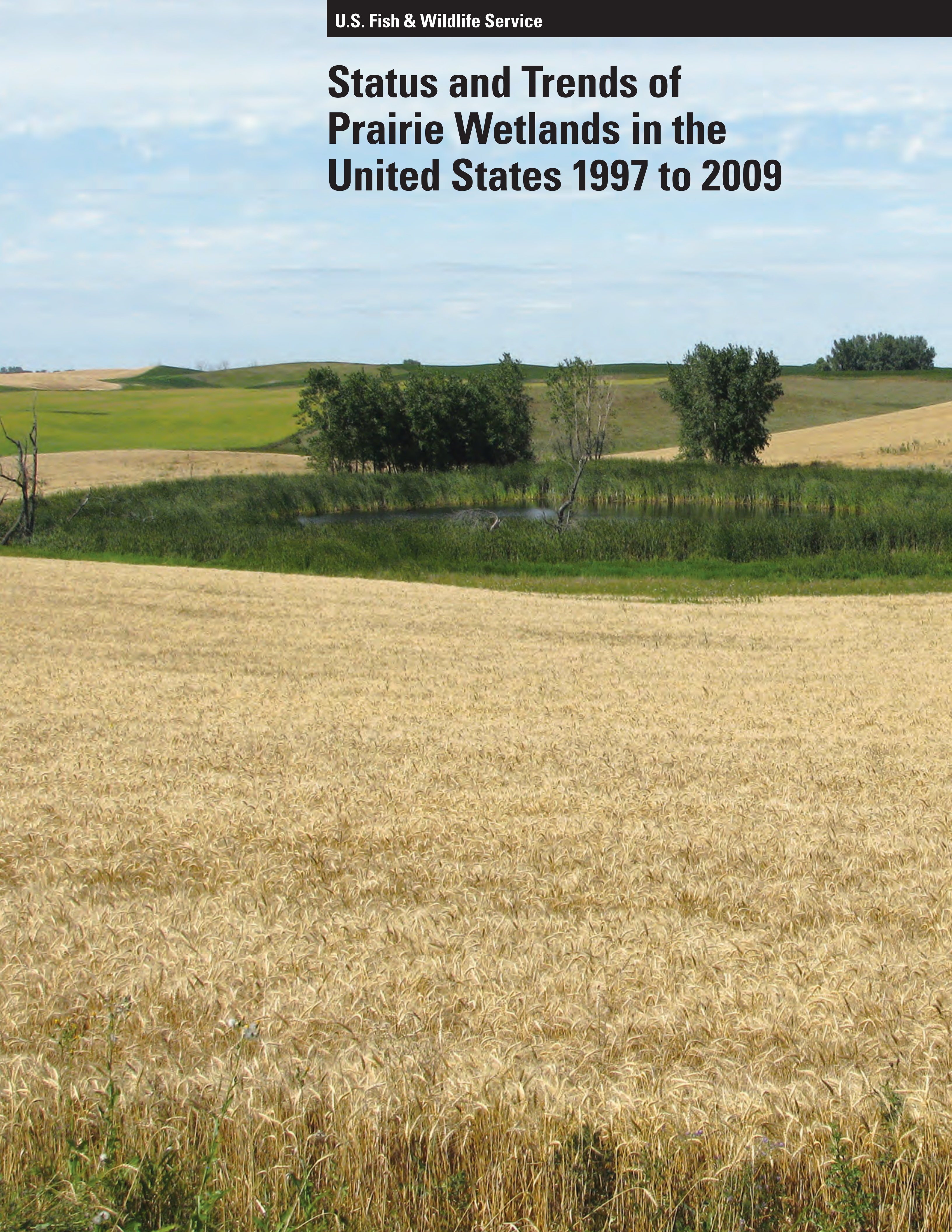
U.S. Fish & Wildlife Service

# Status and Trends of Prairie Wetlands in the United States 1997 to 2009



U.S. DEPARTMENT OF THE INTERIOR
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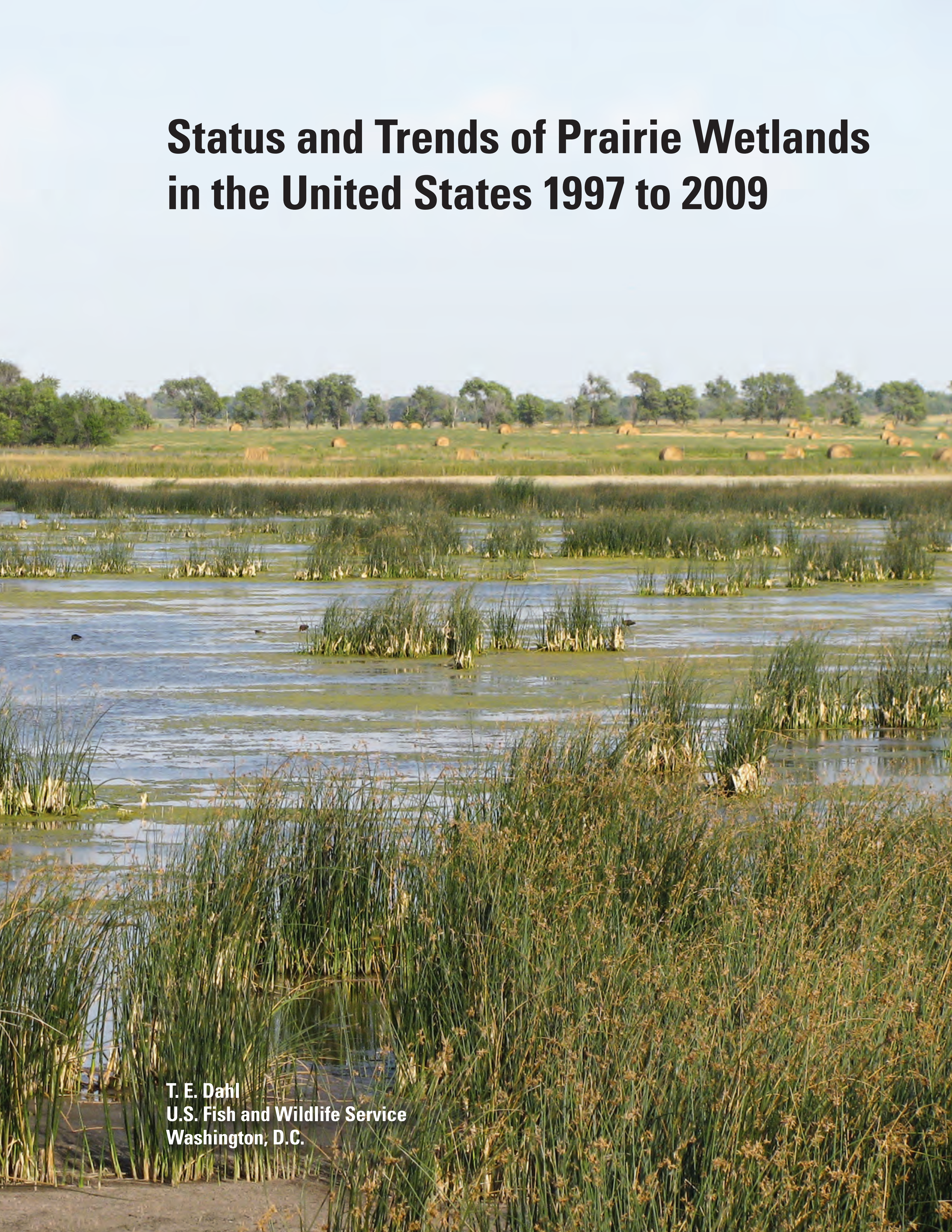

**T. E. Dahl**
**U.S. Fish and Wildlife Service**
**Washington, D.C.**

*Early spring meltwater attracts geese to this temporary wetland, Kulm Wetland Management District, ND.*

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# Conversion Table

### U.S. Customary to Metric

| | | | | |
|---|---|---|---|---|
| inches (in.) | x | 25.40 | = | millimeters (mm) |
| inches (in.) | x | 2.54 | = | centimeters (cm) |
| feet (ft) | x | 0.30 | = | meters (m) |
| miles (mi) | x | 1.61 | = | kilometers (km) |
| square feet ($ft^2$) | x | 0.09 | = | square meters ($m^2$) |
| square miles ($mi^2$) | x | 2.59 | = | square kilometers ($km^2$) |
| acres (A) | x | 0.40 | = | hectares (ha) |
| Farenheit degrees (FE) | | 0.5556 (FE-32) | = | Celsius degrees (CE) |

### Metric to U.S. Customary

| | | | | |
|---|---|---|---|---|
| millimeters (mm) | x | 0.04 = | = | inches (in.) |
| centimeters (cm) | x | 0.39 | = | inches (in.) |
| meters (m) | x | 3.28 | = | feet (ft) |
| kilometers (km) | x | 0.62 | = | miles (mi) |
| square meters ($m^2$) | x | 10.76 | = | square feet ($ft^2$) |
| square kilometers ($km^2$) | x | 0.39 | = | square miles ($mi^2$) |
| hectares (ha) | x | 2.47 | = | acres (A) |

# General Disclaimer

The use of trade, product, industry, or firm names or products in this report is for informative purposes only and does not constitute an endorsement by any agency of the U.S. Government.

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*A seasonally flooded wetland basin (foreground) and a larger semi-permanently flooded wetland (background).*

# Executive Summary

This study examined recent trends in wetland extent and habitat type throughout the Prairie Pothole Region (PPR) in the United States. Wetland trends were measured by the examination of high resolution imagery for 755 randomly selected sample plots covering the prairie regions of Montana, North Dakota, South Dakota, Minnesota and Iowa. The analysis of this imagery in combination with field verification provided a scientific basis for estimations of wetland extent, type and distribution that had occurred between 1997 and 2009.

This information provides a quantitative measure of the areal extent of all wetlands, regardless of ownership, in the PPR. Wetlands were defined using biological criteria and standardized nomenclature for the classification of wetland types. Recently acquired remotely sensed imagery was used as the principle means to assess wetland change with a number of geoprocessing and quality control measures implemented to ensure data completeness and accuracy. The spatial sample design involved randomized sampling of geospatial information on 4 $mi^2$ (10.4 $km^2$) plots. This was a well-established procedure that provided a practical, scientific approach for measuring wetland area extent (status) and change rates (trends). Statistical estimates provided regionally specific status and change information as well as estimates by wetland type. Important procedural enhancements to this study of the PPR included the addition of wetland and water basin morphology, hydrologic descriptors and the addition of an upland grassland category to track changes in grassland area. Field verification was completed for 205 (27 percent) of the sample plots during 2010 to 2013.

This report provides data regarding trends in wetland extent and type; however, it does not draw conclusions regarding the quality or condition of prairie wetlands.

Results from this study indicated that there were an estimated 6,427,350 acres (2,602,165 ha ± 4.3 percent) of wetlands in the PPR in 2009. Emergent wetlands made up about 87.7 percent of the total wetland area and 93 percent of all wetland basins in the PPR. Wetlands classified with woody vegetation (wetland forest or shrubs collectively) composed 8.3 percent of the surface area and open water ponds 4 percent. By area, seasonally flooded emergent marshes had the greatest area with 2,313,650 acres (936,700 ha) followed by semi-permanently flooded marshes with 1,945,460 acres (787,636 ha) and temporarily flooded wetland with 1,187,700 acres (480,850 ha).

The number of wetland/water basins[1] in the PPR was determined using a geospatial model to calculate spatial dominance of basin area by water regime type. There were an estimated 2,624,990 wetland/water basins in the PPR. Temporarily flooded emergent wetland basins were the most numerous, composing almost half of all emergent wetland basins in the PPR. An estimated 41.7 percent of emergent basins were seasonally flooded, 6 percent were semi-permanently flooded and farmed wetlands made up an estimated 2.4 percent of the emergent wetland basins in 2009. There were very few (0.2 percent) saturated emergent wetland areas in the PPR.

The maximum density of wetland was 148 basins per $mi^2$ (57 basins/$km^2$) in portions of North Dakota. Wetland/water basins averaged from 30 per $mi^2$ (12 basins/$km^2$) in North Dakota to 4 and 5 basins per $mi^2$ (1–2 basins/$km^2$) in Iowa and Minnesota. The mean number of wetland/water basins found in the PPR in 2009 was 17.4 basins per $mi^2$ (6.7 basins/$km^2$). The mean size of these basins was 3.2 acres (1.3 ha).

Wetlands as a percentage of surface area in the PPR were most abundant in North Dakota, making up 9 percent of the surface area in the prairie region of that state in 2009. South Dakota was similar with 8.5 percent of the land area identified as wetland. Minnesota had 6.7 percent wetland by area, Iowa 2.7 percent and wetlands were the least common in Montana with 1.9 percent of the land area as wetland.

An estimated 94 percent of wetlands were located within or adjacent to agricultural lands or grassland. Less than 1 percent were within or adjacent to urban or developed areas and about 5 percent were within or adjacent to other types of uplands or river corridors.

Between 1997 and 2009, total wetland area declined by an estimated 74,340 acres (30,100 ha) or 1.1 percent in the PPR. This represents an average annual net loss of 6,200 acres (2,510 ha). However, emergent wetlands (emergent marshes and farmed wetlands) declined by an estimated 95,340 acres (38,600 ha). Shrub wetlands also declined by 46,080 acres (18,660 ha). Forested wetlands increased in area (61,280 acres or 24,810 ha) ameliorating some of the loss of emergent marsh and shrub wetland area. Open water ponds also increased in area by 5,800 acres (2,350 ha) over the 12 year period.

[1]Basin numbers include wetland and lake (deepwater) basin types.

Minnesota sustained the largest loss of emergent wetland area between 1997 and 2009. South Dakota was the only state to exhibit gains in emergent wetland area.

Because most wetlands and water basins in the PPR are hydrologically closed systems, they are sensitive to climate variability and can exhibit dramatic changes in water levels, size and distribution on the landscape. Over the course of this study, high water conditions affected 40 percent of the emergent wetlands. Semi-permanently flooded wetlands, open water ponds and deepwater lakes increased in area, often at the expense of vegetated wetland area.

Emergent wetlands lost to upland land uses (agriculture and development) between 1997 and 2009 accounted for 39 percent of all losses. Small-sized farmed and temporary wetlands experienced substantial losses. Farmed wetlands were very vulnerable to drainage for agricultural crop production because they were usually small, in close proximity to existing farm field operations and could be easily drained, usually without penalty under existing regulations. Temporarily flooded and farmed wetland basins were lost to agriculture even during periods of abnormally high water conditions.

Between 1997 and 2009 wetland/water basins declined by over 107,177 or 4 percent. Wetland basin numbers declined in every state in the PPR with the exception of Montana, where there was a small gain in wetland basins of less than 1 percent.

Ninety-six percent of the basins lost were temporarily flooded emergent and farmed wetlands as these basin types declined by 7.8 percent. The mean size of the basins lost was 0.85 acres (0.3 ha). An estimated 49 percent of the wetlands lost between 1997 and 2009 were geospatially isolated wetlands[2].

The restoration of wetland and grassland in the PPR has been a priority for resource management agencies at the federal and state level for some time. Because the drainage of prairie pothole wetlands typically involves a single outlet ditch or tile drain to put land into agricultural production, the potential for restoration is much greater than if the lands were developed as part of urban areas. Between 1997 and 2009, an estimated 87,690 acres (35,500 ha) of emergent wetland was restored from agricultural lands. These restored wetlands averaged 5.8 acres (2.4 ha) and were seasonally or semi-permanently flooded areas.

The results of these wetland restoration efforts were overshadowed by the loss of 125,400 acres (50,770 ha) of emergent wetland converted to upland agriculture. The deficit, represented by a loss of 37,770 acres (15,270 ha), indicated that the no-net-loss of wetland policy goal had not yet been reached in this region.

Grassland occupied approximately 21.1 million acres (8.6 million ha) in the PPR in 2009 (± 4.2 percent). There was a 3:1 ratio of grassland to wetland region-wide. However, grassland was not evenly distributed and was sparse in the prairie regions of Minnesota and Iowa. Between 1997 and 2009, grassland area declined by an estimated 568,040 acres (229,980 ha) or 2.6 percent. Grassland area declined by 805,000 acres (325,910 ha) in the western prairie states of Montana, North Dakota and South Dakota. Minnesota and Iowa gained grassland area (236,960 acres or 95,935 ha) over the period of this study. Ninety-five percent of the area lost from grassland was reclassified as agriculture.

Grasslands in the PPR have the ability to directly impact up to 32 percent of the remaining wetlands that were either within or directly adjacent to grassland areas. The elimination of grassland may not result in direct wetland loss but can influence wetland condition and landscape function by increasing sedimentation, runoff of chemicals or nutrients, or by otherwise reducing or eliminating surrounding habitat suitability. It is likely that grassland to cropland conversion will increase if agricultural commodity prices continue to follow recent trends.

Changes in wetland extent and type between 1997 and 2009 were the result of cumulative impacts related to ecological change; changes in climate that altered hydrology (e.g. flooding); anthropogenic changes such as draining, ditching or filling wetlands; or a combination of these influences. Evidence from this study indicates that some wetland basins have become wetter. However, the duration and sustainability of this trend is unclear.

[2] Geospatially isolated wetlands are those areas not having a direct connection to other water bodies via channel or navigable water. Isolated wetlands were determined by a geospatial data model developed to identify wetlands not connected to or within a 100 ft. (30 m.) buffer distance ters (rivers, streams or permanent lakes).

# Introduction

*Restored wetland in northwest Iowa. (Photo courtesy of NRCS.)*

The U.S. Fish and Wildlife Service (USFWS) has been entrusted with legal authorities and responsibilities for fish and wildlife conservation including the management of fish and wildlife populations; conserving endangered and threatened species, inter-jurisdictional fish and migratory birds; managing an extensive conservation land base composed of over 560 National Wildlife Refuges; and collaborating in carrying out conservation activities under international conventions, treaties and agreements. The USFWS communicates information essential for public awareness and understanding of the importance of fish and wildlife resources and changes reflecting environmental conditions that will ultimately affect the welfare of people.

Wetlands are transitional from true aquatic habitats to dry land (upland) and as a result, their abundance, type and condition are directly reflected in the health and abundance of many species. In addition to providing habitat for a variety of animal and plant species, wetlands of the Prairie Pothole Region (PPR) perform a number of other environmental services. Depending on their location, type and size, wetlands can attenuate floodwaters, recharge ground water, provide water and forage for livestock and support biodiversity. The ecological condition of many of the remaining wetlands in the PPR have been affected by land use changes including encroachment of development and farming practices, alteration of hydrology via drainage, introduction of invasive species, fragmentation of habitat and reduced diversity in wetland complexes.

Continued pressures on wetland resources require effective monitoring efforts at temporal and spatial scales useful for detecting significant change that leads to effective wetland conservation efforts. Probabilistic sampling to periodically measure wetland area extent (status) and change rates (trends) are an effective means to gather information regarding wetland resources. Resource managers, researchers and policy makers have come to rely on statistically based sampling strategies to capture recent wetlands status and trends information.

Monitoring of wetland resources has been widely considered essential for identifying changes in wetland community types and spatial extent and guiding additional research or management actions. The USFWS has produced a series of reports on wetland status and trends that provide information on wetland extent and types in various parts of the country. These provide resource managers useful data to inform decisions on wetland-related issues such as establishing restoration and habitat enhancement priorities, assessing habitat availability, identifying possible changes from climatic conditions and implementing strategic ecosystem management actions.

Conservation efforts in the PPR reflect USFWS participation with other partner organizations in international management plans and treaties including the North American Waterfowl Management Plan (NAWMP 2012). This plan calls attention to the continuing loss of key wetland and related habitats needed to sustain waterfowl populations at desired levels and identifies the PPR as crucial to the long-term viability of breeding waterfowl habitat in North America (Beyersbergen *et al*. 2004). Federal, state, local and tribal agencies as well as private organizations play key roles in slowing and reversing the trend of habitat loss by protecting and restoring wetland and grassland habitats throughout this region.

Understanding the relationships between extent and types of wetlands and waterbird and waterfowl density and distribution is essential to population monitoring and management (Niemuth and Solberg 2003). Over the past 30 years the scientific community has developed various ecological models that assist biologists and resource managers in identifying land and water resources necessary for supporting various ecological functions and services, including requirements for maintaining migratory bird populations. Many of these models depend on geospatial data that reflect contemporary land-use information to assess landscape-level conditions. This study contributes to those efforts by tracking and quantifying wetland losses, restoration or creation actions and providing a *measureable element* to gauge management actions, assess progress in achieving federal policy objectives and provide further information crucial to understanding the wetland resources of the PPR.

This report presents the latest status information on the extent, type and trends of wetland resources in the PPR and provides estimates of losses or gains[3] that occurred between 1997 and 2009. The information presented provides data on the areal extent of wetland types, both past and present, to help prioritize conservation planning efforts for wetland resources and contribute additional information to facilitate strategy and policy development. This study does not assess wetland condition or other qualitative changes to wetlands in the PPR.

[3]Wetland loss or gain as used in this report is defined as a decline or increase in wetland area.

***This study was supported by the Prairie Pothole Joint Venture and Ecological Services of the U.S. Fish and Wildlife Service. Cooperative efforts for field operations were also provided by the U.S. Environmental Protection Agency, Office of Wetlands, Washington, D.C.***

*McIntosh County, ND, spring 2014.*

# The Prairie Pothole Region of the United States

The glaciated prairie region is an area of about 300,000 $mi^2$ (777,000 $km^2$) located in the central portion of the North American Continent (Smith *et al.* 1964). In the United States, this region encompasses an area of about 150,930 $mi^2$ (390,910 $km^2$) and extends from central Iowa north to the Canadian border and includes portions of the states of Iowa, Minnesota, North Dakota, South Dakota and Montana. The region is characterized by glacial or post-glacial derived depressions or basins resulting from the retreat of the Laurentide ice sheet of the Wisconsin Glacial Episode (Johnson *et al.* 2008). As a result, there are numerous small landscape depressions left behind as the glaciers receded from this part of the continent. These landscape depressions, termed "potholes," collect rainfall and snowmelt, forming small shallow wetlands and ponds (Figure 1).

