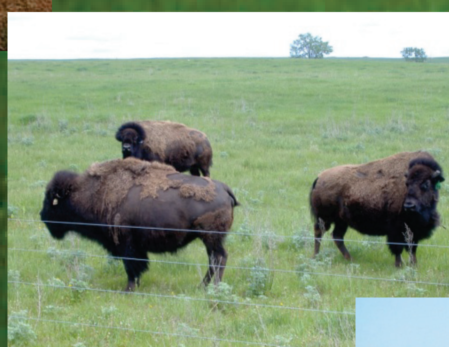
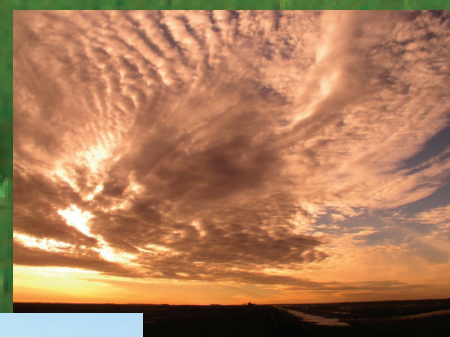
NATIVE ECOSYSTEM DIVERSITY OF THE SOUTH DAKOTA MISSOURI COTEAU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Contents

INTRODUCTION

The South Dakota Wildlife Action Plan (SDGFP 2006) utilized a biodiversity conservation strategy designed to maintain and restore native ecosystem diversity across the state. When implemented, the Plan would provide for the habitat needs of all South Dakota wildlife, while specifically linking the needs of species of greatest conservation need to the identified ecosystem diversity. To accomplish this for the entire state of South Dakota, ecosystem diversity was assessed at a relatively coarse scale with recommendations for conducting regional assessments to apply the ecosystem diversity approach at a finer scale. To that end, a regional project was initiated in the Missouri Coteau subregion to demonstrate how a state-wide plan for native ecosystem diversity can be implemented at this finer scale. This project addressed terrestrial and riparian/wetland ecosystem diversity within the Missouri Coteau. The results of this project will help South Dakota Game, Fish, and Parks (SDGFP) guide other implementation projects in other areas of the state, and to determine what, if any, modifications may be needed to increase the effectiveness of the Action Plan.

The Missouri Coteau is part of the Prairie Pothole Region, an area known as North America's "duck factory" because of its critical importance to waterfowl production. Its location at the western edge of continental glaciation contributes to a hummocky and pothole-filled terrain. Wetlands in the Prairie Pothole Region support an estimated 4.2 million duck pairs. This area is also valuable to shorebirds, breeding waterbirds and grassland-dependent birds (Ringelman 2005). In addition, the Missouri Coteau provides habitat for a number of South Dakota's species of greatest conservation need, including Dakota skipper (*Hesperia dacotae*), regal fritillary (*Speyeria idalia*), Ottoe skipper (*Hesperia ottoe*), Baird's sparrow (*Ammodramus bairdii*), Sprague's pipit (*Anthus spragueii*), chestnut-collared longspur (*Calcarius ornatus*), Franklin's ground squirrel (*Spermophilus franklinii*), and Richardson's ground squirrel (*Spermophilus richardsonii*) (SDGFP 2006).

This project was conducted to assess and describe native ecosystem diversity of terrestrial and wetland and riparian ecosystems at a finer level for the Missouri Coteau subregion. The results of this effort will help SDGFP determine how to implement and, as appropriate, adjust the South Dakota Wildlife Action Plan, which is considered a dynamic document that will be refined and revised as needed to be the most effective tool possible. SDGFP committed to revising the Plan in five years (SDGFP 2006), and the results of this project will provide critical information needed for that revision.

■ OBJECTIVES

South Dakota's Wildlife Action Plan described native ecosystem conditions for ecological sites within delineated regions of the state, and set goals for amounts of desired ecosystem conditions within each region. This project identified the Missouri Coteau as an area to assess and map ecosystem diversity at a finer scale and to evaluate existing conditions using limited field sampling. A more specific description of native ecosystem diversity was developed and quantified. Goals for ecosystem maintenance and restoration were determined from a comparison of historical and existing conditions. Treatments and programs for maintaining or restoring desired ecosystem conditions were identified and recommended. This pilot project was designed to bring the South Dakota Wildlife Action Plan into focus at a local level, serving as an example of how this ecosystem-based approach will help SDGFP and other agencies and organizations can better plan for the future. It also strived to build cooperative relationships among agencies and organizations as well as facilitate outreach to private landowners to mutually address wildlife conservation using voluntary and incentive-based programs.

The specific objectives related to the Missouri Coteau project include:

1. Describe and map native ecosystem diversity for terrestrial and riparian/wetland ecosystems.
2. Identify historical range of variability for terrestrial ecosystems using the spatially explicit landscape model SIMPPLLE.
3. Describe and map today's ecosystem diversity for terrestrial and riparian/wetland ecosystems where possible, using existing data and information sources and conducting field surveys.
4. Describe cumulative impacts to native ecosystem diversity for terrestrial and riparian/wetland ecosystems.
5. Develop restoration objectives for the landscape and discuss possible programs and partners to achieve these objectives for the Missouri Coteau subregion.

Project Area

The Missouri Coteau subregion encompasses 2,949,405 acres within north-central South Dakota (Figure 1) that includes 8 counties: Campbell, McPherson, Brown, Edmunds, Walworth, Spink, Faulk, and Potter. The boundaries of this subregion are based on the Central Dark Brown Glaciated Plains - Major Land Resource Area (53B) (USDA Natural Resources Conservation Service 2006). The major Hydrologic Unit Areas, and the percent they make up this MLRA, include the Missouri-Oahe (47%), James (24%), Missouri-Little Missouri (23%), Souris (4%), Red (1%), and Missouri-Poplar (1%) (USDA Natural Resources Conservation Service 2006).

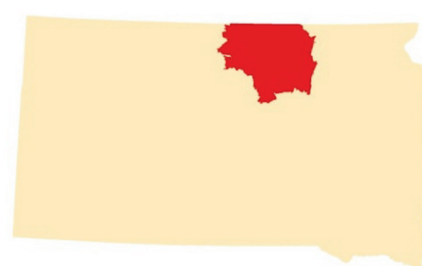

Figure 1. The location of the Missouri Coteau subregion within South Dakota.

Coteau is a French word meaning "little hill" and aptly describes this glacier influenced landscape. As the Wisconsin Glacier retreated over 12,000 years ago, the moraine piles and depressions left behind are seen today as rounded, grassy hills and moist to water-filled prairie potholes. This region is characterized by moderately steep to rolling terrain, a poorly formed natural drainage system, and many depressional wetlands. Land use is predominantly small grain farming mixed with livestock grazing (USDA, Natural Resources Conservation Service 2006).

NATIVE ECOSYSTEM DIVERSITY

Native ecosystems are the product of the combination of communities of living organisms with the physical environment in which they live. The range of ecosystem conditions, or native ecosystem diversity, occurring across a landscape and available as habitat for plants and animals is usually the result of natural disturbance processes (e.g., grazing, fire, etc.) that typically occur within that landscape. Native ecosystem diversity is often described by the range of vegetation types occurring on similar sites, as these are often the most obvious characteristics. While ecosystems can be clearly distinct from each other, more frequently they have less clearly defined edges that transition from one ecosystem type to another. However, in order to describe and quantify the amounts of these ecosystems for assessment and management purposes, it is necessary to map a line between ecosystems while recognizing that these delineations may not always be obvious to the naked eye or easy to define without more detailed field surveys or assessments.

NATURAL DISTURBANCE AND THE HISTORICAL REFERENCE

Prior to Euro-American settlement, natural disturbance processes such as fire, grazing by bison, flooding, and beaver activities were primary influences on the native ecosystem diversity that occurred in the Missouri Coteau (Severson and Hull Sieg 2006). Native Americans have also interacted and influenced ecosystem diversity for thousands of years, but typically in ways that used naturally occurring disturbance processes to benefit their subsistence strategies, such as using fire to create better wildlife habitat for hunted species (Williams 2005). The influences of naturally occurring disturbance processes and their use by Native Americans on historical ecosystem diversity are incorporated in what is known as the historical reference.

Historical references are utilized in ecosystem assessments to help identify, describe and quantify the native ecosystem diversity that occurred in a region. For the purpose of this assessment, an historical reference is defined as the ecosystem diversity that resulted from natural disturbance (i.e., fire, grazing, etc.) and human-influenced disturbance (i.e., native American) that created the dynamic conditions that plant and animal species were familiar with and dependent upon. Natural disturbance regimes are the patterns of frequency and intensity that can be quantified using ecological evidence. For example, both fire and grazing regimes are frequently described relative to frequency of occurrence and relative intensity. The historical reference also incorporates the influence of climate extremes for the time period of reference. Future climate change scenarios can be evaluated against the historical reference to help understand the implications of future change and their influence on native ecosystem diversity.

Another term often used in relation to historical reference is the historical range of variability. Historical range of variability is an important concept because it emphasizes that many ecosystems varied in amounts, compositions, and structures due to variations in climate and stochastic events that influenced natural disturbance regimes (Aplet and Keeton 1999). Historical references are usually confined to a period less than 1000 years prior to Euro-American settlement, as these reflect the habitat conditions most relevant to the species that are present today (Morgan et al. 1994). Quantifying historical references may be a difficult task in some areas due to a lack of ecological information to help describe the effects of natural disturbance, for example fire regimes in grassland ecosystems. Furthermore, native ecosystems were not static during any defined reference period. Species distributions were changing, disturbance regimes were changing, and species themselves were adjusting to these changes through behavioral and genetic alterations. However, developing an understanding of the ecosystem diversity that occurred during an identified timeframe prior to Euro-American settlement provides critical reference information for defining and quantifying a baseline of what should be considered "natural" or "native" for an area.

NATIVE TERRESTRIAL ECOSYSTEM DIVERSITY

The Missouri Coteau subregion is characterized by nearly level to undulating glacial till plains with potholes and Elevation ranges from 1600 feet to 2000 feet. The region receives average annual precipitation ranging from 15 to 20 inches, with half of this occurring during the growing season. Winds average 11 mph on average. The mean annual temperature ranges from 4^{o} F in January to 72^{o} F in July and the growing season is approximately 110 to 135 days (USDA, Natural Resources Conservation Service 2006).

The terrestrial vegetation of the pre-settlement Missouri Coteau subregion was dominated by grassland ecosystems. In general these grasslands are often referred to as the mixed-grass prairie where the integration and influence of both the short-statured warm-season grasses of the Great Plains Steppe region to the west and the tall-statured cool- and warm-season grasses of the Tallgrass region to the east, occur. Shrubs were a relatively minor component of the upland vegetation, occurring primarily on protected microsites. Woodland or forest ecosystems were very rare in the upland areas and primarily occurred in small pockets where fire or bison were unable to access or influence the site. For this reason, upland forest ecosystems are not represented as a primary pre-settlement ecosystem type in the Missouri Coteau for ecosystem diversity purposes. The primary natural disturbance regimes occurring in this landscape included fire and grazing, primarily by bison. The influences of these disturbance elements on terrestrial ecosystem diversity are discussed in more detail in the following sections.

Natural Disturbance

Fire

Fire in the Missouri Coteau subregion of South Dakota was a relatively common disturbance event prior to European settlement (Higgins 1986, Severson and Hull Sieg 2006). Many anecdotal and scientific reports have documented the widespread occurrence of fire throughout the State and the region (Severson and Hull Sieg 2006). The causes of these fires were both natural (i.e., lightning) and human-initiated (i.e., Native Americans). Native Americans were observed on many occasions initiating fires to improve habitat, hunting, or travel conditions (Higgins 1986, Severson and Hull Sieg 2006).

In grassland-dominated landscapes, fire is closely linked with climatic cycles as even brief dry periods can provide conditions that favor fire. For thousands of years on the Great Plains, fire events have been an integral part of the grassland ecosystem (Daubenmire 1968). Many plant species have developed strategies to benefit from fire, thereby contributing to a landscape mosaic of greater species and structural diversity resulting from the fire regime (Daubenmire 1968, Anderson 1990).

Grassland species exhibit a number of characteristics and strategies that are suited to a fire-prone landscape, where low humidity, drying winds, and low soil moisture are common (Daubenmire 1968). In general, fire-dependent ecosystems are expected to burn more easily than non-fire dependent ecosystems, as they have traits that make them more flammable (Mutch 1971). For example, grassland ecosystems often produce biomass that may not decompose in a given year or a multitude of years. If a site is not grazed to remove the year's growth, it will become more vulnerable to fire. Many studies have documented the significance of fire in maintaining the grassland's equilibrium (Collins and Barber 1985, Heisler et al. 2003, Anderson 1982). Yet, it is important to note that even in a single landscape, the differences between abiotic conditions characterizing ecological sites contributes to different fire regime characteristics in terms of frequency, severity, and patch size.

The effects of fire on grassland ecosystems are a function of the fire's frequency and intensity, as well as the season that the fire occurred. Fire return intervals may have varied widely due to climate, site conditions or previous grazing disturbance. Lightning is a primary cause of natural occurring wildfire events in the Missouri Coteau. Higgins (1986) reviewed lightning-caused fire records from 1940 to 1981 and found an average of 6 fires per year per 2.5 million acres in eastern North Dakota grasslands and 22 per year per 2.5 million acres in south-central North Dakota.

Lightning caused fires can occur from March to December but the majority occurred from mid-to late summer (Higgins 1986). Specific information on the spatial extent of historical fires is not available but fires occurring during the growing season are expected to have been limited in spread by green vegetation and higher levels of humidity. Those fires occurring during drought conditions or after the growing season may have had the greatest spatial extent. Even within these fire-dominated landscapes, microhabitats exist in wetland and riparian areas, and other fire-protected locations where fire-intolerant species can persist in relatively small amounts.

Fire influences grassland vegetation in a number of ways. Depending on the season, fire can have a substantial effect on species diversity. For example, spring burning increases the dominance of tall-statured bunchgrasses and reduces the cover of short-statured sodgrasses (Kucera 1978). Fires occurring during the growing season generally limit spread or occurrence of woody vegetation outside of riparian and wetland areas (Kucera 1978). Fire also releases important nutrients into the soil for root uptake as well as releases nutrients bound in litter. Removal of plant litter also changes light and temperature levels at the ground level, influencing plant productivity and growth conditions (Vinton and Collins 1997).

Grazing

Although the Great Plains grasslands were grazed by a multitude of herbivores, no single species was more influential than bison in shaping the grassland ecosystems of the Missouri Coteau ecorgion. Bison was the largest herbivore both in size and numbers, prior to Euro-American settlement. Stevensen (1918) reported "One of the greatest of the ranges for the wild buffalo of seventy five or a hundred years ago was the country east of the Missouri; the coteaus of the Missouri and Coteau des Prairies. This vast country was wonderfully well suited for the great herds that roamed over it, the grass was luxuriant and nutritious, water was there in plenty and the winters not too severely cold nor summers too excessively hot." As late as 1865, Stevensen also reported "…..near the site of the present city of Groton, Brown County, they found a herd of twenty-five or thirty thousand animals." However, by 1890, bison were functionally and physically extirpated from the Missouri Coteau (Shaw 1995, Isenberg 2000). Today, where bison occur, they exist in relatively small herds within fenced boundaries of parks or private lands.

Loss of bison from the Missouri Coteau grasslands occurred before any meaningful research could be conducted on their foraging habits and movement patterns. Much of the information we have today is extrapolated from ungulate studies of similar grazing systems around the world or from research conducted on the remaining small bison herds that are confined within relatively small portions of a landscape. The historical movement pattern of free-ranging bison has been a topic of considerable debate by researchers. The dominant view is that bison had two distinct, but not mutually exclusive bison populations, resident herds and migrant herds. Migrant herds of bison are estimated to have outnumbered resident herds by more than four to one (Shaw 1995). Grazing was often intense in the path of a herd but usually did not last long because the animals were continually moving. The time a bison herd would remain in an area was dependent on the availability of high-quality forage. This long evolutionary history between grasslands and migratory grazers has resulted in an interdependent web of energy and nutrient flows. Removal of migratory grazers from the Missouri Coteau has likely altered the functional character of these grassland ecosystems.

The levels of grazing are further influenced by juxtaposition to water sources and recent fire events. Bison, like most herbivores, require a regular supply of water. Those sites surrounding rivers, lakes, and ponds will receive a disproportionate amount of heavy grazing due to the congregating herd of animals. Those sites farthest from water sources will receive the least amount of grazing (Soper 1941). Many researchers have also found that a recent burn site will attract bison (Frank et al. 1998, Bamforth 1987, and Biondini et al. 1999). The release of soil nutrients and the corresponding rapid new growth represents high-quality forage for several seasons following a fire event. At the landscape level, historical fire and grazing disturbance regimes interacted to provide a mosaic of disturbance states across the Missouri Coteau's grassland ecosystems. On native grasslands throughout the world, it is a rare event for herbaceous re-growth to go un-grazed following a fire (Frank et al. 1998). The amount of forage removed from a site and its distribution in the landscape determines the probability and intensity of the next fire event. Thus, the combination of fire and grazing yielded the dynamic habitat mosaic and landscape heterogeneity to which Missouri Coteau wildlife species are well adapted (Hartnett et al. 1996).

Ecologists frequently characterize grassland ecosystems by the un-grazed height or stature of the dominant grass species (e.g., tallgrass, mixed-grass, and short-grass). The dominant grass species, and consequently grass height, is a function of both precipitation and grazing (Truett 2003). In general, the height and stature of dominant grasses within the Missouri Coteau decrease with corresponding levels of precipitation, as well as drought cycles. The height and stature of dominant grasses will also decrease with increased grazing intensity.

At the ecosystem level, bison grazing influenced the grassland community in many ways (Hartnett et al. 1996, Hartnett et al. 1997, and Knapp et al. 1999). Overall, bison consumed more warm-season grasses. However, early in the season, cool season grasses and sedges represented a higher percentage of the forage. As the season progressed, warm-season grasses were preferred. For this reason, it has been suggested that bison may have grazed the tallgrass prairies in the dormant and early growing season and then moved on to the mixed-grass and shortgrass prairies as the growing season progressed. This pattern exists in other grazing systems of the world containing both short and tallgrass systems (Frank et al. 1998). Bison prefer grasses over forbs, with greater than 90% of the diet consisting of graminoids. Their grazing patterns thereby increased the ratio of forbs in the community. Many of the dominant tall-statured bunchgrass species, such as bluestems or Indiangrass, decrease with increasing bison grazing while many of the short-statured species, such as blue grama and buffalograss, increase.

In addition to bison, another historical grazer that likely had intermittently profound influences on the Missouri Coteau grasslands was the Rocky Mountain grasshopper or locust. The locust periodically formed enormous swarms that moved between their breeding grounds in the Rocky Mountain States and the prairies of the Mississippi and Missouri Valleys. Six major "plagues" covering large portions of the Great Plains were recorded between early 1800 and 1875 (Riley 1877). These plagues could cover thousands of acres where all vegetation in the path of the swarm was consumed (Skinner 2000).

Disturbance States

Terrestrial ecosystems of the Missouri Coteau, as stated previously, are the combination of communities of living organisms with the physical environment in which they live. To characterize native ecosystem diversity for the Missouri Coteau, we used a combination of two primary drivers of ecosystem diversity: ecological sites and disturbance states. Ecological sites represent the physical environment component of an ecosystem and disturbance states represent the vegetation communities that can occur on an ecological site in response to natural disturbance regimes. In this report we use the term disturbance state to refer to a specific plant community that could occur on a specific ecological site in response to a combination of disturbance processes. While the terms disturbance state, plant community, and plant community phase may all refer to a specific plant community as part of state and transition models, in this report we have not distinguished among these terms, and have simply used the term disturbance state. The following sections describe the native terrestrial ecosystem diversity that occurred within the Missouri Coteau relative to these two primary drivers, disturbance states and ecological sites.

Although ecological sites provide valuable information on the physical environment of terrestrial ecosystems, they do not identify the full range of successional conditions, or disturbance states, possible on a site as a result of natural disturbance events and processes. Thus, fire and herbivore grazing (i.e., primarily bison), and their interactions, were included as the primary disturbance mechanisms that historically influenced terrestrial ecosystems of the Missouri Coteau subregion (Figure 2). We refer to the effects of herbivores as grazing, although we recognize the diversity of types of herbivory that could occur. Climate cycles such as drought are an important stochastic process that should also be evaluated and considered in discussions of disturbance states and overall planning. Climate is more fully incorporated in the overall process through the development of the historical range of variability, discussed in a later section.

The natural fire regime was characterized for this area by using information developed for the fire regime condition class Interagency Handbook Reference Conditions (Hahn 2003) as well as supplemental literature (References: SIMPPLLE). Bison grazing disturbance was divided into three levels of influence; light, moderate, and heavy grazing. Fire and grazing disturbance transitions for each ecological site were developed using the best available information on ecosystem and plant species response to these disturbance events. Additional information on disturbance states are provided in the following discussion of native ecosystem diversity and each terrestrial ecological site identified for the Missouri Coteau subregion.

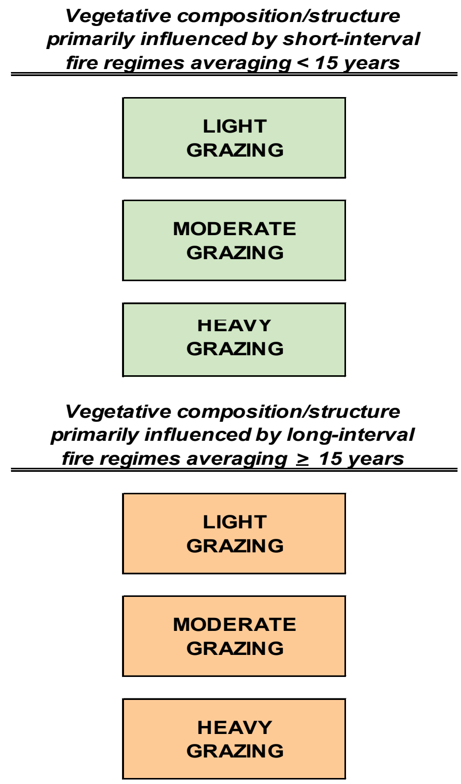

Figure 2. Disturbance states identified for terrestrial ecosystems of the Missouri Coteau, as influenced by natural disturbance regimes of fire and bison grazing.

Ecological Sites

Ecological sites are a type of landscape classification system that identifies the different abiotic conditions (e.g., climate, soils, aspect, elevation, moisture, etc.) that influence disturbance patterns and plant communities that can occur on a site (USDA, Natural Resources Conservation Service 1997). The ecological site classification is correlated to existing soil maps. Soils alone are not sufficient to capture different ecological sites under topographically diverse conditions. However, in grassland dominated landscapes where elevation, slope, and aspect are less influential, the NRCS ecological site classification works well to delineate differences in ecological sites and descriptions developed for ecological sites has included useful information relative to disturbance states as influenced by historical disturbance processes. The Missouri Coteau is a grassland-dominated landscape with relatively low topographic diversity. For this reason, NRCS's ecological site classification was selected for the ecological site component of the ecosystem diversity framework.

While the NRCS ecological site classification is suitable for the objectives of the ecosystem diversity framework described here, some limitations should be noted. A primary limitation is the fact that current soil mapping methodologies are often based on groupings of similar soils and may include inclusions of other soil types that may in fact represent another ecological site occurring within a larger soil type. As with most classification systems, the issue of mapping resolution is a common theme. While soil mapping is often finer resolution data than most existing vegetation classification systems, it still may represent less diverse conditions than actually occur on the landscape.

Mapping Terrestrial Ecological Sites

The Missouri Coteau planning area boundary was derived from the South Dakota portion of Major Land Resource Area (MLRA) 53B - Central Dark Brown Glaciated Plains (USDA, Natural Resources Conservation Service 2006). Within this boundary, NRCS SSURGO GIS layers and attribute data were used to map terrestrial ecosystem diversity. The SSURGO data attribute "ecological site" was evaluated relative to the ecological sites identified for this project and in most cases mapped as identified. In several instances the ecological site may have been grouped with similar ecological sites or re-evaluated to achieve consistency between counties within the MLRA. The results of the mapping effort are displayed in Figure 3. Table 1 identifies the number of acres for each of the 7 mapped terrestrial sites.

Table 1. Number of acres mapped for each of the 7 terrestrial ecological sites and their percent representation within the Missouri Coteau subregion.

Ecological Site	Acres	% of subregion
Clayey	306,006	10.4
Loamy	1,840,877	62.4
Sands	19,435	0.7
Sandy	49,357	1.7
Shallow Loamy	60,130	2.0
Thin Claypan	7,333	0.2
Very Shallow	142,274	4.8
Total	2,425,412	

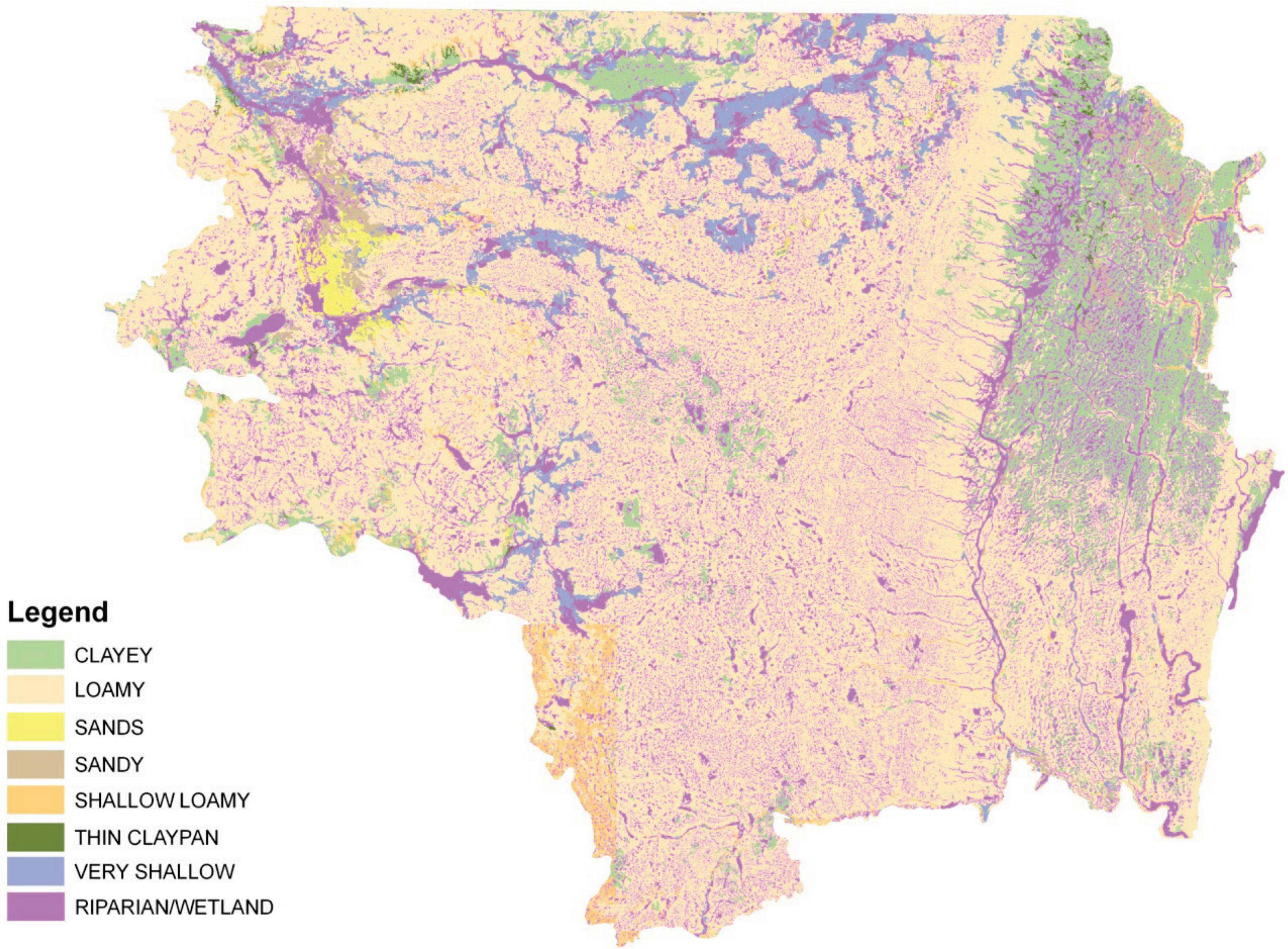

Figure 3. Map of the 7 terrestrial ecological sites, plus riparian/wetland ecological sites, for the Missouri Coteau subregion. See text for a description of the mapping methodology.

