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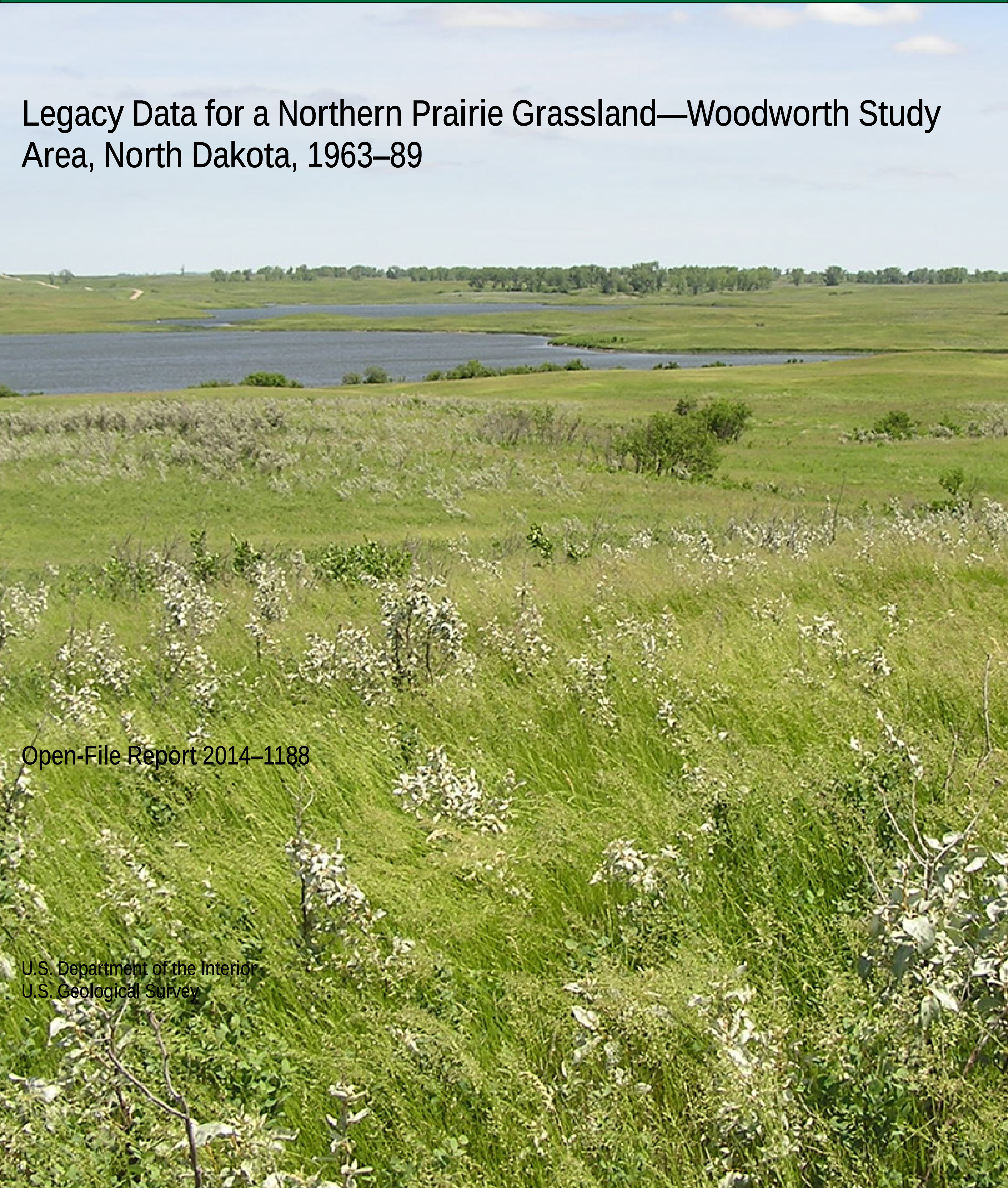
Legacy Data for a Northern Prairie Grassland—Woodworth Study Area, North Dakota, 1963–89



Open-File Report 2014–1188

U.S. Department of the Interior
U.S. Geological Survey

Legacy Data for a Northern Prairie Grassland—Woodworth Study Area, North Dakota, 1963–89

By Shelby H. Williams and Jane E. Austin

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U.S. Geological Survey
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Suggested citation:
Williams, S.H., and Austin, J.E., 2014, Legacy data for a northern prairie grassland–Woodworth Study Area, North Dakota, 1963–89: U.S. Geological Survey Open-File Report 2014–1188, 85 p., *http://dx.doi.org/10.3133/0fr20141188*.

ISSN 2331-1258 (online)

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Conversion Factors

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
decimeter	0.3281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
hectare (ha)	2.471	acre (ac)
square kilometer (km^2)	247.1	acre (ac)
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
	Density	
kilograms per hectare (kg/ha)	0.8922	pounds per acre (lb/ac)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(°Cx1.8)+32

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Abbreviations, Acronyms, and Chemical Symbols

Al_3^+	Aluminum
ASCII	American Standard Code for Information Interchange
C	Coefficient of conservatism
Ca_2^+	Calcium
Cl^-	Chloride
CLSA	Cottonwood Lake Study Area
CLWMD	Chase Lake Wetland Management District
Fe_3^+	Ferrous iron
F^-	Fluoride
FQI	Floristic Quality Index
FWS	U.S. Fish and Wildlife Service
GIS	Geographic Information system
H^+	Hydrogen
HCO_3^-	Bicarbonate
K^+	Potassium
Mg_2^+	Magnesium
Mn_2^+	Manganese
Na^+	Sodium
NEON	National Ecological Observatory Network
NH_4^+	Ammonium
NO_3^-	Nitrate
NPWRC	Northern Prairie Wildlife Research Center
NWI	National Wetland Inventory
PDSI	Palmer Drought Severity Index
PO_4^-	Phosphate
PPR	Prairie Pothole Region
SSURGO	U.S. Department of Agriculture Soil Survey Geographic Database
SO_4^-	Sulfate
USGS	U.S. Geological Survey
VOR	Visual obstruction method
WSA	Woodworth Study Area
Zn_2^+	Zinc

Acknowledgments

This project was funded by the U.S. Fish and Wildlife Service (FWS), Chase Lake Wetland Management District (CLWMD) Inventory and Monitoring initiative, and the U.S. Geological Survey (USGS) at North Prairie Wildlife Research Center (NPWRC). The authors would like to thank the following people for their contributions to this document:

Neil Shook, Project Officer, U.S. Fish and Wildlife Service, Chase Lake Wetland Management District, and Cami Dixon, Inventory and Monitoring Biologist, U.S. Fish and Wildlife Service, for their helpful discussions, project direction, and access to data relating to the Woodworth Study Area.

Staff of Northern Prairie Wildlife Research Center (NPWRC) David Cunningham, Betty Euliss, and Larry Strong for software and technical help, and David Mushet and Robert Woodward for assistance in finding and interpreting historical data.

NPWRC emeritus staff Ken Higgins and David Trauger for consulting on historical data sets and area history.

Donald Rosenberry, Hydrologist, U.S. Geological Survey, and Stan Kohn, Biologist, North Dakota Game and Fish Department, for assistance with finding historical data.

Brian Wangler, Wildlife Biologist, U.S. Fish and Wildlife Service, for loan of aerial imagery.

Clarence Lehman, Professor, University of Minnesota, for data management assistance.

Staff at Alfred Dickey Public Library in Jamestown, North Dakota, and State Historical Society of North Dakota in Bismarck, North Dakota, for help with history of the Woodworth Study Area.

Ken Higgins, David Trauger, and Ryan Limb, North Dakota State Univesity, provided valuable comments on early versions of this report.

Legacy Data for a Northern Prairie Grassland: Woodworth Study Area, North Dakota, 1963–89

By Shelby H. Williams and Jane E. Austin

Abstract

Ecological data commonly become more valuable through time. Such legacy data provide baseline records of past biological, physical, and social information that provide historical perspective and are necessary for assessment of stasis or change. Legacy data collected at the Woodworth Study Area (WSA), a contiguous block of grasslands, croplands, and wetlands covering more than 1,000 hectares of the Prairie Pothole Region of North Dakota, are cataloged and summarized in this study. The WSA is one of the longest researched grassland sites in the Upper Midwest. It has an extensive history of settlement, land use, and management that provides a deeper context for future research. The WSA data include long-term vegetation transect records, land use history, habitat management records, geologic information, wetland hydrology and chemistry information, and spatial images. Substantial parts of these data have not been previously reported. The WSA is representative of many other lands purchased by the U.S. Fish and Wildlife Service in the Prairie Pothole Region from the 1930s to the 1970s; therefore, synthesized data from the WSA are broadly applicable to topics of concern in northern grasslands, such as increases in non-native plants, managing for biodiversity, and long-term effects of habitat management. New techniques are also described that were used to preserve these data for future analyses. The data preservation techniques are applicable to any project with data that should be preserved for 100 years or more.

Introduction

Many North American wetlands were rapidly lost during early half of the 1900s to the combined forces of the severe drought of the 1930s, increasing drainage activities, and mechanization of farming. By the 1950s, leading biologists recognized that migratory waterfowl and their wetland habitats were in “grave danger” (Gabrielson, 1958). One response by the U.S. Fish and Wildlife Service (FWS) was an intensive effort in the late 1950s and 1960s to acquire wetland habitat for migratory waterfowl. Much of that effort, fueled by federal Duck Stamp funds (Higgins, 1981), was focused on the Prairie Pothole Region (PPR; fig. 1) which is known for its abundant wetlands and waterfowl productivity (Mann, 1958; Batt and others, 1989).

Acquisition and protection of wetlands through a combination of fee title purchases and easements, however, were recognized as insufficient to sustain productivity of migratory waterfowl populations. By the 1950s, wildlife biologists and managers were beginning to understand the intricate relation between the welfare of wildlife populations, and the quantity and quality of habitat, but much remained unknown. Nelson and Lee (1966) noted that “[m]ore sophisticated and penetrating research is needed to build a solid foundation of facts to guide future management of the Continent's waterfowl resources.” Biologists also recognized as early as the 1930s that a large percentage of wildlife species were produced on private land (Leopold, 1933). Hence, scientific research was needed to help guide management of upland and wetland habitats for the benefit of waterfowl and other wildlife, yet be economically feasible and acceptable to land owners (Cottam, 1958). New habitat management techniques needed to be properly researched and tested before being made available to managers and landowners.

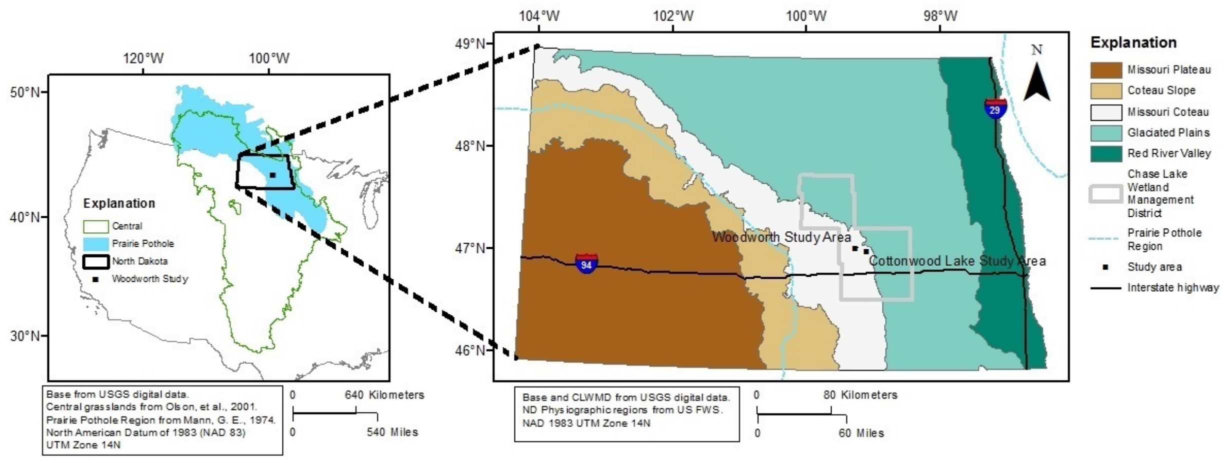

Figure 1. The Woodworth Study Area (WSA; 47º8'N, 99º14'W) lies within the Central Grasslands biome and Prairie Pothole Region (PPR) of eastern North Dakota and along the eastern edge of the Missouri Coteau physiographic region.

To address these pressing needs, FWS personnel sought a permanent study area that would provide opportunities for short-term and long-term research on priority issues confronting the management of migratory birds and their habitats in the PPR. Primary emphasis was on wetland and grassland ecology, waterfowl breeding ecology, and the effects of agricultural land use practices on waterfowl production. In the early 1960s, Dr. Ingalf G. Bue was given a special assignment by FWS to find an appropriate area to establish a field research station. The criteria were that the area (1) be representative of the PPR, (2) be on the Coteau du Missouri (or Missouri Coteau), (3) be a sizeable tract, (4) have a high density of wetlands, and a matrix of native grasslands and croplands, and (5) be within 80 kilometers (km) of the new Northern Prairie Wildlife Research Center (NPWRC) in Jamestown, North Dakota (Nelson and Lee, 1966). Dr. Bue selected a 1,063-hecatare (ha) area near Woodworth, North Dakota (N. Dak.). The Woodworth Study Area (WSA) was purchased using federal Duck Stamp funds in 1963 and designated a waterfowl production area to help meet the research needs of the NPWRC. The initial intent of the WSA was to establish and maintain a long-term study area and collection of baseline data that would serve future studies. The primary mission of the WSA was to conduct research concerning the best land use and water management practices that would also keep with the mission of the FWS to maximize benefits to wildlife, with an emphasis on migratory birds.

The WSA stands as one of the longest researched grassland sites in the Upper Midwest (Johnson and others 1996). The WSA has an extensive history of settlement, land use, and management that provides a deeper context for investigations. It is representative of many other tracts purchased by the FWS in the PPR during the 1930s–1970s. In addition to research on wildlife responses to habitat management, the WSA hosted extensive research on the ecology of waterfowl, grassland birds, and predators (Higgins and others, 1992). Data include vegetation, birds, mammals, soils, lands use and treatments, and weather. More than 30 years of research at the WSA resulted in volumes of data, 66 peer-reviewed publications, 16 theses, and many other published and unpublished reports on management of wetlands and wildlife. Data collected at the WSA also contributed directly to several domestic and international environmental policies including U.S. farm bills and the North American Waterfowl Management Plan (Nelson, 1996).

However, a substantial part of the historical data collected at the WSA, particularly the vegetation data, has never been comprehensively assessed. Long-term records of vegetation composition, structure, and phenology remain largely digitized. Data from the early decades of habitat research were stored in paper files and as American Standard Code for Information Interchange (ASCII) datasets in NPWRC archives, and subject to limited or absent metadata, and often no comprehensive explanation. Extensive information about early land use by settlers, land management histories, and other aspects of the area existed in various unpublished reports (appendix 1) and memos.

This report provides a compilation and synthesis of the WSA's settlement and land management history, geography, abiotic features, vegetation data, and associated research conducted during 1963–89. The first section provides a general orientation to the geography, physical features, and settlement history of the WSA area. The second section describes the land use history and treatments applied under federal management. The third section presents a preliminary summary of the long-term vegetation data. Parts of the WSA vegetation data were published previously as supporting data in wildlife-related publications (appendix 2), but this is the first compilation and synthesis of the core vegetation datasets from the first 3 decades of WSA research. In the final section, the data management strategy used to ensure that these valuable data will be accessible to researchers for a century or more is described. This project meets the diverse requirements of the Chase Lake Wetland Management District (CLWMD), FWS, and NPWRC. It also serves as a foundation for analyzing the WSA legacy data and future data, most notably those from the National Ecology Observatory Network (NEON) Domain 9 core site, which was established at the WSA in 2013 and is expected to remain there until 2047 (NEON, Inc., 2011).

As climate and land use continue to change in the PPR, the historical WSA datasets offer context and a baseline for future work on grassland reserves. These datasets will contribute to CLWMD's planning process for their habitat management plan by forming a solid baseline of historic vegetation conditions. In addition, this information can be critical as biologists consider how abiotic factors and biotic factors have changed, and how the landscape can be better managed considering these changes.

Administrative and Research History

The WSA has been owned by the FWS since its purchase from private landowners (appendix 3) and was managed by NPWRC personnel until 1993. The WSA was managed by Leo M. Kirsch (1964–79), Kenneth F. Higgins (1979–85), and J. Michael Callow (1985–89). Occasionally, private lands adjacent to the WSA also were used with permission in research and monitoring, such as monitoring wetland conditions. Most of the research was conducted by scientists and staff affiliated with the NPWRC; in addition, some 300 visiting scientists from state and federal agencies, universities, and graduate students have conducted research there (Johnson and others, 1996). In 1990, the WSA became headquarters for the Chase Lake Project of the Prairie Pothole Joint Venture under the North American Waterfowl Management Plan. Thus the WSA has been a model of partnerships between government agencies, university researchers, and private ownership.

During 1989–93, the FWS contributed to management of the WSA with on-site biologists in conjunction with researchers from the NPWRC. In 1993, the FWS retained ownership of the WSA lands when the NPWRC was transferred from the FWS to the National Biological Survey and in 1997 to the U.S. Geological Survey. Operational management was shared between the NPWRC and FWS's newly established CLWMD through formal agreements. The NPWRC maintained active research on the WSA until 1996 but continues some long-term data collection.

Area Description

Geography

The WSA is in east-central North Dakota within the PPR and Central Grasslands biome of North America (fig. 1). It is about 5 km east of Woodworth, N. Dak., on the Missouri Coteau at latitude 47º8'N and longitude 99º14'W (fig. 1). The PPR is a formerly glaciated region defined by high densities of shallow wetlands (potholes) embedded in northern mixed-grass prairie. The Missouri Coteau is a prominent terminal glacial moraine, a narrow band of land that separates the more intensively cultivated landscape of the Glaciated Plains to the east from the Missouri Plateau to the west (fig. 1). Its irregular terrain supports hay fields, a variety of crops, native prairie, and range lands with livestock (fig. 2). The WSA consists of 1,063 hectares (ha) of land in federal management; an additional 168 ha of privately owned lands adjoining the WSA have been surveyed occasionally under agreements with their owners (appendix 3; Higgins and others, 1992).

Glacial History

The WSA is representative of how glaciation processes created the high densities of wetlands characteristic of the PPR. Almost one-fifth of the WSA is covered in wetlands formed by glacial retreat. The age of the glacial drift on the Missouri Coteau is estimated to be from 9,000 years (Tutill and others, 1964) to 13,000 years before present (Clayton, 1966; Higgins and others, 1992). The WSA is divided into 2 glacial landforms: hummocky stagnation moraine in the northwest and outwash in the southeast (fig. 3; Winters, 1963). The hummocky stagnation moraine in the northwest was created by glacial stagnation, where the Wisconsin glacier slowly disintegrated and melted in place over thousands of years. Glacial till that accumulated within the glacier eventually rested in a disorganized layer on the surface, forming hummocky stagnation moraine (Bluemle, 1987). The topography is an irregular distribution of mounds and depressions, and some of the rugged local relief exceeds 30 meters per square kilometer (m/km^2) (Higgins and others, 1992). Till material is unsorted, so water moves through it more easily near the surface, affecting wetland hydrology (Sloan, 1972).

The southeast corner of the WSA is a glacial outwash (fig. 3), which contains deposits from streams of glacial melt water flowing on the glacier surface (Winters, 1963). Soil formed on outwash can be highly permeable, which results in fewer but more permanent potholes than in adjacent deposited till (Sloan, 1972). The outwash plain covering the southeast portion of the WSA was characterized as "ice-walled gravel train" by Winters (1963, p. 44). The swath of outwash is about 2.4 km wide (fig. 3) and was once bordered by ice walls on the north and south

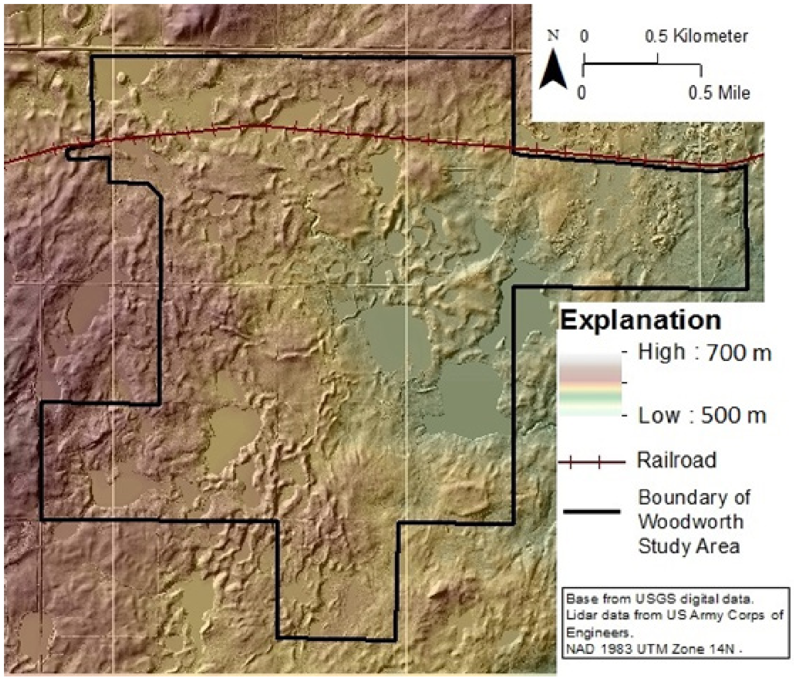

Figure 2. The terrain and elevation above sea level (meters [m]) of the Woodworth Study Area (WSA) based on light detection and ranging (lidar) data.

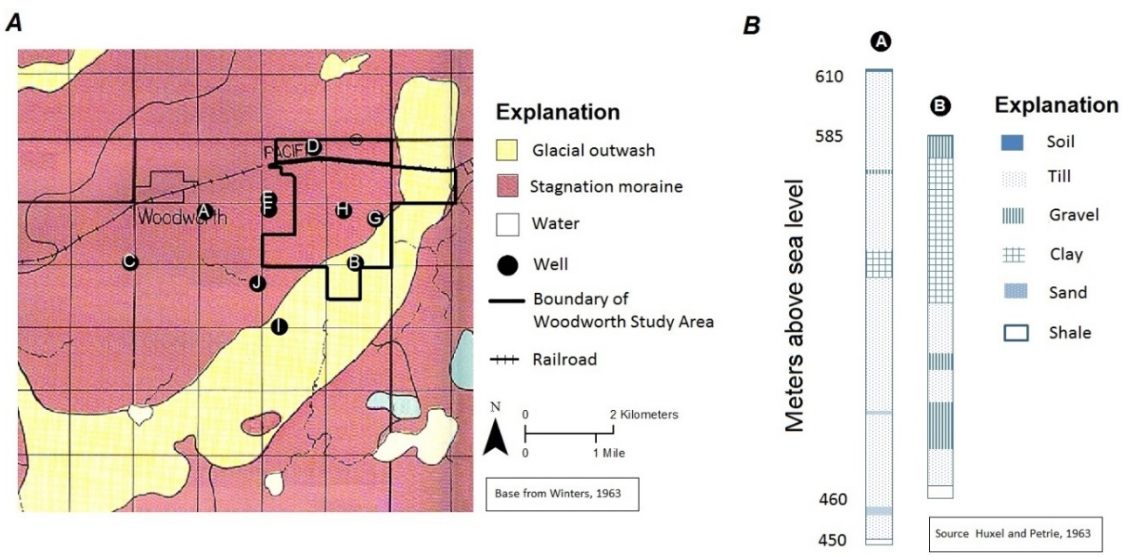

Figure 3. Spatial relation of underlying glacial features to test wells in and around the Woodworth Study Area (WSA).). *A*, A band of glacial stagnation outwash runs through hummocky stagnation moraine in the southeast swath of the WSA. Test wells were located in both areas and were mapped to within 4 ha. *B*, Vertical profiles of substrate material in test wells A and B.

sides. This resulted in rugged terrain similar to hummocky stagnation moraine and is indistinguishable from stagnation based on topography alone (Winters, 1963). In the northeastern study units of the WSA, exposed gravel pits were developed commercially until 1953; coarse gravel deposits were at least 7.5 meters (m) deep (Winters, 1963). The commercial history, and plant and animal communities of this so-called Goldwin gravel pit were published by Higgins (1982). WSA staff also created a small gravel pit about 0.75 km east of headquarters on the outwash.

At least 10 wells, springs, and test holes near the WSA have been examined (table 1; fig. 3; Huxel and Petri, 1963). Data available for 2 wells illustrate the differences between profiles of glacial deposits of hummocky stagnation moraine and stagnation outwash. Test well 1815 (A) was dug about 2.5 km west of the WSA on hummocky stagnation moraine; below a thick layer of soil (0.9 m) was almost 33 m of glacial till (fig. 3). Test well 1814 (B) was dug 4 km east of Test well 1815 (A) on the stagnation outwash (fig. 3). Test 1814 (B) revealed mainly gravel and clay below 0.61 m of soil; 7.3 m of gravel was followed by 49.1 m of clay (fig. 3; Huxel and Petri, 1963).

Table 1. Wells, springs, and test holes in and near the Woodworth Study Area (WSA) as of 1963.

[Ownership indicates whether the well was on federally owned or private land. No data is indicated by nd. Letters were assigned for IDs in the present report and correspond to figure 3. Year established is the year that the well, test hole, or spring was dug, if known. Depth is recorded as meters (m), diameter as centimeters (cm), and specific conductance as micromhos per centimeter (µmho/cm). Material indicates substrate type. Site H had no water depth recorded but water flowed (a fen with moving groundwater). Data from Huxel and Petri, 1963.]

ID	Ownership	Year established	Depth (m)	Diameter (cm)	Material	Water depth (m)	Specific conductance (µmho/cm)
A	Private	1960	160	12.7	nd	nd	nd
B	Federal	1960	121.6	12.7	nd	nd	nd
C	Private	1960	135.6	5.1	fine sand	68.6	nd
D	Federal	nd	64.6	10.2	sand	9.1	1,302
E	Private	nd	12.2	61.0	sand	nd	nd
F	Private	nd	6.1	61.0	sand	nd	nd
G	Federal	nd	12.2	61.0	gravel	8.5	nd
H	Federal	nd	2.6	121.9	gravel	Flow	670
I	Private	1949	15.2	61.0	sand	12.2	nd
J	Private	1956	62.5	5.1	sand	36.6	nd

Glacial formations are the substrata or parent materials from which agricultural soils were formed. According to the Soil Survey Geographic Database (SSURGO) classifications (U.S. Department of Agriculture, 2009), there are eight soil series throughout the WSA (4*B*); the most common is the Buse series, followed by Barnes (fig. 4*B*). Bayha's (written commun., 1963) soil survey contained more categories of soil (fig. 4*A*) but agrees with 2009 SSURGO data that the primary soil type (as defined in 1963) was Buse-Barnes (fig. 4*B*; Omodt and others, 1968; Patterson and others, 1968). Soils also were classified by drainage, runoff, and farmland types (appendix 4). Vegetation studies at the WSA usually accounted for varieties and differences in soil types when choosing locations for transect surveys and controls. For an in-depth discussion of soil types at the WSA and the surrounding area, see the Stutsman County Soil Report (Abel and others, 1995).

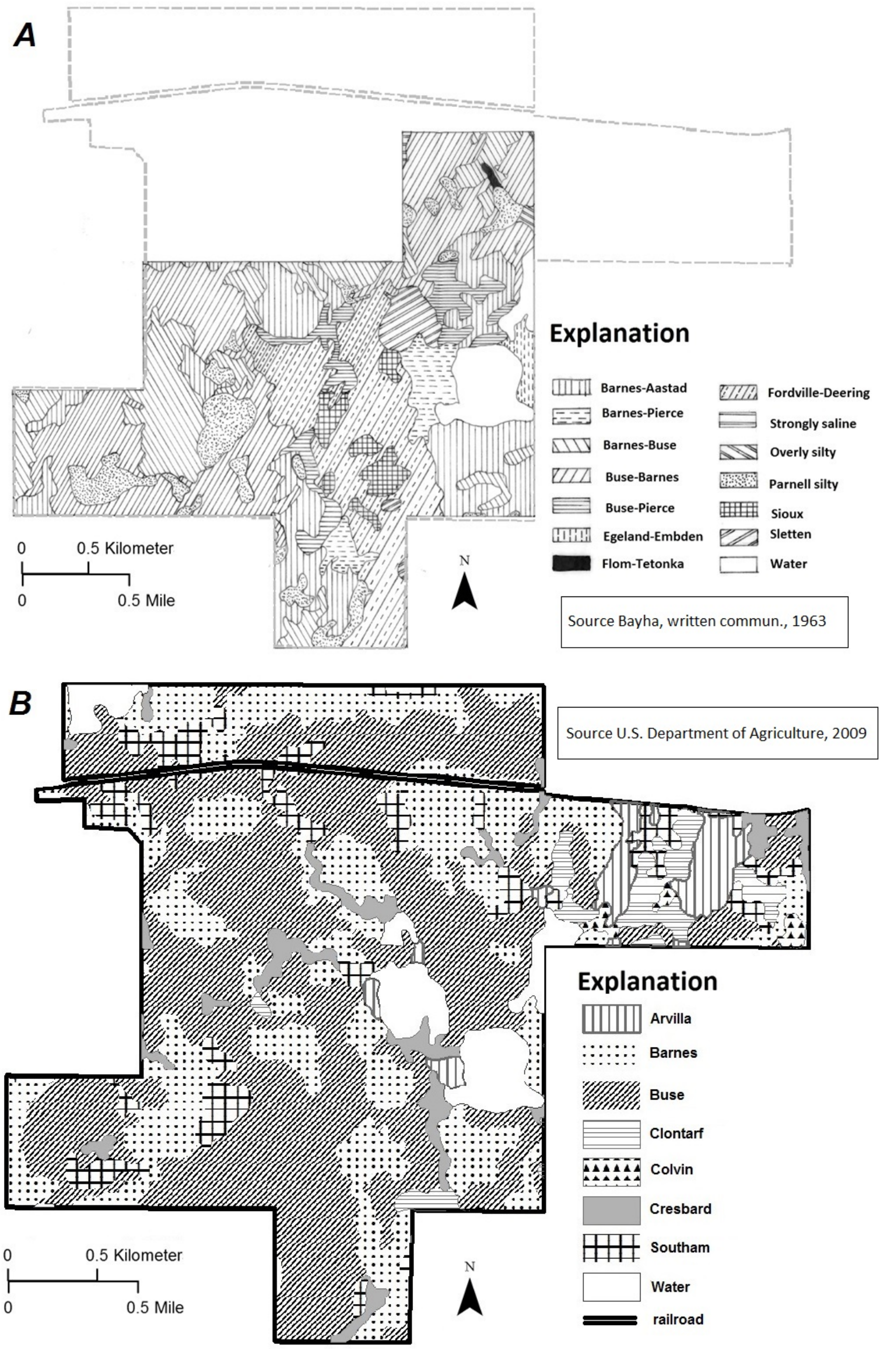

Figure 4. Soils of the Woodworth Study Area (WSA). *A,* Bayha's initial survey in 1963. *B,* Publicly available Soil Survey Geographic Database (SSURGO) database.