The PPR is a grassland ecoregion of regional and global importance for migratory birds and other fauna (Blann *et al.* 2009). The North American prairie as it existed prior to European settlement was dominated by grasses, and a scarcity of shrubs and trees except along river or stream corridors (Weaver 1954). By the late 1990s less than 1 percent of the historic native tall-grass prairie and less than 30 percent of the native mixed-grass prairie remained (Samson *et al.* 1998; Wright and Wimberly 2013). Grasslands are considered one of North America's most endangered ecosystems (Beyersbergen *et al.* 2004; Hoekstra *et al.* 2005). Upland grassland in the PPR provides a range of ecological benefits including trapping of sediment; slowing of water runoff; and a source of food, nesting cover and habitat corridors for many wildlife species.

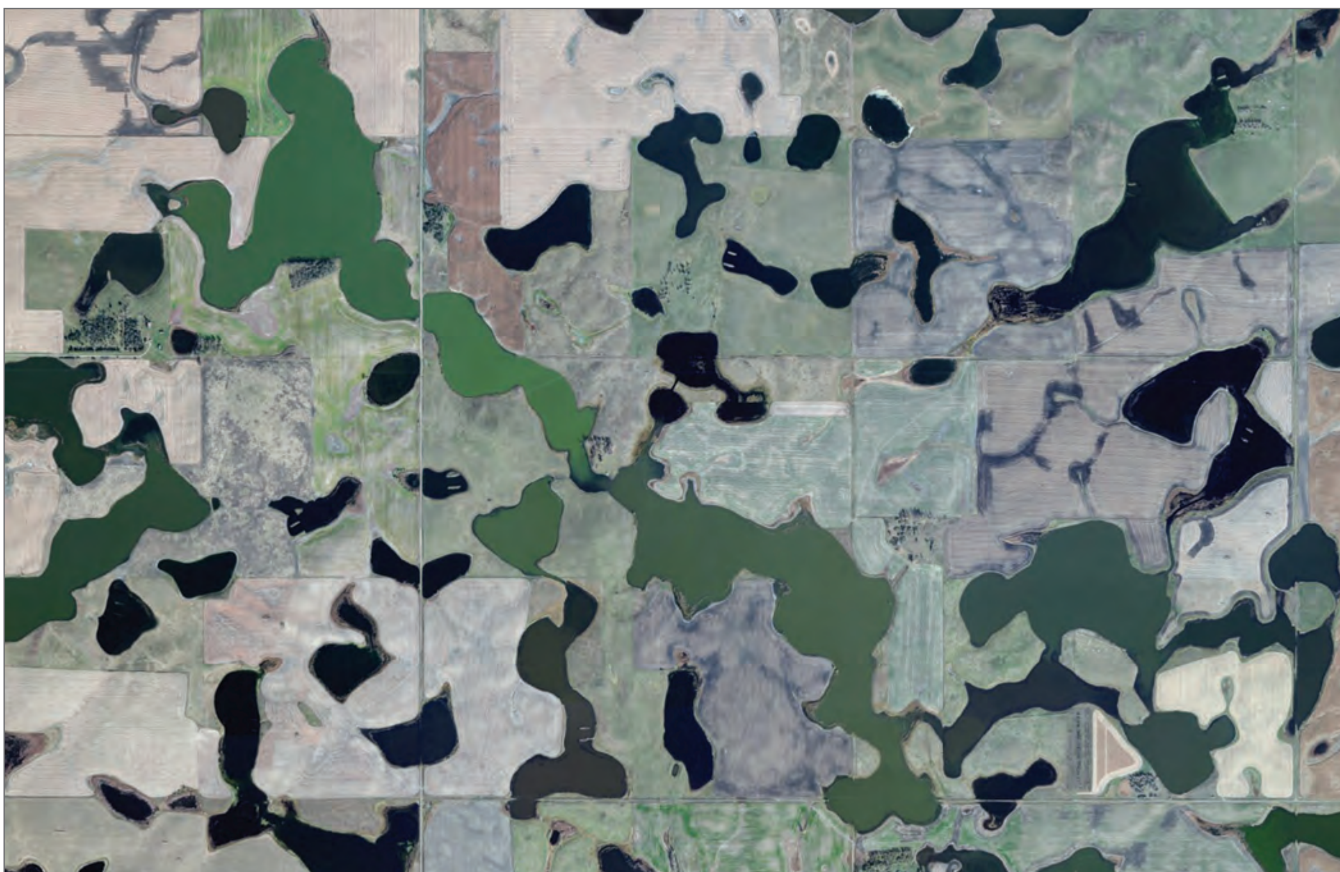


***Figure 1.*** *Aerial image of numerous wetland basins, Day County, SD, circa 2010.*


***Figure 2.*** *An emergent wetland in the Prairie Pothole Region of North Dakota. Semi-permanently flooded to temporarily flooded zones represent different hydrologic regimes reflecting water permanence within a single depressional basin.*

Today, agriculture is the primary land use in the PPR (Gleason *et al*. 2008; Johnson and Higgins 1997). Cropland currently makes up about 69 million acres (27.9 million ha) or 71 percent of the 96.6 million acres in the PPR of the United States (Rashford *et al*. 2010). Small grain and other row crop farming along with grazing of livestock strongly influence the landscape and have a profound effect on wetland communities. Wheat, corn, soybeans, barley, hay, sunflowers, flax and cattle make up some of the agricultural products produced in the PPR of the United States.

In the PPR, wetlands include an array of temporary, seasonal and semi-permanently flooded marshes, sloughs, and swales as well as larger, more permanent water bodies and relatively few shrub and wooded wetlands. Most prairie wetlands receive water from either precipitation in the form of direct rainfall, meltwater from snow, runoff from the surrounding watershed or, to a lesser extent, groundwater discharge. Many prairie potholes form more-or-less concentric bands of wetland vegetation around the deepest portion of the basin (Kantrud *et al*. 1989). These wetland vegetation zones orient themselves from the area where water persists the longest to the periphery where water is less permanent (Figure 2). Each of these zones reflect differences in the persistence of inundation, types of plants, soil and water chemistry. However, it is common for this zonation to be patchy, degraded or missing altogether.

Various wetland classification schemes have been developed for wetlands, ponds and lakes in the prairie region of the United States (Stewart and Kantrud 1971; Cowardin and Johnson 1973; Hubbard 1988). A number of these methodologies classify prairie wetlands using water permanence (hydroperiod) as a descriptor for categorizing these habitats.

Historically, throughout the PPR the average annual precipitation has always been less than the average annual rate of evaporation (Winter 1989). The amount and timing of precipitation affects the duration and depth of water in prairie pothole wetlands on a seasonal or annual basis, and changes in snowfall, rainfall, soil moisture, frost, temperature and winds can cause dramatic fluctuations in surface water conditions and alter the number of ponded prairie wetlands at irregular intervals. There has been a strong tendency for many pothole wetlands to become dry late in the growing season. Smith *et al.* (1964) estimated that in any given year as many as one third of the prairie pothole wetlands will dry up between May and July. Cowardin *et al.* (1988) assumed that only 26 percent of the temporarily flooded wetland basins, 51 percent of the seasonal and 72 percent of the semi-permanent basins may hold water in an average year.

This cyclical pattern of flooding and drying greatly influences wetland ecology in the PPR as it is possible for an intact wetland basin to exhibit different hydrologic traits along a continuum depending on precipitation from year to year or even season to season. For example, during extended wet periods, some wetland basins classified as temporarily flooded can take on the characteristics of seasonally flooded (hierarchically wetter) wetlands. The opposite may apply in dry years as semi-permanently flooded wetlands may be the only basins with surface water and resemble seasonal or even temporarily flooded wetlands in both appearance and function (Johnson *et al.* 2008). These dynamics, compounded by anthropogenic alterations (i.e. drainage or redirection of water) and potential long-term climatic changes, complicate efforts to categorize wetlands in the PPR by type.

Variations in the hydrology of prairie wetlands also make their biological characterization challenging (Euliss and Mushell 2011) as plant community composition and extent change to reflect current water conditions.

Nationally, waterfowl are the most economically important wildlife using prairie pothole wetlands (Figure 3). At least 15 duck species nest in the prairie region (Niering 1985) and an estimated 70 to 80 percent of the production of Mallard (*Anas platyrhynchos*), Northern Pintail (*A. acuta*), Canvasback (*Aythya valisineria*) and Redhead (*A. americana*) are concentrated in the PPR of North America (Smith *et al.* 1964; Munro 1967). Wetlands are the cornerstone that support these species as well as other populations of North American waterbirds including Franklin's Gull (*Leucophaeus pipixcan*), Western Grebe (*Aechmophorus occidentalis*), American Bittern (*Botaurus lentiginosus*), Sora (*Porzana carolina*), Black Tern (*Chlidonias niger*), American White Pelican (*Pelecanus erythrorhynchos*) and Sandhill Crane (*Grus canadensis*) (Figure 4).

Prairie pothole wetlands are also extremely important to other forms of wildlife. There are over 300 animal species known to use wetlands in the PPR (Peterson *et al.* 1985; Fritzell 1989; USGAO 2007; Herman and Johnson 2008). Many game species such as Ring-necked Pheasants (*Phasianus colchicus*) and White-tailed Deer (*Odocoilius virginianus*) use pothole wetlands extensively for habitat cover (Figure 5). Additionally, various state and federally endangered species such as the Whooping Crane (*Grus americana*), Piping Plover (*Charadrius melodus*) and Interior Least Tern (*Sterna antillarum*) use these wetlands as habitat or for forage. Shorebirds such as Long-billed Dowitchers (*Limnodromus scolopaceus*), Stilt Sandpipers (*Calidris himantopus*) and Wilson Phalaropes (*Phalaropus tricolor*) utilize prairie wetlands as staging or stopover sites and seek out wet mud flats and shallow water areas during migration (Skagen and Knopf 1994; Skagen and Thompson 2013).

This report provides a comprehensive, scientifically sound assessment on the status of these wetland resources that has not been summarized for this region as a whole.

***Figure 3.*** *(Right, top). The Prairie Pothole Region is renowned for waterfowl production. Mallards, pictured here, are a common species that use prairie pothole wetlands.*

***Figure 4.*** *(Right, bottom). Wetlands in the Prairie Pothole Region support many species of wildlife including the Sandhill Crane, Logan County, ND.*

***Figure 5.*** *(Right, center). The Ringed-neck Pheasant has become a popular bird for hunters and wildlife enthusiasts. The availability of cover during winter months is important for the health and survival rate of pheasants in the upper Midwest. In agricultural landscapes, pockets of wetland grasses and sedges provide vegetative cover and may be all that is available during the winter season.*



Historically, wetlands probably covered about 16 to 18 percent of the landscape in the tall-grass and mixed-grass prairie regions in the states of North Dakota, South Dakota, Minnesota and Iowa (Table 1). During the past century, prairie wetlands have been extensively drained and in some areas only isolated tracts of wetland habitat remain. Drainage for agriculture during the years preceding the 1980s was pervasive as tile and open-ditch drains eliminated large numbers of wetland basins and converted lands to crop production (Figure 6).

Since the mid-1980s and implementation of conservation provisions contained in successive Farm Bill legislations[4], wetland drainage attributed to agricultural practices has markedly declined nationally (Dahl 2000). Federal policies such as the "Swampbuster" provision reduced or eliminated incentives and other mechanisms that made the destruction of wetlands in the prairies technically and economically feasible (Dahl and Allord 1996). Other conservation programs such as the North American Wetland Conservation Act, Wetland Reserve Program, Conservation Reserve Program, land retirement programs and those programs that encourage wetland restoration or creation and promote grassland reestablishment have also contributed to wetland conservation efforts.

Regionalized studies of wetland status that summarize wetland inventory data or report on more recent changes have been conducted (Johnson *et al.* 1997; Oslund *et al.* 2010; Johnston 2013), but comprehensive wetland trends for the Prairie Pothole Region as a whole have been lacking.

[4]Food Security Act of 1985; Food and Agriculture Trade Act of 1990; Agriculture Improvement and Reform Act of 1996; Food, Conservation and Energy Act of 2008.

**Table 1. Historic extent and trends of wetlands in the Prairie Pothole Region of the United States. Estimates from circa 1850 to the mid-1980s.**

| State | Estimated Wetland Area (acres) Circa 1850 | Estimated Wetland Area (acres) Circa 1980s | Change (percent) | References |
|---|---|---|---|---|
| North Dakota | 4.9 million | 2.5 million | -49% | Natural Resources Conservation Service, wet soils of North Dakota (drained and undrained[1]) unpublished; Dahl 1990 |
| South Dakota | 2.7 million | 2.1 million | -32% | Natural Resources Conservation Service, Huron, SD, unpublished data); Johnson *et al.* 1997 |
| Minnesota | 7 million | 1.4 million | -80% | Redelfs 1980 |
| Iowa | 3.4 million | 30,000–35,000 | -90% | Bishop *et al.* 1998; Bishop 2006; Miller *et al.* 2009 |
| Montana | Estimates not available | — | — | — |
| Prairie Pothole Region | 16.6–17 million | 6 million | -60 to 65% | — |

*[1]Cowardin et al. (1979) utilized the term "undrained hydric soils" to differentiate soils that had not been effectively drained and still maintained wetland hydrology.*

***Figure 6.*** *(Top and bottom). Historic wetland drainage in the Prairie Pothole Region of Iowa and Minnesota, circa 1950.*

# Procedures

## *Study Area and Sampling Design*

Various researchers (Kantrud and Stewart 1977; van der Valk 1989; Omernik 1995; Prairie Pothole Joint Venture 2003; Beyersbergen *et al.* 2004; Gleason *et al.* 2008) have provided slightly different iterations of the geographical boundary of the PPR in the United States. This study used a boundary for the PPR as defined by Bird Conservation Region 11[5] (North American Bird Conservation Initiative 1999). This physiographic area approximated the extent of the PPR in the United States and, as part of this study, was truncated at the South Dakota border and Missouri River in Montana (Figure 7). The area included a portion of the Lake Agassiz Plain Ecoregion in northwestern Minnesota that is a distinct ecotone consisting of aspen parkland and usually considered to be transitional between prairie and boreal forest (Stewart and Kantrud 1971). It has also been expanded to include portions of Montana north of theMissouri River, an area that usually has not been associated with the glaciated "pothole" region of the tall and mixed grass prairie. This study area was intersected with the state boundaries to divide the region into five state sub-regions for reporting purposes.

The sample-based surveys and monitoring methods used in this study have been an effective means to gather information regarding wetland resource types (Johnson *et al.* 1999). Olsen *et al.* (1999) have described the conceptual relationships among the key elements in a probabilistic sampling survey design, and the USFWS has used a scientific probability sample of the surface area of the conterminous United States to produce wetland status and change estimates for wetland monitoring studies that document spatial changes on the landscape (Dahl 2011). These studies have used specialized knowledge of wetland habitats, classification and ecological change processes and have been conducted specifically to monitor the nation's wetland area using a single, consistent definition and study protocol.

This study builds on those scientific foundations for measuring wetland area extent (status) and change rates (trends) in the PPR of the United States. The study determined wetland type, areal extent and change using a statistically stratified, simple random sampling design. The foundations and scientific principles underlying such surveys are well developed and have been applied to formulating national resource estimates as well as conducting regional assessments of wetland extent (Moulton *et al.* 1997; Dahl 1999; 2005; 2011; Dahl and Stedman 2013). These techniques have been used to monitor conversions between ecologically different wetland types, as well as to quantify wetland area gains and losses. Important enhancements specific to this study of the PPR included the addition of basin morphology, hydrologic descriptors and an upland grassland category to track changes in grassland area.

A total of 755 4 $mi^2$ plots (2,560 acres or 1,036 ha) were sampled in this study[6]. To ensure spatial balance and improve precision of estimates, plots from the National Wetlands Status and Trends study (242) were augmented with randomly selected sample plots (106) from the operational breeding waterfowl population and habitat survey[7], and supplemental plots (407) were randomly selected specific to this study to intensify the sample. The entire study area included 96,596,863 acres (39,108,041 ha). The distribution of sample plots by state is shown in Table 2.

Documentation of wetland change relied primarily on observable physical or spectral characteristics evident on high resolution imagery, in conjunction with collateral data, to make decisions regarding wetland extent and classification.[8] Wetlands were identified based on vegetation, visible hydrology and physical geography. Delineations on the sample plots reflected ecological change or changes in land use that influenced the size, distribution or classification of wetland habitats. The heterogeneity of cover types (delineation of cover type within a basin) was retained in the data allowing for aggregation of that information for analysis. Specific procedures used for image interpretation of wetlands followed protocols used for national level wetlands status and trends studies and have been described by Dahl and Bergeson (2009). However, for this study the minimum target size for wetlands included was reduced to 0.2 acres (0.08 ha)[9]. Actual results indicated

[5]Bird Conservation Region 11 is one of 37 physiographic regions defined by the North American Bird Conservation Initiative as a geographic unit for planning and implementation of bird conservation efforts.

[6]Plots split by the study area or by state boundaries were less than 2,560 acres.

[7]A 4 $mi^2$ plot sampling design to assess landscape changes in habitat on waterfowl populations for the USFWS–National Wildlife Refuge System (Loesch *et al.* 2012).

[8]Analysis of imagery was supplemented with field work and ground observations.

[9]Smaller wetlands were detected and included in the study, but it cannot be determined that all wetlands less than 0.2 acres were detected.

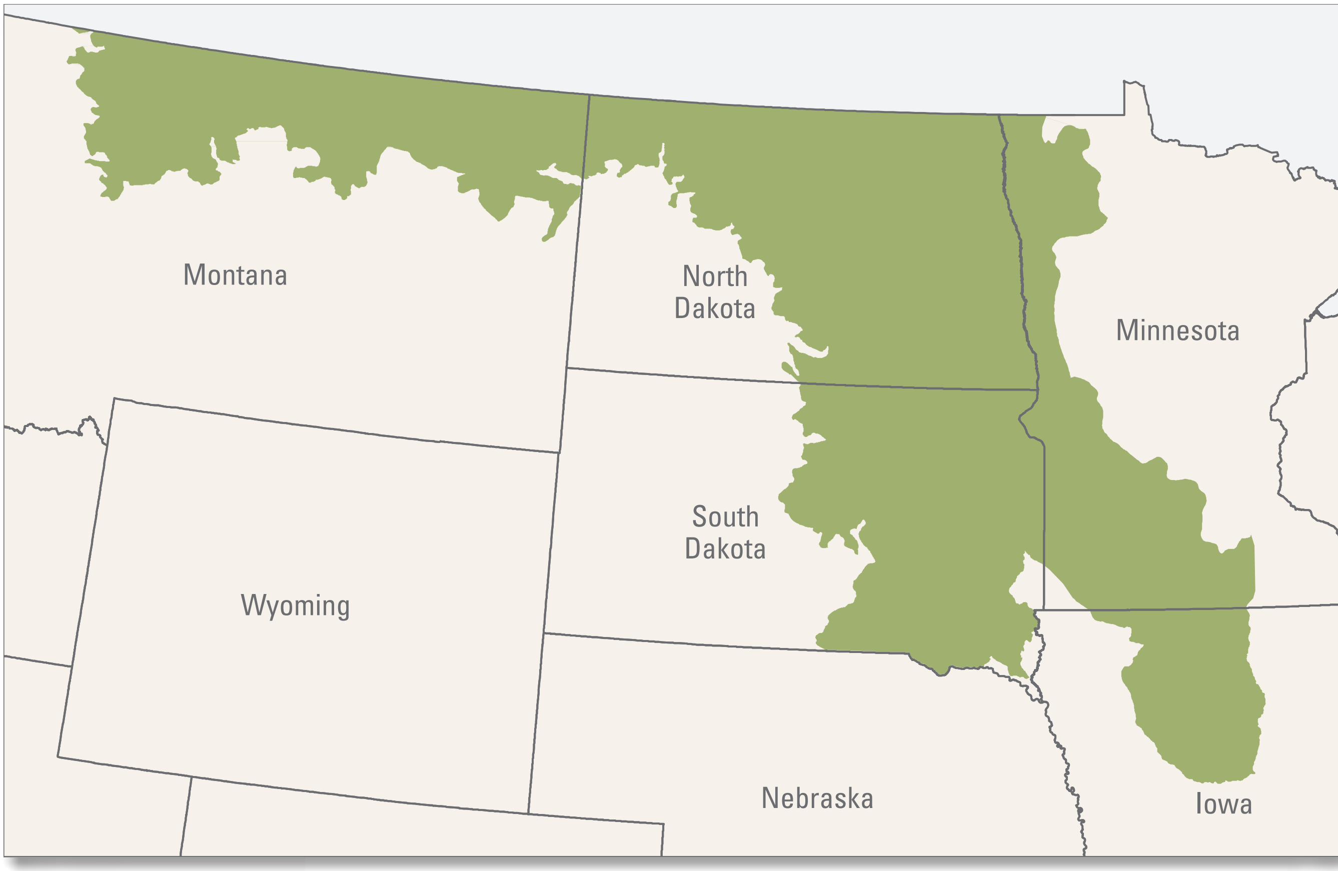



*Figure 7.* *The U.S. Prairie Pothole Region boundary as used in this study. The area shown in green includes 96.6 million acres (39.1 million ha) in portions of five states.*

that for each wetland category included in the study, the minimum size represented was less than 0.2 acres (0.08 ha).

Wetland, deepwater, and upland habitat changes were determined by intensive analysis of the high resolution aerial imagery, determination of wetland types and identification of the changes that occurred between the respective target dates. The mean dates of the aerial imagery used to determine wetland trends were 1997 and 2009, with the difference being an average of 12 years. Changes were recorded in areal extent or type of wetland observed on the sample plots between 1997 and 2009.

Ground verification of features on the aerial imagery was done for portions of 205 sample plots (27.2 percent) from 2010 to 2013. Verification involved site visits to a variety of wetland types and geographical settings. Field verification addressed questions regarding image interpretation, land use coding and attribution of wetland gains or losses. Field work was also performed as one of the quality control measures to verify that plot information was accurate.

To reflect reliability each statistical estimate generated is accompanied by a coefficient of variation expressed as a percentage. The wetland area estimates produced for this study included all wetlands regardless of land ownership. The results represent the latest wetland monitoring information specific to the PPR of the United States that included portions of Montana, North Dakota, South Dakota, Minnesota and Iowa.