The following sections provide more detailed information on the 7 terrestrial ecological sites occurring in the Missouri Coteau subregion and their associated disturbance states, as influenced by natural disturbance regimes. While much of this information has been gathered from NRCS ecological site descriptions, additional information was developed and acquired to augment this information for the purpose of describing native ecosystem diversity. Ecological site descriptions provide valuable information on abiotic conditions that influence disturbance and vegetation processes and they provide information on some of the potential states that could occur on each site. This information was further developed to describe the primary historical states relative to natural disturbance regimes. As discussed previously, fire and large herbivore grazing (i.e., bison) were the primary disturbance mechanisms that historically operated in the grassland dominated ecosystems of the Missouri Coteau. Fire and grazing disturbance transitions for each ecological site were developed using the best available information on ecosystem and plant species response. In addition, USDA-NRCS personnel from North Dakota and South Dakota were consulted on terrestrial ecological sites to better refine our ecosystem descriptions and disturbance states for these areas. For example, canopy cover of plant species that typically increase or decrease with different levels of grazing pressure were used as indicators of historical states driven by different grazing regimes. Plant species likely to occur on a particular ecological site and how those species typically respond to grazing were developed from existing NRCS ecological site descriptions, or developed from a team of range ecologists knowledgeable of the plant dynamics of the area. Plant dynamics and rates of change for each plant species included as indicators of either fire return interval or grazing level were based on input from the team of rangeland ecologists or developed from species information available in existing scientific literature.

Clayey Ecological Sites

Clayey ecological sites occupy approximately 10.4% or 306,006 acres of the ecological sites of the Missouri Coteau subregion. Soils on these sites are characterized as moderately well drained to well drained and with slow to very slow permeability. These soils exhibit surface cracks when dry and are also moderate to very deep, at greater than 20” to bedrock. Associated landforms often include alluvial fans, lake and till plains, and hill sides where slopes are less than 10%. Clayey ecological sites are moderately to highly productive in the planning area with an average annual productivity range of 600 to 3100 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on clayey ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on clayey sites include green needlegrass and porcupine grass. Species like western wheatgrass, thickspike wheatgrass, and big bluestem may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include blue grama and buffalograss. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire.

Areas that were protected from fire likely experienced an increase in western snowberry and prairie sagewort.

Figure 4 demonstrates the clayey ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on clayey ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x clayey ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 4 and are referenced to the letter code in the upper left corner of each box.

A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* - western wheatgrass, green needlegrass, and porcupine grass; *forbs* – white sagebrush, goldenrod, scurfpea, purple locoweed, scarlet globemallow, and western yarrow.
Other Characteristic Species: shortbristle needle-and-thread, prairie dropseed, sideoats grama, and big bluestem
Historical Productivity Estimate: range = 1,300 to 3100 lbs/acre; representative value = 2,300 lbs/acre
Structure: mixed grasses, 11-20" average evegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: green needlegrass>18% and blue grama<25%

B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* - western wheatgrass, blue grama, green needlegrass, and buffalograss; *forbs* – white sagebrush, scurfpea, purple locoweed, scarlet globemallow, and western yarrow.
Other Characteristic Species: shortbristle needle-and-thread, porcupine grass, and big bluestem
Historical Productivity Estimate: range = 1,000 to 2,400 lbs/acre; representative value = 1,750 lbs/acre
Structure: mixed grasses, 7-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: green needlegrass<18% and blue grama<25%

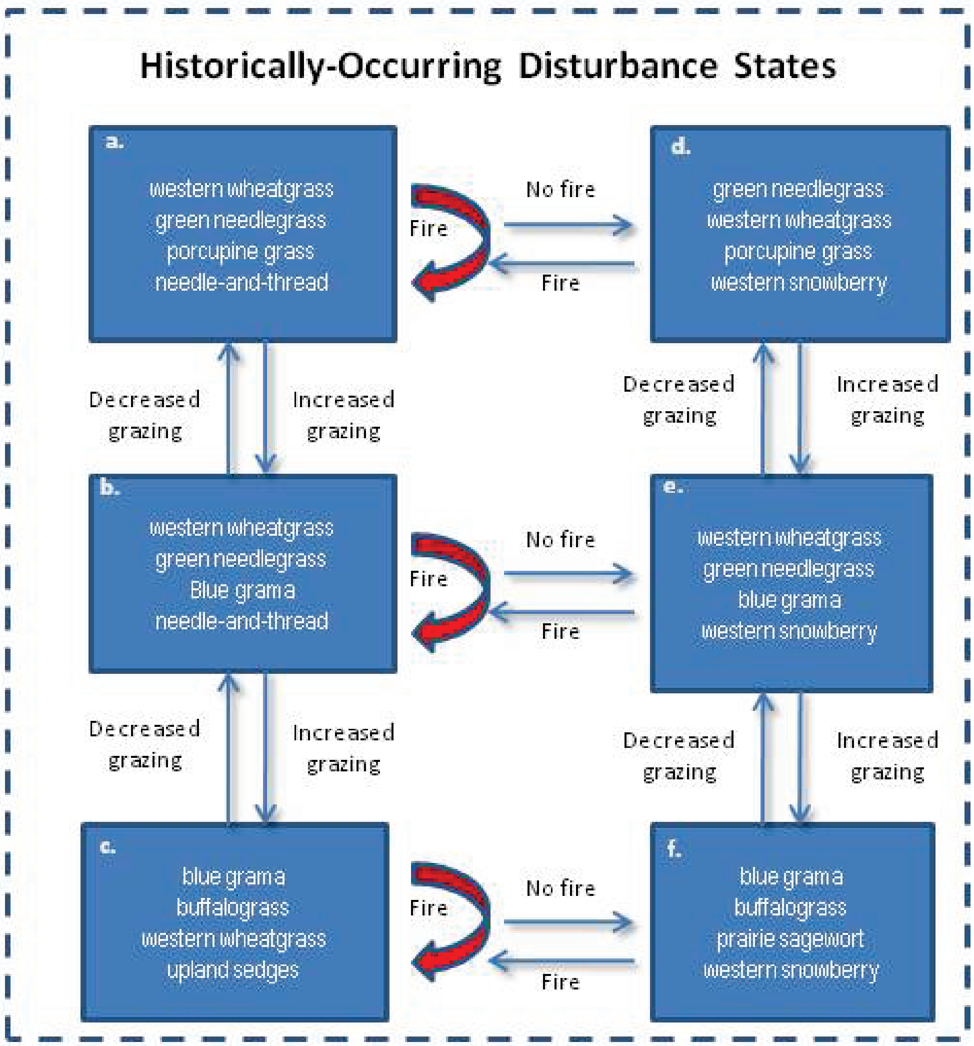

Figure 4. Historical disturbance states (state and transition model) or range of native ecosystem diversity for clayey ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – blue grama, buffalograss, western wheatgrass, and purple threeawn; *forbs* – white sagebrush, scurfpea, prairie coneflower, and western yarrow.
Other Characteristic Species: inland saltgrass and upland sedges
Historical Productivity Estimate: range = 700 to 1,700 lbs/acre; representative value = 1,200 lbs/acre
Structure: mixed grasses, 3-7" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%

Light grazing indicators: green needlegrass<18% and blue grama>25%

- ### D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* - western wheatgrass, green needlegrass, and porcupine grass; *forbs* – white sagebrush, goldenrod, scurfpea, purple locoweed, scarlet globemallow, and western yarrow; *shrubs* – western snowberry, prairie sagewort and prairie rose.
Other Characteristic Species: shortbristle needle-and-thread, thickspike wheatgrass, and big bluestem
Historical Productivity Estimate: range = 1,400 to 2,600 lbs/acre; representative value = 1,900 lbs/acre
Structure: mixed grasses, 11-20" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Long-interval fire indicator: western snowberry>3%
Light grazing indicators: green needlegrass>18% and blue grama<25%

- ### E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
grasses - western wheatgrass, blue grama, green needlegrass, and buffalograss; *forbs* – white sagebrush, scurfpea, purple locoweed, scarlet globemallow, and western yarrow; *shrubs* – western snowberry, prairie sagewort, and plains pricklypear.
Other Characteristic Species: shortbristle needle-and-thread, porcupine grass, and big bluestem
Historical Productivity Estimate: range = 1,000 to 2,000 lbs/acre; representative value = 1,450 lbs/acre
Structure: mixed grasses, 7-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Long-interval fire indicator: western snowberry>3%
Moderate grazing indicators: green needlegrass<18% and blue grama<25%

- ### F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – blue grama, buffalograss, western wheatgrass, and purple threeawn; *forbs* – white sagebrush, scurfpea, prairie coneflower, and western yarrow; *shrubs* – western snowberry, plains pricklypear, and prairie sagewort.
Other Characteristic Species: inland saltgrass and upland sedges
Historical Productivity Estimate: range = 600 to 1,400 lbs/acre; representative value = 1,000 lbs/acre
Structure: mixed grasses, 3-7" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Long-interval fire indicator: western snowberry>3%
Heavy grazing indicators: green needlegrass<18% and blue grama>25%

Thin Claypan Ecological Site

Thin Claypan ecological sites occupy approximately 0.2% or 7,333 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are characterized as moderately well drained to well drained, with very slow permeability. These soils are coarse to fine textured and moderately deep to very deep. It is characterized by a thin surface layer underlain by a dense, sodic subsoil. Salinity is high at depths less than 16". Associated landforms often include nearly level to strongly sloping flats and side slopes on terraces and lake and till plains, where slopes are less than 10%. Thin claypan ecological sites are low to moderately productive in the planning area with an average annual productivity range of 200 to 1300 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on thin claypan ecological sites was influenced by natural disturbance regimes of infrequent fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure include green needlegrass and thickspike wheatgrass. Species like western wheatgrass and needle-and-thread may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include blue grama, buffalograss, and inland saltgrass. The lower productivity of these sites does not provide the fuels required to support a frequent fire return interval on this ecological site. The low productivity of this ecological site also reduces the occurrence of shrub species. In general, grass species were the dominant component and shrubs were a more minor component on these sites. Shrubs that may occur include broom snakeweed and prairie sagewort. Brittle and plains pricklypear cactus are also present and increase with greater grazing pressure.

Figure 5 demonstrates the thin claypan ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of infrequent fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on clayey ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x thin claypan ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 5 and are referenced to the letter code in the upper left corner of each box.

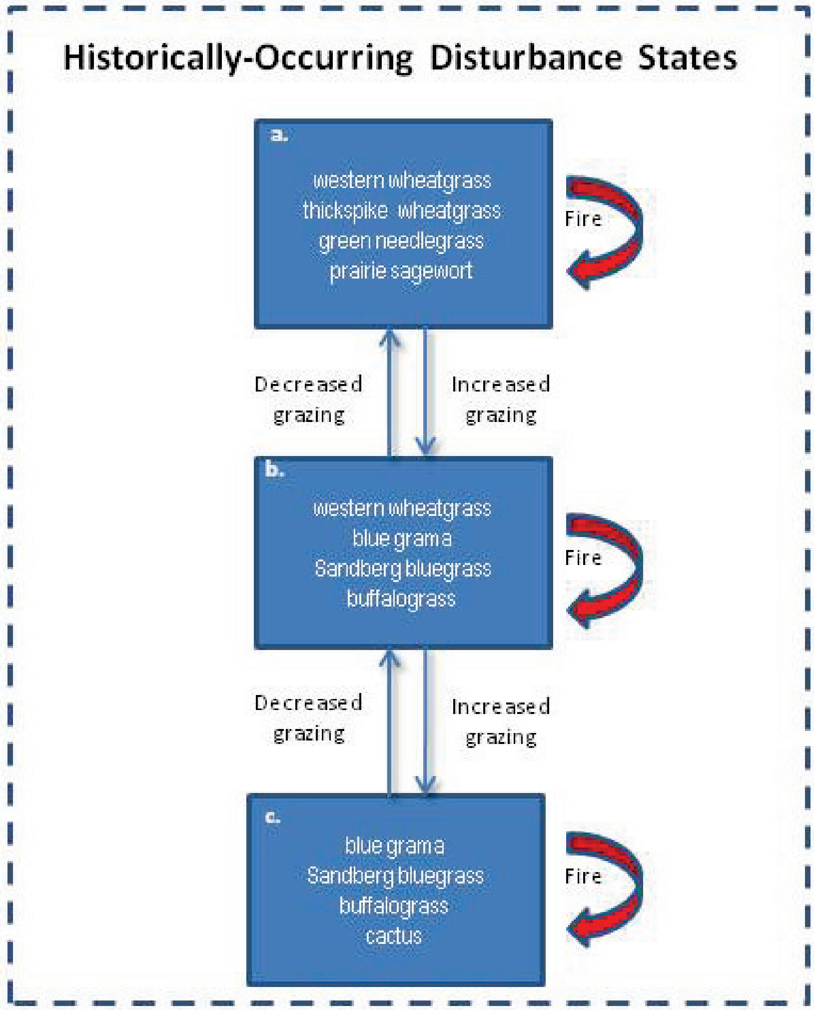

Figure 5. Historical disturbance states (state and transition model) or range of native ecosystem diversity for thin claypan ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- A. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* - western wheatgrass, thickspike wheatgrass, and green needlegrass; *forbs* - scurfpea, leafy wildparsley, scarlet globemallow, and western yarrow; *shrubs* – prairie sagewort.
Other Characteristic Species: blue grama, needleleaf sedge, and needle-and-thread
Historical Productivity Estimate: range = 500 to 1,300 lbs/acre; representative value = 1,000 lbs/acre
Structure: mixed grasses, 8-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Light grazing indicators: western wheatgrass>28% and blue grama<20%

- ### B. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* - western wheatgrass, bluegrama, and Sandberg bluegrass; *forbs* - scurfpea, scarlet globemallow, white sagebrush and western yarrow; *shrubs* – brittle pricklypear, prairie sagewort, broom snakeweed, and plains pricklypear.
Other Characteristic Species: buffalograss, inland saltgrass, and prairie junegrass
Historical Productivity Estimate: range = 350 to 1000 lbs/acre; representative value = 700 lbs/acre
Structure: mixed grasses, 5-10" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Moderate grazing indicators: western wheatgrass<28% and blue grama<20%

- ### C. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – blue grama, Sandberg bluegrass, western wheatgrass, and buffalograss; *forbs* – smartweed, curlycup gumweed, scarlet globemallow, white sagebrush and western yarrow; *shrubs* – brittle pricklypear, plains pricklypear and broom snakeweed.
Other Characteristic Species: inland saltgrass and prairie junegrass
Historical Productivity Estimate: range = 200 to 600 lbs/acre; representative value = 400 lbs/acre
Structure: mixed grasses, 2-5" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Heavy grazing indicators: western wheatgrass<28% and blue grama>20%

Loamy Ecological Site

Loamy ecological sites occupy approximately 62.4% or 1,840,877 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are moderately well to well drained, with moderate permeability. These soils occur on nearly level to hilly till plains, terraces, and lake plains and are also moderate to very deep, at greater than 20" to bedrock. Slopes range from 1 to 20%. Loamy ecological sites are moderately to highly productive in the planning area with an average annual productivity range of 400 to 3400 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on loamy ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on loamy sites include green needlegrass and porcupine grass. Species like western wheatgrass, needle-and-thread, and big bluestem may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include blue grama, and both threadleaf and needleleaf sedges. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire. Areas that were protected from fire likely experienced an increase in western snowberry and chokecherry.

Figure 6 displays the loamy ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the range of conditions or native ecosystem diversity that occurred historically on loamy ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x loamy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 6 and are referenced to the letter code in the upper left corner of each box.

- **A. Short Fire Return Interval x Light Grazing Regime**

Fire Return Interval: averaging less than 15 years
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – green needlegrass, western wheatgrass, slender wheatgrass, needle-and-thread, and porcupine grass; *forbs* - scurfpea, purple locoweed, scarlet globemallow, white sagebrush and western yarrow.
Other Characteristic Species: big bluestem and sideoats grama
Historical Productivity Estimate: range = 1,400 to 3,400 lbs/acre; representative value = 2,400 lbs/acre
Structure: mixed grasses, 11-20" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<5%
Light grazing indicators: green needlegrass>13% and blue grama<23%

- **B. Short Fire Return Interval x Moderate Grazing Regime**

Fire Return Interval: averaging less than 15 years
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – western wheatgrass, blue grama, needle-and-thread, and upland sedges; *forbs* – white sagebrush, goldenrod, prairie coneflower, and Cuman ragweed.
Other Characteristic Species: green needlegrass, shortbristle needle-and-thread, and red threeawn
Historical Productivity Estimate: range = 900 to 2,550 lbs/acre; representative value = 1,700 lbs/acre
Structure: mixed grasses, 7-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<5%
Moderate grazing indicators: green needlegrass<13% and blue grama<23%

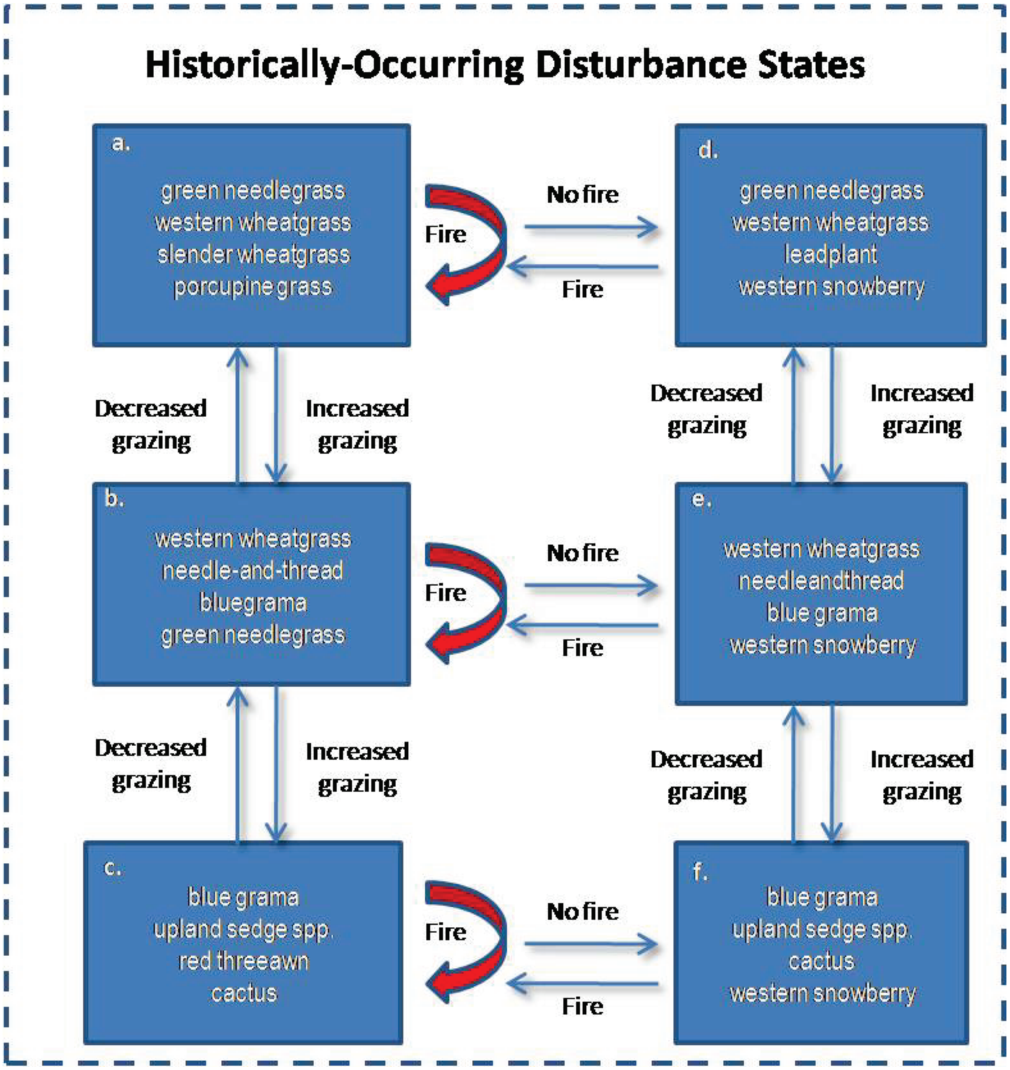

Figure 6. Historical disturbance states (state and transition model) or range of native ecosystem diversity for loamy ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* - blue grama, upland sedges, red threeawn, and western wheatgrass; *forbs* – tarragon, silverfleaf Indian breadroot, goldenrod, curlycup gumweed, and white heath aster.
Other Characteristic Species: needle-and-thread and shortbristle needle-and-thread
Historical Productivity Estimate: range = 500 to 1,600 lbs/acre; representative value = 1,000 lbs/acre
Structure: mixed grasses, 3-7" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<5%

Heavy grazing indicators: green needlegrass<13% and blue grama>23%

- D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – green needlegrass, western wheatgrass, slender wheatgrass, needle-and-thread, and porcupine grass; *forbs* - scurfpea, purple locoweed, scarlet globemallow, white sagebrush and western yarrow; *shrubs* – western snowberry, prairie sagewort, leadplant, wormwood, and prairie rose.
Other Characteristic Species: big bluestem and sideoats grama
Historical Productivity Estimate: range = 1,100 to 2,700 lbs/acre; representative value = 1,900 lbs/acre
Structure: mixed grasses, 11-20" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Long-interval fire indicator: western snowberry>5%
Light grazing indicators: green needlegrass>13% and blue grama<23%

- E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – western wheatgrass, blue grama, needle-and-thread, and upland sedges; *forbs* – white sagebrush, goldenrod, prairie coneflower, and Cuman ragweed; *shrubs* – western snowberry, prairie sagewort, and prairie rose.
Other Characteristic Species: green needlegrass, shortbristle needle-and-thread, and red threeawn
Historical Productivity Estimate: range = 700 to 2,150 lbs/acre; representative value = 1,350 lbs/acre
Structure: mixed grasses, 7-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>5%
Light grazing indicators: green needlegrass<13% and blue grama<23%

- F. Long Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* - blue grama, upland sedges, red threeawn, and western wheatgrass; *forbs* – tarragon, silverfleaf Indian breadroot, goldenrod, curlycup gumweed, and white heath aster; shrubs – western snowberry, prairie sagewort, buckbrush, and prairie rose.
Other Characteristic Species: needle-and-thread and shortbristle needle-and-thread
Historical Productivity Estimate: range = 400 to 1,300 lbs/acre; representative value = 800 lbs/acre
Structure: mixed grasses, 3-7" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>5%
Light grazing indicators: green needlegrass<13% and blue grama>23%

Shallow Loamy Ecological Site

Shallow loamy ecological sites occupy approximately 2.0% or 60,129 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are medium to moderately fine textured, well drained, and with slow permeability. These soils are shallow at less than 20” to bedrock and can be susceptible to water erosion, particularly on steep sites. These sites are typically characterized as moderately sloping to very steep uplands on hills, escarpments, and ridges, where slopes can range from 6 to 60%. Shallow loamy ecological sites are low to moderately productive in the planning area with an average annual productivity range of 350 to 2900 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on shallow loamy ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on shallow loamy sites include green needlegrass, porcupine grass, plains muhly, and sideoats grama. Species like little bluestem and needle-and-thread may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include blue grama, threadleaf sedge, and cactus species. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire. Areas that were protected from fire likely experienced an increase in prairie sagewort and cactus.

Figure 7 demonstrates the shallow loamy ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on shallow loamy ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x shallow loamy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 7 and are referenced to the letter code in the upper left corner of each box.

