Articles

An Integrated Strategy for Grassland Easement Acquisition in the Prairie Pothole Region, USA

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Abstract

Acquisition of perpetual grassland easements is a principal tactic used by the United States Fish and Wildlife Service and its partners to protect nesting habitat for migratory birds in the Prairie Pothole Region of North and South Dakota, USA. This public-private partnership resulted in the conservation of more than 344,000 ha of grassland during 1998–2012. Past easement acquisition has been targeted to landscapes with greatest expected accessibility to breeding duck pairs without active consideration of probability of conversion or cost of protection. The rising cost of easement acquisition in recent years indicates re-evaluation and refinement of the easement acquisition strategy could help to improve programmatic outcomes. We assessed regional patterns of easement acquisition during 1998–2012, evaluated the current targeting strategy, and used a combination of publicly available and proprietary geospatial data to develop an easement targeting Geographic Information System that integrated information about conversion probability and protection cost with current targeting criteria. Our assessment indicated grassland protection was negatively affected by rising land prices during 1998–2012. In the five years between 2008 and 2012, about 100,000 ha of grassland were protected at a cost of $83 M. The 2008–2012 acquisitions represented 30% of total protection during 1998-2012 but composed 47% of the total expenditure. We observed strong evidence easements were targeted to priority landscapes both before and after formalization of the United States Fish and Wildlife Service conservation strategy in 2004. We also found evidence of an opportunity to increase efficiency of future acquisitions. We identified 0.9 M ha of currently unprotected priority grassland in the region with greater than expected conversion risk and smaller than expected protection cost. We suggest future grassland easement acquisition be refocused on this refined priority area and that an adaptive approach to future easement acquisition, including targeted acquisitions, directed

monitoring, and data-based decisions, provides a logical framework for implementation of this new strategy and will facilitate continued conservation success.

Keywords: agricultural landscapes, *Anatinae*, conservation planning, ducks, land protection, private lands conservation

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Short title: Grassland Easement Acquisition in the Prairie Pothole Region

Introduction

The Prairie Pothole Region of North and South Dakota (hereafter PPR) is a globally important region both for agriculture and migratory birds. Most land in the PPR is privately owned and used for production of small grains, row-crops, or livestock (Johnson et al. 1994; Doherty et al. in press). North and South Dakota are major producers of wheat (*Triticum aestivum*) and cattle (*Bos taurus*), and recently the planted area of row crops in these states, particularly corn (*Zea mays*) and soybeans (*Glycine max*), has increased (USDA 2007). For example, during 2006–2011, 271,000 ha of grassland transitioned to corn and soybeans in the Dakotas (Wright and Wimberly 2013). The native grasslands and shallow wetlands of the PPR provide continentally significant breeding habitat for populations of wetland- and grassland-dependent migratory birds (Skagen and Thompson 2001; Kushlan 2002; PPJV 2005). During 1998–2012, this region supported an average population of 7.6 M (range: 4.5 M–12.5 M) breeding ducks (*Anas* spp. and *Aythya* spp.; Zimpfer et al. 2012) at higher recorded densities than any other area on the North American continent. Grassland provides attractive and secure nesting habitat for breeding ducks (Greenwood et al. 1995; Reynolds et al. 2001; Horn et al. 2005; Stephens et al. 2005), thus conservation of grassland in the PPR is a high priority under the North American Waterfowl Management Plan (NAWMP; United States Fish and Wildlife Service and Canadian Wildlife Service 1986).

Purchasing perpetual easements that protect grassland from conversion to cropland, but retain land in private ownership, is currently the principal tactic used by the United States Fish and Wildlife Service (FWS) and other conservation organizations to permanently protect nesting habitat for ducks and other wetland- and grassland-dependent migratory birds in the PPR (PPJV 2005). Although the FWS acquired grassland easements in the PPR since 1970, the majority (73%) of the total protected area has been acquired since 1998. During 1998–2012, FWS and its conservation partners spent $156.2 M on grassland easement acquisition in the PPR (T. Fairbanks and B. Mulvaney, FWS Region 6 Realty Program, unpublished data). Ducks Unlimited, Inc. was the major provider of private matching funds with contributions totaling $26.9 M or about 17% of total funding. This public-private partnership resulted in the permanent protection of more than 344,000 ha of grassland by easements acquired during 1998–2012 (T. Fairbanks and B. Mulvaney, FWS Region 6 Realty Program, unpublished data).

In the past, a combination of professional judgment, logistical considerations, and breeding pair information has been used to target easement acquisitions to landscapes with the greatest abundance of breeding duck pairs (FWS 1992). This approach was further developed and formalized by FWS in 2004 (GAO 2007). Since 2005, easements have been prioritized based on expected accessibility of grassland nesting habitat to breeding duck pairs estimated from ongoing count surveys (i.e., Four Square Mile Breeding Waterfowl Population and Production Survey; Cowardin et al. 1995; Reynolds et al. 2006) and other potential migratory bird and endangered species benefits. The objective of this approach is to direct grassland easement acquisition to landscapes with the greatest potential benefit to upland nesting ducks (*Anas* spp. and *Aythya* spp.) and to maximize the area of protected grassland in these priority landscapes.

Recent assessments of grassland easement objectives indicate that if projected trends in grassland loss and protection cost continue, current acreage goals for grassland protection in the PPR will not be achieved (GAO 2007; Doherty et al. In Press). During 1998–2012, average inflation-adjusted corn prices in North and South Dakota increased 210% (from $1.89 per bushel to $5.88 per bushel) while average inflation-adjusted cropland rental rate in the PPR increased 61% (from $44 per acre to $71 per acre; United States Department of Agriculture, National Agricultural Statistics Service 2012). Concurrently, the average inflation-adjusted cost of grassland easements increased 300% from $79 per acre in 1998 to $315 per acre in 2012. Conversion of grassland to cropland has also increased as the market price of profitable commodity crops like corn has increased (Stubbs 2007; Stephens et al. 2008; Rashford et al. 2011; Wright and Wimberly 2013).

Increased commodity prices, increased cropland value, and rapid cropland expansion in the PPR indicate a need to adapt the current prioritization strategy for grassland easement acquisition in response to increased protection cost. Additional need for refined targeting is evident in the rising demand for easements from private landowners, which consistently exceeds available funding (B. Mulvaney, FWS Region 6 Realty Office, Aberdeen, SD, personal communication). Because conversion probability and protection cost are spatially variable (Rashford et al. 2011; Walker 2011), incorporating information about these factors may help focus grassland easement acquisition to sites with greatest value for breeding ducks and greater risk of loss relative to protection cost and thereby lead to more cost-effective use of limited funding (Newburn et al. 2005; Pressey et al. 2007; Bode et al. 2008; Polasky 2008).

