45347
17	3.711953	0.55946	0.67	1.044838	53.16119	0.8495	0.67	1.239165	56.87314
18	3.878391	0.55946	0.67	1.044838	65.87548	0.8495	0.67	1.239165	69.75387
19	4.052291	0.55946	0.67	1.044838	81.63059	0.8495	0.67	1.239165	85.68288
20	4.233988	0.55946	0.67	1.044838	101.1538	0.8495	0.67	1.239165	105.3878

20-YEAR TOTAL (Millions of Female Ducks) **574.5333**

CRP Mitigation

		North Dakota				South Dakota			Total Females
Year	BPOP	R	S	Lamda	BPOP	R	S	Lamda	
1	1.84	0.53438	0.67	1.028035	1.72	0.83616	0.67	1.230227	3.56
2	1.891584	0.53438	0.67	1.028035	2.115991	0.83616	0.67	1.230227	4.007574
3	1.944613	0.53438	0.67	1.028035	2.603149	0.83616	0.67	1.230227	4.547763
4	1.99913	0.53438	0.67	1.028035	3.202465	0.83616	0.67	1.230227	5.201595
5	2.055175	0.53438	0.67	1.028035	3.93976	0.83616	0.67	1.230227	5.994935
6	2.112791	0.53438	0.67	1.028035	4.8468	0.83616	0.67	1.230227	6.95959
7	2.172022	0.53438	0.67	1.028035	5.962665	0.83616	0.67	1.230227	8.134687
8	2.232914	0.53438	0.67	1.028035	7.335432	0.83616	0.67	1.230227	9.568346
9	2.295513	0.53438	0.67	1.028035	9.024249	0.83616	0.67	1.230227	11.31976
10	2.359866	0.53438	0.67	1.028035	11.10188	0.83616	0.67	1.230227	13.46174
11	2.426024	0.53438	0.67	1.028035	13.65783	0.83616	0.67	1.230227	16.08385
12	2.494037	0.53438	0.67	1.028035	16.80223	0.83616	0.67	1.230227	19.29627
13	2.563956	0.53438	0.67	1.028035	20.67056	0.83616	0.67	1.230227	23.23452
14	2.635836	0.53438	0.67	1.028035	25.42949	0.83616	0.67	1.230227	28.06533

15	2.70973	0.53438	0.67	1.028035	31.28405	0.83616	0.67	1.230227	33.99378
16	2.785697	0.53438	0.67	1.028035	38.48649	0.83616	0.67	1.230227	41.27219
17	2.863792	0.53438	0.67	1.028035	47.34713	0.83616	0.67	1.230227	50.21092
18	2.944078	0.53438	0.67	1.028035	58.24773	0.83616	0.67	1.230227	61.1918
19	3.026614	0.53438	0.67	1.028035	71.65794	0.83616	0.67	1.230227	74.68455
20	3.111464	0.53438	0.67	1.028035	88.15554	0.83616	0.67	1.230227	91.26701