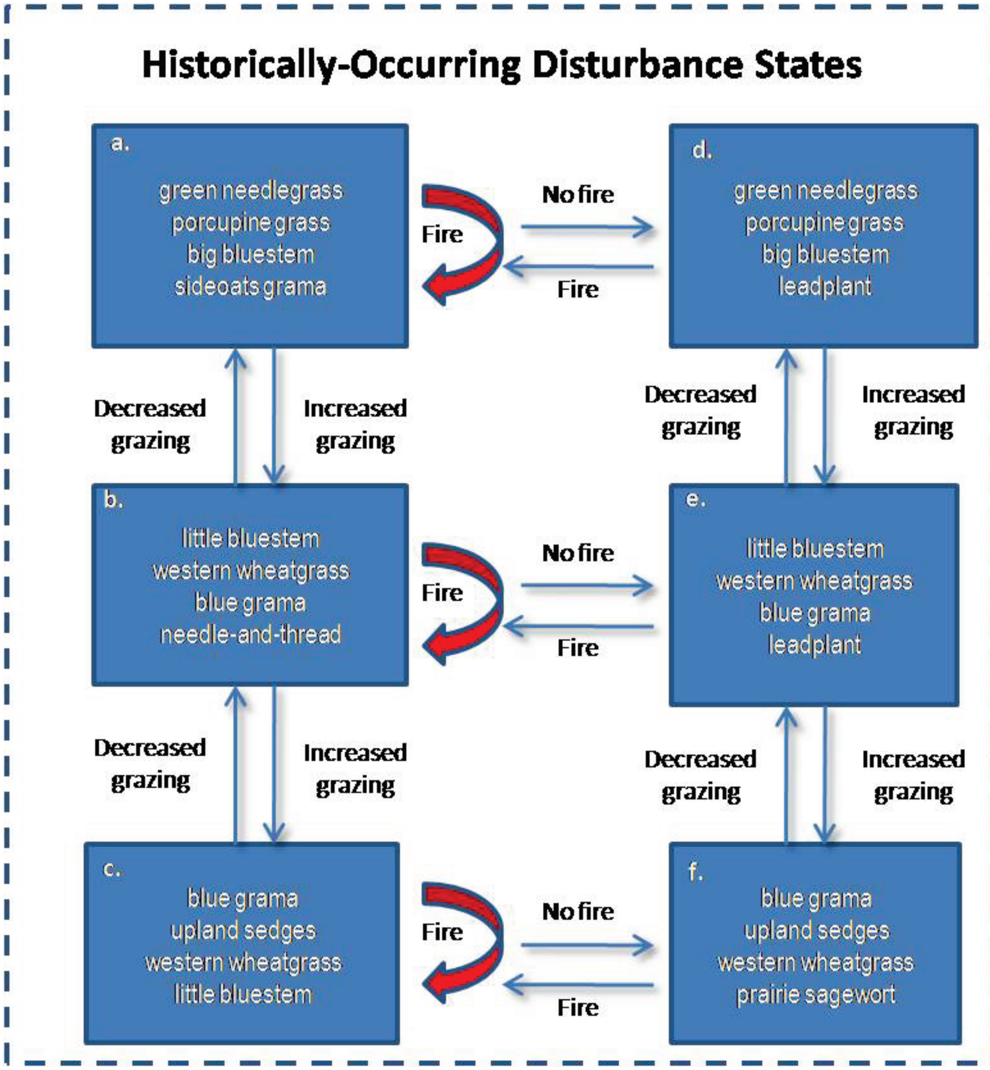

Figure 7. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for shallow loamy ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- **A. Short Fire Return Interval x Light Grazing Regime**

Fire Return Interval: averaging less than 15 years
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – green needlegrass, porcupine grass, big bluestem, little bluestem, and sideoats grama; *forbs* – blazing star, silverleaf Indian breadroot, American vetch, white sagebrush and purple coneflower.
Other Characteristic Species: prairie sandreed, plains muhly, and needle-and-thread
Historical Productivity Estimate: range = 1,500 to 2,900 lbs/acre; representative value = 2,200 lbs/acre
Structure: mixed grasses, 10-18" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant<2%

Light grazing indicators: porcupine grass>13% and blue grama<20%

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – little bluestem, needle-and-thread, blue grama, western wheatgrass, and upland sedges; *forbs* – purple coneflower, scurfpea, scarlet globemallow, white sagebrush and western yarrow.
Other Characteristic Species: green needlegrass, sideoats grama, and big bluestem
Historical Productivity Estimate: range =900 to 2,250 lbs/acre; representative value = 1,500 lbs/acre
Structure: mixed grasses, 6-12" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant<2%
Light grazing indicators: porcupine grass<13% and blue grama<20%

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – blue grama, upland sedges, little bluestem, hairy grama and western wheatgrass; *forbs* - white heath aster, scurfpea, scarlet globemallow, white sagebrush and western yarrow.
Other Characteristic Species: needle-and-thread, red threeawn, and slender wheatgrass
Historical Productivity Estimate: range = 400 to 1,400 lbs/acre; representative value = 800 lbs/acre
Structure: mixed grasses, 3-6" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant<2%
Light grazing indicators: porcupine grass<13% and blue grama>20%

- ### D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – green needlegrass, porcupine grass, big bluestem, little bluestem, and sideoats grama; *forbs* – blazing star, silverleaf Indian breadroot, American vetch, white sagebrush and purple coneflower; *shrubs* – prairie sagewort, leadplant, prairie rose, and skunkbush sumac.
Other Characteristic Species: prairie sandreed, plains muhly, and needle-and-thread
Historical Productivity Estimate: range = 1,250 to 2,450 lbs/acre; representative value = 1,850 lbs/acre
Structure: mixed grasses, 10-18" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant>2%
Light grazing indicators: porcupine grass>13% and blue grama<20%

- **E. Long Fire Return Interval x Moderate Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – little bluestem, needle-and-thread, blue grama, western wheatgrass, and upland sedges; *forbs* – purple coneflower, scurfpea, scarlet globemallow, white sagebrush and western yarrow; *shrubs* – leadplant, prairie sagewort, prairie rose, skunkbush sumac, and pricklypear.
Other Characteristic Species: green needlegrass, sideoats grama, and big bluestem
Historical Productivity Estimate: range = 750 to 1,900 lbs/acre; representative value = 1,250 lbs/acre
Structure: mixed grasses, 6-12" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant>2%
Light grazing indicators: porcupine grass<13% and blue grama<20%

- **F. Long Fire Return Interval x Heavy Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – blue grama, upland sedges, little bluestem, hairy grama and western wheatgrass; *forbs* - white heath aster, scurfpea, scarlet globemallow, white sagebrush and western yarrow; *shrubs* – yucca, prairie sagewort, prairie rose, pricklypear, leadplant, and skunkbush sumac.
Other Characteristic Species: needle-and-thread, red threeawn, and slender wheatgrass
Historical Productivity Estimate: range = 350 to 1,200 lbs/acre; representative value = 675 lbs/acre
Structure: mixed grasses, 3-6" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: leadplant>2%
Light grazing indicators: porcupine grass<13% and blue grama>20%

Sandy Ecological Site

Sandy ecological sites occupy approximately 1.7% or 49,357 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are well to somewhat excessively drained, with moderate to moderately rapid permeability. These soils are deep to very deep and can be susceptible to wind erosion. These sites are typically characterized as nearly level to steep uplands on outwash plains, till plains, and stream terraces where slopes are less than 45%. Sandy ecological sites range from low to very productive in the planning area with an average annual productivity range of 450 to 3400 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on sandy ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on sandy sites include prairie sandreed, green needlegrass, little bluestem, big bluestem, and sand bluestem. Species like western wheatgrass and needle-and-thread may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include blue grama and upland sedges. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire. Areas that were protected from fire likely experienced an increase in western snowberry and prairie sagewort.

Figure 8 displays the sandy ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on sandy ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x sandy ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 8 and are referenced to the letter code in the upper left corner of each box.

- **A. Short Fire Return Interval x Light Grazing Regime**

Fire Return Interval: averaging less than 15 years
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – prairie sandreed, needle-and-thread, big bluestem, western wheatgrass, slender wheatgrass; *forbs* – hairy false goldenaster, penstemon, spiderwort, stiff sunflower, blazing star, and Nuttall's sensitive briar.
Other Characteristic Species: green needlegrass, sand bluestem, little bluestem, and threadleaf sedge
Historical Productivity Estimate: range = 1,600 to 3,400 lbs/acre; representative value = 2,500 lbs/acre
Structure: mixed grasses, 12-24" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed>15% and blue grama<15%

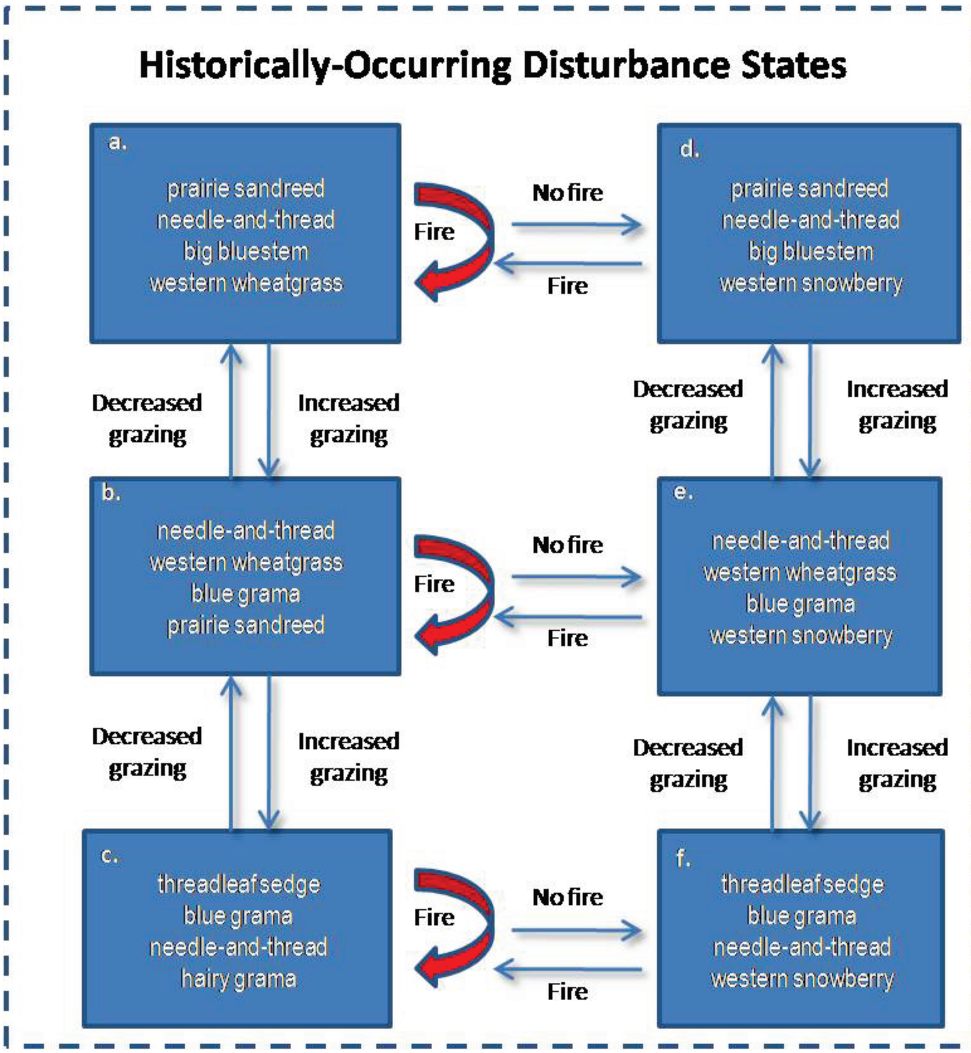

Figure 8. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for sandy ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – needle-and-thread, western wheatgrass, threadleaf sedge, blue grama, and sand dropseed; *forbs* - scurfpea, scarlet globemallow, white sagebrush, prairie clover, and western yarrow.
Other Characteristic Species: slender wheatgrass, little bluestem, and big bluestem
Historical Productivity Estimate: range = 1,000 to 2,500 lbs/acre; representative value = 1,750 lbs/acre
Structure: mixed grasses, 8-16" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed<15% and blue grama<15%

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – threadleaf sedge, blue grama, needle-and-thread, hairy grama, and western wheatgrass; *forbs* – tarragon, goldenrod, Rocky Mountain beeplant, Cuman ragweed, and scurfpea.
Other Characteristic Species: sand dropseed, slender wheatgrass, and prairie sandreed
Historical Productivity Estimate: range = 500 to 1,500 lbs/acre; representative value = 1,000 lbs/acre
Structure: mixed grasses, 4-8" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed<15% and blue grama>15%

- ### D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – prairie sandreed, needle-and-thread, big bluestem, western wheatgrass, and slender wheatgrass; *forbs* – hairy false goldenaster, penstemon, spiderwort, stiff sunflower, blazing star, and Nuttall's sensitive briar; *shrubs* – leadplant, western snowberry, and prairie sagewort.
Other Characteristic Species: sand bluestem, little bluestem, blue grama, and threadleaf sedge
Historical Productivity Estimate: range = 1,600 to 2,800 lbs/acre; representative value = 2,200 lbs/acre
Structure: mixed grasses, 12-24"average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed>15% and blue grama<15%

- ### E. Long Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – needle-and-thread, western wheatgrass, threadleaf sedge, blue grama, and sand dropseed; *forbs* - scurfpea, scarlet globemallow, white sagebrush, prairie clover, and western yarrow; *shrubs* – prairie sagewort, leadplant, prairie rose, yucca, and western snowberry.
Other Characteristic Species: slender wheatgrass, little bluestem, and big bluestem
Historical Productivity Estimate: range = 900 to 2,200 lbs/acre; representative value = 1,550 lbs/acre
Structure: mixed grasses, 8-16" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed<15% and blue grama<15%

- **F. Long Fire Return Interval x Heavy Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – threadleaf sedge, blue grama, needle-and-thread, hairy grama, and western wheatgrass; *forbs* – tarragon, goldenrod, Rocky Mountain beeplant, Cuman ragweed, and scurfpea, *shrubs* – prairie sagewort, prairie rose, yucca, and western snowberry.
Other Characteristic Species: sand dropseed, slender wheatgrass, and prairie sandreed
Historical Productivity Estimate: range = 450 to 1,350 lbs/acre; representative value = 900 lbs/acre
Structure: mixed grasses, 4-8" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed<15% and blue grama>15%

Sands Ecological Site

Sands ecological sites occupy approximately 0.7% or 19,346 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are well to excessively drained, with rapid to very rapid permeability. These soils are deep to very deep and can be susceptible to wind and water erosion. These sites are typically characterized as nearly level to steep uplands on dunes, till plains, and stream terraces where slopes are less than 25%. Sands ecological sites range from low to very productive in the planning area with an average annual productivity range of 350 to 3400 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on sands ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on sands sites include prairie sandreed, sand bluestem, and little bluestem. Species like needle-and-thread, western wheatgrass, and prairie junegrass may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include sand dropseed, upland sedges, and blue grama. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire. Areas that were protected from fire likely experienced an increase in yucca and western snowberry.

Figure 9 displays the sands ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on sands ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x sands ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 9 and are referenced to the letter code in the upper left corner of each box.

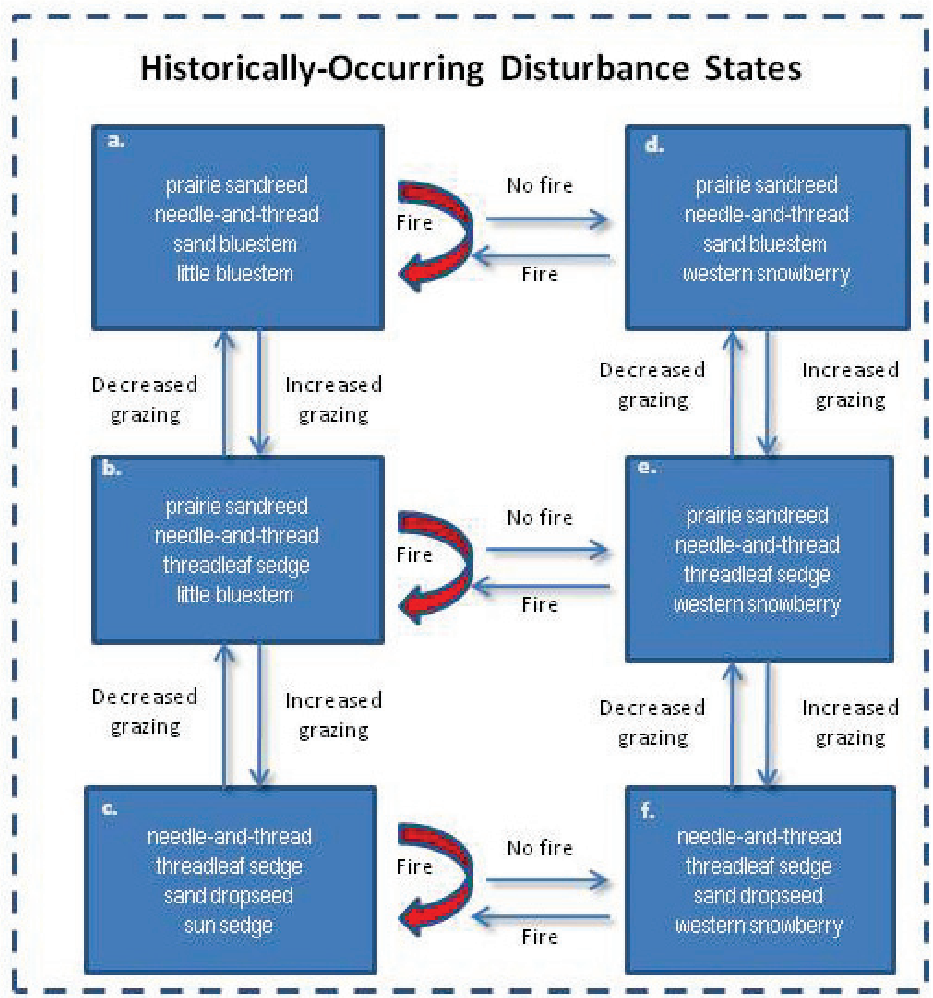

Figure 9. Historical disturbance states (state and transition model) or range of native ecosystem diversity for sands ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- ## A. Short Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers

Dominant Species: *grasses* – prairie sandreed, sand bluestem, little bluestem, and needle-and-thread; *forbs* – green sagewort, white sagebrush, sunflower, and western ragweed.
Other Characteristic Species: western wheatgrass, blue grama, switchgrass, and porcupine grass
Historical Productivity Estimate: range = 1,600 to 3,400 lbs/acre; representative value = 2,500 lbs/acre
Structure: mixed grasses, 12-24" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed>10% and threadleaf sedge<23%

- ### B. Short Fire Return Interval x Moderate Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – prairie sandreed, needle-and-thread, threadleaf sedge, and little bluestem; *forbs* – green sagewort, white sagebrush, sunflower, and western ragweed.
Other Characteristic Species: sun sedge, blue grama, western wheatgrass, and sand bluestem
Historical Productivity Estimate: range = 900 to 2,700 lbs/acre; representative value = 1,700 lbs/acre
Structure: mixed grasses, 8-16" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed<10% and threadleaf sedge<23%

- ### C. Short Fire Return Interval x Heavy Grazing Regime

Fire Return Interval: averaging less than 15 years
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – needle-and-thread, threadleaf sedge, sand dropseed, and sun sedge; *forbs* - green sagewort, white sagebrush, sunflower, and western ragweed.
Other Characteristic Species: blue grama and sand bluestem
Historical Productivity Estimate: Range = 400 to 1,600 lbs/acre; representative value = 900 lbs/acre
Structure: mixed grasses, 4-8" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry<3%
Light grazing indicators: prairie sandreed<10% and threadleaf sedge>23%

- ### D. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factor such as long distance to a water source for grazers
Dominant Species: *grasses* – prairie sandreed, sand bluestem, little bluestem, and needle-and-thread; *forbs* – green sagewort, white sagebrush, sunflower, and western ragweed; *shrubs* – leadplant, dwarf false indigo, and western snowberry.
Other Characteristic Species: western wheatgrass, blue grama, switchgrass, and porcupine grass
Historical Productivity Estimate: range = 1,400 to 3,000 lbs/acre; representative value = 2,200 lbs/acre

Structure: mixed grasses, 12-24" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed>10% and threadleaf sedge<23%

- **E. Long Fire Return Interval x Moderate Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* – prairie sandreed, needle-and-thread, threadleaf sedge, and little bluestem; *forbs* – green sagewort, white sagebrush, sunflower, and western ragweed; *shrubs* – prairie sagewort, prairie rose, and western snowberry.
Other Characteristic Species: sun sedge, blue grama, western wheatgrass, and sand bluestem
Historical Productivity Estimate: range = 800 to 2,400 lbs/acre; representative value = 1,500 lbs/acre
Structure: mixed grasses, 8-16" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed<10% and threadleaf sedge<23%

- **F. Long Fire Return Interval x Heavy Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – needle-and-thread, threadleaf sedge, sand dropseed, and sun sedge; *forbs* - green sagewort, white sagebrush, sunflower, and western ragweed; *shrubs* – prairie sagewort, prairie rose, and western snowberry.
Other Characteristic Species: blue grama and sand bluestem
Historical Productivity Estimate: range = 350 to 1,400 lbs/acre; representative value = 800 lbs/acre
Structure: mixed grasses, 4-8" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Short-interval fire indicator: western snowberry>3%
Light grazing indicators: prairie sandreed<10% and threadleaf sedge>23%

Very Shallow Ecological Site

Very shallow ecological sites occupy approximately 4.8% or 142,274 acres of the ecological sites in the Missouri Coteau subregion. Soils on these sites are excessively drained, with rapid to very rapid permeability. These soils are very deep but are characterized by a restrictive layer within 10" of the surface. This restrictive layer is composed of sand and/or gravel, creating a droughty condition that limits the distribution of a majority of plants. These sites are typically occur on level to very steep uplands on outwash plains, beach ridges, and terraces where slopes are less than 35%. Very shallow ecological sites range from very low to moderately productive in the planning area with an average annual productivity range of 200 to 1400 lbs. per acre, depending on the current disturbance state and the amount of precipitation received during the year.

Native ecosystem diversity on very shallow ecological sites was influenced by natural disturbance regimes of fire and bison grazing. Grazing played an important role in influencing the species composition of ecosystems on this ecological site. Plant species that respond as decreasers with increasing grazing pressure on very shallow sites include plains muhly, little bluestem, and sideoats grama. Species like needle-and-thread and western wheatgrass may initially respond as increasers, however, they decrease as grazing pressure becomes more intense. Species that commonly increase as grazing becomes moderate to heavy include upland sedges and blue grama. The frequent fire return interval historically occurring across this ecological site also played an important role in shaping the structure and species composition of the native ecosystems. In general, grass species were the dominant component and shrubs were a more minor component on these sites due to the frequency of fire. Areas that were protected from fire likely experienced an increase in prairie sagewort and wild rose.

Figure 10 displays the very shallow ecological site state and transition model for different disturbance states within the Missouri Coteau subregion as influenced by natural disturbance regimes of fire and bison grazing. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on very shallow ecological sites. The plant species identified in each box or disturbance state indicates the species that would increase or decrease in occurrence, depending on the influence of the natural disturbance regimes (as indicated by the direction of the arrows). These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x very shallow ecological site characteristics. However, it is important to note that each state represents a diverse ecological community of plant species that would support habitat for associated animal species. The following descriptions provide additional information on each disturbance state identified in Figure 10 and are referenced to the letter code in the upper left corner of each box.

- ### A. Long Fire Return Interval x Light Grazing Regime

Fire Return Interval: averaging 15 years or greater
Grazing: short-term or intermittently moderate to heavy grazing with significant rest periods; used less frequently possibly due to location factors such as long distance to a water source for grazers
Dominant Species: *grasses* – needle-and-thread, blue grama, and threadleaf sedge; *forbs* – purple coneflower, blazing star, prairie clover, scarlet beeblossom, and plains milkvetch; *shrubs* – prairie sagewort, leadplant, prairie rose, and yucca.
Other Characteristic Species: western wheatgrass, plains muhly, sideoats grams, and hairy grama
Historical Productivity Estimate: range - 700 to 1,400 lbs/acre; representative value = 1,200 lbs/acre
Structure: mixed grasses, 8-14" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Light grazing indicators: needle-and-thread>20% and blue grama<20%

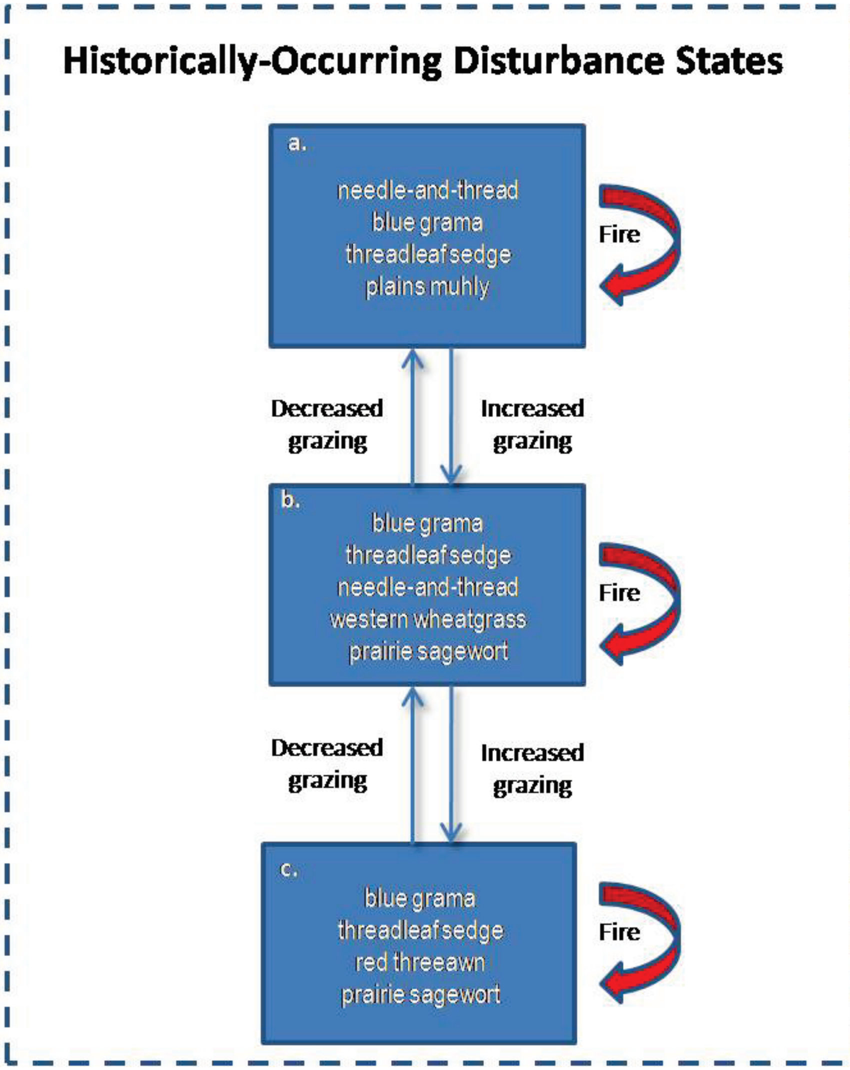

Figure 10. Historical disturbance states (state and transition model) or range of native ecosystem diversity for very shallow ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

- **B. Long Fire Return Interval x Moderate Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: variable, but occurring most years at moderate levels
Dominant Species: *grasses* –blue grama, threadleaf sedge, needle-and-thread, and red threeawn; *forbs*– blazing star, tarragon, prairie clover, lacy tansyaster, spiny phlox, and prairie coneflower; shrubs – prairie sagewort, creeping juniper, pricklypear, leadplant, prairie rose, and yucca.
Other Characteristic Species: western wheatgrass, hairy grama, and sand dropseed
Historical Productivity Estimate: range = 450 to 1,100 lbs/acre; representative value = 800 lbs/acre
Structure: mixed grasses, 5-10" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Moderate grazing indicators: needle-and-thread<20% and blue grama<20%

- **C. Long Fire Return Interval x Heavy Grazing Regime**

Fire Return Interval: averaging 15 years or greater
Grazing: occurring most years as season long grazing; these areas may be used more frequently due to factors such as close proximity to water sources or loafing areas for grazers
Dominant Species: *grasses* – threadleaf sedge, blue grama, hairy grama, and red threeawn; *forbs* – curlycup gumweed, tarragon, eastern pasqueflower, and pussytoes; *shrubs* – prairie sagewort, creeping juniper, prairie rose, pricklypear, creeping juniper, and yucca.
Other Characteristic Species: sand dropseed, western wheatgrass, and needle-and-thread
Historical Productivity Estimate: range = 200 to 700 lbs/acre; representative value = 400 lbs/acre
Structure: mixed grasses, 2-5" average vegetation heights
Primary indicators of natural disturbance regimes (% cover):
Heavy grazing indicators: needle-and-thread<20% and blue grama>20%

Ecosystem Diversity Matrix

While the diversity of ecosystems occurring across each ecological site can be described individually, a tool for displaying all of the native ecosystem diversity in a landscape has been developed and is termed an ecosystem diversity matrix (EDM) (Haufler et al. 1996, 1999). For the purposes of the conservation strategy, the EDM represents the full diversity of native ecosystems for terrestrial ecosystems in the Missouri Coteau subregion. Additional rare or unique ecosystems could occur, but are not expected to be regular or significant features of the landscape. Figure 11 provides an example of the EDM framework. For terrestrial ecosystems, the columns of the EDM identify the terrestrial ecological sites occurring in the planning region that exhibit physical differences in soils, moisture, etc., and that in turn influence the potential for a plant community to occur on that site. The rows of the EDM represent the disturbance states as they relate to vegetation communities that can occur on an ecological site due to the influences of historical (both natural and Native American) disturbance regimes. Terrestrial ecological sites and disturbance states of the Missouri Coteau subregion were discussed in the previous sections. The intersection of ecological sites (i.e., column) with the disturbance state (i.e., rows) can be described by the resulting vegetation community (i.e., cell) that characterizes that particular condition. Figure 12 represents the EDM for native terrestrial ecosystem diversity of the Missouri Coteau subregion. Each of the vegetation communities within a column correspond to the disturbance states discussed previously. All of the vegetation communities within the entire EDM represent the range of conditions or native terrestrial ecosystem diversity that can occur in the subregion. The amount of each vegetation community can vary over time and this variation is often referred to as the historical range of variability, as discussed in a previous section. The EDM framework is a particularly useful tool for quantifying, assessing, and displaying the cumulative impacts or changes in a landscape relative to historical or native ecosystem diversity.