We investigated grassland easement acquisition by FWS and its conservation partners in the PPR during 1998–2012 with three primary objectives: 1) assess the effect of rising protection costs on grassland easement acquisition at the regional level, 2) evaluate whether formalization targeting strategy based in 2004 changed the spatial distribution of acquisitions, and 3) develop a new, spatially-explicit easement targeting Geographic Information System (GIS) to facilitate more strategic easement acquisition by augmenting the existing GIS-based system with information about probability of grassland conversion and cost of protection.

Methods

Analysis area

The analysis area comprised the Prairie Pothole Region of North and South Dakota (Figure 1). The climate, land use, and physical geography of this region are well described elsewhere (e.g., Bluemle 1991; Johnson et al. 1994; Millett et al. 2009). Because of the PPR’s importance to breeding ducks and other grassland birds, this area is the focus of easement acquisition efforts and accounts for 80% (0.9 M ha) of the total area of all types of easements held by FWS nationwide (FWS 2011). We separated North and South Dakota in all comparative analyses, because easement programs in the two states are delivered by different personnel and are subject to different state-level administrative constraints.

Assessment of recent easement acquisitions

We assessed temporal patterns in region-wide grassland easement acquisition in North and South Dakota during 1998–2012 with data from the FWS Region 6 Realty Program (T. Fairbanks and B. Mulvaney, FWS Region 6 Realty Program, unpublished data). Specifically, we used the R environment (R 2.15.1; R Development Core Team 2012) and the contributed package ggplot2 (Wickham 2009) to examine the total number of US dollars spent (in 2005 dollars), the total area protected, and the unit cost of grassland protection (in 2005 dollars per hectare) by year for each state. We looked for patterns in the year-to-year data consistent with recent trends in commodity prices and cropland rental rate: including increased overall cost, decreased area protected, and increased protection cost per unit area.

Evaluation of current targeting strategy

We investigated whether the easement acquisition strategy developed by FWS in 2004 and subsequently adopted by the PPJV (Prairie Pothole Joint Venture; joint ventures are partnerships established under the North American Waterfowl Management Plan to help conserve the continent's waterfowl populations and habitats) changed targeting of easements to priority landscapes after it was implemented in 2005. We used publicly available and proprietary geospatial data (Table 1; publicly available data in Data S1, proprietary FWS grassland easement data available by special request from the current Project Leader, FWS Region 6 HAPET, Bismarck, ND.) and standard tools in ArcGIS Desktop 10.0 (ESRI, Inc., Redlands, CA, USA) to compare the spatial distribution of grassland protected during 1998–2004 (pre-conservation strategy) with the spatial distribution of grassland protected during 2005–2012 (post conservation strategy). To avoid errors when calculating areas, all spatial analyses were conducted in the same map projection and datum (Universal Transverse Mercator Zone 14 North, North American Datum 1983). We ran the repair geometry tool on all feature class layers before converting to grid data. We used the snap raster tool to align all grid layers to a common grid with the same extent as the analysis area.

We characterized the spatial distribution of grassland easements in terms of current priorities by combining the FWS grassland easement layer with the 3-class layer of FWS acquisition priority based on accessibility to breeding duck pairs (Pairs Class 1 comprises areas accessible to at least 23 pairs/km^2 on average, Pairs Class 2 comprises areas accessible to 16 pairs/km^2 –22 pairs/km^2, and Pairs Class 3 comprises areas accessible to 10 pairs/km^2–15 pairs/km^2). These priority classes encompass the spatial distribution of uplands accessible to 94% of the expected breeding duck pairs in the PPR (4,343,248 pairs). Specifically, we converted the FWS priority layer to a 30-m grid and used the Zonal Statistics tool in ArcGIS to calculate the majority (dominant) priority class associated with each grassland easement tract.

After we calculated the dominant priority class associated with existing grassland easements acquired during 1998–2012, we used a chi-squared goodness-of-fit test (Sokal and Rolf 1995) to statistically compare the spatial distribution of protected grasslands before and after implementation of the FWS conservation strategy in 2005 (Fisher and Dills 2012). The null hypothesis predicted no change in the distribution of grassland easements relative to the priority classes in the period before (pre 2005) and after (post 2004) the implementation of the formal conservation strategy. We considered chi-squared statistics that had a probability of 0.05 or smaller under the null hypothesis of identical distributions to be statistically significant, and we conducted all statistical tests in the R environment (R 2.15.1; R Development Core Team 2012). We predicted that ongoing targeting of grassland easement acquisition to areas with greater breeding pair abundance had concentrated easements in the higher-ranking priority classes throughout the life of the program (FWS 1992) and that formalization of the conservation strategy in 2004 would be associated with an increase in the number of easements acquired in higher-ranking priority classes.

Development of the integrated easement prioritization GIS

To facilitate refined targeting of easement acquisition, we combined the existing FWS easement priority classes based on habitat value for breeding duck pairs with information about spatial variation in correlates of conversion probability and protection cost. We were particularly interested in identification of unprotected grasslands in FWS priority class 1 or 2 (areas accessible to at least 16 breeding duck pairs /km^2) with greater expected probability of conversion and reduced expected cost of protection relative to the remaining unprotected grassland in the priority area. We used ArcGIS to combine the existing FWS priority layer based on spatial variation in accessibility of grassland to breeding ducks with two additional layers describing spatial variation in probability of conversion and cost of protection (Table 1; data available in Data S1). To avoid errors when calculating areas, all spatial analyses were conducted in the same map projection (Universal Transverse Mercator Zone 14 North, North American Datum 1983). We ran the repair geometry tool on all feature class layers before converting to grid data. We used the snap raster tool to align all grid layers to a common grid with the same extent as the analysis area.

Conversion probability of grassland in the analysis area is related to Land Capability Class (LCC): an index of suitability for cropping (Stephens et al. 2008; Rashford et al. 2011). Land Capability Class is an ordinal variable that ranges from 1 to 8 and increases with increasing limitations to cultivation (NRCS 1995). As a broad scale index to conversion probability, we used LCC data from the USDA Soil Survey Geographic database (SSURGO; NRCS 1995). We combined the eight LCC values from the SSURGO database (table physical name: muaggatt, column physical name: niccdcd [non-irrigated capability class]) into 3 risk classes (Risk Class1 = LCC values 1 and 2, Risk Class 2 = LCC values 3 and 4, and Risk Class 3 = LCC 5–8). We based our three classes on the results of Rashford et al. (2011) who found conversion probability averaged 0.95% /year in our analysis area, and these classes were associated with a 3-fold (Risk Class 3 to Risk Class 2) and 1.5-fold (Risk Class 2 to Risk Class 1) increase in annual conversion probability, respectively.