Wetland Water Balance

There are no primary stream drainages from the WSA, and most surface runoff on the study site accumulates in wetland depressions (Higgins and others, 1992). The amount of water in a wetland basin is constrained by 2 dynamic factors: groundwater hydrology and atmospheric hydrology (Euliss and others, 2004). Research at the nearby Cottonwood Lake Study Area (CLSA) indicates wetland dynamics were mainly driven by evaporative losses and precipitation inputs (Winter and Rosenberry, 1995). Minor additions to water levels were supplied from overland runoff or groundwater seepage, and direction and volume of seepage between a wetland basin and groundwater can vary on a seasonal or interannual basis (Euliss and others, 2004). Wetlands may also lose water through transpiration via wetland vegetation. Transpiration varied with the amount, height, and moisture content of wetland vegetation, and was about 15 percent higher for vegetated basins than unvegetated basins (Eisenlohr, 1972).

The seasonal and interannual climate cycles that drive wetland water levels are integral to wetland processes and biotic communities (Euliss and others, 2004). Maps created by Bayha (written commun., 1963) illustrated seasonal changes in wetland water volume at the WSA during the dry year of 1963 (fig. 5). Water surfaces shrank from May to November, and demonstrate differences in wetland permanence between the east and west halves of the WSA (fig. 5). The percentage of basins at the WSA containing water at various times throughout the year was first reported in Bayha (written commun., 1963) and later by Higgins and others (1992).

Figure 5. Changing water conditions in wetlands in the Woodworth Study Area (WSA) during 1963. *A*, May, 1963. Wetlands 1, 2, and 3 are also known as Clark Lake, Fish Lake, and Big Lake, respectively; in Northern Prairie Wildlife Research Center archives they are labeled as 11-5, 11-17, and 10-2, respectively. *B*, July, 1963. *C*, August, 1963. *D*, November, 1963.

Changes in individual wetland levels were also measured with gages in some years. Eisenlohr (1972, p. A30) demonstrated the weekly fluctuations in 3 large wetlands at the WSA from 1963 to 1965. Clark Lake (labeled wetland 1 in fig. 5) is spring fed and naturally outflows into Fish Lake (wetland 2) and Big Lake (wetland 3; fig. 5). The outlet of Big Lake was sealed off, and an earthen dam containing a 76.2-cm culvert and a gate valve was constructed in April 1965 (Eisenlohr 1972). This retained all runoff reaching the basin, creating a more permanent wetland. Water heights for an additional 15 wetlands were recorded with gages during 1963–64. In a different dataset from 1964 to 1989, WSA staff recorded water amounts of 651 individual wetlands in and near the WSA using a subjective scale of 1 through 8. There was an average of almost 100 measurements (range 1–129) for each wetland. Both of these datasets are available at the NPWRC. Historical records also illustrate wetland dynamics. Bayha's (written commun., 1964a) social history and early maps recorded that the 3 largest wetlands at the WSA were named Clark Lake (labeled wetland 11-5), Fish or Rosella Lake (wetland 11-17), and Big or Dittbenner Lake (wetland 10-2); these are labeled 1, 2, and 3, respectively on figure 5. Bayha (written commun., 1964a) reported that all of Big Lake and part of Fish Lake were dry in 1936 during a period of severe drought, and residents were able to harvest 20 tons of hay from the basins. Nearly a century earlier, original township surveys from 1875 (appendix 5) documented these primary wetlands. Of the 3 large wetlands in the WSA, only Big Lake appeared in the original township surveys, likely because the others are not located on section lines.

Several wetlands were modified after federal acquisition with small earthwork dams. Dams and other man-made structures associated with wetlands at the WSA are mapped in appendix 6.

Wetland and Water Chemistry

Many surface waters in wetlands interact with groundwater in complex ways (Winter and Rosenberry, 1995). Wetlands tend to be connected with groundwater and exchange water and dissolved solids. Thus, dissolved solids leave a wetland through seepage outflow to groundwater or, less commonly, when a wetland overflows. Therefore, the brackishness of wetlands is determined by the rate of seepage outflow or overflow in relation to the amount of water and input of solids (Eisenlohr, 1972). Wetlands on outwash regions, such as the southeastern one-third of the WSA, tend to have greater seepage from groundwater into basins than from wetlands on till. The trapped salts create brackish or saline water in these outwash wetlands (Stewart and Kantrud, 1972).

Several studies examined water chemistry in wetlands and in groundwater at the WSA since the early 1960s. Dissolved solids in spring-fed wetland 1 (labeled in figure 5) in 1963 ranged from 740 to 800 parts per million (Eisenlohr, 1972). Wetlands 2 and 3 were sampled in 1963 and 1972, and groundwater in a private well near the WSA was analyzed in 1960 (table 2). Water chemistries of Wetlands 2 and 3 were largely consistent with each other and those of wetland 2 was consistent over time. The wetlands sampled had higher concentrations of the magnesium (Mg) and potassium (K) than the well sample, and lower concentrations of chloride (Cl^-), sodium (Na), and bicarbonate (HCO_3^-). Sulfate (SO_4^-) in Wetland 2 samples from 1963 were higher than in the 1972 samples. The specific conductance levels place the wetlands in the slightly to moderately brackish category of Stewart and Kantrud (1972). The groundwater sample from the private well is closer to moderately brackish.

Table 2. Chemical analyses of water samples collected from Well C, Wetland 2, and Wetland 3 in 1960, 1963, and 1972 at the Woodworth Study Area (WSA).

[Location of Well C is shown in figure 3; locations of Wetlands 2 and 3 are shown in figure 5. Wetland 2 was sampled in 1963 and 1972; it is also known as 11-17 by WSA naming convention or informally as Fish Lake. Wetland 3 is also known as 10-2 by WSA naming convention or informally as Dittbenner or Big Lake. Calculated dissolved solids were measured as residue at 180 ºC in parts per million (ppm). Specific conductance is in microsiemens per centimeter (µS/cm) at 25 ºC. Element and compound measurements are milligrams per liter (mg/L). Well C was privately owned, 136 m deep, and had a water temperature of 43 ºF. No data is indicated by nd.]

Attribute	Well C 1960	Wetland 2 1963	Wetland 2 1972	Wetland 3 1972
Data source	Huxel and Petri, 1963	Eisenlohr, 1972	Swanson and others, 1988	Swanson and others, 1988
Date sampled	May 9, 1960	Oct. 29, 1963	July 1972	July 1972
Calculated dissolved solids (ppm)	1,340	796	nd	Nd
Specific conductance (µS/cm)	2,060	1,070	1,160	1,300
pH	7.4	9.1	9.1	9.2
Bicarbonate (HCO_3^-) (mg/L)	677	21	nd	nd
Calcium (Ca) (mg/L)	nd	17	13	15
Chloride (Cl^-) (mg/L)	163	20	20	20
Magnesium (Mg) (mg/L)	25	97	108	130
Potassium (K) (mg/L)	12	29	24	28
Sodium (Na) (mg/L)	357	69	60	89
Sulfate (SO_4^-) (mg/L)	340	326	190	140

Atmospheric Chemistry

Surrounding land use left a fingerprint in precipitation chemistry at the WSA. Results from a North Dakota Department of Health study (Angelo and Anderson, 1983) indicated significantly greater concentration of ammonium (NH_4^+) at the WSA (table 3) than at Dunn Center, N. Dak., or Canfield Lake, N. Dak. Dunn Center is 250 km west of the WSA (appendix 7) and was in the center of coal, oil, and natural gas energy production in 1982. Canfield Lake is 90 km west of the WSA (appendix 7) between the Missouri Coteau and the Missouri River. Angelo and Anderson (1983) speculated that the elevated concentrations of ammonium may be related to the higher conversion of prairie to cropland near the WSA. Use of anhydrous NH_3 fertilizers in agricultural practices in eastern North Dakota and the appearance of ammonium in the WSA precipitation coincide with typical timing of fall fertilizer application (fig. 6). Likewise, elevated levels of manganese (Mn) at the WSA relative to sites in western North Dakota (Park North, Park South, and Dunn Center; appendix 7) may be because of greater soil disturbance near the WSA. Mn is a crustal element that is included in precipitation when the soil is disturbed. Only the differences in Mn and NH_4^+ between WSA and the western sites were statistically significant ($p<0.05$) (Angelo and Anderson, 1983).

Table 3. Concentration of ions from a rainfall sample at the Woodworth Study Area (WSA) from May to October 1982.

[At least 20 samples were tested for each compound. Concentrations are arithmetic mean concentrations in microequivalents per liter (µeq/L) ± standard error of mean concentrations. No data is indicated by nd. From Angelo and Anderson (1983, p. 20)]

Type	Ion	Concentration (µeq/liter)
Cation	NH_4^+	38.53 ± 5.15
	H^+	21.12 ± 7.94
	Ca^{2+}	16.08 ± 3.32
	Mg^{2+}	4.54 ± 0.70
	Na^+	2.03 ± 0.45
	K^+	1.52 ± 0.30
	Zn^{2+}	0.42 ± 0.20
	Al^{3+}	0.70 ± 0.22
	Mn^{2+}	0.27 ± 0.04
	Fe^{3+}	0.12 ± 0.03
Anion	SO_4	23.61 ± 4.42
	Cl^-	7.30 ± 1.49
	F-	0.48 ± 0.13
	NO_3^-	21.91 ± 2.83
	HCO_3^-	31.01 ± 6.23
	PO_4^-	1.16 ± 0.21

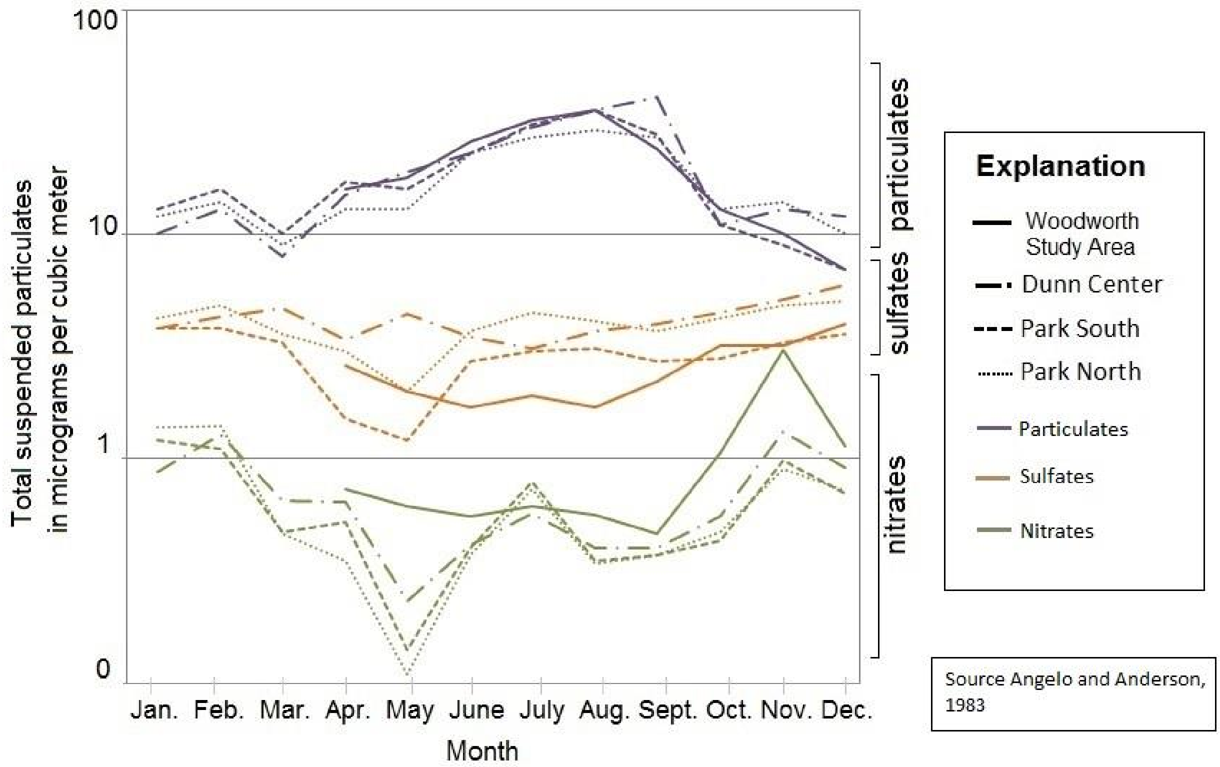

Figure 6. Monthly average concentrations of particulate pollutants at the Woodworth Study Area (WSA), Dunn Center, Park South, and Park North, North Dakota, in 1982. Locations of sampling sites are shown in appendix 7.

Weather History

Precipitation and water budgets are recognized for their importance to understanding vegetation and wetland dynamics. Data of daily total precipitation and ground cover of snow have been collected within 5 km of the WSA headquarters since 1951 as part of the National Weather Service Cooperative Network. In early 1965, 5 rain gages were placed in WSA fields and reported similar precipitation throughout the study area to precipitation collected in the town of Woodworth, N. Dak. In November 1965, official precipitation recording moved from the town to the headquarters building at the WSA, where daily collection of precipitation and snow cover data continued until 2005. Original copies of these data from 1959 to 1990 are available in the NPWRC archives and scanned documents from 1951 to 2005 are available from the National Oceanic and Atmospheric Administration (*http://www.ncdc.noaa.gov/IPS/coop/coop.html*). Daily high and low temperatures on the WSA station were recorded only for March through August of 1979 and 1980. Publications reporting long-term temperature data generally used those collected at Pettibone, N. Dak., which is 18 km west of the WSA. Other long-term temperature and precipitation measurements from the area were recorded in Jamestown or Napolean, N. Dak. (appendix 7) as part of the U.S. Historical Climate Network (*http://cdiac.esd.ornl.gov/ epubs/ndp/ushcn/ushcn.html*).

The WSA has a temperate continental climate typical of the northern Great Plains, with cold winters and warm summers (fig. 7*A*; Higgins and others, 1992). Winds averaged about 16 kilometers per hour and were from the northwest (Angelo and Anderson, 1983; Higgins and

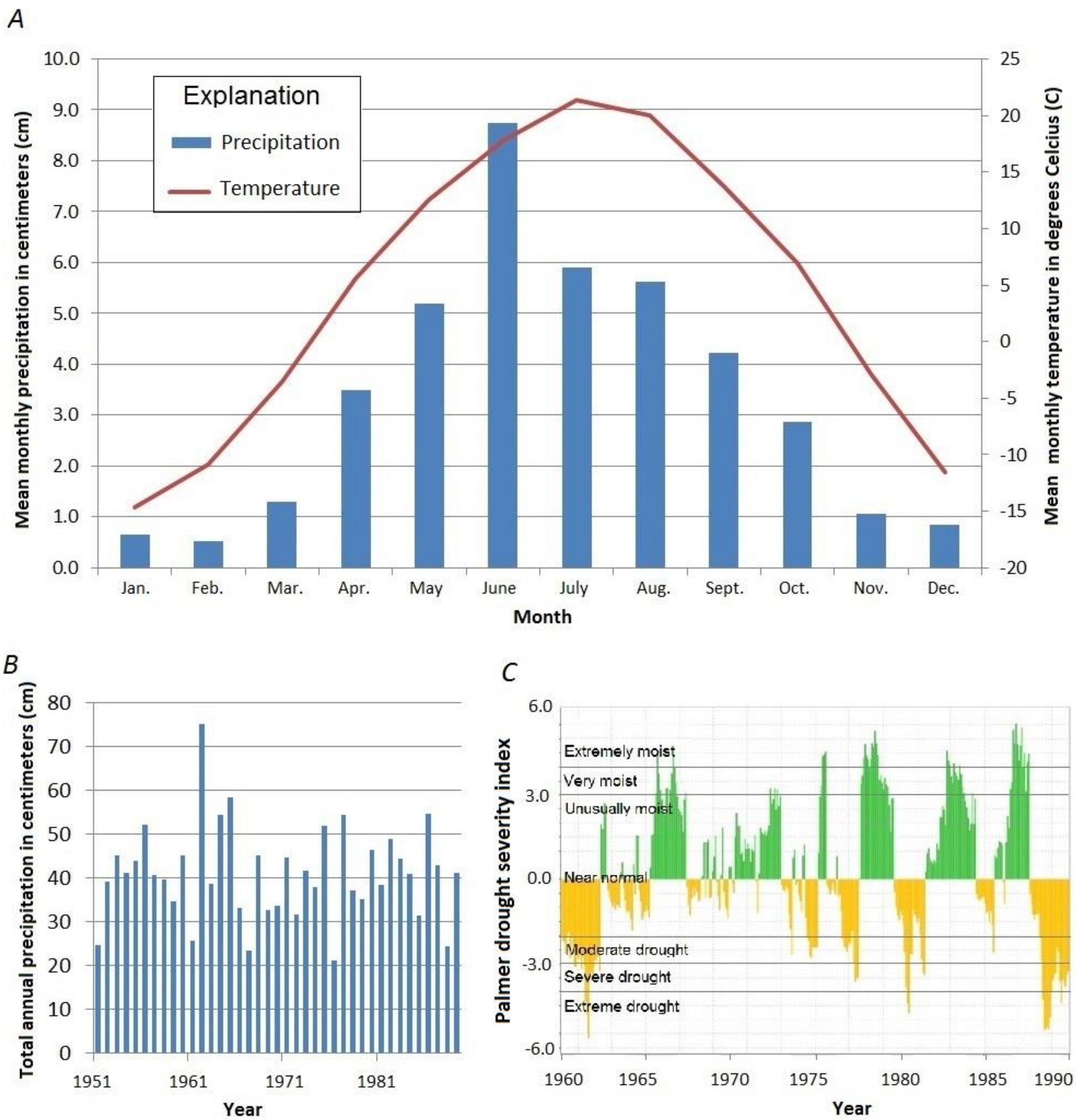

Figure 7. Precipitation, temperature, and the Palmer Drought Severity Indices (PDSI) for the Woodworth Study Area (WSA). *A,* Average monthly precipitation measured at or near the WSA (1963–89) and mean monthly temperature (1962–88) measured at Pettibone, North Dakota, approximately 19 km from the WSA (appendix 7). *B*, Total annual precipitation measured at or near the WSA (1951–88). *C,* PDSI for the south-central region of North Dakota (1960–90).

others, 1992). Average relative humidity was 68 percent. Records from 1962 to 1988 indicate that July was the warmest month in the region, averaging 21 ºC, and January was the coldest, averaging -15 ºC (fig. 7*A*). Average monthly precipitation peaked in June in the form of rain (fig. 7*A*). There were about 120 frost-free days, from mid-May to mid-September, and an average depth of frost penetration of 1.5 m (Higgins and others, 1992; Johnson and others, 1996). Between 1951 and 1988, total annual precipitation averaged 40.9 centimeters (cm; fig. 7*B*). Average annual precipitation between 1963 and 1989 was similar (40.4 cm) and ranged from 21.3 cm in 1976 to 58.5 cm in 1965 (fig. 7*B*).

The Palmer Drought Severity Index (PDSI) estimates the moisture balance accounting for inputs (such as precipitation and stored soil moisture) and losses (such as potential evapotranspiration, water storage, and runoff) (Huang and others, 2011). The PDSI provides a common metric to denote seasonal and long-term trends in moisture conditions that influence wetlands and vegetation. Scores of ±0–6 indicate level of drought (-) or wet (+) conditions. Data for the south-central region of North Dakota during 1960–90 indicate the WSA experienced moderate to extreme drought during its earliest years (fig. 7*C*). The drought of the early 1960s was followed by swings of increasing magnitude between high and low moisture (fig. 7*C*; National Oceanic and Atmospheric Administration, 2013).

Settlement History

Perhaps one of the most novel aspects of the WSA is the availability of land use history and concomitant social history. When lands for the WSA were acquired in the early 1960s, WSA staff members Keith Bayha and David Trauger made diligent efforts to document the land use history by interviewing local residents and mining public records for the history of each quarter section of land. Their sources included the Stutsman County Register of Deeds, files of the former Jamestown Alert newspaper, local officers of the U.S. Department of Agriculture’s Soil Conservation Service and Agricultural Stabilization and Conservation Service, Service books of FWS’s Area Acquisition Office, and books and direct observations by the investigators. Their results were compiled, written, and mapped by Bayha (written commun., 1963, 1964a,b). No comprehensive archaeological survey of the WSA has been completed, but Bayha (written commun, 1964a) and Mason (1938) recorded early land uses and artifacts present in the area. The NPWRC archives maintain a map of the locations of teepee ring remnants and structures created during homesteading settlement (appendix 6). The first semipermanent European settlers were livestock ranchers, some of whom built structures on the land, but nonetheless moved elsewhere when homesteaders arrived. Homesteading farmers began breaking native prairie around 1903 (fig. 8) and usually raised common flax (*Linum usitatissimum*) for the first 2 years (Bayha, written commun., 1964a). They also raised livestock and planted crops such as wheat (*Triticum* spp.) and corn (*Zea mays*). The Northern Pacific Railway cut through the area that is now the WSA, transporting grain, coal, passengers, and cream (Mason, 1938). The railway reached the town of Woodworth in 1912, 1 year after the town was established. The town grew to a population of nearly 300 in 1920, and nearly a century later the population had declined to less than 100 people (North Dakota State Data Center, 2000). The region remains wholly agricultural, and the main products today are soybeans (*Glycine max*), corn, wheat, and livestock (U.S. Department of Agriculture, 2013a).

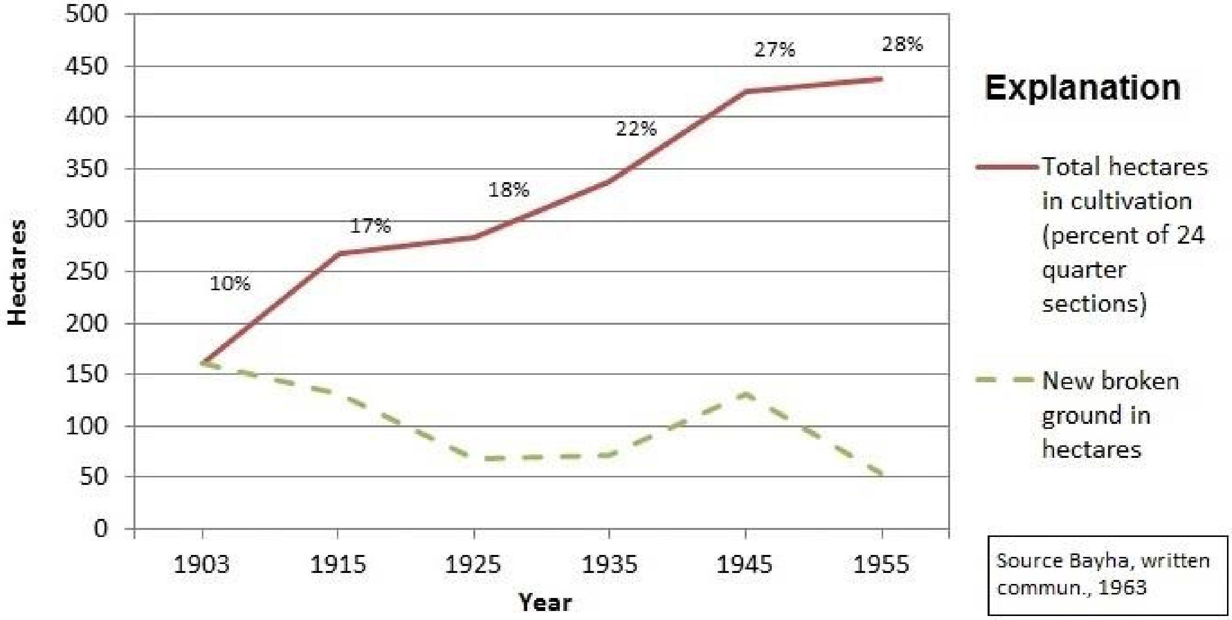

Figure 8. New broken ground and total area in cultivation of 24 quarter sections (1,550 hectares) around and including the Woodworth Study Area (WSA), 1903–55.

Social histories of the WSA and surrounding communities are preserved through Bayha's (written commun., 1964a) report as well as in documents available at institutions such as the State Historical Society of North Dakota (*http://history.nd.gov/archives/index.html*). Staff at CLWMD also compiled a small historical library. Social or cultural data are an often overlooked aspect of land use change (Higgs, 1997; Foster and others, 2003), but the resources available to the WSA offer an interesting opportunity for historical ecologists (Balée, 2006).

Management History

General Land Use History

Much of the WSA is remnant native prairie, although one-third of the area has a history of cultivation (Bayha, written commun. 1963, 1964a,b). The main road running east and west through the WSA serves as a general border between 2 historical land uses. North of the road, the soil is capable of cultivation (appendix 4), and much of that land has a history of agriculture. Land south of the road contains predominately native prairie and the soil is lower quality for cultivation. The first land acquisitions for the WSA were lands composed of 2 farms (referenced as the Eddy and Fish tracts; appendix 3). Appendix 1 contains the histories of each tract of land and the year acquired by the FWS or used for data collection. Physical features of the land look much the same as when it was managed by homesteaders with only minor changes. In addition to the wetland work and gravel pits already discussed, WSA staff planted or replanted 4 tree shelterbelts (appendix 6). A 12-row shelterbelt was planted west of the WSA headquarters in 1965. A second shelterbelt site was planted several meters north and west of this shelterbelt the following spring, and in 1970, an even larger shelterbelt was planted north and west of those plantings. Nearby willow trees growing along the station entrance road were cut to prevent snow drift across the road. A fourth grove of trees was replanted in 1967 0.75 km southeast of headquarters on a former homesteading site. The gravel mining company in the northeast corner of the WSA filled in the gravel pits and built an airstrip on the site in 1948 (Woodworth Betterment Community, 1986, p. 40). A geographic information systems (GIS) layer of shelterbelts, known structures, and remnants on the WSA is available from the NPWRC (appendixes 6 and 8).

Habitat Management

The WSA is divided into 24 units of which 17 units (1–4, 6–9, 9A, 11–13, 15–18, 22) are under federal management (fig. 9). The study units are numbered arbitrarily, although they largely follow quarter section lines and run boustrophedonically, following the conventions of township sections (appendix 6). Correspondingly, most study units are 64.7 ha (160 acres). Although a study unit and a quarter section are largely interchangeable in size, for this report, study unit refers to the WSA labeling system (fig. 9) and quarter section refers to all other geographical references. The WSA contains all or part of 6 township sections. Plat information is listed in appendix 3. Initially, WSA staff used wetlands as the basic unit of study, and thus each wetland was assigned a number within its quarter (for example, 7-10 was wetland 7 within study unit 10), but in 1967 the basic study unit was increased to the quarter section. However, because initial homesteaders worked around the many changes in soil, elevation, and wetlands, actual land use was heterogeneous within a quarter section. Furthermore, most of the federal land management and land use took place at a unit smaller than a quarter section. Hence, we use field as the current land use unit because land within a field has the same land use history and follows many natural boundaries, such as wetlands and soils. A study unit may contain as many as 12 fields. Fields are labeled numerically within each study unit starting at 1 (fig. 9).

The proportional land use of each study unit at the time of federal acquisition is shown in figure 10. Cultivation dominated study units 1, 2, 3, 6, and 7 in the north and 17 in the south, whereas native vegetation dominated land use in study unit 9, which entirely overlays an area of glacial stagnation outwash, and study units 11–15 and 18–22 in the south. Most study units had at least a small native field, and all had wetlands. Study unit 12 contained a farmstead and at the time of acquisition by FWS had more than 50 percent native cover, but that study unit was converted to the headquarters for the WSA, and later for the CLWMD.

During the first 5 years of the WSA, the land was managed in line with previous private management. During this time, the WSA was mapped and characterized (Bayha, written commun., 1963, 1964a,b), and staff developed new monitoring techniques for waterfowl surveys and nesting studies (Higgins and Woodward, 1996). Several years of habitat manipulation followed, which was applied and recorded on the field scale (fig. 11). Widespread grazing in the early years gave way to prescribed burns and seeding by the 1970s (fig. 11).

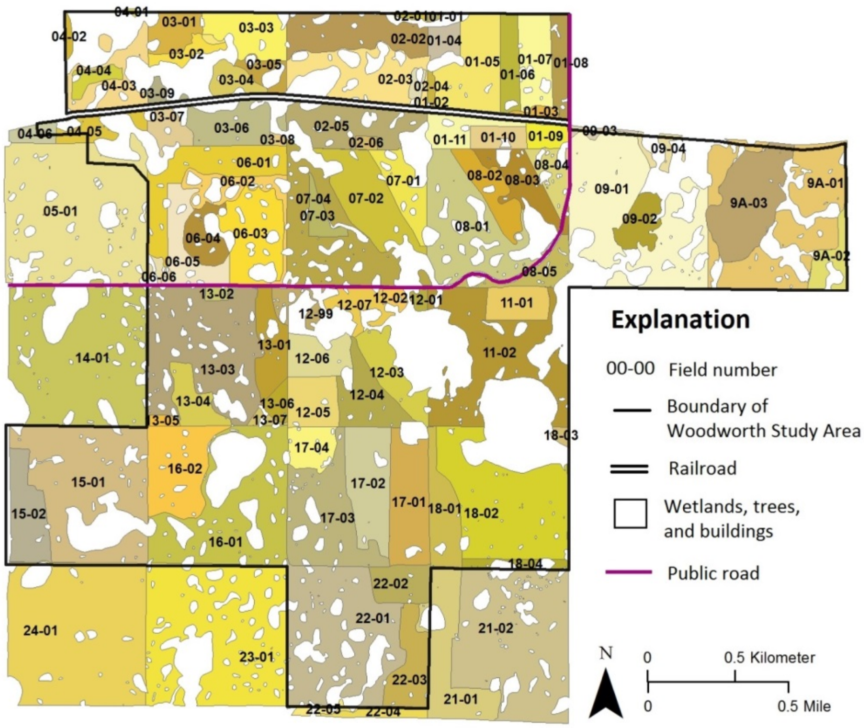

Figure 9. Numbered study units and fields at the Woodworth Study Area (WSA). Field colors are for illustration purposes only.

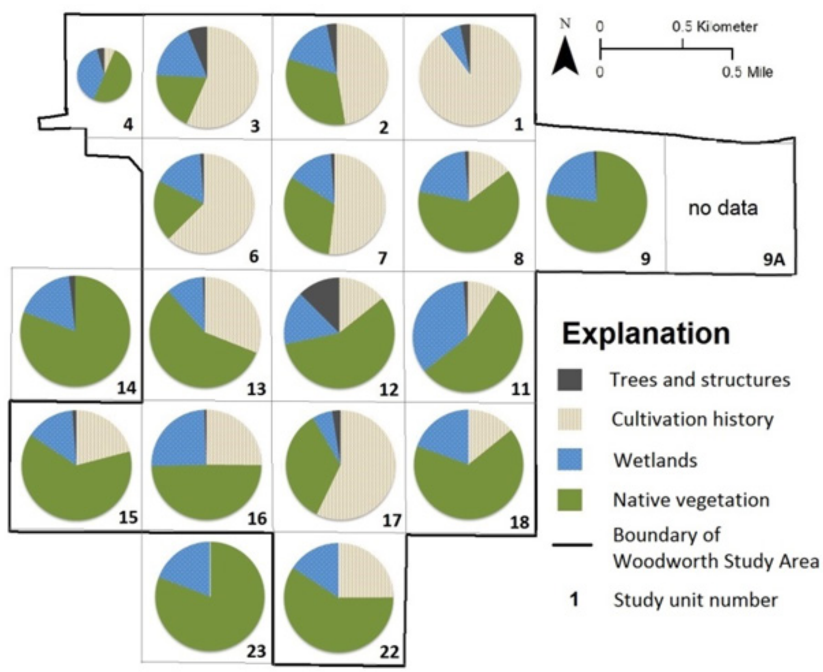

Figure 10. Land use at the time of federal acquisition or agreement to use on the Woodworth Study Area (WSA), by study unit.

