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Original Article

Conservation Planning in an Era of Change: State of the U.S. Prairie Pothole Region

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ABSTRACT We assessed attainability of landscape-level conservation planning goals in the United States portion of the Prairie Pothole Region by summarizing and analyzing data on status, trends, and potential future of grasslands and wetlands. All published literature and new data analyses consistently indicate declines in grassland and wetland area. When we incorporated time as a conservation planning metric, the importance of seemingly small wetland (0.05–0.57%) and grassland (0.4–1.3%) annual loss rates became apparent. Moreover, we highlighted large differences in the amount of future grassland (30–67%) and wetland (47–93%) resulting from seemingly small changes in loss percentages. Our analyses clearly demonstrate that time, along with current status and trends of target habitat(s), must be incorporated when setting habitat conservation goals, otherwise goals may be unrealistic. Prairie Pothole Joint Venture (PPJV) partners protected an average of 0.20% of the 3.3 million ha extant wetlands and 0.26% of the 10.7 million ha extant grasslands/year. Consequently, PPJV partners cannot reach stated conservation goals given current habitat loss rates unless 1) increased funding is secured for land conservation, 2) landowner interest and acceptance of conservation programs remains high, and 3) wetland and grassland loss rates are decreased via public policy, particularly through agriculture programs, or other mechanisms. Otherwise, PPJV habitat conservation goals, and ultimately species population goals, will need to be reduced accordingly. Our comprehensive assessment may help the PPJV and other landscape-level planning efforts discriminate between goals they would like to attain versus goals they are likely to achieve. Published 2013. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS adaptive management, conservation, energy development, grasslands, joint venture, landscape conservation, planning, Prairie Pothole Region, wetland ecosystems.

There is a trend among conservation organizations to develop landscape-level plans for conservation. Among the first efforts to adopt this approach was the North American Waterfowl Management Plan, which formalized partnerships called joint ventures to create plans and deliver landscape-level conservation (U.S. Department of the Interior and Environment Canada 1986). The action of bird conservation joint ventures, guided in part by spatially explicit landscape models, has positively influenced >5 million ha of breeding, migration, and wintering waterfowl habitat in North America (Abraham et al. 2007). In 1999, joint ventures began to integrate an all-birds approach in their conservation activities.

Following the successes of the North American Waterfowl Management Plan, other efforts, including Partners in Flight (Rich et al. 2004), the U.S. Shorebird Conservation Plan (Brown et al. 2001), and the Waterbird Conservation Plan for the Americas (Kushlan et al. 2002), explicitly adopted a landscape approach in their conservation planning. In essence, these plans utilized a step-down process to partition population objectives set at a continental or national level to specific joint ventures or Bird Conservation Regions. Step-down approaches using sampling theory to estimate abundance of wildlife can produce reliable population estimates as evidenced for waterfowl (Zimpfer et al. 2011). However, goals derived from step-down population processes often fail to incorporate overall trends in habitats that support populations (i.e., loss rates) or, arguably more important, the resources available to managers to protect or create desired habitat conditions.

The North American Waterfowl Management Plan identified the Prairie Pothole Region (PPR) as the continent's top priority for waterfowl conservation and established the Prairie Pothole Joint Venture (PPJV) in 1987 as 1 of the original 6 joint ventures to protect the U.S. portion of this region (see Supplementary Information 1 for list of partners: SI 1). Given its ecological uniqueness, rapid

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changes occurring across its landscape, and its vital importance to waterfowl and other wildlife, large-scale efforts are underway to conserve the prairie pothole ecosystem (Beyersbergen et al. 2004, Ringelman et al. 2005). Despite these factors, no comprehensive evaluation of conservation efforts, coupled with historic, current, and future land-use status and trends, exists for the PPJV. Specifically, the PPJV partners asked whether permanent protection goals of 4.2 million ha of grasslands and 0.57 million ha of wetlands, in addition to wetlands and grassland currently protected as of 2005, were attainable given unknown status and trends in land-use and land cover. We evaluated the attainability of both wetland and grassland protection goals by combining a scientific literature review supplemented by synthesis of state and federal data. We focused on status and trends of grasslands and wetlands because these habitats are critical to bird populations in the PPJV. Biologically, our objective was to determine the effectiveness of the PPJV's current conservation efforts, considering both historic habitat losses and projected future rates of habitat conversion. Specifically, our objectives were to 1) determine whether current PPJV habitat goals set to support specific bird populations are attainable, and 2) evaluate the ramifications of increasing or decreasing habitat protection rates on future landscape conditions and attainability of bird population goals.

STUDY AREA

The PPR is one of the richest, most diverse, and unique wetland–grassland ecosystems in the world (Baldassarre and Bolden 2006). Created by retreating glaciers at the end of the last ice-age (Bluemle 2000), the PPR historically consisted of vast grasslands, ranging from tallgrass prairie in the eastern portion to mixed-grass prairie in the central portion, and shortgrass prairie in the western portion. These grasslands were interspersed with millions of depressional wetlands called prairie potholes. The PPR (particularly the eastern PPR) is one of the most altered landscapes in the world due to productive soils and the relative ease with which the landscape can be altered (see fig. 4 in Hoekstra et al. 2005). The PPJV conservation boundary encompasses the entire U.S. PPR (47.9 million ha), which includes parts of 5 states: the northern tier of Montana, northern and eastern North Dakota, eastern South Dakota, western Minnesota, and north-central Iowa (Fig. 1).

Climatic conditions within PPJV boundaries are extremely variable, characterized by high inter-annual and regional variation in precipitation (Niemuth et al. 2010). This greatly influences the number of wetland basins holding water, depth of water within basins, and abundance of wetland-associated wildlife. Many species of wildlife are adapted to this variable environment and respond to wetland conditions

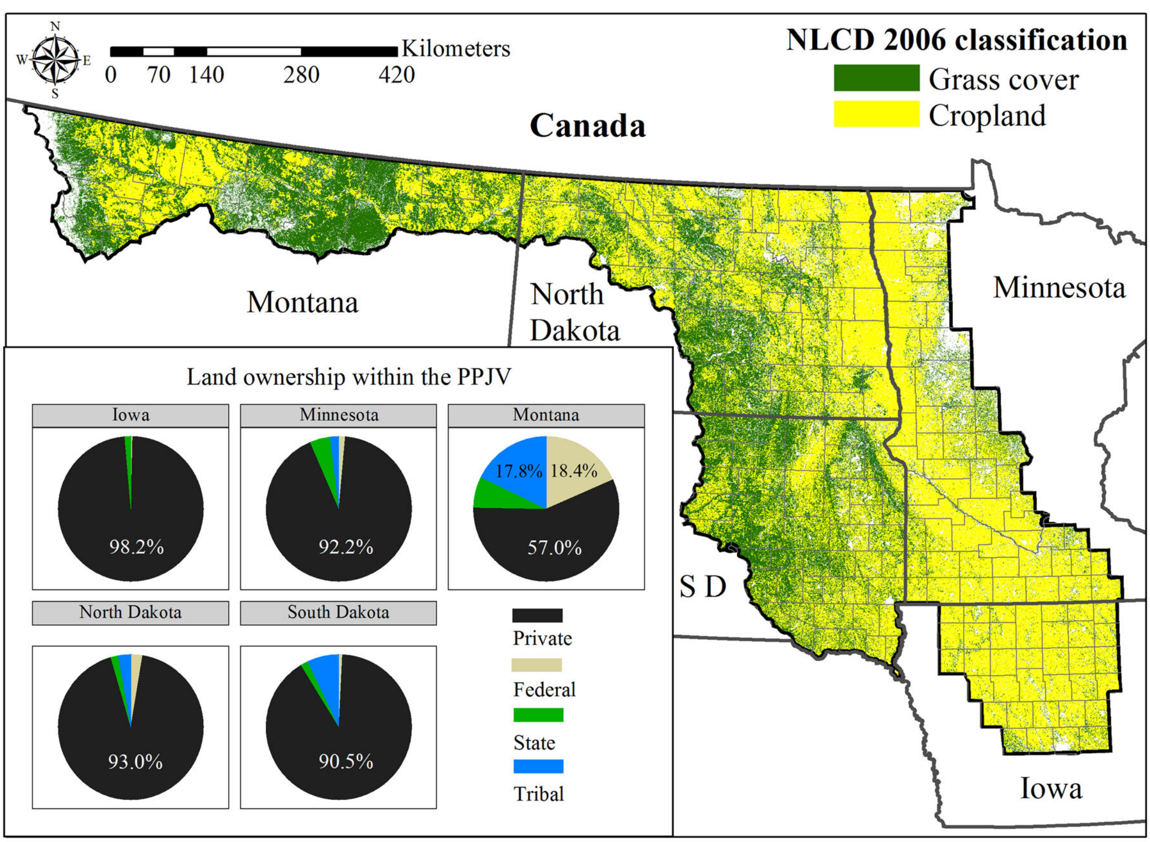


Figure 1. Location of the counties that make up the Prairie Pothole Joint Venture (PPJV) region within the United States. The majority of the PPJV is privately owned. Grass cover is a combination of the National Land Cover Database (NLCD) hay–pasture and grassland–herbaceous classes. All other NLCD classes are in white.

and precipitation-driven grass conditions by changes in distribution and numbers.

Existing wetlands and grasslands provide vital habitat for a diverse array of plant, fish, and wildlife species. Most notably, large populations of migratory birds depend on this habitat for food and cover, primarily during the breeding season, but also during migration. These migratory species include waterfowl (Smith 1970, Johnson and Grier 1988), waterbirds (Peterjohn and Sauer 1997, Niemuth and Solberg 2003), and grassland birds (Niemuth et al. 2008). In 2011, approximately 67% of all ducks estimated in the entire Waterfowl Breeding Population and Habitat Survey area occurred within the U.S. and Canadian PPR (Zimpfer et al. 2011). The myriad wetlands also make the PPR valuable to other migratory birds. For example, estimates suggest the PPR harbors 70% of the continental population of Franklin's gull (*Leucophaeus pipixcan*); >50% of the continental population of pied-billed grebe (*Podilymbus podiceps*), American bittern (*Botaurus lentiginosus*), sora (*Porzana carolina*), American coot (*Fulica americana*), and black tern (*Chlidonias niger*); and 30% of the continental population of American white pelican (*Pelecanus erythrorhynchos*) and California gull (*L. californicus*; (Beyersbergen et al. 2004); as well as approximately 80% of the North American population of marbled godwit (*Limosa fedoa;* estimate calculated following methods of Rosenberg and Blancher [2005]). Remaining grasslands also support large populations of grassland birds, including 91% of Baird's sparrow (*Ammodramus bairdii*), 87% of Sprague's pipit (*Anthus spragueii*), and 71% of chestnut-collared longspur (*Calcarius ornatus*; Rich et al. 2004).