We used producer-reported average county-level cropland rental rates for 2010–2012 (USDA National Agricultural Statistics Service 2012) as an index to variation in easement cost. These rental rates are correlated (r = 0.97) with per acre cost of easements across the study area (Walker 2011). We used the Interpolation tool in ArcGIS with average county-specific cropland rental rate during 2010–2012 assigned to geographic centroid of the outer extent of each county to calculate a continuous surface of inverse-distance-weighted county-level cropland rental rates. We then combined the resulting 30-m grid into a 3-class protection cost index layer based on the empirical quantiles of the observed cropland rental rate distribution across the analysis area during 2010–2012 (Cost Class 1= lowest 1/3 of rental rate, Cost Class 2 = middle 1/3, and Cost Class 3 = top 1/3).

To develop a single layer for targeting easement acquisition, we combined the FWS priority layer based on accessibility to breeding pairs, the grassland conversion risk layer based on LCC, and the protection cost layer based on cropland rental rate. First, we used the Map Algebra tool to sum the pairs, risk, and cost layers. Then, to adjust the resulting summed layer to the remaining unprotected grassland in the analysis area, we multiplied it by a binary landcover grid (1 = unprotected grassland as of 2012 associated with 55-acre Grassland Bird Conservation Area Cores [Johnson et al. 2010], 0 = other landcover classes). The result was a 30-m grid describing remaining unprotected priority grassland on a summed scale from 3 to 9. Unprotected grassland with a summed value of 3 was therefore associated with at least 23 breeding duck pairs/km^2, LCC rated 1 or 2, and cropland rental rate in the lowest 1/3 of the distribution (i.e., Pairs Class value = 1, Risk Class value = 1, and Cost Class value = 1). Unprotected grassland with a summed value of 9 was associated with 15 or fewer breeding duck pairs/km^2, LCC rated 5, 6, 7, or 8, and in the top 1/3 of the cropland rental rate distribution. We then recombined the 7 grid sum values and created 3 integrated priority classes. Priority 1 included grid values 3 and 4, Priority 2 included grid values 5 and 6, and Priority 3 included grid values 7, 8, and 9. Priority 1 consisted of unprotected grasslands that fell below grid value 1 on no more than one criteria, Priority 2 consisted of unprotected grasslands that fell below grid value 1 on no more than two criteria, and Priority 3 consisted of unprotected grasslands that fell below grid value 1 on at least two criteria. This prioritization was based on two ideas. First, we thought a relatively simple structure would result in a more readily implemented conservation strategy (Knight et al. 2008). Second, and more importantly, this structure focused on unprotected grassland within the existing highest priority area with likely greatest probability of conversion and lowest cost of protection, which was our primary interest.

Results

Assessment of recent easement acquisitions

During 1998–2012, FWS and its conservation partners spent $149.0 M (all amounts adjusted to constant GDP deflated 2005 US dollars) on grassland easement acquisition in the PPR. More than 344,000 ha of grassland were protected at an average cost of $432 per ha. Most of those funds ($104.9 M) were spent to protect grassland (191,000 ha) in South Dakota. Average unit costs of grassland protection were $549 per ha in South Dakota and $287 per ha in North Dakota. Despite a substantial increase in expenditure during the study period, there was little realized gain in the annual rate of protection. Funds expended on grassland easement acquisition increased 3-fold in South Dakota from $3.7 M in 1998 to $11.8 M in 2012 and 9.7-fold in North Dakota from $0.6 M in 1998 to $5.8 M in 2012 (Figure 2). Area protected in South Dakota ranged from 7,100 ha in 2010 to 19,300 ha in 2000 and averaged 12,750 ha/yr during 1998–2012. Area protected in North Dakota ranged from 3,800 ha in 1998 to 16,300 ha in 2000 and averaged 10,300 ha/yr during 1998–2012 (Figure 3). In South Dakota, average unit cost of protection ranged from $201 per ha in 1998 to $1,103 per ha in 2010. In North Dakota, average unit cost of protection ranged from $136 per ha in 2002 to $568 per ha in 2012 (Figure 4).

Evaluation of current targeting strategy

We rejected the null hypothesis that easements were identically distributed among FWS priority classes before and after the 2005 implementation of the FWS conservation strategy. The observed distribution of easements relative to the distribution of unprotected grassland in FWS priority classes differed from expectations in both South ($\chi^2_3 = 17.67$, $p = 0.0005$) and North ($\chi^2_3 = 25.61$, $p < 10^{-4}$) Dakota. Counter to our prediction, these results, although statistically significant, did not provide material evidence of practically significant changes associated with implementation of the conservation strategy (Figure 5). There were 3,032 and 792 easements purchased in South and North Dakota, respectively, before the implementation of the conservation strategy. In South Dakota, 72% of easements were expected in Pairs Class 1 landscapes based on observed locations of easements acquired before the implementation of the conservation strategy, and 72% of the 868 easements acquired after 2004 were in Pairs Class 1 landscapes. In North Dakota, 93% of easements were expected in Pairs Class 1 landscapes based on observed locations of easements acquired before the implementation of the conservation strategy, and 89% of the 920 easements acquired after 2004 were in Pairs Class 1 landscapes.

Development of the integrated easement prioritization GIS

There were 3.2 M ha of unprotected grasslands in the analysis area located in priority landscapes accessible to at least 10 duck pairs/km^2. Unprotected grassland was distributed unevenly among FWS Pairs Classes with 1.8 M ha (56%) in Pairs Class 1, 0.8 M ha (25%) in Pairs Class 2, and 0.6 M ha (19%) in Pairs Class 3. Among conversion classes within priority landscapes, we observed 1.0 M ha (32%) of unprotected grassland in Risk Class 1, 1.2 M ha (39%) in Risk Class 2 and 0.9 M ha (29%) in Risk Class 3. Among Cost Classes, there were 1.4 M ha (44%) of unprotected priority grassland in Cost Class 1 (cropland rental rate from $72/ha to $124/ha), 1.3 M ha (40%) in Cost Class 2 (cropland rental rate from $125/ha to $216/ha), and 0.5 M ha (16%) in Cost Class 3 (cropland rental rate from $217/ha to $400/ha). When current FWS Pairs Classes were combined with the new Risk Classes and Cost Classes, there were 0.9 M ha of Priority 1, 1.7 M ha of Priority 2, and 0.6 M ha of Priority 3 unprotected grasslands in the analysis area (Figure 6). Most of the Priority 1 and Priority 2 unprotected grassland was located in central and northwest North Dakota with a band of Priority 1 and Priority 2 grassland in the westernmost portion of the analysis area in South Dakota (Figure 7).