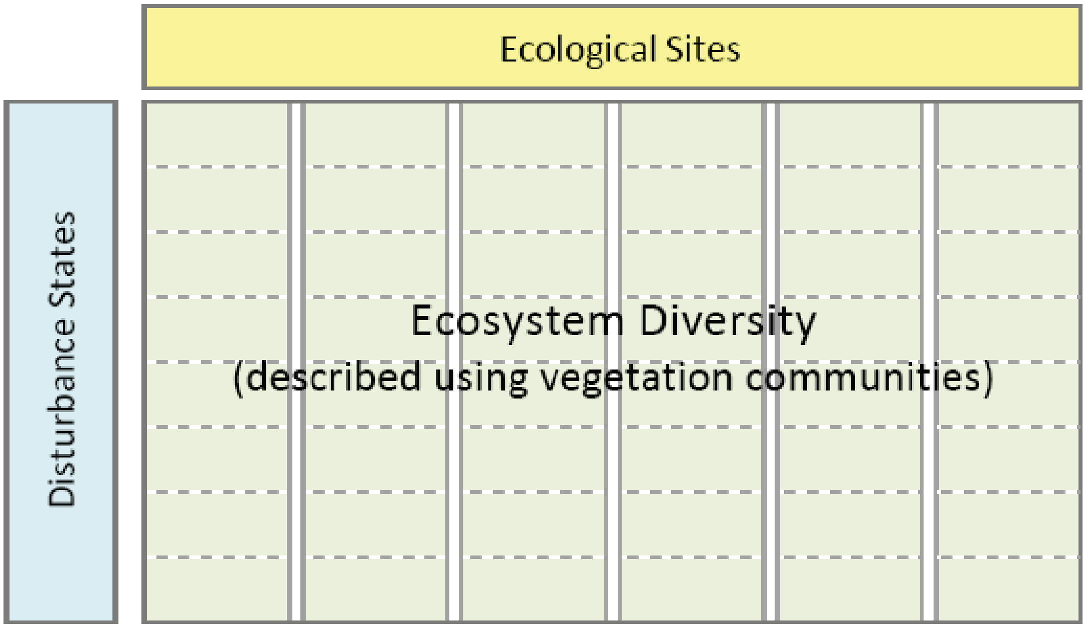

Figure 11. Example of the Ecosystem Diversity Matrix framework.

Characterizing Historical Ecosystem Diversity

Historical range of variability was modeled for terrestrial ecosystems in the Missouri Coteau using the spatially explicit landscape model SIMPPLLE (SIMulating Patterns and Processes at Landscape scales)(Chew et al. 2004). SIMPPLLE was used to simulate plant community dynamics as a result of natural disturbance events (e.g., fire and bison grazing), climate, and landscape elements (e.g., ecological site, proximity to water, and elevation). SIMPPLLE uses stochastic probabilities and disturbance response parameters that are specified to annually assign climate disturbance patterns discussed below. Although SIMPPLLE has a variety of potential applications, it was specifically used to derive the historical range of variability (HRV) for each terrestrial ecosystem. HRV was characterized using the average, minimum, and maximum number of acres that each terrestrial ecosystem occupied in simulations. Below is a description of the model parameters and model assumptions used in the SIMPPLLE simulations of the Missouri Coteau subregion.

Figure 12. The ecosystem diversity matrix representing native terrestrial ecosystem diversity for the Missouri Coteau subregion.

ECOSYSTEM DIVERSITY MATRIX - SOUTH DAKOTA MISSOURI COTEAU SUBREGION

TERRESTRIAL ECOSYSTEMS

Ecological Site Grouping	Clayey	Thin Claypan	Loamy	Shallow Loamy	Sandy	Sands	Very Shallow
Disturbance Influenced Pathways	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species	Potential Dominant Species
Early Seral	red threeawn sixweeks fescue needle-and-thread	sixweeks fescue needle-and-thread curlycup gumweed	red threeawn sixweeks fescue needle-and-thread	red threeawn sixweeks fescue needle-and-thread	red threeawn needle-and-thread sand dropseed	red threeawn needle-and-thread sand dropseed	red threeawn sixweeks fescue needle-and-thread
Vegetative composition/structure primarily influenced by short-interval fire regimes (<15 yrs.)							
Light Grazing	western wheatgrass green needlegrass thickspike wheatgrass porcupine grass		green needlegrass western wheatgrass slender wheatgrass porcupine grass	green needlegrass porcupine grass little bluestem green needlegrass sideoats grama	prairie sandreed needle-and-thread big bluestem western wheatgrass	prairie sandreed sand bluestem needle-and-thread little bluestem	
Moderate Grazing	western wheatgrass needle-and-thread blue grama thickspike wheatgrass		western wheatgrass needle-and-thread blue grama green needlegrass	little bluestem green needlegrass porcupine grass blue grama	needle-and-thread western wheatgrass blue grama prairie sandreed	prairie sandreed needle-and-thread sand bluestem threadleaf sedge	
Heavy Grazing	blue grama buffalograss upland sedge spp. prairie junegrass		blue grama upland sedge spp. red threeawn cactus	blue grama upland sedge spp. prairie sagewort	threadleaf sedge blue grama needle-and-thread hairy grama	needle-and-thread threadleaf sedge sand dropseed blue grama	
Vegetative composition/structure primarily influenced by long-interval fire regimes (>15 yrs.)							
Light Grazing	western wheatgrass green needlegrass thickspike wheatgrass western snowberry	western wheatgrass green needlegrass needle-and-thread broom snakeweed	green needlegrass western wheatgrass leadplant western snowberry	green needlegrass porcupine grass little bluestem leadplant	prairie sandreed needle-and-thread big bluestem western snowberry	prairie sandreed sand bluestem needle-and-thread western snowberry	needle-and-thread blue grama threadleaf sedge plains muhly
Moderate Grazing	western wheatgrass needle-and-thread blue grama western snowberry	western wheatgrass blue grama Sandberg bluegrass cactus	western wheatgrass needle-and-thread blue grama western snowberry	little bluestem green needlegrass blue grama leadplant	needle-and-thread western wheatgrass blue grama western snowberry	prairie sandreed needle-and-thread sand bluestem western snowberry	blue grama needle-and-thread western wheatgrass prairie sagewort
Heavey Grazing	blue grama buffalograss prairie sagewort western snowberry	blue grama Sandberg bluegrass inland saltgrass cactus	blue grama upland sedge spp. cactus western snowberry	blue grama upland sedge spp. prairie sagewort leadplant	threadleaf sedge blue grama needle-and-thread western snowberry	needle-and-thread threadleaf sedge sand dropseed western snowberry	blue grama threadleaf sedge red threeawn prairie sagewort
TOTAL ACRES IN EACH ECOLOGICAL SITE	**306,006**	**7,333**	**1,840,877**	**60,130**	**49,357**	**19,435**	**142,274**
USDA/NRCS Ecological Sites	R053C, R053B Clayey 053C Dense Clay	053B, R053B Thin Claypan 053B Claypan	053B Silty Loamy	053B Thin Upland 053B Thin Loamy	053B, R053B Sandy	053B, R053B Sands	053B, R053B Very Shallow 053B, R053B Shallow to Gravel

KEY
[grey box] - Ecosystems that did not occur

Model Attributes and Assumptions

- **Model Landscape**

The model landscape was created for the Missouri Coteau planning area in ArcGIS. The planning area was divided into 3 subregions for computing feasibility. These three subregions represented 1,168,000 acres or 40% of the project area. Each modeled area was delineated into 2.2 acre cells and each cell was identified as a specific vegetation unit based on its ecological site and by its disturbance state, which was based on its vegetation composition. Ecological sites were considered static landscape features in each simulated area. The starting point was developed for the Missouri Coteau planning landscape using general vegetation descriptions that were based on historical accounts of the area from early explorer surveys. Ecological sites were mapped using the NRCS ecological site classification applied to soils data and overlaid with National Wetlands Inventory to further refine the wetland and riparian classification. Digital elevation models were used to map elevation within the planning area.

- **Plant Dynamics**

The response of key plant species to climate (i.e., precipitation and temperature) and disturbance (i.e., fire and grazing) were tracked annually for each 2.2 acre cell within SIMPPLLE. Within a given year plant species within each cell were subject to change based on the interaction of climate (e.g., above average, average, or below average precipitation), grazing (e.g., light, moderate, or heavy grazing), and the occurrence of fire. Subsequently each 2.2 acre cell was given an ecosystem (terrestrial ecosystems only) classification that placed it into a disturbance state within each NRCS designated ecological site based on its species composition. That is, classification rules were developed that used percent cover of species within a cell to identify what historical state it belonged to, and over time climate and disturbance induced changes in plant species composition caused shifts among historical states. Plant species response parameters to climate and disturbance, as well as shifts among historical states were based on expert opinion from a team of ecosystem and rangeland ecologists, and on scientific literature.

- **Fire**

Fire starts were caused by lightning strikes in this model and were stochastically selected, resulting in variations designed to simulate historical variations in lightning-caused fires over time. The number of lightning strikes was adjusted in the model to cause increases or decreases in the number of fire starts, but the overall influence of fire was more dependent on the burn patterns than on the number of fire starts. Once a fire started in a given cell it had the opportunity to spread to adjacent cells until it encountered cells that reduced the ability of fire to spread (see below), or encountered a stochastic weather ending event. The probability of fire occurrence was influenced by the climate (precipitation and temperature) in a given year and the grazing history on individual units (e.g., a heavily grazed 2.2-acre unit in a given year had a lower probability of burning, whereas a lightly grazed 2.2-acre unit had a higher probability of burning). Fire spread probabilities were also influenced by landscape features such as permanent water sources representing 44,121 acres and that provided natural fire breaks. Intermittent water sources (479,871 acres) that might remain moist during wet precipitation cycles could also influence fire spread probabilities under the right conditions. Terrestrial ecological sites that had low probability of fire because of sparse fine fuel included the following ecological sites; very shallow and thin claypan which combined represented 149,607 acres within the planning area. The terrestrial ecological sites clayey, loamy, shallow loamy, sands, and sandy, represented the remaining 2,275,805 acres. Mean fire return intervals by terrestrial ecological site included:

- Clayey – 6.4 years
- Thin Claypan – 18.7 years
- Loamy – 6.7 years
- Shallow Loamy – 7.7 years
- Sands – 12.0 years
- Sandy – 7.9 years
- Very Shallow – 17.6 years

- **Grazing**

Bison grazing intensity was dependent on the proximity of the 2.2-acre vegetation units to water and the fire history of the vegetation units within the areas simulated. For instance, based on knowledge of bison grazing behavior it was assumed that the closer the 2.2 acre vegetation units were to water and the more recently burned the vegetation units were, the heavier bison would graze. Vegetation units located between 0 to 4,000 feet away from water had a higher probability of receiving heavy bison grazing, whereas vegetation units located between 4,000 to 15,840 and 15,841 or greater feet away from water had increasingly higher probabilities of receiving moderate or light grazing, respectively. Likewise, the probability of heavy grazing on 2.2-acre vegetation units 1 to 2 years after a fire was higher, whereas 3 to 5 years and 6 or more years after fire the vegetation units had a higher probability of moderate and light grazing, respectively.

Each of the three sub-sections of the Missouri Coteau region was initially run for 200 years of simulation to ensure initial starting conditions did not unduly influence the model results. The output of these runs for each section was then used to simulate historical ecosystem dynamics. Five simulations, each representing 100 years, were performed in SIMPPLLE for each of the three sections of the Missouri Coteau subregion. In each of the simulations, the weather patterns were varied but within the range of weather patterns recorded for the Missouri Coteau region. Fire starts were also stochastic, resulting in variations designed to simulate historical variations over time. Following the simulations the data were combined from the three sections to reflect the entire planning region and results were summarized using the Ecosystem Diversity Matrix framework described previously.

Results of the SIMPPLLE Model Simulations

Results of the SIMPPLLE model simulation of the historical range of variability can be found in Table 2 and includes the average, minimum, and maximum percent of total acres for a terrestrial ecological site occurring in the Missouri Coteau subregion. Table 3 summarizes the historical range of variability by the average, minimum, and maximum number of acres in the Missouri Coteau subregion occupied by each terrestrial ecosystem. The historical range of variability simulation illustrated that the majority of the terrestrial ecosystems in this area were historically in the vegetation conditions described by the short interval fire regime and the heavy grazing regime (Table 4).

Table 2. Results of the SIMPPLLE modeling effort to estimate the historical range of variability (HRV) for the Missouri Coteau subregion. The numbers represent the average and the minimum to maximum, also known as HRV (%), percent of the overall ecological site acres for each ecological site. Refer to the text for a description of the methods used to obtain these results.

		Clayey	Thin Claypan	Loamy	Shallow Loamy	Sandy	Sands	Very Shallow
MFRI <15 years								
Light Grazing	avg.	**20.4**		**18.8**	**44.3**	**25.5**	**56.6**	
	min-max	(4.0 - 35.9)		(7.1 - 36.8)	(26.8 - 58.0)	(5.5 - 41.3)	(33.2 - 74.1)	
Moderate Grazing	avg.	**19.8**		**15.8**	**9.4**	**9.9**	**3.7**	
	min-max	(4.5 - 61.9)		(2.9 - 42.5)	(0.6 - 32.9)	(0.4 - 31.8)	(0 - 15.8)	
Heavy Grazing	avg.	**39.8**		**50.5**	**25.0**	**45.0**	**29.5**	
	min-max	(20.5 - 61.5)		(32.4 - 70.1)	(21.9 - 31.5)	(33.3 - 66.9)	(18.6 - 38.1)	
MFRI $\geq$ 15 years								
Light Grazing	avg.	**12.9**	**16.5**	**7.2**	**9.1**	**11.4**	**3.4**	**50.2**
	min-max	(3.3 - 31.3)	(6.5 - 23.3)	(4.5 - 21.7)	(2.6 - 27.7)	(3.5 - 30.0)	(0 - 43.0)	(36.9 - 64.1)
Moderate Grazing	avg.	**3.1**	**24.0**	**3.6**	**2.4**	**2.2**	**0.8**	**11.2**
	min-max	(0 - 17.6)	(1.9 - 35.5)	(0 - 7.2)	(0 - 12.8)	(0 - 7.3)	(0 - 3.9)	(0.2 - 38.9)
Heavy Grazing	avg.	**4.1**	**59.5**	**4.0**	**9.8**	**6.0**	**6.0**	**38.5**
	min-max	(0 - 20.9)	(44.6 - 78.5)	(0 - 7.5)	(0 - 15.5)	(0.05 - 15.8)	(0.3 - 13.8)	(5 - 61.4)
Total Acres		**306,006**	**7,333**	**1,840,877**	**60,130**	**49,357**	**19,435**	**142,274**

Table 3. Results of the SIMPPLLE modeling effort to estimate the historical range of variability (HRV) for the Missouri Coteau subregion. The numbers represent the average and the minimum to maximum, also known as HRV (acres), number of acres for each native ecosystem. Refer to the text for a description of the methods used to obtain these results.

		Clayey	Thin Claypan	Loamy	Shallow Loamy	Sandy	Sands	Very Shallow
MFRI < 15 years								
Light Grazing	avg.	**62,279**		**345,798**	**26,662**	**12,588**	**11,001**	
	min-max	(12,154-109,878)		(130,605-677,283)	(16,128-34,853)	(2,700-20,394)	(6,446-14,405)	
Moderate Grazing	avg.	**60,463**		**291,006**	**5,626**	**4,864**	**719**	
	min-max	(13,800-189,372)		(54,245-783,075)	(355-19,810)	(206-15,689)	(0 - 3,076)	
Heavy Grazing	avg.	**121,638**		**930,484**	**15,032**	**22,204**	**5,733**	
	min-max	(62,815-188,178)		(596,179-1,289,615)	(13,148-18,933)	(16,446-33,036)	(3,614-7,400)	
MFRI ≥ 15 years								
Light Grazing	avg.	**39,498**	**1,209**	**132,523**	**5,436**	**5,608**	**667**	**71,486**
	min-max	(10,108-95,821)	(480-1,709)	(83,596-399,552)	(1,578-16,654)	(1,743-14,825)	(0 - 8,350)	(52,549-91,173)
Moderate Grazing	avg.	**9,540**	**1,760**	**67,108**	**1,469**	**1,106**	**156**	**15,988**
	min-max	(0-53,868)	(142-2,604)	(0-131,908)	(0 - 7,713)	(0 - 3,625)	(0 - 764)	(208-55,325)
Heavy Grazing	avg.	**12,589**	**4,364**	**73,958**	**5,906**	**2,977**	**1,160**	**54,800**
	min-max	(0-64,019)	(3,268-5,757)	(0-138,436)	(0 - 9,291)	(25 - 7,804)	(49 - 2,678)	(7,176-87,288)
Total Acres		**306,006**	**7,333**	**1,840,877**	**60,130**	**49,357**	**19,435**	**142,274**

Table 4. Summary of the results of SIMPPLLE model simulations illustrating the % of the Missouri Coteau subregion with vegetation conditions that are characteristic of the combination of short (<15 year) or long (>15 year) fire return intervals with light, moderate, and heavy grazing regimes.

Grazing Regime	Mean Fire Return Interval < 15 years	Mean Fire Return Interval ≥ 15 years
	---------% of landscape---------	
Light	18.9	10.6
Moderate	14.9	4.0
Heavy	45.2	6.4
Total	79.0	21.0

Native Wetland and Riparian Ecosystem Diversity

Riparian and wetland ecosystems are represented by those ecological sites that are inundated or saturated by surface or groundwater at a frequency and duration that will support vegetation that is adapted to these conditions. For the most part, these ecological sites were well distributed throughout the Missouri Coteau subregion, although perennial streams were relatively uncommon and widely spaced. Prairie pothole type wetlands, as they are often referred to today, were common and occurred in various densities of a few- to many per square mile. They have been estimated to have covered approximately 20% of the historical landscape for this subregion (Johnson and Higgins 1997).

Riparian and wetland ecosystems varied widely because of differences in soils, topography, hydrology, water chemistry, vegetation, and natural disturbance factors such as fire, bison grazing, beaver activities, and flooding. In general, wetland ecosystems were composed of primarily grasses and herbaceous vegetation due to the frequency of fire and bison grazing. Riparian systems, particularly perennial stream floodplains, may have exhibited some shrub and tree communities, although overall these vegetation communities are believed to have been relatively limited in this subregion.

Natural Disturbance

Fire

Historical fire regimes and their effects on wetland and riparian ecosystems have not been well-studied in the Missouri Coteau or the Great Plains in general and are, overall, poorly understood. While quantitative data are lacking, there are some inferences that can be gleaned based on our understanding of fire effects in the surrounding uplands, the effects of fire in other landscapes, and our understanding of the general ecology of riparian and wetland plant species. Those inferences are applied here with the caution that additional information on the effects of historical fire in wetland and riparian ecosystems of the Missouri Coteau should be a high priority for future research and study.

The historical fire regimes of wetlands and riparian ecosystems in the Missouri Coteau were likely heavily influenced by the fire regimes occurring in the surrounding uplands. In addition, the hydrology of a site could also influence fire regimes with those wetlands flooded for the least length of time being more likely to burn in comparison to those with more permanent water sources. The lack of references to trees and shrubs by early explorers would support that trees and shrubs were fairly uncommon outside of the floodplains of mid- to large streams and rivers.

The flammability of a wetland and riparian plant community can depend on vegetation types, drought cycles, and the season. In general, wetland and riparian communities are expected to recover rapidly after a fire. Woodland riparian areas can take more time, especially if larger trees were killed by the fire. Some species will re-sprout while others will re-colonize a site from seeds remaining in the soil or from nearby sources. Some suggest that fire may be important to maintaining diversity in some ecological sites, where the soil may be exposed allowing germination of infrequently occurring annual plants with seeds still present in the seed bank. Fires, and to a lesser but important degree heavy grazing, are believed to be major limiting factors to the establishment of shrubs and trees in wetlands and riparian communities in the Missouri Coteau. This is particularly true of the drier perimeter zones of wetland vegetation occurring in these communities where most trees and shrubs would occur. Moister interior zones likely burned less frequently and primarily under drought conditions. Some plant species, such as willows, are less affected by fires than other plant species. Fire can also remove organic matter in some wetlands, thereby helping to maintain deeper water over time. Some plants also benefit from the release of nutrients following fire.

Grazing

As described and discussed previously in the terrestrial ecosystems section historical grazing by bison and other herbivores was a significant disturbance process and influence on native ecosystem diversity within the Missouri Coteau landscape. This is also true of wetland and riparian native ecosystem diversity, with some differences in scope and effect (Timoney 2008). Bison grazing, browsing, trampling, wallowing, soil compaction, and bank shearing influenced the structure and species composition of riparian or wetland ecosystems. Bison congregated around water sources and contributed to changes in wetlands and riparian areas. Deposits of urea and manure likely resulted in higher nutrient inputs and reduced water quality in some areas. Grazing of wetland and riparian areas likely reduced vegetation and possibly contributed to increasing temperatures and evaporation of water. With reduction in vegetation along streams, stream banks were likely impacted by sloughing and erosion. Shrubs and trees were likely impacted from both rubbing for relief from insects and browsing by bison and other herbivores.

Heavy grazing in the adjacent uplands could also result in reduced infiltration of surface water and increased runoff that could contribute to sedimentation and hydrologic changes to wetlands. Some impacts also were likely related directly to grazing of wetland plants. Depending on its intensity, grazing can influence species composition and structure along environmental gradients. Heavy grazing and severe trampling will usually reduce plant cover and increase the amount of bare soil. The effects of trampling can be zonal, occurring mainly on the drier exterior margins of a wetland. In addition, winter grazing by bison would likely concentrate on wetlands and wetland edges, removing much of the residual dead vegetative cover (Timoney 2008). Many wetland plant species have adapted to differences in bison grazing influences, and can withstand these variable grazing pressures.

Muskrat grazing on emergent vegetation can also influence the species composition and structure of some wetland types. Where sufficient food supplies (i.e., emergent vegetation) and surface water exist, muskrat populations can increase to the point that they have harvested all or most of their food supply. The cover of emergent vegetation decreases significantly and the wetland changes to a mostly open water wetland. The wetland may not return to higher cover of emergent's until the muskrat population declines significantly or the next drought cycle reduces the level of surface water and drives the muskrat out of the area.

Flood Events

Flood disturbance has been an important part of the natural cycle of wetland and riparian ecosystems throughout the Missouri Coteau and has played an important role in maintaining ecosystem function and biological diversity within these systems. Flood events within the Missouri Coteau can result from seasonal snow melt and/or large precipitation events. Flood events help maintain ecosystem productivity and diversity through both above- and below-ground processes that transport sediments, nutrients, and organisms throughout riverine floodplains, as well as across and between depressional and lake systems (Ward et al. 1999, Junk et al. 1989, Tockner et al. 1999, and Reeves et al. 1995). For riparian systems, short-duration flood events of high stream-power result in channel and sediment movement, increased vegetation and deadwood in the channel, and upwelling of groundwater. The interaction of flooding influences promotes overall biodiversity, and complex food webs (Reeves et al. 1995). Both the plants and animals of flood-prone systems have adapted to flood disturbance, and many even require flood events to regenerate or complete their life cycle (Merigliano 1996, Pollock 1998). Flood events play a critical role in ecological succession and determining the structure and composition of the effected ecosystem (Sparks and Spink 1998).

The fluctuation of water levels resulting from seasonal or recurring flood events can influence the species composition and structure of wetland and riparian ecosystems. Fluctuating water levels can increase the amount of open water and bare soils that are present during a growing season (LaBaugh et al. 1998). Open water generally increases immediately following a flood event and as water disappears from the site, a drawdown phase may occur that exposes bare dirt and leads to emergent species colonizing or re-colonizing portions of the wetland (Stewart and Kantrud 1971).

