Valuing Ecosystem and Economic Services across Land Use Scenarios in the Prairie Pothole Region of the Dakotas

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Presentation Outline

- Study Objectives
- Background
  - What has been done?
  - Study Area
- Methodology
  - Valuation Process/Integrating Ecology and Economics
  - Deriving Biophysical Values
  - Deriving Economic Values
- Results
  - Model Results
  - Sensitivity Analysis
- Conclusions

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Study Objectives

- To model and analyze the primary ecosystem and economic services in the Prairie Pothole Region (PPR) of North and South Dakota
- To illustrate and assess the societal values of agricultural products and ecosystem services produced under policy-relevant, future land use scenarios (ex. native prairie conversion)
- Explore the effectiveness of mitigating native prairie loss with conservation program lands

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What has been done?

- Many ecosystem service valuations, yet integration relatively new phenomenon
- Incorporating spatial component (ex. GIS) (ex. include: Troy and Wilson, 2006; Kreuter et al., 2001; Eade and Moran, 1996, Zhao et al., 2003, Lant et al., 2004)
- Broad scale of multiple services (Costanza et al., 1997; Troy and Wilson, 2006) vs. Highly detailed functional analysis of single service at smaller scales (Polasky et al., 2008; Smith, 2007)
- Very few look attempt to model future conditions and/or combine other revenue streams (Nelson et al., 2009-uncommon example)

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Study Area

- Covers approx. 900,000 km^2 (incorporating parts of Iowa, Minnesota, North Dakota, South Dakota, and Montana, as well as south-central part of Canada)
- Composed historically of mixed prairie grasses, interspersed with extensive wetlands
- High ecological value
- High agricultural value
- Conversion threats

Ecosystem Service Valuation Process

1. Identify the ecosystem services by land use
2. Quantify the biological values (down to annualized per-acreage values)
3. Monetize those values
4. Track and sum the flux in those values as acreage changes by policy scenario

$$V(ES_i) = \sum_{k=1}^{n} A(LU_i) \quad V(ESk_i)$$

V(ESi) = total (or net) ecosystem service value by land use/cover type (i)
A(LUi) = area of land use/cover type (i)
V(ESki) = annual value per unit area for ecosystem service type (k) generated by land use/cover type (i) (adopted from Troy and Wilson, 2006).

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Valuation Breakdown of Study

1) **Identify Services and Land uses:**

Three Ecosystem Services:	Three land uses:
1. Carbon Sequestration	1. Native Prairie
2. Reduction in Sedimentation	2. CRP & WRP ("Restored") Prairie
3. Waterfowl Production	3. Cropland

2) **Quantify Biological Values:**

- "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" –Gleason et al., 2008

3) **Monetize Biological (and other) Values:**

- Benefit (Value) Transfer

4) **Track and Sum Changes:**

- Determined acreage figures and produced an accounting model that estimates changes as acreage fluctuates by scenario

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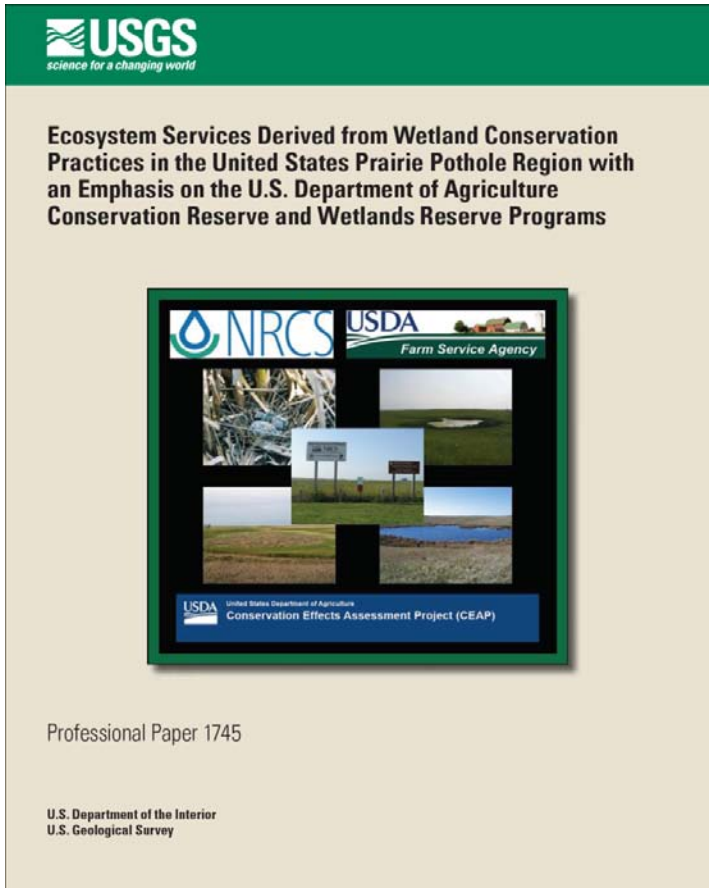
Biophysical Values