Discussion

Recent assessments of regional habitat protection rates indicate regional goals for grassland easement acquisition (PPJV 2005) will not be achieved given current grassland loss rates and increasing protection costs (GAO 2007; Doherty et al. in press). Our analyses of recent grassland protection activity in the PPR corroborated these results. Largely due to increasing unit cost of protection, the annualized rate of grassland protection in the PPR did not increase during 1998–2012. The effect of diminishing buying power in an appreciating land market was most apparent in recent years. In the five years between 2008 and 2012, about 100,000 ha (247,000 acres) were protected at a cost of $83 M. This acquisition represented 30% of the total area protected during 1998–2012 but 47% of total expenditure. Increases in funding to the easement program have only kept pace with increasing land values and, as a result, the annual rate of protection has not increased. For example, in 1998, 22,000 ha were protected for $5.3 M, and in 2012, 22,000 ha were protected for $20.8 M. The 14% average year-over-year increase in easement expenditure only matches recent increases in protection cost, mandating cost-efficient targeting of resources to unprotected grasslands. Given a continued trend of increasing cropland value in the PPR, we suspect a larger area of at-risk priority grassland will ultimately be protected if conversion risk and protection cost are formally integrated into the conservation strategy (Newburn et al. 2005; GAO 2007).

At the parcel-level, grassland easements acquired during 1998–2012 were effectively targeted to the highest priority landscapes in terms of the current conservation strategy, and formalization of the conservation strategy in 2004 did not change the pattern of targeting. Over 95% of the grassland easements acquired during 1998–2012 were located in landscapes associated with the greatest expected accessibility to breeding duck pairs. This result has two implications. First, parcel-level prioritization decisions made by field personnel over the 15-year analysis period were compatible with the regional targeting strategy implemented by FWS in 2004. Second, our analysis provided evidence that regional-scale prioritization schemes and local-scale, parcel-specific acquisition decisions can be coherent. Thus, efforts to add information about conversion risk and protection cost to the current targeting strategy have the potential for successful cross-scale implementation.

Implementation of easement prioritization GIS will be most effective when parcel-level protection decisions are made in the context of the local knowledge base. The statistical relationships that formed the basis for our GIS do not predict parcel-level characteristics with certainty. Rather, they describe expected long-term, broad-scale outcomes. For example, at the regional and programmatic level, our GIS can direct easement acquisition to landscapes with greater expected abundance of breeding pairs, greater expected risk of conversion, and smaller expected cost of protection. It can also facilitate avoidance of areas with greater expected breeding pair abundance but smaller expected conversion risk or greater protection cost. Therefore, as an initial step, the easement prioritization GIS could be used by field personnel to provide a ranking of competing opportunities. Then, local knowledge could be applied by field personnel to improve the initial rankings. For example, if field personnel know a local landowner who plans to convert a parcel that has relatively small expected conversion probability or a relatively costly parcel is offered in a bargain sale or as a partial donation, then those parcels should be given additional priority. Nonetheless, when parcel-specific knowledge is lacking, acquisitions made using the rankings provided by our easement prioritization GIS are likely to balance costs and benefits in terms of the potential benefits lost per unit cost more effectively than a strategy based strictly on breeding pair abundance.

Global change in economics, demographics, and climate is predicted to increase worldwide demand for food and energy, while increasing the uncertainty of supply (Ramankutty et al. 2008; Searchinger et al. 2008; Cirera and Masset 2010). As a result, expansion of cultivated land (Wright and Wimberly 2013) onto former grasslands is likely to continue in the PPR. Integrated targeting of easement acquisitions can help to counter this force by directing grassland protection efforts to at-risk areas with a larger benefit-cost ratio. Our assessment indicated there were 3.3 M ha of unprotected grasslands in the priority areas defined by the current targeting strategy based on abundance of breeding duck pairs. This area was nearly 10 times larger than the 344,000 ha protected during 1998–2012. We suggest future grassland easement acquisitions would likely be more cost-efficient if efforts were refocused on the 0.9 M-ha highest-priority unprotected grasslands identified by our analysis. Targeting of grassland easement acquisition to a smaller area with greater expected probability of conversion and smaller expected cost of protection could provide needed support to easement acquisition efforts during a time when purchasing power is being diminished by rising land prices. For example, this approach could help to both maximize the effect of limited funding and buy time for efforts to affect land-use policies that promote grassland conservation (Carriazo et al. 2009).

Renewed focus on the strategic foundation of the grassland easement program could help to mitigate the negative effects of increasing protection cost and conversion rate. Our work to develop an integrated targeting system addresses some potential deficiencies of the acquisition strategy, but in many respects our targeting utility represents a working hypothesis supported by data and past studies. In keeping with the principles of Strategic Habitat Conservation (i.e., the current FWS adaptive habitat conservation paradigm based on iterative planning, implementation, and evaluation; FWS 2008), we suggest that implementation of an integrated strategy could proceed as part of an adaptive framework for easement acquisition guided by directed monitoring and evaluation. By testing critical assumptions on a periodic basis, an adaptive approach provides needed structure for evaluating progress toward near-term programmatic objectives and for making strategic adjustments (Rissman et al. 2007; Conroy and Peterson 2009). For example, our proposed targeting strategy is focused on protection of tracts with greater than average values of breeding pair abundance and conversion probability and smaller than average values of protection cost. These assumptions could be periodically evaluated by comparing the characteristics of acquired easements to data generated by monitoring 1) distribution and abundance of breeding ducks, 2) conversion of grassland to cropland, and 3) cost of protection across the analysis area. The resulting comparison of observation with predictions would provide the objective basis for adapting easement acquisition efforts to the current ecological, economic, and political environment. By continually testing key assumptions and incorporating new information, this approach would help ensure continued success of the grassland easement program in the changing environment of the PPR.

Supplemental Material

Please note: *The Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Publicly available geospatial and tabular data for analysis of easement acquisition in the PPR of North and South Dakota is contained in the zip folder titled PPR_Easement_Acquisition (47.4 MB ZIP).

Found at DOI: http://dx/doi.org/10.3996/052013-JFWM-035.S1.

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Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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Table 1. Description of geospatial data sources used to test hypotheses about spatial distribution of grassland easements acquired during 1998–2012 and create a GIS-based targeting system for grassland easement acquisitions.