METHODS

Methodological Organization

We organized this report into 5 main sections: Wetlands, Grasslands, Conservation, Conservation Planning, and An Uncertain Conservation Future. The Grasslands, Wetlands, and Conservation sections are further divided into 1) historical perspective, 2) current status, and 3) current trends. In each subsection, we first synthesized available published scientific literature. When information was lacking or sparse, we summarized available independent data to assess whether data sources supported or refuted each other. We maintain that review and re-analysis of studies of land-use trends conducted using different methodologies, but reaching similar conclusions, creates stronger inference than does a single study or database (Johnson 2002).

Study Extents

Whenever possible, we summarized county-level data to obtain a state-level estimate for areas within the PPJV (Fig. 1). In certain cases, information was available only at the state level; we explicitly identify such instances. We strived to present data and published papers specific to the PPJV, because joint-venture boundaries are defined to represent areas with similar geological histories and ecological processes. These geological and ecological differences result in different ecotypes across joint-venture boundaries within the same state, and result in different land-use pressures and habitat trends. For example, there is approximately twice the amount of grass cover on a percent basis in the Northern Great Plains Joint Venture of North Dakota as compared with the PPJV portion of North Dakota. In certain instances, joint-venture boundaries are political boundaries within the same ecotype. This is the case within the PPR, with the PPJV representing the U.S. portion of the PPR and the Prairie Habitat Joint Venture representing the Canadian portion of the PPR. In this instance, different environmental laws and regulations, as well as farm policies and programs, can result in different land-use pressures and habitat trends.

WETLANDS

Historical Perspective

The high density of wetlands, exceeding 40/km^2 in some areas (Kantrud et al. 1989), makes the PPJV region unique. Prior to European settlement, wetlands may have encompassed >20% of total land area in the PPJV region (Euliss et al. 2006). Historic wetland losses (state-scale estimate) across the Prairie Pothole States ranged from 27% in Montana to 89% in Iowa (Dahl 1990). Minnesota, North Dakota, and South Dakota lost 42%, 49%, and 35% of their wetlands, respectively, when compared with pre-settlement conditions (Dahl 1990). The percentage of wetlands lost in the PPJV portion of Minnesota is actually much higher, because state-scale estimates include many non-drained wetlands in the northern deciduous and coniferous forest biomes (Oslund et al. 2010). Drainage peaked across the United States during the 1950s through the early 1970s, when 185,346 ha of wetlands were drained annually (Dahl 2011). When compared with the 44.6 million ha of wetland area remaining across the lower 48 states in 2009, this would equate to an annual drainage rate of 0.42% (Dahl 2011). Peaks in wetland drainage were partially a result of larger, more powerful farm equipment and efficiencies derived in larger crop fields (Higgins et al. 2002).

Methods—Wetland Status

We summarized National Wetland Inventory (NWI) data at a wetland basin level to produce estimates of number and area of temporary, seasonal, semi-permanent, and permanent wetlands (i.e., lacustrine and permanent palustrine wetlands; Johnson and Higgins 1997, USDI-FWS 2011). We produced NWI basin classification and individual wetland basin-area estimates using methods of Johnson and Higgins (1997) by the U.S. Fish and Wildlife Service (USFWS) Mountain-Prairie (Region 6) and Midwest (Region 3) regional Habitat and Population Evaluation Teams. The wetland basin classification refers to the length of time a wetland retains water during the growing season. Temporary and seasonal wetlands are generally smallest and retain water the shortest amount of time during the growing season (Stewart and Kantrund 1971). National Wetland Inventory imagery was collected during the following years: Iowa and Minnesota 1980–1983; Montana 1980–1989, with the bulk of images coming from 1984 through 1987; and North and South Dakota 1979–1986.

We used 2006 National Land Cover Database (NLCD; Wickham et al. 2010) for our second source of wetland data. We generated wetland estimates by combining NLCD's woody wetland, emergent–herbaceous wetlands, and open-water classes. Accuracy estimates for 2006 NLCD ranged between 70% and 98%, with an overall accuracy of 84% (Wickham et al. 2010). Because we lacked independent data to assess accuracy of NLCD or NWI wetlands, we evaluated reliability of NLCD and NWI estimates of wetland area by comparing results between the 2 products. Using this approach (i.e., 2 independent data sources arriving at similar conclusions), would increase our confidence in both estimates (Johnson 2002).

Results—Wetland Status

National Wetland Inventory data indicated 3.44 million wetland basins covering 3.68 million ha in temporary (13.0% of total area), seasonal (23.7%), semi-permanent (24.1%), riverine, (7.7%) and permanent wetlands or lakes (31.4%) within the boundaries of the PPJV region (SI 2). Distribution of wetland area varied widely from 137,500 ha in Iowa to 1.3 million ha in North Dakota. The vast majority of wetlands in the PPJV hold water temporarily or seasonally (47.5% and 42.6% of basins, respectively). Semi-permanent and permanent wetlands comprised 8.6% and 1.2% of wetland basins, respectively, yet these regimes accounted for 55.6% of total wetland area. Wetland area and number of basins are fixed to years and conditions when NWI basins were originally mapped (SI 2). We estimated 3.34 million ha of wetlands using NLCD for our contemporary estimate of wetland area, which was comparable to NWI estimates derived during the early 1980s. The prairies were exiting a dry cycle in 2006 and were relatively dry when NLCD data were collected (Niemuth et al. 2010). Therefore, it is logically consistent that NLCD estimates are lower than NWI estimates because of drier conditions in 2006 (Niemuth et al. 2010) and wetland drainage that occurred after NWI basins were mapped (Oslund et al. 2010).

Wetland Trends

Published literature and government reports.—We obtained 4 estimates of wetland loss rates relevant to the PPJV region to assess trajectory of wetland trends. We first investigated summary reports from inventories conducted in both 1997 and 2007 by the National Resource Inventory program to investigate modern loss rates (USDA-NRCS 2000, 2009). Specific estimates for the PPJV region are not available from the National Resource Inventory. At a state scale, ability to detect change is low for National Resource Inventory data for non-lake wetlands within specific land-cover classes (see tables 16 and 17 in USDA-NRCS 2009). The margin of error for wetlands embedded in cropland, pastureland, or Conservation Reserve Program (CRP) grassland for the PPJV states ranged from 12.3% in North Dakota and 32.1% of the mean wetland estimate in Montana.

The second source of data we used to assess wetland status and trends was the NWI Status and Trends from 2004 through 2009 (Dahl 2011). Unfortunately, information presented in Dahl (2011) was tabulated at a national scale, which limits inference to the PPJV. Nevertheless, the United States experienced a 1.0% increase in area of freshwater emergent wetlands, yet Dahl (2011) documented that wetland area was lost in some areas, including the PPJV states. Loss of freshwater marshes in agriculture areas was attributed to "efforts to improve drainage of farm fields as a result of economic and climatic conditions" (Dahl 2011:60). Nationwide, the largest increases in wetland area resulted from construction of urban (+18.0%) and industrial ponds (+9.9%).

Analyses conducted by Habitat and Population Evaluation Teams staff in USFWS Region 3 (Oslund et al. 2010) and Region 6 (C. R. Loesch, United States Fish and Wildlife Service, unpublished data) provided the finest resolution information on wetland trends for the PPJV region. Both Oslund et al. (2010) and C. R. Loesch (unpublished data) utilized aerial photographs to determine evidence of wetland ditching, draining, or loss. In the Minnesota portion of the PPJV, 4.3% of wetland area was lost from 1980 to 2007, or 0.16%/year (Oslund et al. 2010). Drainage rates varied by upland cover types, as delineated by Bailey's Ecoregions (Bailey 2004). The Prairie Coteau ecoregion, which has been converted primarily to cropland, experienced the highest rate of loss at 15%, or 0.57%/year. However, 72% of drained wetlands documented in Oslund et al. (2010) had prior impacts of a ditch or partial drainage prior to 1980. Therefore, Prairie Coteau ecoregional estimates could be biased high when extrapolating to wetlands without prior drainage history. C. R. Loesch (unpublished data) found 1.27% (0.05%/yr) of wetland area was lost from 1979 through 2003 in the PPJV portions of North Dakota and South Dakota. Consistent with other studies (USDA-NRCS 2000, 2009; Dahl 2006, 2011; Oslund et al. 2010), wetland loss was higher in agricultural landscapes, where 2.1% of temporary and 1.33% of seasonal wetlands were converted to cropland during 1979–2003 (C. R. Loesch, unpublished data). However, both Oslund et al. (2010) and C. R. Loesch (unpublished data) may be biased low and serve as lower bounds of drainage because detecting drainage efforts with small spectral signatures, such as contour draining and tile drainage is difficult (F. Oslund and C. Loesch, United States Fish and Wildlife Service, personal communication).

GRASSLANDS

Historical Perspective

Globally, temperate grasslands are the most human-altered biome with the highest risk of biome extinction (Hoekstra et al. 2005). The major manifestations of temperate grasslands are the veldts of South Africa, the puszta of Hungary, the pampas of Argentina and Uruguay, the steppes of Russia, and the plains and prairies of central North America. Rich soils formed by long-term growth and decay of deep-rooted grasses that retain carbon and other nutrients make these soils attractive for agricultural production (Fargione et al. 2008). Accordingly, converted and extant grassland areas are some of the most important ecosystems for modern human subsistence, because they occupy large areas of continent interiors and supply the majority of the world's food (Coupland 1979). This has created a trade-off between cropland production and conserving native grasslands, a struggle that grasslands have historically lost. According to the U.S. National Agriculture Statistics Service, the U.S. PPR accounts for approximately 33% of the nation's annual production of corn, wheat, and soybeans and is one of the most productive agricultural regions in the world.