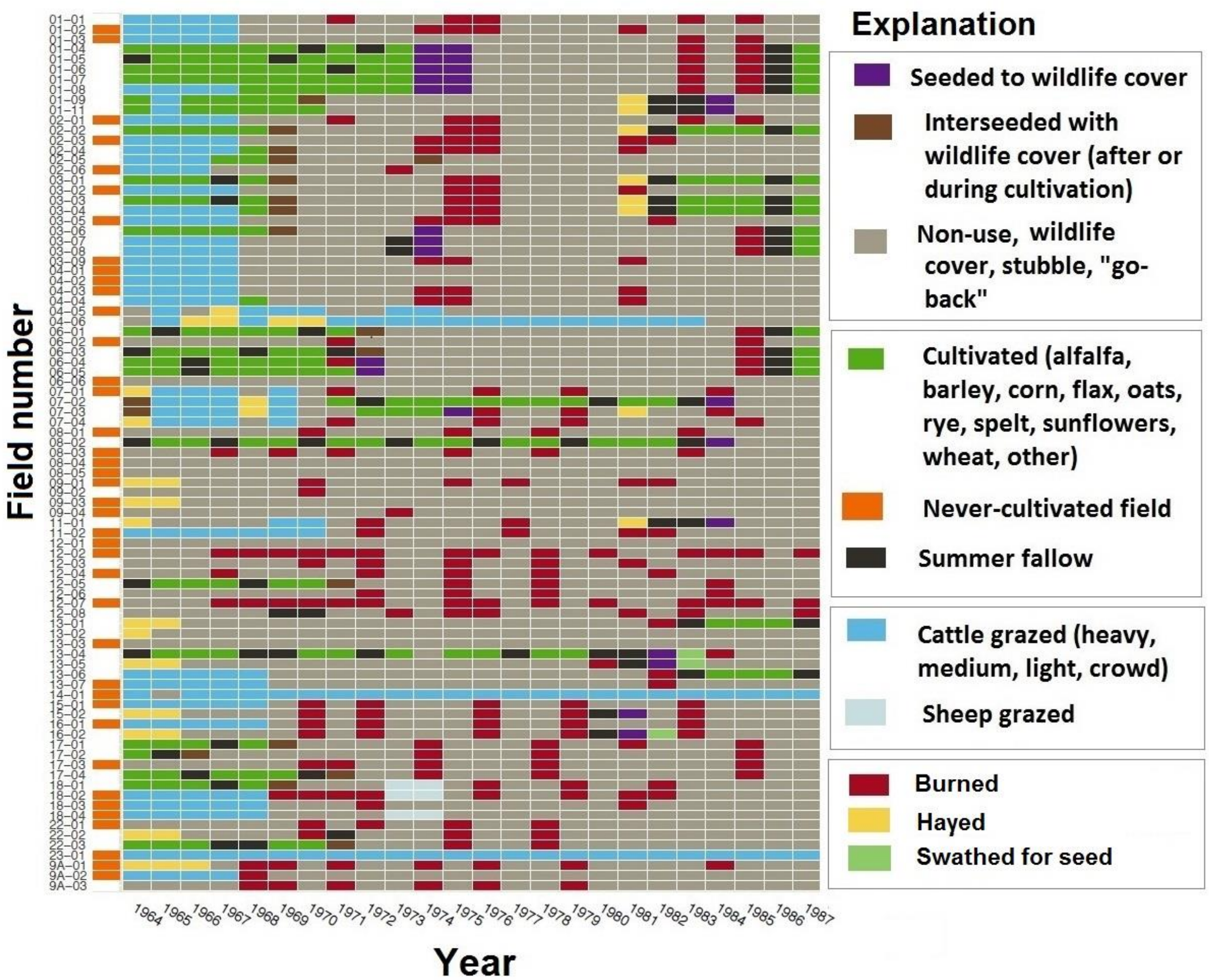

Figure 11. Land uses and treatments for all fields on the Woodworth Study Area (WSA) during 1964–87.

Some of the management practices illustrated in figure 11 can be difficult to define precisely. To facilitate analysis and synthesis, the working definition of land treatments applied at the WSA and the resulting land cover are described in table 4. The definitions follow Kantrud and Higgins's (1992) convention of distinguishing land use and land treatment based on time. For example, fallow refers to idling tilled land during a growing season; this was a common crop rotation practiced in the PPR through the 1960s. The lack of vegetative cover makes fallow fields subject to erosion or soil loss (Gleason and Euliss, 1996), so a field is generally left fallow for only one season in preparation for seeding in crops or nesting cover. Therefore, fallow is a short-term treatment that can be applied to fields of various land uses or cover (such as a long-term pasture or cultivated field). Three other treatments that were commonly applied at the WSA were prescribed burning, seeding, and grazing.

Table 4. Working definitions of actions applied to land at the Woodworth Study Area (WSA).

[Actions are land management treatments or experimental activities applied at WSA. Definitions are gleaned from WSA reports, publications, and unpublished memos, and summarize the action as used at the WSA.]

Action	Definition
Burned	Prescribed, accidental, or wildfire.
Cropland	Cultivated or hayed broken field.
Fallow	Cropland, then idled for one season.
Old field succession or “go-back”	Pre-1960s cropland, which was idled for more than one season.
Grazed	Grazed with sheep or cattle in low, medium, high, or crowd-grazed intensities.
Man-made	Buildings, dams, or shelterbelts.
Native prairie	Never cultivated.
Tame or seeded grassland	Seeded with domestic forage or nesting cover.

Burning

Burning was a management tool developed and regularly applied at the WSA. The prescribed burning work during the 1960s and 1970s (fig. 11) provided new information on its use in maintaining optimum grassland conditions for nesting waterfowl, other migratory bird species, and resident wildlife species. The research and demonstrations were instrumental in leading FWS to embrace fire as a valuable management tool (for example, Higgins and others, 1989a). More than 200 separate burns were recorded from 1965 to 1984 on the WSA; the vast majority was prescribed, but 5 were wild fires or accidentally caused. Data include field location, date, time, weather, and logistical information. Areas from 0.4 to 65 ha were burned at one time, and the average burn covered 12 ha. Most fires occurred in the spring but timing ranged from February to November (fig. 12). The frequency of burns of a particular field varied. Several patterns of frequency emerge from figure 12, including many repeated fires, sporadic fires, and never burned under federal management. For example, fields 12-2 and 12-7 received yearly burns, whereas some fields in study units 15 and 16 received burns every 2–4 years (fig. 11). Maps of prescribed burns by year and a GIS layer of fire breaks, such as trails and roads, are available in the NPWRC archives. From 30 to 50 km of bare-soil fire breaks were tilled several times per season, but a few fire breaks established on section lines were graded rather than tilled.

Aside from research studies, prescribed burns were applied for other purposes, such as to stimulate seed head production on wild rye (*Elymus* sp.) for a harvestable seed crop, to evaluate effects on cattails (*Typha* sp.), or to remove annual weed seeds. For example, a 1977 memo (Kirsch, L., written commun.) notes that a treatment plot with 3 prescribed burns at 3-year intervals concurrent with dry weather reduced cover of non-native grasses by more than 90 percent, whereas cover of native grasses increased more than 70 percent. In a control plot over the same period, native grass cover decreased 31 percent, whereas non-native grass cover increased 14 percent.

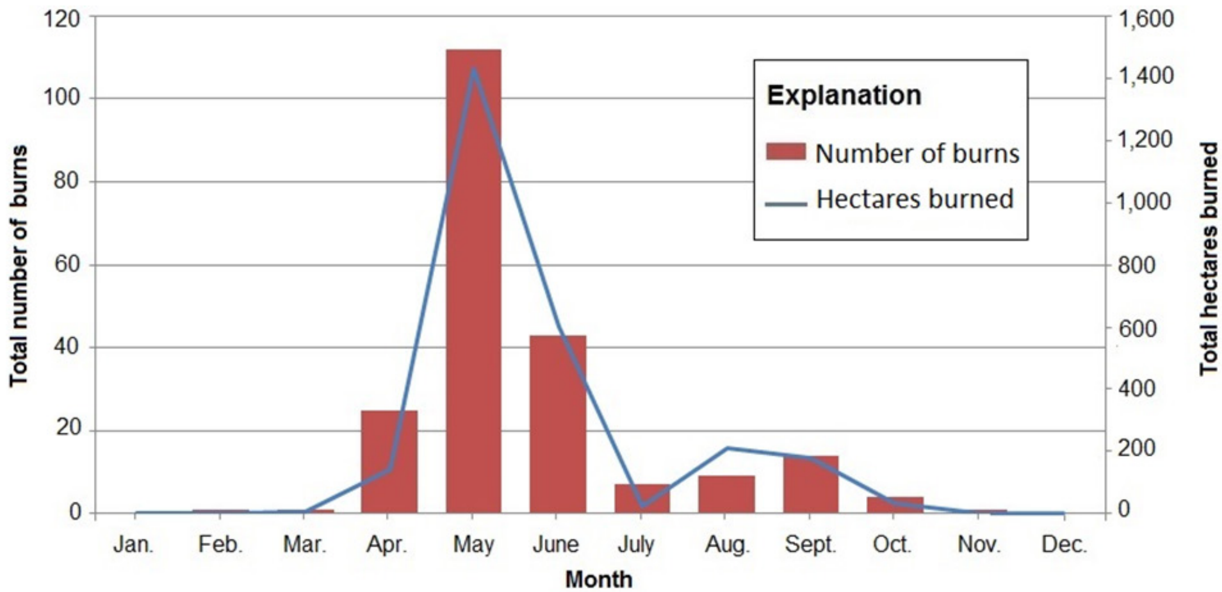

Figure 12. Total number and hectares of prescribed burns per month at the Woodworth Study Area (WSA) during 1965–84.

WSA staff published reports on various aspects of fires based on experience at the WSA, including guidelines (Higgins and others, 1989a), management reviews (Higgins and others, 1989b), effects on breeding birds (Johnson, 1976), fires caused by lightning (Higgins, 1984), fires that did not go as planned (Higgins, 1978), and effects on vegetation and wildlife (Kirsch and Kruse, 1973; Kirsch and Higgins, 1976; Kirsch, 1978).

Seeding

Another treatment often applied at the WSA was seeding cover. Seeding a tilled field to create nesting cover is variably referred to as wildlife cover, tall dense rank cover, or dense nesting cover by state and federal wildlife agencies. However, the same field may be called forage or tame hayland by farmers and ranchers, or land retirement cover or wildlife cover plantings by agriculture agencies (Higgins and Barker, 1982). The WSA records generally use the wildlife terms but also use tame hayland term.

Seeded fields shared a history of cultivation occurring either before the 1960s (fields that had become tame hay or “go-back” fields by the time of federal management; fig. 11) or after the 1960s (considered cultivated fields; fig. 11). The NPWRC archives document specific seed combinations for some fields, such as in field 3-6. This field was first broken around 1910 (Bayha, written commun., 1964a) and had regular cultivation until the early 1970s (fig. 11). The standard preparation for a field was to plow it in the fall and leave it fallow the following summer to kill aboveground vegetation and rhizomes (Higgins and Duebbert, 1982). After a year of summer fallow, field 3-6 was seeded in June 1974 to a mixture of wheat and other seeds to create tall, dense, rank cover. The seeding mixtures for this and 3 other fields are listed in table 5.

Table 5. Seeding mixtures used on a sample of fields at the Woodworth Study Area (WSA).

[Study units refer to the location, following WSA convention, which contained the field that was planted. All values of seeding mixtures are in kilograms per hectare (kg/ha), with pounds per acre (lb/ac) in parentheses. Wheat was also included in the mix for some fields.]

Species	Study unit 1 [kg/ha (lb/ac)]	Study unit 2 [kg/ha (lb/ac)]	Study unit 3 [kg/ha (lb/ac)]	Study unit 6 [kg/ha (lb/ac)]
Date seeded	August 19, 1974	June 3, 1974	June 3, 1974	May 1972
Intermediate wheatgrass *Thinopyrum intermedium*	6.7 (6)	4.5 (4)	4.5 (4)	6.7 (6)
Tall wheatgrass *Thinopyrum ponticum*	2.2 (2)	4.5 (4)	4.5 (4)	3.4 (3)
Alfalfa *Medicago sativa*	2.2 (2)	1.1 (1)	1.1 (1)	2.2 (2)
Yellow sweetclover *Melilotus officinalis*	1.1 (1)	1.1 (1)	1.1 (1)	2.8 (2.5)

Several studies of grassland establishment were conducted at the WSA with a focus on how to establish wildlife cover using appropriate seed mixtures and techniques. Jacobson and others (1994) seeded a 12-ha field at the WSA in 1981 using "sculpted" seeding, which planted seeds according to changes in soil and topography; Higgins and Duebbert (1982) reported on the seed bed preparation for this field. Duebbert and others (1981) published a comprehensive seeding guide for managers throughout the glaciated PPR and presented a review of this topic (Duebbert, 1983), as well as a proceedings paper (Duebbert, 1987). The NPWRC also published a pamphlet on seeding methods for wider distribution to the public (Meyer, 1987).

Meyer (1996) recorded that "by 1970, more than 200 ha of former cropland were seeded into mostly non-native, cool-season grasses and legumes. The primary grass species were intermediate wheatgrass (*Thinopyrum intermedium*), tall wheatgrass (*Thinopyrum ponticum*) and slender wheatgrass (*Elymus trachycaulus*), and the legumes were alfalfa (*Medicago sativa*) and yellow sweetclover (*Melilotus officinalis*). Two fields were seeded into basin wild rye (*Leymus cinereus*)." Meyer (1996) also reported that the WSA hosted experiments of "native grass seedings during the mid-1970s. About 15 percent of the area was seeded with native grasses by 1980. The principal cool-season species were green needlegrass (*Nassella viridula*) and western wheatgrass (*Pascopyrum smithii*). Some fields were over-seeded with warm season species including switchgrass (*Panicum virgatum*), big bluestem (*Andropogon gerardii*), and Indian grass (*Sorghastrum nutans*)."

The combination of intermediate wheatgrass, tall wheatgrass, alfalfa, and sweetclover was planted at the WSA because these species were relatively easy to establish and they created good habitat for nesting ducks (Duebbert and others, 1981). This species combination was adaptable to many soils and conditions throughout the PPR and could enhance the soil when used in rotation with tillage (Duebbert and others, 1981). Cool-season plants, such as tall and intermediate wheatgrasses, were in general easier to establish than native, warm season grasses even though they need rejuvenation sooner than native species. For example, intermediate wheatgrass deteriorates in height, density, and vigor after 8–10 years (Duebbert and others, 1981).

Higgins and others (1984) discussed 3 fields that were seeded to native grasses in 1981 and 1982. In the publication, they refer to fields 1, 2, and 3 (equivalent to WSA conventions fields 15-2, 16-2, and 13-4, respectively; figs. 9, 11). After leaving the fields in summer fallow, the fields were seeded the following year to a combination of cool- and warm-season grasses. The fields were then subjected to a burning, swathing, or herbicide regime (see Higgins and others, 1984, for details). The costs of re-seeding a field were offset by harvesting seeds from existing WSA fields (for example, study unit 16 in 1982) and proceeds from crop-sharing and grazing agreements with local producers.

Grazing and Agriculture

Cattle and sheep historically grazed on the WSA before and during federal management (Bayha, written commun., 1964a, b; fig. 11). Grazing by cattle was recorded on almost one-half of the fields in the 1960s (fig. 11), and the intensity was classified as heavy, moderate or light. Kirsch (1969) gave one early definition of those terms at the WSA; grazing intensity was judged by residual vegetation left in the spring before new growth commenced. If two-thirds of the vegetation remained, the pasture was classified as lightly grazed. Between one-third and two-thirds remaining was moderate, and less than one-third remaining was heavily grazed. At the WSA, light, moderate, and heavy grazing corresponded to 1 animal unit month per 6 acres (2.4 ha), 1.35 acres (0.55 ha), and 1.0 acre (0.4 ha), respectively (Kirsch, 1969). Grazing records for the WSA are in hardcopy, primarily in the form of contracts and receipts from private producers. WSA researchers analyzed grazing effects on upland nesting waterfowl pair numbers, nesting densities, and nest success (Kirsch, 1969), and waterfowl distribution, abundance, and productivity (Kirsch and others, 1978). However, little to no analysis has been conducted on the effects of cattle grazing on the vegetation. The general effects of grazing and burning on prairie wetlands were reviewed by Kantrud (1986).

Sheep grazing is noted in a 1973 memo (L. Kirsch, written commun., 1973), which recorded sheep on nearly the entire study unit 18. Under contract with a livestock owner, about 550 sheep and lambs were pastured in study unit 18 from July 29 to October 1, 1973. WSA staff recorded qualitative descriptions of vegetation during sheep grazing. The sheep were noted as patchy eaters, cutting grass short in places and leaving other areas untouched. Forbs were heavily browsed, and sheep preferred alfalfa after the rains started in mid-August. The following spring, 450 ewes and 650 lambs were again grazed on this unit from late May to mid-July 1974 (fig. 11), and the effects were described in various memos.

In addition to qualitative descriptions, researchers also conducted controlled experiments of sheep's effect on vegetation. Four controlled plots were placed in study unit 18 for enclosure/exclosure experiments (appendix 8), and stem counts were recorded in 1973 and 1975. Researchers were particularly interested in the effects of sheep browsing on wolfberry (*Symphoricarpos occidentalis*), silverberry (*Elaeagnus commutata*), and Wood's rose (*Rosa woodsii*).

Chemicals

Chemicals and fertilizers have been applied periodically both for land management and experimental reasons. For land management, Banvel® (dicamba) was used for treatment of leafy spurge (*Euphorbia esula*) at 7 points across the WSA (fig. 13). Knapweed (*Centaurea* sp.) was treated with consecutive years of Tordon® (picloram), Banvel®, and 2,4-D (2,4-Dichlorophenoxyacetic acid) applications along with aggressive weeding. No records were apparently kept on the outcomes of these efforts.

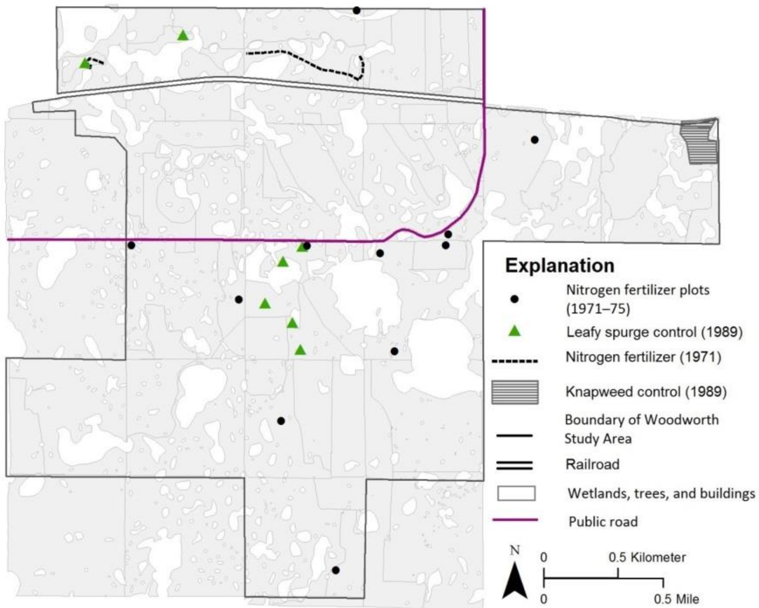

Figure 13. Location of chemical treatments for control of undesirable species and fertilization on the Woodworth Study Area (WSA). The background map is delineated into functional fields which share a homogenous land-use history.

Seeding a field after a summer fallow offered weeds opportunities to take hold. Plants such as lambquarters (*Chenopodium album*), annual marshelder (*Iva annua*), absinth wormwood (*Artemisia absinthium*), and field bindweed (*Convolvulus arvensis*) were sprayed several times with 2,4-D to stop their establishment in new fields (Higgins and Duebbert, 1982).

Experimental applications of fertilizers were tested on the WSA from 1971 to 1975 (appendix 9; fig. 13) to expand on results from nearby research plots of the U.S. Department of Agriculture. Lorenz and Rogler (1971) reported that semiarid grasslands of the Northern Plains did not appear to be primarily limited by soil moisture, and that nitrogen application increased forage production on seeded or native prairie. Soon after, WSA researchers similarly tested the use of nitrogen fertilizer in 11 native and seeded plots (fig. 13). The plots were placed throughout the WSA from high ridge to low prairie (fig. 13). Treatments were also stratified by plot treatments of grazing, burning, and an idled control plot. Each of the 11 plots was divided into 7 strips and 7 controls. Nitrogen (34-0-0) was applied once in spring 1971 to each of the 7 treatment strips with the plots at rates of 56–673 kg per hectare. Researchers revisited the plots in late summer from 1971 to 1975 and measured the average height of vegetation crowns of grass and percent cover of plant species. Results from the tests are reported only as unpublished data belonging to K.F. Higgins in Duebbert and others (1981, p. 19). The report states that preliminary analysis indicated a significant difference in crown height between fertilized and control plots. Furthermore, nitrogen treatments of less than 112 kg/ha increased plant height for 1–2 years, whereas applications of 280–673 kg per hectare increased grass height for 3–5 years, generally relative to the amount applied.

In treatments separate from that unpublished test, nitrogen fertilizers were applied to isolated strips of land in study units 2 and 4 in 1971 at a rate of 280 kg/ha (dashed line in fig. 13). Nitrogen, phosphorous, and potassium were also applied to select fields from 1969 to 1975 (appendix 9).

Vegetation Surveys

General Vegetation Description

In the post-glacial landscape, grassland vegetation was a product of increased aridity, greater frequency of drought, ensuing fires, and intermittent foraging and trampling from herbivores. These factors kept shrubs and trees sparse, although they occur throughout the grasslands, implying that aridity is not the limiting factor for trees and shrubs (Axlerod, 1985). The WSA and, more broadly the Missouri Coteau, are in the mixed-grass prairie, which is botanically distinct from the tallgrass prairie to the east and shortgrass prairie to the west. The grasslands of the northern Great Plains have few endemic taxa and most occur near borders with other ecosystems (Axlerod, 1985). Axlerod (1985) attributed these patterns of endemism of grassland plants to the relatively young landscape compared to bordering forest or desert biomes.

The WSA lies at an important location for measuring plant biodiversity because a greater variety of species grow where there is topographic variation (Coupland, 1979). Woody vegetation at the WSA is patchy because of the hummocky topography and occurs in thickets where soil and slope are discontinuous. Distinct data collections of upland vegetation include an initial survey of vegetation (1963), vegetation structure (1974–89), 2 sets of upland plant transects (1966–84 and 1979–81), plant phenology (1979–84), and photograph stations (1970–89). A list of the 450 plant species present in the WSA from 1966 to 1989 is in appendix 10. This list is cumulative and was compiled from unique plant species noted in several surveys. The NPWRC herbaria collections contain 191 samples of plants collected at the WSA (appendix 11). Publications that used these datasets are in appendix 2. Note that no data were collected for biomass or other measures of aboveground productivity.

Early Studies

Early studies of the area's vegetation were modeled after those conducted by the FWS in Canadian parkland areas of Alberta and Saskatchewan (Higgins and others, 1992). Studies were largely qualitative or observational in nature. In 1963 and 1964, baseline surveys of the WSA wildlife, vegetation types, water, and physical characteristics were conducted (Bayha, written commun., 1964b). In the first year, those surveys included 583 ha of federal land and 85 ha of private land, and in the second year they included 1,554 ha (Bayha, written commun., 1964b). A field inspection of plant species composition was used to map partial land use history and vegetative characteristics present in 1963, and the complete WSA in 1964 (fig. 14, from Bayha, written commun., 1964b). Vegetation around wetlands was characterized according to principal species and abundances. These data are available in hardcopy in the NPWRC archives. Non-native fields were characterized by the dominant use or cover as hayed, grazed, cultivated, or not used (fig. 11). Native prairie was further surveyed by establishing transects in 1963 (fig. 15). Native fields were categorized at each ten-step interval along the transects as upland prairie, slope prairie, lowland prairie, or brush (fig. 16). Plant species were also recorded at the intervals and were reported in Bayha (written commun., 1963, 1964b) along with qualitative abundance values (fig. 16). These data provide an early documentation of species distribution by topographic location.

Long-term Vegetation Transects

An accidental burn during 1966 on the WSA resulted in noticeably increased growth of desirable grass species. Transects were established to test whether prescribed fire could be a management tool for prairie vegetation composition, and this was expanded to test additional treatments such as grazing, haying, or nonuse. The first systematic and quantitative vegetative surveys at the WSA were conducted by R. E. Stewart and L. Kirsch on November 23, 1966. Two transects were created initially: 1 in the northeast corner of study unit 8 and the second in study unit 12 (fig. 15). Five additional transects were established in 1968, 2 of which were discontinued in 1972 (fig. 15). As many as 13 transects were established, although a maximum of 12 were surveyed in any 1 year (fig. 15). Transects ranged from 215 m to 425 m long and included 7–14 sampling points or "stations." The fields containing transects were mostly upland, native grassland sites, but 1 was on a "go-back" field, and several stations were in or near wetlands.

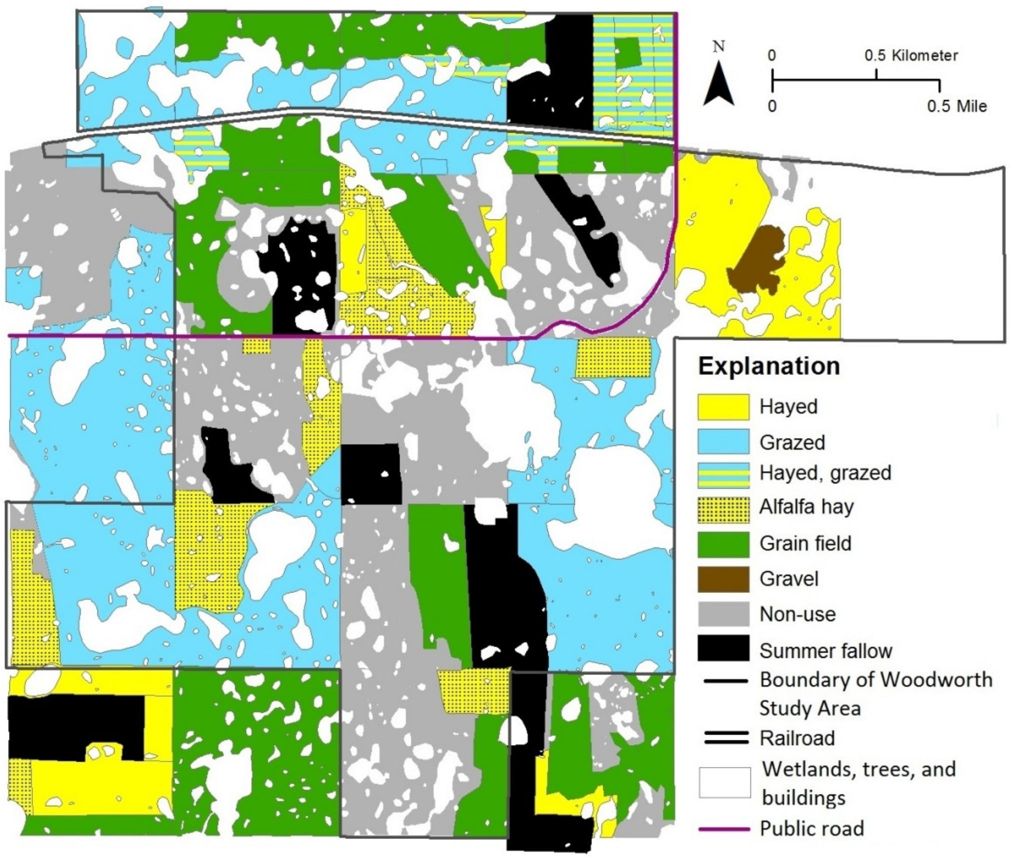

Figure 14. Land uses of the Woodworth Study Area (WSA) under federal management in 1964. Digitized from figure 10 in Bayha (written commun., 1964b).

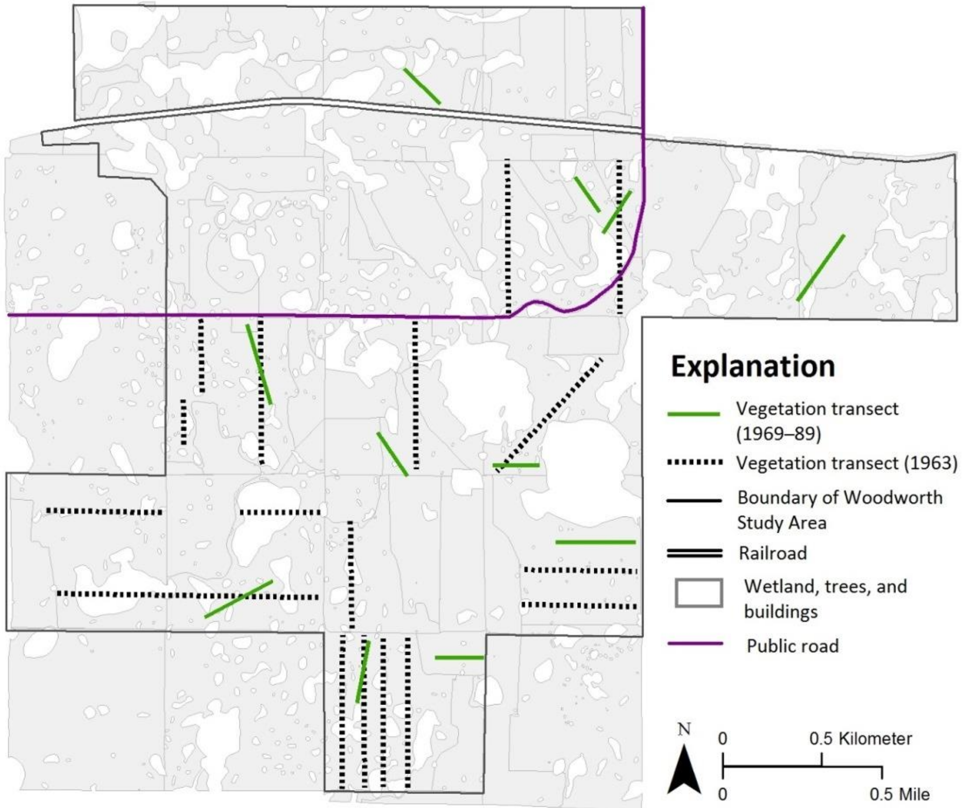

Figure 15. Locations of long-term vegetation transects (1966–89) and early vegetation transects (1963). The background map is delineated into functional fields which share a homogenous land-use history.