Beaver

Prior to European settlement, beaver were found in nearly all waterbodies throughout North America that supported adequate water and food resources (Naiman et al. 1988). In the Missouri Coteau subregion, beaver densities were likely lower than surrounding landscapes due to limited food sources and water habitat associated with the lower amounts of more permanent water bodies (Johnson and Higgins 1997). While not well documented, current beaver dams and populations in the Missouri Coteau are likely less than numbers present at the time of the early French-Canadian trappers (late 1600's) (Jenkins and Busher 1979) due to trapping and dam removal, as well as changes in stream hydrology.

Beaver are well known for their disturbance effects in wetland and riparian ecosystems. The beaver's ability to influence and in some instances, drastically modify ecosystem structure and dynamics through dam building, wood cutting activities, and even pond abandonment, has been well-documented (Naiman et al. 1988, Ford and Naiman 1988, McDowell and Naiman 1986, Medin and Torquemada 1988). In riparian systems, these activities alter stream morphology and patterns of discharge, decrease current velocity, increase retention of sediment and organic matter, elevate water tables and expand areas of flooded soil. In lakes and permanently flooded depressional systems, beaver can influence water levels by placing dams at outlets. Spatially and temporally the effects of beaver fluctuated with population dynamics that were influenced by drought, food supply, disease, flood disturbance, and predation (Naiman et al. 1988). These population dynamics were important to overall diversity at both the ecosystem and landscape levels.

Beaver pond creation is limited by geomorphology and food supply within the Missouri Coteau. In riparian systems, most beaver dams occur on 1st to 4th order streams, as dams on larger streams are often removed by high flow events (Naiman et al. 1988). On low order streams, beaver dams can provide a more constant flow of water during summer and fall months when many streams might otherwise dry up. Beaver preferentially select areas for dam building that create the largest ponds with the greatest potential for expansion (Johnston and Naiman 1990).

The importance of beaver dam building and feeding activities to plant and wildlife diversity of an area has also been well-documented (Dieter and McCabe 1989, Schlosser 1995, Johnston and Naiman 1990, Barnes and Dibble 1988). Dam building and feeding activities usually result in removal of trees and shrubs adjacent to streams, lakes, and ponds. Abandonment of an area results in increased grass encroachment and shrub cover (Aznar and Desrochers 2008). Riparian zones dominated by deciduous tree species that are preferred by beaver may be essentially clear-cut. The dams also impound water that expands existing wetlands or creates and maintains new wetlands. With the increased soil moisture, the existing upland vegetation will likely die and be replaced by moisture loving trees and shrubs such as cottonwoods, willows, and green ash. These are also the preferred foods of the beaver. In this way, beaver can reset the ecological development of the riparian or wetland ecosystem and often modify habitat to the point of creating an entirely different environment. At the aquatic level, beaver activities can influence the invertebrate community structure, even changing from running-water taxa to pond taxa (Merigliano 1996).

Disturbance States

Wetland and Riparian ecosystems of the Missouri Coteau, are the combination of communities of living organisms with the physical environment in which they live. To characterize native ecosystem diversity for wetland and riparian ecosystems of the Missouri Coteau, we used a combination of two primary drivers of ecosystem diversity: ecological sites and disturbance states. Ecological sites represent the physical environment component of an ecosystem and disturbance states represent the vegetation communities that can occur on an ecological site in response to natural disturbance regimes. The following sections describe the native wetland and riparian ecosystem diversity that occurred within the Missouri Coteau relative to these two primary drivers, disturbance states and ecological sites.

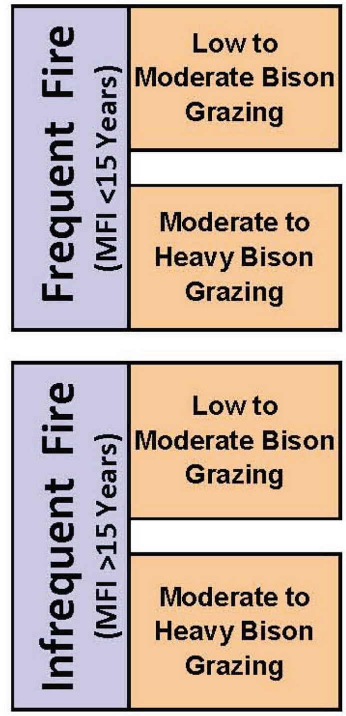

Figure 13. Disturbance states identified for wetland and riparian ecosystems of the Missouri Coteau resulting from the interaction of fire and bison grazing.

Although ecological sites provide valuable information on the physical environment of wetland and riparian ecosystems, they do not identify the full range of successional conditions, or disturbance states, possible on a site as a result of natural disturbance events and processes. Thus, fire and large herbivore grazing (i.e., primarily bison) were included as the primary disturbance mechanisms that historically influenced wetland and riparian ecosystems of the Missouri Coteau subregion (Figure 13). Flooding is also a disturbance mechanism that can have varying influences on wetlands depending on the ecological site. Some of the influences of flooding are captured in the underlying geomorphology and hydrological processes influencing ecological sites and will be discussed further in the ecological site descriptions. Due to the limited information on flood regimes and vegetation successional trajectories in wetland and riparian ecosystems of the Missouri Coteau, flooding effects were not incorporated into disturbance states at this time but should be recognized as a need for future research. Beaver activity is limited to certain ecological sites due to the requirement for a permanent water source. It will be further discussed in the applicable descriptions of ecological sites.

Climate cycles such as drought are a particularly important stochastic process in wetland and riparian systems that should also be evaluated and considered in discussions of disturbance states and overall planning. The ability to incorporate climate in this process will be developed more fully with the ability to describe the historical range of variability for wetland and riparian ecosystems of the Missouri Coteau subregion.

Fire and grazing disturbance transitions for each ecological site were developed using the best available information on ecosystem and plant species response to these disturbance events. The natural fire regime was incorporated using two categories: mean fire intervals of < 15 years and mean fire intervals >= 15 years. These two categories capture the significant influence of fire on shrub and tree occurrence in wetland and riparian systems of the Missouri Coteau. Mean fire intervals < 15 years occur frequently enough to significantly reduce the cover of shrubs and trees in the landscape. Mean fire intervals >=15 years will normally allow shrubs and trees to establish and propagate. Bison grazing disturbance was divided into two levels of influence; light to moderate and moderate to heavy grazing. While three categories of bison grazing were used in terrestrial ecosystems, it was decided that the interaction of multiple disturbance regimes within wetland and riparian ecosystems warrant reducing to two levels of bison grazing to describe grazing influences to reduce the overall complexity of the EDM framework. The effects of bison grazing on wetland and riparian ecosystems were extrapolated from cattle grazing inferences provided by Stewart and Kantrud (1971) and NRCS ecological site descriptions. It is important to note, however, that most information on plant responses to grazing are developed from studies of cattle, which has been determined to differ slightly from the effects of bison grazing on vegetation.

Additional information on disturbance states are provided in the following discussion of native ecosystem diversity and each wetland and riparian ecological site identified for the Missouri Coteau subregion.

Ecological Sites

NRCS ecological sites are not as well-developed for wetland and riparian ecosystems of the Missouri Coteau subregion as they are for terrestrial systems. No classification system currently exists in the Missouri Coteau that will identify the full range of native ecosystem diversity that occurred in this landscape under historical conditions (i.e., prior to Euro-American settlement). For the purpose of describing native ecosystem diversity in wetland and riparian ecosystems of the Missouri Coteau, we have developed the ecosystem diversity matrix framework that uses a combination of existing classification systems including Stewart and Kantrud (1971), Cowardin et al. (1979), and the hydrogeomorphic (HGM) system (Brinson 1993). The following sections will summarize how these classification systems were combined to meet the objectives for describing native ecosystem diversity. First, however, a brief description of each classification system will provide the foundation for this discussion.

Stewart and Kantrud (1971) developed a regional classification system for ponds and lakes of the glaciated prairie region that includes the Missouri Coteau. The primary objective of this classification system was to allow for the inventory of existing wetland plant communities. They grouped wetland vegetation into zones characterized by distinctive plant community compositions and structure and ponding regime (i.e., hydrology). Cowardin et al. (1979), hereinafter referred to as the Cowardin system, is similar in several respects to Stewart and Kantrud's system but was developed as a national classification system. The Cowardin system has become the most widely used wetland classification system in the United States. The overall emphasis of the Cowardin system also remains on the inventory of existing plant communities. More recently, the hydrogeomorphic (HGM) wetland classification system was introduced by Brinson (1993) to provide a tool for measuring functional changes in wetland ecosystems. The HGM system emphasizes the geomorphic setting and hydrologic attributes of a site rather than the existing biological characteristics of the plant communities. The geomorphic setting identifies the topographic location of the site within the surrounding landscape and the hydrological attributes that characterize the source of water to the site.

As discussed previously in the terrestrial ecosystem section, the importance of identifying and classifying the underlying abiotic conditions and primary drivers responsible for both the functional and vegetative differences between ecological sites cannot be overstated. The HGM system was developed to capture these underlying abiotic conditions and has the most applicability in this regard relative to the other classifications. While both Stewart and Kantrud and the Cowardin systems resemble the HGM system in some components, they lack the ability to capture the underlying interaction of geomorphic and hydrological drivers that represent the abiotic influence on wetland and riparian ecological sites.

To apply the HGM system for ecological site classification within the Missouri Coteau, four hydrogeomorphic classes were identified including Lacustrine, Depressional, Riverine, and Slope classes. The four HGM classes are defined using slight modifications to NRCS (2008) definitions (Table 5). In addition, 7 hydrology sub-classes and 2 water chemistry sub-classes were identified to capture important drivers and attributes which influence the native functional and vegetative characteristics of wetland and riparian ecological sites within the Missouri Coteau subregion. The hydrology sub-classes are described and defined relative to the Cowardin system's "modifier" level of classification, with considerable overlap with Stewart and Kantrud's "class" level (Table 6).

Stewart and Kantrud (1971, 1972) identified six levels of water chemistry in wetlands of the Missouri Coteau. While species composition changes in response to salinity levels may occur gradually along a continuum, their results indicated a reasonably consistent shift from freshwater species to saline species at a common point, depending on the wetland site. Saline wetlands develop in closed basins where water enters the wetland via groundwater seepage and surface flow. In these basins, water can only leave through evaporation. Over time, dissolved salts present in the water entering the wetland are concentrated and deposited on the soil surface (Hammer and Heseltine 1988). The water chemistry sub-class uses two levels, fresh and saline, which are indicated by the primary break between less salt tolerant and more salt tolerant plant species as described by Stewart and Kantrud (1971), for a particular ecological site (Table 7).

While not required as part of the ecosystem diversity classification, vegetation zones as defined by Steward and Kantrud (1971) (Table 8) provide a useful tool in identifying the hydrological subclass and for describing vegetation communities as influenced by hydrological and water chemistry subclasses. Vegetation zones are advocated as a valuable tool for determining average hydrological conditions for an ecological site (Stewart and Kantrud 1971). For the purpose of describing native ecosystem diversity, each disturbance state was characterized using expected species compositions relative to defined vegetation zones.

Table 5. A description of the hydrogeomorphic classes identified for wetland and riparian ecological sites of the Missouri Coteau (as definitions modified from NRCS 2008 and Brinson et al. 1995).

HGM Class	Definition
LACUSTRINE	Lacustrine wetlands are adjacent to lakes (>20 acres) where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and ground water discharge, the latter dominating where lacustrine wetlands integrade with uplands or SLOPE wetlands. Lacustrine wetlands are indistinguishable from depressional wetlands where the size of the lake becomes so small relative to fringe wetlands that the lake is incapable of stabilizing water tables. Lacustrine wetlands lose water by flow returning to the lake after flooding, by saturation surface flow, and by evapotranspiration. Organic matter normally accumulates in areas sufficiently protected from shoreline wave erosion. Lacustrine wetlands were relatively rare in the Missouri Coteau under historical conditions but are more frequent today due to the damming of permanent stream courses.
DEPRESSIONAL	Depressional wetlands occur in topographic depressions (≤20 acres). Dominant water sources are precipitation, ground water discharge, and both interflow and overland flow from adjacent uplands. The direction of flow is normally from the surrounding uplands toward the center of the depression. Elevation contours are closed, thus allowing the accumulation of surface water. Depressional wetlands may have any combination of inlets and outlets or lack them completely. Dominant hydrodynamics are vertical fluctuations, primarily seasonal. Depressional wetlands may lose water through intermittent or perennial drainage from an outlet, by evapotranspiration and, if they are not receiving ground water discharge, may slowly contribute to ground water discharge. Prairie potholes are a common example of depressional wetlands.
RIVERINE	Riverine wetlands occur in flood plains and riparian corridors in association with stream channels. Dominant water sources are often overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Sources may be interflow and return flow from adjacent uplands, occasional overland flow from adjacent uplands, tributary inflow, and precipitation. At their headwater, riverine wetlands often are replaced by slope or depressional wetlands where the channel morphology may disappear. They may intergrade with poorly drained flats or uplands. Perennial flow in the channel is not a requirement.
SLOPE	Slope wetlands normally are found where there is a discharge of ground water to or near the land surface. They normally occur on sloping land; elevation gradients may range from steep hillsides to slight slopes. Slope wetlands are usually incapable of depressional storage because they lack the necessary closed contours. Principle water sources are usually ground water return flow and interflow from surrounding uplands, as well as precipitation. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if ground water discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturation subsurface and surface flows by evapo-transpiration. They may develop channels but they serve only to convey water away from the Slope wetlands. Fens are common examples of Slope wetlands.

Table 6. The seven hydrology sub-classes utilized for wetland and riparian ecological sites of the Missouri Coteau subregion.

Hydrology Subclass	Definition
Permanent	Water covers the land surface or flows throughout the year, except under very extreme drought conditions.
Intermittent	Surface water is present but variable due to evapotranspiration throughout the year or absent in years of extreme drought.
Semi-permanent	Surface water persists throughout the growing season but is absent by late summer to early fall in most years.
Seasonal	Surface water is typically present from spring to early summer, but is absent by the end of the season in most years.
Temporary	Surface water is present for brief periods, a few weeks in spring or a few days after a heavy rain or the channel contains flowing water for only a few weeks in the spring or after a heavy rain, and when not flowing may remain in isolated pools or surface water may be absent altogether.
Subirrigated	Hydraulic activity caused by slope produces conditions where sub-surface water is present at varying levels throughout the growing season, but usually within 1.5 to 3.5 feet from the surface.
Seep/saturated	Groundwater saturated soils on gently sloping terrain; rarely ponded; may be slightly flowing early in the growing season but with no recognizable channel.

Table 7. Species most likely to indicate fresh water versus saline water chemistry for the Missouri Coteau subregion by vegetation zone (WM=wet meadow, SM=shallow marsh, DM=deep marsh, and OW=open water).

Scientific Name	Common Name	Plants Code	Vegetation Zone
Fresh Water Chemistry			
Boltonia asteroides	white doll's daisy	BOASL	WM
Vernonia fasciculata	prairie ironweed	VEFA2	WM
Helenium autumnale	common sneezeweed	HEAU	WM
Calamogrostis candensis	Macoun's reedgrass	CACAM	WM
Hierochloe hirta	nothern sweetgrass	HIHIA	WM
Carex vulpinoidea	fox sedge	CAVU2	WM
Ranunculus macounii	Macoun's buttercup	RAMA2	WM
Rorippa islandica	northern marsh yellowcress	ROIS2	WM
Potentilla norvegica	Norwegian cinquefoil	PONO3	WM
Lysimachia hybrida	lowland yellow loosestrife	LYHY	WM
Glyceria grandis	American mannagrass	GLGR	SM
Sparganium eurycarpum	broadfruit bur-reed	SPEU	SM
Glyeria borealis	small floating mannagrass	GLBO	SM
Schoenoplectus heterochaetus	slender bulrush	SCHE5	SM
Schoenoplectus tabernaemontani	softstem bulrush	SCTA2	DM
Typha latifolia	broadleaf cattail	TYLA	DM
Utricularia macrorhiza	common bladderwort	UTMA	DM
Riccia fluitans	aquatic liverwort	RIFL4	OW
Lemna trisulca	star duckweed	LETR	OW
Saline Water Chemistry			
Distichlis spicata	saltgrass	DISP	WM
Triglochin maritima	seaside arrowgrass	TRMA20	WM
Muhlenbergia asperifolia	scratchgrass	MUAS	WM
Spartina gracilis	alkali cordgrass	SPGR	WM
Puccinellia nuttalliana	Nuttall's alkaligrass	PUNU2	SM
Salicornia rubra	red swampfire	SARU	SM
Scirpus nevadensis	Nevada bulrush	SCNE	SM
Suaeda calceoliformis	Push seepweed	SUCA2	SM
Schoenoplectus maritimus	cosmopolitan bulrush	SCMA8	DM
Chara spp.	muskgrass	CHARA	OW
Ruppia maritima	widgeongrass	RUMA5	OW
Potamogeton pectinata	sago pondweed	STPE15	OW

Table 8. The seven vegetation zones identified by Stewart and Kantrud (1971) and used in the wetland and riparian ecological sites of the Missouri Coteau to help describe vegetation communities by hydrological subclass.

Vegetation Zones	Description
Low Prairie (LP)	Characterized by moist site prairie grasses, forbs, shrubs, and trees. The hydrology influencing this zone is typically ephemeral, i.e., moist for a few days in spring.
Wet Meadow (WM)	Characterized by fine-textured grasses, rushes, and sedges of relatively low stature. The hydrology influencing this zone is typically temporary.
Shallow-marsh (SM)	Characterized by a mix of 3 phases depending on annual, seasonal, or site specific water levels: normal emergent phase of intermediate height grasses/grass-like plant species, open-water phase with submerged aquatic plants, and a drawdown phase of emergent/pioneering species or bare dirt. The hydrology influencing this zone is typically seasonal.
Deep-marsh (DM)	Characterized by a mix of 3 phases depending on annual, seasonal, or site specific water levels: normal emergent phase of coarser and taller grasses/grass-like plant species, open-water phase with submerged or floating aquatic plants, and a drawdown phase of emergent/pioneering species or bare dirt. The hydrology influencing this zone is typically semi-permanent.
Open Water (OW)	Characterized by water areas completely devoid of vegetation and areas where two species of vascular plants (widgeongrass and pondweed) may be present. The hydrology influencing this zone is typically permanent.
Fen (FEN)	Characterized by floating or surface mats of emergent vegetation; may be intermixed with small open water areas. Springs may be present. The hydrology influencing this zone is typically seep/saturated.
Intermittent-Alkali (IA)	Characterized by highly saline and relatively shallow water. The hydrology of this zone is typically intermittent.

Mapping Wetland and Riparian Ecological Sites

Wetland and riparian ecosystems were mapped within the South Dakota portion of Major Land Resource Area (MLRA) 53B - Central Dark Brown Glaciated Plains (USDA, Natural Resources Conservation Services 2006). Data sources used in this mapping effort included a combination of NRCS ecological sites and National Wetlands Inventory (NWI), reclassified to delineate 9 of the 11 ecological sites for native wetland and riparian ecosystems, as described previously. The NRCS ecological site and NWI information were available as GIS layers with associated attribute data. However, the ability to map slope systems from existing data sources is particularly lacking at this time. In addition, the ability to map fresh from saline systems using existing data sources is also lacking at this time.

The methodology used to map the wetland and riparian ecological sites included the following steps:

Step 1. Clip the NRCS SSURGO layer to riparian/wetland ecological sites that include loamy overflow, subirrigated, saline lowland, wetland, wet meadow, closed depression, and shallow marsh.

Step 2. Union above NRCS SSURGO layer with NWI GIS layer.

Step 3. Use step 2 to create a layer of geomorphic sites by merging polygons adjacent to lakes as lacustrine systems, polygons adjacent to rivers as riverine systems, and polygons not associated with lakes or rivers as depressional systems

Step 4. Overlay step 3 results with step 2 results and depending on the moistest vegetation class (NRCS ecological site) or NWI hydrology modifier, identify the hydrology subclass for each of the 9 ecological sites. Where NWI and NRCS overlap, the NWI classification was used to determine the hydrology subclass.

Table 9 identifies the combination of NRCS ecological sites and NWI attribute data that were used in the reclassification to the hydrogeomorphic component of the native ecosystem diversity classification described in this document. Table 10 identifies the percentage of the source data, NRCS ecological site versus NWI attribute data, used to map each ecological site.

The resulting map of wetland and riparian ecological sites for the Missouri Coteau subregion is provided in Figure 14. The number of acres identified for each of the wetland and riparian ecological sites is provided in Table 11. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO/ecological site data that do not fully capture the historical extent of these sites prior to the extensive cropland conversion, draining, filling, etc. that has occurred in the last century (Dahl 1990 and Dahl and Johnson 1991). In addition, some depressional sites such as depressional-permanent may have expanded in acreage due to excavation activities. Some lacustrine systems may have expanded in acreage today due to damming and impounding that has occurred in the last century. Impoundments occurring on historically riverine systems would reduce those acres as riverine and identify them today as lacustrine systems.

Table 9. The combination of NRCS ecological sites and NWI attribute data based on Cowardin et al. (1979) classification system. Where NWI and NRCS ecological sites overlapped, the NWI classification was primarily used to help delineate hydrogeomorphic setting and hydrology.

DEPRESSIONAL									
Temporary		Seasonal		Semi-permanent		Permanent		Intermittent	
Ecosites	NWI	Ecosites	NWI	Ecosites	NWI	Ecosites	NWI	Ecosites	NWI
Wet Meadow	PEMA	Shallow Marsh	PEMC	Shallow Marsh	PEMC	Water	PEMC	Shallow marsh	PAB/EMF
Loamy Overflow		Wet Meadow	PEMA	Closed Depression	PEMA	Loamy Overflow	PABF	Loamy Overflow	PEMC
		Closed Depression		Wet Meadow	PEMF		PEM/ABF	Subirrigated	PABG
					PEM/ABF		PEMF	Wet Meadow	PEMF
							PEMA		PEMA

RIVERINE			
Permanent		Intermittent	
Ecosites	NWI	Ecosites	NWI
Subirrigated	PEMA	Saline Lowland	PEMC
Loamy Overflow	PEMC	Subirrigated	PEMA
Saline Lowland			

LACUSTRINE			
Permanent		Intermittent	
Ecosites	NWI	Ecosites	NWI
Water	L2ABG	Water	L2ABF
Subirrigated	L1UBG	Subirrigated	PEMA
Shallow marsh			

Table 10. The percentage of each ecological site mapped using either NRCS ecological sites or the NWI classification. See the text for a full description of the mapping methodology for wetland and riparian ecosystems.

Ecological Site	NRCS Ecological Sites (%)	NWI (%)
LACUSTRINE		
Permanent	25.6	74.4
Intermittent	29.0	71.0
DEPRESSIONAL		
Temporary	52.4	47.6
Seasonal	40.2	59.8
Semipermanent	38.9	61.1
Permanent	31.5	68.5
Intermittent	49.8	50.2
RIVERINE		
Permanent	76.2	23.8
Intermittent	67.4	32.6
SLOPE		
Subirrigated	unk	unk
Seep/saturated	unk	unk

Table 11. The number of acres identified for each of the wetland and riparian ecological sites occurring today using a combination of NRCS ecological site and NWI data. Slope systems could not be mapped with existing data.

Ecological Site	Number of Acres
LACUSTRINE	
Permanent	2,328
Intermittent	30,002
DEPRESSIONAL	
Temporary	43,042
Seasonal	151,421
Semipermanent	98,035
Permanent	5,216
Intermittent	1,165
RIVERINE	
Permanent	5,259
Intermittent	187,714
SLOPE	
Subirrigated	unknown
Seep/saturated	unknown
Total	524,182

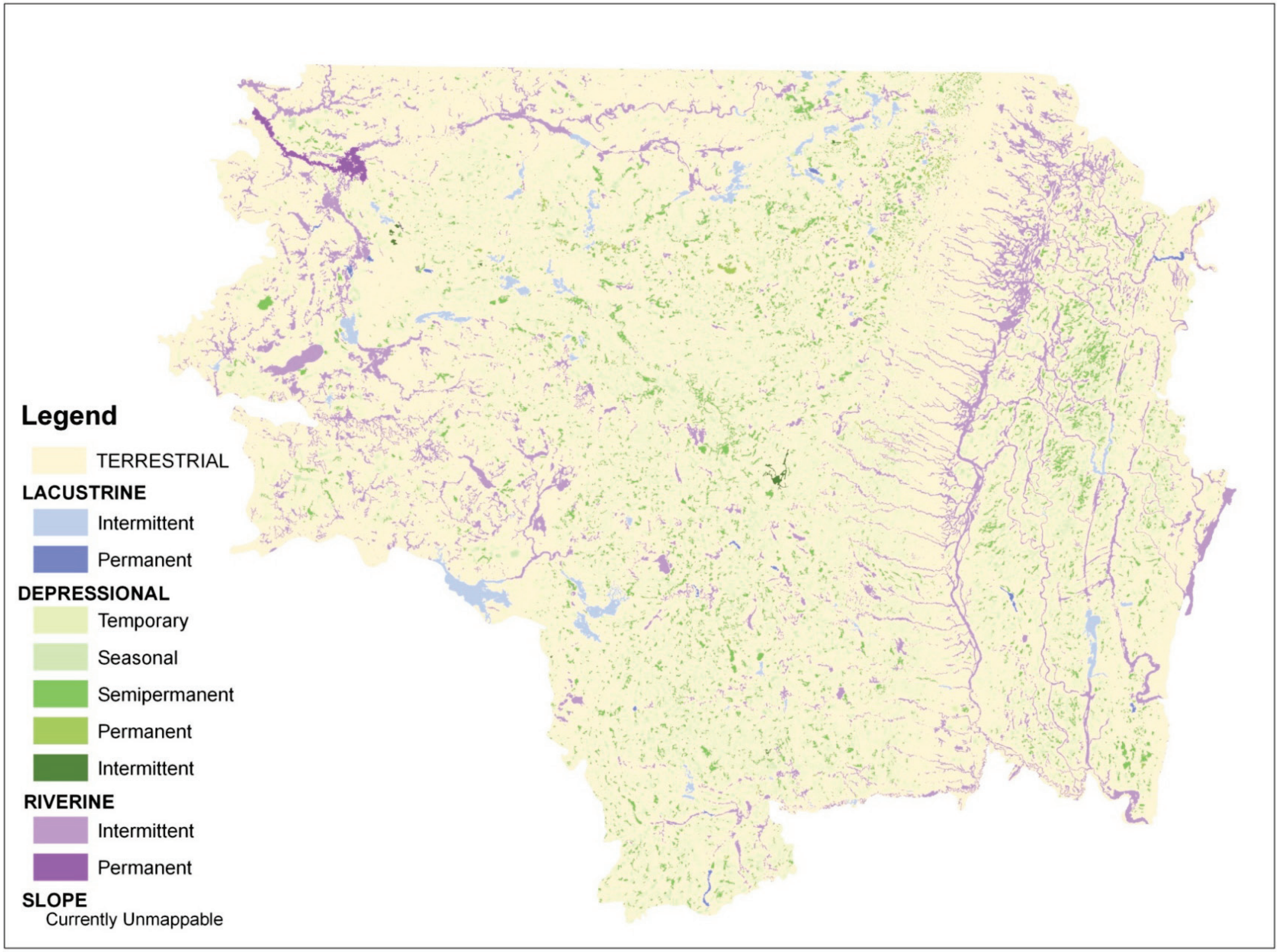

Figure 14. Map of the 9 wetland and riparian ecological sites (slope systems are not included) plus terrestrial ecological sites, for the Missouri Coteau subregion. See text for a description of the mapping methodology.