**Table 2. Area of the U.S. Prairie Pothole Region with number of sample plots and area sampled as part of this study.**

| *State* | *Area (acres)* | *Number of Sample Plots* |
|---|---|---|
| Montana | 18,111,122 | 85 |
| North Dakota | 31,638,333 | 269 |
| South Dakota | 21,992,065 | 190 |
| Minnesota | 17,299,763 | 156 |
| Iowa | 7,555,580 | 55 |
| Total—Prairie Pothole Region | 96,596,863 | 755 |

## *Habitat Definitions*

During the mid-1970s USFWS began work on a biological definition of wetland and standardized nomenclature for the classification of wetland types. This system described by Cowardin *et al.* (1979), was adopted as a standard by USFWS and subsequently became a Federal Geographic Data Committee (FGDC) Standard for mapping, monitoring and reporting on wetlands (FGDC 1996). This institutionalization of a biological definition and classification system has facilitated its use in numerous federal applications and has provided consistency and continuity by defining the biological extent of wetlands and common descriptors for wetland types. It is a two-part definition as indicated below:

> ***Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water.***
>
> ***For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes, (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year.***

Cowardin *et al.* (1979) and other researchers (Gosselink and Turner 1978; Mitsch and Gosselink 1993) recognized that hydrology was universally regarded as the most basic feature of wetlands and that hydrology, not the presence of vegetation, determines the existence of wetland (Cowardin and Golet 1995). For this reason, in areas that lack vegetation or soils (e.g. sand or rock beaches bars, and shorelines) hydrology determines that these areas are wetlands. In practice, three indicators—hydrophytic vegetation, undrained hydric soil, and wetland hydrology; two indicators—hydrophytic vegetation and wetland hydrology or undrained hydric soil and wetland hydrology; or a single indicator—wetland hydrology, respectively, may be used to identify wetland based on the conditions at any particular site (FGDC 2013).

The majority of all depressional prairie wetlands are in the palustrine system as defined by Cowardin *et al.* (1979). Class-level descriptors indicated dominant vegetation or substrate types and water regime designations provide indicators of the duration of flooding or ponding of water in these areas.

Because prairie pothole wetlands are dominated by several principal wetland basin types (emergent marsh with various water regime indicators), these wetlands have been the primary focus of prairie wetland conservation and management efforts. Five types of emergent wetland basins were characterized using water regimes based on the Cowardin *et al.* (1979) classification system (Table 3). The assessment of these wetland types composes an essential part of this study. Table 4 provides a synopsis of all wetland types found in the prairies and as used in this study. Complete definitions of wetland types and upland categories used in this study are provided in the Appendix.

The use of water regimes to distinguish between wetland types in the prairies is based on a spatial dominance concept where an entire basin, spatially dominated by a particular hydrologic type, may be described as temporarily, seasonally, semi-permanently flooded, etc. However, distinct zones within a single basin may be described by using several different water regimes to indicate heterogeneity of habitat types and hydrologic gradients (Figure 8). While this delineation approach is often used to impart more information about wetland habitats, it confounds efforts to accurately and consistently characterize wetlands by a single basin type. Because of this limitation, basin number determined by a single descriptive hydrologic type has been an important metric used to assess wetland resources in the PPR, especially for waterfowl management purposes (Stewart and Kantrud 1971) and wetland restoration work (Galatwoistsch and van der Valk 1994). A number of researchers have used the deepest part of the wetland basin to describe the basin type by hydrology and go on to summarize basin numbers by that single basin type (Johnson and Higgins 1997; Johnson *et al.* 1999; Reynolds *et al.* 2006; Niemuth *et al.* 2010).

For this study a geoprocessing model was developed to classify wetland basins by hydrologic characteristics (water regime) by considering both the areal extent of the expected duration of surface water persistence as well as the spatial dominance of the basin zones represented by different hydrologic conditions. A "basin" for the purposes of this study is defined as a wetland on the landscape that may contain different but contiguous hydrologic zones.

**Table 3. Emergent wetland types used to describe herbaceous prairie wetland basins in this study.**

| Common Descriptors | Hydrologic Regime | Habitat Description |
|---|---|---|
| **Farmed wetland** | Temporarily flooded | Farmed wetlands are wetlands that have been tilled for agriculture but are not actively drained and will retain their wetland characteristics if farming is discontinued. Under drier conditions these wetlands may be tilled and planted for crop production, but in wetter years they return as shallow emergent marshes. |
| **Temporarily flooded emergent marsh; temporary ponds; low wet prairie** | Temporarily flooded | Temporarily flooded emergent wetlands typically outnumbered all other wetlands in the PPR. They occur in shallow depressions that fill with rain or snow-melt early in the spring and retain water for short periods (2–4 weeks) during the growing season. Although variable in numbers, depending on rainfall conditions, these wetlands are extremely important to waterfowl. There is generally little vegetation that remains to identify temporary wetlands if they are planted to cropland. |
| **Saturated emergent wetland; wet meadow; prairie fen** | Saturated | Saturated wetlands are dominated by grasses and sedges that may be grazed or left fallow. Saturated emergent wetlands are characterized by poorly drained soils where the water table is at or very near the land surface. They are isolated pockets of low prairie, prairie fens or streamside swales and are most common in portions of Minnesota where a transition to aspen parklands begins at the PPR periphery. |
| **Seasonally flooded emergent marsh; shallow marsh; seasonal ponds** | Seasonally flooded | Seasonally flooded emergent wetlands are commonly referred to as shallow marshes. The soils are normally waterlogged during the growing season and surface water will persist for extended periods (30–90 days). Seasonal wetlands will usually lack appreciable standing water during the late summer months (July and August). These wetlands are subject to cropping and are often tilled later in the growing season. During dry years standing water may be absent. |
| **Semi-permanently flooded emergent wetland; deep marsh; semi-permanent ponds** | Semi-permanently flooded | These emergent wetlands are typified by the persistence of surface water throughout the growing season in most years. During years of normal precipitation, water is deep enough to support a variety of wildlife species including waterfowl and Muskrats (*Ondatra zibethicus*). Semi-permanent marshes will lack standing water in drought years and may be cropped or hayed. |

**Table 4. Wetland, deepwater and upland classifications used in this study.**

| *Freshwater Habitats* | *Common Description* |
|---|---|
| Palustrine forested | Forested wetlands |
| Palustrine shrub | Shrub wetlands |
| Palustrine emergents | Marshes/sloughs/wet meadows |
| Palustrine unconsolidated bottom | Open water ponds |
| Palustrine farmed | Farmed wetlands |
| Lacustrine[1] | Lakes and reservoirs |
| Riverine[1] | River and stream channels |
| ***Upland Habitats*** | ***Common Description*** |
| Agriculture | Row-crop agriculture, farmsteads and supporting infrastructure |
| Urban | Cities and incorporated developments |
| Rural development | Non-urban developed areas and infrastructure |
| Other uplands | Undeveloped, rural uplands not in any other category (i.e. barren lands, gravel pits) |
| Grasslands | Native prairie, hay land, planted grasses, fallow fields, pasture, rangeland |
| ***Water Regimes Applicable to Wetland and Deepwater Habitats*** | ***Common Description*** |
| Temporarily flooded | Temporary ponds, low prairie wetland |
| Saturated | Wet meadows, prairie fens, aspen parkland wetland |
| Seasonally flooded | Seasonal ponds, shallow marsh |
| Semi-permanently flooded | Semi-permanent ponds, dugout ponds, deep marsh |
| Intermittently exposed | Alkali lakes, shallow lakes, deep marsh/open water |
| Permanently flooded | Open water lakes, perennial rivers |

[1]*Constitutes deepwater habitat.*

Ephemeral waters[10], which are not recognized as a wetland type, and certain types of "farmed wetlands" as defined by the Food Security Act[11] were not included in this study because they do not meet the Cowardin *et al.* (1979) definition.

[10]This refers to temporary surface water and should not be confused with ephemeral (temporary) wetlands.

[11]For purposes of administration of the Farm Bill legislation, some areas are identified as "prior converted" wetlands. These areas may or may not be wetland under the Cowardin *et al.* definition.

Wetlands and deepwater habitats are defined separately by Cowardin *et al.* (1979) because the term "wetland" does not include deep, permanent water bodies. Deepwater habitats are permanently flooded land lying below the deepwater boundary of wetlands. Deepwater habitats include environments where surface water is permanent and often deep, so that water, rather than air, is the principal medium in which the dominant organisms live, whether or not they are attached to the substrate. For the purposes of conducting status and trends work, all lacustrine (lake) and riverine (river) waters were considered deepwater habitats.

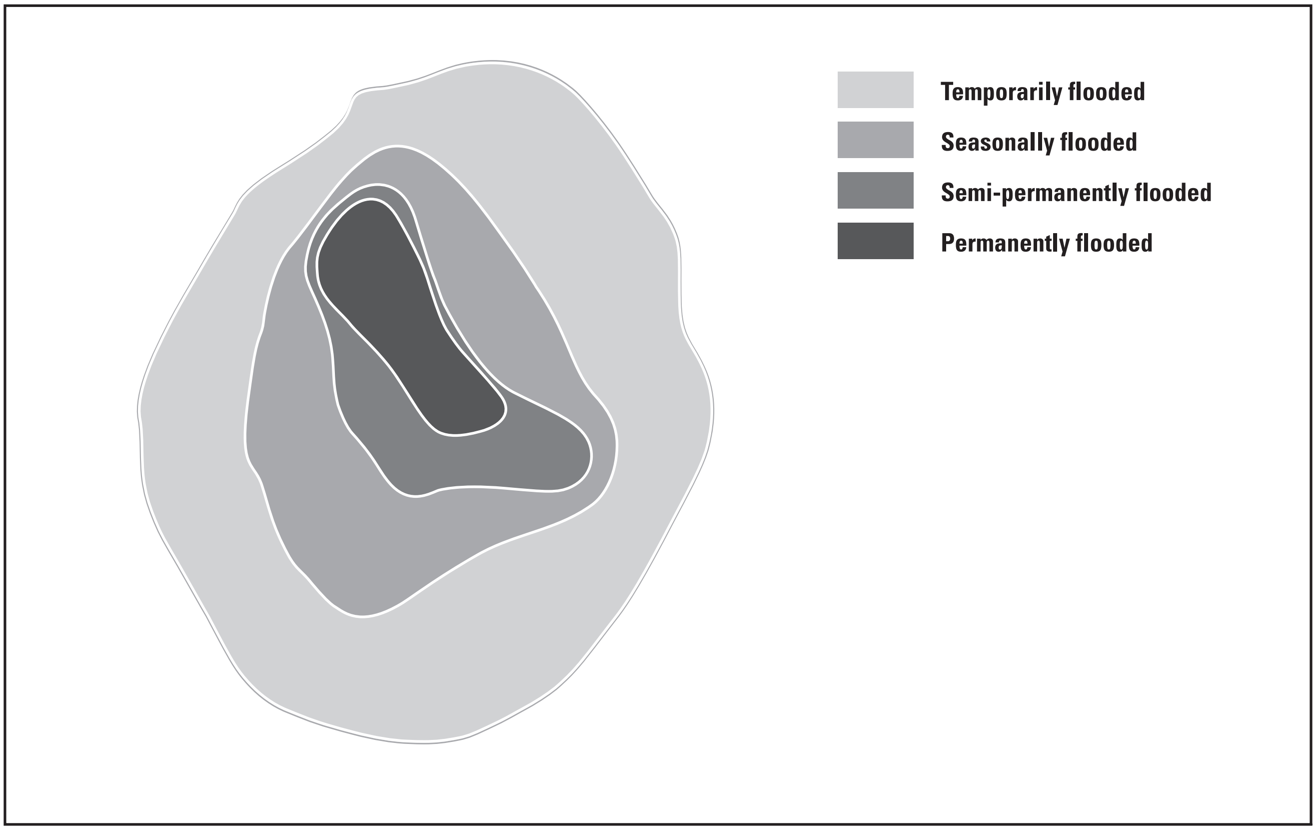



***Figure 8.*** *A single wetland basin in the Prairie Pothole Region may contain different zones reflecting hydrologic gradients depending on the persistence of surface water.*

Upland categories included lands not meeting the definition of either wetland or deepwater habitats. An abbreviated upland classification system patterned after the land classification scheme described by Anderson *et al.* (1976) was used to describe generalized upland land-use categories. For this study, an additional upland category of "grassland" was added. Different grass cover types are often difficult to distinguish using remotely sensed imagery (Wright and Wimberly 2013); consequently the grassland category included a broad range of grassland types including minimally managed or native grasslands, extensively managed hay land (i.e. alfalfa), pasture or rangeland, Conservation Reserve Program lands in perennial grass cover and fallow or retired cropland in grass. The definition of grassland as used in this study was similar to the description of grassland types used by the U.S. Department of Agriculture (Claassen *et al.* 2011).

## Study Limitations

The identification and delineation of wetland habitats through image analysis formed the foundation for deriving the wetland status and trends data results reported here. Because of the limitations of aerial imagery as the primary data source to detect some wetlands, certain wetland types were excluded from the study. These limitations included the inability to detect some small (fractional acre) wetland areas and to accurately detect or monitor submerged aquatic vegetation.

# Results

## *Status of Prairie Wetlands, 2009*

In 2009, there were an estimated 6,427,350 acres (2,602,166 ha) of wetland in the PPR of the United States (±4.3 percent). The population of wetlands in the PPR represents 5.8 percent of the total area of wetlands found in the conterminous United States in 2009. There were also an estimated 1,843,220 acres (746,240 ha) of deepwater lakes and rivers in the prairie region in 2009.

In 2009, wetland accounted for 6.7 percent of the total surface area of the U.S. PPR. This is slightly higher than the national average of 5.5 percent found in the conterminous United States. Emergent marshes comprised about 87 percent of the total wetland area and 93 percent of all wetland basins in the PPR. Wetlands classified with woody vegetation (wetland forest and shrubs collectively) composed 8.3 percent of the surface area and open water ponds 4 percent. Wetland area by vegetated type for the PPR is shown in Figure 9.

The estimated area for all wetland and deepwater habitats in the U.S. PPR is shown in Table 5.

The distribution of wetland area by state in the PPR is shown in Figure 10. By area, wetlands were most common in North Dakota, making up 9 percent of the surface area in the PPR of that state. South Dakota was similar with 8.5 percent of the land area in the prairie region having been wetland in 2009. Minnesota had 6.7 percent wetland by area, Iowa 2.7 percent, and wetlands were the least common in Montana with 1.9 percent of the land area classified as wetland in the prairie portions of the state.

The majority of forested and shrub wetlands (82.9 percent) were located in Minnesota as part of the transitional region from prairie to parkland/forest. Depressional wetland basins dominated by trees or shrubs (Figure 11) were scarce outside of this transition zone or as part of river or stream corridors.

An estimated 94 percent of wetland was within or adjacent to agricultural lands or grassland. Less than 1 percent was within or adjacent to urban or developed areas, and about 5 percent was within or adjacent to other types of uplands or river corridors.

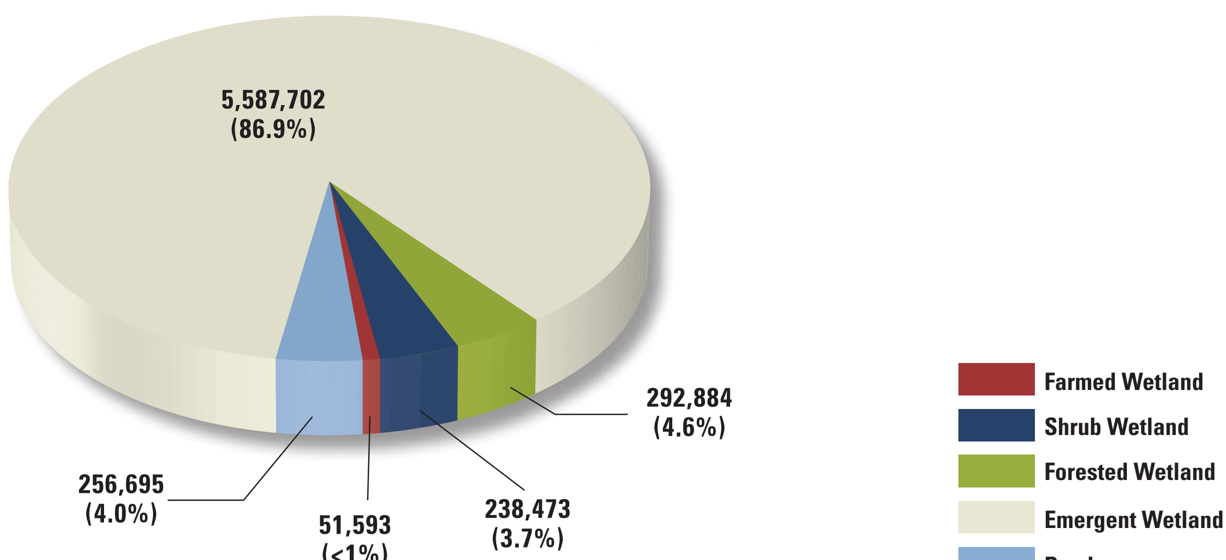



***Figure 9.*** *Estimated wetland area (acres) by type as found in this study in the U.S. Prairie Pothole Region, 2009.*

**Table 5. Estimated area and change for all wetland and deepwater habitat types in the U.S. Prairie Pothole Region, 1997 to 2009. (The Coefficient of Variation [CV] for each estimate is given in parentheses.)**

| Habitat Type | Area 1997 (acres) | Area 2009 (acres) | Change Area (acres) | Change as Percentage |
|---|---|---|---|---|
| Shrub wetland | 284,553 (31.4) | 238,473 (29.6) | -46,080 (93.4) | -16.2 |
| Emergent wetland[1] | 5,734,634 (3.7) | 5,639,295 (3.8) | -95,339 (44.4) | -1.7 |
| Forested wetland | 231,606 (19.2) | 292,884 (20.9) | 61,277 (65.8) | 26.5 |
| Open water wetlands | 250,895 (6.9) | 256,695 (6.4) | 5,800 (*) | 2.3 |
| All wetland | 6,501,688 (4.2) | 6,427,350 (4.3) | -74,340 (58.2) | -1.1 |
| Lakes | 1,656,989 (13.3) | 1,712,502 (12.9) | 55,513 (34.9) | 3.4 |
| Rivers | 128,362 (14.1) | 130,720 (14) | 2,359 (66.2) | 1.8 |
| All deepwater | 1,785,351 (12.3) | 1,843,222 (12) | 57,871 (33.6) | 3.2 |
| ***Total wetland and deepwater*** | ***8,287,039*** | ***8,270,572*** | ***-16,467*** | ***-0.2*** |

*[1]Includes emergent and farmed wetland categories.*

*[*]Statistically unreliable.*

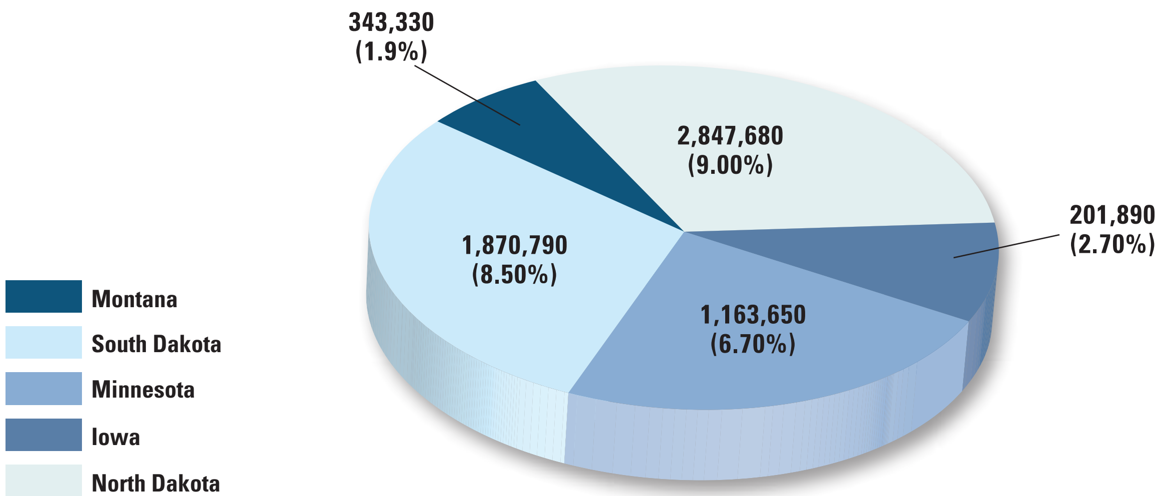



***Figure 10.*** *Estimated wetland area in the U.S. Prairie Pothole Region, 2009. (Percentage shown is the land area of the Prairie Pothole Region that is wetland in each state.)*

***Figure 11.*** *A depressional pothole basin with forest canopy in the Prairie Pothole Region of Minnesota. Pothole wetlands with woody vegetation (forest and shrubs) make up about 8 percent of the total area of wetland in the U.S. Prairie Pothole Region.*

There were an estimated 21.1 million acres of grassland in the PPR in 2009. This represented a 3:1 ratio of grassland to wetland region-wide.

Wetlands were not distributed evenly across the PPR. The current wetland distribution is influenced by topography, hydrology and past conversions of wetland to other land uses. The relative wetland density by area in the PPR is shown in Figure 12.

In determining wetland/water basin number and type, this study utilized a geospatial model to account for spatial dominance of basin area by water regime type[12]. For example, a 10 acre (4 ha) basin containing 9 acres (3.6 ha) of seasonally flooded wetland with a 1 acre (0.4 ha) semi-permanently flooded portion would have been classified as a semi-permanently flooded basin by the protocols used in previous studies (Johnson and Higgins 1997; Kahara *et al.* 2009), whereas this study recognized spatial dominance as a crucial factor in basin classification and categorized this type of wetland as a seasonally flooded basin.

Wetland density based on basin type was determined on a per unit basis and was calculated using the equation:

$$\textbf{Density} = \frac{\textbf{Total basin number}}{\textbf{Total landscape area}}$$

By using this method, wetlands and water bodies were distributed in 2,624,990 distinct basins throughout the PPR in 2009. An estimated 88 percent of these basins by count were geospatially isolated[13]. The

[12]Basin calculations excluded some wetlands within or connected to river or stream channels. Examples include gravel outwashes, sand bars and hydrologically connected oxbows.

[13]Geospatially isolated wetlands are those areas not having a direct connection to other water bodies or wetland complexes via channel or navigable water. Isolated wetlands were determined by a geospatial data model developed to identify wetlands not connected to or within a 100 ft. (30 m.) buffer distance of navigable waters (rivers, streams, wetland complexes or permanent lakes).