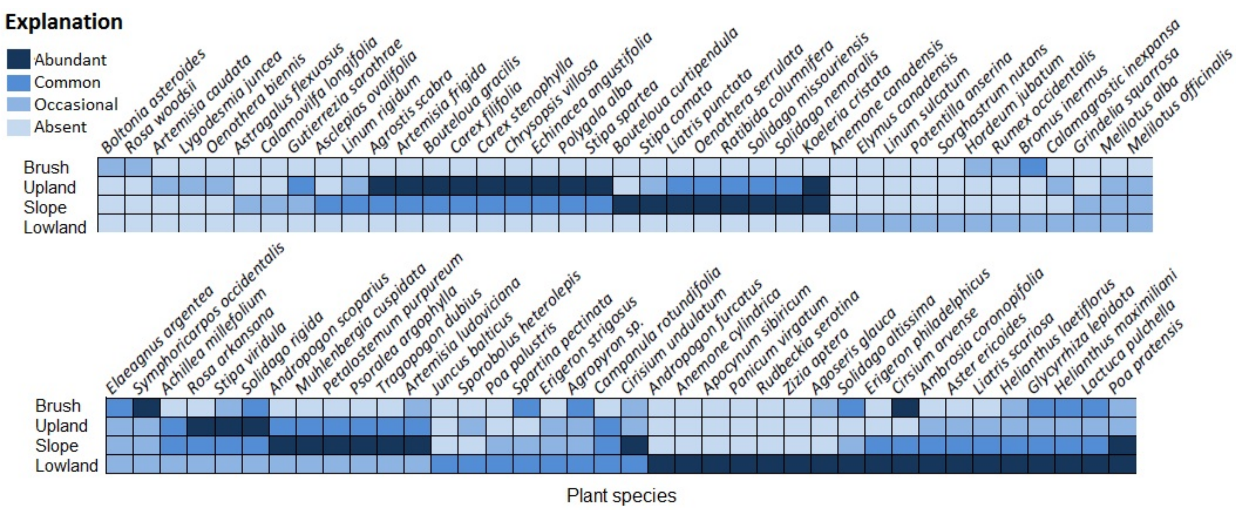

Figure 16. Relative abundance of plant species surveyed in native fields at the Woodworth Study Area (WSA) in 1963, by their location in brush, upland, slope, or lowland areas.

Stations were surveyed once per year in summer or fall (Johnson and others, 1996). The methods generally followed the Daubenmire (1959) method, using a 1.5 m × 1.5 m quadrat. Vegetation was recorded by aerial coverage of each species based on percent coverage levels of less than 5, 5–25, 25–50, 50–75, 75–95, and 95–100. Environmental data recorded at each station included soil type, moisture, slope, and aspect, as well as land uses such as grazing, idle, or burning. The end points of the transects were physically marked using steel t-posts. From 1966 to 1972, the sampling stations were located by counting paces. In 1973, the individual stations were permanently marked by a 1-inch diameter pipe. These were pounded flush to the ground to prevent chain drags from catching (K.H. Higgins, oral commun., 2014). Hence, the number of stations in each transect was consistent during 1973–89, and station data may be compared year to year. Data are available from the initial survey in 1966 through August 16, 1989, when regular transect surveys were discontinued. Johnson (written commun., 1982) summarized methods and data collected from 1966 to 1982 in an unpublished report. About 230 plant species were identified on the transects during that time, and since Johnson's analysis, more than 25 new species were identified on the transects (fig. 17).

Johnson (written commun., 1982) discussed challenges of this dataset and study design, such as plant data being inherently non-independent from 1 year to the next because some grassland plants persist perennially. Annual differences in staff and volunteers conducting the surveys may have introduced some inconsistencies, although this information is recorded and available for 1966–81. Inconsistent sampling dates (May to November; fig. 18) may introduce some longitudinal inconsistencies into the dataset. Finally, the design of the long-term transects is unbalanced in terms of number of replicates per treatment (Johnson, written commun., 1982).

Data from 4 of the 13 transects were reported by Kirsch and Kruse (1973), but other than Johnson's unpublished report (written commun., 1982), vegetation data from these long-term transects have not been summarized or analyzed before this report. Digital data and paper copies of the original data are available in the NPWRC archives.

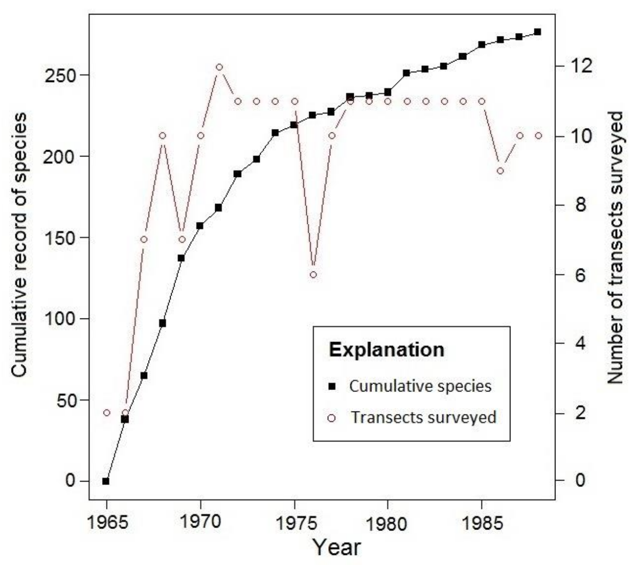

Figure 17. Cumulative number of species recorded and number of long-term transects surveyed on the Woodworth Study Area (WSA) during 1966–89.

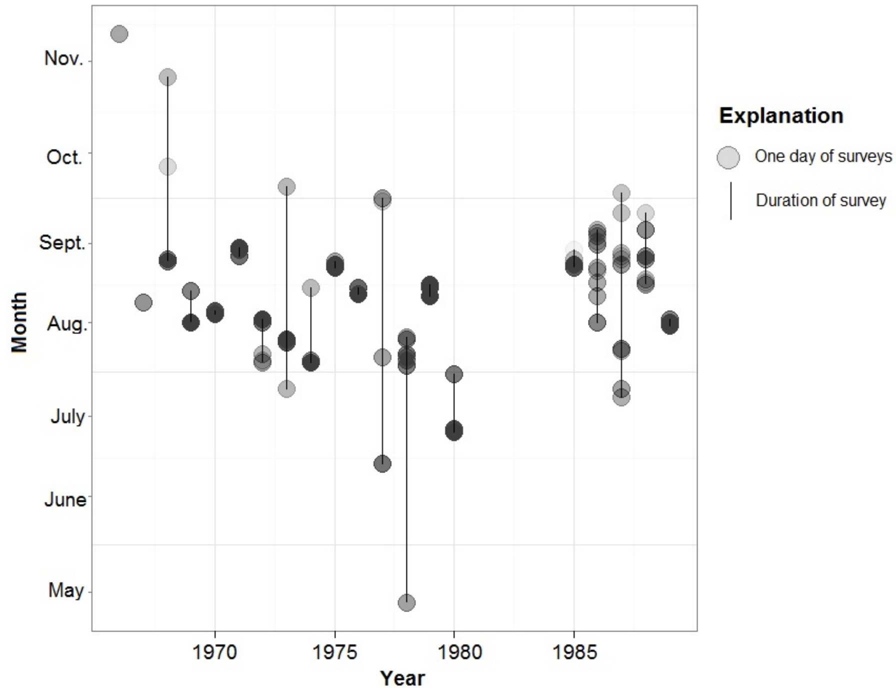

Figure 18. Survey dates for long-term transects at the Woodworth Study Area (WSA) during 1966–89. Darker shading of circles represents greater number of transects surveyed on the same day.

Meyer 1980 Vegetation Transects

A separate set of vegetation transects were established and surveyed in 1980 by Meyer (fig. 19) to provide additional quantitative results that would help interpret these data from other on-going transect surveys. The objectives of this study were to collect voucher specimens of vascular plants occurring at the WSA; describe natural plant communities; relate them to soil, aspect, and land use; and to map the mosaic of vegetation types throughout the WSA. Thus, the transects for this study were chosen to represent vegetation from several soil type, slope, and aspect combinations. Forty-two transects were established (fig. 19), and each had a number of 1 m × 0.5 m stations depending on the size of the transect. There were 292 stations spaced 3–4 m apart along each 32-m transect. Each transect was marked at the beginning and end with 30-cm tent stakes (K.H. Higgins, oral commun., 2014). Cover abundance was assessed using a modified Braun-Blanquet (1932) method similar to the long-term transects (aerial percent cover categories of 0–1, 1–10, 10–25, 25–50, 50–75, 75–90, and 90–100). These transects were surveyed between July 9 and August 19, 1980. All native vegetation was classified into 5 communities and mapped (fig. 20).

Results from the survey were published (Meyer, 1985), and copies of the original field cards are available at the NPWRC. As of 1980, WSA's 587 ha of native grasslands included 432 ha of mixed grass, 87 ha of shrub, 42 ha of tall grass, 14 ha of forbs, and 3 ha of trees (fig. 20; Meyer, 1985). Additional products were generated from this study but are unpublished. Meyer surveyed all study units of the WSA on a sub-field scale and noted dominant vegetation; original data sheets are available in the NPWRC archives. Also, the plant communities of 3 select study units were mapped in detail (fig. 21). Voucher specimens of vascular plant species were collected and are stored in the herbaria at the NPWRC (appendix 11) and the WSA.

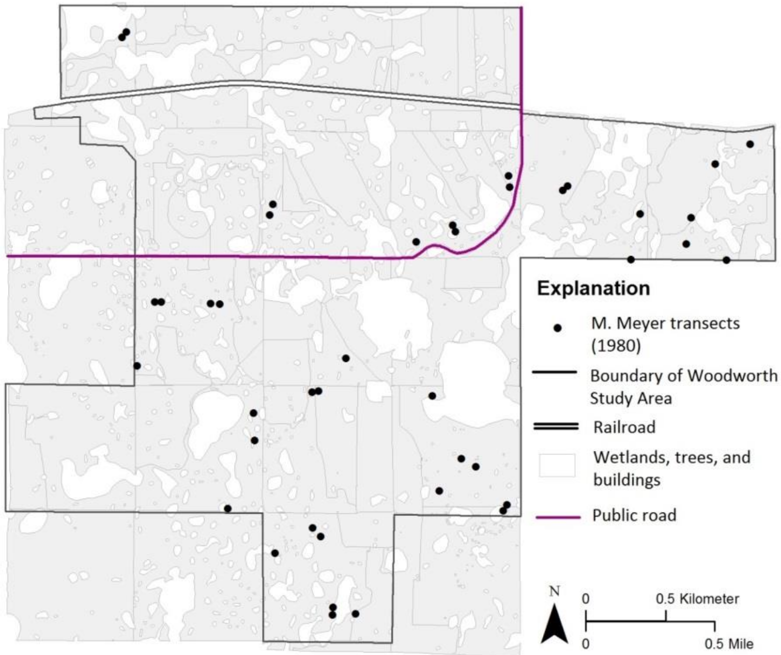

Figure 19. Approximate locations for the known vegetation transects surveyed in 1980 by Meyer (1985). The background map is delineated into functional fields that share a homogenous land-use history.

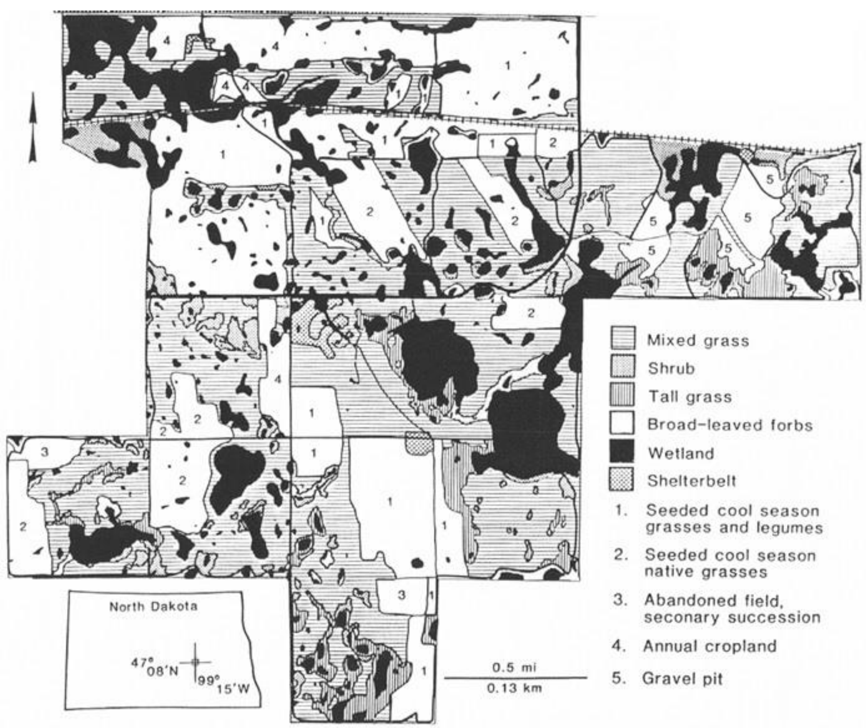

Figure 20. First thorough vegetation map at the Woodworth Study Area (WSA). From Meyer (1985: fig. 1), reprinted with permission.

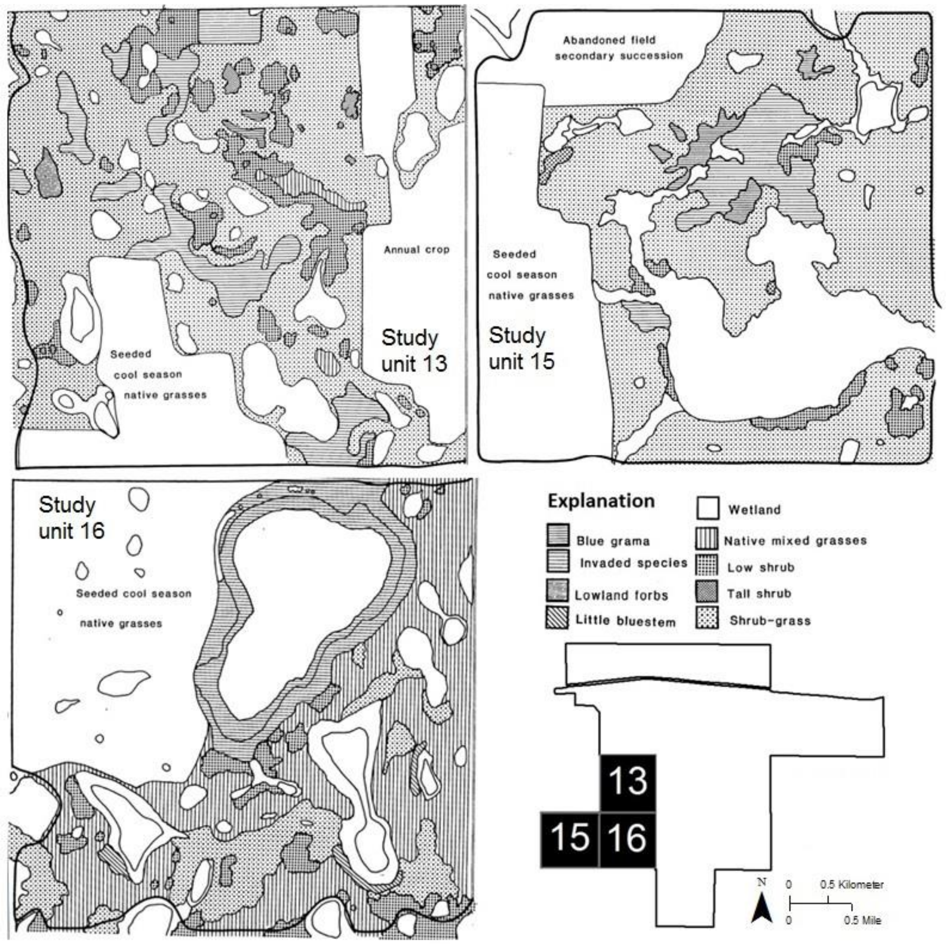

Figure 21. Detailed plant community maps of 3 study units of the Woodworth Study Area (WSA) from Meyer's 1980 surveys.

Plant Phenology

Several surveys of plant phenology have been conducted at the WSA. The most extensive was Callow and others' (1992) bloom survey, which was conducted during 1979–84. They recorded bloom stages for 97 native and introduced angiosperms at the WSA. Variables included date of first flowering or emergence, first 10 flowering individuals, full flowering aspect, flowering 95 percent complete, last flowering, and start of seed dissemination. A summary of each plant over the course of the study was published in Callow and others (1992). Paper data cards, recording each plant by year rather than summarized over the study, are kept in the NPWRC archives. The cumulative list of plants occurring at the WSA around that time identified more than 300 species, so the Callow and others' study included about one-third of all plant species recognized at the WSA at the time of the study.

Preceding Callow and others, 2 short phenology surveys were conducted at the WSA in 1975. On May 22, 1975, Stewart (written commun., 1975) recorded 32 species in bloom and 4 species with well-developed flower buds. During the course of a 6-hour survey on August 6, 1975, Stewart and Kantrud (written commun., 1975) recorded 190 species in fruit or flowering at the WSA. It is unclear what type of field or cover either survey traversed.

Vegetative Structure

Managing grasslands for nesting waterfowl was a focus of much of the work at the WSA. By the 1930s biologists recognized the importance of vegetative cover to attract nesting ducks and protect their nests from detection by predators (for example, Grange and McAtee, 1934; Williams and Marshall, 1938). Several species, particularly mallards (*Anas platyrhynchos*) and northern pintails (*Anas acuta*), begin nesting in early April before the new vegetation growth begins (Higgins and others, 1992). Therefore, residual vegetation from the previous growing season is important to spring-nesting ducks in the PPR. Kantrud and Higgins (1992) concluded that nesting birds respond to the structure of vegetation, especially height-density and litter layer, more than the specific plant species that were present. Terrestrial bird communities of the northern Great Plains were similarly influenced by vegetation structure, height, soils, and grazing effects (Kantrud and Kologiski, 1982).

The amount of vegetative coverage, i.e., the quality of nesting cover, is a combination of the height and density of the vegetation. To measure these 2 factors, researchers at the WSA used 2 methods. From 1964 to 1975, they created and used a subjective method where in the early spring each field was assigned a cover value of 1 (poor), 2 (fair), 3 (good), or 4 (excellent). Poor sites had little nesting material and secure cover, such as in overgrazed pastures, mowed areas with little or no regrowth, or brush clumps with no understory. Fair cover provided thin uniform cover or scattered clumps of fairly dense cover in sites such as standing stubble fields, moderately grazed pastures, or brush clumps with some understory vegetation. Good cover had large expanses of nesting cover, including lightly grazed pastures and idled vegetation on poor sites that had few openings or paths. Excellent cover provided dense vegetation not interrupted by roads or trails, and offered a heavy barrier for predator movement (Kirsch and Higgins, 1976). Nesting surveys conducted at the WSA (such as Higgins and others, 1992) also routinely used this method to assign cover ratings to the area immediately around a nest. More than one-half of upland duck nests were found in cover deemed fair, and one-quarter of upland duck nests were found in good cover (Higgins and others, 1992). About an equal number were found in either poor or excellent cover. Composition of vegetation surrounding individual nests, hatching success, as well as the shape of the cover, are reported elsewhere and summarized in Higgins and others (1992).

Starting in 1974, researchers used a recently developed and more objective method for quantifying vegetative structure, the visual obstruction reading (VOR), which is informally referred to as the Robel method (Robel and others, 1970). Visual obstruction readings were made at 25 stations along each transect (fig. 22), with transects placed in various fields representing different land use histories. Mean VOR for each transect was the average of full obstruction heights for 4 cardinal directions around each station along a transect. Surveys from 1979 to 1989 also measured vegetation height by sliding a clear, plastic disc, 30 cm in diameter, down the pole until the first piece of vegetation touched the disc (fig. 23). Measurements of full visual obstruction and vegetation height were rounded to the nearest 0.5 decimeter (dm).

VOR data are available for 30 transects within 17 study units at the WSA. Litter height was recorded for 1974–75, and aspect or exposure of each station was recorded for 1974–77. Data from all years (1974–89, excluding 1986) are available in the original datasheets in the NPWRC archive. Subsets have been digitized (data files ROBEL6A and VISUALOB) or included in publications (Higgins, 1986b; Higgins and others, 1984; Kirsch and others, 1978), but they have not been analyzed as a whole dataset.

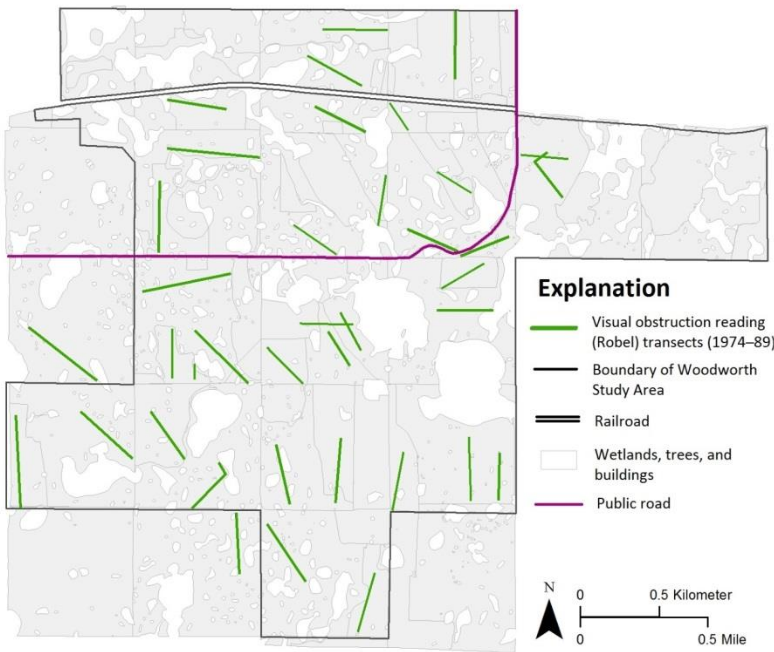

Figure 22. Transect locations for visual obstruction readings (VOR) at the Woodworth Study Area (WSA) surveyed during 1974–89. The background map is delineated into functional fields that share a homogenous land-use history.

Figure 23. Measurement methods for vegetation density (visual obstruction reading [VOR]) and vegetation height using a Robel pole at the Woodworth Study Area (WSA). *A*, WSA staff members recorded visual obstruction of the pole from 4 meters away. *B*, Vegetation height was measured in decimeters using a clear plastic disc at the height of first contact with vegetation. Photographs taken by U.S. Fish and Wildlife Service personnel.

Wetlands and Wetland Vegetation

The WSA contains over 300 wetland basins, thus the vegetation in and around them is a significant determinant of habitat for the study area. The pattern, density, and species composition of wetland vegetation are affected by the wetland’s water depth, brackishness, and permanence. Because water chemistry tends to vary seasonally and interannually, vegetation communities integrate the fluctuations in salinity to give a more average picture of seasonal changes (Stewart and Kantrud, 1972).

Wetland vegetation surveys began soon after the study area was established and pond numbers assigned. In 1963, Bayha (written commun., 1963) identified 294 wetlands. This was expanded in 1964 to 648 wetlands and totaled 241 ha within and immediately around the study area. About 450 of these wetlands were within the federally managed bounds. All wetlands were categorized as fresh to slightly brackish ponds and classified according to an early version (Stewart and Kantrud, written commun., 1963) of the Stewart and Kantrud (1971) wetland classification system. The dominant vegetation surrounding each wetland was classified once in each decade (early 1960s, 1970s, and 1980s). Original paper data sheets are available in the NPWRC archives; it is not clear to what extent they have been used in any publications.

National Wetland Inventory data classified wetlands according to Cowardin and others (1979). Within the federally managed bounds of the WSA, 376 wetlands that represented ten classes were recognized (table 6). The 3 largest wetlands on the WSA were littoral lacustrine systems, where aquatic plants dominate and surface water is present except in extreme droughts. Almost one-half of wetlands were classed as palustrine emergent seasonally flooded but averaged only 0.2 ha in size. These wetlands are characterized by perennial vegetation that is usually present through the growing season and seasonal surface water that dries by the end of the growing season. The WSA had greater numbers of seasonal wetlands than semipermanent wetlands and relatively few temporary wetlands (fig. 24). The discrepancy between Bayha’s (written commun., 1963) earlier, higher numbers of wetlands and NWI estimates has not been explored in detail, but is likely because of Bayha’s inclusion of more ephemeral and temporary wetlands not detected in NWI data, and the loss of some wetlands to modifications.

Two pilot studies took place around wetlands in early years of federal management. In 1968 and 1969, WSA staff mowed the shorelines of ponds to test effects on distribution of breeding waterfowl (Klett and others, written commun., 1969). The mowed shorelines contained greater density of breeding waterfowl than the control wetlands even when the locations of the treatment and control were reversed. In the second pilot study, WSA staff installed snow fences around wetlands to test whether they could help accumulate moisture around shallow wetlands (K.F. Higgins, oral commun., 2014); no results are apparently available for this pilot study.

Table 6. Wetland types within the federal boundaries of the Woodworth Study Area, according to National Wetland Inventory classification (NWI).

[The codes are for wetland types as defined in NWI (Cowardin and others 1979) and described in text form under Description.]

NWI Code	Number of wetlands	Total hectares	Average wetland size (hectares)	Description
PEM/ABF	49	59.7	1.2	Palustrine, emergent, aquatic bed, semipermanently flooded
L2ABG	3	54.3	18.1	Lacustrine, littoral, aquatic bed, intermittently exposed
PEMF	66	52.6	0.8	Palustrine, emergent, semipermanently flooded
PEMC	180	28.3	0.2	Palustrine, emergent, seasonally flooded
PEMA	50	17.4	0.3	Palustrine, emergent, temporary flooded
PABF	3	5.3	1.8	Palustrine, aquatic bed, semipermanently flooded
PEMCx	12	1.6	0.1	Palustrine, emergent, seasonally flooded, excavated
PEM/SSC	1	1.1	1.1	Palustrine, emergent, scrub-shrub, seasonally flooded
PEMAd	2	0.6	0.3	Palustrine, emergent, temporary flooded, partially drained/ditched
PABFx	1	0.1	0.1	Palustrine, aquatic bed, semipermanently flooded, excavated
Total	*367*	*221.0*		

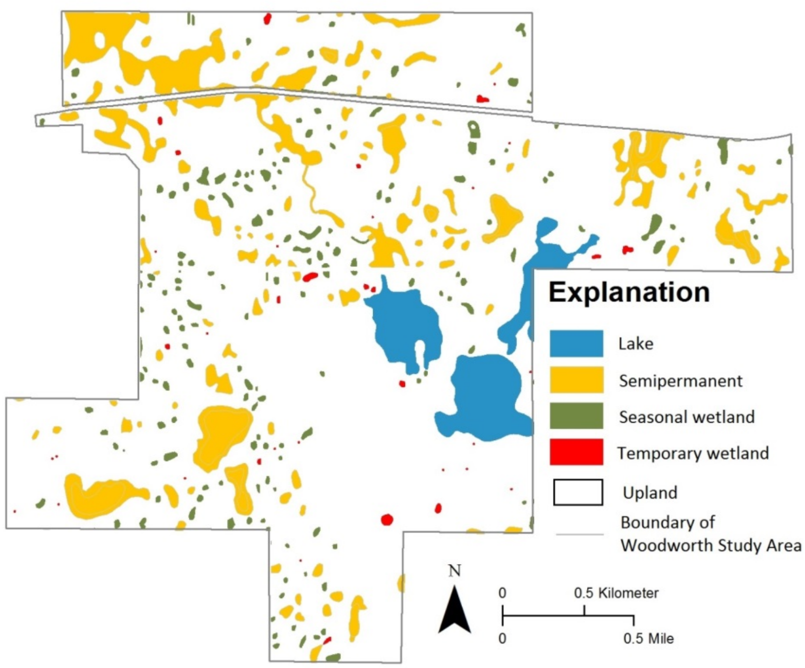

Figure 24. Wetland water regimes as identified by the National Wetland Inventory (NWI) at the Woodworth Study Area (WSA).

Preliminary Summary of the WSA Plant Community

The WSA Plant Community

The digitized WSA vegetation datasets cumulatively consist of 450 plant species (appendix 10). The datasets included were from transect data and studies that focused mainly on upland vegetation, so although some wetland species were represented, there are likely more than 450 plant species historically found at the WSA. More than 20 years of wetland vegetation surveys are available in the NPWRC archives but are available only as original data sheets at this time. As those data are converted to digital files and examined relative to the cumulative species list, the number of wetland species recorded at the WSA may increase.

The WSA vegetation datasets include 71 taxonomic families, but 42 families were represented by only 1 or 2 species (fig. 25*A*). The top 5 families (Asteraceae, Poaceae, Fabaceae, Cyperaceae, and Rosaceae) contained one-half of all species at the WSA. Most species at the WSA were perennial forbs, followed by perennial grasses and annual forbs (fig. 25*B*). Sedges and woody species (vines, shrubs, or trees) contributed similar numbers of species, and rushes were the least numerous group (fig. 25*B*), which might be related to the limited number of data-collection points in wetlands. Of the forbs, 22 species were biennial (not plotted in fig. 25*B*). Native species outnumber non-natives in all functional categories (fig. 25*C*). The WSA had 348 native species and at least 69 (16.5 percent) known non-natives (fig. 25*C*). This is comparable to the known proportion of non-natives (15 percent) observed at the nearby CLSA during 1992–2001 (Mushet and others, 2004: fig. 1). The CLSA is a waterfowl production area 16 km southeast of the WSA that has been idled since purchased by the FWS in the early 1960s.

Nitrogen-fixing species are an important contribution to grassland productivity (LeBauer and Treseder, 2008). There were 28 plant species at the WSA able to fix nitrogen (fig. 25*D*). Cool-season graminoids such as crested wheatgrass (*Agropyron cristatum*) and smooth brome (*Bromus inermis*) were twice as numerous as warm-season species such as alkali cordgrass (*Spartina gracilis*; fig. 25*D)*. The mean annual temperature of 5.6 ºC at the WSA falls below the 10 ºC threshold where cool-season plants occur more often than warm-season plants (Sims and Risser, 2000).

Non-native species and some invasive native species were undesirable to biologists as they were perceived to reduce habitat quality by offering little cover for wildlife or by outcompeting those plants that do benefit wildlife. In 1977, the primary "pest" plants identified in the WSA records were Kentucky bluegrass (*Poa pratensis*), wolfberry, and silverberry. Once established, these tended to outcompete other plants deemed more desirable for waterfowl nesting cover. Other grasses such as smooth brome and quackgrass (*Elymus repens*) were common non-native species on unmanaged grasslands, which also competed with native plants. However, these species were considered more acceptable than Kentucky bluegrass for wildlife management because when in vigorous growth, they provided good nesting cover. From a potential community of over 200 plants, those deemed desirable for wildlife habitat in 1977 (L. Kirsch, written commun.) included big bluestem, switchgrass, Indian grass, green needlegrass (*Nassella viridula*), porcupine grass (*Hesperostipa spartea*), blue grama (*Bouteloua gracilis*), prairie cordgrass (*Spartina pectinata*), bearded wheatgrass (*Elymus caninus*), prairie dropseed, (*Sporobolus heterolepis*), wild timothy (marsh muhly, *Muhlenbergia racemosa*), prairie sandreed (*Calamovilfa longifolia*), little bluestem (*Schizachyrium scoparium*), sideoats grama (*Bouteloua curtipendula*), western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), and native legumes.