- Mean estimates and dynamic flows for carbon sequestration/leaching and changes in sedimentation for accounting model were calculated from Gleason et al. (2008).



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Waterfowl Production

- Relied on a waterfowl production model developed by Terry Shaffer (NPWRC) and Ron Reynolds (HAPET-USFWS)
- Principle production parameters include:
  - Overall nest success
    - Duck Preference
    - Daily Survival Rate (DSR)
  - Recruitment rate (number of females fledged/adult females in the breeding population)
  - Recruits (total males and females fledged)

➔ Model able to estimate duck production ("Recruits") under current and future land configurations

- Model assumptions (2007 land configuration as baseline)

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Carbon Valuation ($)

- Marginal *social cost of carbon* (SCC)
  - $12/Mg$CO_2$ ➔ consistent with mean estimates from IPCC and Tol's (2004) meta-analysis
- Total carbon fluxes (converted into CO_2) are tracked for each land use in each scenario for the 20-yr. time period
- Amount sequestered/leached multiplied by SCC and discounted back to NPV using 4% real discount rate

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Reduction in Sedimentation ($)

- Per-ton benefits derived from Hansen and Ribaudo's 2008 USDA-ERS study/database
- We include values from 10 applicable categories pertaining to water (sheet and rill erosion)
  - Marginal values are provided for each county within study area
- Total benefits equate to soil-loss values multiplied by the changes in erosion (summed across all changes)

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Waterfowl Values ($)

- Satisfying recreational hunting demand
  - Quantity Effect vs. Quality Effect
- Hammack and Brown (1974)
  - Present marginal values of an additional duck "bagged"

➔ Combine with average take of waterfowl to determine shadow price for an additional duck produced in the PPR and added to the fall flight ($8.21)

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Ag. Production and Gov't.-related Payments

- Cash Rent Values (Mg/ha) for general cropland (individualized by county)
  - USDA—NASS 2008

- CRP/WRP Payments
  - USDA—2007 Census: Total government payment made for CRP/WRP (by county) divided by estimated program acreage

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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	738,685.35 (1,825,291.49)	+50	-738,685.35 (-1,825,291.49)	-8.21
Scenario 2 ("CRP Mitigation")	-399,491.93 (-987,131.05)	-10	399,491.93 (987,131.05)	+27.04	0	0
Scenario 3 ("Market Forces")	-399,491.93 (-987,131.05)	-10	0	0	399,491.93 (987,131.05)	+4.4
Scenario 4 ("Ultimate Conversion")	-399,491.93 (-987,131.05)	-10	-369,342.67 (-912,633.24)	-25	768,834.61 (1,899,790.32)	+8.54

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Model Results

Values from Land-use Change (Over 20 yr. time period)		Scenario 1	Scenario 2	Scenario 3	Scenario 4
		$	$	$	$
Annual Flow Value	Carbon (SOC+VOC)	33,938,139	-118,518,705	-154,991,619	-179,922,123
	Soil Loss	6,854,726	0.00	-3,806,020	-7,233,383
	Waterfowl	25,305,070	-15,740,267	-30,007,272	-37,324,621
	CRP/WRP Market Value	66,285,552	35,393,139	0.00	-33,142,776
	Cropland Market Value	-91,980,124	0.00	49,865,177	95,855,239
	Net Ecosystem Service Value	66,097,935	-134,258,972	-188,804,913	-224,480,129
	Net Land Income	-25,694,571	35,393,139	49,865,177	62,712,463
	Overall (Net) Value of Scenario	40,403,363	-98,865,833	-138,939,735	-161,767,665
	Overall Value/Hectare (acre)	0.35 (0.85)	-0.85 (-2.09)	-1.19 (-2.94)	-1.38 (-3.42)