U.S. grasslands west of the Mississippi River declined by 105 million ha from 1850 to 1950, with an additional loss of 11 million ha between 1950 and 1990 (Conner et al. 2001). Since 1830, native prairie losses exceed rates of all other biome losses within North America (Samson and Knopf 1994). Grasslands in the PPR complement wetlands, because many species of wetland-dependent birds nest in surrounding grasslands (Greenwood et al. 1995, Reynolds et al. 2001, Herkert et al. 2003, Stephens et al. 2005). Grass cover is essential for successful nesting for a wide variety of ground-nesting birds from passerines to waterfowl (Klett et al. 1988, Winter et al. 2005, Drever et al. 2007). Loss of grasslands resulted in large declines in grassland bird populations, making grassland birds one of the most imperiled guilds of birds in North America (Brennan and Kuvlesky 2005, Askins et al. 2007).

Three grassland prairie types are found in the PPJV region. The east to west gradient from tallgrass to mixed-grass to shortgrass prairie is indicative of the large difference in precipitation between the eastern and western portions of the PPJV. Historically, grasslands with higher annual precipitation experienced higher rates of conversion to agriculture. Tallgrass prairies occur at the higher end of the precipitation gradient of global grasslands and are almost extirpated (Samson and Knopf 1994). This crop conversion–precipitation gradient is evident when looking at state-scale land class estimates produced for the National Resource Inventory (USDA-NRCS 2009). Minnesota and Iowa, on the eastern edge of the PPJV region, have the highest conversion rates, while Montana, constituting the western edge, has the lowest rate of grassland conversion (Fig. 1).

Methods—Grassland Status

No published estimates exist regarding status of grasslands specific to the PPJV region, so we generated independent estimates. We derived estimates by summarizing digital land-cover maps from satellite imagery. We did not present point estimates from the National Resource Inventory because it is reported at a state level and because higher resolution information was available specific to the PPJV region. We followed this approach because differences in soils, geology, and ecology create different ecotypes across the PPJV, thereby resulting in different land-use pressures across each state.

We summarized data from the 2006 NLCD across the PPJV region because it was the only available seamless land cover for upland habitats (Wickham et al. 2010). We summarized percentage of cropland, grassland, wetland, trees, and developed areas across the entire PPJV region. We combined Grassland–Herbaceous and Hay–Pasture NLCD classes because of high misclassification rates between these 2 classes. We collected independent field data from 2006 to test overall accuracy of combined grassland cover class, which we found 75% accurate. We combined NLCD's Deciduous Forest, Evergreen Forest, and Mixed Forest classes into a single forest class. We also combined Developed Open Space, Developed Low Intensity, Developed Medium Intensity, and Developed High Intensity classes into a single developed class.

Results—Grassland Status

We found that 80.2% and 67.3% of the Iowa and Minnesota portions of the PPJV, respectively, have been converted to cropland (Table 1). Similarly, 54.2% and 45.6% of North Dakota and South Dakota portions of the PPJV, respectively, have been converted to cropland (Table 1). Rates of conversion were lower in Montana portions of the PPJV, with 34.1% cropland covering the region (Table 1). Despite historical losses, 10,694,000 ha of grass cover remain within the PPJV, excluding CRP grass cover (Table 2; *see Conservation section for CRP methods*).

Grassland Trends

Published literature.—Conversion of grasslands for crop production continues today. In the Missouri Coteau region of North and South Dakota, 0.4% of grasslands (36,540 ha) were lost annually during 1989–2003 (Stephens et al. 2008). From 1979 through 1997, 1.33% of grasslands were lost annually across the entire U.S. PPR (Rashford et al. 2011*b*). Within the U.S. Northern Plains (specifically ND, SD, NE, and KS), approximately 311,608 ha (1% of the region's rangeland) were converted to cropland during 1997–2007 (Claassen et al. 2011*a*, *b*). This region encompasses 18% of the nation's grasslands, but accounted for 57% of grassland conversions to cropland. Percentage estimates were not

Table 1. Landscape composition of the Prairie Pothole Joint Venture (PPJV) region of the United States classified by the 2006 National Land Cover Database (NLCD).

State	Area (thousand ha)	% Cropland	% Grassland	% Wetland	% Tree	% Developed
IA	5,083.0	80.2	7.3	2.3	2.3	7.9
MN	10,492.3	67.3	9.3	10.5	6.7	5.7
MT	9,895.8	34.1	48.0[a]	2.5	5.0	1.8
ND	13,252.9	54.2	30.0	9.9	1.2	4.5
SD	9,167.0	45.6	43.1	6.1	0.7	4.3
PPJV total	47,891.0	54.0	29.3	7.0	3.2	4.5

[a] Estimate does not include NLCD class Shrub–Scrub, which = 7.7% of the MT PPJV.

Table 2. Hectares (in thousands) of grass cover within the Prairie Pothole Joint Venture (PPJV) of the United States classified by the 2006 National Land Cover Database (NLCD). We calculated the area and percent of 1) grass cover including grass cover from the Conservation Reserve Program (CRP), 2) grass cover excluding CRP, and 3) CRP enrolled in 2006. Non-CRP grass areas are used as the baseline status for grass in conservation planning analyses.

State	Grass cover[a]	% Grass	Non-CRP grass	% Non-CRP grass	CRP 2006	CRP % of grass[b]
IA	369	7.3	218	4.3	150	40.8
MN	981	9.3	318	3.0	663	67.6
MT	4,751	48.0	3,800	38.4	951	20.0
ND	3,981	30.0	2,851	21.5	1,130	28.4
SD	3,949	43.1	3,507	38.3	442	11.2
PPJV total	14,031	29.3	10,694	22.3	3,336	23.8

[a] Included NLCD classes grassland–herbaceous and hay–pasture combined and CRP. There are 1,894,168 acres (766,543 ha) of shrub–scrub land not included in grass estimates. This equates to 7.7% of the entire MT PPJV.
[b] Denominator is total grass cover estimate, which included CRP.

directly comparable to the PPJV region because areas west of the Missouri River are outside of the PPJV and have much higher percentages of land in grass cover, but still provide evidence that broad-scale conversion from grassland is occurring. We found no published estimates of grassland loss for the Montana portion of the PPJV region.

CONSERVATION

Historical Perspective

Historically, the foundation of conservation in the PPJV involved a combination of federal lands, state-managed lands, and numerous non-governmental organization interests. However, over the past decade, most conservation gains in the PPJV have been achieved through 1) fee and limited-interest easement acquisition, 2) state-level funding initiatives, and 3) short-term agency policy actions (i.e., U.S. Department of Agriculture Farm Bill).

The USFWS and numerous partners (states, non-governmental organizations) annually spend millions of dollars in the PPJV to protect wetlands and grasslands. The most notable tool used is the Small Wetlands Acquisition Program, which was created in 1958 with an amendment to the 1934 Migratory Bird Hunting Stamp Act (commonly known as the Duck Stamp Act; 16 U.S.C. 718-718j, 48 Stat. 452). The Duck Stamp Act allows proceeds from sale of Federal Duck Stamps to be used to acquire lands that benefit waterfowl populations. Conservation through this mechanism is achieved by purchasing priority lands in fee title or limited-interest easements (the latter leaves land in private ownership). In the case of limited-interest easements, specific rights are purchased that benefit wildlife species. For instance, USFWS wetland easements protect wetland basins from burning, draining, and/or filling. During years that basins are dry, normal agricultural practices (i.e., tillage–cropping) are permitted. Grassland easements protect the surface from conversion (i.e., tillage practices) in perpetuity, but do not restrict grazing. Within identified landscapes, local biologists and partners work with private landowners on select tracts of grasslands and wetlands to protect these habitats in perpetuity to help achieve conservation goals.

Short-term conservation programs such as the CRP, Grassland Reserve Program, and Wetlands Reserve Program are administered by the U.S. Department of Agriculture (USDA) and typically offer protection for <30 years. Lastly, restoration of wetland complexes and grasslands is an important conservation practice in parts of the PPJV region that have experienced significant levels of land conversion. Restoration efforts primarily seek to create connected complexes of wetlands and grasslands similar to historic conditions.

Methods—Conservation Status

We asked 3 primary questions to inform our conservation planning scenarios by giving context to possible conservation strategies and understand risk to wetland and grassland resources. First, what is the amount of private and public land ownership? Second, how many hectares of wetlands and grasslands are currently protected? Third, despite being a short-term management treatment, what is the status of areas enrolled in CRP? We need to understand the status of CRP acreages given the documented biological benefits on the prairie pothole ecosystem and extent of CRP across the PPJV region (Reynolds et al. 2001, 2006).

To answer the first question, we assembled spatial geographic information system (GIS) data on land ownership and summarized land ownership into 4 categories: federal, state, tribal, and private. We followed this approach because some federal or state lands are not managed for conservation purposes, yet they are subject to public policy that influences management. We calculated the percentage of land in private ownership because voluntary private land conservation is a function of individuals responding to conservation programs, agricultural market prices, and farm policy (Rashford et al. 2011*b*). We split tribal lands from private ownership because they are owned by sovereign nations and have unique conservation opportunities. Our estimates of tribal ownership are biased high, however, because we could not obtain updated GIS files that tracked non-tribal in-holdings (i.e., lands held in private ownership) for tribal lands within the PPJV region. Further, we did not include data on lands owned and managed by non-governmental organizations because data were incomplete and could only provide a partial summary of their conservation activities in some states.

Secondly, we quantified the amount of wetlands and grasslands currently protected to understand relative risk to this ecosystem. We classified lands as protected if current legal authority exists to prevent conversion of grasslands or drainage of wetlands. If lands were restored and had permanent legal protection, we included them in our analyses. We classified state and federal land as protected if land conservation is part of the land-owning state or federal agencies' missions (SI 3). We supplemented the amount of protected grasslands and wetlands generated via our GIS analyses by adding the area of grassland and wetlands protected on private lands through easements. We obtained these non-spatial data sets from the USFWS Mountain–Prairie and Midwest regions' realty offices. Easements donated to the USFWS by non-governmental organizations for management or easement purposes are included in the USFWS databases. We obtained our final estimate of wetland and grassland protections by adding final easement areas to estimates from our GIS analysis.