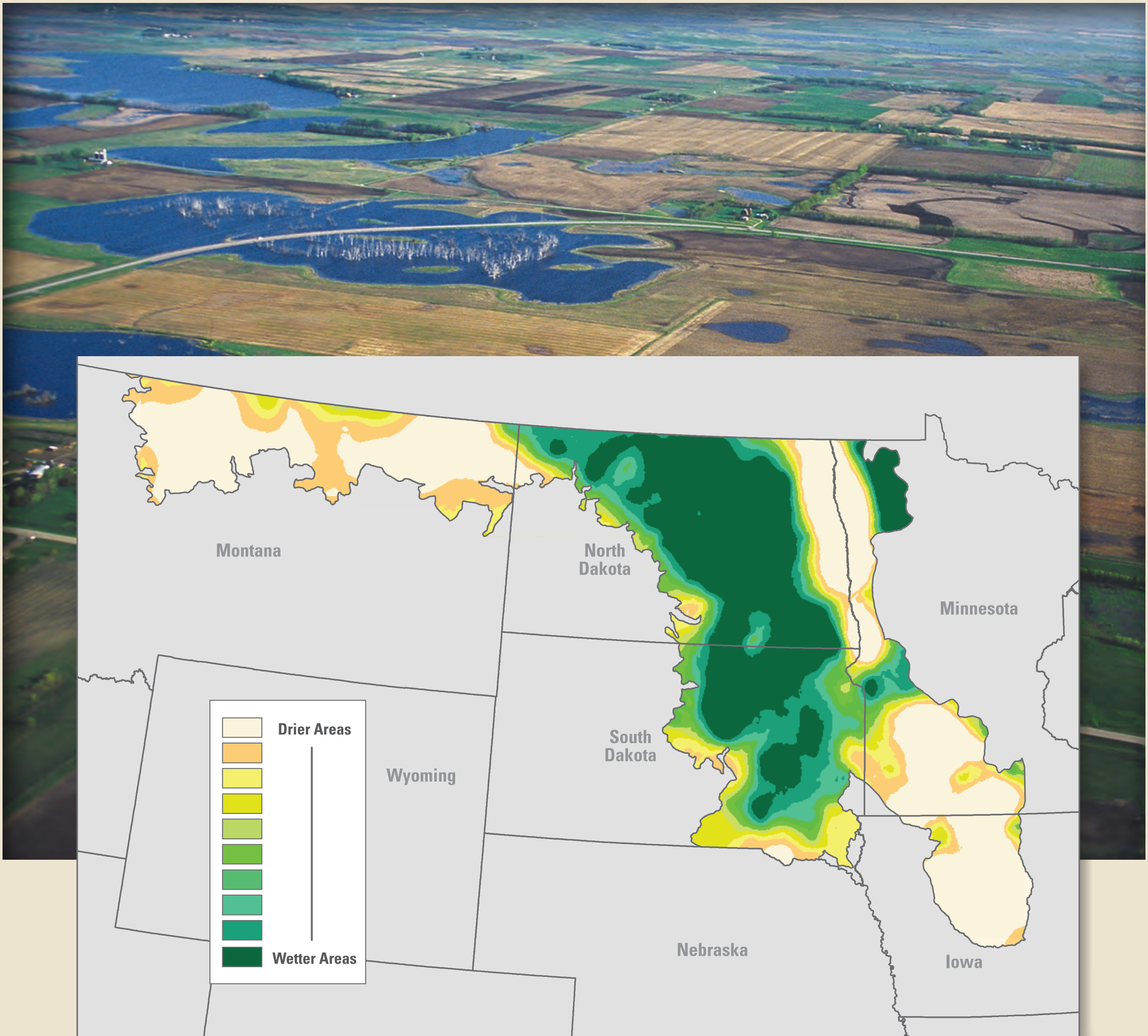



*Figure 12.* *Relative wetland density based on wetland area in the U.S. Prairie Pothole Region, 2009. Wetlands were not distributed evenly across the prairie region. (Drier regions may have no wetland whereas wetter areas may contain up to 100+ wetland basins per square mile.) Current density and distribution has been influenced by topography, hydrology and past conversions of wetland to other land uses.*

maximum density of wetland was 148 basins per $mi^2$ (57 basins/$km^2$) in portions of North Dakota. There was considerable variation in the density of wetlands across the landscape of the PPR. Wetland and water basins averaged from 30 per $mi^2$ (12 basins/$km^2$) in North Dakota to 4 and 5 basins per $mi^2$ (1–2 basins/$km^2$) in Iowa and Minnesota (Table 6). The mean number of wetland and water basins found in the PPR in 2009 was 17.4 basins per $mi^2$ (6.7 basins/$km^2$). The mean basin size by state ranged from 2.1 acres (0.9 ha) in Montana to 12.3 acres (5 ha) in Minnesota. The mean size wetland/water basin in the PPR was 3.2 acres (1.3 ha) in 2009.

Wetland/water basins[14] declined by over 107,177 or 4 percent between 1997 and 2009.

Because wetland basin types in the PPR are dominated by emergent marshes (emergent wetlands made up 93 percent of all wetland basins in the PPR in 2009), wetland resources have been described by using hydrologic characteristics (water regimes indicating flooding or ponding duration) to differentiate wetland type. The distribution of these emergent wetland types in 2009 is shown in Table 7.

[14]Basin numbers include wetland and lake (deepwater) basin types.

Temporarily flooded emergent wetlands were the most numerous type, composing almost half of all emergent wetland basins in the PPR. An estimated 41.7 percent of emergent basins were seasonally flooded, 6 percent were semi-permanently flooded and farmed wetlands made up an estimated 2.4 percent of all emergent wetland basins in 2009. There were very few (0.2 percent) saturated emergent wetland basins in the PPR.

By area, seasonally flooded emergent marshes had the greatest area with 2,313,660 acres (936,705 ha) followed by semi-permanently flooded marshes with 1,945,460 acres (787,637 ha) and temporarily flooded wetland with 1,187,700 acres (480,850 ha). Collectively, temporarily flooded and seasonally flooded emergent wetland basins made up 85 percent of the total number of wetland basins (all wetland types) in the PPR and 55 percent of the total wetland area.

The remaining other wetland/water body types that are not classified as emergent marshes include forested, shrub wetlands, open water ponds and lake basins. Pond numbers make up an estimated 4.6 percent of the basin numbers. Shrub and forested wetlands were each about 1 percent and lake basins were less than 0.5 percent by basin number. All of the basin types and estimates sampled in this study are shown in Figure 13.

**Table 6. Wetland and lake basin numbers, change, mean size and density for portions of the states in the U.S. Prairie Pothole Region, 1997 to 2009.**

| *State* | *Basin No. 1997* | *Basin No. 2009[1]* | *Change in Basin No. 1997–2009* | *Change (percent)* | *Mean Basin Size 2009 (acres)* | *Basin No. per Square Mile 2009* |
|---|---|---|---|---|---|---|
| **Montana** | 199,754 | 201,312 | 1,558 | 0.8% | 2.1 | 7 |
| **North Dakota** | 1,550,497 | 1,498,716 | -51,781 | -3.3% | 2.5 | 30 |
| **South Dakota** | 774,568 | 752,943 | -21,625 | -2.8% | 3.1 | 22 |
| **Minnesota** | 156,650 | 128,330 | -28,320 | -18.1% | 12.3 | 5 |
| **Iowa** | 50,699 | 43,689 | -7,010 | -13.8% | 5.8 | 4 |
| **U.S. Prairie Pothole Region** | 2,732,167 | 2,624,990 | -110,718 | -4% | 3.2 | 17.4 |

*[1]Includes all wetland lake basins not directly associated with river channels.*

**Table 7. Estimates of emergent wetland areal extent and basin number by type for the U.S. Prairie Pothole Region, 2009. (The Coefficient of Variation [CV] for the area estimate is given in parentheses.)**

| *Emergent Wetland Type* | *Area in 2009 (acres)* | *Area of Emergents (percent)* | *Number of Basins* | *Mean Size (acres)* | *Basin Type (percent)* | *Change in Basin No. 1997 to 2009* |
|---|---|---|---|---|---|---|
| Emergent-Temporary | 1,187,700 (6.2) | 21.1% | 1,213,970 | 0.98 | 49.7% | -102,574 |
| Emergent-Seasonal | 2,313,660 (4.2) | 41% | 1,019,940 | 2.26 | 41.7% | -16,010 |
| Emergent-Semi-permanent | 1,945,460 7.1) | 34.5% | 147,040 | 13.23 | 6% | 8,920 |
| Farmed Wetland | 51,590 (11.4) | 0.9% | 57,830 | 0.89 | 2.4% | -9,072 |
| Emergent-Saturated | 140,880[1] (42.2) | 2.5% | 6,010 | 23.45 | 0.2% | -1,212 |
| All Emergent Wetland Types | 5,639,295 | 100% | 2,444,790 | 2.31 | 100% | -119,948 |

[1]*Eighty eight percent of saturated emergent wetland area was in located in Minnesota. Many saturated wetland areas may not conform to "pot-hole" basin configuration but can occur as swales, meanders or fens.*

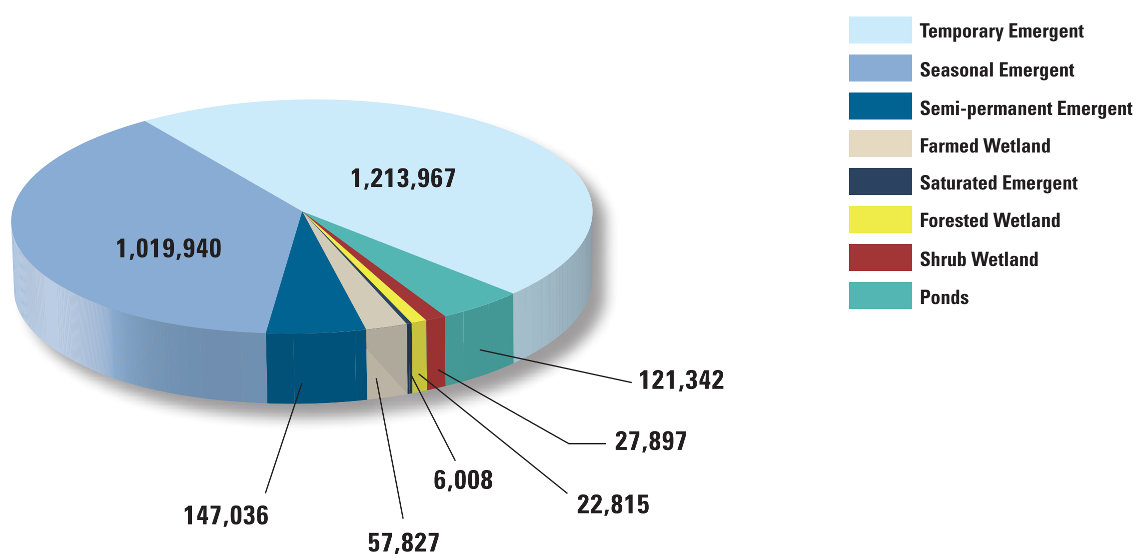



***Figure 13.*** *Wetland basin numbers for all wetland classification types in the U.S. Prairie Pothole Region, 2009.*

Wetland basin distribution by type within the PPR states is shown in Table 8. The basin number for each wetland/water body type for states in the PPR indicates that North Dakota had the highest number of temporary emergent basins. Minnesota had the highest number of saturated emergent, shrub and forested wetland basins.

**Table 8. Wetland basin number by wetland type for each of the states in the U.S. Prairie Pothole Region, 2009.**

| State | Farmed Wetland | Temporary Emergent | Saturated Emergent | Seasonal Emergent | Semi-Permanent Emergent | Ponds | Shrub Wetland | Forested Wetland | Lakes |
|---|---|---|---|---|---|---|---|---|---|
| Montana | 0 | 96,729 | 2,105 | 66,872 | 6,569 | 25,667 | 2,358 | 420 | 590 |
| North Dakota | 29,991 | 677,163 | 906 | 661,099 | 80,053 | 34,776 | 8,445 | 3,160 | 3,125 |
| South Dakota | 11,591 | 398,386 | 295 | 250,220 | 43,101 | 40,465 | 2,069 | 4,750 | 2,068 |
| Minnesota | 12,671 | 26,875 | 2,701 | 31,632 | 12,971 | 13,227 | 14,827 | 11,448 | 1,978 |
| Iowa | 3,576 | 14,813 | 0 | 10,117 | 4,342 | 7,208 | 199 | 3,037 | 397 |

## Trends in Wetlands 1997 to 2009

Between 1997 and 2009, total wetland area in the PPR declined by an estimated 74,340 acres (30,100 ha) or 1.1 percent. This was an average annual net loss of 6,200 acres (2,510 ha). However, emergent wetlands (emergent marshes and farmed wetlands) declined by an estimated 95,340 acres (36,250 ha) or 7,950 acres (3,020 ha) per year. Shrub wetlands also declined by 46,080 acres (18,660 ha). Forested wetlands increased in area (61,280 acres or 24,810 ha), ameliorating some of the losses of emergent marsh and shrub wetland area. Open water ponds also increased in area by 5,800 acres (2,350 ha) over this 12 year period. Table 9 summarizes the changes in wetlands and deepwater habitats between 1997 and 2009.

Emergent wetlands (including farmed wetlands) declined by an estimated 1.7 percent between 1997 and 2009. The largest percentage of the changes in area to emergent wetland was attributed to an increase in deepwater habitat. An estimated 40 percent (40,550 acres or 16,420 ha) of emergent wetland area was lost or converted to deepwater lake systems or open water ponds (Figure 14). An additional 39,050 acres (15,810 ha) were lost to upland land uses (agriculture and development). All of the net wetland losses to agriculture were farmed wetlands or temporarily flooded wetlands.

**Table 9. Change in wetland, deepwater habitats and grassland area in the U.S. Prairie Pothole Region, 1997 to 2009. (The Coefficient of Variation [CV] for each estimate is given in parentheses.)**

| Habitat Type | Area in 1997 (acres) | Area in 2009 (acres) | Change in Area 1997–2009 (acres) | Change 1997–2009 (percent) | Area of All PPR Wetland 2009 (percent) |
|---|---|---|---|---|---|
| Farmed wetland | 96,900 (15.7) | 51,590 (11.4) | -45,310 (30.1) | -46.8% | 0.8% |
| Emergent—temporary | 1,275,175 (5.9) | 1,187,700 (6.2) | -87,480 (15.3) | -6.9% | 18.5% |
| Emergent—saturated | 156,700 (40.6) | 140,880 (42.2) | -15,820 (45.5) | -10.1% | 2.2% |
| Emergent—seasonal | 2,304,090 (3.9) | 2,313,660 (4.2) | 9,570 (*) | 0.4% | 36% |
| Emergent—semi-permanent | 1,901,770 (7.2) | 1,945,460 (7.1) | 43,700 (63) | 2.3% | 30.3% |
| **All emergent wetland** | **5,734,634 (3.7)** | **5,638,695 (3.8)** | **-95,339 (44.4)** | **-1.7%** | **87.7%** |
| **Open water ponds** | **250,895 (6.9)** | **256,695 (6.4)** | **5,800 (*)** | **2.3%** | **4%** |
| Shrub—temporary | 20,590 (23) | 23,760 (21.9) | 3,160 (52.7) | 15.4% | 0.4% |
| Shrub—saturated | 161,180 (40.6) | 115.480 (38.4) | -45,700 (92.9) | -28.4% | 1.8% |
| Shrub—seasonal | 102,780 (59.6) | 99,240 (54.6) | -3,540 (*) | -3.5% | 1.5% |
| **All shrub wetland** | **284,550 (31.4)** | **238,470 (29.6)** | **-46,080 (93.4)** | **-16.2%** | **3.7%** |
| Forested—temporary | 95,290 (19) | 97,570 (18.3) | 2,280 (*) | 2.4% | 1.5% |
| Forested—saturated | 77,900 (43.7) | 130,970 (41) | 53,080 (74.7) | 68.1% | 2% |
| Forested—seasonal | 58,420 (23.1) | 64,340 (28.3) | 5,920 (*) | 10.1% | 1% |
| **All forested wetland** | **231,610 (19.2)** | **292,880 (20.9)** | **61,280 (65.8)** | **26.5%** | **4.5%** |
| **All wetland types** | **6,501,688 (4.2)** | **6,427,350 (4.3)** | **-74,340 (58.2)** | **-1.1%** | **100%** |
| Lakes | 1,656,990 (13.3) | 1,712,500 (12.9) | 55,510 (34.9) | 3.4% | — |
| Rivers | 128,362 (14) | 130,720 (14.1) | 2,360 (66.2) | 1.8% | — |
| Upland grassland | 21,689,400 (4.1) | 21,121,360 (4.2) | -568,040 (27.2) | -2.6% | — |

*Statistically unreliable.

The mean size of wetland lost between 1997 and 2009 as measured by this study was 0.85 acre (0.3 ha). An estimated 49 percent of the wetlands lost between 1997 and 2009 were geospatially isolated wetlands[15].

Minnesota sustained the largest loss of emergent wetland area between 1997 and 2009. South Dakota was the only state to exhibit gains in emergent wetland area (Figure 15).

The number of wetland and open water basins (including lake basins) in the PPR declined between 1997 and 2009 by 107,177 or 4 percent. This was an average annual loss of 8,931 basins.

[15]Geospatially isolated wetlands are those areas not having a direct connection to other water bodies via channel or navigable water. Isolated wetlands were determined by a geospatial data model developed to identify wetlands not connected to or within a 100 ft. (30 m.) buffer distance of navigable waters (rivers, streams or permanent lakes).

Ninety-six percent of the basins lost were temporarily flooded emergent wetlands as temporary basin numbers declined by 7.8 percent. Semi-permanent wetlands increased by 8,920 basins or 6.5 percent.

Overall, wetland basins declined in every state in the PPR with the exception of Montana, which experienced a gain in wetland basins of <1 percent. While North Dakota lost the largest number of wetland basins (51,780), Minnesota sustained the largest percentage loss of remaining wetland basins, declining by over 18 percent. Iowa lost 14 percent of the remaining basin numbers, and both North and South Dakota each lost about 3 percent. Changes in basin number by state are shown in Figure 16.

All states except South Dakota experienced net losses in emergent wetland area. South Dakota had a net gain of an estimated 19,170 acres (7,760 ha). Emergent wetland changes are shown for each state in Figure 17 A–E.

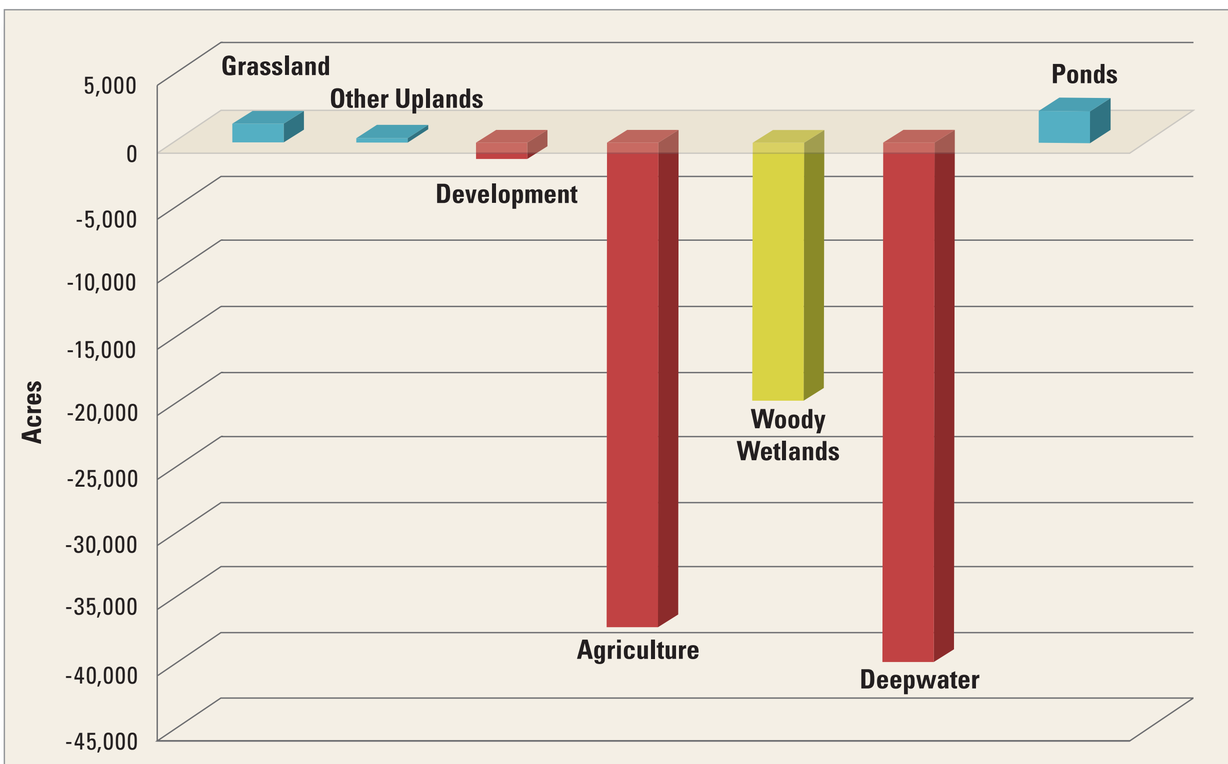



*Figure 14.* *Attribution of gains (blue), losses (red) and conversions (yellow) of emergent wetlands in the U.S. Prairie Pothole Region to other upland land-use, wetland or deepwater types, 1997 to 2009.*