Depressional-temporary Ecological Site

The depressional-temporary ecological site occurs in very shallow topographic depressions embedded in a matrix of adjacent upland ecosystems. The dominant water sources usually include a combination of precipitation, groundwater discharge, and both interflow and overland flow with adjacent wetlands or uplands. In general, elevation contours are closed thereby allowing the accumulation of surface water. Under average precipitation, surface water is present for a few weeks following the early spring snowmelt and also following heavy rainstorms that may occur throughout the growing season. Water loss from this ecological site may include drainage from an outlet, evapotranspiration, or loss to ground water. Water chemistry is fresh or saline, with saline conditions more commonly observed on closed sites with some groundwater discharge to the site and where evapotranspiration is the primary reason for water loss. Salinity under these conditions is usually greater toward the center of the wetland and becomes fresher at the outer edges.

The depressional-temporary ecological site represents 8.2% or 43,042 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the extensive cropland conversion and to a lesser extent, draining and filling, which have occurred in the last century (Dahl 1990, Dahl and Johnson 1991).

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the wet meadow zone as the central and wettest portion of the depression and the low prairie zone along the drier outer margins (Figure 15). Native ecosystem diversity on depressional-temporary ecological sites was primarily influenced by natural disturbance regimes of fire, bison grazing, and flood events.

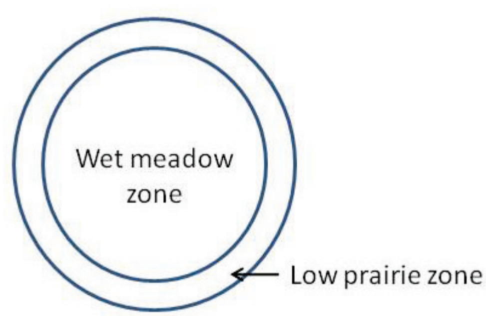

Figure 15. Typical vegetation zones under average precipitation conditions for the depressional-temporary ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971).

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. To understand these influences, some plant species can be characterized as indicators of average grazing conditions and are often described as either decreasers – species that descrease in occurrence with increasing grazing pressure, or increasers – species that increase in occurrence with increasing grazing pressure. Table 12 provides a summary of the decreaser and increaser plant species for low prairie and wet meadow vegetation zones of the depressional - temporary ecological site. As discussed previously, some plant species can also be used as indicators of fresh water chemistry vs. saline water chemistry. Those species are also identified in Table 12 by vegetation zone. In general, saline conditions are believed to have less effect on the species composition of the low prairie zone as compared to the wet meadow zone (Stewart and Kantrud 1971).

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site. Fire, particularly during drought cycles, could remove the build-up of organic matter and release nutrients to the wetland system. For the low prairie zone in particular, grass species were the dominant component and shrubs and trees were a more minor component in this vegetation zone due to the frequency of fire. Browsing and rubbing by bison and other herbivores likely further reduced the coverage of shrubs and trees in this ecological site. Where shrub and tree species occurred, they were more commonly associated with the low prairie vegetation zone. Those species that would decrease with more frequent fires are identified in Table 12.

Flood events further influenced the diversity of plant communities on this ecological site through fluctuating water levels. These fluctuating water levels may increase the amount of open water and drawdown conditions occurring throughout the growing season. Water depths and related stages of cover interspersion often changed drastically from year to year and season to season due to these fluctuating water levels (Stewart and Kantrud 1971). This may also influence the amounts and types of vegetation zones over time such as gaining a moister vegetation zone under above average precipitation or losing a vegetation zone under below average precipitation, but under average conditions, the wet meadow and low prairie vegetation zones were the primary zones present on this ecological site.

Figure 16 demonstrates the depressional-temporary ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional -temporary ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete plant description of each disturbance state identified in Figure 16.

Table 12. Plant species that serve as indicators of hydrology, water chemistry, grazing pressure, and fire frequency by vegetation zone (Stewart and Kantrud 1971) for wetland and riparian ecological sites of the Missouri Coteau subregion.

Vegetation Zone	Fresh Water Chemistry	Saline Water Chemistry
Low Prairie	Grazing decreasers[a] – switchgrass, Indian grass, little bluestem, big bluestem Grazing increasers[b] – western wheatgrass, slender wheatgrass Fire decreasers[c] – western snowberry, green ash, plains cottonwood, American plum	Grazing increasers – species composition has not been documented to be different from fresh water chemistry Grazing decreasers – species composition has not been documented to be different from fresh water chemistry Fire decreasers – species composition has not been documented to be different from fresh water chemistry
Wet Meadow	Grazing decreasers – northern reedgrass, sedges, fowl bluegrass Grazing increasers – spikerush, foxtail barley, mountain rush	Grazing decreasers – sedges, curlytop knotweed, scratchgrass, alkali cordgrass Grazing increasers – inland saltgrass
Shallow-marsh	Grazing decreasers - wheat sedge, common rivergrass Grazing increasers – spikerush, American bulrush, broadfruit bur-reed	Grazing decreasers - Nuttall's alkaligrass Grazing increasers – spikerush, American bulrush
Deep-marsh	Grazing decreasers – broadleaf cattail Grazing increasers - Hardstem bulrush, broadfruit bur-reed, softstem bulrush	Cosmopolitan bulrush, sago pondweed – grazing levels do not appear to significantly affect the species composition
Open Water	Spiral ditchgrass	widgeongrass
Intermittent-Alkali	Not applicable	widgeongrass
Fen	Grazing decreasers – water sedge, broadleaf cattail Grazing increasers – softstem bulrush, common reed Fire decreasers – willows	Not applicable

[a]Grazing decreasers – species that decrease with increased grazing
[b]Grazing increasers – species that increase with increased grazing
[c]Fire decreasers – species that decrease with more frequent fires (<15 years)

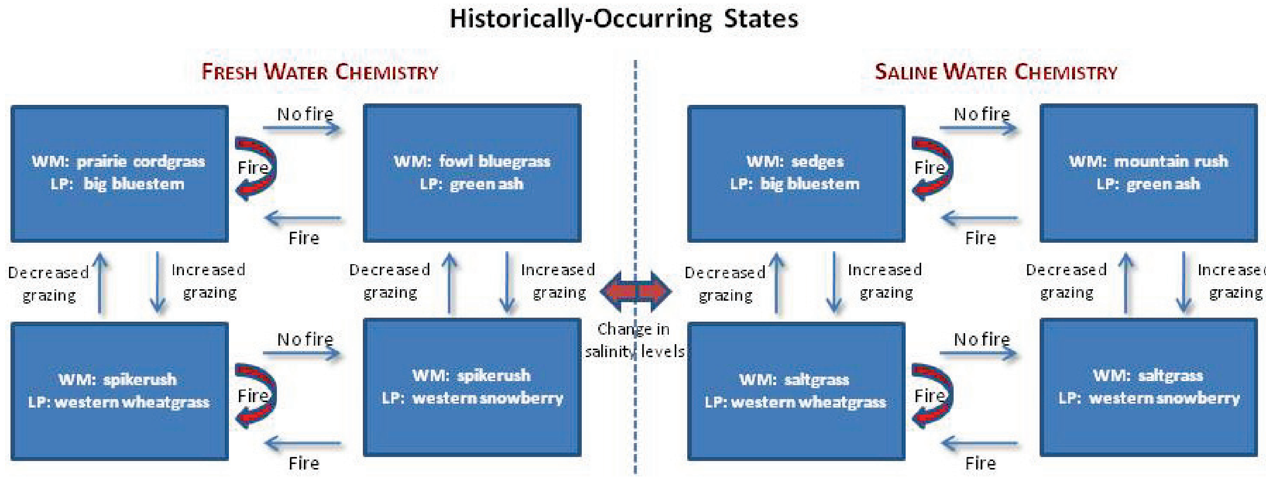

Figure 16. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for depressional - temporary ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Depressional-seasonal Ecological Site

The depressional-seasonal ecological site occurs in shallow topographic depressions. The dominant water sources in the Missouri Coteau usually include a combination of precipitation, ground water discharge, and both interflow and overland flow with adjacent wetlands or uplands. In general, elevation contours are closed thereby allowing the accumulation of surface water. Under average precipitation, surface water is present on this ecological site for an extended period in spring and early summer but is frequently dry during late summer and fall. Water loss from this ecological site may include drainage from an outlet, evapotranspiration, or loss to ground water. Water chemistry is fresh or saline, with saline conditions more commonly observed on closed sites with some groundwater discharge to the wetland and where evapotranspiration is the primary reason for water loss. Salinity under these conditions is usually greater toward the center of the wetland and becomes fresher at the outer edges.

The depressional-seasonal ecological site represents 28.9% or 151,421 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the extensive cropland conversion and to a lesser extent, draining and filling, which have occurred in the last century (Dahl 1990, Dahl and Johnson 1991).

Vegetation zones frequently occur as concentric peripheral bands in response to different water levels, with the shallow-marsh zone as the central and wettest portion of the depression and the wet meadow and low prairie zones along the drier outer margins (Figure 17). Native ecosystem diversity on depressional-seasonal ecological sites was primarily influenced by natural disturbance regimes of fire, bison grazing, and flood events.

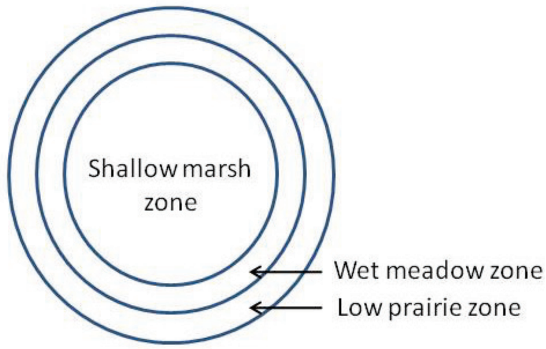

Figure 17. Typical vegetation zones under average precipitation conditions for the depressional-seasonal ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971).

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the shallow marsh zone, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for the depressional-temporary ecological site that had similar bands of vegetation zones. Where shrub and tree species occurred, they were more commonly associated with the low prairie vegetation zone. Those species that would decrease with more frequent fires are identified in Table 12.

Flood events further influenced the diversity of plant communities on this ecological site, as described above. These fluctuating water levels may increase the amount of open water and drawdown conditions occurring throughout the growing season. Water depths and related stages of cover interspersion often changed considerably from year to year and season to season due to these fluctuating water levels (Stewart and Kantrud 1971). Under average conditions, the shallow marsh, wet meadow, and low prairie vegetation zones were the primary zones present on this ecological site.

Figure 18 displays the depressional-seasonal ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional-seasonal ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 17.

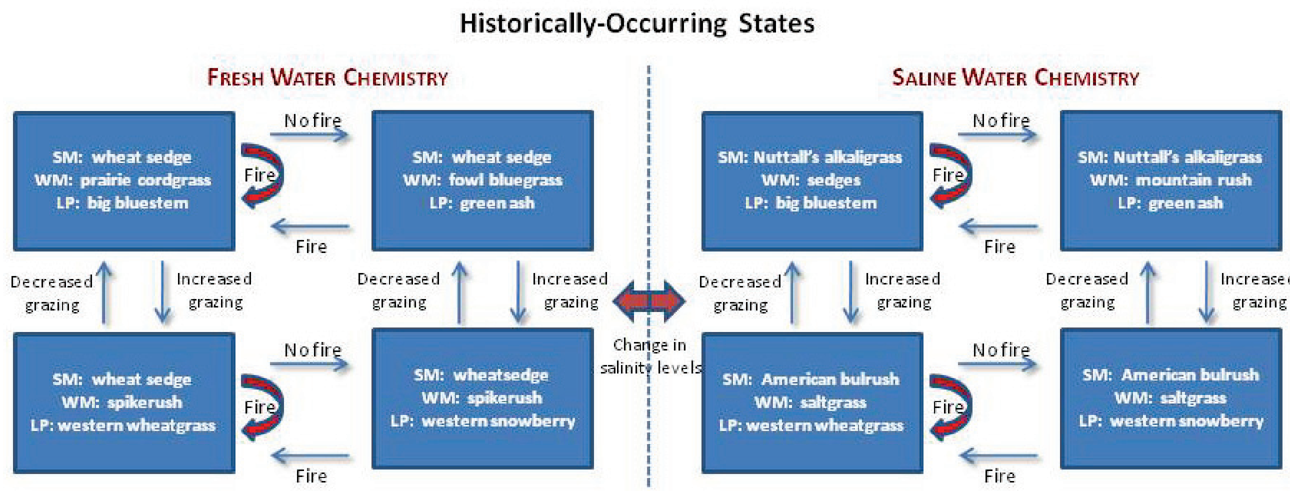

Figure 18. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for depressional - seasonal ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Depressional - semipermanent Ecological Site

The depressional-semipermanent ecological site occurs in topographic depressions. The dominant water sources in the Missouri Coteau usually include a combination of precipitation, ground water discharge, and both interflow and overland flow with adjacent wetlands or uplands. In general, elevation contours are closed thereby allowing the accumulation of surface water. Under average precipitation, surface water is present on this ecological site throughout the spring and summer and frequently into fall and winter. Under drought conditions, surface water may disappear as early as mid-summer. When surface water is absent the groundwater table is usually at or very near the soil surface. Water loss from this ecological site may include drainage from an outlet, evapotranspiration, or loss to ground water. Water chemistry is fresh or saline, with saline conditions more commonly observed on closed sites with groundwater discharge to the wetland and where evapotranspiration is the primary reason for water loss. Salinity under these conditions is usually greater toward the center of the wetland and becomes fresher at the outer edges.

The depressional-semipermanent ecological site represents 18.7% or 98,035 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the cropland conversion, draining, filling, or excavation activities which have occurred in the last century (Dahl 1990, Dahl and Johnson 1991).

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the deep marsh zone as the central and wettest portion of the depression and the shallow marsh, wet meadow, low prairie, and fen zones along the drier outer margins (Figure 19). The fen zone occurs most frequently along the margins of saline sites. They result from seeps on gently sloping terrain adjacent to the depression. Native ecosystem diversity on depressional-semipermanent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, and flood events.

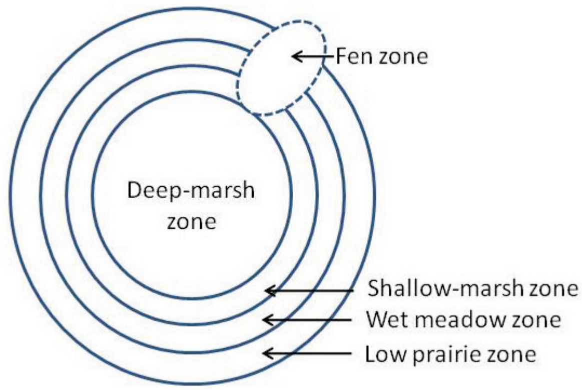

Figure 19. Typical vegetation zones under average precipitation conditions for the depressional-semipermanent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the deep marsh and shallow marsh zones, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for the other ecological sites that had similar bands of vegetation zones. Those species that would decrease with more frequent fires are identified in Table 12.

As with other sites, flood events further influenced the diversity of plant communities on this ecological site through fluctuating water levels. These fluctuating water levels may increase the amount of open water and drawdown conditions occurring throughout the growing season (Stewart and Kantrud 1971). Under average conditions, the deep marsh, shallow marsh, wet meadow, and low prairie vegetation zones were the primary zones present on this ecological site.

Figure 20 displays the depressional-semipermanent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional -semipermanent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 20.

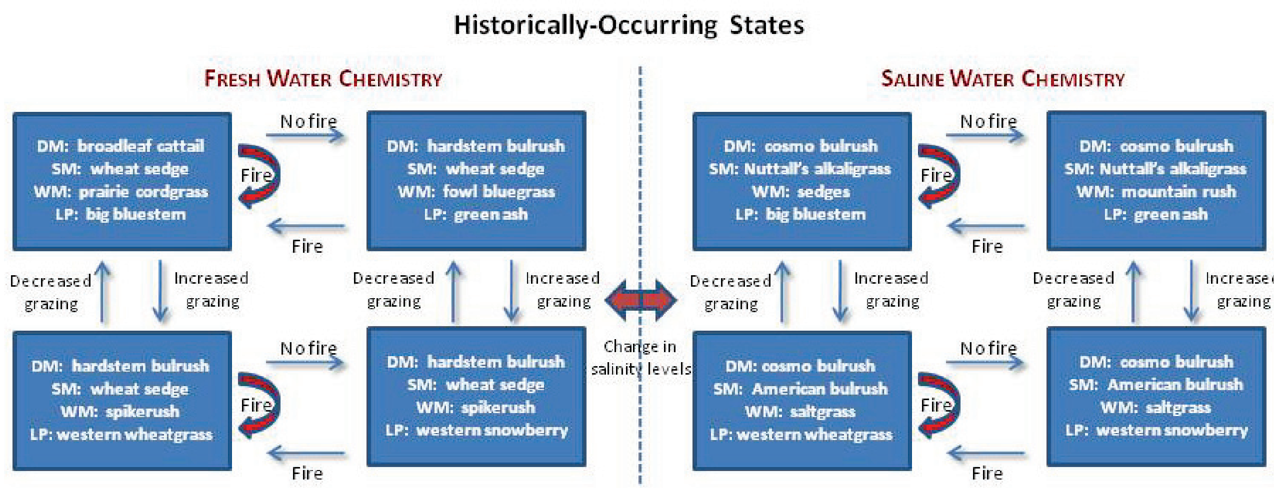

Figure 20. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for depressional - semipermanent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Depressional-permanent Ecological Site

The depressional-permanent ecological site occurs in more pronounced topographic depressions. The dominant water sources in the Missouri Coteau usually include a combination of precipitation, ground water discharge, and both interflow and overland flow with adjacent wetlands or uplands. In general, elevation contours are closed thereby allowing the accumulation of surface water. Under average precipitation, surface water is present throughout the year in all years. The groundwater table is usually at or very near the soil surface. Water loss from this ecological site may include drainage from an outlet, evapotranspiration, or loss to ground water. Water chemistry is fresh or saline, with saline conditions more commonly observed on closed sites with groundwater discharge to the wetland and where evapotranspiration is the primary reason for water loss. Salinity under these conditions is usually greater toward the center of the wetland and becomes fresher at the outer edges.

The depressional-permanent ecological site represents 1.0% or 5,216 acres within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the cropland conversion, draining, filling, or excavation activities which have occurred in the last century (Dahl 1990, Dahl and Johnson 1991).

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the open water zone as the central and wettest portion of the depression and the deep marsh, shallow marsh, wet meadow, low prairie, and fen zones along the outer margins (Figure 21). The fen zone occurs most frequently along the margins of saline sites. They result from seeps on gently sloping terrain adjacent to the depression. Native ecosystem diversity on depressional-permanent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, and flood events.

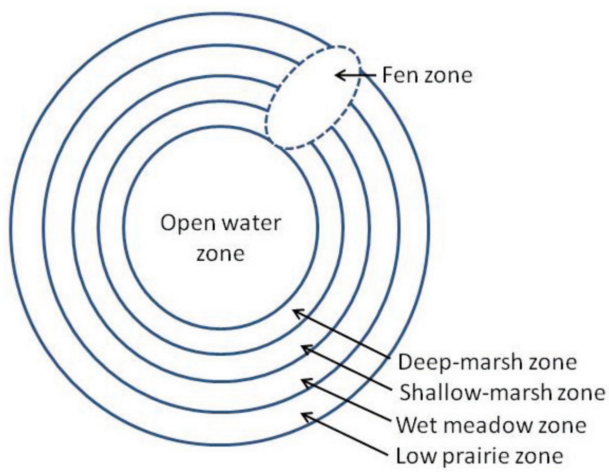

Figure 21. Typical vegetation zones under average precipitation conditions for the depressional-permanent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the open water zone, grazing pressure had little to no influence on species composition. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the deep marsh and shallow marsh zones, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for the other ecological sites that had similar bands of vegetation zones. Where shrub and tree species occurred, they were more commonly associated with the low prairie and fen vegetation zones. Those species that would decrease with more frequent fires are identified in Table 12.

Flood events further influenced the diversity of plant communities on this ecological site through fluctuating water levels, but under average conditions, the open water, deep marsh, shallow marsh, wet meadow, low prairie, and fen vegetation zones were the primary zones present on this ecological site.

Figure 22 displays the depressional-permanent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional-permanent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 21.

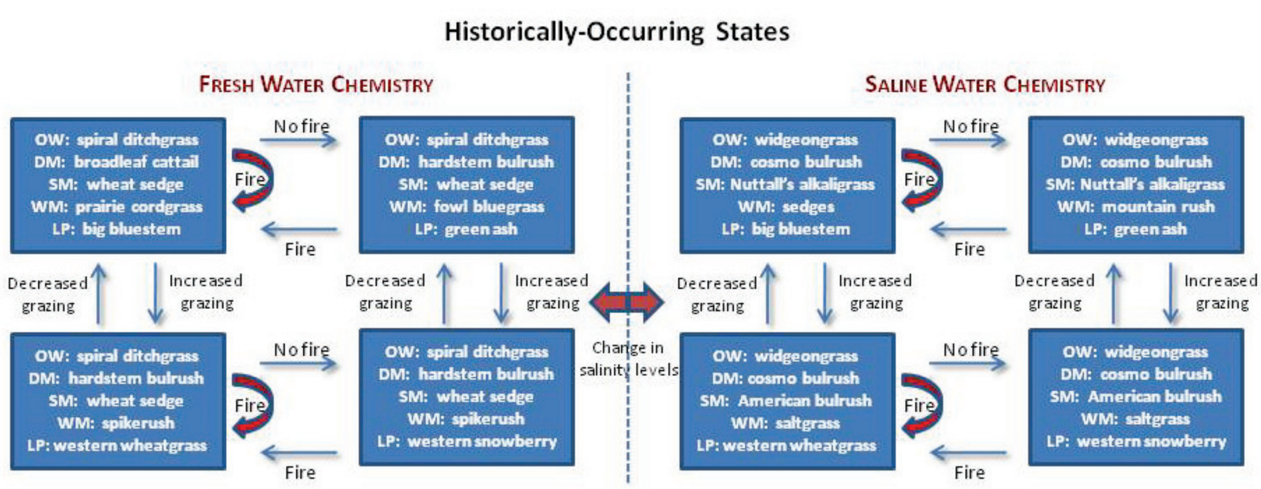

Figure 22. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for depressional - permanent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Depressional-intermittent Ecological Site

The depressional-intermittent ecological site occurs in relatively flat and shallow topographic depressions. The dominant water sources in the Missouri Coteau usually include a combination of precipitation, ground water discharge, and both interflow and overland flow with adjacent wetlands or uplands. In general, elevation contours are closed thereby allowing the accumulation of surface water. Under average precipitation, surface water is present but variable due to evapotranspiration throughout the year or absent in years of extreme drought. These sites are typified by shallow standing water intermingled with exposed salt flats. These large, relatively flat, shallow basins usually exhibit a high evaporation to precipitation ratio. The groundwater table is usually at or very near the soil surface. Water chemistry is saline and frequently referred to alkali. Dissolved salts are supplied to the site by surface runoff and groundwater discharge but as water in the lake evaporates, the salts stay behind becoming more concentrated over time. Under these conditions, salt concentrations are usually greater near the shoreline of the lake.

The depressional-intermittent ecological site represents 0.2% or 1,165 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the cropland conversion, draining, filling, or excavation activities which have occurred in the last century (Dahl 1990, and Dahl and Johnson 1991).

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the intermittent-alkali zone as the central and wettest portion of the depression and the shallow marsh, wet meadow, low prairie, and fen zones along the drier outer margins (Figure 23). The fen zone occurs most frequently along the margins of saline sites. They result from seeps on gently sloping terrain adjacent to the depression. Native ecosystem diversity on depressional-intermittent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, and flood events.

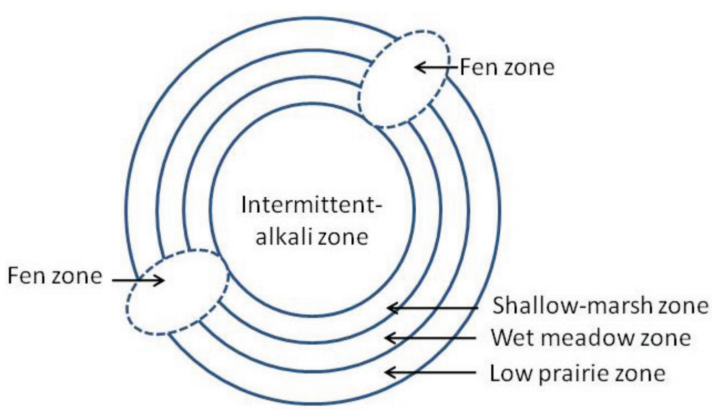

Figure 23. Typical vegetation zones under average precipitation conditions for the depressional-intermittent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the intermittent alkali zone, grazing would, on average, have little influence due to the paucity of plant species. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the shallow marsh zones, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for the other ecological sites that had similar bands of vegetation zones. Where shrub and tree species occurred, they were more commonly associated with the low prairie and fen vegetation zones. Those species that would decrease with more frequent fires are identified in Table 12.

Flood events further influenced the diversity of plant communities on this ecological site through fluctuating water levels, but under average conditions, the intermittent-alkali, shallow marsh, wet meadow, low prairie, and fen vegetation zones were the primary zones present on this ecological site.

Figure 24 displays the depressional-intermittent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional-intermittent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 24.