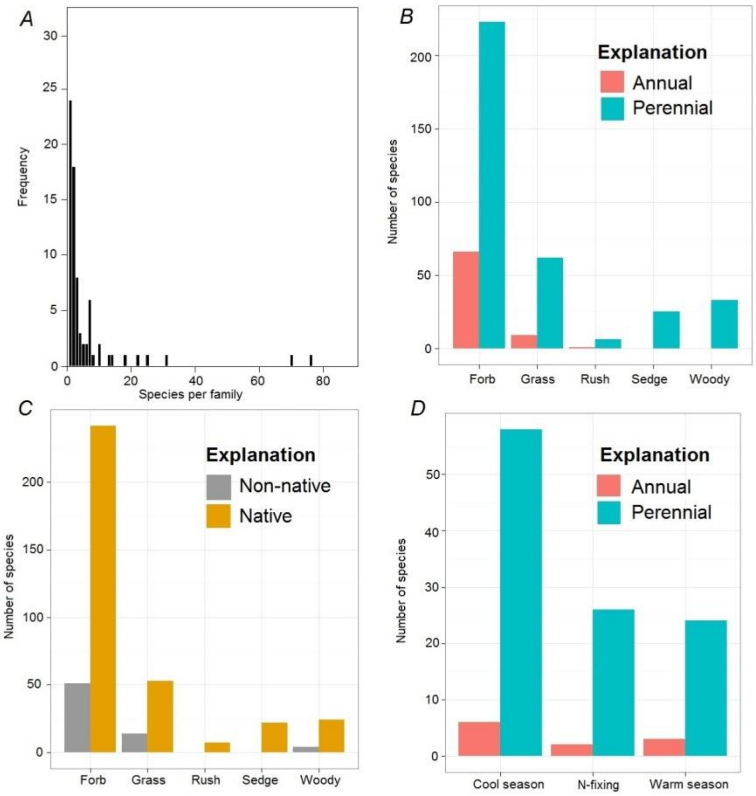

Figure 25. Summaries of plant types recorded on the Woodworth Study Area (WSA) during 1963–89. *A*, Histogram of the number of species per family. *B*, Plant functional groups by growth form. *C*, Numbers of native and non-native species by growth form. *D*, Numbers of annual or perennial cool-season, nitrogen (N)-fixing, and warm-season species.

Floristic Quality Assessment

Coefficients of conservatism and floristic quality assessments are tools for measuring the conservation status of a plant community. The coefficient of conservatism (C) is a number (0–10) assigned to each plant by a committee of experts on the region’s flora (Swink and Wilhelm, 1979, 1994; Mushet and others, 2001). It is a composite score of fidelity of a species to specific environmental conditions or habitat, and tolerance to disturbance. For example, if a plant has low tolerance to disturbance and high fidelity to a region (i.e. rare or hard to find), its C value would be 10. In contrast, a plant that grows in many conditions and is robust to disturbance is assigned a C near 0. Non-native species are not assigned a C value. The Floristic Quality Index (FQI) uses the C values of plants in an area to provide a standardized metric to evaluate the closeness of the plant community to undisturbed conditions (Swink and Wilhelm, 1994). For any area, FQI equals the average C times the square root of the number of species.

The mean C for the WSA master list of vegetation species was 5.3, and the median was 5. The FQI was 98.6 (348 native species). Twenty-two species assigned a 10 have been observed at the WSA during 1966-89 (fig. 26). The data included in this assessment are the long-term vegetation transects, phenology records, and the most recent plant list of the WSA from 1986. To examine changes in C over time, we used the systematic surveys from the long-term vegetation transects, and separated the transects that had been treated by fire or grazing from transects that remained idle as a control. Mean C remained largely stable throughout the long-term data, and no clear pattern emerged across years or between idle and treated areas (fig. 27).

Similarly, the distribution of C values appears largely stable across years (fig. 28). The increasing proportion of plants with C values of 8–10 in the first 5 years (fig. 28) may reflect improved coverage by transects, better plant identification, or actual changes in plant occurrences. Overall, the observed occurrences of non-native species from 1966 to 1989 averaged to 4.1 percent ± 5.5 percent (standard deviation) of species identified.

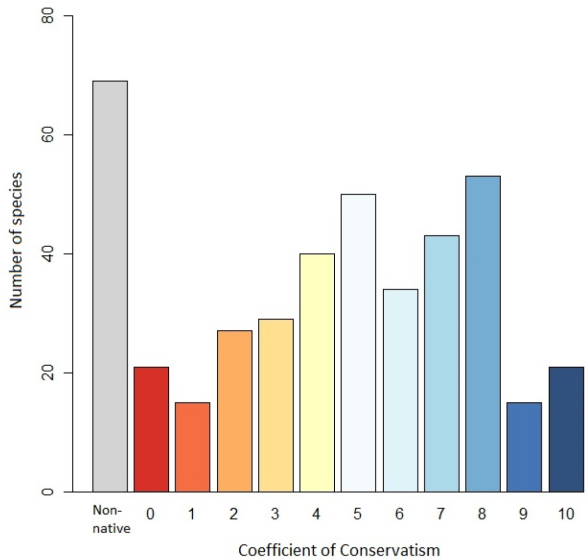

Figure 26. The frequencies of coefficients of conservatism (C) scores for all taxa recorded at the Woodworth Study Area (WSA) during 1966–89. Bar colors correspond to colors in figure 28.

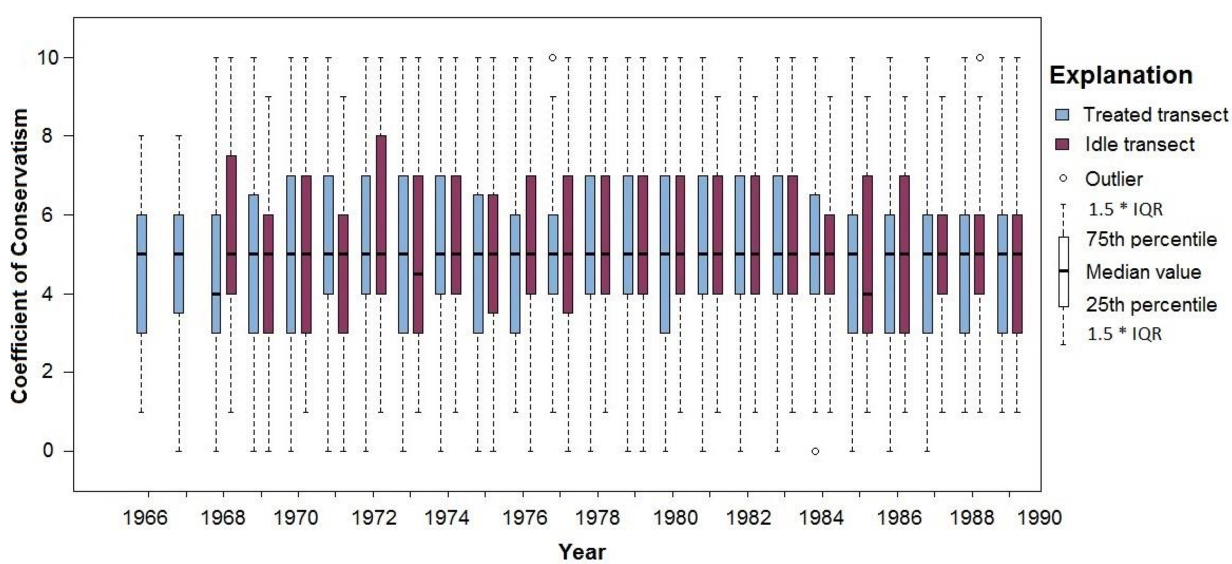

Figure 27. Boxplots of the coefficients of conservatism (C) of plants recorded on long-term transects on idle and treated fields during 1966–89.

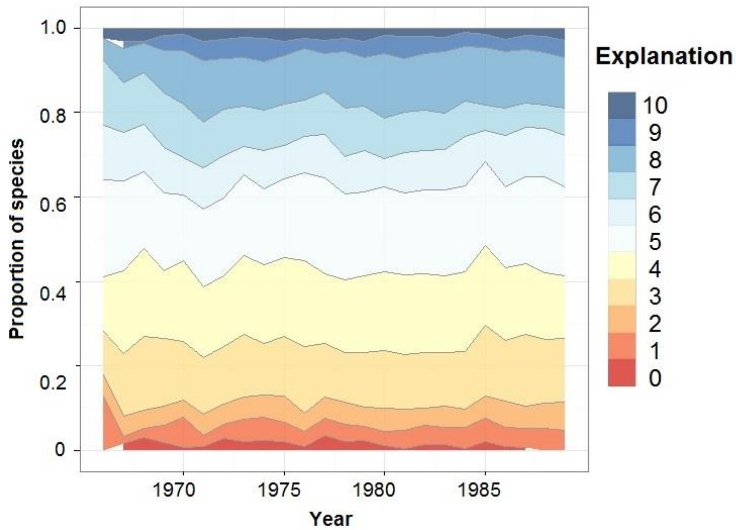

Figure 28. Proportion of native plant species recorded each year (1966–89) by coefficients of conservatism (C) on long-term transects at the Woodworth Study Area (WSA).

Additional Data Resources

Wildlife Data

In addition to the vegetative surveys discussed in this report, regular surveys included counts of duck breeding pairs and broods (Higgins and others 1992), upland waterfowl and shorebird nesting surveys, and terrestrial passerine surveys (Johnson, 1996, 1997). Surveys were conducted for varying lengths of time for other waterfowl and waterbird research (e.g., Klett and Kirsch 1976; Ryan and others, 1984). As part of state-wide surveys, sharp-tailed grouse (*Tympanuchus phasianellus*) surveys were conducted at the WSA and surrounding areas from 1964 to 1985 (appendix 8). Surveys of white-tailed deer (*Odocoileus virginianus*), ring-necked pheasants (*Phasianus colchicus*), small mammals, and predators were conducted occasionally, as were surveys of nests in nesting structures and on islands (Higgins and Woodward, 1996; Nelson, 1996). Early surveys of birds and small mammals were reported by Bayha (written commun., 1963). A systematic survey of small mammals was conducted in 1972 (Ladd, written comm., 1972). These data and unpublished reports are available in the NPWRC archive.

Photograph Stations

Photograph stations have been in place at the WSA since 1970. Over 30 permanent markers are placed throughout the WSA on fields with various land-use histories (native, seeded native, or seeded nesting cover) and treatments (grazed, burned, or idled). Photographs of the landscape were oriented in the same direction and taken as many as 3 times per year (fig. 29). The timing was meant to show vegetative conditions before new growth occurred in April or May, during the growing season, and near the end of the growing season in August (fig. 29; Johnson and others, 1996). All photographs have been scanned and georeferenced in a geodatabase. In recent years, photographs continue to be made at several photograph stations, so a 40-year record is available for certain stations. No analysis or reporting has been done on this dataset.

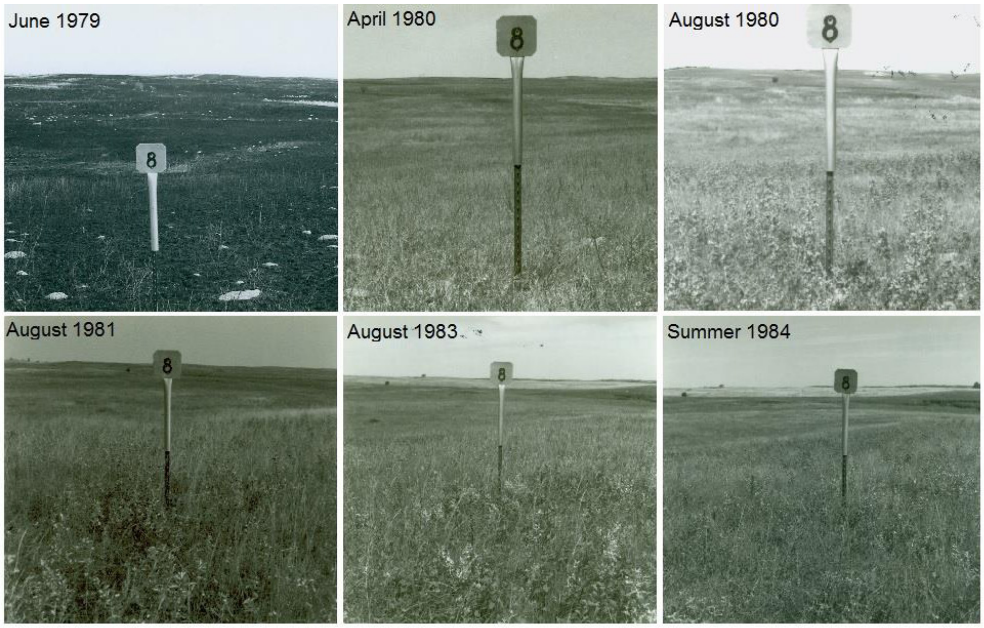

Figure 29. Example of photographs taken at a photograph station (Station 8 in study unit 16) at the Woodworth Study Area (WSA) over multiple years. Photograph taken by U.S. Fish and Wildlife Service personnel.

Herbaria

Plant species collected from the WSA are maintained in herbaria at the WSA and the NPWRC. By 1986, over 300 of the 450 identified plant species occurring on the WSA, representing 18 taxonomic families, were cataloged in the NPWRC herbaria. Appendix 11 lists the plants collected at the WSA that are archived in the NPWRC herbarium. The plants were collected by WSA staff from May 1978 to August 1981. All specimens have associated date, location, and collector metadata.

Spatial Data

During most of the WSA history, biologists relied on aerial photographs, hand-drafted maps (for example, habitat maps of Bayha, written commun., 1963; Meyer, 1985), and printed maps (for example, soils maps) to link field data to location. Geographic information systems were rapidly embraced by the NPWRC as the technology became available, and many different types of spatial data have since been captured for use in GIS applications. As part of this project, several GIS layers have been digitized from maps held in the NPWRC archive. See appendix 8 for a list of GIS data layers and appendix 12 for a list of aerial imagery. The GIS layers that were created from hardcopy maps in the NPWRC archives were produced in ESRI ArcGIS® (ESRI, 2011) and are available for download and viewing. Readers without access to ESRI ArcGIS® Desktop 10+ can download and install the free ESRI ArcReader® 10 software that allows read, view, print, and identify features (ESRI, 2004). Features and layers that are currently available are categorized as locations of land treatments, features of the WSA, geophysical formations, base layers and outlines, land use and cover digitized from previous analyses, and vegetative transect locations. Light detection and ranging (lidar) data obtained in fall 2011 and spring 2012 are also available for the WSA at a vertical accuracy of less than or equal to 18.5 cm (Carswell, 2014). Aerial photographs and negatives are available for several years beginning in July 1957 (appendix 12; for example, fig. 30). WSA staff also made 2 aerial videos from 1988 and 1989 (appendix 12). All media are available in the NPWRC archives.

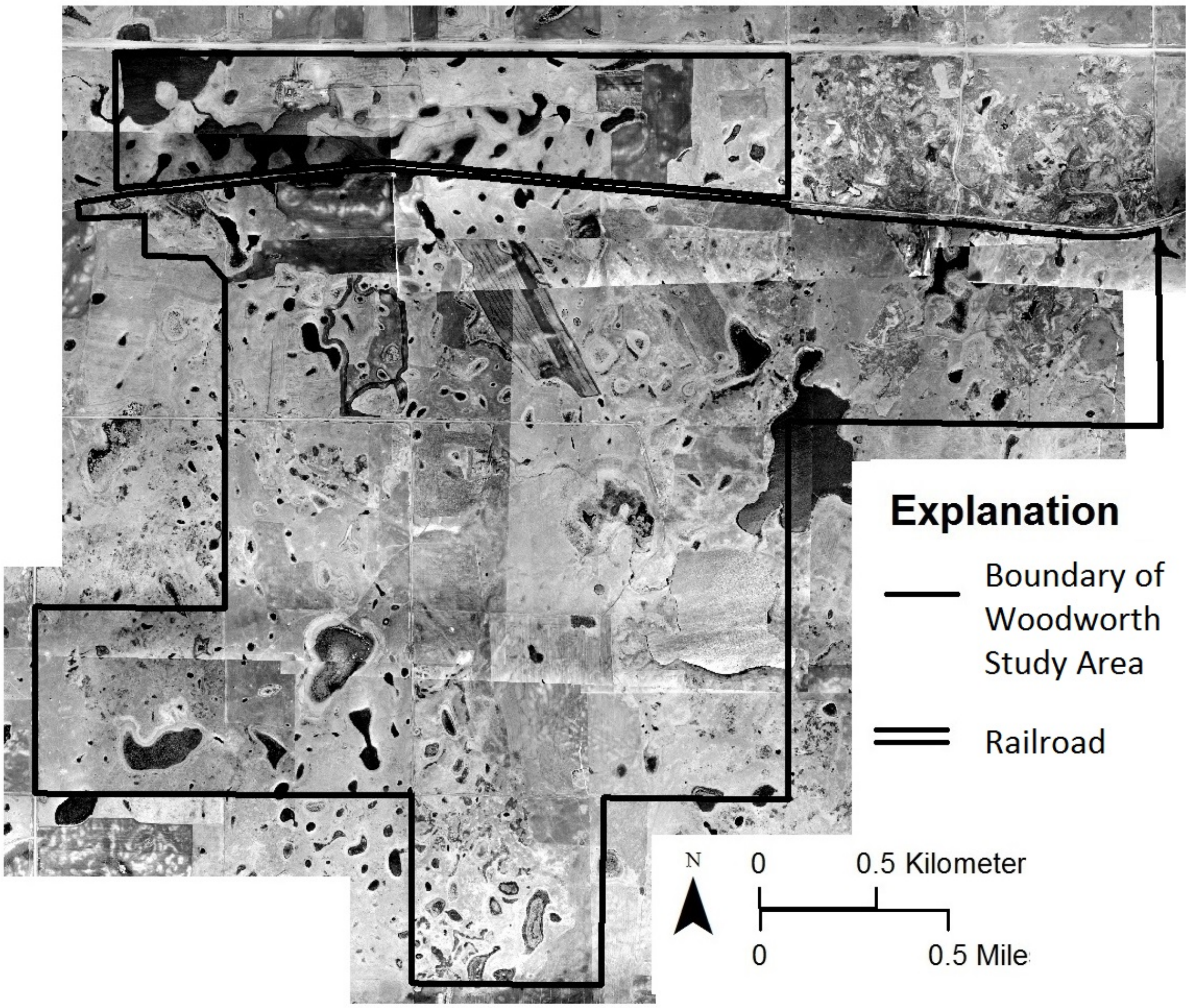

Figure 30. Composite aerial photograph of the Woodworth Study Area (WSA) taken from 9,000 feet above the surface in May, 1963. Photograph taken by U.S. Fish and Wildlife Service personnel.

Data Management Strategy

Data management for the WSA must satisfy several agencies. The CLWMD requires short- to mid-term use of the data addressing management options, whereas the NPWRC seeks a long-term data archiving solution to ensure the longevity and viability of these data for future study. Valuable data become obsolete quickly if not managed properly. The seemingly safe and well-organized compact disks used in the1990s–2000s were once the well-organized 8.5-inch floppy disks of the early 1980s or the magnetic tapes of the 1960s. In addition, storing data solely in proprietary formats is risky should a researcher or lab lose track of their copy of that software or find that it is no longer functional on newer computer systems.

We used a management strategy for this project to ensure the reliability and accessibility of the WSA data for 100 years or more. The so-called centinel system (Lehman and other, 2012) has 4 main tenets: (1) store a copy of the data in plain ASCII-text format, (2) store metadata in the same file as the data, (3) protect data against accidental changes or omissions; and (4) print several copies and store them in separate locations for permanent or archival data.

ASCII

Numerical data should be both human and machine readable. We find that ASCII files stored in columns and delimited by vertical bars or colons, or the like, work well. The files can be visually understood on a computer screen or paper, as well as scanned into a computer or imported to spreadsheet software. The numerical data products of the WSA vegetation project will be stored in ASCII-based datasets. These products include (1) all historical vegetation data gathered in the paper archives or already stored electronically, (2) concatenated data files, where possible, to maximize the amount and value of data, (3) a new crosswalk database to translate between original species symbols recorded at the WSA, current USDA Plant Database acronyms (appendix 10), species physiognomy, and the coefficient of conservatism codes, and (4) complete accompanying metadata. Core layers of GIS data were also converted to an ASCII-based format (GeoJson; Butler and others, 2008) for long-term storage. This creates a digital format that can be archived on paper, and it also removed the GIS layer from a proprietary format.

The data that we have archived as part of this project are at least 20 years old, so few regular edits are expected in the future. However, in practice, editing may be necessary as more robust metadata are discovered. In this case, changes should be made primarily to the ASCII-text files stored on the network, and the changes should be noted in the accompanying metadata.

Metadata

A primary focus of this project was to provide metadata that specify data sources, formats, storage locations, and procedures for data collection and data quality. For numerical data, the Centinel system (Lehman and others, 2012) recommends storing the metadata for a file with the data. Preferably, metadata will form a header for the data that includes a description of the data that addresses the what, why, when, who, and where of the data (appendix 13). Following that should be a description of each variable including any meanings of codes or abbreviations. A complete description of abbreviations in the heading will compact the data files in the value (for example, assigning the value “native prairie” to “a”, “cultivation history” to “b”, etc.), and in the variable heading (for example, assigning the heading “Land use cover” to “L”). Metadata should be written to be understandable to researchers not familiar with the project. For geospatial data, standards in Executive Order 12906 (The White House, 1994) were recognized, and metadata will be prepared in compliance with the Federal Geographic Data Committee Content Standards for Digital Geospatial Metadata and Biological Resources Division Policy Issuance Number 8 (U.S. Geological Survey, 1999) following completion of the study. Data will be stored at CLWMD headquarters and at the NPWRC in compliance with FWS standards for metadata records.

Centinels

Digital data are a precise method of recording data and can be stored electronically as well as on paper. For example, compare gathering data from a table (digital) to data from a graphical version (analog). Alphanumeric symbols can present a problem; for example, the letter l and the number 1 might be confused by either a reader or a scanner. To detect, prevent, and fix accidental changes or omissions, each line of data and metadata is protected by a string of characters called "centinels." The methods and code needed to use centinels are freely available in Lehman and others (2012).

Paper Copies

Given the value of the historical vegetation datasets from the WSA, at least 2 paper copies of the ASCII-based data should be made. For the WSA data covered in this report, copies have been printed, bound, and stored in both the NPWRC archive and at CLWMD headquarters. Digital copies are stored on the facilities' network drives as well. Data can be easily imported into the analysis software of the user's choice.

Conclusion

The Woodworth Study Area (WSA) has been called one of the largest controlled grassland research sites in North America (Higgins and Woodward, 1996). Research at the WSA was scaled down in the late 1980s, which unfortunately occurred just before the onset of a significant drought (1988–92) and a series of extremely wet years (1993–95). Although the 1990s and 2000s went largely unrecorded at the WSA, new attention is being given to future research there. The long record of baseline data, existing facilities at the WSA (such as the office, lab, bunkhouse, shop), and land management information that has become available in the intervening years make the future of research promising at the WSA. The WSA was selected as a core site for the National Ecological Observatory Network (NEON), a National Science Foundation-funded initiative that is committing to 30 years of ecological data collection. These WSA data, and those from the nearby Cottonwood Lake Study Area, should provide invaluable resources to help understand long-term changes in this prairie ecosystem. All the data discussed in this report are available to researchers interested in legacy vegetation data, and researchers using NEON data in particular may find the historical context helpful in their analyses. Initial data collection for NEON will begin in 2014 on study units 16 and 17. Study unit 16 is native prairie, and study unit 17 was former cropland cultivated between the 1920s and 1969, after which it was seeded to nesting cover. Photograph stations 10, 14, and 15; visual obstruction transect 17A; long-term transects 2 and 12; and Meyer transects 1 and 27 are also nearby.

Compiling and summarizing the available WSA data may be helpful in interpreting future data in a historical context and in designing future long-term monitoring surveys, such as vegetative responses to management practices. The available data may also be valuable in addressing pressing management issues at the CLWMD, such as determining (1) reference states for the mixed-grass prairie in North Dakota (i.e. historic species composition before increases of Kentucky bluegrass, smooth brome, and the effects of decades of rest), (2) trends that identify shifts in plant species composition, (3) effects of management (such as fire, grazing, rest), and (4) effects of landscape factors that may be causing shifts in plant species composition and abundance.

Although legacy datasets provide valuable opportunities, there are also distinct challenges for researchers. Long-term data collection may suffer from staff turnover, observational errors, chronological gaps, identification mistakes, undocumented protocol changes, or uncontrolled environmental changes. Study protocol and data at the WSA reflect the rapidly evolving nature of ecological science of the 1960s–1980s. Land management activities were not always conducted with research in mind. In addition, several datasets provide only a few years of data or breadth rather than depth of data. The WSA hosted researchers with diverse interests, creating a patchwork of projects; analyzing these smaller datasets may require supplementation with other datasets or a qualitative rather than quantitative approach. The purpose of this report was to present a summary of the individual datasets along with metadata and context without critical analysis. However, before using any of these datasets researchers should recognize both the accompanying opportunities and challenges.

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Appendices

Appendix 1. Unpublished reports relating to the Woodworth Study Area (WSA) archived at Northern Prairie Wildlife Research Center

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——— 1964a, History of the Woodworth Study Area with emphasis on land use: Jamestown, N. Dak., U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, unpublished report, 76 p.

——— 1964b, Inventory of wildlife populations and habitat conditions on the Woodworth Study Area, 1963–1964: Jamestown, N. Dak., U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center, unpublished report, 81 p.

Johnson, D.H., 1982, Relations of selected prairie plants with environmental attributes on the Woodworth Study Area, North Dakota: Jamestown, N. Dak., U.S. Fish and Wildlife Service, Northern Prairie Wildlife Research Center internal files, 30 p.

Klett, A.T., Kirsch, L.M., Higgins, K.F., King, R., Dwyer, T., and Murdy, H.W., 1969, Effect of land-use on waterfowl and other wildlife populations, zone of influence of land-use on waterfowl populations, Annual Progress Report 1968–1969: Jamestown, N. Dak., Northern Prairie Wildlife Research Center, unpublished report, 30 p.

Ladd, W.N., 1972, Relationships of small mammals to land use treatments, Woodworth Study Area, North Dakota, 1972: Jamestown, N. Dak., Northern Prairie Wildlife Research Center, unpublished report, 39 p.

Stewart, R.E., and Kantrud, H.A., 1963, Long-term investigations of pothole complexes on the Missouri Coteau in Stutsman County, North Dakota, Annual Progress Report, Wildlife Research Work Unit A-7.1: Denver, Colo., U.S. Fish and Wildlife Service, Denver Wildlife Research Center, unpublished report, 62 p.

Appendix 2. Published and unpublished reports that use vegetation or weather data from the Woodworth Study Area (WSA) region

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Meyer, M.I., 1985, Classification of native vegetation at the Woodworth Station, North Dakota: Prairie Naturalist, v. 17, p. 167–175.

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Appendix 3. Woodworth Study Area (WSA) tract locations and ownership

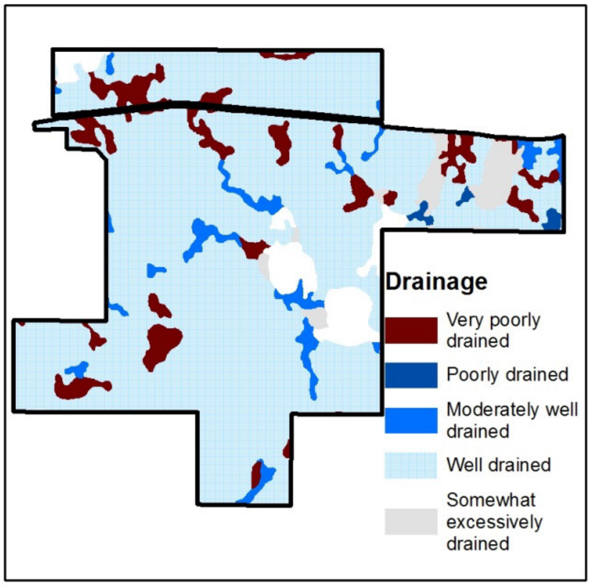
[Study unit follows WSA convention. Year acquired is when the tract came under federal management; NA indicates the tract remained in private ownership. Tract name is the reference name used on land management records. The final three columns are number of wetlands on the tracts in 1970, the tract size in both hectares (ha) and acres (ac), and township plat location. T. = Township, R. = Range, sec.= section, and R.R = railroad. Tracts with no wetland data are indicated by nd.]

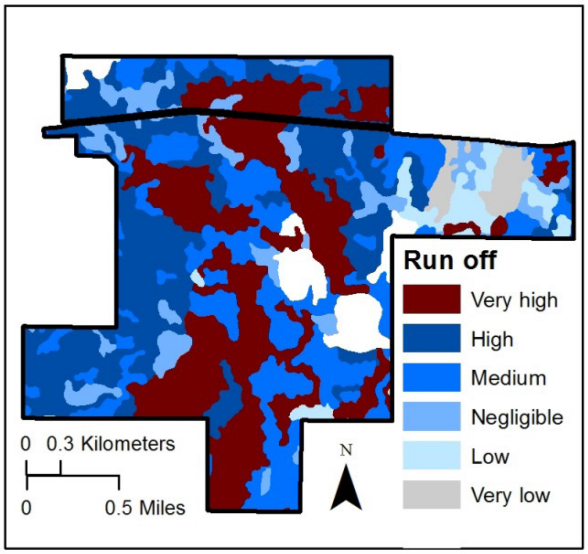
Study unit	Year acquired	Tract name	Number of wetlands in 1970	Tract size in ha (ac)	Plat location
1	1968	Rickford	21	64.7 (160)	NE¼ sec. 1, T. 142 N., R. 68 W.
2	1968	Rickford	35	64.7 (160)	NW¼ sec. 1, T. 142 N., R. 68 W.
3	1968	Rickford	18	64.7 (160)	NE¼ sec. 2, T. 142 N., R. 68 W.
4	1968	Rickford	9	26.4 (65.1)	E½NW¼ north of R.R. sec. 2, T. 142 N., R. 68 W.
4	1975	Hotchkiss	nd	12.6 (31.1)	NW¼ south of R.R. sec. 2, T. 142 N., R. 68 W.
5	NA	Hotchkiss	nd	59.47 (147)	SW¼ sec. 2, T. 142 N., R. 68 W.
6	1967	Bohl	39	64.7 (160)	SE¼ sec. 1, T. 142 N., R. 68 W.
7	1969	Kutz	35	64.7 (160)	SW¼ sec. 1, T. 142 N., R. 68 W.
8	1963	Eddy	34	64.7 (160)	SE¼ sec. 1, T. 142 N., R. 68 W.
9	1966	Railroad	11	70 (173)	SW¼ sec. 6, T. 142 N., R. 67 W.; NW¼ south of R.R.
9A	1966	Railroad	nd	65.5 (161.8)	W. 435 ft of SE¼ sec. 6, T. 142 N., R. 67 W.; NE¼ south of R.R.
10	NA	Holzworth	nd	64.7 (160)	NW¼ sec. 7, T. 142 N., R. 67 W.
11	1962	Fish	22	64.7 (160)	NE¼ sec. 12, T. 142 N., R. 68 W.
12	1963	Eddy	19	64.7 (160)	NW¼ sec. 12, T. 142 N., R. 68 W.
13	1963	Eddy	47	64.7 (160)	NE¼ sec. 11, T. 142 N., R. 68 W.
14	NA	Hotchkiss	36	64.7 (160)	NW¼ sec. 11, T. 142 N., R. 68 W.
15	1963	Eddy	24	64.7 (160)	SW¼ sec. 11, T. 142 N., R. 68 W.
16	1963	Eddy	32	64.7 (160)	SE¼ sec. 11, T. 142 N., R. 68 W.
17	1962	Fish	28	64.7 (160)	SW¼ sec. 12, T. 142 N., R. 68 W.