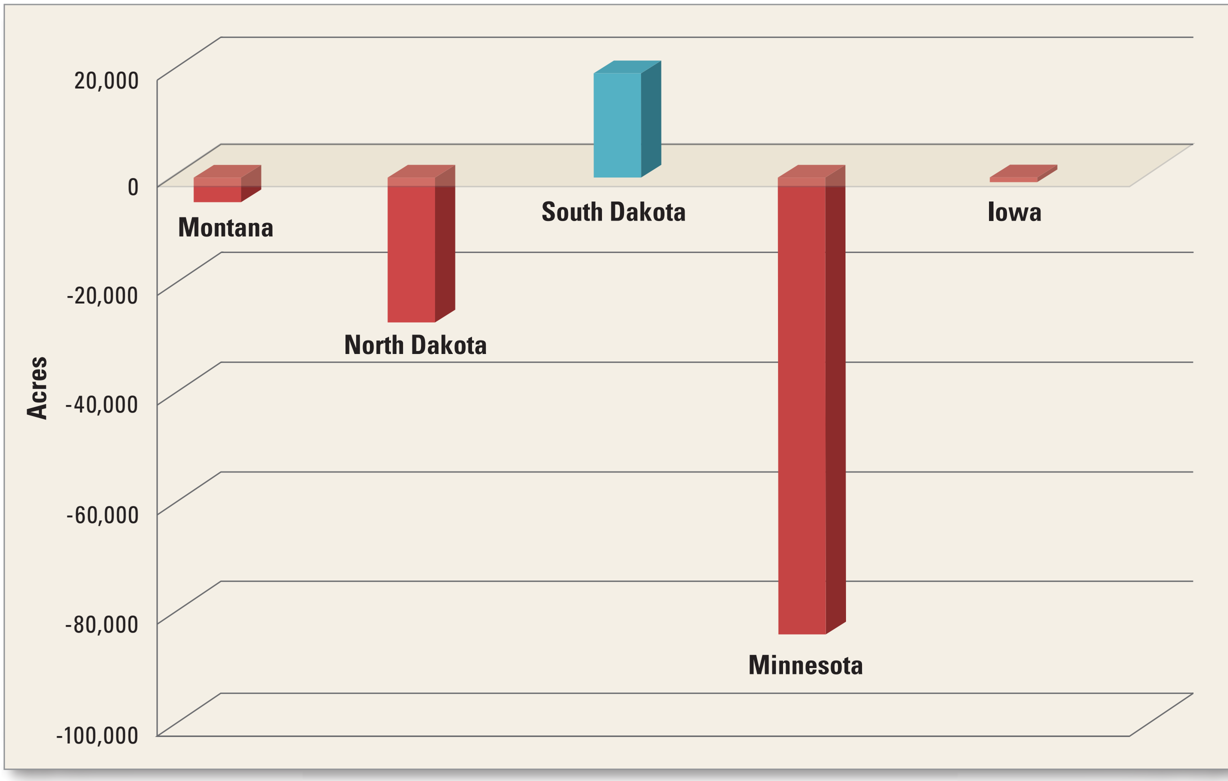



***Figure 15.*** *Emergent wetland gains (blue) and losses (red) in the U.S. Prairie Pothole Region, 1997 to 2009.*

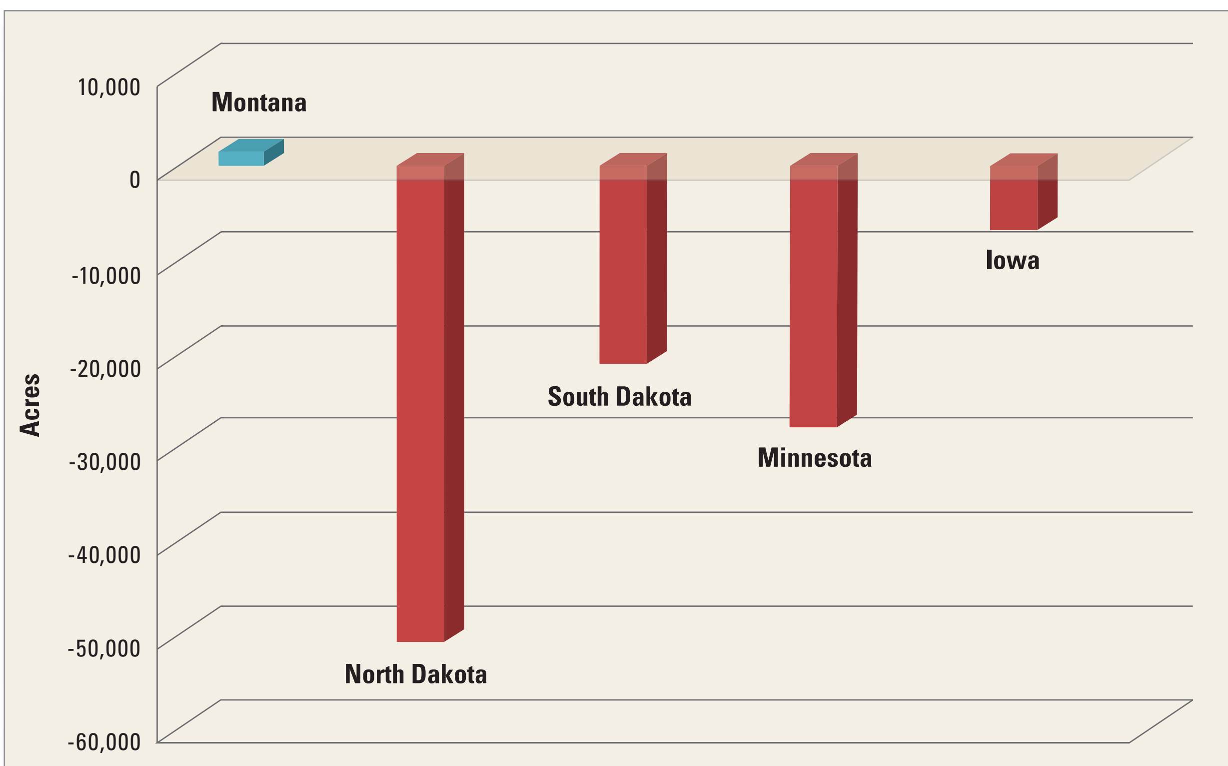
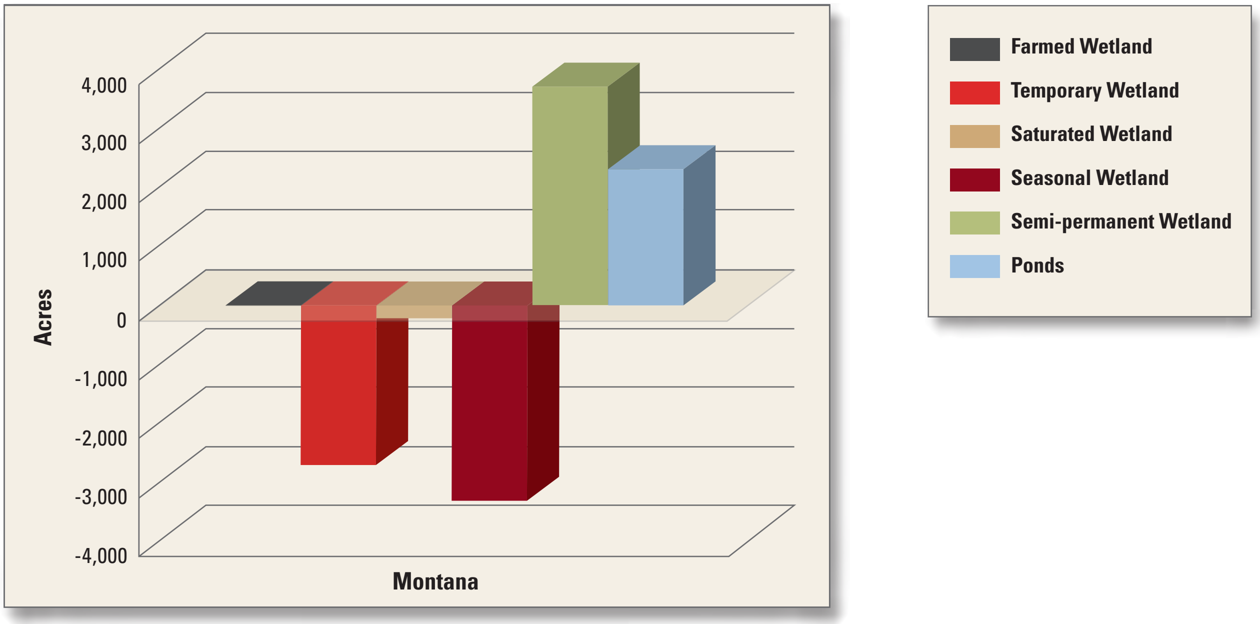


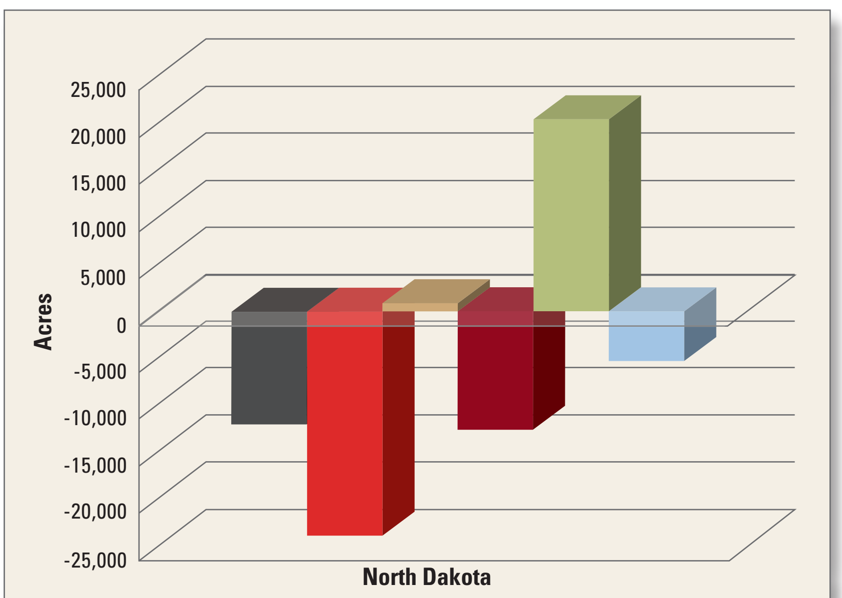

***Figure 16.*** *Wetland basin gains (blue) and losses (red) for each state in the U.S. Prairie Pothole Region, 1997 to 2009.*

***Figure 17 A–E.*** *Loss or conversion in area of emergent wetland hydrologic types and ponds in each of the states in the U.S. Prairie Pothole Region, 1997 to 2009.*

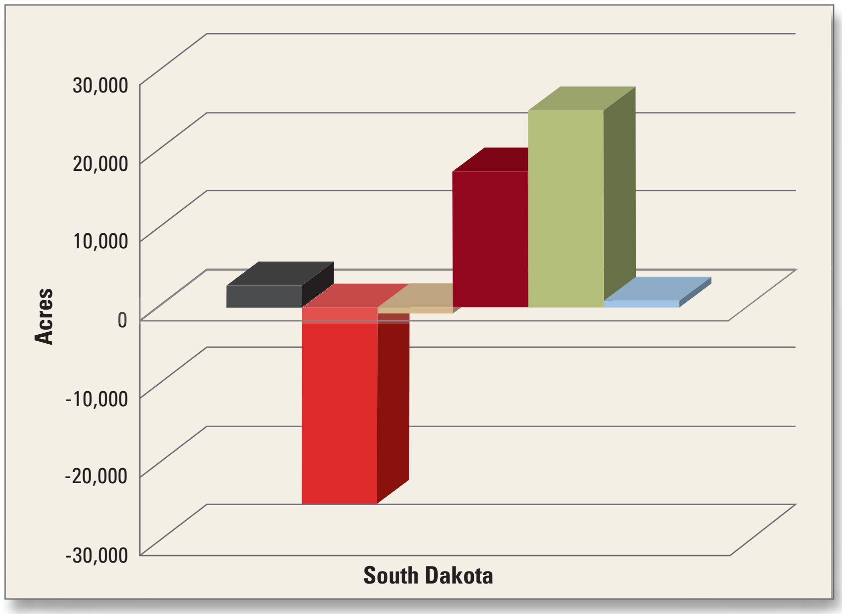
***A***



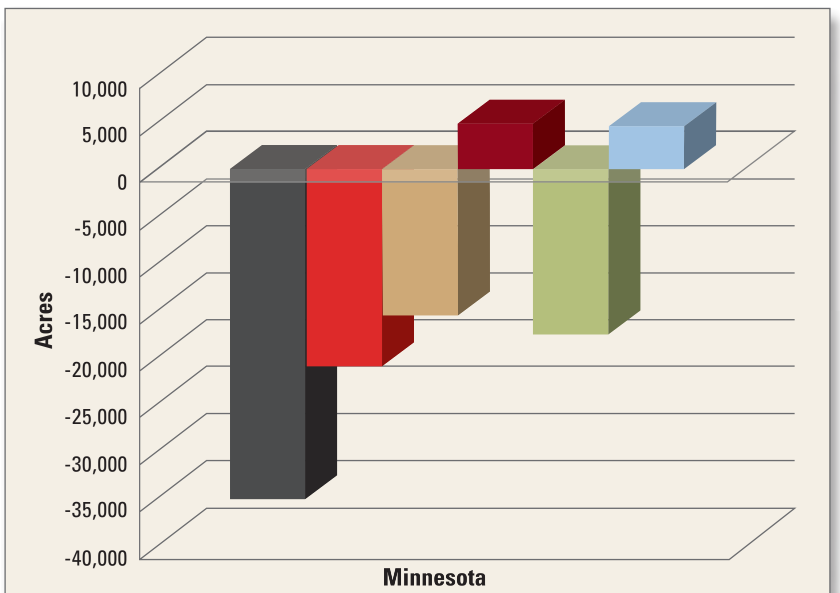

***B***



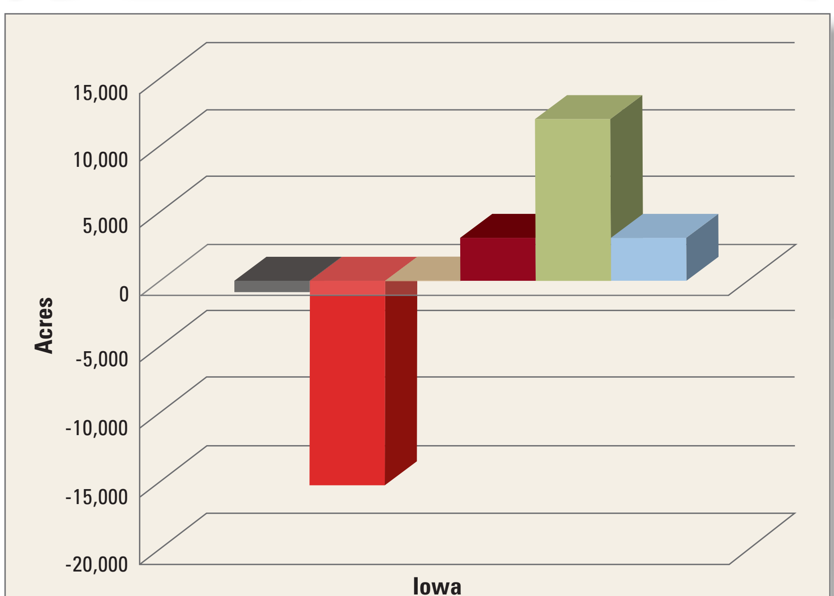
*C*


30,000
20,000
10,000
0
-10,000
-20,000
-30,000
Acres
South Dakota

*D*


10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
-25,000
-30,000
-35,000
-40,000
Acres
Minnesota

*E*


15,000
10,000
5,000
0
-5,000
-10,000
-15,000
-20,000
Acres
Iowa

## *Changes in Grassland Area, 1997 to 2009*

Grassland occupied approximately 21,121,360 acres (8,551,158 ha) in the PPR in 2009 (±4.2 percent). Between 1997 and 2009, grassland declined overall by an estimated 568,040 acres (229,980 ha) or 2.6 percent. Ninety-five percent of the area lost from grassland was reclassified as agriculture. Another 4.8 percent of grassland was lost to development and a fractional percentage went to open water ponds and lakes. There was a small gain in upland grassland area from "other" uplands most likely, from planted grasses on managed conservation lands.

Grassland area declined by 805,000 acres (325,910 ha) in the western prairie states of Montana, North Dakota and South Dakota. Minnesota and Iowa gained grassland area (236,960 acres or 95,935 ha) over the period of this study (Figure 18).

This study estimated that region-wide the grassland to wetland ratio was 3:1 in 2009. An estimated 32 percent of all remaining wetlands in the PPR are within or directly adjacent to upland grasslands[16]. Montana had the highest ratio of grassland to wetland at 24:1. By contrast, the prairie region of Minnesota has more wetland than grassland with an estimated grassland to wetland ratio of 0.7:1. North Dakota, South Dakota and Iowa have similar ratios of 2.3:1; 2.7:1 and 2.5:1, respectively.

[16]This was determined by geospatial analysis. The distance to grassland from wetlands other than those within or adjacent to grassland was undetermined.

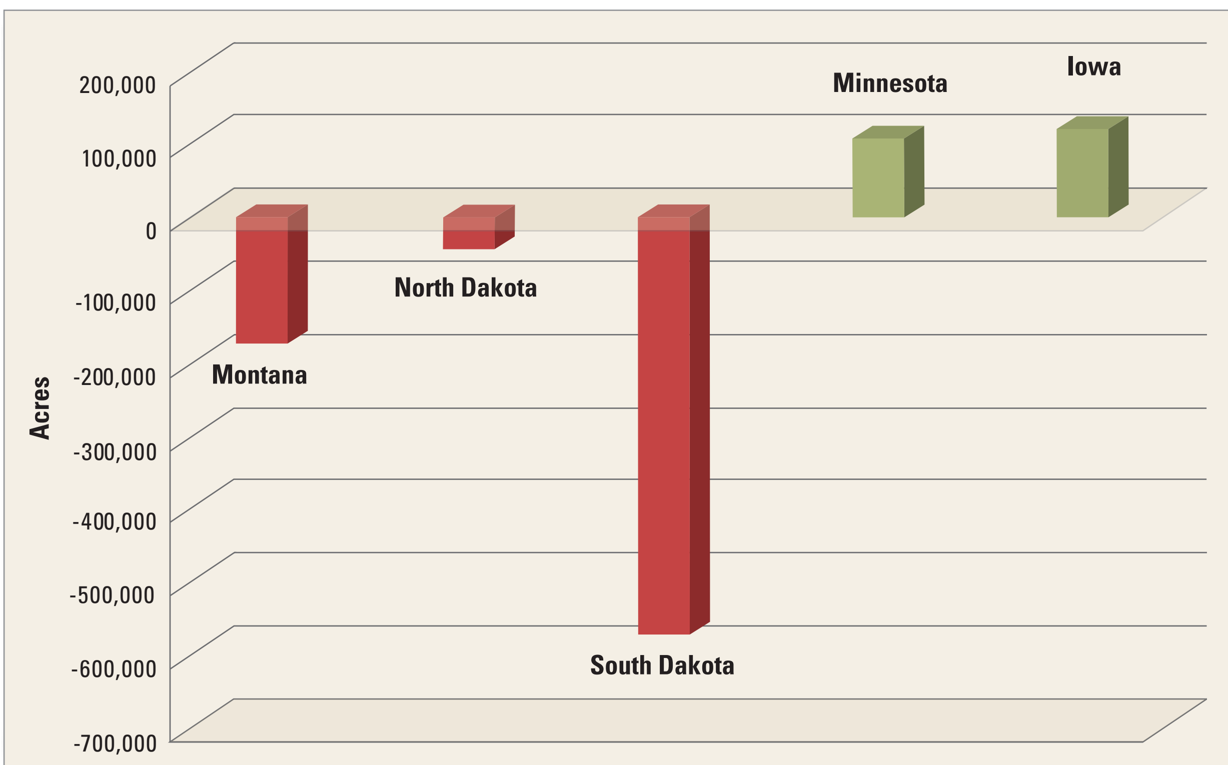



***Figure 18.*** *Gains (green) and losses (red) in upland grassland area within the U.S. Prairie Pothole Region, by state, 1997 to 2009.*

*Wetlands among the managed mixed-grass prairie of North Dakota.*

# Discussion

## *Changes in Wetland Extent in the Prairie Pothole Region*

The surface area that comprises the PPR represents about 4.8 percent of total surface area of the conterminous United States. This region is often discussed as an area of high ecological importance principally for migratory birds, waterfowl production and as an area continuing to experience wetland losses that directly affect the regional ecology. Past studies (Dahl 1990; Johnson *et al.* 1997; van der Valk and Pederson 2003) indicate that this region supported between 16.6 to 17 million acres (6.7 to 6.9 million ha) of wetland prior to settlement in the 1800s. The results of this study indicate that there were 6.4 million acres (2.6 million ha) of wetland remaining in 2009, a decline of 61 percent.

From the period between 1997 and 2009, wetlands losses continued throughout the PPR. The average annual net loss of wetland was estimated to have been 6,200 acres (2,510 ha) over this 12 year time span. This rate of loss represents a disproportional amount of the total net wetland loss for the nation, estimated to have been 13,800 acres (5,590 ha) between 2004 and 2009 (Dahl 2011). Findings from this study support those conclusions as the PPR experienced a net loss of 74,340 acres (30,100 ha) between 1997 and 2009.

Between 1997 and 2009, wetland area in the PPR declined by an estimated 1.1 percent. The number of wetland basins also declined over that period by 107,177. Small farmed wetlands and temporary wetlands experienced substantial losses. Conversely, semi-permanently flooded wetlands, open water ponds and deepwater lakes increased in area. In the PPR, temporary wetland area declined in all states between 1997 and 2009, whereas semi-permanent wetland area increased in all states with the exception of Minnesota. The remaining wetlands of the PPR were fewer in number and many exhibited changes in hydroperiod toward wetter conditions. When data from this study were compared to National Wetlands Inventory data (circa 1983—USFWS 2014) the mean size of the remaining wetland population had increased from 2.1 acres (0.9 ha) in 1983 to 3.2 acres (1.3 ha) in 2009. This reflects the loss of many small wetlands over time. Figure 19 shows a longer term trend in wetland area for the primary wetland and water body types in the PPR.

Emergent wetlands declined in the number of basins (119,948 or 4.7 percent) and area (95,340 acres [38,600 ha] or 1.7 percent) between 1997 and 2009. Of the principal emergent wetland types in the PPR, temporarily flooded emergent basins (including farmed wetland basins) declined in number by 8.1 percent and in area by 9.7 percent. Seasonally flooded emergent basins declined in number by 1.6 percent but increased in total area by 0.4 percent. Semi-permanently flooded emergent basins increased both in number (6.5 percent) and area (2.3 percent). This difference between wetland gains and losses of basin numbers and wetland area was also observed by Kahara *et al.* (2009) in study areas in South Dakota. They hypothesized that some smaller wetland basins either merged together or merged with larger wetter basins, thus reducing basin number but increasing wetland area.

In this study, an estimated 40 percent of the emergent wetland losses resulted from the expansion of deep, more permanent water areas.

Ninety-six percent of the wetland basins lost were classified as temporary emergent wetlands. Gains in semi-permanent emergent wetland basins, open water ponds and lake basins offset some of the overall decline in basin numbers.