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The long-term average conversion rate of 0.5%/yr of NP is coming at an estimate cost of $138.9 million

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Model Results

CRP cannot mitigate the ecosystem service values (1 for 1) of Native Prairie

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	Overall Value/Hectare (acre)	0.35 (0.85)	-0.85 (-2.09)	-1.19 (-2.94)	-1.38 (-3.42)
Total Stock Value	Carbon (SOC+VOC)	461,230,392	-1,610,707,887	-2,106,386,696	-2,445,200,379
	Soil Loss	93,157,783	0.00	-51,724,965	-98,303,856
	Waterfowl	343,904,160	-213,915,367	-407,808,632	-507,253,789
	CRP/WRP Market Value	900,840,540	481,003,379	0.00	-450,420,270
	Cropland Market Value	-1,250,037,481	0.00	677,682,726	1,302,701,466
	Net Ecosystem Service Value	898,292,336	-1,824,623,255	-2,565,920,293	-3,050,758,025
	Net Land Income	-349,196,941	481,003,379	677,682,726	852,281,196
	Overall (Net) Value of Scenario	549,095,395	-1,343,619,875	-1,888,237,567	-2,198,476,829
	Overall Value/Hectare (acre)	4.70 (11.60)	-11.49 (-28.39)	-16.15 (-39.90)	-18.80 (-46.45)

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	Net Land Income	-349,196,941	481,003,379	677,682,726	852,281,196
	Overall (Net) Value of Scenario	549,095,395	-1,343,619,875	-1,888,237,567	-2,198,476,829
	Overall Value/Hectare (acre)	4.79 (11.83)	-11.49 (-28.39)	-16.15 (-39.90)	-18.80 (-46.45)

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Results (Cont.)