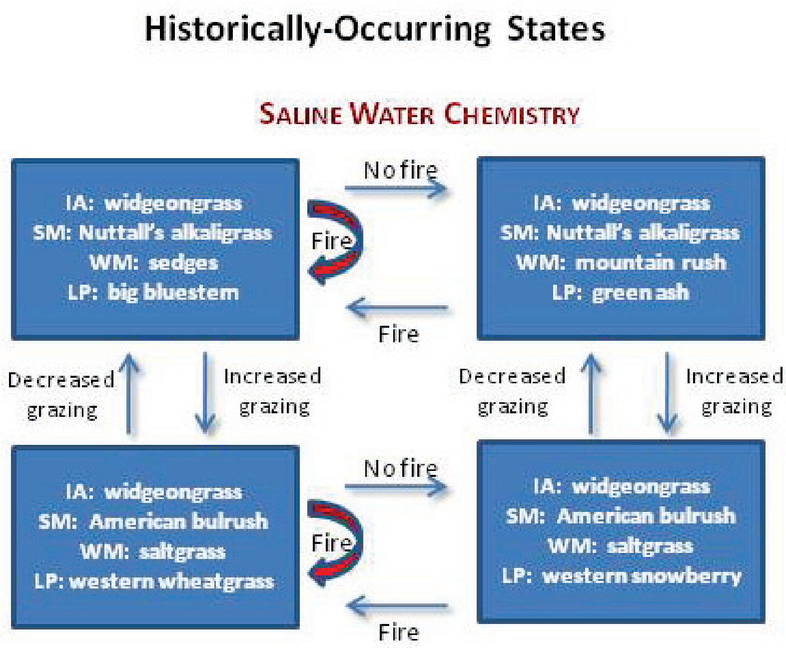

Figure 24. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for depressional – intermittent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Lacustrine - permanent Ecological Site

Lacustrine-permanent ecological sites are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. Additional sources of water are precipitation and ground water discharge, with the latter dominating where these sites intergrade with adjacent SLOPE ecological sites. Lacustrine-permanent ecological sites lose water by flow returning to the lake after flooding, by saturation surface flow, and by evapotranspiration. Under average precipitation, surface water is present in the lacustrine-permanent ecological site throughout the year in all years. The groundwater table is usually at or very near the soil surface. Water loss from this ecological site may include drainage from an outlet, evapotranspiration, or loss to ground water. Water chemistry is fresh or saline, with saline conditions more commonly observed on sites with groundwater discharge to the wetland. Salinity under these conditions is usually greater near the areas where groundwater is discharged to lake.

The lacustrine-permanent ecological site represents 0.4% or 2,328 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the potential damming and impounding that may have increased the aerial extent of this ecological site.

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the open water zone as the central and wettest portion of the depression and the deep marsh, shallow marsh, wet meadow, low prairie, and fen zones along the progressively drier outer margins (Figure 25). The fen zone occurs most frequently along the margins of saline sites. They result from seeps on gently sloping terrain adjacent to the lacustrine system. Native ecosystem diversity on lacustrine-permanent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, beaver activities, and flood events.

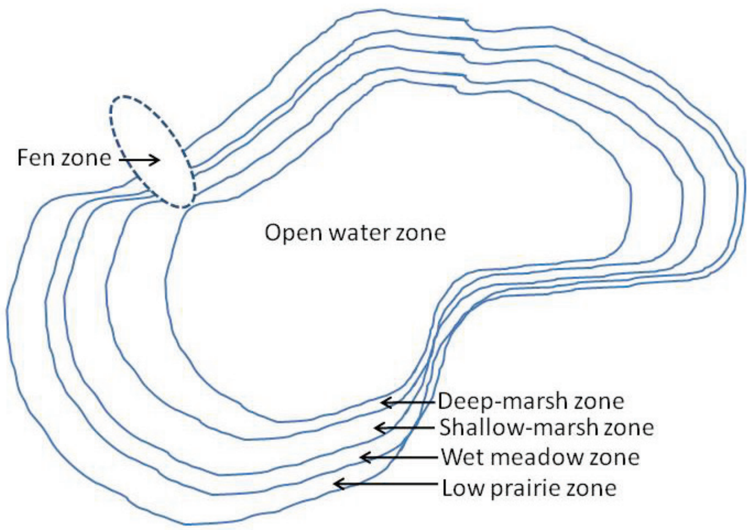

Figure 25. Typical vegetation zones under average precipitation conditions for the lacustrine – permanent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the open water zone, grazing pressure had little to no influence on species composition. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the deep marsh and shallow marsh zones, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for the other ecological sites that had similar bands of vegetation zones.

Flood events further influence the diversity of plant communities on this ecological site through fluctuating water levels, but under average conditions, the open water, deep marsh, shallow marsh, wet meadow, low prairie, and fen vegetation zones are the primary zones present on this ecological site.

Figure 26 displays the lacustrine-permanent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes.

The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on lacustrine-permanent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 26.

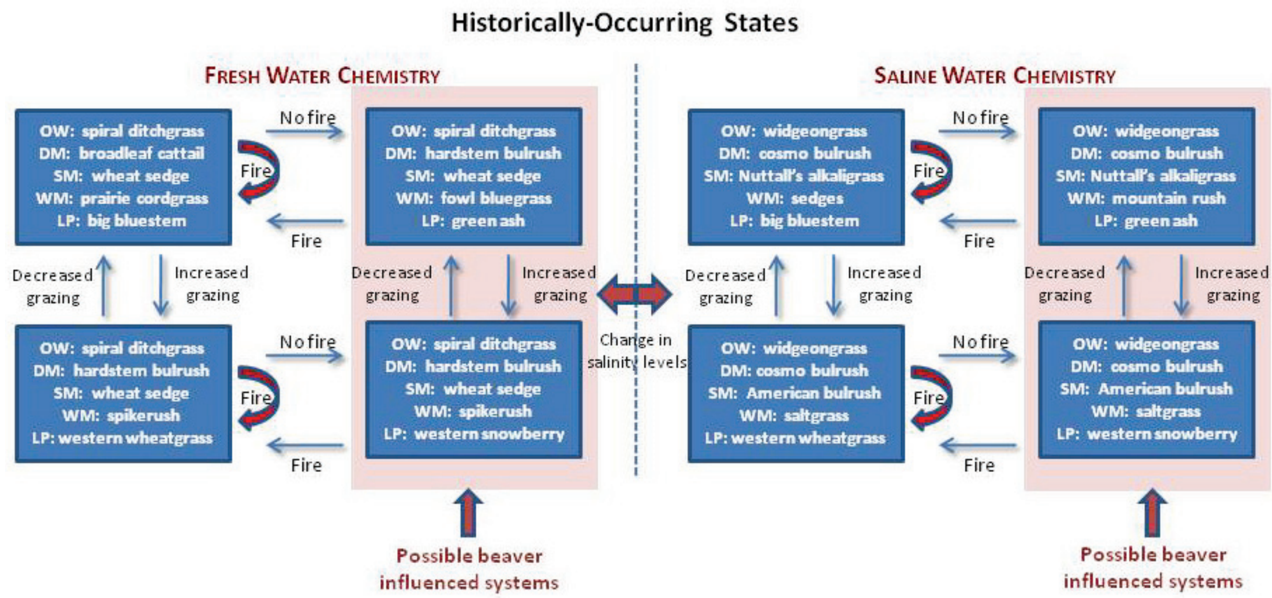

Figure 26. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for lacustrine - permanent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Lacustrine – intermittent Ecological Site

Lacustrine-intermittent ecological sites are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland, when surface water is present. Additional sources of water are precipitation and ground water discharge, with the latter dominating where these sites intergrade with adjacent SLOPE ecological sites. These sites are typified by shallow standing water intermingled with exposed salt flats. These large, relatively flat, shallow basins usually exhibit a high evaporation to precipitation ratio. Under average precipitation, surface water is present but variable due to evapotranspiration throughout the growing season or absent in years of extreme drought. The groundwater table is usually at or very near the soil surface. Water chemistry is saline and often referred to as alkali, as well. Dissolved salts are supplied to the site by surface runoff and groundwater discharge but as water in the lake evaporates, the salts stay behind becoming more concentrated over time. Under these conditions, salt concentrations are usually greater near the shoreline of the lake.

The lacustrine-intermittent ecological site represents 5.8% or 30,143 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the potential damming and impounding that may have increased the aerial extent of this ecological site.

Vegetation zones as described by Stewart and Kantrud (1971) frequently occur as concentric peripheral bands in response to different water levels, with the intermittent-alkali zone as the central and wettest portion of the depression and the shallow marsh, wet meadow, low prairie, and fen zones along the progressively drier outer margins (Figure 27). The fen zone(s) frequently occur along the margins of these sites. They result from seeps on gently sloping terrain adjacent to the lacustrine system. Native ecosystem diversity on lacustrine-intermittent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, and flood events.

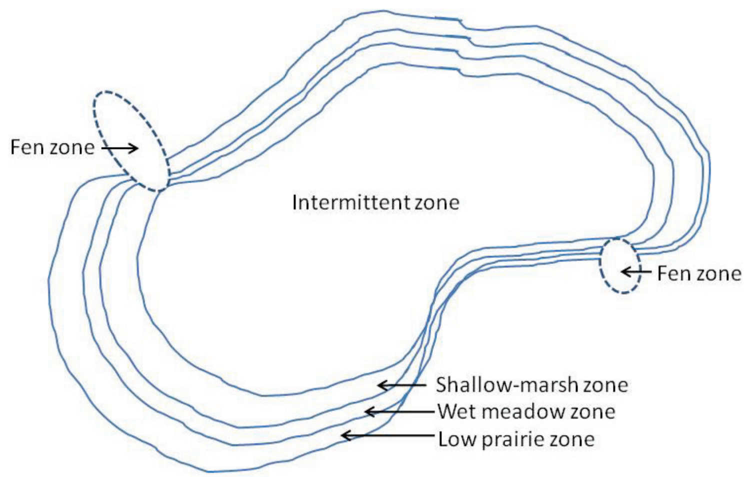

Figure 27. Typical vegetation zones under average precipitation conditions for the lacustrine - intermittent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the intermittent alkali zone, grazing would, on average, have little influence due to the paucity of plant species. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the shallow marsh zone, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described for other ecological sites. Where shrub and tree species occurred, they were more commonly associated with the low prairie and fen vegetation zones. Those species that would decrease with frequent fires are identified in Table 12.

Flood events further influence the diversity of plant communities on this ecological site through fluctuating water levels, but under average conditions, the intermittent-alkali, shallow marsh, wet meadow, low prairie, and fen vegetation zones are the primary zones present on this ecological site.

Figure 28 displays the depressional-intermittent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on depressional-intermittent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 28.

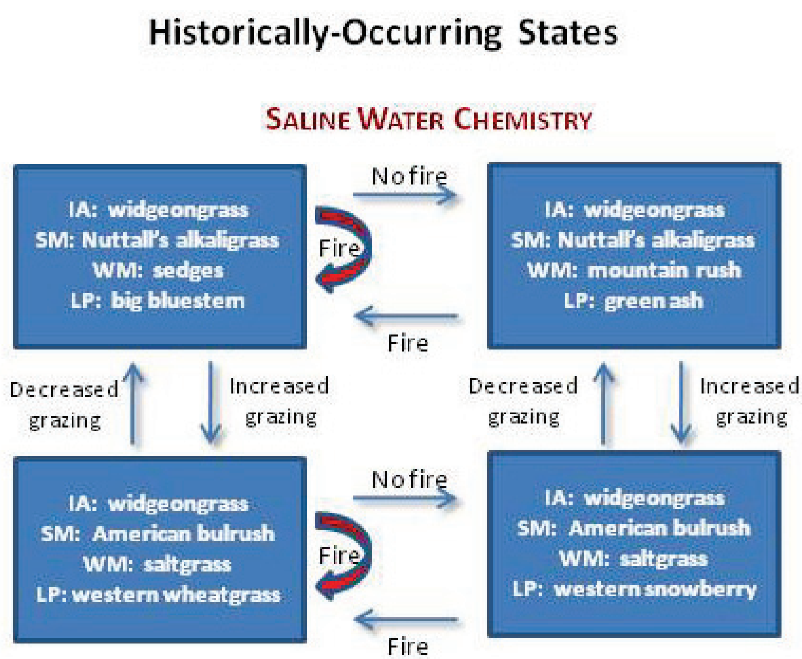

Figure 28. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for lacustrine - intermittent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Riverine - permanent Ecological Site

The riverine - permanent ecological site occur adjacent to permanently flowing streams within the floodplain and riparian corridors. The primary water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and adjacent ecological sites. Additional water sources may be interflow and return flow from adjacent uplands, overland flow from adjacent uplands, and precipitation.

The riverine – permanent ecological site represents 1.0% or 5,259 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the potential damming and impounding that may have increased the aerial extent of this ecological site or converted this site to lacustrine conditions. In addition, changes to the hydrology of some riverine systems through activities such as creating dugouts or irrigation, may have reduced the amount of water available to the system and created intermittent conditions where they were historically permanent.

Vegetation zones in riverine – permanent ecological sites often occur parallel to the flowing water, with moister zones being closer to and drier zones being further from the flowing water source. However, vegetation zones can also occur as a mosaic within the floodplain, particularly where glacial depressions or old meander channels may influence the hydrology of the site. The riverine-permanent ecological site can exhibit diverse characteristics of the deep marsh, shallow marsh, wet meadow, low prairie, and fen vegetation zones as previously described for depressional and lacustrine systems (Figure 29). However, it is expected that some undocumented differences in species composition occur in response to the hydrogeomophic position and the influence of a flowing water source. The fen zone(s) frequently occur along the margins of these sites. They result from seeps on gently sloping terrain adjacent to or within the riverine system. Native ecosystem diversity on riverine-permanent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, beaver, and flood events.

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the open water zone, grazing pressure had little to no influence on plant species composition. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the deep marsh and shallow marsh zones, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

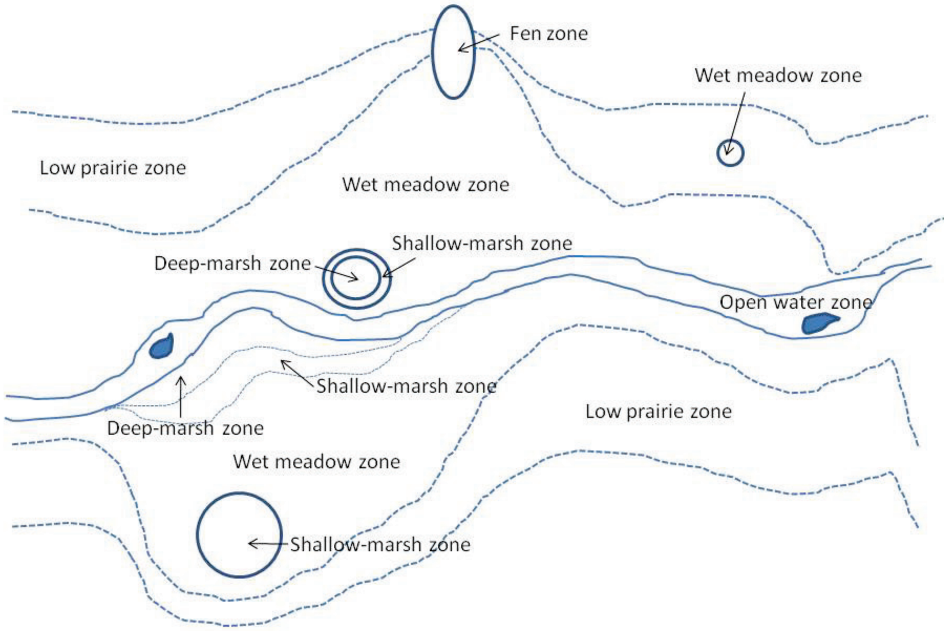

Figure 29. Typical vegetation zones under average precipitation conditions for the riverine-permanent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971)

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as described above. Fire, particularly during drought cycles, could remove the build-up of organic matter and release nutrients to the wetland system. For the low prairie zone in particular, grass species were the dominant component and shrubs and trees were a more minor component in this vegetation zone due to the frequency of fire. Browsing and rubbing by bison and other herbivores likely further reduced the coverage of shrubs and trees in this ecological site. Where shrub and tree species occurred, they were more commonly associated with the low prairie and fen vegetation zones. Those species that would decrease with more frequent fires are identified in Table 12. Flood events further influence the diversity of plant communities on this ecological site but under average conditions, the open water, deep marsh, shallow marsh, wet meadow, low prairie, and fen vegetation zones are the primary zones present. In addition, flood events associated with flowing water create a favorable condition for some plants to regenerate such as plains cottonwood and willows, where the scouring action can create alluvial bars and other features that promote regeneration.

The effects of beaver activity on South Dakota streams and riparian vegetation have not been well documented. For the purposes of the ecosystem diversity framework, some assumptions were necessary. In particular, it is assumed that beaver activity would be associated with riverine ecological sites with a longer mean fire return interval to allow the growth of trees and shrubs necessary to sustain a beaver population. Where damming occurs, the water table typically rises, further influencing the hydrology of the adjacent riparian vegetation communities and probably benefitting tree and shrub species. This change can be relatively temporary or more long-term, where there are sufficient food supplies to support a population. Beavers typically feed on and build dams from the surrounding small trees and shrubs. If the food supply is exhausted, the beavers will move on to a new site with better food sources. Vegetation within or close to the floodplain is expected to be the most heavily influenced by beaver activity. Where dams do occur, the result of going from a flowing water system to a pond system is expected to have an effect on the species composition and structure, as well as the associated biodiversity, but this change has not been evaluated or documented in the Missouri Coteau subregion.

Figure 30 displays the riverine - permanent ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. The fen zone is covered separately in the slope-seep/saturated ecological site state and transition model. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on riverine-permanent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 30.

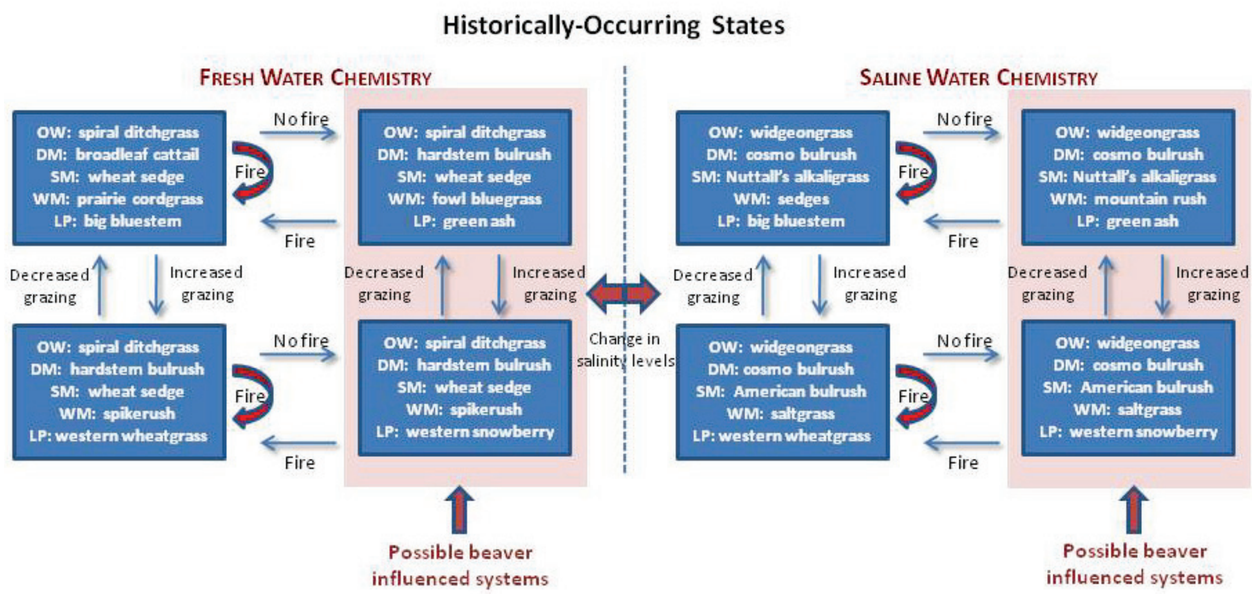

Figure 30. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for riverine - permanent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Riverine - intermittent Ecological Site

The riverine - intermittent ecological site occurs adjacent to intermittently flowing streams within the floodplain and riparian corridors. The primary water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and adjacent ecological sites. Additional water sources may be interflow and return flow from adjacent uplands, overland flow from adjacent uplands, and precipitation.

The riverine – intermittent ecological site represents 35.8% or 187,714 acres of the wetland and riparian ecological sites within the Missouri Coteau subregion. It is important to note that these acres were calculated based on existing NWI and NRCS SSURGO data that do not capture the historical extent of these sites prior to the influence of creating adjacent dugouts or water diversion/irrigation that may have reduced the water table or surface flow on these sites

Vegetation zones in riverine – intermittent ecological sites often occur parallel to the intermittently flowing water, with moister zones being closer to and drier zones being further from the water source. However, vegetation zones can also occur as a mosaic within the floodplain, particularly where glacial depressions or old meander channels may influence the hydrology of the site. The riverine- intermittent ecological site can exhibit diverse characteristics of the shallow marsh, wet meadow, and low prairie vegetation zones as previously described for depressional and lacustrine systems (Figure 31). However, it is expected that some undocumented differences in species composition occur in response to the hydrogeomophic position and the influence of a flowing water source. Native ecosystem diversity on riverine-intermittent ecological sites was influenced by natural disturbance regimes of fire, bison grazing, and flood events.

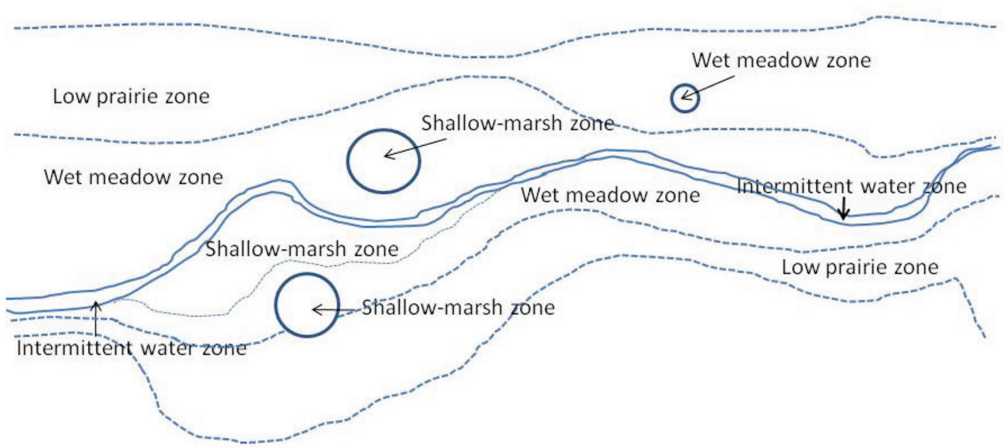

Figure 31. An example of vegetation zones that might occur under average precipitation conditions for the riverine - intermittent ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971).

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the intermittent water zone, grazing would, on average, have little influence due to the paucity of plant species. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the shallow marsh zone, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

The frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site, as discussed for other ecological sites. Flood events also further influenced the diversity of plant communities on this ecological site, but under average conditions, the shallow marsh, wet meadow, low prairie zones are the primary zones present on. In addition, flood events associated with flowing water create a favorable condition for some plants to regenerate such as willows.

Figure 32 displays the riverine - intermittent ecological site state and transition model for different historical disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on riverine-permanent ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 32.

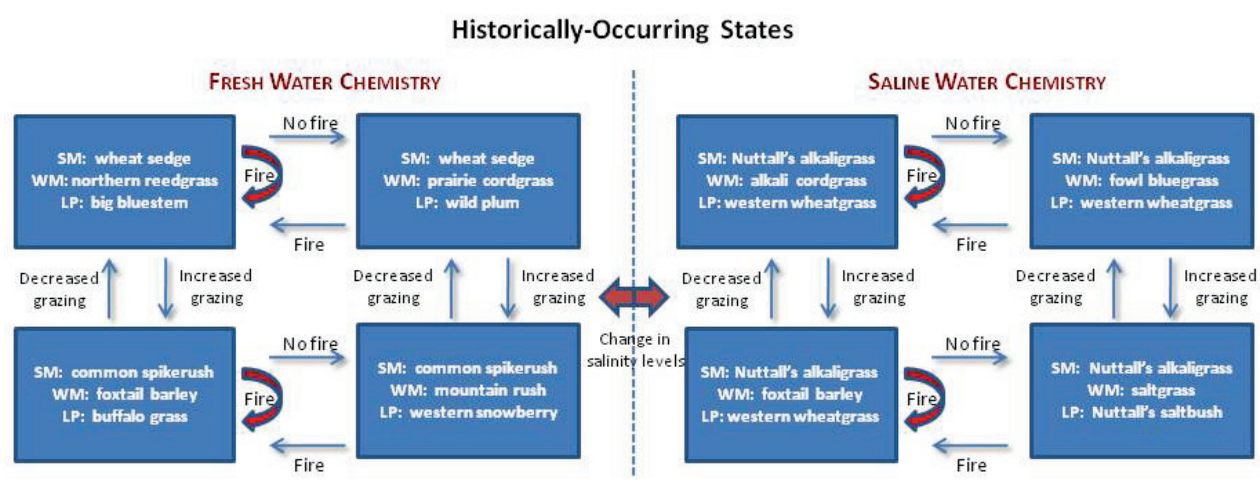

Figure 32. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for riverine - intermittent ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Slope - subirrigated Ecological Site

The slope - subirrigated ecological site occurs where there is a shallow sub-surface groundwater flow and possible small discharge of ground water near the land surface. They are usually associated with gradually sloping land where land contours are open. The primary water source is ground water flow and interflow from surrounding uplands, as well as precipitation. The slope- subirrigated ecological site can lose water by a decrease in groundwater discharge near the surface and by evapotranspiration at the soil surface.

Due to insufficient existing data to map the slope – sub irrigated ecological site, the number of acres representing this ecological site within the Missouri Coteau subregion, are not available at this time.

Vegetation zones as described by Stewart and Kantrud (1971) on these sites may or may not occur as concentric peripheral bands in response to different groundwater levels. Groundwater discharge to the surface of a site appears to be more commonly associated with sites exhibiting more saline water chemistry. On saline slope-subirrigated ecological sites, the shallow marsh zone is usually the wettest portion of the site and the wet meadow, and low prairie zone associated with progressively drier conditions respectively (Figure 33). On fresh water sites, the wet meadow zone is usually the wettest portion of the site and the low prairie zone the drier portion of the site. Native ecosystem diversity on slope-subirrigated ecological sites was primarily influenced by natural disturbance regimes of fire and bison grazing, and was less influenced by flood events than other wetland and riparian ecological sites.