We verified our determination of protected status by calculating amount of land in the protected category by ownership that was converted to cropland in the 2006 NLCD. We quantified current amount of grassland cover and wetlands within protected areas by intersecting 2006 NLCD land-cover data with GIS polygons. We generated an estimate of historical grass area by adding the area of lands currently converted (cropland), or that have been converted but are currently enrolled in the CRP (Table 2), and lands currently in non-CRP grass cover. We did this to determine how estimates of remaining percent grass based upon the status of grass area in 2006 relate to estimates of remaining percent grass based upon conditions prior to European settlement. Unfortunately, no comprehensive data on location of drained wetlands across the entire PPJV region existed at the time of our analyses, so we were unable to generate historic wetland area estimates. As a third and final check of our wetland data, we evaluated reliability of NLCD estimates of protected wetland area by comparing final protection results using NWI data with those obtained using NLCD data. We found an increase of 28,920 ha protected when using NWI data, which equates to a 0.35% difference in total wetland area from NLCD. Because of the large scale of our analyses, the desire to have a more contemporary database, and to maintain consistency with grassland analyses, we chose to use NLCD data for all reporting and conservation planning analyses hereafter.

Third, we summarized data on CRP enrolment for 1986–2010. We summarized data at a county level to produce annual CRP estimates for the PPJV area. We divided total CRP hectares by grass cover classified by NLCD to quantify the percent of 2006 NLCD grass cover attributed to CRP.

Results—Conservation Status

Ownership.—Private and tribal land ownership in PPJV portions of each state ranged from 94.2% to 98.2%, with the exception of Montana, which was 74.8% (Fig. 1). Across the PPJV region, tribal lands accounted for 3.0 million ha or 6.2%; however, estimates were biased high because we could not obtain GIS files that included private in-holdings. Federal ownership accounted for 2.4 million ha (5.0% of PPJV region), while state ownership accounted for 1.6 million ha (3.4% of PPJV region). We found that 85.4% of land in the PPJV region was privately owned (range = 90.5% in SD to 98.2% in IA). The PPJV area of Montana was an exception, with 57.0% private ownership (Fig. 1). The majority of publicly owned land in Montana was under federal ownership at 1.8 million ha (18.4% of PPJV portion of MT; Fig. 1).

We found that 3% of federally owned and managed land experienced cropland conversion, as indicated by NLCD 2006. On state-owned lands with a conservation mandate, 16.3% of the area was classified as cropland. We found that 17.2% of non-protected school-trust land was classified as cropland even though these lands are not protected from conversion by mandate. Thirty-six percent of tribal lands were classified as cropland, but we could not distinguish whether conversion occurred on private in-holdings or on tribal-managed lands.

Protection.—We found that 18.4% (1.97 million ha) of grassland present in 2006 was protected, which equates to 4.9% of the historic grass area (Table 3), while 1.15 million

Table 3. Area and percent of grassland and wetland protected within the Prairie Pothole Joint Venture (PPJV) of the United States. Historic estimates related to wetland protections were not available because no comprehensive data set on locations of all drained wetlands across the PPJV exists.

Conservation program[a]	Grass area (ha)	% Current grass	% Historic grass	Wetland area (ha)	% Current wetland area
Total habitat protection 2010[b]					
Total USFWS & PPJV Partners fee	1,458,434	13.6	3.7	564,542	16.9
USFWS easements	509,574	4.8	1.3	586,071	17.5
Total FEE & easements[c]	1,968,007	18.4	4.9	1,150,613	34.4
Average annual protection 2001–2010[d]					
USFWS easements	25,725	0.24	0.06	4,489	0.13
USFWS fee	817	0.01	0.00	638	0.02
State conservation	1,057	0.01	0.00	1,662	0.05
Total yearly average	27,599	0.26	0.07	6,788	0.20

[a] USFW—U.S. Fish and Wildlife Service, fee land means absolute title to the land.
[b] Total conservation protection percentages do not include non-protected state lands or tribal lands. However, 12.4 and 5.6% of current grasslands and 6.3 and 1.5% of current wetlands are within tribal boundaries or non-protected state lands (e.g., school trust lands).
[c] Total area calculations do not include area of protection by non-governmental organizations, unless land was donated to the USFWS or permanent wetland and grassland easements through the U.S. Department of Agriculture grassland or wetland reserve programs.
[d] Yearly average estimates do not include area of land protected by non-governmental organizations or permanent wetland and grassland easements through the U.S. Department of Agriculture grassland or wetland reserve programs.

ha, or 34.4%, of wetland area within the PPJV region was protected. Current protected grassland and wetland areas were a mix of fee ownership and working land (i.e., limited-interest) conservation easements. Conservation easements accounted for approximately 25% and 50% of all current grassland and wetland protection within the PPJV region, respectively (Table 3). We estimated that 12.4% of remaining grasslands and 6.3% of remaining wetlands existed within non-protected tribal lands. We also found 5.6% of grassland and 1.5% of wetland areas were located in non-protected state lands, primarily school trust lands.

CRP.—We found that 23.8% of all grass cover within the PPJV region was attributable to the CRP when compared with total grass area estimates from the 2006 NLCD (Table 2). The relative importance of CRP to total grass cover varied by state, with South Dakota having the lowest percentage (11.2%) and Minnesota having the highest percentage (67.6%) of grass cover. The amount of grassland under the CRP within the PPJV region peaked during 2007 at 3.38 million ha (SI 4). As of 2010, approximately 510,000 ha of CRP (15% of peak area) had expired from 2007 levels.

Methods—Conservation Trends

We compared current rates of conservation protection with grassland and wetland loss rates from previous sections to inform our conservation planning scenarios and provide insight into potential future landscape conditions. We obtained average annual rate of wetland and grassland protection from 2001 through 2010 from state and federal agencies that have active acquisition or easement programs.

We focused on rates of permanent protection during the past decade, because temporary conservation protection programs are ephemeral and land restoration can be converted if not subsequently protected from future conversion. Therefore, if land was restored, but not protected from future conversion, it was not included in our analyses. Specifically, we included in our analyses all USFWS fee and conservation easements, state agency fee and conservation easements, and lands protected by non-governmental organizations that were donated to the USFWS for easement enforcement or management. Our analyses did not include habitat acquisitions from the 2008 Clean Water, Wildlife, Cultural Heritage and Natural Area Minnesota Constitutional Amendment, because acquisitions had not begun as of 2010 in the PPJV region. We also quantified the amount of grass in CRP that is eligible for re-enrolment cumulatively and by year even though CRP is temporary because grass in CRP contracts comprises significant grassland cover within the PPJV region (Table 2).

We summarized the financial investment by USDA to provide insight into federal spending on conservation and agricultural priorities within the PPJV region. We used USDA data obtained by the Environmental Work Group (farm.ewg.org) and USDA Risk Management Agency (USDA-RMA 2011) to summarize data on 4 major classifications of farm and conservation programs: conservation, crop subsidy, other farm programs, and crop insurance (SI 5). We calculated yearly net losses from the crop insurance program by subtracting producer premiums from total indemnities paid within a county for each year. Producer premiums were calculated by subtracting subsidized cost (i.e., paid by the government) from the total cost of the insurance program for each year.

The cost of conservation easements are tied directly to the price of cropland and pastureland by legal mandate and are calculated on the effect of the easement on property values. Therefore, we assessed trends in cost of agricultural land from 2001 through 2010 at the state level. Information on cropland values was assembled and summarized directly by USDA in their 2005 and 2010 land values and cash rents summary reports. Information presented below is taken directly from tables labeled Cropland [Pastureland] Average Value per Acre by Region and State (USDA-NASS 2011).

Results—Conservation Trends

CRP.—In 2012, agreements for 23.8% of all CRP area are set to expire across the PPJV region. However, this varies from 7.3% in Iowa to 33.3% in North Dakota (SI 4). By 2017, >70% of all CRP area will be up for re-enrollment (SI 4), although expiring areas do not necessarily result in conversion back to cropland. For example, during the past 2 general signups, 19–40% of expiring CRP area was re-enrolled at a state scale for Iowa, Minnesota, Montana, South Dakota, and North Dakota, and new contracts offset part of the area lost. However, as noted in CRP status, re-enrolments and new contracts are not replacing total CRP area. In fact, 15% of peak area in 2007 was lost by 2010.

Protection rates.—During 2001–2010, on average, 0.26% (27,599 ha) of extant grasslands and 0.20% (6,788 ha) of extant wetlands were protected per year. We found that 93% of grassland and 66% of wetland protection during 2001–2010 was in private ownership and under USFWS grassland or wetland easements (Table 3). On average, the USFWS spends US$19.4 million annually (2001–2010; all currency in U.S. dollars) on grassland and wetland protection in either fee title or working land easements in the PPJV.

Farm programs.—Expenditures under USDA farm programs were substantially higher when compared with other conservation spending in the PPJV region (Table 4). The

Table 4. U.S. Department of Agriculture (USDA) farming and conservation programs from 2000–2009[a]. Detailed lists of how farm programs, subsidies, and conservation programs were grouped into subcategories are available in Supplemental Information (SI 5).

Average annual cost (millions of US$) 2000–2009	
USDA farm programs	
Crop subsidies	9.7
Disaster payments	221.1
Farm programs	1,731.4
Crop insurance losses	326.0
Total farm programs	$2,288.2
USDA conservation programs	
Conservation Reserve Program	376.2
Other conservation	13.6
Total conservation programs	$389.8

[a] Data were obtained from the Environmental Working Group, who received the information directly from the USDA. Information on crop insurance losses was obtained from USDA Risk Management Agency (FCIC).

average annual expenditure for farm programs within the PPJV region was $2.3 billion during 2000–2009 (Table 4). Annual crop insurance losses and disaster payments accounted for $547.1 million. Direct crop subsidies accounted for $9.7 million annually, while farm programs accounted for the remaining costs (Table 4). The USDA spent $389.8 million annually within the PPJV region on conservation programs; however, $376.2 million was allocated annually to the CRP, which equates to 96.5% of USDA conservation expenditures in the region. Other conservation programs administered by the USDA accounted for $13.6 million (Table 4); these include permanent easements such as the Wetland Reserve Program and Grassland Reserve Program. Area and location of permanent protections through these programs were unavailable and not included within this report.