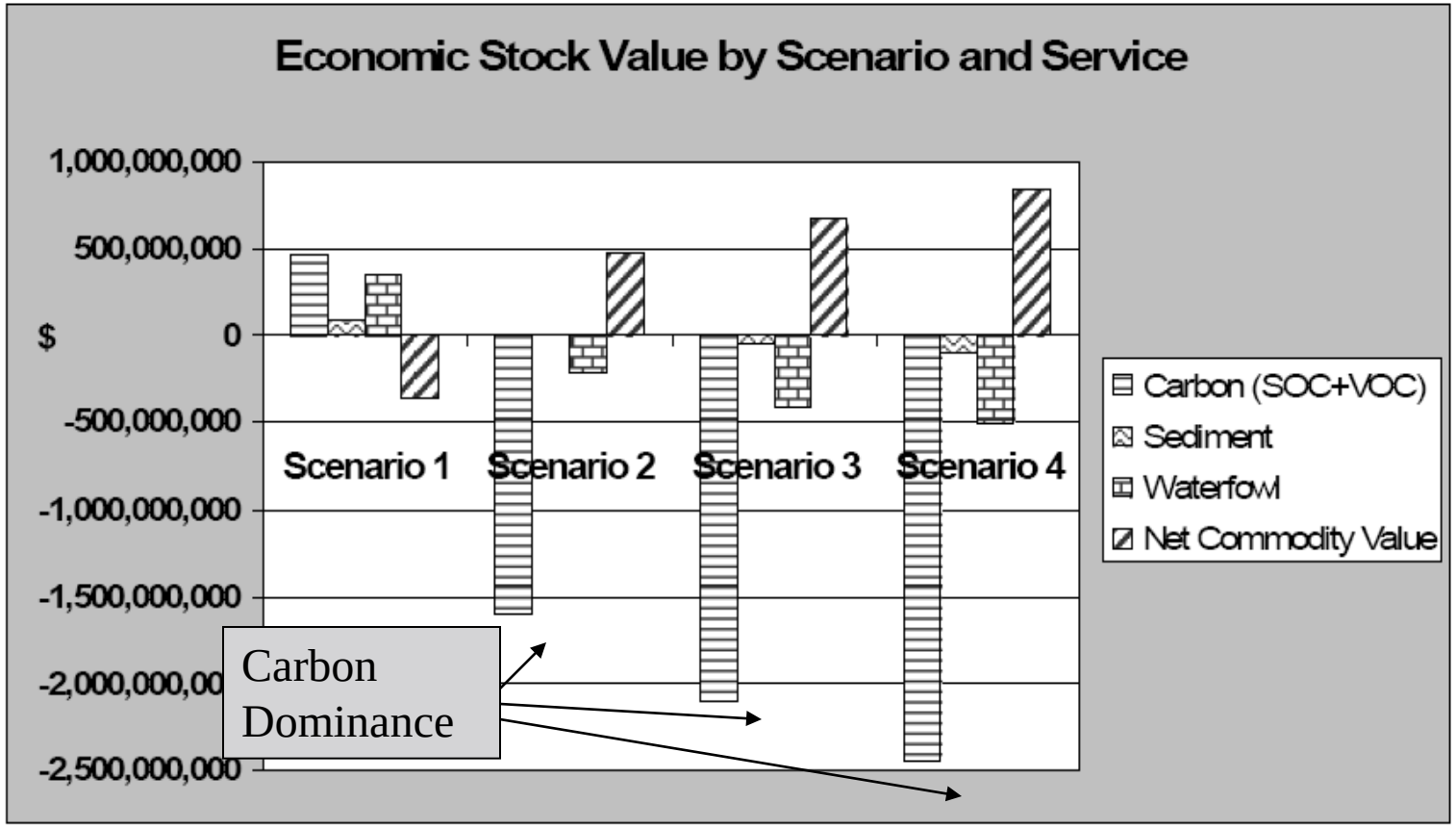

Figure 4. Economic stock value of 20-yr. period by scenario and ecosystem service.

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Sensitivity Analysis

- Carbon prices a driving force in model + uncertainties of carbon price ➔ need for sensitivity analysis
- SCC vs. Market Prices
- Future implications

CO_2e Price	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*
$12.00	549,095,395.23	-1,343,619,875.58	-1,888,237,567.44	-2,198,476,829.00
$4.43	258,135,889.15	-327,531,649.89	-559,458,626.68	-655,962,922.62
$1.95	162,814,941.32	5,347,980.19	-124,138,709.49	-150,621,510.75

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Conclusions

- Large investment in restoration programs and NP preservation would provide a net benefit to society over policy time-period
  - Largest benefits arise from increases in carbon sequestration, followed by additional waterfowl fledged to the fall flight
- CRP/WRP cannot mitigate the entire ecological loss of NP lands (1 for 1)
- The projected 10 percent conversion of native prairie to cropland over the next 20 years is estimated at having an ecosystem service cost of over $2.5 billion (NPV)

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The End—Thank you

- Comments, Questions, Suggestions

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Carbon Sequestration—Biophysical Values

- Need to consider three land conversion scenarios:
  1. Native Prairie being converted to Cropland
  2. CRP/WRP converted back to Cropland
  3. Cropland becoming enrolled in CRP/WRP
- We calculated net differences of SOC for each land use (using mean estimates from CEAP Report)
- Mean estimates coupled with historic sequestration/leaching rates (from the biological literature)

  ➔Timeline for sequestration/leaching produced

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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 ($Mg \cdot ha^{-1} \cdot yr^{-1}$)		
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

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Reduction in Sedimentation—Biophysical Values

- Gleason et al. (2008) quantified the potential of CRP and WRP to reduce upland soil losses and sedimentation of wetland basins

- Used RUSLE to estimate the change in soil erosion rates on upland zones of catchments when tillage was replaced by CRP/WRP cover ➔ estimates for restored CRP/WRP lands were conservatively assigned to NP

- Physiographic regions were averaged and net differences calculated

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Biophysical Values

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)	12,551,454.13	-34,525,992.28	-49,299,699.22	-56,686,552.68
Veg. Organic Carbon (Mg)	1,242,467.34	-68,642.23	-630,013.37	-1,251,247.04
Soil Lost (-) or Retained (Mg)	80,595,677.23	0.00	-44,971,047.66	-85,268,886.27
Waterfowl (Additional/Lost Fledgings)	76,284,125	-48,670,082	-92,165,626	-113,876,648

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Valuation Breakdown of Thesis (Cont.)