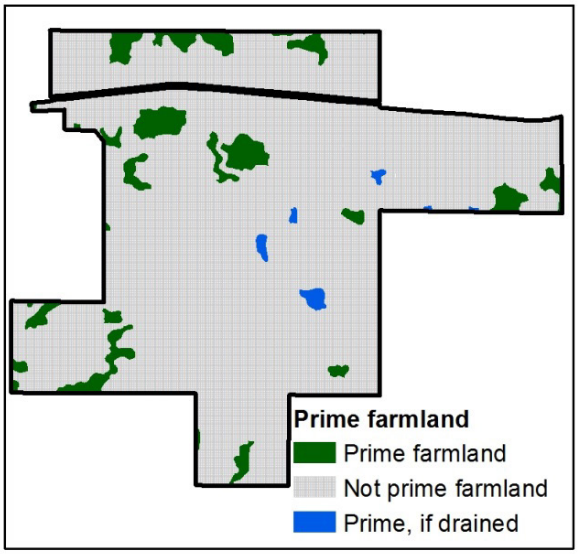
Study unit	Year acquired	Tract name	Number of wetlands in 1970	Tract size in ha (ac)	Plat location
18	1962	Fish	23	64.7 (160)	SE¼ sec. 12, T. 142 N., R. 68 W.
19	NA	Holzworth	nd	64.7 (160)	SW¼ sec. 7, T. 142 N., R. 68 W.
20	NA	Holzworth	nd	34.2 (84.5)	E½NW¼ sec. 18, T. 142 N., R. 67 W.
20	NA	Stoppleworth	nd	29.4 (72.6)	W½NW¼ sec. 18, T. 142 N., R.67W.
21	NA	Stoppleworth	nd	64.7 (160)	NE¼ sec. 13, T. 142 N., R. 68 W.
22	1962	Fish	39	64.7 (160)	NW¼ sec. 13, T. 142 N., R. 68 W.
23	NA	Krenz	49	64.7 (160)	NE¼ sec. 14, T. 142 N., R. 68 W.
24	NA	Krenz	nd	64.7 (160)	NW¼ sec. 14, T. 142 N., R. 68 W.

Appendix 4. Soil classifications at the Woodworth Study Area (WSA) using the Soil Survey Geographic Database (SSURGO)

Data source is the U.S. Department of Agriculture (2009). Scale is consistent across the 3 maps.

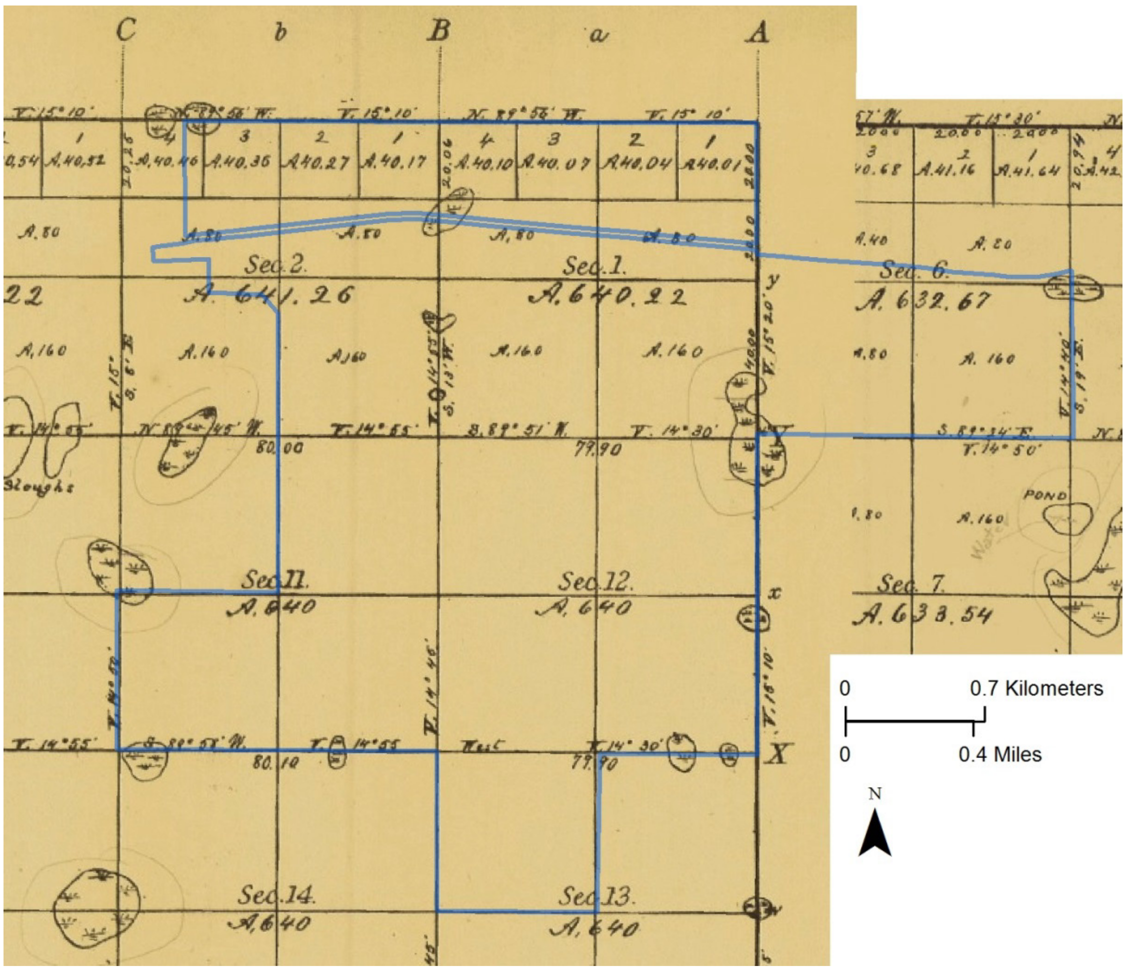




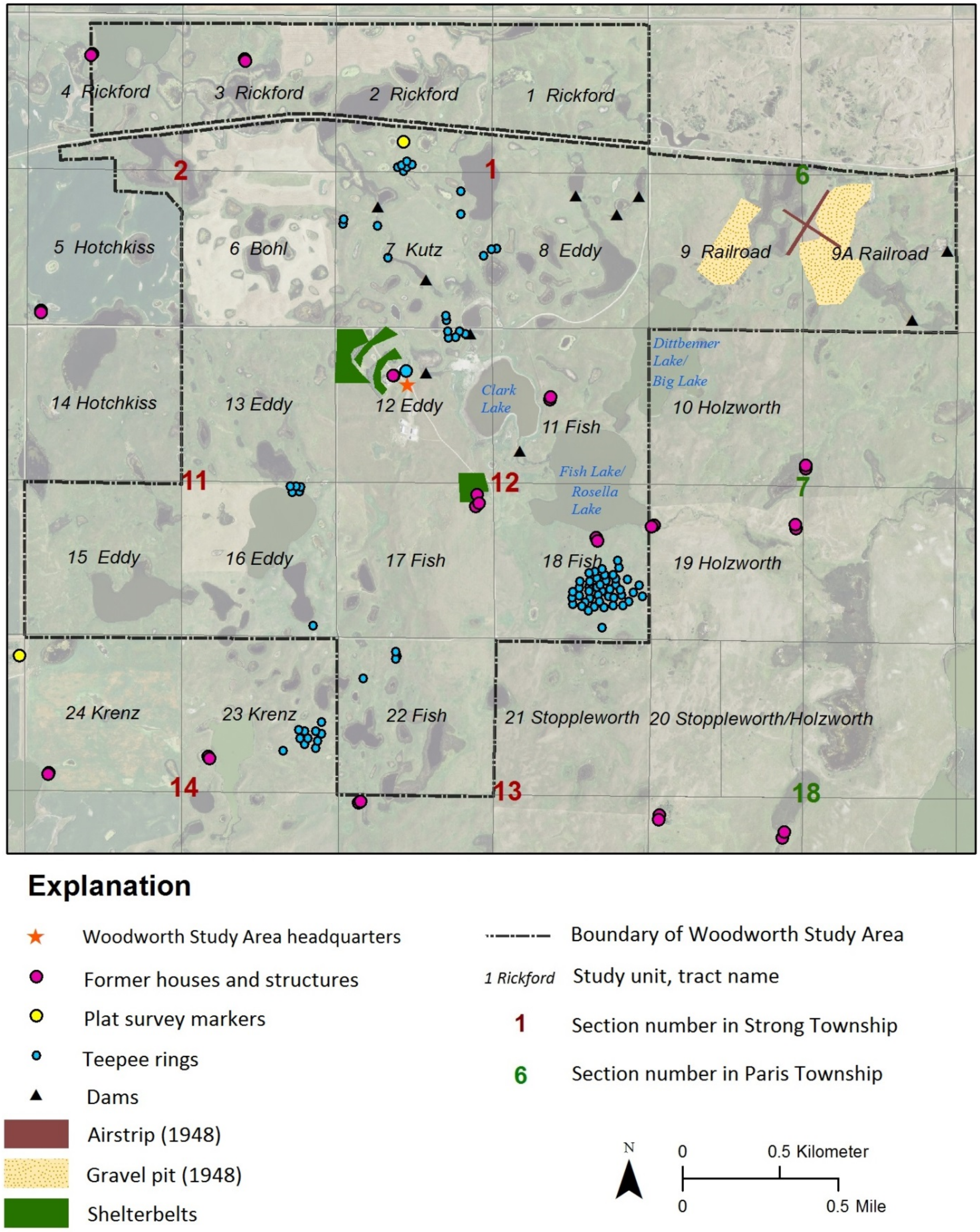


Appendix 5. Original survey map of townships encompassing the Woodworth Study Area (WSA) from 1875

The original township survey from 1875 shows several of the Woodworth Study Area's larger wetlands that lie on the section survey lines. Big Lake is the large wetland mapped along the A line. Plat maps and notes are available online at *http://survey.swc.nd.gov/*. Accessed 14 April, 2014.

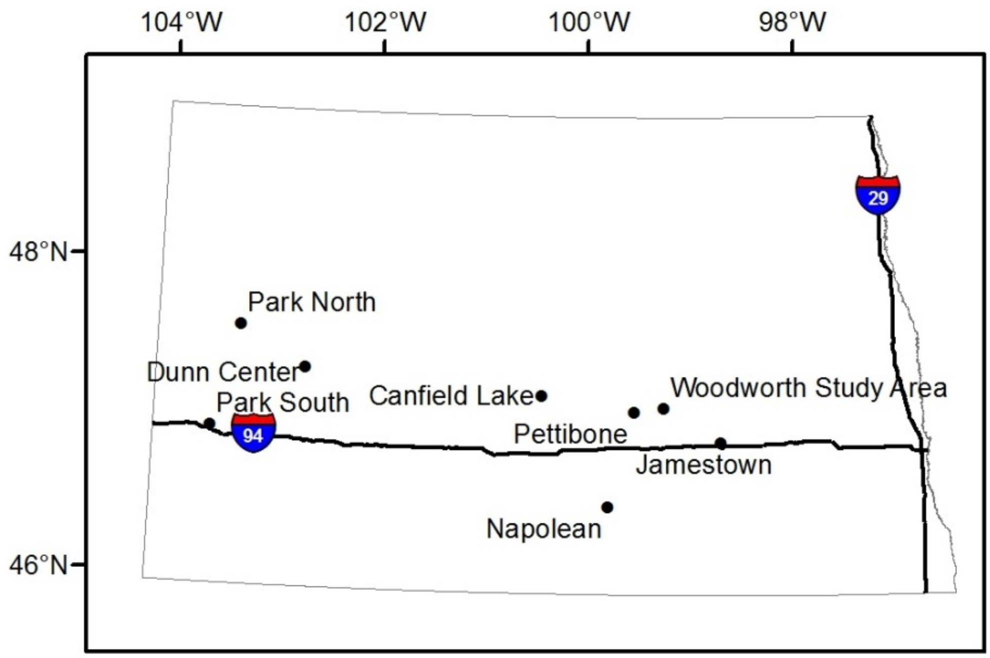


Appendix 6. Locations of man-made structures at the Woodworth Study Area (WSA)



Appendix 7. Location of North Dakota cities and survey sites mentioned in the text

Jamestown is the location of the Northern Prairie Wildlife Research Center. Locations of U.S. Historical Climate Network data sites near the Woodworth Study Area are in Pettibone and Napolean, N. Dak. Dunn Center and Canfield Lake, N. Dak. were two additional sampling sites for precipitation chemistry, and Park North, Park South, and Dunn Center, N. Dak., were additional sites of air chemistry sampling in Angelo and Anderson (1983).



Appendix 8. Geographic Information System (GIS) layers of the Woodworth Study Area (WSA) available as shapefiles

[Feature is a general keyword description of the layer. Year is the associated time of the activity or creation of the feature; dashes indicate not applicable. Source is from where the digital file was procured. Hardcopy maps were digitized into ESRI ArcGIS® 10 (ESRI, 2011) in 2013. FWS is U.S. Fish and Wildlife Service.]

Feature	Years	Description	Source
		Features	
Buildings	~1900–50	Homes, farms	Bayha (written comm., 1964a)
Dams	1960s	Wetland dams	Existing file
Water gauges	1963–1965	Wetland water depths	Hardcopy map
Teepee rings	Unknown	Reported teepee rings	Hardcopy map
Shelterbelt trees	~1900–65	Trees planted by settlers and staff	Archived memos
Auto tour	2000s	Features for visitors	Existing digital file
Sharp-tailed grouse	1964–85	Survey locations	Hardcopy map
Railroad	1912–2014	Northern Pacific railroad	Existing digital file
Roads	1900s–2014	Main road through the WSA	Existing digital file
Water wells	1963	Private wells	Huxel and Petri (1963)
Airstrip	1948	Historical airstrip	Bayha (written commun., 1964a); Woodworth Betterment Community (1986)
Plat markers	1934, 1951	Federal survey markers	*http://survey.swc.nd.gov*
		Treatments	
Weed chemical	1989	Leafy spurge and knapweed spray treatment	Hardcopy map
Nitrogen fertilizer	1971–75	Experimental and treatment applications	Hardcopy map
Prescribed burns	1965–90	Areas burned by year	Hardcopy map
Fire breaks	1987	Dirt, mowed, trail breaks	Hardcopy map
Sheep grazing	1973, 1975	Enclosure, exclosure areas	Hardcopy map
		Geophysical	
Permeable soils	---	Band of few wetlands	Bayha (written commun., 1964b)
Glacial features	---	Hummocky stagnation and outwash border	Winters (1963)
Physiographic	---	Four physical regions of N. Dak.	FWS existing digital file
Current soil series	---	SSURGO soils (U.S. Department of Agriculture, 2011)	Existing digital file
Wetland classes	---	National Wetland Inventory	FWS; Cowardin and others (1979)

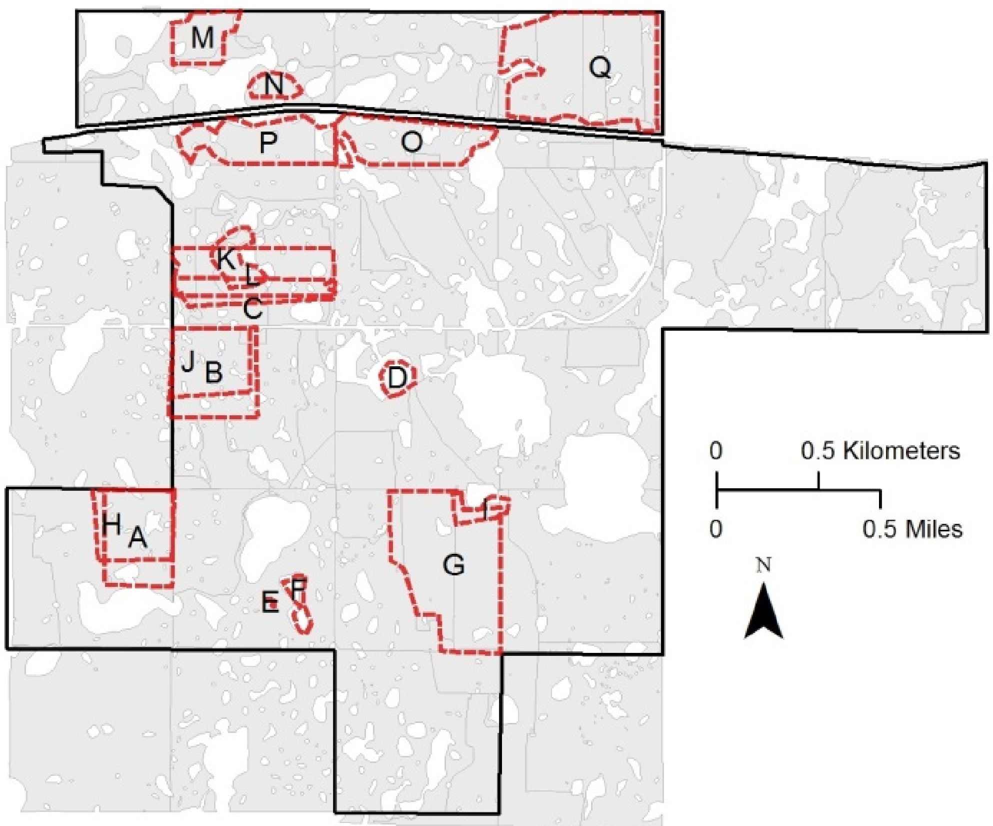
Feature	Years	Description	Source
		Base layers	
Field outlines	Pre-1960s	Pioneer fields, delineated by use	Bayha (written commun., 1964b)
Field outlines	Post-1960s	Fields delineated after federal management	Bayha (written commun., 1964b)
WSA border	1975	Federally managed land	Existing digital file
Study units	1975	Study unit or quarter section lines	Existing digital file
		Vegetation transects	
Bayha	1963	First upland transects at the WSA	Bayha (written commun., 1963)
Meyer	1980	One year of percent cover	Hardcopy map
Higgins, approximate	1966	Approximate transect locations	Existing digital file
Higgins, ground truthed	1966	Existing transect end poles	Ground truthed in 2013 by K. Higgins
Robel	1975	Approx. transect locations	Hardcopy maps
Photograph stations	1970	Current photograph stations	Existing digital file
		Land cover	
Bayha land cover	1964	Habitat types	Bayha (written commun., 1964b)
Bayha land cover	1963	Upland vegetation	Bayha (written commun., 1963)
Field land use	1964–87	Available as GeoJson file	Hardcopy file

Appendix 9. Fertilizer treatments and locations at the Woodworth Study Area (WSA), 1966–75

[ID was arbitrarily assigned for the present report and corresponds to the location of the treatment in the map figure below. Study unit follows WSA convention. Date is the month (if known) and year of fertilizer application. Original descriptions are as written in archived notes and maps in the Northern Prairie Wildlife Research Center archives; see Conversion Factors for metric equivalents. Descriptions indicate application rates in pounds (lbs) or pounds per acre (lb/ac) of phosphorous (phos.), nitrogen (N), or potassium (K).]

ID	Study unit	Date	Original description
A	15	October 1971	100 lb/ac actual phos., 100 lbs/ac actual N on ~40 acres
B	13	October 1971	100 lb/ac actual phos., 100 lbs/ac actual N, on ~40 ac
C	6	October 1971	100 lbs/acres actual phosphate on 36.80 acres
D	12	September 1969	100 lbs 25-25-0
E	16	1969	25-25-0
F	16	1969	25-25-0
G	17	September 1969	100 lbs 0-46-0
H	15	November 1972	100 lbs K, 100 lbs N; 400 lbs 25-25-0/acre
I	17	1968	46 lbs K; 100 lbs/acre 0-46-0
J	13	November 1972	100 lbs K, 100 lbs N; 400 lbs 25-25-0/acre
K	6	September 1969	46 lbs K; 100 lbs 0-46-0
L	6	November 1972	100 lbs phos.; 217 lbs of 0-46-0/acre
M	3	September 1969	100 lbs 0-46-0; 46 lbs K
N	3	September 1969	100 lbs 0-46-0; 46 lbs K
O	2	1969	25 lbs K, 25 lbs N; 100 lbs+ 25-25-0
O	2	October 1974	11-48-0, 200 lbs/acre; 96 lbs K; 22 lbs N
P	3	October 1974	200 lbs, 11-48-0; almost all covered by low areas
Q	1	1975	41 lbs phos; 16 lbs N

Appendix 9 – Figure 1. Location of the fertilizer treatment on the Woodworth Study Area (WSA) between 1969 and 1975.



Appendix 10. Master list of vegetation found at the Woodworth Study Area (WSA) during 1966–89

[Plants that were recorded in at least one survey at the WSA during 1966–89, listed alphabetically by scientific name. Scientific species name and USDA symbol are from USDA Plant Database (2014). Common name(s) are from USDA Plant Database (2014), WSA files, or the Northern Great Plains Floristic Quality Assessment Panel (Mushet and others, 2001); INV is invasive species, UNK is unknown C value. The C is coefficient of conservatism assigned by Mushet and others (2001). Functional group is sedge, forb, grass, or VST (vine, shrub, or tree).]

Scientific name	Common name(s)	USDA	C	Functional group
Acer negundo	boxelder	ACNE2	1	VST
Achillea millefolium	common yarrow	ACMI2	3	forb
Acroptilon repens	hardheads	ACRE3	INV	forb
Agalinis tenuifolia	slenderleaf false foxglove, slender gerardia	AGTEM	8	forb
Agoseris glauca	pale agoseris, false dandelion	AGGL	8	forb
Agoseris retrorsa	spearleaf agoseris	AGRE	UNK	forb
Agrimonia striata	roadside agrimony, agrimony	AGST	5	forb
Agropyron cristatum	crested wheatgrass	AGCR	INV	grass
Agrostis hyemalis	winter bentgrass, ticklegrass	AGHY	1	grass
Agrostis scabra	rough bentgrass	AGSC5	1	grass
Alisma gramineum	narrowleaf water plantain	ALGR	2	forb
Alisma subcordatum	American water plantain	ALSU	2	forb
Allium stellatum	autumn onion, pink wild onion	ALST	7	forb
Allium textile	textile onion, white wild onion	ALTE	7	forb
Alopecurus aequalis	shortawn foxtail	ALAE	2	grass
Amaranthus retroflexus	redroot amaranth, rough pigweed	AMRE	0	forb
Ambrosia psilostachya	Cuman ragweed, western ragweed	AMPS	2	forb
Amelanchier alnifolia	Saskatoon serviceberry, juneberry	AMAL2	6	VST
Amorpha canescens	leadplant	AMCA6	9	VST
Amorpha fruticosa	false indigo bush	AMFR	4	VST
Amorpha nana	dwarf false indigo, dwarf wild indigo	AMNA	9	VST
Andropogon gerardii	big bluestem	ANGE	5	grass
Androsace occidentalis	western rockjasmine	ANOC2	5	forb
Anemone canadensis	Canadian anemone, meadow anemone	ANCA8	4	forb
Anemone cylindrica	candle anemone	ANCY	7	forb
Antennaria neglecta	field pussytoes	ANNE	5	forb
Antennaria parvifolia	small-leaf pussytoes, pussy toes	ANPA4	6	forb
Antennaria rosea	rosy pussytoes	ANRO2	UNK	forb
Anthriscus caucalis	bur chervil	ANSC8	UNK	forb
Apocynum androsaemifolium	spreading dogbane	APAN2	6	forb
Apocynum cannabinum	Indianhemp, prairie dogbane	APCA	4	forb
Arabis × divaricarpa	spreadingpod rockcress, rock cress	ARDI2	9	forb

Scientific name	Common name(s)	USDA	C	Functional group
Arabis hirsuta	hairy rockcress, rock cress	ARHI	7	forb
Arabis holboellii	Holboell's rockcress, rock cress	ARHO2	5	forb
Arabis spp.	rockcress	ARABI	UNK	forb
Arctium minus	lesser burdock	ARMI2	INV	forb
Argentina anserina	silverweed cinquefoil, silverweed	ARAN7	2	forb
Artemisia absinthium	absinthium, wormwood	ARAB3	INV	forb
Artemisia biennis	biennial wormwood	ARBI2	INV	forb
Artemisia campestris	field sagewort, western sagebrush	ARCAC	5	forb
Artemisia dracunculus	tarragon, silky wormwood	ARDR4	4	forb
Artemisia frigida	prairie sagewort	ARFR4	4	VST
Artemisia ludoviciana	white sagebrush, white sage	ARLU	3	forb
Asclepias ovalifolia	oval-leaf milkweed	ASOV	9	forb
Asclepias speciosa	showy milkweed	ASSP	4	forb
Asclepias syriaca	common milkweed	ASSY	0	forb
Asclepias verticillata	whorled milkweed	ASVE	3	forb
Asclepias viridiflora	green comet milkweed, green milkweed	ASVI	8	forb
Asclepias incarnata	swamp milkweed	ASIN	5	forb
Asclepias pumila	plains milkweed	ASPU	7	forb
Astragalus agrestis	purple milkvetch	ASAG2	6	forb
Astragalus bisulcatus	twogrooved milkvetch	ASBI2	5	forb
Astragalus canadensis	Canadian milkvetch	ASCA11	5	forb
Astragalus canadensis var. *brevidense*	shorttooth Canadian milkvetch	ASCAB	5	forb
Astragalus crassicarpus	groundplum milkvetch	ASCR2	7	forb
Astragalus flexuosus	flexile milkvetch, slender milkvetch	ASFL2	4	forb
Astragalus gilviflorus	plains milkvetch, tufted milkvetch	ASGI5	7	forb
Astragalus laxmannii	prairie milkvetch	ASLAR	8	forb
Astragalus pectinatus	narrowleaf milkvetch	ASPE5	8	forb
Astragalus racemosus	cream milkvetch	ASRA2	7	forb
Astragalus tenellus	looseflower milkvetch	ASTE5	8	forb
Astragalus lotiflorus	lotus milkvetch	ASLO4	6	forb
Avena fatua	wild oat	AVFA	INV	grass
Avenula hookeri	spikeoat	AVHO3	9	grass
Bassia scoparia	burningbush, kochia	BASC5	INV	forb
Beckmannia syzigachne	American sloughgrass	BESY	1	grass
Bidens frondosa	devil's beggartick, beggarticks	BIFR	1	forb
Bidens vulgata	big devils beggartick, beggarticks	BIVU	1	forb
Bidens comosa	threelobe beggarticks, swamp tickseed	BICO3	2	forb
Boltonia asteroides	white doll's daisy, violet boltonia	BOASL	3	forb
Bouteloua curtipendula	sideoats grama	BOCU	5	grass
Bouteloua gracilis	blue grama	BOGR2	7	grass

Scientific name	Common name(s)	USDA	C	Functional group
Bromus arvensis	field brome, Japanese brome	BRAR5	INV	grass
Bromus inermis	smooth brome	BRIN2	INV	grass
Bromus tectorum	cheatgrass, downy brome	BRTE	INV	grass
Calamagrostis canadensis	bluejoint	CACA4	5	grass
Calamagrostis montanensis	plains reedgrass	CAMO	8	grass
Calamagrostis stricta	northern reedgrass	CASTI3	5	grass
Calamovilfa gigantea	giant sandreed	CAGI3	UNK	grass
Calamovilfa longifolia	prairie sandreed	CALO	5	grass
Callitriche hermaphroditica	northern water-starwort	CAHE2	7	forb
Calochortus lyallii	Lyall's mariposa lily, yellow evening primrose	CALY	7	forb
Calylophus serrulatus	yellow sundrops	CASE12	7	forb
Calystegia sepium	hedge false bindweed, hedge bindweed	CASEA2	0	forb
Campanula rotundifolia	bluebell bellflower, harebell	CARO2	7	forb
Capsella bursa-pastoris	shepherd's purse	CABU2	INV	forb
Carex atherodes	wheat sedge, slough sedge	CAAT2	4	sedge
Carex brevior	shortbeak sedge, fescue sedge	CABR10	4	sedge
Carex duriuscula	needleleaf sedge	CADU6	4	sedge
Carex filifolia	threadleaf sedge	CAFI	7	sedge
Carex inops	sun sedge	CAINH2	7	sedge
Carex interior	inland sedge	CAIN11	10	sedge
Carex laxiculmis	spreading sedge	CALAC	UNK	sedge
Carex pellita	woolly sedge	CAPE42	4	sedge
Carex pensylvanica	Pennsylvania sedge	CAPE6	8	sedge
Carex praegracilis	clustered field sedge	CAPR5	5	sedge
Carex rostrata	beaked sedge	CARO6	8	sedge
Carex aquatilis	water sedge	CAAQA5	10	sedge
Carex crawei	Crawe's sedge	CACR3	9	sedge
Carex obtusata	obtuse sedge	CAOB4	8	sedge
Carex sartwellii	Sartwell's sedge	CASA8	5	sedge
Castilleja sessiliflora	downy paintedcup	CASE5	8	forb
Castilleja coccinea	scarlet Indian paintbrush	CACO17	UNK	forb
Ceanothus arboreus	feltleaf ceanothus	CEAR	UNK	VST
Celastrus scandens	American bittersweet	CESC	5	VST
Centaurea maculosa	spotted knapweed	CEMA4	INV	forb
Cerastium arvense	field chickweed, prairie chickweed	CEAR4	2	forb
Chamaerhodos erecta	little rose	CHER	6	forb
Chamaesyce serpyllifolia	thymeleaf sandmat, thyme-leaved spurge	CHSES	0	forb
Chamaesyce maculata	spotted sandmat	CHMA15	UNK	forb
Chamaesyce serpens	matted sandmat	CHSE4	UNK	forb

Scientific name	Common name(s)	USDA	C	Functional group
Chamerion angustifolium	fireweed	CHANA2	5	forb
Chenopodium album	lambsquarters	CHAL7	INV	forb
Chenopodium glaucum	oakleaf goosefoot	CHGL3	INV	forb
Cicuta maculata	spotted, common water hemlock	CIMA2	4	forb
Cirsium arvense	Canada thistle	CIAR4	INV	forb
Cirsium flodmanii	Flodman's thistle, prairie thistle	CIFL	5	forb
Cirsium undulatum	wavyleaf thistle	CIUN	7	forb
Cirsium vulgare	bull thistle	CIVU	INV	forb
Cistanthe umbellata	Mt. Hood pussypaws	CIUM	UNK	forb
Collomia linearis	tiny trumpet, collomia	COLI2	5	forb
Comandra umbellata	bastard toadflax	COUM	8	forb
Convolvulus arvensis	field bindweed	COAR4	INV	forb
Conyza canadensis	Canadian horseweed, horseweed	COCA5	0	forb
Cornus sericea	redosier dogwood	COSES	UNK	VST
Crataegus chrysocarpa	fireberry hawthorn, roundleaf hawthorn	CRCH	UNK	VST
Crepis runcinata	fiddleleaf hawksbeard, hawk's-beard	CRRU3	8	forb
Cypripedium parviflorum	lesser yellow lady's slipper	CYPAP4	10	forb
Cypripedium parviflorum	greater yellow lady's slipper	CYPAP3	10	forb
Dalea candida	white prairie clover	DACA7	8	forb
Dalea purpurea	purple prairie clover	DAPU5	8	forb
Dalea candida	white prairie clover	DACAC	8	forb
Dalea leporina	foxtail prairie clover	DALE3	2	forb
Deschampsia cespitosa	tufted hairgrass	DECE	9	grass
Descurainia sophia	herb sophia, flixweed	DESO2	INV	forb
Dichanthelium leibergii	Leiberg's panicum	DILE2	8	grass
Dichanthelium wilcoxianum	fall rosette grass, Wilcox panicum	DIWI5	8	grass
Distichlis spicata	saltgrass	DISP	2	grass
Draba nemorosa	woodland draba, yellow whitlowwort	DRNE	1	forb
Echinacea angustifolia	blacksamson echinacea, purple coneflower	ECAN2	7	forb
Echinochloa crus-galli	barnyardgrass	ECCR	INV	grass
Elaeagnus angustifolia	Russian olive	ELAN	INV	VST
Elaeagnus commutata	silverberry	ELCO	5	VST
Eleocharis acicularis	needle spikerush	ELAC	3	sedge
Eleocharis erythropoda	bald spikerush	ELER	2	sedge
Eleocharis palustris	common spikerush, spike rush	ELPA3	4	sedge
Eleocharis compressa	flatstem spikerush	ELCO2	8	sedge
Eleocharis macrostachya	pale spikerush	ELMA5	4	sedge
Elymus canadensis	Canada wildrye	ELCA4	3	grass
Elymus caninus	bearded wheatgrass, slender wheatgrass	ELCA11	6	grass