Cost of conservation.—From 2001 to 2010, cropland prices increased 58% to 150%, with largest increases occurring in South Dakota (Fig. 2). At a state level, average cropland prices are correlated with the grassland conversion and/or precipitation patterns, with higher prices of cropland corresponding to higher grassland conversion (Figs. 1 and 2; Tables 1 and 2). Iowa has the highest precipitation and longest growing season within the PPJV region, and cost per hectare averaged $10,310 in 2010. This was 48%, 181%, 400%, and 426% more expensive than Minnesota, South Dakota, North Dakota, and Montana cropland, respectively (Fig. 2). Pastureland prices also increased 120–167% during 2001–2010 (Fig. 2). The price of land with a cropping history was 1.5 to 3.3 times more than pastureland. There is a clear latitudinal gradient in cropland prices, with Iowa cropland values 1.5 times more expensive than Minnesota and South Dakota cropland values and 1.8 times more expensive than North Dakota cropland values (Fig. 2).

CONSERVATION PLANNING

Methods—Conservation Planning

We compared annual wetland and grassland loss rates from published literature with average annual conservation rates during the past decade to assess conservation-planning efforts within the PPJV. Specifically, we evaluated whether the PPJV protection goals of an additional 4.2 million ha of grasslands and 0.57 million ha of wetlands (Ringelman et al. 2005) were attainable given status and trends in land-use and land cover assembled in the sections above. Further, we evaluated ramifications of increasing or decreasing conservation rates on future habitat areas.

We applied a constant loss rate for wetlands and grasslands and compounded losses at yearly intervals for 200 years from 2010, or until losses intersected current area of grasslands or wetlands protected. We multiplied the percentage of grasslands and wetlands remaining at each time step by the loss rates to the estimated area of wetland and grassland from the 2006 NLCD (equation 1).

$$\text{Habitat remaining} = 100 \times (1 - x)^t \quad (1)$$

where x = loss rates, and t = yearly time step.

We quantified average yearly area of wetland and grassland protection by collecting and summarizing data from the USFWS and state agency partners from 2001 through 2010 (Table 3). We added average annual grassland and wetland protection areas to final 2010 protection values (Table 3) to generate an estimate of protection in 2011. We repeated this

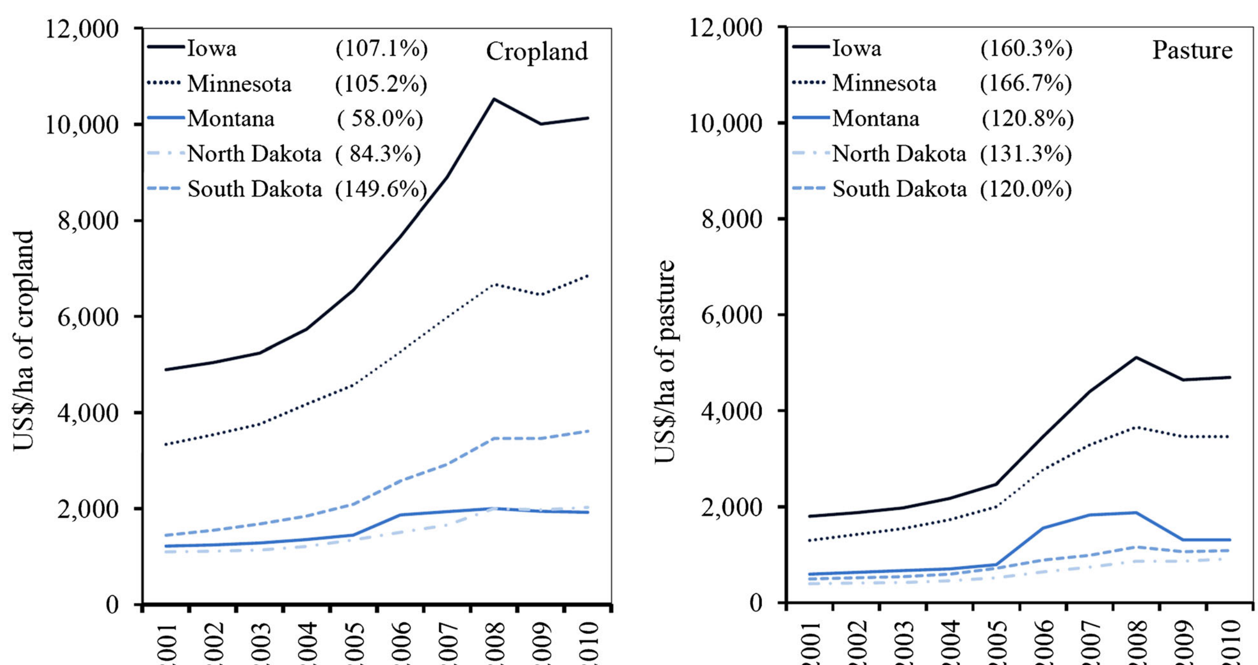


Figure 2. Average value of a hectare of cropland and pastureland by state and year, 2001–2010, within the Prairie Pothole Joint Venture (PPJV) region within the United States. Percent increases are derived from 2001 versus 2010.

process at yearly intervals for 200 years or until protected area intersected the lowest level of habitat loss. We conducted 2 scenarios on effects of increasing or decreasing average conservation rates. First, we multiplied the average conservation rate during the past decade by 0.5 and repeated the steps above, because budgets for land conservation have remained largely static during the past decade, while land costs have doubled (Fig. 2). If land conservation funding fails to keep pace with the increasing price of agriculture land, gains in land conservation will decrease in the future. In a second scenario, we multiplied the average grassland and wetland conservation rates by 2.0. We did this to understand whether doubling our conservation efforts would achieve conservation goals.

These scenarios were intended to provide insight into potential future outcomes. They utilized the best available information on status and trends in both conservation and land-use change within the PPJV region. We fully acknowledge that straight linear annualization of current protection and constant loss rates are naïve when projected far into the future. However, scenario planning gives context to consequences of seemingly small, annual wetland and grassland loss rates. Moreover, scenario planning offered an opportunity to assess conservation goals for the ecosystem.

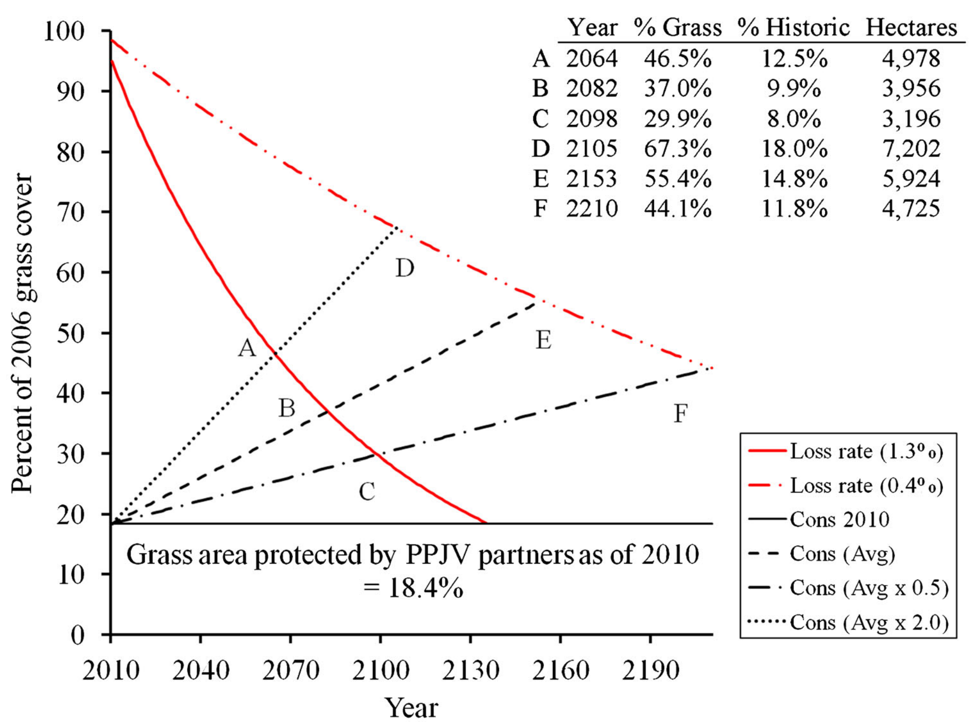
Results—Conservation Planning

Under current rates, we will protect 30–67% of 2006 grassland area, or 8–18% of historic grassland area, when grassland loss intersects grassland protection in the future (Fig. 3). A 0.9% difference between the 2 published estimates of grassland loss (Stephens et al. 2008, Rashford et al. 2011*b*) resulted in large differences in intersection values (Fig. 3). A 1.3% loss rate intersected mean grass conservation in year 2082 with 37% of current grass protected (10% historic levels; Fig. 3). However, a 0.4% loss rate intersected mean conservation rates in year 2153 with 55% of current grasslands protected (15% of the historic grasslands; Fig. 3). Therefore, a 0.9% difference in loss rate equates to a 71-year difference in intersection points and an 18% difference in protection levels (Fig. 3).

The proportions of PPJV wetlands currently and projected to be conserved exceed proportion of PPJV grasslands currently and projected to be conserved. Consequently, intersections generally occurred further in the future (Figs. 3 and 4). We estimated that protected area intersected wetland loss between years 2083 and 2201, with 47–93% of remaining wetland area protected at our current rates of protection. This is a result of higher wetland protection levels in year 2010, coupled with generally lower wetland loss rates (Table 3; Fig. 4). Again, small changes in annualized wetland losses resulted in large differences in year of intersection and total protection levels (Fig. 4).