Layer name	Type	Resolution	Data source
North and South Dakota PPR[a]	Polygon feature class	NA	United States Census Bureau
North and South Dakota PPR Counties	Polygon feature class	NA	United States Census Bureau
Priority classes for FWS[b] easement acquisition	Polygon feature class	NA	FWS Four Square Mile Survey
Grassland Bird Conservation Area cores	Raster grid	30 m	FWS Partners in Flight
Grassland easements	Polygon feature class	NA	FWS Region 6 Realty Program
Grassland cover	Raster Grid	30 m	Landsat Thematic Mapper satellite imagery (2000–2003)
Land Capability Class	Raster Grid	30 m	USDA[d] NRCS[e]
Average cropland rental rate 2010–2012	Raster grid	30 m	USDA NASS[f] cropland rental rate survey data

[a]Prairie Pothole Region

[b]United States Fish and Wildlife Service

[c]Habitat and Population Evaluation Team

[d]United States Department of Agriculture

[e]Natural Resources Conservation Service

[f]National Agricultural Statistics Service

Figure legends

Figure 1. Location and extent of the Prairie Pothole Region in North and South Dakota.

Figure 2. Annual expenditure (2005 United States Dollars [USD]) of the grassland easement acquisition program in the Prairie Pothole Region of North and South Dakota 1998–2012.

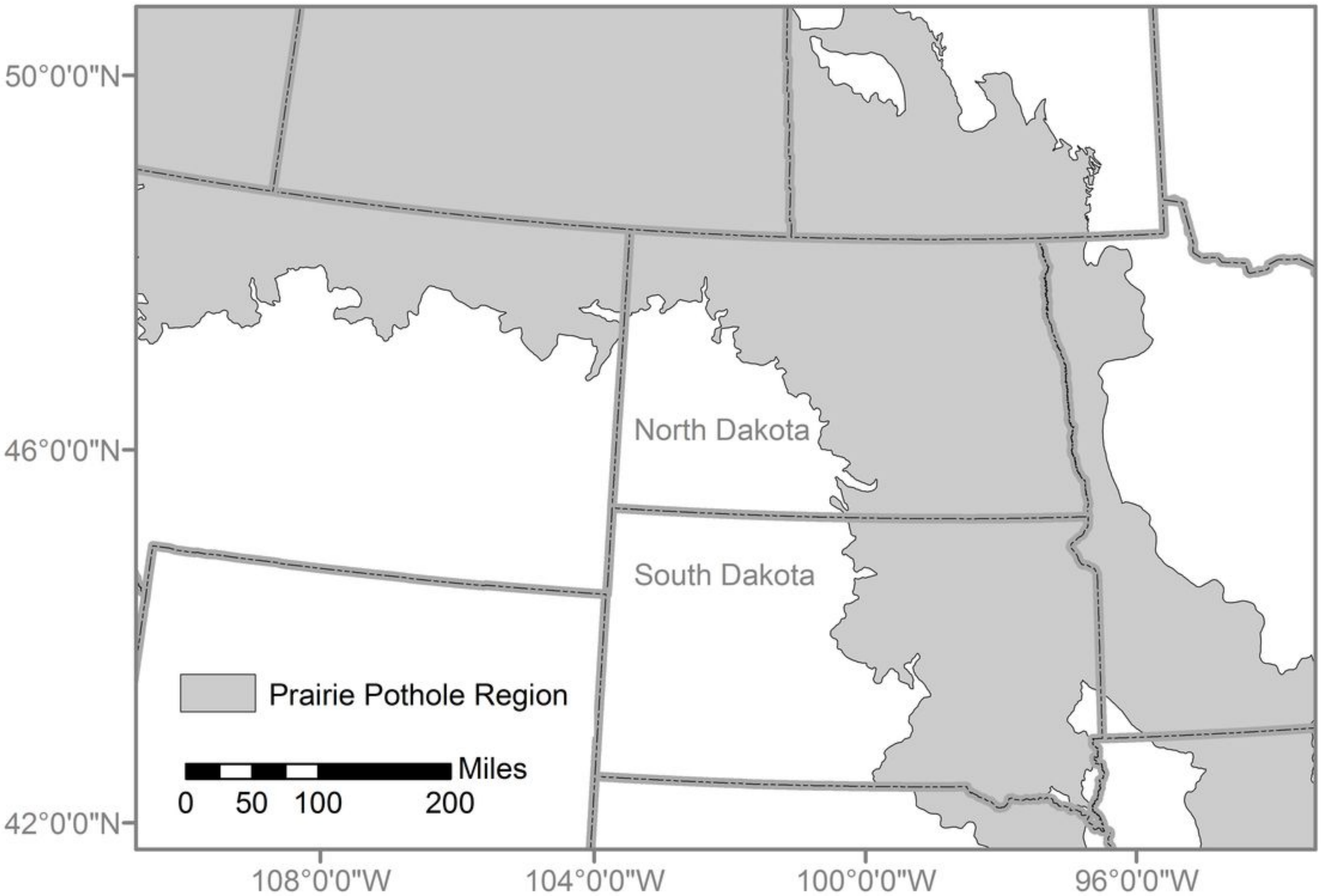
Figure 3. Area (ha) of grassland easements acquired during 1998–2012 in the Prairie Pothole Region of North and South Dakota.