The size distribution of emergent marshes by hydrologic type indicated that temporary basins were most numerous, making up almost 50 percent of all emergent wetland basins in 2009 (Figure 20). Forty two percent were seasonally flooded basins. Although temporary emergent wetland basins were found to be the most numerous by basin type, these basins contained less area than either seasonal or semi-permanently flooded emergent wetlands. They were smaller in size, averaging 0.98 acres (0.4 ha) per temporary basin. Past wetlands studies in the PPR have also characterized wetland size with most wetland basins being small <1.2 acres (<0.5 ha) in area (Cowardin *et al.* 1981; Kantrud *et al.* 1989).

The maximum density of wetland and water basins found in this study of 148 per $mi^2$ ($57/km^2$) occurred in portions of North Dakota. This number exceeds past estimates of 100 basins per $mi^2$ ($40/km^2$) reported by Kantrud *et al.* (1989). Other estimates of wetland density for portions of the PPR[17] have indicated an average 83 wetlands per $mi^2$ or 32 wetlands per $km^2$ (Zohrer 2001; USGAO 2007). This study estimated the mean wetland density by state in the PPR and found a range from a high of 30 wetland basins per $mi^2$ (12 basins/$km^2$) in North Dakota to 4 and 5 basins per $mi^2$ (1–2 basins/$km^2$) in Iowa and Minnesota. The overall basin density for the PPR in this study was 17.4 basins per $mi^2$ (7 basins/$km^2$) with an overall decline of 4 percent in the total number of wetland and water basins in the PPR between 1997 and 2009. Minnesota experienced a loss of over 18 percent of the remaining wetland basins between 1997 and 2009.

[17]Some studies estimated wetland density for only portions of the PPR and for different eras.

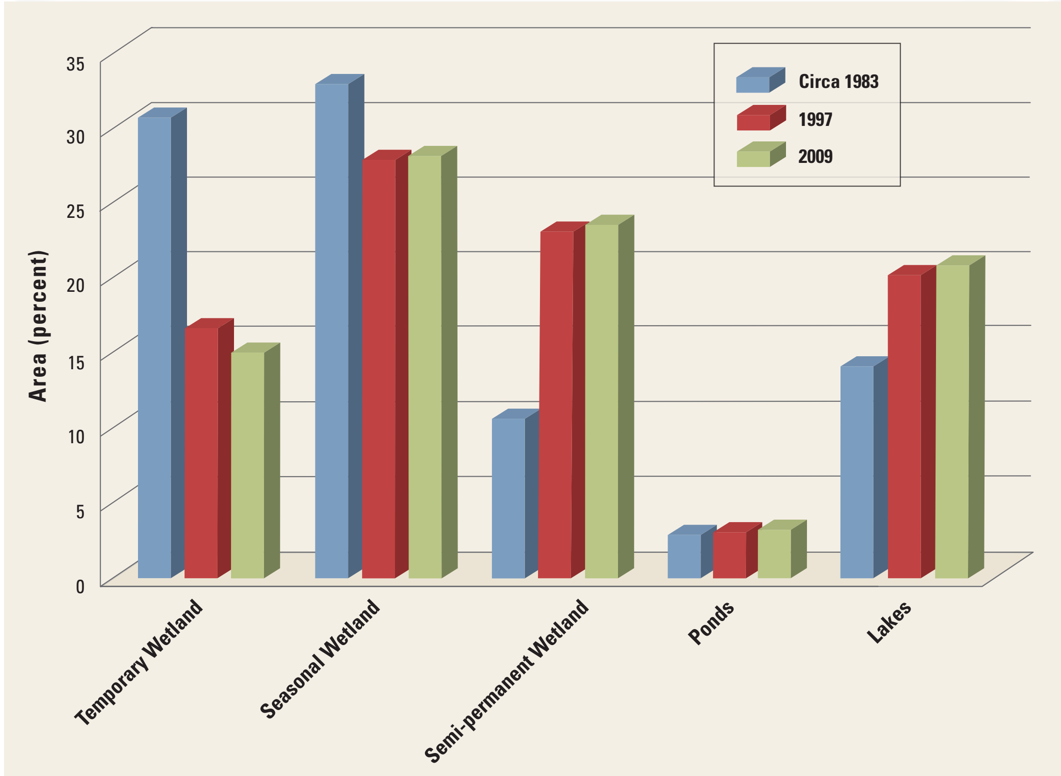



***Figure 19.*** *Trends showing percentage of area for the primary wetland and water body types in the U.S. Prairie Pothole Region from 1983 to 2009. Temporary wetlands (including farmed wetlands) and seasonal wetland area have declined while semi-permanent wetland, open water ponds and deepwater lakes have increased in area. (Source: USFWS National Wetlands Inventory data; this study.)*

***Figure 20.*** *This photograph shows a temporarily flooded wetland in a wheat field in late summer. Almost half of all emergent wetland basins in the U.S. Prairie Pothole Region are temporary wetlands.*

## *Trends Affecting Wetland Changes in the PPR*

In the U.S. PPR, wetland trends were driven by stressors on emergent wetlands. There were two primary factors influencing emergent wetlands observed in this study: The first involved climatic changes that effectively changed the hydrologic characteristics of wetlands by making some basins wetter and in some cases (i.e. semi-permanent wetlands) increasing wetland area. The second factor was the loss of wetland area due to drainage for agricultural production. Both of these processes exhibit nuances and complexities associated with how they interact at the landscape level in the PPR.

In a simplistic analysis, increased water levels affected 40 percent of the emergent wetlands by changing their hydroperiod to a wetter condition. Of the total emergent wetland area that experienced changes in hydroperiod, cover type or land use, 39 percent were lost to upland, primarily via conversion to agriculture (Figure 21).

Figure 22 shows areas where wetland losses and gains occurred in the PPR between 1997 and 2009.

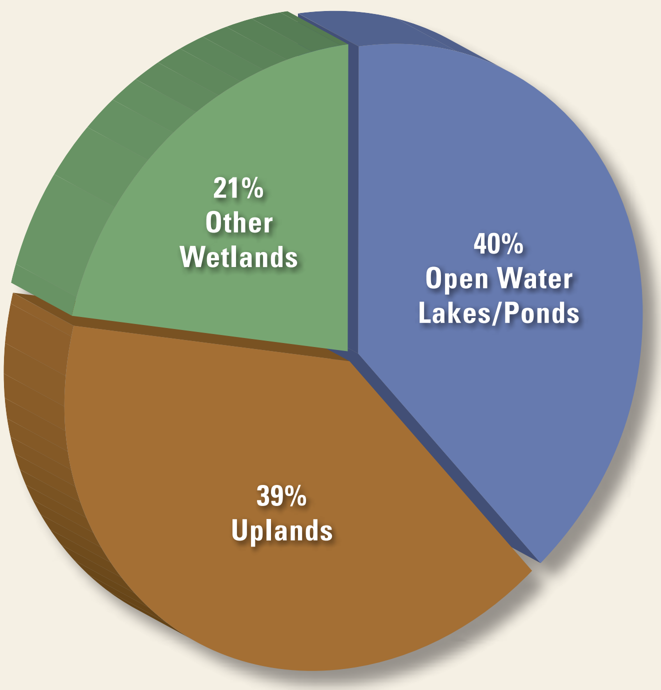
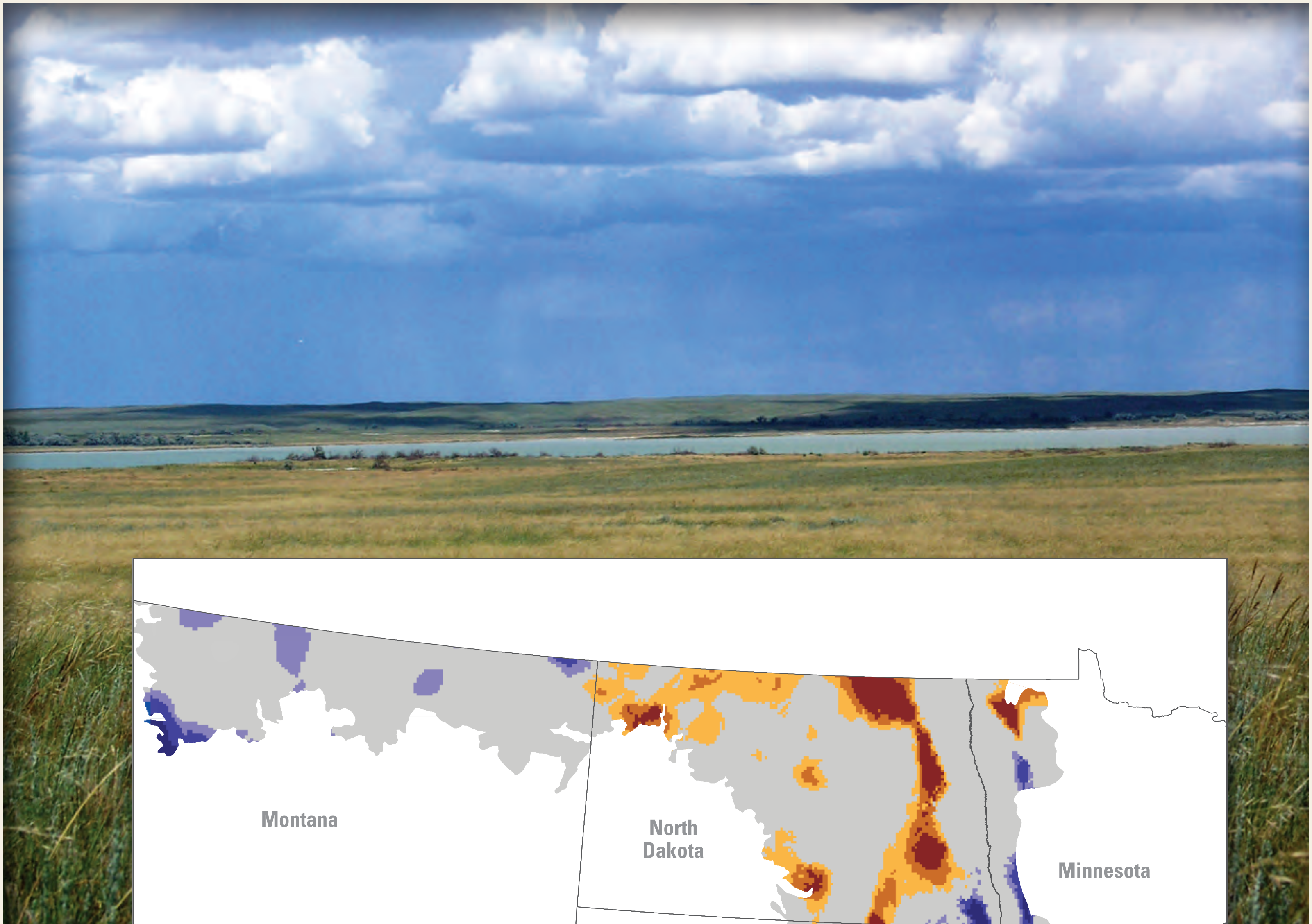



***Figure 21.*** *Attribution of changes to emergent wetlands in the U.S. Prairie Pothole Region, 1997 to 2009. Emergent wetland area declined by an estimated 95,340 acres (38,600 ha). Forty percent of the emergent wetland area was changed to deepwater lakes or ponds, 39 percent was lost to upland land uses and 21 percent was converted to other types of wetland.*



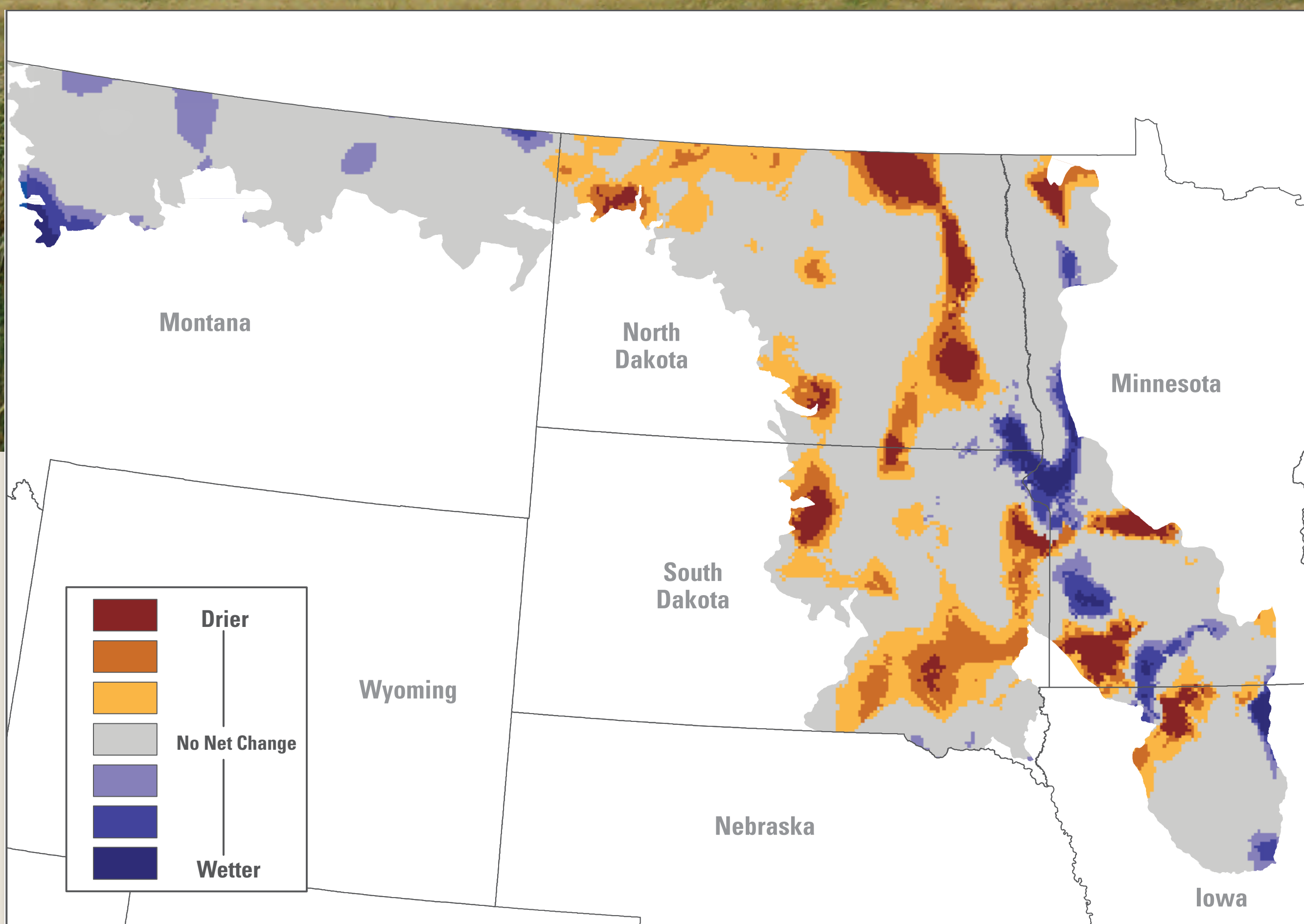



*Figure 22.* *Areas exhibiting changes in wetland hydrologic indicators, wetland loss or wetland gain in the U.S. Prairie Pothole Region, 1997 to 2009.*

## *Changes in Hydrology and Climate*

Most PPR wetlands and water basins are hydrologically closed systems, are sensitive to climate variability (Liu 2011) and demonstrate dramatic changes in water levels, size and distribution on the landscape. Long-term climate change in the PPR has the potential to alter temperature, precipitation amounts and patterns, length of the growing season and possibly timing and location of routes for migratory birds, all of which could result in changes to this regional ecosystem. Climatic changes may pose especially difficult challenges in the prairie regions of Iowa and Minnesota where a large majority of wetlands have already been effectively drained (Johnson *et al.* 2010).

Cyclical natural drawdowns in water levels due to unstable climatic conditions in the PPR are an important part of the “marsh cycle” (Weller 1981; van der Valk 1989; 2005). When surface water levels are low or non-existent (dry cycle), wetlands are in a drawdown stage allowing emergent or pioneer plant species to germinate. As precipitation cycles change to wetter conditions, increasing water levels selectively eliminate some of the less water-tolerant species and promote the growth of hydrophytes. At the high water portion of this cycle, prolonged inundation can kill the emergent vegetation and the wetland becomes dominated by open water. These wet and dry periods can persist for 10 to 20 years (Diaz 1986) and on a recurring cycle. An important issue in understanding the role of climate and climate change in the PPR involves distinctions between “normal” cyclical patterns of flooding and drought from longer term climatic changes that have the ability to alter wetland characteristics and landscape-level functions.

Precipitation (climate) plays a major role in what type(s) and how many wetlands are on the landscape in the PPR (Figure 23). However, wetland changes as determined from this study resulted from cumulative actions that changed wetland area, number and type that occurred between 1997 and 2009. Those impacts can be related to ecological change; changes in climate such as altered hydrology (e.g. flooding); anthropogenic changes such as draining, ditching or filling wetlands; or a combination these influences.

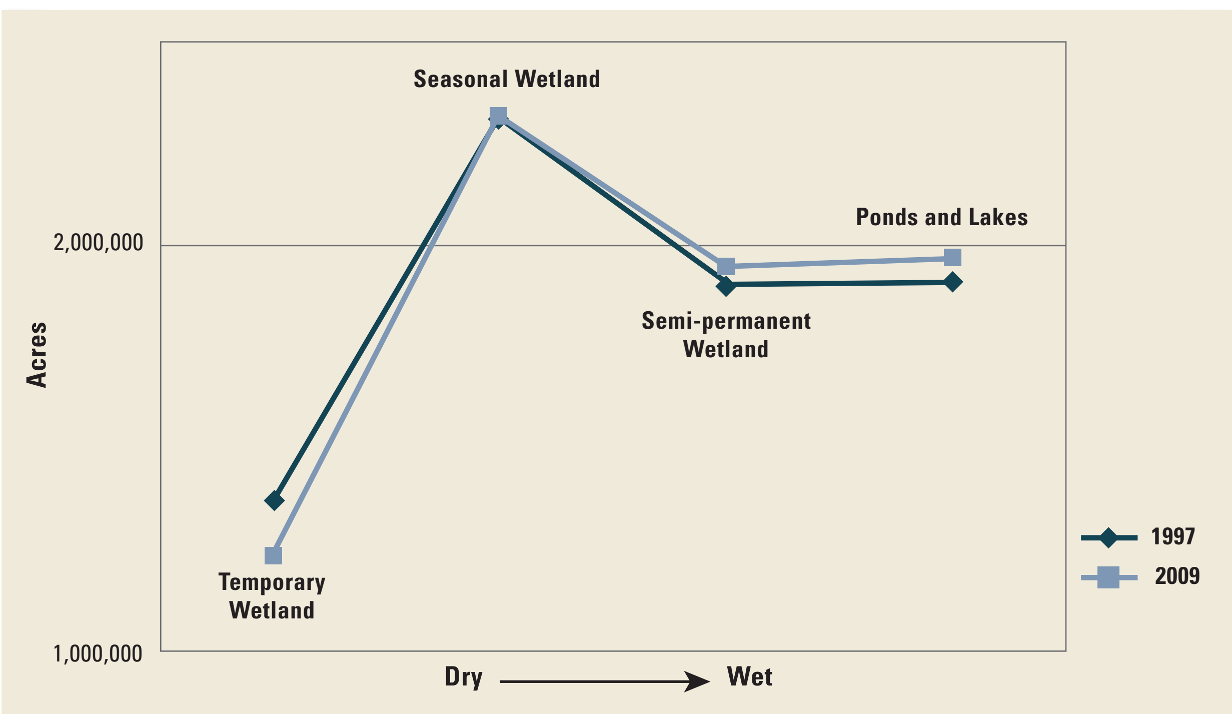



***Figure 23.*** *Between 1997 and 2009 drier wetland types (shorter hydroperiod) declined as wetter types increased in area.*

The Palmer Drought Severity Index (PDSI; Palmer 1965) has been strongly correlated to water levels and wetland hydrologic status (Euliss and Mushet 2011; Johnston 2013) and is a good indicator of regional water conditions. By using this information, it was determined that the PPR was in a period of above average precipitation between the years covered by this study (Figure 24) and portions of the region may be experiencing the wettest period in the past 130 years (Winter and Rosenberry 1998; Loesch *et al.* 2012; Johnston 2013). Prolonged periods of high water produce more lake-like conditions that can eliminate emergent wetland vegetation in basins that tend to hold water throughout the growing season or along the periphery of some pond/lake margins (Figure 25). Water can also overflow from one basin to another, thereby creating new surface water connections. These high water conditions influence the areal extent and type (hydroperiod) of wetlands. It is not clear whether these periods of high water reflect cyclical fluctuations in precipitation or are indicative of longer-term climate change (Niemuth *et al.* 2010). Tying wetland gain, loss or change to a definitive cause does not always have a clear linkage, and in many cases there is no distinguishing between multiple drivers of change(s) that influence wetland resources. Consequently, it is difficult to quantify some of the changes associated with any specific factor affecting wetlands such as climate.