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Elyleymus hirtiflorus	Canadian wildrye	ELHI4	UNK	grass
Elymus lanceolatus	thickspike wheatgrass	ELLAL	7	grass
Elymus repens	quackgrass	ELRE4	INV	grass
Elymus trachycaulus	slender wheatgrass	ELTRS	6	grass
Epilobium brachycarpum	tall annual willowherb, willow herb	EPBR3	3	forb
Epilobium ciliatum	fringed willowherb	EPCIC	3	forb
Epilobium palustre	marsh willowherb, narrow-leaved willow herb	EPPA	6	forb
Epilobium angustifolium	fireweed	EPAN2	5	forb
Equisetum arvense	field horsetail	EQAR	4	forb
Equisetum laevigatum	smooth horsetail	EQLA	3	forb
Equisetum hyemale	scouringrush horsetail	EQHY	3	forb
Erigeron glabellus	streamside fleabane, smooth fleabane	ERGL2	7	forb
Erigeron philadelphicus	Philadelphia fleabane	ERPH	2	forb
Erigeron strigosus	prairie fleabane, daisy fleabane	ERST3	3	forb
Eriophorum viridicarinatum	thinleaf cottonsedge	ERVI9	10	sedge
Eriophorum polystachion	cottongrass	ERPO6	8	sedge
Erucastrum gallicum	common dogmustard, dog mustard	ERGA	INV	forb
Erysimum asperum	western wallflower	ERAS2	3	forb
Erysimum cheiranthoides	wormseed wallflower	ERCH9	INV	forb
Erysimum inconspicuum	shy wallflower, smallflower wallflower	ERIN7	7	forb
Escobaria vivipara	spinystar, pincushion cactus	ESVIV	10	forb
Eupatoriadelphus maculatus	spotted trumpetweed, spotted joe-pye-weed	EUMAM3	9	forb
Euphorbia esula	leafy spurge	EUESE	INV	forb
Eurybia sibirica	arctic aster, simple aster	EUSI13	3	forb
Euthamia graminifolia	flat-top goldentop, narrow-leaved goldenrod	EUGRG	6	forb
Festuca ovina	sheep fescue	FEOV	8	grass
Fragaria virginiana	Virginia strawberry, wild strawberry	FRVI	4	forb
Fumaria officinalis	drug fumitory	FUOF	UNK	forb
Gaillardia aristata	common gaillardia, blanketflower	GAAR	5	forb
Galium boreale	northern bedstraw	GABO2	4	forb
Galium trifidum	threepetal bedstraw, small bedstraw	GATR2	8	forb
Gaura coccinea	scarlet beeblossom, scarlet gaura	GACO5	4	forb
Gentiana affinis	pleated gentian, northern gentian	GEAF	10	forb
Gentiana andrewsii	closed bottle gentian	GEAN	10	forb
Gentianella amarella	autumn dwarf gentian	GEAM3	7	forb
Gentianopsis procera	lesser fringed gentian	GEPR6	10	forb
Geum aleppicum	yellow avens	GEAL3	4	forb
Geum triflorum	old man's whiskers, purple avens	GETR	8	forb
Glyceria grandis	American mannagrass, tall mannagrass	GLGR	4	grass

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Glyceria striata	fowl mannagrass	GLST	6	grass
Glycyrrhiza lepidota	American licorice, wild licorice	GLLE3	2	forb
Graphina sophisticascens	sophisticated graphina lichen, curly-top gumweed	GRSO	1	forb
Gutierrezia sarothrae	broom snakeweed	GUSA2	6	VST
Hackelia virginiana	beggarslice, Virginia stickseed	HAVI2	0	forb
Hedeoma hispida	rough false pennyroyal, rough pennyroyal	HEHI	2	forb
Helianthus × laetiflorus	cheerful sunflower, stiff sunflower	HELA	UNK	forb
Helianthus annuus	common sunflower	HEAN3	0	forb
Helianthus maximiliani	Maximilian sunflower	HEMA2	5	forb
Helianthus nuttallii	Nuttall's sunflower	HENU	8	forb
Helianthus nuttallii ssp. Rydbergii	Rydberg's sunflower, Nuttall's sunflower	HENUR	8	forb
Hesperis matronalis	dames rocket	HEMA3	INV	forb
Hesperostipa comata	needle and thread	HECOC8	6	grass
Hesperostipa spartea	porcupinegrass	HESP11	8	grass
Heterotheca camporum	lemonyellow false goldenaster, golden aster	HECAC2	UNK	forb
Heterotheca villosa	hairy false goldenaster	HEVIV	3	forb
Heuchera richardsonii	Richardson's alumroot	HERI	8	forb
Hierochloe odorata	sweetgrass	HIOD	10	grass
Hippuris vulgaris	common mare's-tail, mare's-tail	HIVU2	5	forb
Hordeum jubatum	foxtail barley	HOJU	0	grass
Hypoxis hirsuta	common goldstar, yellow stargrass	HYHI2	8	forb
Iva annua	annual marsh elder, marsh elder	IVAN2	INV	forb
Juncus arcticus	mountain rush, Baltic rush	JUARL	5	rush
Juncus bufonius	toad rush	JUBU	1	rush
Juncus dudleyi	Dudley's rush	JUDU2	4	rush
Juncus interior	inland rush	JUIN2	5	rush
Juncus longistylis	longstyle rush	JULO	10	rush
Juncus nodosus	knotted rush	JUNO2	7	rush
Juncus torreyi	Torrey's rush	JUTO	2	rush
Koeleria macrantha	prairie junegrass, junegrass	KOMA	7	grass
Lactuca serriola	prickly lettuce	LASE	INV	forb
Lactuca tatarica	blue lettuce	LATAP	1	forb
Lappula occidentalis	flatspine stickseed, low stickseed	LAOCO	2	forb
Lappula squarrosa	European stickseed, blue stickseed	LASQ	INV	forb
Lathyrus ochroleucus	cream pea, yellow vetchling	LAOC2	8	forb
Lathyrus venosus	veiny pea	LAVE	8	forb
Lemna minor	common duckweed	LEMI3	9	forb
Lemna trisulca	star duckweed	LETR	2	forb
Lepidium densiflorum	common pepperweed, peppergrass	LEDE	0	forb

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Lesquerella ludoviciana	foothill bladderpod, silver bladderpod	LELU	6	forb
Leymus cinereus	basin wildrye	LECI4	UNK	grass
Liatris ligulistylis	Rocky Mountain blazing star, gay-feather	LILI	10	forb
Liatris punctata	dotted blazing star, blazing star	LIPU	7	forb
Lilium philadelphicum	wood lily, wild lily	LIPH	8	forb
Lilium canadense	Canada lily	LICAC	10	forb
Linaria vulgaris	butter and eggs	LIVU2	INV	forb
Linum rigidum	stiffstem flax	LIRI	5	forb
Linum sulcatum	grooved flax	LISU4	7	forb
Lithospermum canescens	hoary puccoon, Indiana plant	LICA12	7	forb
Lithospermum incisum	narrowleaf stoneseed, narrow-leaved puccoon	LIIN2	7	forb
Lobelia kalmia	Ontario lobelia, Kalm's lobelia	LOKA	10	forb
Lobelia spicata	palespike lobelia	LOSP	6	forb
Lomatium foeniculaceum	desert biscuitroot, yellow wild parsley	LOFO	6	forb
Lomatium orientale	northern Idaho biscuitroot, wild parsley	LOOR	8	forb
Lonicera tatarica	Tatarian honeysuckle	LOTA	INV	VST
Lotus unifoliolatus	American bird's-foot trefoil, prairie bird's feet trefoil	LOUNU	3	forb
Lycopus americanus	American water horehound, American bugleweed	LYAM	4	forb
Lycopus asper	rough bugleweed	LYAS	4	forb
Lygodesmia juncea	rush skeletonplant	LYJU	2	forb
Lysimachia ciliata	fringed loosestrife, fringed loosestripe	LYCI	6	forb
Lysimachia hybrida	lowland yellow loosestrife, loosestrife	LYHY	5	forb
Lysimachia thyrsiflora	tufted loosestrife	LYTH2	7	forb
Machaeranthera canescens	hoary tansyaster, skeleton weed	MACA2	2	forb
Machaeranthera pinnatifida	machaeranthera, spiny ironplant	MAPIS	7	forb
Maianthemum stellatum	starry false lily of the valley, spikeard	MAST4	5	forb
Matricaria discoidea	disc mayweed, pineappleweed	MADI6	INV	forb
Medicago lupulina	black medick	MELU	INV	forb
Medicago sativa	alfalfa	MESA	INV	forb
Melilotus officinalis	yellow sweetclover, white sweet clover	MEOF	INV	forb
Mentha arvensis	wild mint, field mint	MEAR4	3	forb
Mirabilis hirsuta	hairy four o'clock	MIHI	4	forb
Mirabilis nyctaginea	heartleaf four o'clock	MINY	2	forb
Moehringia lateriflora	bluntleaf sandwort, grove sandwort	MOLA6	8	forb
Muhlenbergia asperifolia	scratchgrass	MUAS	2	grass
Muhlenbergia cuspidata	plains muhly	MUCU3	8	grass
Muhlenbergia racemosa	marsh muhly	MURA	4	grass
Muhlenbergia richardsonis	mat muhly	MURI	10	grass

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Muhlenbergia glomerata	spiked muhly	MUGL3	10	grass
Myriophyllum spicatum	shortpike watermilfoil	MYSPE	INV	forb
Nassella viridula	green needlegrass	NAVI4	5	grass
Nepeta cataria	catnip	NECA2	INV	forb
Oenothera nuttallii	Nuttall's evening primrose, white stemmed evening primrose	OENU	8	forb
Oenothera villosa	hairy evening primrose, common evening primrose	OEVIS	0	forb
Oenothera biennis	common evening primrose	OEBI	0	forb
Oligoneuron album	prairie goldenrod, sneezewort aster	OLAL2	5	forb
Oligoneuron rigidum	stiff goldenrod, rigid goldenrod	OLRIR	4	forb
Onobrychis viciifolia	sainfoin	ONVI	UNK	forb
Onosmodium bejariense	western marbleseed, false gromwell	ONBEO	7	forb
Orobanche fasciculata	clustered broomrape	ORFA	9	forb
Orobanche ludoviciana	Louisiana broomrape, broomrape	ORLU	10	forb
Orthocarpus luteus	yellow owl's-clover, owl clover	ORLU2	6	forb
Oxalis stricta	common yellow oxalis, yellow wood sorrel	OXST	0	forb
Oxytropis lambertii	purple locoweed	OXLA3	5	forb
Packera cana	woolly groundsel, gray ragwort	PACA15	8	forb
Packera plattensis	prairie groundsel, prairie ragwort	PAPL12	6	forb
Panicum capillare	witchgrass	PACA6	0	grass
Panicum virgatum	switchgrass	PAVI2	5	grass
Parnassia palustris	marsh grass of parnassus, northern grass-of-parnassus	PAPA8	10	forb
Parthenocissus quinquefolia	Virginia creeper	PAIN10	2	VST
Pascopyrum smithii	western wheatgrass	PASM	4	grass
Pastinaca sativa	wild parsnip	PASA2	INV	forb
Pediomelum argophyllum	silverleaf Indian breadroot, silver leaf scurf pea	PEAR6	4	forb
Pediomelum esculentum	large Indian breadroot, breadroot scurf pea	PEES	9	forb
Penstemon albidus	white penstemon, white beardtongue	PEAL2	7	forb
Penstemon gracilis	lilac penstemon, slender beardtongue	PEGR5	6	forb
Phacelia viscida	tacky phacelia	PHVI	UNK	forb
Phalaris arundinacea	reed canarygrass	PHAR3	0	grass
Phleum pratense	timothy	PHPR3	INV	grass
Phlox hoodii	spiny phlox, hood's phlox	PHHO	6	forb
Phragmites australis	common reed	PHAU7	0	grass
Physalis heterophylla	clammy groundcherry	PHHE5	5	forb
Physalis virginiana	Virginia groundcherry, ground cherry	PHVI5	4	forb
Plantago eriopoda	redwool plantain, alkali plantain	PLER	5	forb
Plantago major	common plantain	PLMA2	INV	forb
Plantago lanceolata	narrowleaf plantain	PLLA	INV	forb

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Platanthera aquilonis	northern green orchid	PLAQ2	9	forb
Poa compressa	Canada bluegrass	POCO	INV	grass
Poa nemoralis	inland bluegrass	PONEI2	5	grass
Poa paludigena	bog bluegrass	POPA	UNK	grass
Poa palustris	fowl bluegrass	POPA2	4	grass
Poa pratensis	Kentucky bluegrass	POPR	INV	grass
Polygala alba	white milkwort	POAL4	5	forb
Polygala senega	Seneca snakeroot	POSE3	10	forb
Polygala verticillata	whorled milkwort	POVE	8	forb
Polygonatum biflorum	smooth Solomon's seal	POBI2	8	forb
Polygonum achoreum	leathery knotweed, erect knotweed	POAC3	INV	forb
Polygonum aviculare	prostrate knotweed, common knotweed	POAV	0	forb
Polygonum convolvulus	black bindweed, wild buckwheat	POCO10	INV	VST
Polygonum lapathifolium	curlytop knotweed, pale smartweed	POLA4	1	forb
Polygonum persicaria	spotted ladysthumb, lady's thumb	POPE3	INV	forb
Polygonum amphibium	water smartweed	POAMS	6	forb
Pontederia cordata	pickerelweed	POCO14	UNK	forb
Populus deltoides	eastern cottonwood, cottonwood	PODE3	3	VST
Portulaca oleracea	little hogweed	POOL	INV	forb
Potamogeton gramineus	variableleaf pondweed	POGR8	6	forb
Potamogeton pusillus	small pondweed	POPUP5	2	forb
Potamogeton richardsonii	Richardson's pondweed	PORI2	4	forb
Potentilla arguta	tall cinquefoil	POAR7	8	forb
Potentilla concinna	elegant cinquefoil, early cinquefoil	POCO13	8	forb
Potentilla gracilis	slender cinquefoil, graceful cinquefoil	POGR9	5	forb
Potentilla hickmanii	Hickman's cinquefoil, woolly cinquefoil	POHI5	8	forb
Potentilla norvegica	Norwegian cinquefoil, strawberryweed	PONO3	0	forb
Potentilla pensylvanica	Pennsylvania cinquefoil	POPE8	9	forb
Potentilla rivalis Nutt.	brook cinquefoil	PORI3	3	forb
Potentilla concinna	elegant cinquefoil	POCOC3	8	forb
Prenanthes racemosa	purple rattlesnakeroot	PRRA	10	forb
Prunus americana	American plum, wild plum	PRAM	4	VST
Prunus virginiana	chokecherry	PRVI	4	VST
Puccinellia nuttalliana	Nuttall's alkaligrass, alkali grass	PUNU2	4	grass
Pulsatilla patens	cutleaf anemone, pasque-flower	PUPAM	9	forb
Ranunculus glaberrimus	sagebrush buttercup, shiny-leaved buttercup	RAGL	8	forb
Ranunculus macounii	Macoun's buttercup	RAMA2	4	forb
Ranunculus rhomboideus	Labrador buttercup, prairie buttercup	RARH	8	forb
Ranunculus aquatilis	white water crowfoot	RAAQ	UNK	forb

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Ranunculus cymbalaria	alkali buttercup	RACY	3	forb
Ranunculus flabellaris	yellow water buttercup	RAFL	7	forb
Ranunculus gmelinii	Gmelin's buttercup	RAGM	8	forb
Ranunculus longirostris	longbeak buttercup	RASU	7	forb
Ranunculus sceleratus	cursed buttercup	RASC3	3	forb
Ratibida columnifera	upright prairie coneflower, prairie coneflower	RACO3	3	forb
Rhamnus cathartica	common buckthorn	RHCA3	INV	VST
Ribes americanum	American black currant, wild black currant	RIAM2	7	VST
Ribes missouriense	Missouri gooseberry	RIMI	4	VST
Rorippa palustris	bog yellowcress	ROPA2	2	forb
Rosa arkansana	prairie rose, prairie wild rose	ROAR3	3	VST
Rosa woodsii	Woods' rose, western wild rose	ROWO	5	VST
Rubus idaeus	grayleaf red raspberry	RUIDS2	5	VST
Rudbeckia hirta	blackeyed susan	RUHI2	5	forb
Rumex aquaticus	western dock	RUAQF	7	forb
Rumex crispus	curly dock	RUCR	INV	forb
Rumex longifolius	dooryard dock	RULO2	INV	forb
Rumex maritimus	golden dock	RUMA4	1	forb
Rumex salicifolius	Mexican dock, willow-leaved dock	RUSAM	1	forb
Sagittaria cuneata	arumleaf arrowhead	SACU	6	forb
Salix discolor	pussy willow	SADI	7	VST
Salsola kali	Russian thistle	SAKA	INV	forb
Schedonnardus paniculatus	tumblegrass	SCPA	1	grass
Schizachyrium scoparium	little bluestem	SCSC	6	grass
Schoenoplectus acutus	hardstem bulrush	SCACA	5	sedge
Schoenoplectus fluviatilis	river bulrush	SCFL11	UNK	sedge
Schoenoplectus tabernaemontani	softstem bulrush	SCVA	3	sedge
Scirpu americanus	chairmaker's bulrush	SCAM2	UNK	sedge
Scirpus atrovirens	green bulrush	SCAT2	5	sedge
Scolochloa festucacea	common rivergrass, sprangletop	SCFE	6	grass
Scutellaria galericulata	marsh skullcap	SCGA	7	forb
Senecio congestus	marsh fleabane, swamp ragwort	SECO2	2	forb
Senecio integerrimus	lambstongue ragwort, entire-leaved groundsel	SEIN2	7	forb
Senecio pseudoarnica	seaside ragwort, falsegold groundsel	SEPS	5	forb
Setaria pumila	yellow foxtail	SEPUP2	INV	grass
Setaria viridis	green bristlegrass	SEVI4	INV	grass
Silene csereii	Balkan catchfly, smooth catchfly	SICS	INV	forb
Silene latifolia	bladder campion, white cockle	SILAA3	INV	forb
Silene noctiflora	nightflowering silene, night-flowering catchfly	SINO	INV	forb

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Sinapis arvensis	wild mustard, charlock	SIARA	INV	forb
Sisymbrium altissimum	tall tumblemustard, tumbling mustard	SIAL2	INV	forb
Sisyrinchium angustifolium	narrowleaf blue-eyed grass, blue eyed grass	SIAN3	UNK	forb
Sisyrinchium montanum	strict blue-eyed grass	SIMO2	8	forb
Sium suave	hemlock waterparsnip	SISU2	3	forb
Smilax herbacea	smooth carrionflower, carrion-flower	SMHE	8	VST
Solanum americanum	American black nightshade	SOAM	UNK	forb
Solanum campechiense	redberry nightshade	SOCA	UNK	forb
Solanum nigrum	black nightshade	SONI	0	forb
Solanum triflorum	cutleaf nightshade	SOTR	0	forb
Solidago arguta	Atlantic goldenrod	SOAR	UNK	forb
Solidago canadensis	Canada goldenrod	SOCA6	1	forb
Solidago gigantea	giant goldenrod	SOGI	4	forb
Solidago missouriensis	Missouri goldenrod, prairie goldenrod	SOMI2	5	forb
Solidago mollis	velvety goldenrod, soft goldenrod	SOMO	6	forb
Solidago nemoralis	gray goldenrod	SONE	6	forb
Sonchus arvensis	field sowthistle, field sow thistle	SOAR2	INV	forb
Sonchus oleraceus	common sowthistle	SOOL	INV	forb
Sorghastrum nutans	Indiangrass	SONU2	6	grass
Sparganium eurycarpum	broadfruit bur-reed, giant burreed	SPEU	4	forb
Spartina gracilis	alkali cordgrass	SPGR	6	grass
Spartina pectinata	prairie cordgrass	SPPE	5	grass
Sphaeralcea coccinea	scarlet globemallow, red false mallow	SPCO	4	forb
Sphenopholis obtusata	prairie wedgescale, prairie wedgegrass	SPOB	7	grass
Spiraea alba	white meadowsweet, meadowsweet	SPAL2	7	VST
Sporobolus compositus	composite dropseed, rough dropseed	SPCOC2	4	grass
Sporobolus cryptandrus	sand dropseed	SPCR	6	grass
Sporobolus heterolepis	prairie dropseed	SPHE	10	grass
Stachys palustris	marsh hedgenettle, hedge nettle	STPA	3	forb
Stellaria longifolia	longleaf starwort, long-leaved stitchwort	STLO	8	forb
Stellaria media	common chickweed	STME2	INV	forb
Stuckenia pectinata	sago pondweed	STPE15	4	forb
Symphoricarpos occidentalis	western snowberry	SYOC	3	VST
Symphoricarpos orbiculatus	coralberry	SYOR	UNK	VST
Symphyotrichum boreale	northern bog aster, rush aster	SYBO2	10	forb
Symphyotrichum ericoides	white heath aster	SYERE	UNK	forb
Symphyotrichum laeve	smooth blue aster	SYLAL3	5	forb
Syringa vulgaris	common lilac	SYVU	UNK	VST
Taraxacum laevigatum	rock dandelion, red-seeded dandelion	TALA2	INV	forb

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Taraxacum officinale	common dandelion, dandelion	TAOF	INV	forb
Teucrium canadense	Canada germander	TECA3	3	forb
Thalictrum dasycarpum	purple meadow-rue	THDA	7	forb
Thinopyrum intermedium	intermediate wheatgrass	THIN6	INV	grass
Thinopyrum ponticum	tall wheatgrass	THPO7	INV	grass
Thlaspi arvense	field pennycress, penny cress	THAR5	INV	forb
Toxicodendron rydbergii	western poison ivy	TORY	3	VST
Tragopogon dubius	yellow salsify, goatsbeard	TRDU	INV	forb
Trifolium hybridum	alsike clover	TRHY	INV	forb
Trifolium repens	white clover	TRRE3	INV	forb
Triglochin maritima	seaside arrowgrass	TRMA20	5	grass
Typha angustifolia	narrowleaf cattail	TYAN	INV	forb
Typha latifolia	broadleaf cattail	TYLA	2	forb
Urtica dioica	stinging nettle	URDI	0	forb
Utricularia vulgaris	common bladderwort	UTVU	2	forb
Verbena bracteata	bigbract verbena, bracted vervain	VEBR	0	forb
Verbena hastata	swamp verbena, blue vervain	VEHA2	5	forb
Verbena stricta	hoary verbena	VEST	2	forb
Vernonia fasciculata	prairie ironweed	VEFA2	3	forb
Vicia americana	American vetch	VIAM	6	VST
Viola adunca	hookedspur violet, small blue violet	VIAD	8	forb
Viola nuttallii	Nuttall's violet	VINU2	8	forb
Viola pedata	birdfoot violet	VIPE	UNK	forb
Viola pedatifida	prairie violet	VIPE2	8	forb
Viola nephrophylla	northern bog violet	VINE	8	forb
Zannichellia palustris	horned pondweed	ZAPA	2	forb
Zigadenus elegans	mountain deathcamas, white camass	ZIEL2	8	forb
Zigadenus venenosus	meadow deathcamas, death camass	ZIVE	7	forb
Zizia aptera	meadow zizia, meadow parsnip	ZIAP	8	forb

Appendix 11. Plants collected at the Woodworth Study Area (WSA) and stored in the Northern Prairie Wildlife Research Center herbarium

[Plant scientific names are those recorded at the time of collection; taxonomy was primarily based on Gray's Manual of Botany (Fernald, 1950). U.S. Department of Agriculture (USDA) acronyms reflect accepted taxonomy as of 2014; see Appendix 10 for accepted scientific and common names. Collector is the staff or researcher at WSA who collected the sample, listed by their initials: AB = Allison Banks, CS = Charles Schaiffer, EL = Eric Larsen, KH = Kenneth F. Higgins, LHM = Lyla (Hotchkiss) Martin, MM = Mavis Meyer, MC = Michael Callow, RK = R.O. Kologiski, and WB = William J. Berg. Date is the date of plant collection. Location and original description are notes as recorded by the collectors. Location is described by field or plat location: T = Township (north [N]), R = Range (west [W]), sec= section, quarter (qtr). Later locations were determined by geographic position unit (GPS) and described by Universal Transverse Locator (UTM) system in zone 14: meters east (mE) and north (mN). Other abbreviations in the description include vegetation height (meters, m; decimeters, dm); W.P.A. is Waterfowl Production Area; slope angle, deg. is degree; and DNC is dense nesting cover.]

Scientific name	USDA acronym	Collector	Date	Location and original description
Acer negundo	ACNE2	MM	25-May-79	Shelterbelt south of station building. Quarter 12. UTM: 81,950mE, 19,600mN, zone 14.
Acer negundo	ACNE2	AB	18-Jun-79	Old farmstead, along road ditch. Tree, 10m tall. Quarter 4. UTM: 80,700mE, 21,880mN, zone 14.
Acer negundo	ACNE2	MC	6-May-80	In Quarter 3 at the Rickford farm site. Tree planting.
Agropyron caninum	ELCA11	MM, MC	16-Jul-80	Located in Quarter 13 in Buse Soil on dry prairie hill.
Agropyron caninum	ELCA11	KH	16-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec. 6. On sandy gravely soils.
Agropyron caninum	ELCA11	KH	16-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec. 6. On sandy gravely soils.
Agropyron caninum	ELCA11	KH	16-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec.6. On sandy gravely soil.
Agropyron cristatum	AGCR	KH, EL	22-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #146
Agropyron cristatum	AGCR	AB	24-Jul-79	Located in Quarter 9-A on the old airstrip. Plant to 1m. Tall.
Agropyron dasystachyum	ELLAL	MM	12-Jul-79	Wet Meadow. Quarter 20, NW1/4.
Agropyron elongatum	THPO7	KH	16-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 14, T142N, R68W, Sec. 11. Collected on a seeded road right-of-way.
Agropyron elongatum	THPO7	KH	16-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 14, T142N, R68W, Sec. 11. Collected on a seeded road right-of-way.
Agropyron intermedium	THIN6	KH	16-Aug-81	Located 3 miles East of Woodworth, ND on the Woodworth Study Area in Quarter 6, T142N, R68W, Sec. 2. Specimen collected from a stand of seeded cover in heavy soils.
Agropyron repens	ELRE4	KH, MC	1-Jul-80	Located in Quarter 9-A in low area.
Agropyron smithii	PASM	MM	14-Jul-80	Located in Quarter 7 on East facing slope in Barnes Soil.

Scientific name	USDA acronym	Collector	Date	Location and original description
Agrostis hyemalis	AGHY	AB	17-Jul-79	Dry prairie hillside. Quarter 22. UTM: 81, 520mE, 18, 770mN, zone 14.
Agrostis hyemalis	AGHY	MC, KH	1-Jul-80	Located in Quarter 9-A in low moist prairie.
Agrostis hyemalis	AGHY	MM	29-Jul-80	Located in Quarter 9-A.
Agrostis hyemalis	AGHY	MM	8-Jul-81	Located in Quarter 22 growing on exposed soil in dry wetland.
Agrostis hyemalis	AGHY	MM	8-Jul-81	Located 3 miles East of Woodworth on WSA in Quarter 22, T142N, R68W, Sec.13. On exposed soils in a dry wetland.
Alisma plantago-aquatica	ALSU	AB	12-Jul-79	Growing in standing water in marshy pothole. Petals white. Plants to 1m tall Quarter 2. UTM: 82, 000mE, 21, 750mN, zone 14.
Alisma plantago-aquatica	ALSU	AB	12-Jul-79	Growing in standing water in marshy pothole. Petals white. Plants to 1m tall Quarter 2. UTM: 82, 000mE, 21, 750mN, zone 14.
Allium stellalum	ALST	AB	1-Aug-79	Upland prairie, burned in Spring. Silty loam. Flowers pink with *Andropogon gerardi*. Quarter 18. UTM: 82, 240mE, 19, 050mN, zone14.
Allium stellalum	ALST	AB	1-Aug-79	Upland prairie, burned in Spring. Silty loam. Flowers pink with *Andropogon gerardi*. Quarter 18. UTM: 82, 240mE, 19, 050mN, zone14.
Allium stellalum	ALST	MM, MC	6-Aug-80	Located in Quarter 9-A in Svea Soil.
Allium textile	ALTE	KH, EL	18-May-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #105
Allium textile	ALTE	MM	13-May-81	Located in Quarter 18. Fairly common on dry prairie, flowers white.
Allium textile	ALTE	MM	13-May-81	Located in Quarter 18. Fairly common on dry prairie, flowers white.
Alopecurus aequalis	ALAE	MM	20-Aug-79	Growing in 1.5 feet of water. Wetland 3, Quarter 9. UTM: 82, 900mE, 21, 250mN, zone 14.
Alopecurus aequalis	ALAE	MM	17-Jun-80	West shore of Fish Lake in Quarter 12 on the Woodworth Study Area.
Andropogon gerardi	ANGE	AB	1-Aug-79	Moist base of hill near pothole, in silty clay loam. To 1.6m tall. Quarter 16. UTM: 81, 200mE, 19, 240mN, zone 14.
Andropogon gerardi	ANGE	MM	29-Jul-80	Located in Quarter 9.
Andropogon scoparius	SCSC	AB	30-Aug-79	Damp lowland prairie. Bunch grass to 1m tall. Quarter 22. UTM: 81, 730mE, 19, 580mN, zone 14.
Andropogon scoparius	SCSC	MM	29-Jul-80	Located in Quarter 9 in Barnes Soil.
Andropogon scoparius	SCSC	MM	29-Jul-80	Located in Quarter 9 in Barnes Soil.
Andropogon scoparius	SCSC	MM	15-Aug-80	Located in Quarter 22 in Hamerly Soil.
Andropogon scoparius	SCSC	MM	15-Aug-80	Located in Quarter 22 in Hamerly Soil.
Asclepias incarnata	ASIN	KH	24-Jun-80	Located in Quarter 22 along 22-18.
Asclepias ovalifolia	ASOV	KH, EL	21-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #140
Asclepias ovalifolia	ASOV	AB	28-Jun-79	Damp depression between 2 hills leading to pothole. E. 30 deg. slope. Flowers greenish white, plant 2-3 dm tall. Quarter 8. UTM: 82,110mE, 20,880mN, zone 14.
Asclepias ovalifolia	ASOV	KH	27-Jul-79	Kutz W.P.A.- DNC in Woodworth, North Dakota in Stutsman County.