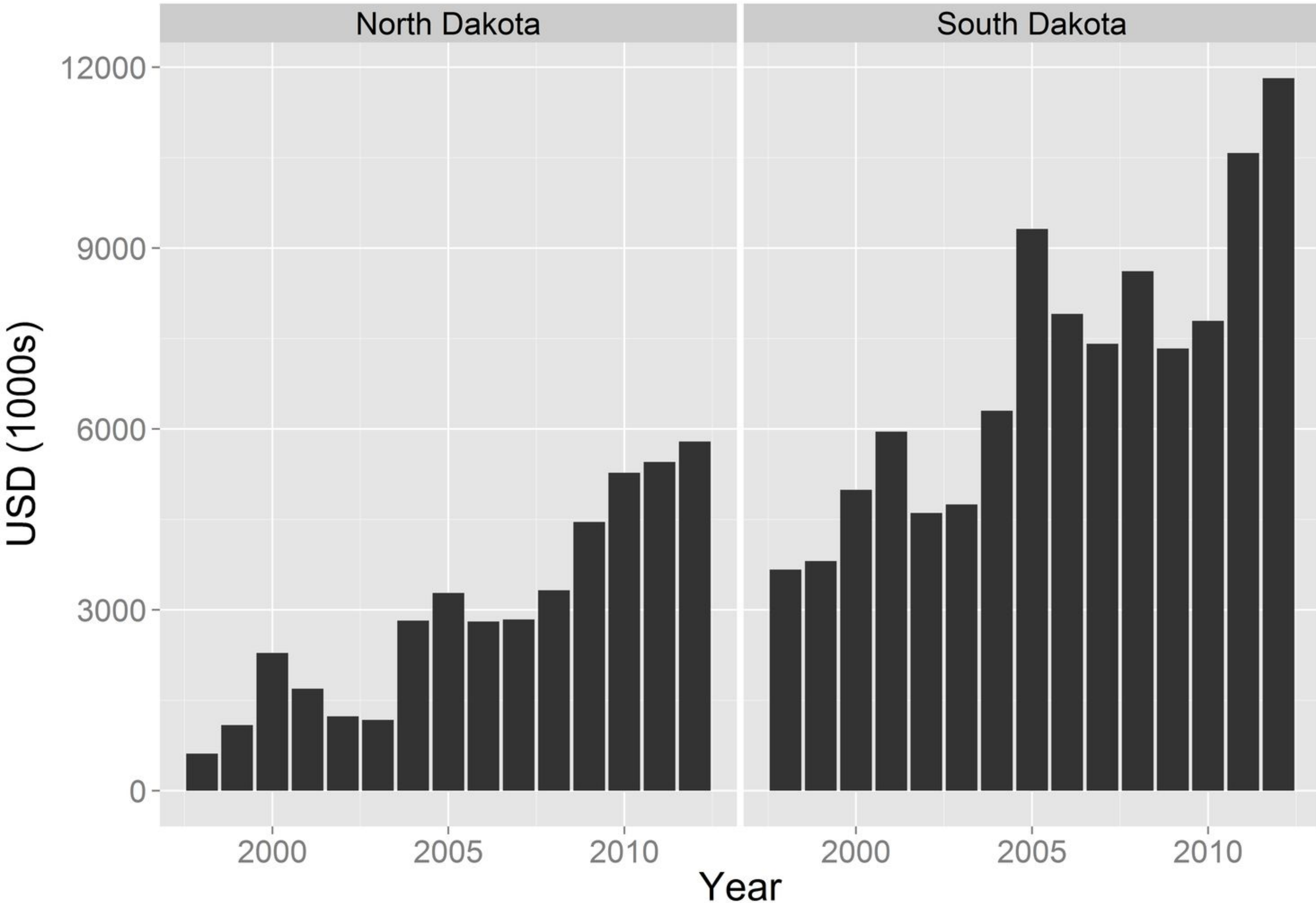
Figure 4. Unit cost (2005 United States Dollars [USD]/hectare) of grassland easements in the Prairie Pothole Region of North and South Dakota 1998–2012.

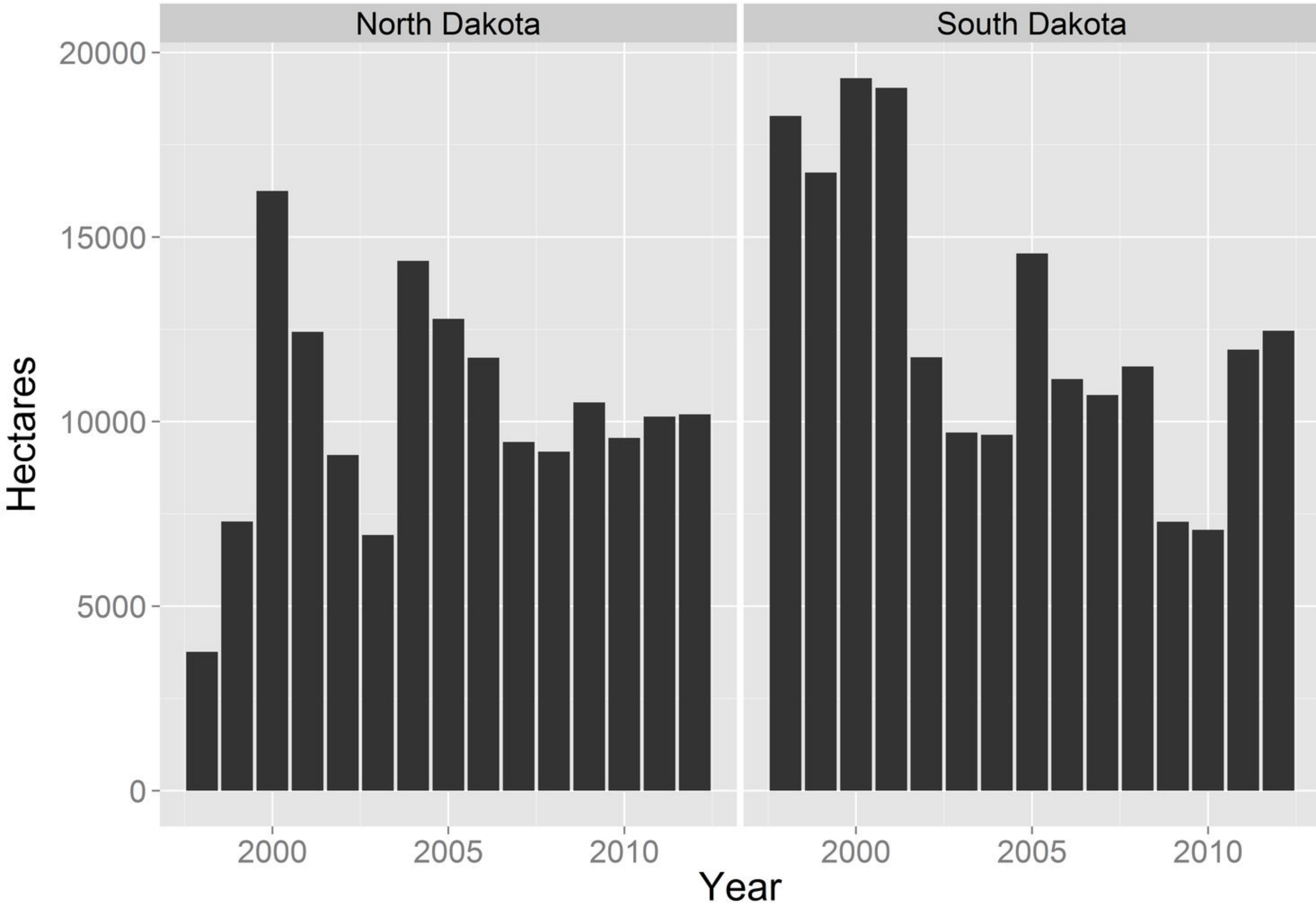
Figure 5. Expected and observed distribution of grassland easements acquired in the Prairie Pothole Region of North and South Dakota among United States Fish and Wildlife Service priority classes based on expected acessibility to breeding duck pairs. Expected distribution corresponds to the distribution of easments acquired prior to the implementation of a formal conservation strategy in 2005. Observed distribution corresponds to the distribution of easments acquired after the implementation of a formal conservation strategy in 2005.