Although climatic conditions are suspect in accounting for some wetlands merging with larger/wetter wetland basins as hydrology has shifted from a more temporary/seasonal status to semi-permanent or even lake-like conditions, wetland drainage practices may also contribute to this trend. Some wetlands are drained into other wetlands (Figure 26) or water bodies and increase the hydrologic connections that exist between basins as water is shunted off the landscape, forming more permanently flooded areas (McAllister *et al.* 2000). This study did not differentiate wetland loss/gain or change explicitly due to climate in cases where anthropogenic factors (i.e. drainage) also strongly influenced some changes in wetland hydrology. For example, by using remote sensing it is difficult to

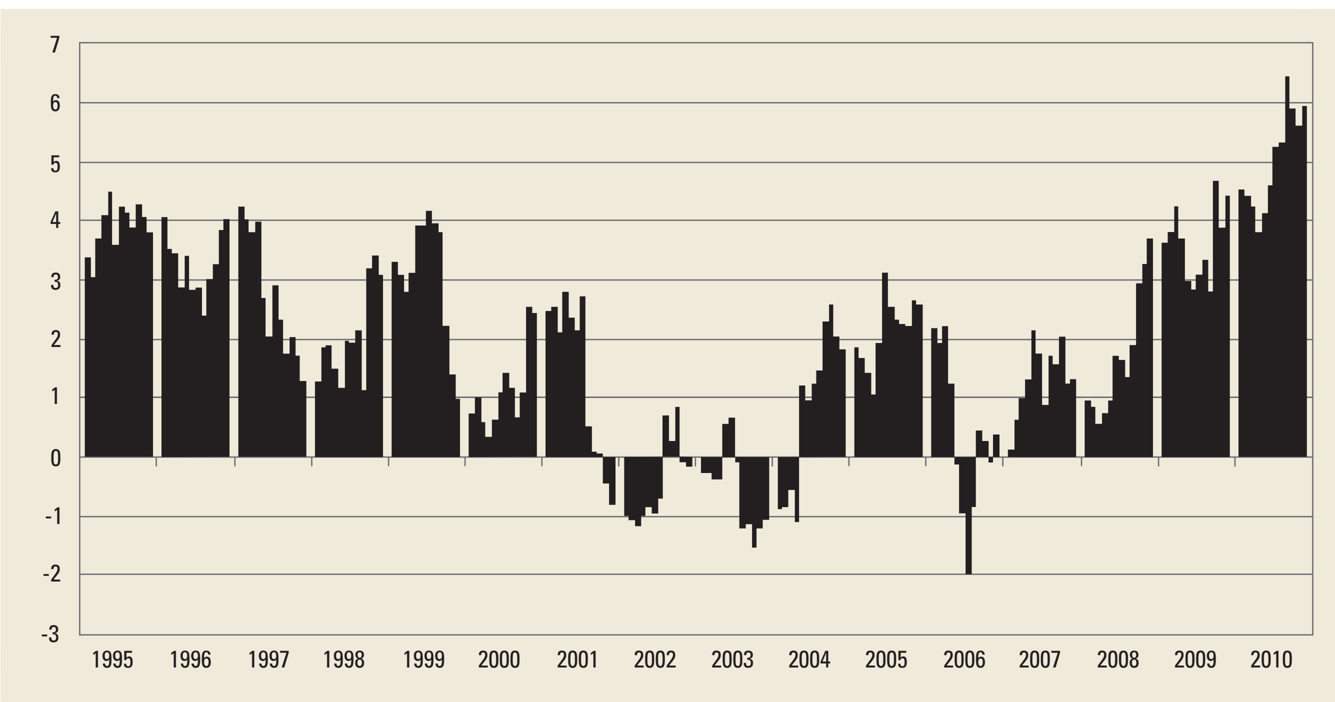



***Figure 24.*** *The Palmer Drought Severity Index (Palmer 1965) is a meteorological drought index used to assess the severity of dry or wet conditions. The average PDSI values for all 25 climatic zones covering the U.S. Prairie Pothole Region between 1995 and 2010 are shown here. Values above zero indicate periods of wet conditions and values below zero indicate periods of dry conditions.*

***Figure 25.*** *Overflow basins have merged across a road crossing in North Dakota. These emergent wetland basins had become open water and increased in size due to prolonged periods of high water. The depth of the water prohibited the growth of emergent or aquatic vegetation.*

distinguish between some wetland restoration projects (reflooding land) from other areas where wetland has been reestablished via wet climatic conditions (deluge or prolonged high water).

Recent projections of regional climate change (Johnson *et al.* 2005; 2010) indicate prairie wetlands could potentially become drier with shorter hydroperiods for seasonal and semi-permanent wetlands in the western and central portions of the PPR. Those studies proposed that waterfowl management interests should consider shifting conservation efforts east and north, concluding that the areas in Minnesota and Iowa would provide more suitable waterfowl habitat under future climate projections. While there are many management considerations and constraints in this alternative approach (Loesch *et al.* 2012), there would also seem to be substantial social, economic and logistical challenges in this strategic shift in waterfowl management. Based on historical land-use patterns and recent wetland trend information, there may be insufficient wetland resources remaining in the prairie regions of those states to attract moderate to high numbers of breeding hens to successfully maintain waterfowl populations. In areas such as the Agassiz Lake Plain along the North Dakota/South Dakota border, very few wetlands remain and this area would require extensive and costly wetland restoration efforts (Niemuth *et al.* 2009). This situation would also apply to other areas in Minnesota and Iowa where prairie wetlands have been extensively drained, and although topographic depressions (former wetland basins) remain, they lack wetland hydrology.

***Figure 26.*** *An example of wetland drainage into a larger wetland/water complex, Kingsbury County, SD, circa 2010. The red arrows show areas of former wetland that are being drained for agriculture. Dark gray and black tones are indications of wet soils as surface water is being removed. This type of drainage not only eliminates some wetland area but changes the hydrology of the wetland basin receiving the water being shunted off the landscape.*

Climate change models are predictive tools that forecast potential changes into the future. These hypothetical trends may not correspond directly to observed changes. Evidence from this study as well as other recent studies (Solberg *et al.* 2008; Niemuth *et al.* 2010) indicates that some wetland basins in the PPR have become wetter; however, the duration and sustainability of this trend is unclear and will depend on additional information that will help distinguish between cyclical weather patterns versus longer term climate change. Due to natural variability of precipitation trends in the PPR, shorter term studies such as this (<15 years) may not reflect long-term climate trends and should not be used to support or dispute arguments regarding climatic changes or draw conclusions beyond the intended use.

Climate change should be viewed as a potential source of environmental variability (Nichols *et al.* 2011) that, along with other stressors, undoubtedly contribute to the overall landscape-level changes that influence wetland distribution and characteristics in the PPR.

## *The Effects of Development and Agriculture*

Wetland losses to development between 1997 and 2009 included 1,420 acres (575 ha) lost to urban and suburban development (Figure 27) and accounted for an estimated 5 percent of the wetland lost to uplands over the course of this study.

Loss of wetlands to agriculture accounted for about 95 percent of the wetland area lost to uplands between 1997 and 2009. The impacts of agriculture on wetlands in the PPR vary. Threats to the ecological integrity of wetlands related to agricultural practices can result in direct habitat loss from wetland drainage or indirect effects (Figure 28) such as pesticide-induced loss of invertebrate populations in wetlands and water bodies (Beyersbergen *et al.* 2004).

Farmed wetlands are wetlands that have been tilled for agriculture but retain their wetland characteristics. For example, it was not uncommon in the prairie region for some shallow, temporary wetlands to be dry in certain years, depending on the amount of snow cover and early spring precipitation. Under these drier conditions, wetlands may be tilled and planted for crop production, but in wetter years return as shallow emergent marshes. Because of the wet and dry cycles experienced in the prairies, many wetlands have a history of being intermittently cropped (Figure 29). Reynolds *et al.* (2006) assumed that small wetlands (<1 acre or 0.4 ha) that were temporarily or seasonally flooded could be farmed in most years and were the most likely wetland type to be drained and converted to cropland.

***Figure 27.*** *Filling a wetland for urban development near Devils Lake, ND. Development such as this accounted for 5 percent of all wetland losses between 1997 and 2009.*

***Figure 28.*** *The effects of drift from chemical applications to this farm field impact this emergent wetland in the prairie region of North Dakota as evident by the discoloration of the remaining vegetation. Grue et al. (1989) noted this impact to wetlands in agricultural fields as the effects of land use on wetlands can be varied.*

***Figure 29.*** *A farmed wetland in North Dakota's Prairie Pothole Region with remnant wetland vegetation in the center portion of the basin. Drier conditions allowed this wetland to be tilled, but because this basin is not artificially drained, the area should return to wetland if farming is discontinued.*

The losses of wetland to agriculture between 1997 and 2009 focused on the conversion of farmed wetlands and small temporarily flooded emergent wetland basins. Net losses attributed to agriculture involved these wetland types. In a period of high water, temporarily flooded and farmed wetlands would also experience prolonged periods of ponded water, making farming without artificial drainage difficult. In Iowa, some effectively drained former wetland basins were holding ephemeral water during the growing season (Figure 30). However, high water conditions may not always result in increases in wetland area, because these conditions have the potential to stimulate additional drainage in efforts to remove water, especially in small temporary basins that have an established history of farming. This drainage can be done effectively and without penalty under existing regulations and the costs may be off-set by higher crop prices.

This study found that between 1997 and 2009 farmed wetlands declined by an estimated 45,310 acres (18,340 ha). An estimated 6,175 acres (2,500 ha) or 13.6 percent of these areas were converted to other wetland types, primarily seasonal or semi-permanent marshes, either by way of abandonment of farming practices, wetland restoration efforts or as a result of wetter climatic conditions. The majority of farmed wetlands (86.4 percent) that were no longer considered to be wetland were converted to upland agriculture. The loss of farmed wetland to upland agriculture was determined by the loss by wetland hydrology (i.e. drainage via ditching, tile drains or land leveling [fill] in some cases). These farmed wetlands are very vulnerable to drainage because they are usually small, in close proximity to existing farm field operations and can be easily drained, usually without penalty under existing regulations.

***Figure 30.*** *A historic wetland basin in Iowa (effectively drained by subsurface tile) has been flooded by recent rain storms and holds ephemeral surface water that will persist for only a few days under normal conditions.*

The loss or degradation of these wetlands is deleterious to shorebird utilization for feeding in shallow water or exposed mudflats that support aquatic invertebrates.

Recently there has been renewed interest and increased installation of subsurface tile drainage systems that effectively drained some wetlands in this region (Blann *et al.* 2009). Subsurface tile drainage systems have been popular with some landowners for removing surface waters and wetlands in both southwestern Minnesota and Iowa, and this trend has extended into portions of the Dakotas. In portions of the prairie region, pattern tile drainage systems are being installed to replace aging networks of tile drains and to further facilitate drainage in agricultural fields. In some areas, these drainage networks are so extensive they have effectively altered regional hydrology (Galatowitsch and van der Valk 1994; Dahl 2011) and may have ramifications for the success of any future wetland restoration projects that attempt to reestablish hydrologic connectivity to wetland complexes.

It is evident that small, temporary and seasonal wetland basins contribute substantially to the overall make-up of the wetland resource base in the PPR. Temporary wetlands are a major component of the wetland ecosystem both in terms of function and area, comprising an estimated 49 percent of all remaining wetland basins in 2009, and losses of temporary and farmed wetland area approached 133,000 acres (53,700 ha) between 1997 and 2009. The loss of these temporarily flooded wetlands is important, and although they are typically smaller in size than other wetlands, they determine the carrying capacity of a

PPR landscape. Because these wetlands are disproportionally used by breeding waterfowl, their disappearance can disrupt habitat connectivity and reduce diversity (Beyersbergen *et al.* 2004).

Researchers have found that a variety of wetland types and sizes is essential to sustain waterfowl populations as well as other ecological processes, and the importance of small, temporary basins to waterfowl in the PPR has been well documented (Batt *et al.* 1989; Swanson and Duebbert 1989). Johnson and Hubbard (1998) have shown that the density of ducks during the breeding season is inversely related to wetland size as seen in Figure 31. Early in the spring female ducks feed at temporarily flooded wetlands to satisfy protein demands for egg production (Krapu and Swanson 1975). As breeding pairs isolate themselves to establish territories, they use seasonally flooded wetlands and require more space (generally larger wetlands) to maintain a degree of isolation for courting and breeding (Murkin and Caldwell 2000). Later in the season duck broods tend to move to deeper marshes and ponds ringed with emergent vegetation and more persistent water conditions (Flake and Vohs 1979). Thus, wetland complexes, made up of wetlands of various sizes and types, support greater species richness compared to single, isolated basins (Naugle *et al.* 1999).

The interrelationship between different wetland types and uplands that form habitat complexes supports other birds and animals (Skagen and Knopf 1994; Leibowitz and Vining 2003). For example, migrating shorebirds are influenced by the regional location and availability of such wetland complexes.

Temporarily flooded wetland basins are particularly important as components of these larger wetland clusters or complexes. However, because these wetlands are typically small basins (<1 acre or 0.4 ha) that are only temporarily flooded early in the growling season, they tend to be more vulnerable to agricultural activities (Bartzen *et al.* 2010).

Temporarily flooded and farmed wetland basins were lost to agriculture even during periods of abnormally high precipitation. The prairie region of Minnesota experienced the highest loss and conversion rate of emergent wetland, totaling 74 percent of all emergent wetland changes measured in the PPR between 1997 and 2009. An estimated 36 percent were lost to deepwater lakes, 34 percent to agriculture, 23 percent were converted to forest or shrub wetlands, 4.5 percent to open water ponds and 2.5 percent were lost to other types of upland development.

A number of studies have shown that agricultural drainage continues to be one of the greatest threats to wetlands in the PPR (van der Valk and Pederson 2003; USGAO 2007; Blann *et al.* 2009; Johnston 2013). The continuing emphasis on increased crop production for biofuels places additional pressure on wetland conversion to agriculture in the PPR (Fargione *et al.* 2009; Johnston 2013). Drainage can have multiple impacts on wetland complexes by decreasing the area of wetland as well as decreasing the spatial and temporal frequency of surface water connections formed between basins during periods of high water (Leibowitz and Vining 2003). Wetland drainage may also lead to flooding downstream as water is quickly moved off from the landscape and into streams, channels or other drainage systems.

Despite these deleterious effects, the majority of emergent wetland restoration or creation in the PPR stems from conservation programs on agricultural lands or agricultural land management approaches. Conservation provisions as part of the Farm Bill legislation have deterred some wetland drainage for crop production in the Dakotas, but have not totally eliminated wetland losses to agriculture (Johnston 2013). Studies indicate that considerable wetland gains (upwards of 59 percent of wetland restoration or creation) by area occurred on agricultural lands between 1997 and 2007 (U.S. Department of Agriculture 2010).

***Background photo, right, Northern Shovelers (Anas clypeata) on a prairie wetland.***

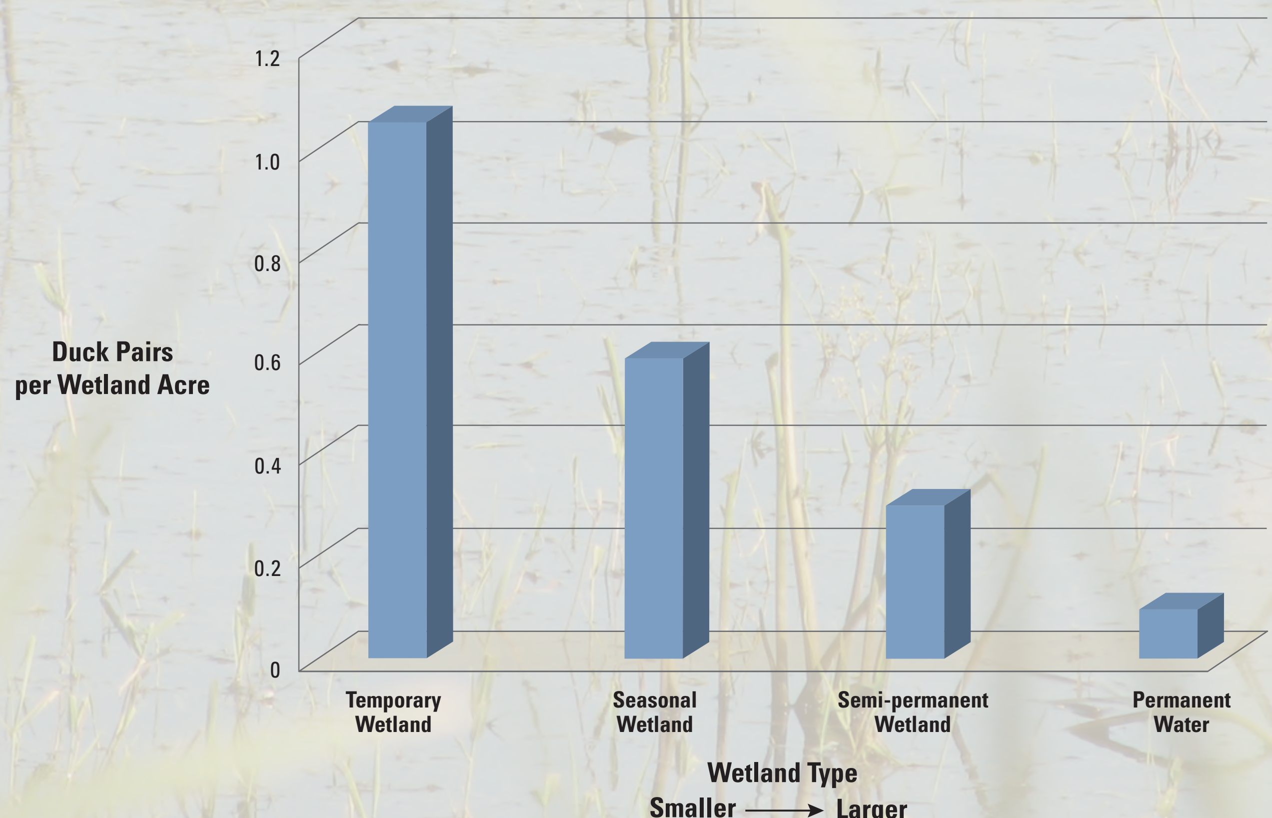



***Figure 31.*** *The density of breeding duck pairs in the spring is inversely related to wetland size where size increases with water permanence. (Adapted from Johnson and Hubbard 1998.)*

## *Wetland Restoration*

The objective of most wetland restorations is to mitigate some of the past loss of wetland habitat. Cumulative wetland losses, due primarily to drainage for agriculture, have altered the landscape patterns and hydrology of the remaining wetlands in the PPR. Portions of this region have transitioned from areas of wetland clusters consisting of diverse wetland types and sizes to fewer, more isolated and more permanent wetlands and water bodies (Krapu *et al.* 2004; Bann *et al.* 2009). Given this extensive wetland drainage, it is unrealistic to restore wetlands in the PPR to mirror their historic extent or spatial distribution. Restored wetlands are usually more isolated because there are relatively few of them and they are not normally part of wetland complexes (Galatowitsch and van der Valk 1994). As a consequence, at the landscape level, areas that have restored wetland(s) are very different from pre-settlement conditions.

Because losses of prairie pothole wetlands typically involve water drainage via a single outlet ditch or the tile drain, the potential for restoration on agricultural lands is much higher than if the lands were developed as part of urban areas or the basins were filled and leveled.

This study found an estimated 87,690 acres (35,500 ha) of emergent wetland reestablished from agricultural lands between 1997 and 2009. However, pressures to put lands into agricultural production outdistanced area gains. Wetland restoration or creation actions were overshadowed by losses of 125,400 acres (50,770 ha) of emergent wetland resulting in a net loss of 37,700 acres (15,270 ha) attributed to agriculture over the 12 year period of this study.

There has been considerable wetland restoration activity in the PPR since the passage of the Food Security Act in 1985 (Galatowitsch and van der Valk 1994; Bishop 2006). The restoration of wetland and grassland in the PPR has been a priority for resource management agencies in both the U.S. Department of the Interior and U.S. Department of Agriculture for some time (Gleason *et al.* 2008). The USFWS has developed goals in collaboration with conservation and land-use agencies for restoring an additional 682,000 acres (276,110 ha) of wetland in the PPR (USGAO 2007). Some states have also undertaken efforts to restore prairie landscapes. For example, the Iowa Department of Natural Resources has placed major emphasis on land acquisition in the PPR of Iowa and has identified potential wetland complexes, targeted land acquisition priorities and restored wetland and upland habitats (Zohrer 2001; Bishop 2006). Substantial state funding in Minnesota is also contributing to wetland and prairie restoration in the PPR region of that state (MNDNR 1997).

Although there is no comprehensive accounting of all restoration actions, regional studies such as reported by Galatowitsch and van der Valk (1996), have provided information about restoration numbers and characteristics. These studies indicated wetland restorations in the PPR are usually small areas (less than 10 acres or 4 ha), and they have tended to have wetter hydroperiods (seasonally or semi-permanently flooded). In this study, wetlands reestablished from agricultural lands (Figure 32) averaged 5.8 acres or 2.4 ha. Temporary wetlands have been under-represented in restoration projects compared to their historic number and extent (Galatowitsch and van der Valk 1996), and that trend has continued over the period of this study as the majority of restorations were seasonal and semipermanent wetlands.

Wetland restoration programs at the state and federal level have become more common as federal policy has shifted away from regulation to an incentive-based approach to reduce wetland losses and promote conservation and/or restoration of wetland areas (Dahl 2011). The federal resource agencies supporting wetland restoration work consider regional and programmatic priorities, available funding and technical limitations and depend largely on willing landowner participation. These programs have realized successes in increasing the area of wetland restored or created on a national level (Dahl 2006), but since current estimates of wetland area losses in the PPR outdistance wetland gains, a no-net-loss goal for this region has yet to be achieved. Despite ongoing efforts to restore wetland habitats in the PPR, current land-use trends and market forces continue to encourage wetland drainage and point to continued habitat losses in this region (USGAO 2007).

***Figure 32.*** *A temporary wetland as part of a conservation easement on former agricultural land in Minnesota's prairie region, 2009. This wetland reestablished naturally once farming was discontinued.*

## *Federal Wetland Protection Mechanisms in the Prairie Pothole Region*

The Federal Government has a multi-faceted role in the protection of prairie wetland resources. This role includes mechanisms for wetland regulation (including mitigation of losses), incentive programs for conservation, land acquisition and conservation easement programs.

Section 404 of the Clean Water Act (CWA) established a permit program to regulate the discharge of dredged or fill material into the waters of the United States, including wetlands. CWA Section 404(f) exempts from regulation discharges associated with certain specified activities, provided the discharges do not convert an area of waters of the United States to a new use, and do not impair the flow or circulation of waters of the United States or reduce the reach of waters of the United States. For example, a permit is generally not needed for discharges of dredged or fill material associated with normal farming, ranching and forestry activities, such as plowing, cultivating, minor drainage and harvesting for the production of food, fiber and forest products or upland soil and water conservation practices. This exemption pertains to normal farming and harvesting activities that are part of established, ongoing farming or forestry operations.

Federal legislation to reduce wetland destruction under the CWA has been subject to various interpretations as to its ability to include or exclude prairie pothole wetlands (Johnson and Higgins 1997; van der Valk and Pederson 2003). Supreme Court decisions regarding the exclusion of some "isolated" wetlands have further ramifications. This study estimated that 88 percent of wetlands and water bodies in the PPR are geospatially isolated from navigable waters, streams, larger wetland complexes or river systems. Following a Supreme Court decision in 2001 relating to federal jurisdiction over wetlands (SWANCC[18]), van der Valk and Pederson (2003) concluded that the majority of wetlands in the PPR were no longer considered waters of the United States and thus not afforded federal protection under the CWA. More recently, Johnston (2013) recognized that federal permits are not required under the CWA for agricultural uses of isolated wetlands and consequently many wetland losses to row crops have gone unrecognized by federal regulatory agencies in North and South Dakota.