20-YEAR TOTAL (Millions of Female Ducks) **512.0562**

Market Forces

	North Dakota				South Dakota				Total Females
Year	BPOP	R	S	Lamda	BPOP	R	S	Lamda	
1	1.84	0.52713	0.67	1.023177	1.72	0.83091	0.67	1.22671	3.56
2	1.882646	0.52713	0.67	1.023177	2.109941	0.83091	0.67	1.22671	3.992587
3	1.92628	0.52713	0.67	1.023177	2.588285	0.83091	0.67	1.22671	4.514565
4	1.970926	0.52713	0.67	1.023177	3.175074	0.83091	0.67	1.22671	5.146
5	2.016606	0.52713	0.67	1.023177	3.894894	0.83091	0.67	1.22671	5.9115
6	2.063345	0.52713	0.67	1.023177	4.777904	0.83091	0.67	1.22671	6.841249
7	2.111168	0.52713	0.67	1.023177	5.861102	0.83091	0.67	1.22671	7.972269
8	2.160098	0.52713	0.67	1.023177	7.18987	0.83091	0.67	1.22671	9.349968
9	2.210163	0.52713	0.67	1.023177	8.819883	0.83091	0.67	1.22671	11.03005
10	2.261388	0.52713	0.67	1.023177	10.81944	0.83091	0.67	1.22671	13.08082
11	2.313801	0.52713	0.67	1.023177	13.27231	0.83091	0.67	1.22671	15.58611
12	2.367428	0.52713	0.67	1.023177	16.28127	0.83091	0.67	1.22671	18.6487
13	2.422298	0.52713	0.67	1.023177	19.97239	0.83091	0.67	1.22671	22.39469
14	2.47844	0.52713	0.67	1.023177	24.50032	0.83091	0.67	1.22671	26.97876
15	2.535883	0.52713	0.67	1.023177	30.05479	0.83091	0.67	1.22671	32.59067
16	2.594657	0.52713	0.67	1.023177	36.8685	0.83091	0.67	1.22671	39.46315
17	2.654794	0.52713	0.67	1.023177	45.22694	0.83091	0.67	1.22671	47.88174
18	2.716324	0.52713	0.67	1.023177	55.48033	0.83091	0.67	1.22671	58.19665
19	2.779281	0.52713	0.67	1.023177	68.05826	0.83091	0.67	1.22671	70.83754
20	2.843696	0.52713	0.67	1.023177	83.48773	0.83091	0.67	1.22671	86.33142

20-YEAR TOTAL (Millions of Female Ducks) **490.3084**

Ultimate Conversion

	North Dakota				South Dakota				Total Females
Year	BPOP	R	S	Lamda	BPOP	R	S	Lamda	
1	1.84	0.51506	0.67	1.01509	1.72	0.82888	0.67	1.22535	3.56
2	1.867766	0.51506	0.67	1.01509	2.107601	0.82888	0.67	1.22535	3.975367
3	1.895951	0.51506	0.67	1.01509	2.582548	0.82888	0.67	1.22535	4.478499
4	1.924561	0.51506	0.67	1.01509	3.164525	0.82888	0.67	1.22535	5.089086
5	1.953603	0.51506	0.67	1.01509	3.877649	0.82888	0.67	1.22535	5.831252
6	1.983083	0.51506	0.67	1.01509	4.751476	0.82888	0.67	1.22535	6.734559
7	2.013009	0.51506	0.67	1.01509	5.822219	0.82888	0.67	1.22535	7.835227
8	2.043385	0.51506	0.67	1.01509	7.134254	0.82888	0.67	1.22535	9.177639
9	2.07422	0.51506	0.67	1.01509	8.741955	0.82888	0.67	1.22535	10.81618
10	2.105521	0.51506	0.67	1.01509	10.71195	0.82888	0.67	1.22535	12.81747
11	2.137294	0.51506	0.67	1.01509	13.12588	0.82888	0.67	1.22535	15.26318
12	2.169546	0.51506	0.67	1.01509	16.0838	0.82888	0.67	1.22535	18.25334
13	2.202285	0.51506	0.67	1.01509	19.70827	0.82888	0.67	1.22535	21.91056
14	2.235518	0.51506	0.67	1.01509	24.14953	0.82888	0.67	1.22535	26.38504
15	2.269252	0.51506	0.67	1.01509	29.59161	0.82888	0.67	1.22535	31.86086
16	2.303495	0.51506	0.67	1.01509	36.26007	0.82888	0.67	1.22535	38.56357
17	2.338256	0.51506	0.67	1.01509	44.43126	0.82888	0.67	1.22535	46.76952
18	2.37354	0.51506	0.67	1.01509	54.44383	0.82888	0.67	1.22535	56.81737
19	2.409358	0.51506	0.67	1.01509	66.71273	0.82888	0.67	1.22535	69.12208
20	2.445715	0.51506	0.67	1.01509	81.74641	0.82888	0.67	1.22535	84.19213
20-YEAR TOTAL (Millions of Female Ducks)									**479.4529**