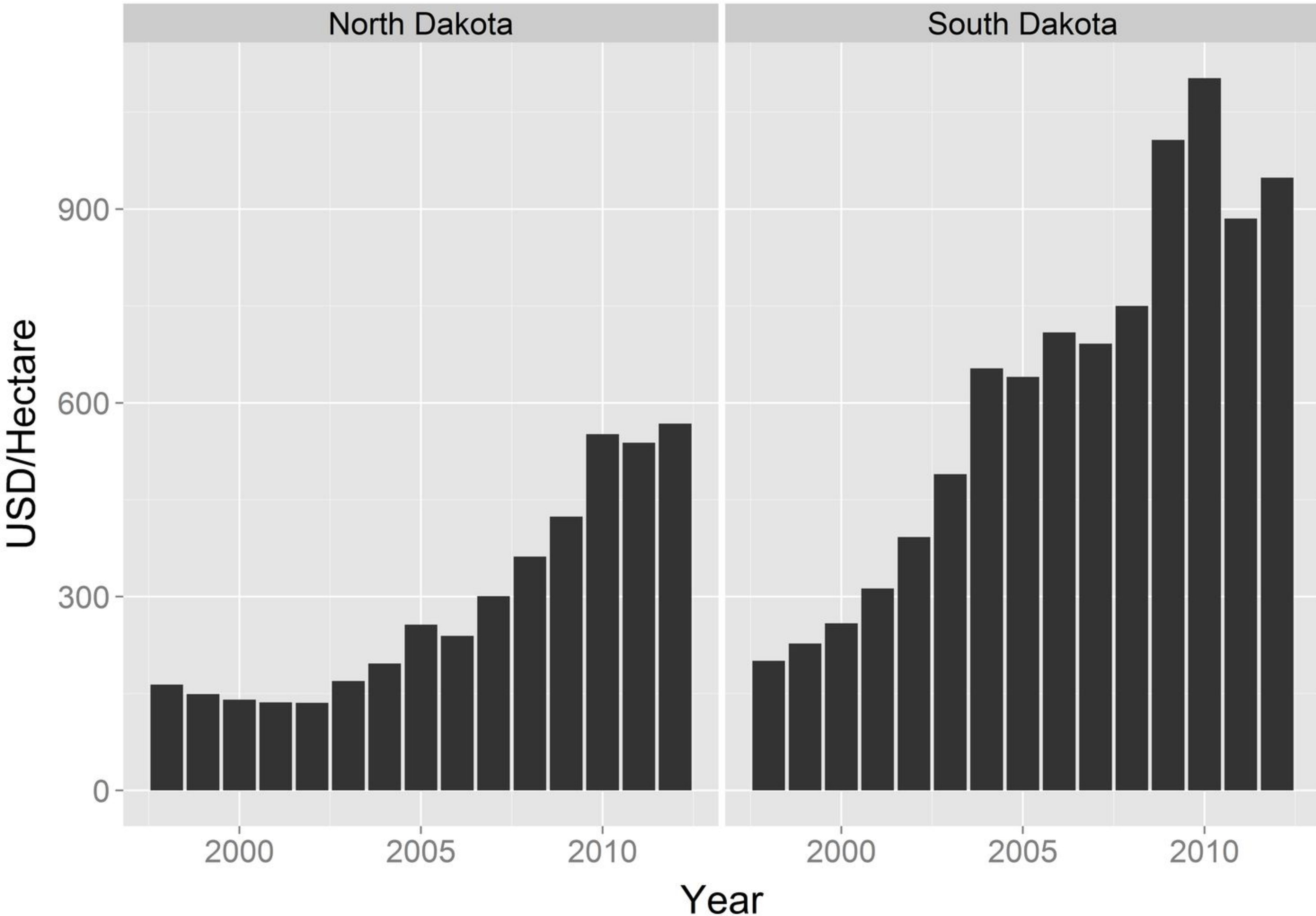
Figure 6. Area of remaining unprotected grassland in the Prairire Pothole Region of North and South Dakota arranged by priority classes (1= highest priority, 2 = high priority, 3 = lower priority) corresponding to variation in expected abundance of breeding duck pairs (Pairs), risk of conversion (Risk), cost of protection (Cost), and Pairs, Risk, and Cost combined (Combined).

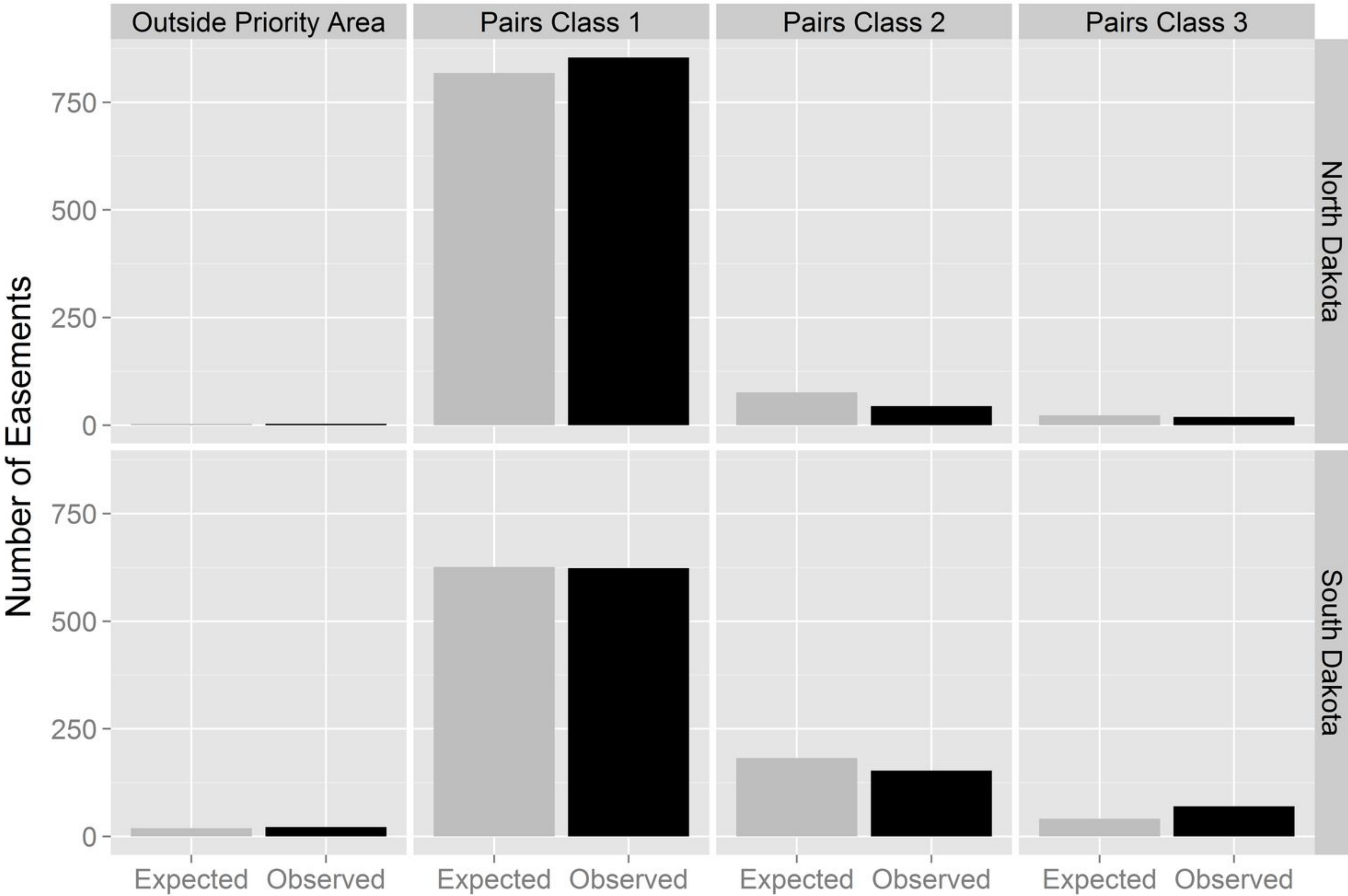
Figure 7. Location and extent of remaining unprotected grasslands in the Prairie Pothole Region of North and South Dakota by priority classes corresponding to variation in expected abundance of breeding duck pairs, risk of conversion, and cost of protection.