[18]Solid Waste Management Agencies of Northern Cook County v. United States Army Corps of Engineers [531 U.S. 159 - SWANCC].

In an agreement reached between the principle federal agencies, the U.S. Army Corps of Engineers delegated the lead for identifying wetlands on agricultural lands to the U.S. Department of Agriculture–Natural Resources Conservation Service for purposes of implementing the Swampbuster program[19] (U.S. EPA 2013). Under the Swampbuster provision of the 1985 and subsequent Farm Bill legislation, wetlands with an established history of cropping prior to 1985 are termed "converted" or "prior converted" croplands, are not considered waters of the United States and are exempt from regulation under Section 404 of the CWA. Prior converted croplands are also exempt from the wetland conservation (Swampbuster) provisions. In the PPR, where the transitory nature of surface water allows even some of the deepest emergent marshes to dry sufficiently and have an established history of cropping, there are very few prairie wetlands on private lands that appear to have any federal protection status either through CWA (because they are likely to be considered "isolated") or through other exemptions in the Farm Bill legislation (because of past cropping practices). The lack of federal protection may also exclude areas that have recently become more permanent water features on the landscape as a result of hydrologic changes (Figure 33) as well as other "isolated" wetlands that have been restored. Other mechanisms for conserving PPR wetland resources that are especially important are the conservation provisions of Farm Bill legislation that include agricultural incentive programs linked to wetland conservation, such as the Conservation Reserve Program or Agricultural Conservation Easement Programs[20]. Federal wetland acquisition and easement programs in the PPR also have added importance.

To this end, the USFWS acquires wetlands and related areas either by outright purchase (fee title) of land or through the purchase of conservation easements. Areas purchased in fee title are owned by the USFWS and are usually open to wildlife-oriented public use. Wetlands with conservation easements remain under control of the private landowner, but draining, leveling or filling of wetlands is prohibited under terms of the agreement. The objectives of the USFWS in acquiring lands in the PPR are to preserve wetland functions

[19]NRCS wetland determinations may not be valid for determining Clean Water Act jurisdiction on a specific site.

[20]The Agricultural Act of 2014 established the Agricultural Conservation Easement Program.

***Figure 33.*** *Increased water levels in some areas of the U.S. Prairie Pothole Region have reclaimed some wetland shallow lake basins. However, because of established land-use practices, federal regulations likely will not accommodate extending protection status to these areas. North Dakota, 2013.*

(i.e. waterfowl habitat) and eliminate the threat of future drainage of properties of high resource value. Ideally, land acquisition programs in the PPR should seek to protect or restore features that represent the natural size, type and distribution of wetland basins historically found on the prairie landscape. However, this is not always possible given the extent of past drainage and wetland loss and changes in size, type and distribution of wetlands from historic patterns to simply what remains. Land acquisition for conservation purposes is often on a willing seller basis. Consequently the most desirable or the most threatened wetland areas may not be available for purchase.

Restored wetlands that are smaller, isolated basins are not protected by current legislation in many jurisdictions (Blann *et al.* 2009) unless they are part of a contractual easement agreement or land acquisition from a resource agency/organization. As an example, the USFWS had acquired perpetual, limited interest easements on 543,000 acres (219,840 ha) of wetland as of 2012 (USFWS 2012). U.S. Fish and Wildlife Service easement wetlands account for about 8.5 percent of the remaining wetland area in the PPR. Approximately 70 percent of the remaining prairie wetlands are in private ownership and largely unprotected by federal mechanisms.

## *Trends in Grassland Habitat*

Because of the important relationship between upland grasslands and wetlands in the PPR, examination of recent changes in grassland area helps to understand landscape-level impacts and trends. In this study, grasslands were generalized to include an array of lands that produce legumes, forbs or grasses[20]. There is inherently some overlap between grassland as defined in this study with agricultural lands. For example, agricultural fields planted to alfalfa as a crop rotation practice or fallow fields are still agricultural lands that produce "grass." The juxtaposition and extent of these lands complement wetlands monitoring efforts in the PPR.

[20]This study was not intended to be an authoritative source regarding upland land use characteristics or extent. Other monitoring efforts such as the Natural Resources Inventory (NRI) conducted by the Natural Resources Conservation Service provide more complete data on farmland and land-use categories for non-federal, rural lands.

This study estimated that grassland occupied about 21.1 million acres (8.6 million ha) or 22 percent of the land area in the PPR in 2009. The density of grassland in the PPR as found in this study is shown in Figure 34.

Net losses of grassland between 1997 and 2009 totaled 568,040 acres (229,980 ha) or 2.6 percent of the grassland area. The annual rate of loss of grassland area was estimated at 0.2 percent. An estimated 95 percent of the grassland area lost between 1997 and 2009 was attributed to agricultural operations, primarily crop production. Development (urban and rural construction) accounted for the loss of 4 percent of the grassland area. About 1 percent was lost to open water habitats such as lakes, rivers or ponds and less than 1 percent was converted to wetland.

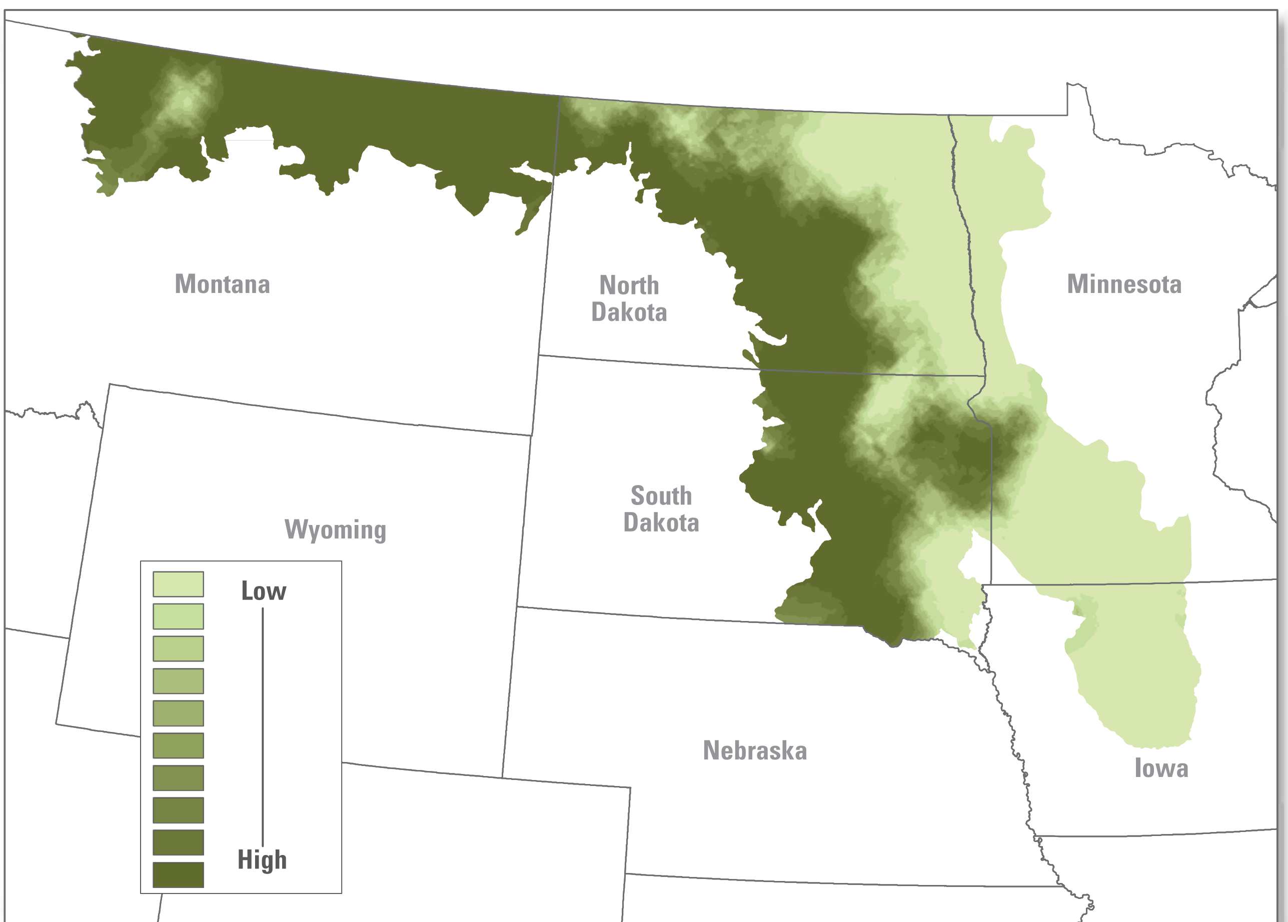



***Figure 34.*** *Density of upland grassland in the U.S. Prairie Pothole Region, 2009.*

Grassland buffers around wetlands can have important beneficial effects on wetland water quality and increase the suitability of habitat for wetland-dependent wildlife. Euliss *et al.* (1999) noted that increased siltation, contamination from agricultural chemicals, altered hydrology and habitat fragmentation resulting from wetland drainage and the conversion of native grasslands to agriculture impacted wetland systems. Tilling the upland directly adjacent to wetlands can increase sediment inputs to PPR wetlands by several orders of magnitude (Gleason and Euliss 1998) and grassland buffers adjacent to wetlands and streams have been shown to greatly reduce sedimentation and improve water quality (Figure 35).

Both wetland and grassland habitats are also essential for maintaining waterfowl populations at current levels (Loesch *et al.* 2012). Various strategies relating to the conservation of grasslands to support bird populations have emphasized the importance of landscape-level interactions between wetland and interconnected uplands in order to sustain healthy bird populations. Upland grasslands connected or in close proximity to wetlands are crucial for nesting waterfowl and a variety of other birds and wildlife species (Figure 36). The USFWS's National Wildlife Refuge System and the Partners for Fish and Wildlife Program have restored some of the historic grasslands in the PPR in efforts to expand grassland habitats (Johnson *et al.* 2010), and many wildlife managers have made the protection and restoration of grassland cover a priority for lands managed for waterfowl production throughout the PPR (Reynolds *et al.* 2006; Pardieck and Sauer 2007).

***Figure 35.*** *Soil erosion and sedimentation can adversely affect wetlands as seen in this photograph from the prairie region in Minnesota. Grassland buffers help reduce these impacts.*

***Figure 36.*** *Upland grassland adjacent to wetlands provides valuable habitat for waterfowl and other wildlife in the U.S. Prairie Pothole Region (Mclean County, ND).*

In the past, the conversion of grasslands to agriculture in the central portion of the United States has significantly influenced declines in some bird populations (Peterjohn and Sauer 1999; Murphy 2003; Johnson *et al.* 2010). Over time, grassland area has diminished substantially in the PPR and recent evidence suggests that grasslands continue to be lost with many potential ecological consequences (Rashford *et al.* 2010; Claassen *et al.* 2011; Wright and Wimberly 2013). A number of studies (Johnson 1996; Mac *et al.* 1998; Stephens *et al.* 2008; Fargione *et al.* 2009; Johnson *et al.* 2010) have pointed to declines in grassland area as an indicator of an alarming land-use trend in the PPR.

This study found that any land-use change to the remaining grasslands in the PPR has the ability to directly impact up to 32 percent of the remaining wetlands that are either surrounded by or directly adjacent to grassland areas. The elimination of grass may not result in direct wetland loss but certainly can influence wetland condition and landscape function by increasing sedimentation, runoff of chemicals or nutrients, or by otherwise reducing or eliminating surrounding habitat suitability (Figure 37). Based on economic analysis, Rashford *et al.* (2010) predicted that grassland to cropland conversion will increase if agricultural commodity prices continue to follow recent trends.

Concern about the effect of federal agricultural programs on grassland to cropland conversion has been growing over the past number of years. In a recent study, agricultural producers in the Northern Plains states were more likely to convert grassland to cropland or retain land in crops rather than return it to grass (Claassen *et al.* 2011), likely due to high commodity prices for corn and soybeans resulting from demand for biofuel production (Wright and Wimberly 2013). The role of federal crop insurance and disaster relief programs may also mitigate the risk of crop failure due to flooding or drought as some marginal lands are put into crop production (Faber *et al.* 2012). In Minnesota, researchers have found a high proportion of grassland conversion on lands with excess wetness that will likely lead to additional drainage (Wright and Wimberly 2013).

***Figure 37.*** *Wetlands without grassland buffers are subject to additional environmental stressors and potentially provide less suitable habitat than wetlands with grassland buffers.*

Contributing to this trend has been a reduction in the number of acres enrolled in agricultural conservation programs. Targeting the conservation or restoration of native prairie and promoting the expansion of upland grasslands found in conjunction with wetlands are important mechanisms for increasing upland-nesting waterfowl habitat. Some federal programs important for grassland conservation and restoration include the Conservation Reserve Program (CRP), which pays farmers to establish and maintain grassland (or trees) on former cropland based on a rental payment over a fixed time period. This program was designed to increase wildlife habitat and help improve water quality by limiting nutrient runoff and sedimentation. The CRP has been a major factor in returning croplands to grass in the prairie region. However, when crop prices are high or payments are available for farmers to produce crops, this can encourage grassland to cropland conversion and work at cross purposes with conservation programs such as CRP. In 2007 and 2008 the area of lands enrolled in the CRP shrank as higher prices for corn and soybeans resulted in more land being used for crop production (Miller 2008). In 2007 alone, CRP acreage in North Dakota declined by 12.4 percent (Wilson 2008) as incentives for corn production for biofuels resulted in additional acreage put into row crop agriculture.

While the interaction between grassland and row crop agriculture is the primary cause for land use change in the PPR, some grassland was also lost to non-agricultural land uses. An estimated 27,310 acres (11,060 ha) were developed as a result of expanding urban areas and infrastructure in the PPR between 1997 and 2009. Loss of grassland habitat has also been reported owing to planting trees and suppression of grazing and fire in the prairie region (Bakker 2003; Quamen 2007).

# Summary

Past wetland drainage in the PPR has been extensive and has altered the landscape and hydrology considerably. This long-term trend continues to change the complexion of prairie wetlands from one of diverse wetland sizes and types to fewer wetland basins characterized by longer hydroperiods. Prolonged high water conditions may be contributing to this situation as many small wetland basins that flooded and dried on an intermittent basis move toward becoming larger, more permanent wetland/water basins.

The losses of wetland to agriculture between 1997 and 2009 were due to the conversion of farmed wetlands and small temporarily flooded emergent wetland basins. In some areas, these agricultural drainage networks are so extensive they have effectively altered regional hydrology and may have ramifications for the success of any future wetland restoration projects that attempt to reestablish hydrologic connectivity to wetland complexes. Additional wetland losses and impacts are still a concern due to these cumulative effects and other changes to wetland hydrology exhibited in this region. Geospatially isolated wetland basins in the PPR are generally not likely to be protected by current federal regulatory or legislative jurisdiction. This places added importance on conservation measures that target agricultural program incentives to conserve wetland resources.

There has always been a close correlation between declines in waterfowl population numbers and the decline in wetland area in the PPR. In the United States the amount and quality of waterfowl habitat decreased substantially up until the early 1980s as wetland drainage, regionally dry conditions and the loss of grassland adversely affected the amount and quality of habitat. The continued loss and degradation of waterfowl habitat is one of the most serious threats facing waterfowl populations today. The loss of grassland in the PPR is particularly disturbing because this has been shown to seriously reduce bird populations, influence sedimentation rates and impair water quality in remaining wetlands and surface waters. Grassland conversion to other land uses will further reduce wildlife diversity across this region and have other environmental effects.

Climate change, along with other stressors, undoubtedly contribute to the overall landscape-level changes that influence wetland distribution and characteristics in the PPR. However, there are often multiple drivers of change and linking wetland changes to a definitive cause such as climate may not be straightforward.

Despite efforts to conserve and restore wetlands in the PPR, these resources continue to decline in number, diversity and extent. This puts the future of wetlands and prairie ecosystems in general in flux, depending upon climatic shifts in temperature and precipitation with the compounding influences of anthropogenic alterations to local and regional land use and hydrology.

***A prairie pothole wetland with a mix of emergent and aquatic bed vegetation in an agricultural landscape, North Dakota.***

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# Appendix

## Definitions of Habitat Categories Used in This Status and Trends Study

## Wetlands[22]

In general terms, wetlands are lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface. The single feature that most wetlands share is soil or substrate that is at least periodically saturated with or covered by water. The water creates severe physiological problems for all plants and animals except those that are adapted for life in water or in saturated soil.

> ***Wetlands are lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes[23], (2) the substrate is predominantly undrained hydric soil[24], and (3) the substrate is non-soil and is saturated with water or covered by shallow water at some time during the growing season of each year.***

The term wetland includes a variety of areas that fall into one of five categories: (1) areas with hydrophytes and hydric soils, such as those commonly known as marshes, swamps, and bogs; (2) areas without hydrophytes but with hydric soils—for example, flats where drastic fluctuation in water level, wave action, turbidity, or high concentration of salts may prevent the growth of hydrophytes; (3) areas with hydrophytes but non-hydric soils, such as margins of impoundments or excavations where hydrophytes have become established but hydric soils have not yet developed; (4) areas without soils but with hydrophytes such as the seaweed-covered portions of rocky shores; and (5) wetlands without soil and without hydrophytes, such as gravel beaches or rocky shores without vegetation.

### Palustrine System

The Palustrine (freshwater) System includes all non-tidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, farmed wetlands, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 parts per thousand. It also includes wetlands lacking such vegetation, but with all of the following four characteristics: (1) area less than 20 acres (8 ha); (2) active wave-formed or bedrock shoreline features are lacking; (3) water depth in the deepest part of basin less than 6.6 feet (2 meters) at low water and (4) salinity due to ocean-derived salts less than 0.5 parts per thousand.

### Wetland Classes

#### Emergent Wetland

Emergent Wetlands are characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. These wetlands are usually dominated by perennial plants.

[22]Adapted from Cowardin *et al.* 1979.

[23]Lichvar and Kartesz 2009.

[24]U.S. Department of Agriculture, Natural Resources Conservation Service maintains the list of hydric soils for the United States (U.S. Department of Agriculture, NRCS 2010).

**Shrub Wetland**

Shrub Wetlands include areas dominated by woody vegetation less than 20 feet (6 meters) tall. The species include true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions.

**Forested Wetland**

Forested Wetlands are characterized by woody vegetation that is 20 feet (6 meters) tall or taller.

**Farmed Wetland**

Farmed Wetlands are wetlands that meet the *Cowardin et al. (1979)* definition where the soil surface had been mechanically or physically altered for production of crops, but where hydrophytes would become reestablished if farming were discontinued. Farmed Wetlands lack artificial drainage systems that would effectively eliminate wetland hydrology.

**Ponds**

Open water, unconsolidated bottom, less than 20 acres (8.0 ha).

# Deepwater Habitats

Wetlands and deepwater habitats are defined separately because the term wetland does not include deep, permanent water bodies. For conducting status and trends studies, riverine and lacustrine are considered deepwater habitats. Elements of marine or estuarine systems can be wetland or deepwater. Palustrine includes only wetland habitats.

Deepwater habitats were permanently flooded land lying below the deepwater boundary of wetlands and included environments where surface water was permanent and often deep, so that water, rather than air, was the principal medium within which the dominant organisms lived, whether or not they were attached to the substrate. As in wetlands, the dominant plants were hydrophytes; however, the substrates were considered non-soil because the water is too deep to support emergent vegetation (U.S. Department of Agriculture 1975).

## Riverine System

The Riverine System included deepwater habitats contained within a channel, with the exception of habitats with water containing ocean derived salts in excess of 0.5 parts per thousand. A channel was "an open conduit either naturally or artificially created which periodically or continuously contains moving water, or which forms a connecting link between two bodies of standing water" (Langbein and Iseri 1960).

## Lacustrine System

The Lacustrine System included deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, emergent mosses or lichens with greater than 30 percent coverage; (3) total area exceeds 20 acres (8 ha).

## Uplands

### Agriculture[25]

Agricultural land was defined broadly as land used primarily for production of food and fiber. Agricultural activity was evidenced by distinctive geometric field and road patterns on the landscape and the traces produced by livestock or mechanized equipment. Examples of agricultural land use included cropland; orchards, groves, vineyards, nurseries, cultivated lands, confined feeding operations; and other agricultural land inclusive of livestock feed lots and farmsteads (including houses, support structures (silos) and adjacent yards, barns, poultry sheds, etc.).

### Urban

Urban land was comprised of areas of intensive use in which much of the land was covered by structures (high building density). Urbanized areas were cities and towns that provide the goods and services needed to survive by modern-day standards through a central business district. Services such as banking, medical, legal office buildings, supermarkets, and department stores made up the business portion of urban areas. Commercial strip developments along main transportation routes, shopping centers, contiguous dense residential areas, industrial and commercial complexes, transportation, power and communication facilities, city parks, ball fields and golf courses were also included in the urban category.

### Rural Development

Rural Developments occurred in sparse rural and suburban settings outside distinct urban cities and towns and were characterized by non-intensive land use and sparse building density. Typically, a rural development is a cross-roads community that has a corner gas station and a convenience store that are surrounded by sparse residential housing and agriculture. Scattered suburban communities located outside of a major urban center were also included in this category as well as some industrial and commercial complexes; isolated transportation, power, and communication facilities; strip mines; quarries; and recreational areas.

### Other Land Use

Other Land Use was composed of uplands not characterized by the previous categories. Typically these lands included unmanaged or non-patterned upland forests and scrub lands and barren land. Lands in transition were also included in this category. Transitional lands were lands characterized by the lack of any remote sensor information that would enable the analyst to reliably predict future use. The transitional phase occurred when wetlands were drained, ditched, filled, leveled, or the vegetation had been removed and the area was temporarily bare

### Grassland

Upland Grassland was developed as a generalized category to include an array of lands that produce legumes, forbs or grasses. This included a broad range of grassland areas such as minimally managed or native grasslands, extensively managed hay land (including alfalfa), pasture or rangeland, Conservation Reserve Program lands in perennial grass cover and fallow or retired cropland in grass. The definition of Grassland as used in this study is similar to the description of grassland types used by the U.S. Department of Agriculture (Claassen *et al.* 2011).

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[25] Adapted from Anderson *et al.* 1976.

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Front cover, a prairie pothole wetland surrounded by wheat and grassland, North Dakota. Title page, bulrush (*Scirpus* spp.) near the end of the growing season. Inner back cover, mallards at sunset in Lacreek NWR.

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