- Acreage Estimates:
  - Made using data extracting software (ESRI ArcMap 9.2)
    - Regional boundaries for the PPR were overlaid to produce exact acreage (and percentages)
    - County, Physiographic Region, MLRA, Catchment zone, and Land use
  - Catchment zones defined using 1997 National Resources Inventory (NRI)
  - Cultivated Cropland and Native Prairie estimates—HAPET land cover data set (2002)
  - CRP—FY 2007 USDA-FSA
  - WRP—FY 2007 USDA-NRCS

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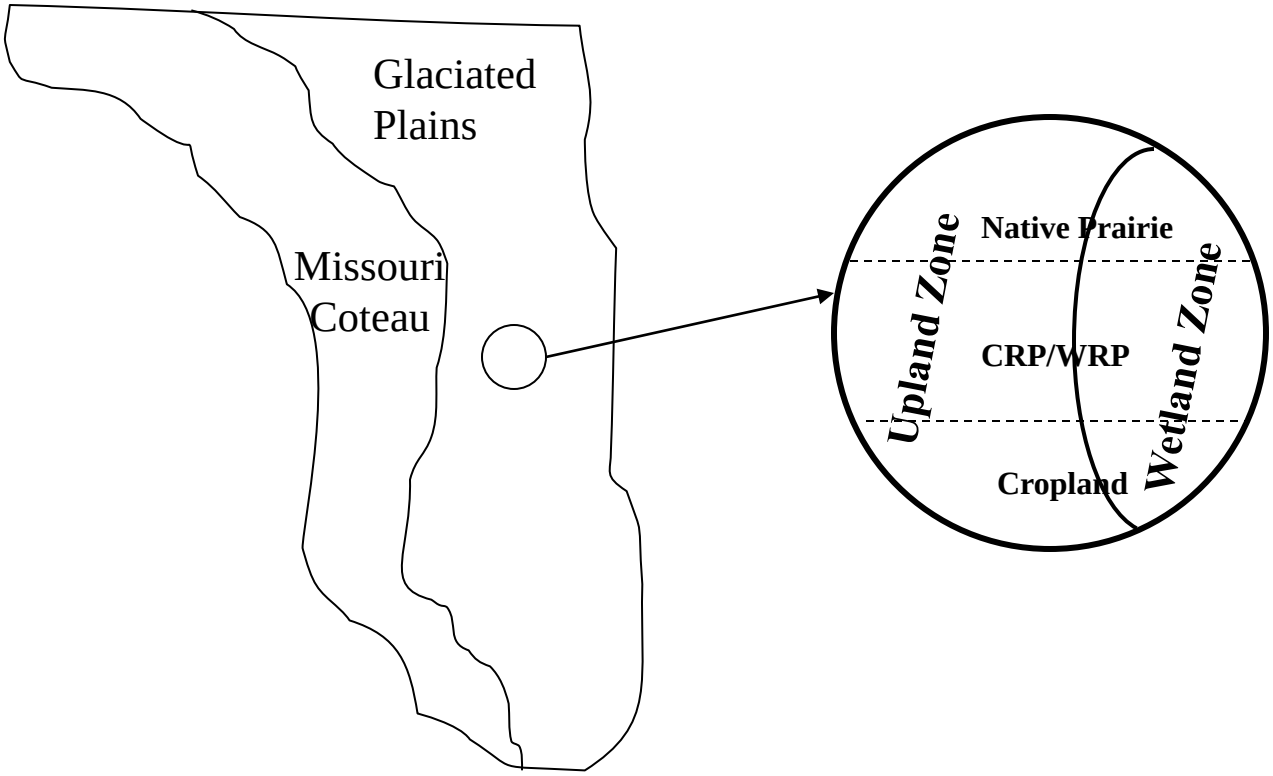
Biophysical Value Breakdown



Results (Cont.)