AN UNCERTAIN CONSERVATION FUTURE

Land-use changes in the prairies have occurred primarily to support larger, more intensive agriculture practices since European settlement in the late 1800s (Higgins et al. 2002). All scientific papers and data we reviewed indicate conversion of grasslands and drainage of wetlands will continue within the PPJV region. However, uncertainties



	Year	% Grass	% Historic	Hectares
A	2064	46.5%	12.5%	4,978
B	2082	37.0%	9.9%	3,956
C	2098	29.9%	8.0%	3,196
D	2105	67.3%	18.0%	7,202
E	2153	55.4%	14.8%	5,924
F	2210	44.1%	11.8%	4,725

Figure 3. Percent of grass cover protected within the Prairie Pothole Joint Venture (PPJV) of the United States, and 200-year projections of grassland protection and grassland loss. Projected yearly conservation areas (Cons) are based upon an annualization of actual area protected by PPJV partners during 2001–2010. We applied a constant loss rate derived from published literature specific to the PPJV region to project annual grassland losses. Intersection points are labeled to illustrate potential future conservation outcomes. Areas are in thousands of hectares.

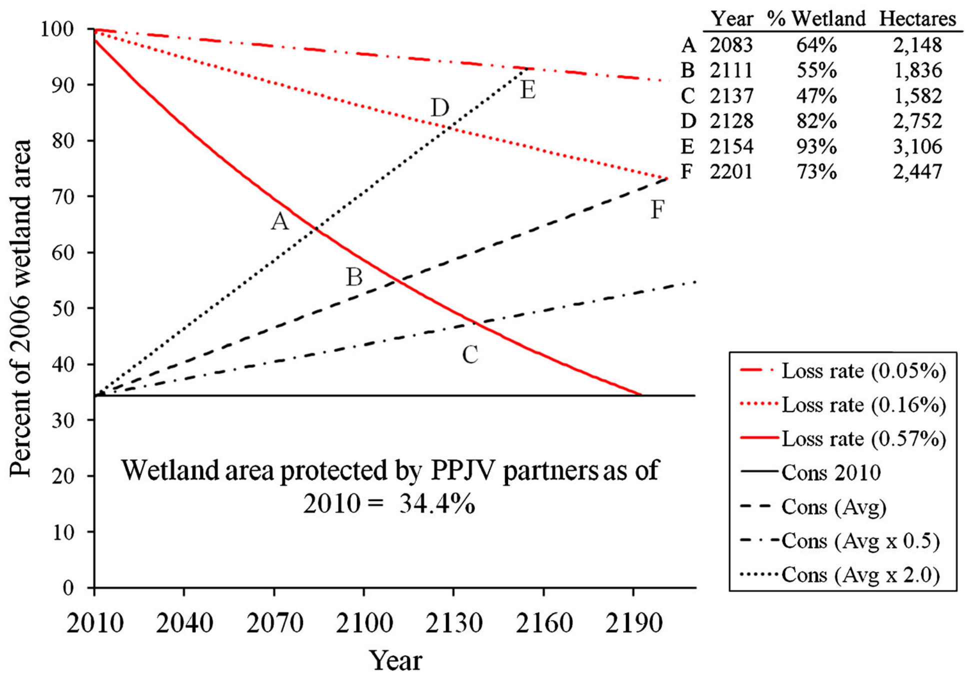


Figure 4. Percent of wetland area protected within the Prairie Pothole Joint Venture (PPJV) of the United States, and 200-year projections of wetland protection and wetland loss. Projected yearly conservation areas (Cons) are based upon an annualization of actual area protected by PPJV partners during 2001–2010. We applied a constant loss rate derived from published literature and a USFWS study specific to the PPJV region to project annual wetland losses. Intersection points are labeled to illustrate potential future conservation outcomes. Areas are in thousands of hectares.

still exist in drivers of land conversion, such as how a growing world human population affects trends in agriculture or how increasing the amount of traditional and renewable energy development influences landscapes.

We assembled data on 4 major land-use changes over the past decade to characterize development of biofuel energy, industrial wind energy, oil and gas extraction, and trends in the 3 major agricultural crops in the PPJV. We selected these land-use types because they are contemporary issues facing land managers and highlight challenges of addressing uncertainties in conservation planning. We quantified land-use changes by summarizing available public data by year. Explicit details on methods and context of findings are included in Supplementary Information (SI 6).

Agriculture Trends

Agricultural producers in the PPR are changing to less diverse and more intensive cropping practices. Within the PPJV region, in all states other than Montana, the area planted to corn increased 132–468% since 1970 (SI 7). The area planted to soybeans also increased during 1970–2009 in all states, and rates of increase have also increased over time (SI 8). In particular, North and South Dakota experienced an increase in the area planted to soybeans by 2,081% and 1,623%, respectively, from 1970 to 2009. Since 2000, area planted in soybeans has increased 201% in North Dakota, but declined 5% in South Dakota. Increases in corn and soybean area are not necessarily from new grassland conversions, but rather changes in crop type on lands already in crop production (SI 9). This change is most evident in North Dakota, where area planted to wheat declined 69% to 1.3 million ha since its peak of 4.3 million ha in 1996.

Oil and Gas Development

There were no active oil or gas wells in Minnesota, Iowa, or South Dakota inside the PPJV region. As of 2010, we found 12,419 active oil and gas wells within the Montana and North Dakota portions of the PPJV region. The number of active oil and gas wells across the landscape has steadily increased through time (Fig. 5). The outlier to this trend was North Dakota, where well production nearly doubled from 2004 to 2010, increasing from 1,393 to 2,672 wells.

Biofuels and Industrial Wind-Energy Development

As of 2010, we identified 10 biodiesel and 60 ethanol plants within the PPJV region, which produced 4.06 billion gallons of ethanol and 265 million gallons of bio-diesel/year (SI 10). We calculated that 4.2 million ha of cropland are required to supply ethanol plants within the PPJV region, using the equations of Fargione et al. (2010) and averaged 10-year data on corn yields from the USDA. Within the PPJV region, we estimated 18.5% of all areas classified as crop from the 2006 NLCD were required to produce 4.06 billion gallons of ethanol (Table 1; SI 10). To our knowledge, every ethanol plant within the PPJV region uses corn as feedstock. One cellulosic ethanol plant is scheduled to open in the PPJV portion of Iowa in 2013 that will use corn waste residue in production. We did not calculate area requirements for biodiesel plants because no data were available on ratios of source stock types used to make the fuel.

Industrial wind energy development in the PPJV region began in 1992 with one tower in Minnesota, but development did not start in earnest until after 2000 (Fig. 5). As of 2010, there were 3,759 individual wind turbines within the PPJV region, and an additional 5,631

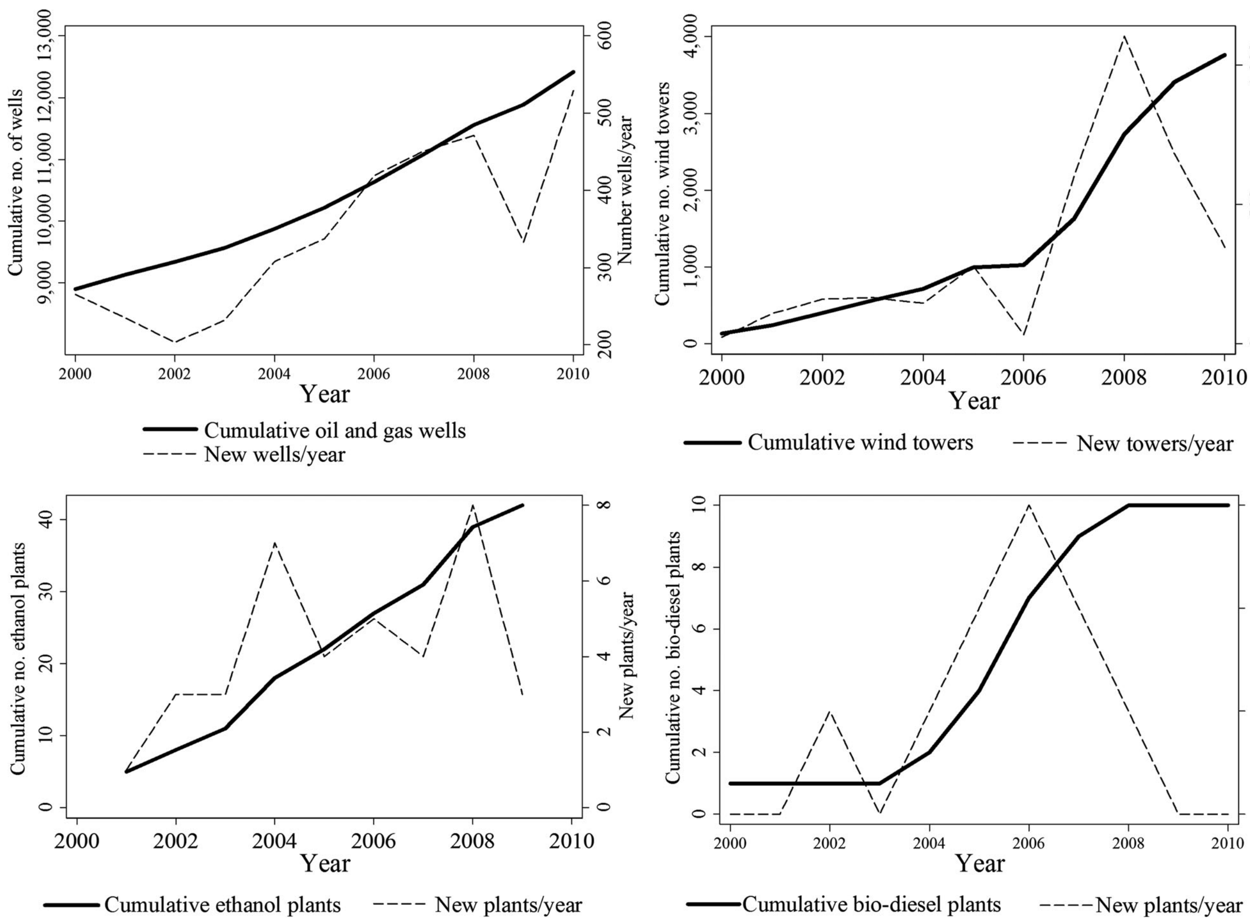


Figure 5. Both oil and gas, and renewable energy development, have shown increasing trends within the Prairie Pothole Joint Venture (PPJV) of the United States during the past decade. All data represent a census of energy development within the PPJV. Year of first production was available for 74% of ethanol plants, so data for ethanol plants represent a sample of the total plants.

approved turbine locations have yet to be constructed. Even though numbers of approved turbine locations demonstrate a large demand, they do not guarantee that towers will be erected. Wind turbines were generally located in crop fields in Iowa and Minnesota and in areas surrounded by crop fields (i.e., >75% human footprint within 1 km; SI 11; Kiesecker et al. 2011). In states with more grassland (Tables 1 and 2), siting did not always implement a disturbance-oriented approach (SI 11).