Scientific name	USDA acronym	Collector	Date	Location and original description
Asclepias ovalifolia	ASOV	KH, MC	28-Jul-79	Native grassland on the Kutz W.P.A.- DNC field in Woodworth, North Dakota. #615
Asclepias ovalifolia	ASOV	MM	18-Jun-80	Growing in lowland with *Anemone canadensis*. Quarter 9. UTM: 82,800mE, 20,800mN.
Asclepias syriaca	ASSY	MM	28-Jul-81	Located in Quarter 9-A in low area with *Bromus inermis*. Flowers pale pink/purple.
Asclepias verticillata	ASVE	MC	25-Jul-80	Located in Quarter 9-A in association with *Andropogon* and *Sorghastrum*. Flowers white.
Asclepias verticillata	ASVE	MM	29-Jul-80	Located in Quarter 9 with *Liatrus ligulistylis*. Site has high water table in undisturbed native prairie.
Avena fatua	AVFA	MM, CS	28-Jul-81	Located in Quarter 8 growing near field.
Bouteloua curtipendula	BOCU	AB	1-Aug-79	Upland prairie hillside, burned in spring. 3-5dm tall. With *Bouteloua gracilis*. Quarter 16. UTM: 81, 160mE, 19, 180mN, zone 14.
Bouteloua curtipendula	BOCU	MM	14-Jun-80	Located in Quarter 7 on East facing slope in Barnes Soil.
Bouteloua curtipendula	BOCU	MM	14-Jun-80	Located in Quarter 7 on East facing slope in Barnes Soil.
Bouteloua curtipendula	BOCU	KH	13-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 4, T142N, R68W, Sec. 2. In good soil along west side of 3-5 by crossing, east facing slope.
Bouteloua curtipendula	BOCU	KH	13-Aug-81	Located 3 miles East of Woodworth on WSA in Quarter 4, T142N, R68W, Sec. 2. In good soil along west side of 3-5 by crossing, east facing slope.
Bouteloua gracilis	BOGR2	MM	18-Jul-79	Growing on dry sites in mixed grass native prairie. Quarter 12. UTM: 81, 600mE, 19, 800mN, zone 14.
Bouteloua gracilis	BOGR2	MM	7-Jul-80	Located in Quarter 9-A in Sioux soils.
Bromus inermis	BRIN2	MM	18-Jun-80	With *Symphorocarpus occidentalis* in Quarter 22.
Bromus inermis	BRIN2	MC	23-Jun-80	Located in Quarter 22.
Bromus japonicus	BRAR5	AB	10-Jul-79	Steep, dry bank near gravel pit. Quarter 9. UTM: 83, 080mE, 20, 780mN, zone 14.
Bromus japonicus	BRAR5	MM	30-Jun-81	Located 3 miles East of Woodworth on WSA in Quarter 9, T142N, R67W, Sec. 6. In gravel pit area on thin soils.
Bromus japonicus	BRAR5	MM	30-Jun-81	Located in Quarter 9 in the gravel pit area.
Carex atherodes	CAAT2	KH, EL	22-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #148
Carex atherodes	CAAT2	MM	18-Jun-80	Located on West shore of Fish Lake at Woodworth Station.
Carex brevior	CABR10	MM	28-Jun-79	Growing in moist grassy low area with *Poa pratensis*. Quarter 14 in pasture. UTM: 80, 330mN, zone 14.
Carex brevior	CABR10	MM	21-Jul-80	Located in Quarter 11 in Eckman Gardena Soil. UTM: 82, 700mE; 19,650mN.
Carex eleocharis	CADU6	MM	28-Jun-79	Growing in native short grass prairie. Quarter 12. 81, 500m E, 20, 000m N UTM. Zone 14.
Carex eleocharis	CADU6	MM	8-Jun-81	Located in Quarter 9 on dry prairie in mixed grasses.

Scientific name	USDA acronym	Collector	Date	Location and original description
Carex filifolia	CAFI	MM	27-Jun-79	Growing on short grass hill tops with *Bouteloua gracilis*. Quarter 22. 81, 600mE, 18, 400mN utm. Zone 14.
Carex interior	CAIN11	MM	17-Jun-80	Located on West shore of Fish Lake in Quarter 12.
Carex interior	CAIN11	MM	18-Jun-80	Located on West shore of Fish Lake at Woodworth Station.
Carex interior	CAIN11	MM	30-Jun-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec. 6. In moist meadow with other sedges.
Carex interior	CAIN11	MM	30-Jun-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec. 6. In moist meadow with other sedges.
Carex lanuginosa	CAPE42	MM	17-Jun-80	Located in Quarter 12 on west shore of Fish Lake with *Erigeron philadelphicus* and *Carex interior*.
Carex obtusata	CAOB4	MM	6-Jun-79	Dry sites in mixed grass prairie. Quarter 22. UTM: 81, 350m E, 18, 700m N, zone 14.
Carex obtusata	CAOB4	MM	28-Jun-79	Mixed grass prairie. Quarter 12. UTM: 81, 500m E, 20, 000m N, zone 14.
Carex obtusata	CAOB4	MM	28-Jun-79	Mixed grass prairie. Quarter 12. UTM: 81, 500m E, 20, 000m N, zone 14.
Carex obtusata	CAOB4	MM	28-Jun-79	Mixed grass prairie. Quarter 12. UTM: 81, 500m E, 20, 000m N, zone 14.
Carex obtusata	CAOB4	MM	8-Jun-81	Located in Quarter 17 in Sioux Soil on the dry prairie.
Carex pensylvanica	CAPE6	MM	6-Jun-79	Located in Quarter 22 with *Artemisia ludoviciana* and *Allium* and *Symphoricarpos*.
Carex pensylvanica	CAPE6	MM	27-Jun-79	Mixed grass prairie on slopes. Quarter 22. UTM: 81, 600m E, 18, 400m N, zone 14.
Carex pensylvanica	CAPE6	MM	28-Jun-79	Growing on dry mixed grass prairie slopes. Quarter 23 UTM: 80, 900m E, 18, 500m N, zone 14.
Carex pensylvanica	CAPE6	MM	28-Jun-79	Growing on dry, mixed grass prairie on slopes. Quarter 23. UTM: 80, 900m E, 18, 500m N, Zone 14.
Carex praegracilis	CAPR5	MM	24-Aug-79	Drier high areas in mixed grass prairie. Growing in transect. Quarter 12.
Carex praegracilis	CAPR5	MM	9-Jun-80	Tall grass prairie in Quarter 9-A.
Carex praegracilis	CAPR5	MM	7-Jul-80	Located in Quarter 9-A in wet meadow.
Carex preagracilis	CAPR5	MM	10-Jun-80	Located in Quarter 4 near wetland.
Carex rostrata	CARO6	MM	26-Jul-79	Growing in wet boggy marsh with other *Carex*, *Epilobium* and *Sium suave*. Quarter 9-A. UTM: 83, 800m E, 21, 200m N, Zone 14.
Carex rostrata	CARO6	MM	26-Jul-79	Growing in wet boggy marsh with other *Carex*, *Epilobium* and *Sium* suave. Quarter 9-A. UTM: 83, 800m E, 21, 200m N, Zone 14.
Cicuta maculata	CIMA2	MM	16-Jul-79	Growing on moist ground around wetlands. Flowers white. Plants up to 1.5 m tall. Quarter 7. UTM: 81,950m E, 20,700m N, zone 14.
Cypridpedium calceolus	CYPAP3	LK, WB	26-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #174
Cypridpedium calceolus	CYPAP3	MM	2-Jun-80	Located in Qtr 22 growing in colony of plants. In Hamerly soil. UTM: 81, 750m E, 18, 250m N.

Scientific name	USDA acronym	Collector	Date	Location and original description
Eleocharis compressa	ELCO2	MM	21-May-80	Located in Quarter 10 in moist area in small valley.
Eleocharis macrostachya	ELMA5	MM	20-Aug-79	Growing near wetland 3, quarter 9. UTM: 82, 900m E, 21, 300m N, zone 14.
Equisetum arvense	EQAR	MM	26-Jul-79	Wet marsh near airstrip. Quarter 9-A. UTM: 83, 700m E, 21, 200m N, zone 14.
Equisetum arvense	EQAR	MM	21-May-80	Located in Quarter 9-A. Sandy area around wetland near gravel pit. Sterile shoots.
Equisetum arvense	EQAR	MM	27-May-80	Located in Quarter 9 around wetland in sandy soil. UTM: 83, 150m E, 20, 600m N.
Equisetum hyemale	EQHY	MM, MC	29-Jul-80	Located in Quarter 9-A. Fen Area.
Equisetum hyemale	EQHY	MM, MC	30-Jul-80	Located in Quarter 9-A. Fen Area.
Equisetum laevigatum	EQLA	MM	28-Jun-79	Moist low area with *Poa pratensis*. Quarter 22. UTM: 81, 530m E, 18, 800m N, zone 14.
Equisetum laevigatum	EQLA	MM	9-Jun-80	In moist depression in Quarter 12.
Equisetum laevigatum	EQLA	MM	30-Jun-81	Located 3 miles East of Woodworth on WSA in Quarter 9-A, T142N, R67W, Sec. 6. In a low prairie site in heavy soils.
Habenaria hyperborea	PLAQ2	MC, MM	29-Jul-80	Located in Quarter 9-A. Fen area.
Hypoxis hirsuta	HYHI2	MM	28-Jun-79	Low grassland around wetland 33. Quarter 23. UTM: 80, 800m E, 18, 450m N, zone 14.
Hypoxis hirsuta	HYHI2	MC	22-May-80	In Quarter 7 along wet zone of pond 7-1. Flowers yellow.
Hypoxis hirsuta	HYHI2	MM	27-May-80	Located in Quarter 22. In wet meadow around wetland. UTM: 81, 350m E, 18, 100m N.
Juncus balticus	JUARL	MM	26-Jul-79	Growing in moist low area near wetland 2. Qtr 16. UTM: 81, 000m E, 19, 500m N, zone 14.
Juncus bufonius	JUBU	MM	20-Jul-79	Growing in moist low area in fire break. Quarter 22. UTM: 81, 500m E, 18, 050m N, zone 14.
Juncus bufonius	JUBU	MM	20-Jul-79	Growing in moist lowland area in fire break. Quarter 22. UTM: 81, 500m E, zone 14.
Juncus dudleyi	JUDU2	MM	8-Jun-80	Located on West Shore of Fish Lake. Woodworth Study Area.
Juncus interior	JUIN2	MM	20-Jul-79	Growing in moist lowland area in fire break. Qtr 22. UTM: 81, 450m E, 18, 050m N, zone 14.
Juncus interior	JUIN2	MM	20-Jul-79	Growing in moist lowland area in fire break. Qtr 22. UTM: 81, 450m E, 18, 050m N, zone 14.
Juncus interior	JUIN2	MM, MC	16-Jun-80	Located in Quarter 21 near dugout.
Juncus interior	JUIN2	MM	17-Jun-80	Located in Quarter 12 on west shore of Fish Lake.
Juncus longistylis	JULO	AB	8-Aug-79	Growing in wet meadow trampled by cattle. Clay soil. Quarter 20. UTM: 82, 970m E, 18, 810m N, zone 14.
Juncus longistylis	JULO	AB	8-Aug-79	Growing in wet meadow trampled by cattle. Clay soil. Quarter 20. UTM: 82, 970m E, 18, 810m N, zone 14.

Scientific name	USDA acronym	Collector	Date	Location and original description
Juncus longistylis	JULO	MM, MC	29-Jul-80	Located in Quarter 9-A in Fen Area.
Juncus nodosus	JUNO2	AB	8-Aug-79	Growing in wet meadow trampled by cattle. Clay soil. Quarter 20. UTM: 82, 970m E, 18, 810m N, zone 14.
Juncus torreyi	JUTO	AB	8-Aug-79	Growing in wet meadow trampled by cattle. Clay soil. Quarter 20. UTM: 82, 970m E, 18, 810m N, zone 14.
Lemna trisulca	LETR	MM	18-Jul-79	Growing in 2 to 3 feet of water in wetland #35, qtr 7. UTM: 81, 900m E, 20, 450m N, zone 14.
Lemna trisulca	LETR	MM	20-Aug-79	Growing in 2 to 3 feet of water in wetland #3, qtr 9. UTM: 82, 900m E, 21, 300m N, zone 14.
Lilium philadephicum	LIPH	LK, WB	6-Jul-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #186
Lilium philadephicum	LIPH	MM	10-Jul-79	Growing in low prairie near wetland. Flowers deep red-orange. Quarter 14. UTM: 80, 100m E, 19, 650m N, zone 14.
Lilium philadephicum	LIPH	MM	10-Jul-79	Growing in low prairie near wetland. Flowers deep red-orange. Quarter 14. UTM: 80, 100mE, 19, 650mN, zone 14.
Lomatium foeniculaceum	LOFO	AB	14-May-79	Located in Quarter 4, Sec 2, NE Corner. Flowers yellow, 7-8 cm high.
Lomatium foeniculaceum	LOFO	MM	23-May-79	Growing in mixed grass native prairie. Flowers yellow. With *Anemone patens*, *Bouteloua*, and *Artemisia*. Quarter 4. UTM: 80,300mE, 21,900mN, zone 14.
Lomatium orientale	LOOR	MM	8-May-79	Located in Quarter 12, Sec. 2, east half at center. Whitish flowers with pale pink cast.
Lomatium orientale	LOOR	MM	21-Apr-80	Located in Quarter 9 on *Bouteloua*, *Agropyron smithii* prairie. Flowers pinkish white. UTM: 83,000mE, 20,900mN.
Lomatium orientale	LOOR	MC	23-Apr-80	Located in Quarter 10. Grazed pasture in association with Blue grama. Flowers yellow. Native prairie habitat.
Lomatium orientale	LOOR	MC	23-Apr-80	Located in Quarter 10. Grazed pasture in association with Blue grama. Flowers white.
Pastinaca sativa	PASA2	AB	28-Jun-79	Growing on sandy lake shore south of Fish Lake. Flowers yellow. Plant 1 m tall. With *Scirpus* and *Potentilla anserina*. Quarter 18. UTM: 82,720mE, 19,410mN, zone 14
Polygonatum biflorum	POBI2	MC	18-Jun-80	Located in Quarter 11 along steep shore of Big Lake in brushy area.
Polygonatum biflorum	POBI2	MC	18-Jun-80	Located in Quarter 11 along steep shore of Big Lake in choke cherry thicket.
Potamogeton gramineus	POGR8	MM	30-Jul-79	Emersed in 0.5-1.0m water in semi-permanent wetland. With *P. pusillus* and *P. gramineus*. Quarter 9. UTM: 82,850mE, 21,450, zone 14.
Potamogeton pectinatus	STPE15	MM	26-Jul-79	Growing in 12-18 inches of water with *Lemna* and *Drepanocladus*. Quarter 16, wetland 2. UTM: 80,950mE, 19,500mN, zone14.
Potamogeton pusillus	POPUP5	MM	30-Jul-79	Emersed in 0.5-1.0m water with *P. gramineus* and *P. richardsonii.* Quarter 9. UTM: 82,850mE, 21,450mN, zone 14.
Potamogeton richardsonii	PORI2	MM	30-Jul-79	Emersed in 0.5-1.0m water in semi-permanent wetland. With *P. pusillus* and *P. gramineus*. Quarter 9. UTM: 82,850mE, 21,450, zone 14.

Scientific name	USDA acronym	Collector	Date	Location and original description
Potamogeton richardsonii	PORI2	MM	17-Jun-80	Located in Quarter 12 in shallow water in west side of Fish Lake.
Potamogeton richardsonii	PORI2	MM	17-Jun-80	Located in Quarter 12 in shallow water on west shore of Fish Lake.
Puccinellia nuttalliana	PUNU2	MM	12-Jul-79	Growing in low prairie in pasture. Qtr. 20. UTM: 82,900mE, 18,800mN, zone 14.
Puccinellia nuttalliana	PUNU2	MM	18-Jun-80	Located in Quarter 12 West shore of Fish Lake.
Puccinellia nuttiana	PUNU2	MM	12-Jul-79	Growing in low prairie pasture. Quarter 20. UTM: 82,900mE, 18,800mN, zone 14.
Rhus radicanis	TORY	MC	29-Aug-80	Large patch growing near *Crataegus* Clumps.
Sagittaria cuneata	SACU	MM	2-Jul-80	Located in Quarter 12 in wetland near station in draw down damp basin.
Sagittaria cuneata	SACU	MM	2-Jul-80	Located in Quarter 12 in wetland near station. In a damp basin.
Schedonnardus paniculatus	SCPA	MC	6/25/1980	Located in Quarter 10 on dry prairie in association with *Bouteloua*.
Scirpus actutus	SCACA	MM, CS	28-Jul-81	Located in Quarter 4 around wetlands.
Scirpus americanus	SCAM2	MM	6-Aug-79	Growing in 2 inches of water near edge of large wetland. Quarter 9-A. UTM: 84, 150mE, 20, 450mN, zone 14.
Scirpus atrovirens	SCAT2	MM	6-Aug-79	Growing in *Carex* wet marsh. Quarter 9. UTM: 83, 800mE, 21, 200mN, aone14.
Scirpus fluviatilis	SCFL11	MM	30-May-79	Located in wet marsh of sedge bordered with willows. Quarter 9. UTM: 83, 750mE, 21, 200mN, zone14.
Scirpus fluviatilis	SCFL11	MM	30-May-79	Wet *Carex* marsh boarded with Willows. Quarter 9. UTM: 83, 750mE, 21, 200mN, zone 14.
Scirpus validus	SCVA	AB	27-Jun-79	Emerging from 1 ft. water in channel leading into large lake. With *Senecio congestus*. To 1 m tall. Quarter 12. UTM: 81, 750mE 20, 200mN, zone 14.
Scirpus validus	SCVA	AB	20-Jul-79	Border of large lake to 2m tall. Quarter 12. UTM:81, 700mE, 20, 100mN, zone 14.
Scirpus validus	SCVA	MM	28-Jul-81	Located in Quarter 12 around Clark Lake.
Scirpus validus	SCVA	MM, CS	28-Jul-81	Located in Quarter 12 around Clark Lake.
Scirpus validus	SCVA	AB	27-Jun-79	Located in Channel leading into large lake emerging from lift of water. Quarter 12. UTM: 81, 750mE, 20, 200mN, zone 14.
Scolochloa festucacea	SCFE	MM	20-Jul-79	Growing in 2 feet of water in wetland 23. Quarter 22. UTM: 81,450mE, 18,050mN, zone 14.
Scripus americanus	SCAM2	MM	6-Aug-79	Growing in 2 inches of water near edge of large wetland. Quarter 9-A. UTM: 84, 150mE, 20, 450mN, zone 14.
Setaria glauca	SEPUP2	MM	22-Aug-79	Growing in disturbed prairie which had been burning during spring. Quarter 18. UTM: 82,100mE, 19,200mN, zone 14.
Setaria viridis	SEVI4	MM	22-Aug-79	Growing in disturbed prairie which had been burning during spring. Quarter 18. UTM: 82,000mE, 19,400mN, zone 14.
Sisyrinchium angustifolium	SIAN3	MM	23-Jun-80	Located in Quarter 8 on dry prairie hilltops.
Sisyrinchium montanum	SIMO2	KH, EL	26-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #176

Scientific name	USDA acronym	Collector	Date	Location and original description
Sisyrinchium montanum Greene	SIMO2	AB	12-Jun-79	Damp loam in lowland prairie. Aspect NW, 20 degree slope. Quarter 15, 80200mE, 19550mN, UTM zone 14. Flowers purple, plant 14 cm tall. Associates: *Poa pratensis*
Smilacina stellata	MAST4	MM	6-Jun-79	Growing in understory of shrubs along south side of Fish Lake, flowers white. Quarter 18. UTM: 82, 800mE, 19, 400mN, zone 14.
Smilacina stellata	MAST4	MM	6-Jun-79	Growing in understory of shrubs along south side of Fish Lake, flowers white. Quarter 18. UTM: 82, 800mE, 19, 400mN, zone 14.
Smilax herbacea	SMHE	AB	21-Jun-79	Growing along rocky lake shore. Vine, woody base, flowers pale green in clusters. With *Amelanchier*, *Smilacina*, *Rhus*. Quarter 18. UTM: 82, 490mE, 19, 390mN, zone 14.
Smilax herbacea	SMHE	MM	18-Jul-79	Growing in shrub area on S. side of Fish Lake. Qtr 18. UTM: 82, 500mE, 19, 400mN, zone 14.
Smilax herbacea	SMHE	KH, LHM	17-Jul-81	Located 2 miles East of Woodworth. T142N, R68W, Sec. 10. Located on the edge of a Juneberry clump.
Sorghastrum avenaceum	SONU2	AB	20-Aug-79	Damp grassy meadow with *Andropogon gerardi*. Plants to 1m tall. Quarter 9. UTM: 83,500mE, 20,700mN, zone 14.
Sparaganium eurycarpum	SPEU	MM	10-Jul-79	Growing in 1-2 ft of water in wetland 10. Qtr 7. UTM: 81,300mE, 21,150mN, zone 14.
Sparganium eurycarpum	SPEU	MM	2-Jul-80	Located in Quarter 12 in wetland near station.
Sparganium eurycarpum	SPEU	MM	2-Jul-80	Located in Quarter 12 in wetland near station.
Sparganium eurycarpum	SPEU	MM	8-Jul-81	Located 3 miles East of Woodworth on WSA in Quarter 12, T142N, R68W, Sec. 12. Site was in moist ground around dry wetland
Sparganium eurycarpum	SPEU	MM	8-Jul-81	Located in Quarter 12 in moist ground around dry wetland. 2 stigmas.
Spartina gracilis	SPGR	KH, EL	22-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #143
Spartina pectinata	SPPE	MM	6-Aug-79	Growing in wet Carex marsh. Quarter 9. UTM: 83,800mE, 21,150mN, zone 14.
Sporobolus cryptandrus	SPCR	MC	29-Aug-80	Along a R.R. track in Quarter 9-A in heavily sprayed area only plant growing in this spray zone.
Sporobolus heterolepis	SPHE	RK, MM	27-Aug-79	Transect 8, Quarter 9.
Stipa comata	HECOC8	MM	9-Jun-80	Found on airstrip in Quarter 9-A
Stipa Comata	HECOC8	MM	10-Jul-80	Located in Quarter 12 in Fordville Soil.
Stipa spartea	HESP11	MC	23-Jun-80	Located in Qtr. 22.
Stipa spartea	HESP11	MM	10-Jul-80	Located in Quarter 12 in Fordville Soil.
Stipa viridula	NAVI4	MM	10-Jul-80	Located in Quarter 12 in Fordville Soil.
Stipa viridula	NAVI4	MM	18-Jul-80	Located in Quarter 9.
Triglochin maritimum	TRMA20	AB	16-Jul-79	Growing in wet meadow around slough. Flowers greenish yellow. Quarter 19. UTM: 83, 370mE, 19540mN, zone 14.
Triglochin maritimum	TRMA20	MM, MC	29-Aug-80	Located in Quarter 9-A. Fen Area.

Scientific name	USDA acronym	Collector	Date	Location and original description
Typha augustifolia	TYAN	MM	10-Jul-79	Growing in 2 dm water in quarter 7, Wetland 10. UTM: 81,300mE, 21,150mN, zone 14.
Zannichellia palustris	ZAPA	MM	18-Jul-79	Emersed in two feet of water in seasonal wetland. Quarter 8. UTM: 81,950mE, 20,450mN, zone 14.
Zigadenus elegans	ZIEL2	AB	2-Jul-79	Located in Quarter 9; section 6, SW corner. UTM: 83, 080E, 20, 580N. Soil-loose, moist, silty loam. Flowers greenish white. Plants 60-100cm tall.
Zigadenus elegans	ZIEL2	AB	2-Jul-79	Located in Quarter 9; section 6, SW corner. UTM: 83, 080E, 20, 580N. Soil-loose, moist, silty loam. Flowers greenish white. Plants 60-100cm tall.
Zigadenus elegans	ZIEL2	AB	2-Jul-79	Moist depression along marshy pothole. Loose, moist silty loam. Flowers greenish white. Plants 6-10dm tall. With *Commandra, Asclepias*. Quarter 9. UTM: 83, 080mE, 20, 580mN, zone 14.
Zigadenus elegans	ZIEL2	AB	2-Jul-79	Moist depression along marshy pothole. Loose, moist silty loam. Flowers greenish white. Plants 6-10dm tall. With *Commandra, Asclepias*. Quarter 9. UTM: 83, 080mE, 20, 580mN, zone 14.
Zizia aptera	ZIAP	KH, EL	8-Jun-78	Native grassland on the Woodworth Study Area 3-East of Woodworth. #121
Zizia aptera	ZIAP	AB	6-Jun-79	Growing in boggy pothole in tall dead grass. Petals yellow, plant 2.5 dm tall. With *Viola nephrophylla* and *Stipa*. Quarter 9. UTM: 83,900, 21,200mN, zone 14.

Appendix 12. Aerial imagery available for the Woodworth Study Area (WSA) and surrounding area for 1957–97

[Date is when the images or recording was made; media is the format. Originals prints, where available, are kept in the archive room of Northern Prairie Wildlife Research Center, and select collections are currently available digitally. Notes provide useful information describing the imagery. A mark under the last column indicates that the images are immediately viewable, meaning they are in photographic form, the WSA area is complete, and the images have an associated month and year.]

Date	Media	Notes (complete, label names)	Area	X
1949–1951	Black and white print	Eddy tract folder; study units 8, 12, 13, 15, 16	Eddy tract	
1957–July	Digital color image		Full WSA and surrounding area	X
1963–May 3	Black and white prints	Altitude of 3,000 feet; A1–>A3, B1–>B6, C1–>C8, D1–>D6, E1–>E3; flying from south to north beginning on the west, into a northwest wind; taken same day at 1b.	Full WSA	X
1963–May 3	Black and white prints	Altitude of 9,000 feet; I1 –> I6, II–>II6, III1–>III6; one photo is missing from this collection (I–2)	Full WSA	X
1963–August 22	Black and white prints	Labeled 1–35	Full WSA	X
1964– May 24	Digital Black and white images		Full WSA and surrounding area	X
1966–May	Black and white prints	Labeled 1–8 (WSA), 28–31, and 36–39	Full WSA	X
1968– May 31	Black and white prints, positive transparencies	“High” and “low” altitude, 2 inch × 2 inch prints		X
1969–May 1	Black and white prints	168–170, 177, 179, 186	Full WSA and 49 square-mile area around WSA	X
1969–May 1	Black and white prints	Labeled 269–304	Full WSA and 9 square-mile area around WSA	X

Date	Media	Notes (complete, label names)	Area	X
1970–July 31	Color-infrared prints	70 mm		
1972–July 28	Black and white prints and positive transparencies	Altitude of 4,500 feet		X
1973–May 12	Various media	Altitude of 4,500 feet; Prints (9 inch × 9 inch), color 70mm	WSA in 6 transects	X
1973–August 12	Various media	Color infrared (9 inch × 9 inch), 70mm positive transparency; 2 inch × 2 inch black and white prints		X
1980–August 21	Negatives	Altitude of 6,000 feet; Labeled 1–19	Full WSA	
1978–79–May	Negatives, prints	Labeled by study unit; unclear if the negatives (1978) or the prints (1979) are labeled correctly; photographs are slightly out of focus.	Full WSA, with surrounding area	
1979–May 16	Color digital images	National Wetland Inventory	WSA and surrounding areas	X
1983–1991	Color digital images	NRCS slides for all WSA study units; Month, date unclear		
1996 or 1997	Black and white digital images	Digital orthophoto quadrangles in .bil raster forma; month and date unclear.	WSA proper	
1988–April 30	Aerial video	Altitude of 12,500 feet; 10.5 mm lens		
1989–Nov 28	Aerial video			
Unknown	Prints	Labeled 1–1 through 1–43; noted on back “Must be after 1965.”		
Unknown	Prints	WSA photos are labeled 207–210, 214, 239; surrounding area is 211–213, 215; HQ has the south building by this time.	WSA	
Unknown	Photos	Labeled lines 1–6 and 2–11	Full WSA; Missing 3 of 60 for surrounding areas	

Appendix 13. Example of metadata used to document and preserve Woodworth Study Area (WSA) datasets

Dataset: Coordinate endpoint of Meyer vegetation transects at Woodworth Study Area, 1980

Description: This dataset includes the approximate latitude and longitude of endpoints of the Meyer vegetation transects. Tent stakes were apparently placed as markers (K.F. Higgins, pers. commun., 2014), but these points have not been ground truthed. The transects were traced into ArcMap from the 1979 protocol report (1979-proposal-unknownauthor-Meyer-vegetation-survey.pdf, page 7). Because the transects were traced into ArcMap 10.1 using the map in the Meyer report, and because no physical markers have been found to validate their location, coordinates recorded here are approximate. Coordinates are in decimal degrees in coordinate system NAD83 UTM Zone 14N. It is unknown whether the coordinates reported here are the beginning or end of the transects. The ID values were pieced together from maps, the most helpful being 1979-notes-Meyer-vegetation-soil-survey.pdf. IDs with values of 99 (3 locations, all in study unit 9A) are approximate locations of transects that were marked as needing posts (1979-map-Meyer-transects-needing-posts.pdf). The points are included here for completeness, though some or all may actually be the same transects as any of their neighboring transects in study unit 9A. The data collected at these transects were percent cover of vegetation and environmental data, similar to long-term studies VEGETRAN, NV2TRAN, and WWVEG. Data was reported in Meyer, M. (1985) Classification of native vegetation at the Woodworth Station, North Dakota, Prairie Naturalist 17(3), p. 167-175.

Source: Digitized to ArcMap 10.1 from 1979-proposal-unknownauthor-Meyer-vegetation-survey.pdf, labeled with 1979-notes-Meyer-vegetation-soil-survey.pdf

File: Meyer-transects-approx-points.txt

Related: 1979-notes-Meyer-vegetation-soil-survey.pdf, 1979-proposal-unknownauthor-Meyer-vegetation-survey.pdf, 1979-protocol-vegetation-study-codes.pdf, 1979-map-Meyer-transects-needing-posts.pdf

Label SU: Study unit the transect lies in, following conventional WSA assignment (1-24).

Label TR_M1: Identifies the transect number. Unless noted, assigned at the time of survey.

Label TYPE: Object type. The transects are represented by only an endpoint.

Label XCOORD: X coordinate of one end of the transect, decimal degrees in coordinate system NAD83 UTM Zone 14N.

Label YCOORD: Y coordinate of one end of the transect, decimal degrees in coordinate system NAD83 UTM Zone 14N.

SU	TR_M1	TYPE	XCOORD	YCOORD
4	11	point	-99.26067	47.15143
4	12	point	-99.26032	47.15174
7	13	point	-99.24844	47.14146
7	14	point	-99.2482	47.14205
7	45	point	-99.24679	47.13984
7	46	point	-99.24693	47.13951
8	15	point	-99.23637	47.13998
8	22	point	-99.23313	47.14056
8	23	point	-99.23334	47.14092
8	41	point	-99.22874	47.14371
8	42	point	-99.22863	47.14307
8	99	point	-99.23036	47.13965
9	2	point	-99.22385	47.14313
9	3	point	-99.22427	47.14289
9	4	point	-99.2186	47.13902
9	32	point	-99.21788	47.14159
12	7	point	-99.24214	47.13341
13	16	point	-99.25792	47.13654
13	17	point	-99.25329	47.13645
13	24	point	-99.25255	47.13643
13	25	point	-99.25736	47.13654
13	26	point	-99.25937	47.13294
16	18	point	-99.24974	47.13029
16	19	point	-99.24963	47.12874
16	39	point	-99.25184	47.1249
17	1	point	-99.24493	47.1315
17	27	point	-99.24437	47.13155

ISSN 2331-1258 (online)
http://dx.doi.org/10.3133/ofr20141188