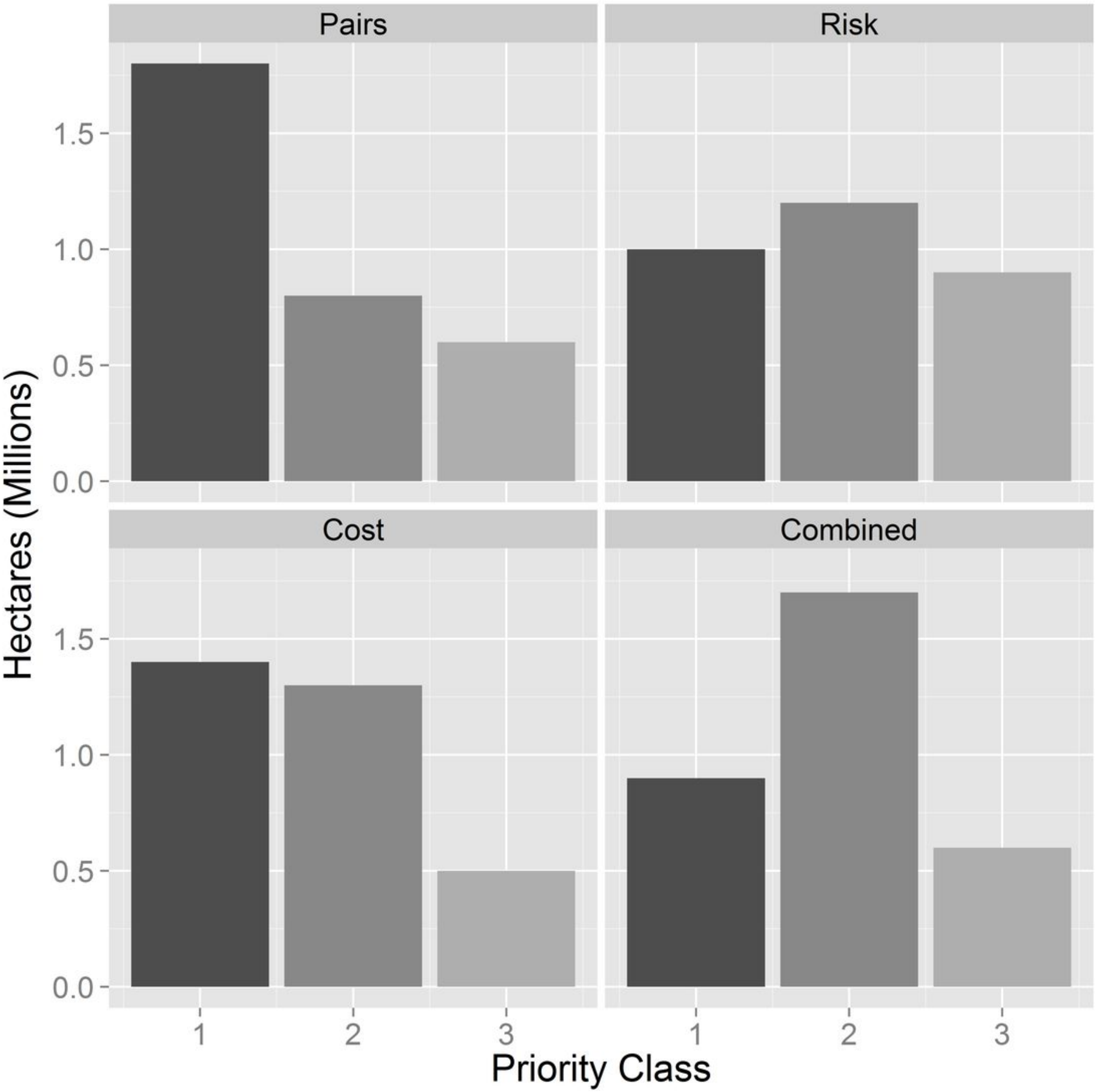

50°0'0"N
46°0'0"N
42°0'0"N
108°0'0"W
104°0'0"W
100°0'0"W
96°0'0"W
North Dakota
South Dakota
Prairie Pothole Region
Miles
0 50 100 200


North Dakota
South Dakota
12000
9000
6000
3000
0
2000
2005
2010
2000
2005
2010
Year
USD (1000s)


North Dakota
South Dakota
Hectares
20000
15000
10000
5000
0
2000
2005
2010
Year


North Dakota
South Dakota
USD/Hectare
900
600
300
0
2000
2005
2010
2000
2005
2010
Year


Outside Priority Area
Pairs Class 1
Pairs Class 2
Pairs Class 3
North Dakota
South Dakota
Number of Easements
0
250
500
750
Expected
Observed


Pairs
Risk
Cost
Combined
Hectares (Millions)
0.0
0.5
1.0
1.5
1
2
3
Priority Class

Grassland Protection Priority