DISCUSSION—THE STATE OF THE PRAIRIES

Conservation Planning Evaluation

At current rates of habitat loss and protection, and if predicted rates of future loss are accurate, habitat conservation goals in the PPJV 2005 Implementation Plan will not be attained. Consequently, the PPJV may need to reduce conservation goals and/or focus conservation investments into areas with higher biological value to provide the greatest long-term conservation benefits in face of declining funds and ongoing habitat loss (USDA-NRCS 2000, 2009; Stephens et al. 2008, Oslund et al. 2010; Claassen et al. 2011*a*, *b*; Rashford et al. 2011*a*, *b*; USDA-NASS 2011). During the past decade, PPJV partners protected an average of 0.20% of the 3.34 million ha of extant wetlands and 0.26% of the 10.7 million ha of extant grasslands per year, but annually lost between 0.05–0.57% of wetlands and 0.4–1.3% of grasslands, respectively. Our conservation planning strategies demonstrate that time and habitat loss trajectories must be incorporated explicitly when undertaking conservation planning efforts. The importance of seemingly small wetland and grassland loss rates become evident, from both policy and conservation planning perspectives, only when incorporating time as a conservation planning metric (Figs. 3 and 4). Further, failure to explicitly consider the quantified impacts of habitat loss through time—and the impact these losses have on achieving habitat goals—may have been an oversight in the PPJV and could occur with other biological planning efforts. If population and subsequent habitat goals are derived using a step-down process from continental objectives, or if habitat quantities are treated as static when using a model-based approach, conservation plans run the risk of creating an implicit assumption that time is not a critical component in conservation delivery. Within the PPJV, we have shown this is false.

To develop reasonable planning goals, conservation practitioners must also assess habitat status and trends that support priority species when designing a conservation program. For example, a Partners in Flight goal for Sprague's pipit (a declining grassland bird within the PPJV region) is to double the size of the population (Rich et al. 2004). Partners in Flight's goals were adopted by the PPJV in the 2005 Implementation Plan. However, given current rates of grassland loss in the PPJV, it is doubtful this population goal can be met, unless populations are limited by reduced habitat quality (i.e., not quantity) or loss or degradation of non-breeding habitat, or if funding for conservation increases dramatically (Fig. 3). As expected, we found that differences in conservation protection rates have large impacts on attaining grassland and wetland protection goals in the PPJV region (Figs. 3 and 4).

The PPJV grassland protection goal appears unattainable given habitat loss and current conservation trajectories (Fig. 3). This appears true even in our most optimistic scenario of doubling our conservation protection rate, coupled with the lowest published grassland loss rate specific to this region (Stephens et al. 2008). Loss of native grassland occurred in the moist mixed-grass (0.43%) and mixed-grass ecoregions (0.50%) of the Canadian PPR from 1985 to 2001 (Watmough and Schmoll 2007) and were similar to losses estimated by Stephens et al. (2008).

Wetland protection efforts within the PPJV region exemplify the power of small actions through time (Table 3). During the past decade, average size of a wetland easement in the Dakotas was approximately 18 ha, which usually contained numerous small wetlands of various sizes and permanency (T. Fairbanks, U.S. Fish and Wildlife Service, personal communication). Nevertheless, annually, we protect an average of 6,788 ha of wetlands: easements on private land account for >50% of all wetland protection in the PPJV region (Table 3). Wetland goals may be attainable (Fig. 4); however, achieving these goals is contingent upon conservation funding increasing commensurate to land prices, continued landowner interest in protection, and the rate of wetland drainage being lower than documented in the Prairie Coteau of Minnesota on wetlands with partial prior drainage (Oslund et al. 2010). During the past decade, the price of agricultural land has doubled within the states that make up the PPJV, while funding targeted toward wetland conservation has not increased. The documented 15% wetland loss from 1980 to 2007 (0.57%/yr) in the Prairie Coteau ecoregion of Minnesota is comparable to the nationwide peak of wetland drainage that occurred during the 1950s through the early 1970s, with an annual wetland loss rate of 0.42% when compared with 2009 wetland area (Dahl 2011). Wetland loss in the Prairie Coteau ecoregion is also comparable to wetland losses within the Canadian moist mixed grass and mixed grass ecoregions where there is no regulatory protection; these regions experienced an annual loss rate of 0.31% to 0.50% from 1985 to 2001 (Watmough and Schmoll 2007).

Protecting habitat from conversion is a primary step necessary for future opportunities to influence habitat quality, especially when habitat is being lost (Figs. 3 and 4). Currently, lack of detailed spatial data and of data from studies conducted at short time intervals in a highly variable ecosystem limits our ability to assess habitat quality at the scale of the PPJV region (Gleason et al. 2011). Quantity and/or quality of grasslands and wetlands notwithstanding continued private landowner acceptance of conservation programs will be imperative in the PPJV given the amount of land privately held (90–98%, with the exception of MT). This point is increasingly important when we recognize that conservation easements on private land accounted for 93% of grassland and 66% of wetland protections during the past decade. Limited-interest conservation easements within the PPJV protect land from conversion and loss of habitat quantity, but they do not purchase all management rights relating to habitat quality. Land management actions such as controlling invasive weeds, grazing management, cropping wetland basins, and haying are all examples of decisions of private landowners that affect habitat quality for wildlife. Because the vast majority of conservation gains made in the PPJV region occur on private lands, we need to ensure that we have opportunities to work with private landowners. We should focus research on the economic and social aspects of agriculture while specifically incorporating species-specific responses in abundance, survival, and reproduction. By doing this, we can identify which agricultural practices are most favorable to wildlife yet still acceptable to private landowners (Brunson and Huntsinger 2008, Barnes 2011).

An uncertain Conservation Future

Changes in drivers of agricultural production, such as increasing crop prices, new land conversion pressures from bio-fuel mandates (International Energy Agency 2009, Fargione et al. 2010), displaced cropland production from urban expansion (USDA-NRCS 2009), and/or weakening or strengthening of protective laws and policies for wetlands and grasslands could effectively change projected outcomes. Both grassland and wetland conservation scenarios provide insight into our planning efforts, but should be viewed with caution because of the large cumulative effect of changing loss rates by tenths of a percent (Figs. 3 and 4). Currently, wetland protection under the Farm Bill (conservation subtitle Swampbuster provision; Public Law 99–198) is the primary protective legislation for wetlands in agriculture landscapes (van der Valk and Pederson 2003). However, this protection is subject to voluntary farmer participation in certain farm programs. This is due, in part, to recent legal rulings (e.g., *Solid Waste Agency of Northern Cook County v. U.S. Army Corps of Engineers*, 531 U.S. 159 [2001] and *Rapanos v. United States*, 547 U.S. 715 [2006]), which resulted in approximately 95% of prairie pothole wetlands no longer having legal protection under the Clean Water Act. Further, there are currently no comprehensive data quantifying impacts of pattern tile or contour drainage of wetlands in the PPJV region, so we are unable to determine intensity and potential impacts on the ecosystem. Nevertheless, managers within the tallgrass and mixed-grass ecosystems think that tile drainage could potentially affect wetland resources by increasing overall drainage rates, because tile drainage has been promoted recently by the farm community as a way to increase crop yields. For example, in South Dakota, estimates from USDA for wetland determination requests increased 119% from 1,600 in 2009 to 3,500 in 2011 (K. Luebke, Natural Resource Conservation Service-South Dakota, personal communication). A request for determination does not mean the wetland will be drained, but these data highlight landowners' increased desire to drain wetlands. The PPJV needs to develop a methodology for creating an independent system for monitoring land-use changes, given the large differences in future condition that result from small changes in habitat loss percentages.

The largest drivers of land use within the PPJV are world agricultural demand and U.S. agricultural and energy policies. The demand for food will increase as the global human population grows to approximately 8.4 billion people by 2100 (Lutz et al. 2001). As world demand for food increases, so will economic incentives to crop available land (Rashford et al. 2011*a*, *b*), unless dramatic increases in crop yields occur (Edgerton 2009). Increases in crop yields in developing countries—not just farm lands in the United States—will be critical to displacing additional conversion pressures on remaining grasslands because agricultural sales operate in a world market. Further, as grasslands are converted to crop production, risk of drainage resulting in small temporary and seasonal wetlands will increase (Watmough and Schmoll 2007, Oslund et al., 2010). Major drivers of grassland conversion are soil quality and agricultural commodity prices (Rashford et al. 2011*b*). The majority of high-quality soil types most favorable for crop production already have been converted in the PPJV (Walker 2011). Within the larger extent of the entire Northern Plains, Claassen et al. (2011*a*, *b*) found that 35% of existing grasslands are classified as medium productivity for agriculture; with economic and policy incentives, there is high probability of additional conversion of these grasslands. Federal farm program subsidies also provide incentives for grassland conversion in the PPJV region (GAO 2007). For example, federal farm programs reduce financial risks associated with cropping marginal soils and make farming more profitable, which creates economic incentives to convert privately owned grasslands from ranching operations to agricultural cropland.

Future evaluation of conservation programs in the PPJV also should compare importance of quantity versus quality of habitat, particularly in relation to changing crop types and effects of both renewable and traditional energy development. Responses of wildlife to different crops are poorly known, although a vast majority of information suggests that most grassland bird species respond poorly to cropland relative to undisturbed land (Herkert et al. 2003, Brennan and Kuvlesky 2005, Stephens et al. 2005, Askins et al. 2007, Fletcher et al. 2010). Our results clearly demonstrate that crop types are changing to less diverse and more intensive cropping practices with large increases in both corn and soybean production within the PPJV region (SI 7, SI 8). Energy development is known to directly influence wildlife by altering habitat use (Sawyer et al. 2006, Bayne et al. 2008, Doherty et al. 2008, Gilbert and Chalfoun 2011) and population dynamics (Walker et al. 2007, Sorensen et al. 2008, Doherty et al. 2010), and indirectly by facilitating spread of non-native invasive plants (Bergquist et al. 2007) and new diseases such as West Nile virus in North America (Zou et al. 2006). Large increases in energy production, whether wind, oil and gas extraction, or biofuels, will have major effects on land use (Fargione 2010, Fargione et al. 2010, Naugle 2011). Our results document substantial oil and gas development within the PPJV region, and this trend is expected to continue well into the future both in and around the PPJV region (Pollastro et al. 2008).