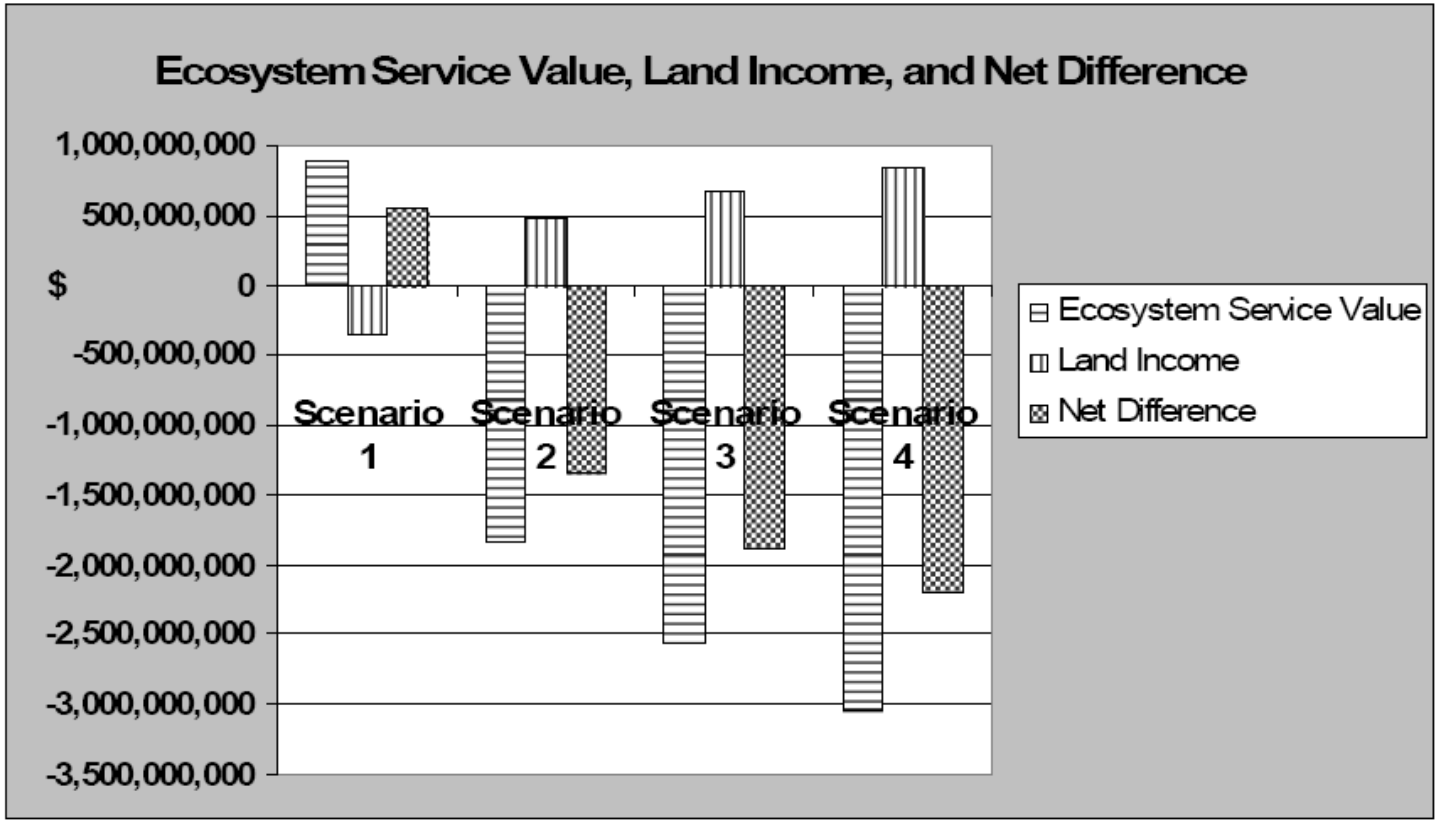


Figure 5. Ecosystem service (stock) value, land income, and net difference by scenario.

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CO_2 Price	Scenario 1	Scenario 2	Scenario 3	Scenario 4
$12.00	549,095,395	-1,343,619,876	-1,888,237,567	-2,198,476,829
$4.43	258,135,889	-327,531,650	-559,458,627	-655,962,923
$1.95	162,814,941	5,347,980	-124,138,709	-150,621,511
$0.10	91,708,589	253,665,446	200,595,906	226,346,881

Contributions

- Contributions to an emerging literature
- Highlights the value of native prairie, conservation programs, and potential ecosystem service markets (ex. importance of carbon value)
- Allowing policy makers and land managers to make more knowledgeable, efficient, and defensible decisions

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Limitations & Future Directions

- Ecosystem and economic services included/excluded
- Regional multipliers
- Reliability of Benefit Transfer

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