Renewable energy development in the form of industrial wind energy production and bio-fuels is a relatively new phenomenon within the PPJV region, but is already affecting large areas. Although biofuels provide incentives for economic development and augment alternative energy strategies, these developments have the largest operational footprint per terawatt-hour produced of all current energy sources within the United States (McDonald et al. 2009). Depending on the type produced, biofuels could incentivize grassland conversion or provide additional wildlife habitat (Fargione et al. 2010, Fletcher et al. 2010). Biofuel production is a catalyst driving conversion of wild lands, including grasslands, when source stocks are derived from food-producing crops (Fargione et al. 2008). We found that 18.5% of all croplands are diverted from food production to produce ethanol, and all use corn as feedstock within the PPJV region. Biofuels from food crops are expected to increase by 170% by 2020 (Fargione et al. 2010). However, if biofuels are grown from perennial plants on degraded lands abandoned from agriculture, they could result in reductions in carbon emissions and improve wildlife habitat and water quality (Robertson et al. 2008, Tilman et al. 2009, Fargione 2010, Fletcher et al. 2010, Meehan et al. 2010). Current U.S. renewable fuel standards include mandates for cellulosic ethanol from sources such as switchgrass (*Panicum virgatum*) and crop waste, but because cellulosic ethanol production is not currently economically viable in the United States, mandates for production targets have been reduced substantially. Second-generation biofuels, such as switchgrass, will likely not be commercially viable until after 2020 (International Energy Agency 2009). Nevertheless, in the PPJV portion of Iowa, a cellulosic ethanol plant using corn waste residue is in production and scheduled to open in 2013.

We documented that wind energy has increased across the PPJV during the past decade. Wind energy is second only to biofuels in land area required to produce a terawatt-hour of energy (McDonald et al. 2009). North Dakota is ranked first in the United States for potential wind power, followed by South Dakota (fourth), Montana (fifth), Minnesota (ninth), and Iowa (tenth; AWEA 2011). Research has shown some negative impacts to avian communities in response to industrial-scale wind development, but because development is relatively new there are many uncertainties and species-specific responses are poorly understood (Johnson and Stephens 2011). Johnson and Stephens (2011) summarized 6 studies that documented displacement of certain species of prairie passerines from between 50 m and 200 m distance from wind turbines. Results of an initial 3-year study on waterfowl settling patterns also suggests wind energy development causes avoidance by breeding waterfowl (Loesch et al. 2013). Further, industrial wind energy development shares many of the same features of conventional oil, gas, and coal extraction. These include increased linear features, edge habitats, and invasive species, all of which have been shown to negatively affect open-country avian species in numerous studies (see summary table 6.2 in Bayne and Dale 2011). Grassland patch size and landscape composition also influence the presence, density, and reproductive success of wildlife in the PPR (Herkert et al. 2003, Horn et al. 2005, Ribic et al. 2009). Although both renewable and traditional energy development is a major concern for managers, comprehensive cross-jurisdictional planning does not exist in the PPJV region. Lack of cross-jurisdictional comprehensive planning creates difficulties because of the large uncertainties that exist in specifics of development.

Conservation Planning in an Era of Change

In summary, our analyses highlight the need to adapt our conservation delivery strategy. We also must consider a broader conservation portfolio if we are to meet our grassland and wetland goals. First, conservation planning tools that increase efficiencies may increase protection rates. Ability to identify areas of high biological value, as well as to assess the potential for adverse habitat alteration, is a critical component of proactive conservation (Groves 2003). Explicitly incorporating spatial and temporal threats to conservation planning (Pressey et al. 2007), as well as the cost of conservation (Bode et al. 2008, Polasky 2008), may allow more strategic targeting of resources for conservation protection within the PPJV. Unfortunately, higher risk of grassland conversion or wetland drainage generally equates to higher suitability for competing economic uses such as cropland agriculture (Rashford et al. 2011*a*, *b*). Therefore, lands with higher risk of conversion or drainage cost more to protect. Partners within the PPJV are currently working on systematic conservation planning tools that balance cost of conservation with the risk of conversion (J. Walker, Ducks Unlimited, Inc., personal communication).

Second, the PPJV will have to diversify its conservation portfolio beyond permanent habitat protection. We need to consider augmenting our conservation strategy with shorter term conservation programs, further promoting agricultural practices that provide benefits to wildlife, working more closely with tribal partners and state school-trust land departments, and striving for agriculture policies that slow loss rates of grasslands and wetlands. Enrolment in the CRP has fallen significantly since 2007 (SI 4), largely in response to record commodity prices and limited ability of landowners or lessees to utilize the grass resource while enrolled. The CRP accounts for 96.5% of conservation spending by the USDA within the PPJV region (Table 4). When we compare this cost to USFWS conservation easements on an annual basis, CRP payments are 19.7 times greater annually. This is important because CRP provides term protection, whereas USFWS easements offer permanent protection. Modifications to CRP that allow increased management flexibility, such as more frequent grazing, may need to be considered to create another, non-monetary incentive to help generate and/or maintain landowner interest. Additionally, such modifications create an opportunity to reduce CRP rental rates and the cost of conservation, which could increase the area affected by the program. A change to a more working-lands CRP model would mirror changes that happened in the Canadian PPR with their Permanent Cover program. Research also has shown that some farming practices are more beneficial to wildlife than others are. Minimum-till and autumn-sown crops can be more attractive and or productive for songbirds (Martin and Forsyth 2003). For waterfowl, nest success was 3 times higher in autumn-seeded winter wheat fields (38%) compared with spring-seeded crops (12%) in the Canadian PPR (Devries et al. 2008). Ongoing research within the PPJV is verifying these results for waterfowl (J. Walker, personal communication); thus, incentives for landowner to plant autumn-seeded crops could play a part in our conservation portfolio. Lastly, as evidenced by the large differences in outcomes in our conservation planning scenarios, agricultural policies that slow conversion rates, even by tenths of a percent, allow more time to achieve protections goals.

This paper was an attempt to take a holistic view of dominant habitats (i.e., grasslands and wetlands) within a specific landscape and consider all known and potential factors affecting our ability to meet conservation goals in the face of ongoing habitat loss. Preponderance of evidence on land-use change presents a compelling case for the PPJV to adapt and diversify its conservation strategy, yet no individual publication or data source was absolute. Our scenarios provide insight into potential future outcomes and use the best available information on status and trends in both conservation and land-use change. Moreover, they offer an opportunity to assess broadly the attainability of conservation goals. We maintain that this approach can be replicated on other landscapes and may help discriminate between goals managers would like to attain versus goals they are likely to achieve.

MANAGEMENT IMPLICATIONS

The incorporation of time and habitat trends into conservation planning for the PPJV highlighted the fact we cannot reach stated conservation–protection goals, and may need to adapt our conservation planning paradigms unless 1) additional funding resources are secured for land conservation, 2) landowner interest and acceptance of conservation programs remains high, and 3) wetland and grassland loss rates are decreased via public policy, particularly agriculture programs, or through other mechanisms. Alternatively, we will have to diversify our conservation portfolio beyond permanent habitat protection and habitat protection goals will have to be reduced to be realistic. This diversification will need to include programs that are beneficial to wildlife, as well as profitable and socially acceptable to private landowners. Building and maintaining relationships with private landowners will be critical to conservation delivery, because the vast majority of lands within the PPJV are privately held (Fig. 1).

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

SI 1. List of partners for the Prairie Pothole Joint Venture.

SI 2. Wetland hectares (in thousands) by water regime and the number of individual wetland basins (in thousands) within the Prairie Pothole Joint Venture region. Basin-specific wetland hectares are calculated from the National Wetland Inventory data.

SI 3. List of lands classified as protected.

SI 4. Top figures: Cumulative total of cropland enrolled in the U.S. Department of Agriculture Conservation Reserve Program by state areas within the Prairie Pothole Joint Venture (PPJV) region and the entire PPJV in millions of hectares, September 1986–2010. Conservation Reserve Program enrollment peaked in 2007 with 3.37 million ha (8.34 million acres) and has declined by 0.51 million ha (1.26 million acres) to 2.86 million ha (7.08 mill acres) by September 2010. Bottom figures: Percentage of September 2010 CRP area expiring during 2011–2017, by state areas within the PPJV and the entire PPJV.

SI 5. List of 41 farm and 13 Conservation Programs from the U.S. Department of Agriculture from Table 4.

SI 6. Additional information—uncertain conservation future, status, and trends.

SI 7. Hectares of planted corn 1970–2009 within Prairie Pothole Joint Venture region. The dashed straight line represents a linear regression trend estimate.

SI 8. Hectares of planted soybeans 1970–2009 within Prairie Pothole Joint Venture region. The dashed straight line represents a linear regression trend estimate. Planted soybean hectares in Montana are negligible.

SI 9. Hectares of planted wheat 1970–2009 within Prairie Pothole Joint Venture. The dark straight line represents a linear regression trend estimate. Iowa never planted above 7,050 ha of wheat and planted 501 ha of wheat in 1997, the last reported planting. Iowa was therefore excluded from figures.

SI 10. Number of bio-diesel and ethanol plants, amount of fuel produced, and hectares of cropland (in thousands) required to feed fuel production from cropland within the Prairie Pothole Joint Venture region as of March 2011.

SI 11. Percent of wind turbines on undisturbed land at a site scale (30-m) and by disturbance classes for turbines built as of 2010 and for turbine locations that are approved by the Federal Aviation Administration but not built. Disturbance classes queried are from Kiesecker et al. (2011). Existing wind turbines are primarily located within disturbed land.