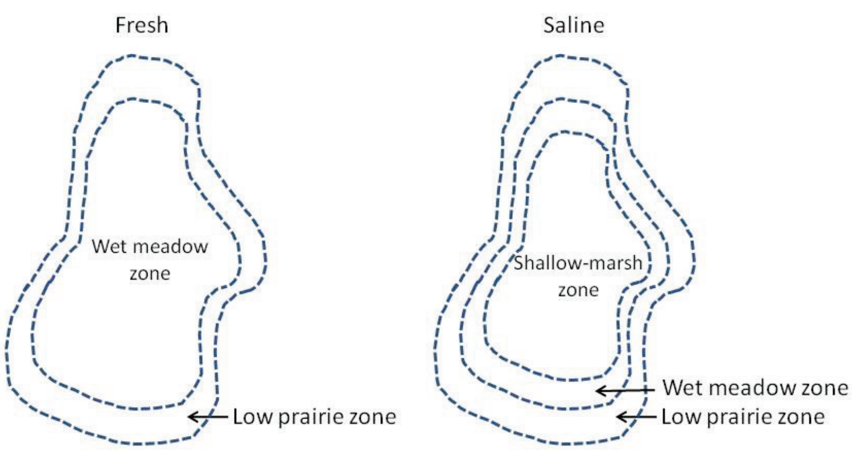

Figure 33. Typical vegetation zones under average precipitation conditions and different water chemistry for the slope-subirrigated ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971, NRCS Ecological Sites).

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Within the intermittent alkali zone, grazing would, on average, have little influence due to the paucity of plant species. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12. Within the shallow marsh zone, bison grazing likely also influenced the vegetation community structure in terms of creating patchy openings by knocking down vegetation or grazing heavily in this zone during drought years.

As with other ecological sites, the frequent fire return interval in the adjacent uplands also played an important role in shaping the structure and species composition of this ecological site. Floods were not as significant an influence as in other ecological sites.

Figure 34 displays the slope-subirrigated ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on slope-subirrigated ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 34.

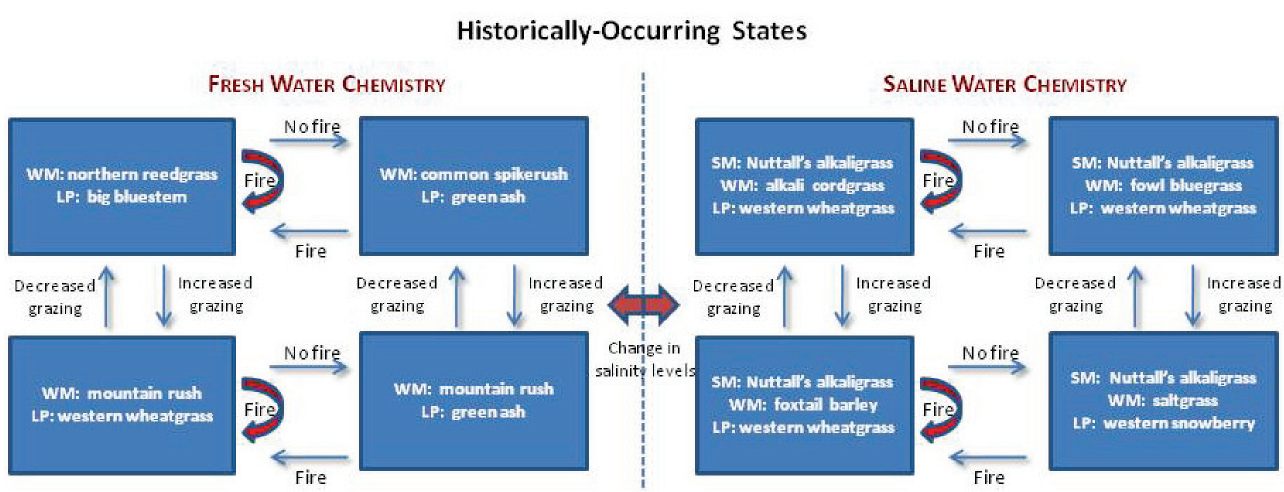

Figure 34. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for slope – subirrigated ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Slope - seep/saturated Ecological Site

The slope - seep/saturated ecological site occurs where there is a discharge of ground water to the land surface. They are usually associated with gradually to steeply sloping land where land contours are mostly open. The primary water source is ground water discharge flow. Interflow from surrounding uplands, as well as precipitation, are secondary water sources on this site. The slope- seep/saturated ecological site can lose water by a decrease in groundwater discharge to the land surface and by evapotranspiration at the soil surface. Under average precipitation, this ecological site contains water in the root zone during most of the growing season, yet is not usually inundated. Water chemistry of the slope-seep/saturated ecological site appears to be limited to the fresh sub-class. These sites also frequently accumulate organic and/or carbonate substrates.

Due to insufficient existing data to map the slope – seep/saturated ecological site, the number of acres representing this ecological site within the Missouri Coteau subregion, are not available at this time.

Vegetation zones as described by Stewart and Kantrud (1971) on these sites may or may not occur as concentric peripheral bands in response to different water levels (Figure 35). Many sites exhibit a mosaic pattern of vegetation zonation with the fen zone as the wettest portion of the site and the wet meadow and low prairie zones along the drier portions of the site. The fen zone may also exhibit somewhat unique characteristics in that the vegetation occurs as a floating surface mat or raised mound of wet organic and/or calcareous material covered with dense vegetation. Native ecosystem diversity on slope-seep/saturated ecological sites was primarily influenced by natural disturbance regimes of fire and bison grazing, and was less influenced by flood events than the other wetland and riparian ecological sites.

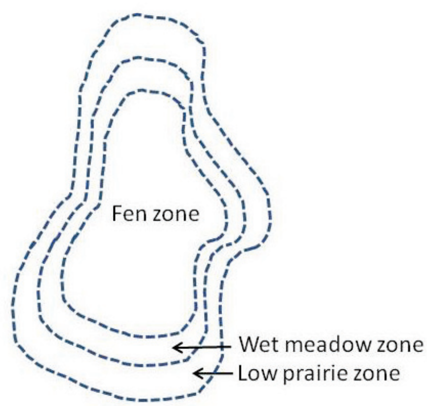

Figure 35. Typical vegetation zones under average precipitation conditions for the slope-seep/saturated ecological site of the Missouri Coteau subregion (Stewart and Kantrud 1971). Some sites may also exhibit more of a mosaic of these vegetation zones rather than the concentric pattern displayed here.

Grazing played an important role in influencing the structure and species composition of ecosystems on this ecological site. Grazing of this ecological site would have frequently produced hummocks. For a description of plant species that would indicate grazing influences on this ecological site by vegetation zone and water chemistry, see Table 12.

Fire played a role on this ecological site as described above for other ecological sites. Floods were not as important of a disturbance factor as for other ecological sites.

Figure 36 displays the slope-seep/saturated ecological site state and transition model for different disturbance states within the Missouri Coteau subregion, as influenced by natural disturbance regimes. Differences in species compositions resulting from water chemistry at fresh and saline levels are also identified. The combined total of these disturbance states represents the full range of conditions or native ecosystem diversity that occurred historically on slope-seep/saturated ecological sites. The plant species identified in each box or disturbance state indicates the species that may increase or decrease in occurrence, depending on the influence of the natural disturbance regimes, as indicated by the direction of the arrows. These species are considered the primary indicators of a particular disturbance state based on their sensitivity to natural disturbance processes that includes the interaction of grazing intensity x fire frequency x ecological site characteristics. It is important to note, however, that each state represents a diverse ecological community of plant species and their associated animal species. See Appendix A for a more complete description of each disturbance state identified in Figure 36.

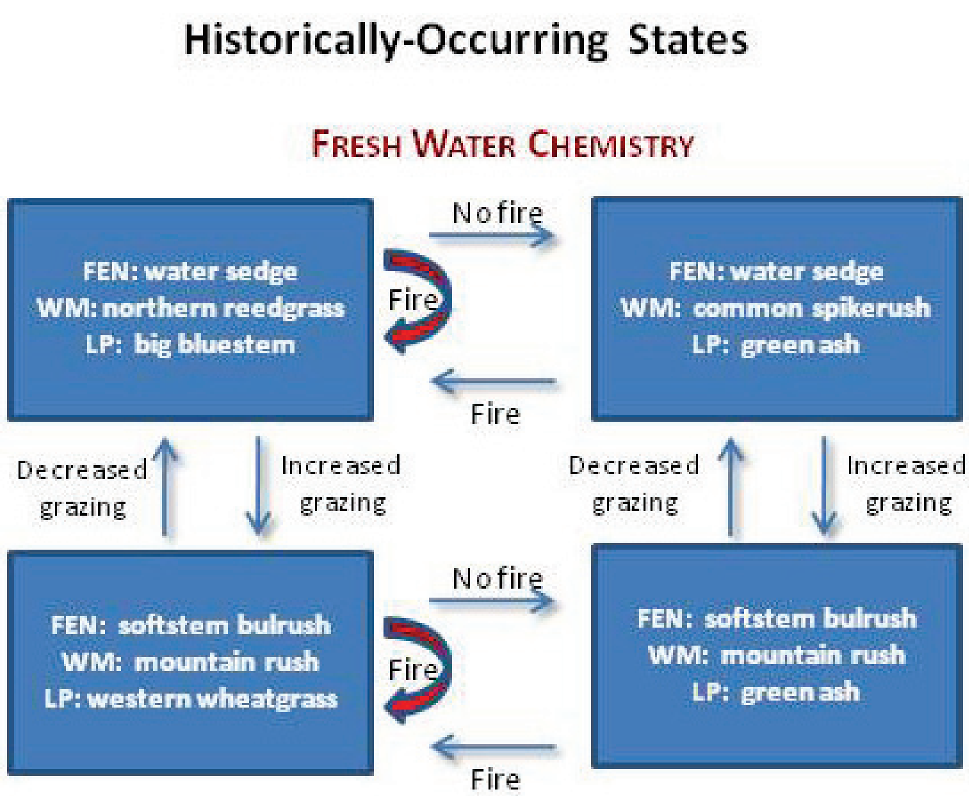

Figure 36. Historical disturbance states (i.e., state and transition model) or range of native ecosystem diversity for slope – seep/saturated ecological sites of the Missouri Coteau subregion, resulting from natural disturbance regimes.

Ecosystem Diversity Matrix

Figure 37 represents the EDM for native wetland and riparian ecosystem diversity of the Missouri Coteau subregion. Each of the vegetation zones, and their associated community, occurring within a column correspond to the disturbance states discussed previously. All of the vegetation communities within the entire EDM represent the range of conditions or native wetland and riparian ecosystem diversity that can occur in the subregion. The amount of each vegetation community can vary over time and this variation is often referred to as the historical range of variability, as discussed in a previous section.

Characterizing Historical Ecosystem Diversity

The ability to model wetland and riparian historical ecosystem diversity is not currently available with existing landscape models. Incorporating the changes to vegetation communities as influenced by interaction of fire, grazing, and hydrological site drivers, as well as flooding and beaver disturbance, will require additional research and model development and should be a priority for future research efforts in the Missouri Coteau.

Figure 37. The ecosystem diversity matrix representing native wetland and riparian ecosystem diversity for the Missouri Coteau subregion

ECOSYSTEM DIVERSITY MATRIX - SOUTH DAKOTA MISSOURI COTEAU SUBREGION
Wetland and Riparian Ecosystems

Hydrogeomorphic Class (Water Source)			LACUSTRINE		DEPRESSIONAL (non-floodplain)					RIVERINE (floodplain)		SLOPE	
		Hydrology / ***Water Chem.***	**Intermittent**	**Permanent**	**Temporary**	**Seasonal**	**Semi-permanent**	**Permanent**	**Intermittent**	**Permanent**	**Intermittent**	**Subirrigated**	**Seep/Saturated**
Frequent Fire (MFI <15 Years)	**Low to Moderate Bison Grazing**	Fresh		**OW:** RUCI2-RIFL4 **DM:** TYLA-SCACA **SM:** CAAT2-SCFE **WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2_SONU2	**WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2-SONU2	**SM:** CAAT2-SCFE **WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2-SONU2	**DM:** TYLA-SCACA **SM:** CAAT2-SCFE **WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2-SONU2	**OW:** RUCI2-RIFL4 **DM:** TYLA-SCACA **SM:** CAAT2-SCFE **WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2-SONU2		**OW:** RUCI2-RIFL4 **DM:** TYLA-SCACA **SM:** CAAT2-SCFE **WM:** SPPE-SEDGES-CASTI3 **LP:** ANGE-PAVI2-SONU2	**SM:** CAAT2-SCFE **WM:** CASTI3-SPPE **LP:** ANGE-PASM-PAVI2	**WM:** CASTI3-SPPE **LP:** ANGE-PAVI2-SONU2	**FEN:** CAAQ-TYLA-PHAU7 **WM:** CASTI3-SPPE **LP:** ANGE-PAVI2-SONU2
		Saline	**IA:** RUMA5 **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**OW:** RUMA5-STPE15 **DM:** SCAMA8-SCACA **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2	**SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2	**DM:** SCAMA8-SCACA **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**OW:** RUMA5-STPE15 **DM:** SCAMA8-SCACA **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**IA:** RUMA5 **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**OW:** RUMA5-STPE15 **DM:** SCAMA8-SCACA **SM:** PUNU2-SCAM6 **WM:** CAREX-POLA4-DISP **LP:** ANGE-PASM-PAVI2 **FEN:** CAAT-TYLA-PHAU7	**SM:** PUNU2 **WM:** SPGR-SPPE **LP:** PASM	**SM:** PUNU2 **WM:** SPGR-SPPE **LP:** PASM	
	Moderate to Heavy Bison Grazing	Fresh		**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE	**WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE	**SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE	**DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE	**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE		**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** PASM-ELTR7-ANGE	**SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** BOGR2-PASM	**WM:** JUARL-ELPA3 **LP:** PASM-ELTR7-ANGE	**FEN:** SCTA2 **WM:** JUARL-ELPA3 **LP:** PASM-ELTR7-ANGE
		Saline	**IA:** RUMA5 **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI	**SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI	**DM:** SCMA8-SCACA **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**IA:** RUMA5 **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELAC **WM:** DISP-HOJU-POPA2 **LP:** PASM-ELTR7-MURI **FEN:** SCTA2	**SM:** PUNU2 **WM:** HOJU-DISP **LP:** PASM	**SM:** PUNU2 **WM:** HOJU-DISP **LP:** PASM	
Infrequent Fire (MFI >15 Years)	**Low to Moderate Bison Grazing**	Fresh		**OW:** RUCI2-RIFL4 **DM:** SCACA-TYLA **SM:** CAAT2-SCFE **WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM	**WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM	**SM:** CAAT2-SCFE **WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM	**DM:** SCACA-TYLA **SM:** CAAT2-SCFE **WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM	**OW:** RUCI2-RIFL4 **DM:** SCACA-TYLA **SM:** CAAT2-SCFE **WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM		**OW:** RUCI2-RIFL4 **DM:** SCACA-TYLA **SM:** CAAT2-SCFE **WM:** POPA2-SEDGES-SPPE **LP:** FRPE-SYOC-PODEM	**SM:** CAAT2-SCFE **WM:** SPPE-CASTI3 **LP:** SYOC-PRAM-ELTR7	**WM:** ELPA3-JUARL **LP:** FRPE-SYOC-PODEM	**FEN:** CAAQ-TYLA-SALIX **WM:** ELPA3-JUARL **LP:** FRPE-SYOC-PODEM
		Saline	**IA:** RUMA5 **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM -POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC	**SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC	**DM:** SCMA8-SCACA **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**IA:** RUMA5 **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM -POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** PUNU2-ELPA3 **WM:** JUARL-POPA2-SEDGE **LP:** PASM-POAR3-SYOC **FEN:** CAAT-TYLA-SALIX	**SM:** PUNU2 **WM:** POPA2-HOJU **LP:** PASM-POAR3	**SM:** PUNU2 **WM:** POPA2-HOJU **LP:** PASM-POAR3	
	Moderate to Heavy Bison Grazing	Fresh		**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM	**WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM	**SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM	**DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM	**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM		**OW:** RUCI2-RIFL4 **DM:** SCACA-SCTA2 **SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-PODEM-PASM	**SM:** CAAT2-ELPA3 **WM:** ELEOC-HOJU-JUARL **LP:** SYOC-BOGR2	**WM:** JUARL-ELPA3 **LP:** FRPE-SYOC-PASM	**FEN:** SCTA2-SALIX **WM:** JUARL-ELPA3 **LP:** FRPE-SYOC-PASM
		Saline	**IA:** RUMA5 **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM	**SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM	**DM:** SCMA8-SCACA **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**IA:** RUMA5 **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**OW:** RUMA5-STPE15 **DM:** SCMA8-SCACA **SM:** SCAM6-ELPA3-ELAC **WM:** DISP-HOJU-POPA2 **LP:** SYOC-PODEM-PASM **FEN:** SCTA2-SALIX	**SM:** PUNU2 **WM:** HOJU-DISP **LP:** PASM	**SM:** PUNU2 **WM:** HOJU-DISP **LP:** PASM	

Stewart & Kantrud			Cowardin et al.
OW:	Open Water Zone	=	Permanently flooded
DM:	Deep Marsh Zone	=	Semi-permanently flooded
SM:	Shallow Marsh Zone	=	Seasonally flooded
WM:	Wet Meadow Zone	=	Temporarily flooded
LP:	Low Prairie Zone	=	Non-wetland
IA:	Intermittent-Alkali Zone	=	Intermittently flooded
FEN:	Central Fen Zone	=	Saturated

TODAY'S ECOSYSTEM DIVERSITY

Native ecosystems and habitats of the Missouri Coteau subregion have and continue to be directly and indirectly altered by human actions. Although Native Americans interacted and influenced this landscape for thousands of years, these influences are incorporated in the historical reference. It is the extent of human influence over the last 150 years that is of primary concern to native ecosystem diversity of the Missouri Coteau. Land conversion to cropland, pasture, urban uses, and roads are the most obvious impacts. However, there are also less obvious human-induced changes as well. The implications of a century of alterations to and interruptions of natural disturbance regimes on native ecosystem diversity of the Missouri Coteau region are still poorly understood. Studies in other landscapes have shown that the suppression, alteration, or cessation of natural disturbance has gradually changed ecosystem processes and the species composition, structure, and function of many ecosystems (Fuhlendorf and Engle 2001, Knight 1994, Perryman and Laycock 2000, Haufler et al. 2008). Developing a better understanding of these changes will be critical to evaluating cumulative impacts, changes to habitat, and the potential future impacts of climate change.

TERRESTRIAL ECOSYSTEM DIVERSITY

Developing a clear understanding of the terrestrial ecosystem conditions present in the Missouri Coteau subregion today is an important step toward identifying and quantifying cumulative changes to native terrestrial ecosystem diversity. To initiate this understanding, an assessment of terrestrial ecosystems was undertaken in 2007 in the Missouri Coteau. The assessment utilized a combination of vegetation field surveys and remotely sensed data to identify and describe today's ecosystem conditions. The following sections provide a summary of the methods used and the results obtained from this assessment. However, it should be clarified that this terrestrial ecosystem assessment should be viewed as preliminary as it does not evaluate existing conditions relative to the historical disturbance states resulting from the influence of natural disturbance regimes. Future inventories and assessments should strive to evaluate the existing disturbance state relative to historical states wherever native ecosystem conditions are identified on the landscape.

Characterizing Ecosystem Diversity

Methods

In 2007, native terrestrial grasslands within the Missouri Coteau were sampled and assessed. The location of the sampling points were randomly selected using the results of the ecosystem diversity mapping effort and GIS layers to exclude wetlands, riparian areas, and areas that have been cultivated or mechanically disturbed. To identify native grasslands we used GAP land cover layers and excluded all land cover types except those that could include native grasslands (e.g., idle grassland, pastureland, and hayland).

To establish sample points, GAP potential "native grassland" land cover types were intersected with the ecological site layer and randomly stratified sample points. Plots were stratified across ownership by ecological sites within the landscape. Each plot selected by the above stratified random design received an individual identification number and a GPS designation. Prior to field sampling, 2-meter resolution National Agriculture Imagery Program (NAIP) aerial imagery was used to identify whether the sample plots were located in areas that were obviously cultivated, wetlands, or riparian areas. NAIP imagery data used were from 2006 so it was also used to fill in the time lag from when the GAP layers were classified in 2001. In addition, the NAIP imagery was a higher resolution at 2-m versus the GAP layer derived from 30-m Landsat images.

Prior to initiating the field season, public and private landowners were contacted throughout the Missouri Coteau to obtain permission to sample their land. Eighty five landowners were sent a letter describing South Dakota's wildlife action plan and our field sampling protocol. Prior to and throughout the field season, individuals who had received these letters were contacted to request sampling permission on their land. As the list of 85 individual landowners was exhausted, we called additional private landowners to request permission to access their lands. In addition, we had several samples that fell on lands owned by South Dakota Schools, the United States Fish and Wildlife Service (USFWS), SDGFP, and the Nature Conservancy (TNC). We requested and obtained written permission to conduct sampling on State, USFWS, and TNC lands.

Field crews navigated to the random sample points using GPS. Plots sampled were rejected if they were determined to have been previously cultivated or otherwise mechanically modified (Figure 38). Signs of previous mechanical disturbance included rock piles rather than rocks scattered through a pasture, homogeneous plant communities consisting primarily of 3 dominant species (e.g., smooth brome, Kentucky bluegrass, alfalfa), and visible signs of seeding introduced species. If a sample point was accepted, site characteristics were recorded such as the ecological site, soil mapping symbol, elevation, slope, aspect and soil surface texture determined using the texture by feel method.

Figure 38. Example of rock pile indicative of previous mechanical disturbance.

Vegetation at each sample point was sampled for frequency, cover, and structure. A 50 m vegetation transect was placed in a randomly assigned direction from the designated plot location. The vegetation transect was placed to keep its entire length within the selected ecological site. Beginning 1 m from the start of a transect microplots (20 cm x 50 cm) were placed every 3 m for a total of 15 samples. One side of the microplot frame was consistently placed along the vegetation transect. Canopy cover of plants occurring in each microplot was estimated and recorded by cover class for each species. Canopies of plants extending over the microplot were included in the estimates, and overlapping canopy cover was included in estimates, therefore the total cover in a microplot could exceed 100 percent.

A 375 m^2 rectangular macroplot (15 x 25 m) was placed 7.5 m on either side of the first 25 m of the line transect (Figure 39). This macroplot was used to capture rare species not found in the microplots or line intercept, and to estimate tree densities. All herbaceous or shrub species not previously recorded in either the microplot or line intercept sampling were recorded. When trees were encountered, individual trees were tallied by species and 1" diameter classes, starting with the 1-2" diameter class (D.B.H.).

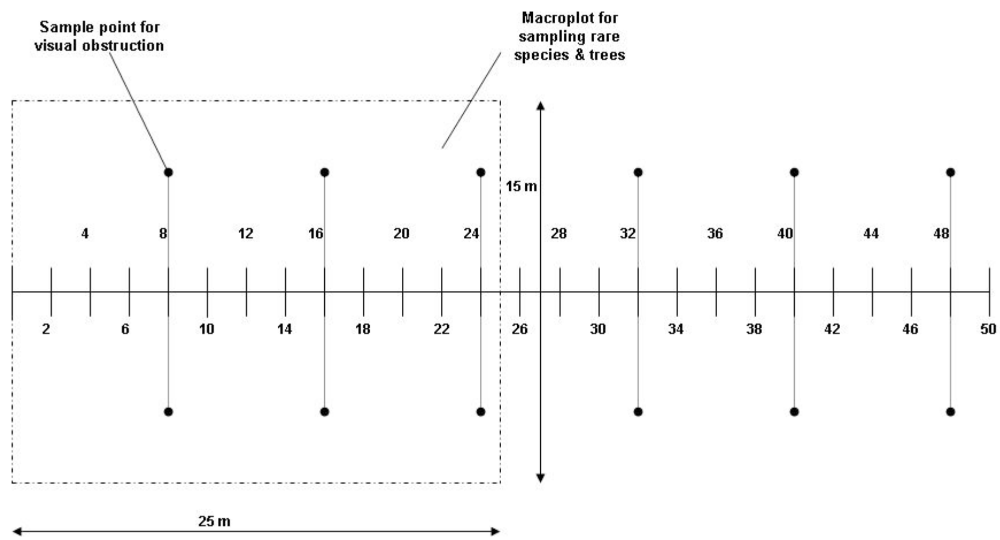

Figure 39. Vegetation plot sampling design utilized to assess existing ecological site conditions in the Missouri Coteau in 2007.

Canopy cover of all species of woody vegetation, in addition to being estimated within the Daubenmire frames, was sampled using the line-intercept method along the 50 m transect. Shrub cover was sampled separately for each species of shrub occurring <1 m in height and for shrubs >1 m in height. Vegetation structure was measured using Robel pole sampling. Robel poles measure the visual obstruction from vegetation from a set height and a set distance away from the observer in 1" height classes. Robel pole measurements were made on either side of the line transect at the 8m, 16m, 24m, 32m, 40m, and 48m points for a total of 12 measurements per plot. In addition to each visual obstruction measurement we also recorded the maximum standing height of grasses, forbs, and shrubs within 0.5m from the Robel pole.

Each identified species was assigned a species code, using USDA-NRCS PLANTS species codes (USDA, Natural Resources Conservation Service 2008; Appendix B). Cover information, for each species sampled from microplots within a plot was averaged, and the average value was used for further plot analyses. Relative cover was calculated for each species within a plot by taking a species average absolute cover and dividing it by the plots total cover. Plot data were summarized by ecological site.

Species were identified as native or introduced, and the relative proportion of native and introduced species observed in each ecological site was determined.

Results

Cultivation and other land use conversions have greatly altered the landscape with the most profound effect being loss of native grasslands. According to GAP land cover classification (Figure 40), native grasslands currently occupy a fraction of the acres they formally did, with the greatest loss occurring in loamy and clayey ecological sites (Table 13). In preparation for the field investigations, verification of the randomly selected sample points using aerial imagery indicated that an additional 37% (mean value) of the GAP identified grassland acres were not in fact native grassland. These percentages were further extrapolated to the native grassland acres by ecological sites, resulting in a considerable reduction in expected native grassland acres (Table 13).

Table 13. Summary of the total acres by ecological sites, the GAP land cover grassland acres, grassland sample point acceptance based on reinterpretation of finer-scale aerial imagery, and aerial imagery corrected grassland acres indicating the amount of native grassland we estimated occurred in the South Dakota Missouri Coteau prior to conducting field sampling.

Ecological Site	Total Acres	GAP Land Cover Grasslands Acres	Aerial Imagery Grassland Sample Acceptance (%)	Aerial Imagery Corrected Grassland Acres
Clayey	306,006	163,693	68	111,311
Thin Claypan	7,333	4,391	72	3,162
Loamy	1,840,877	833,633	32	266,763
Shallow Loamy	60,130	37,091	82	30,415
Sandy	49,357	24,821	63	15,637
Sands	19,435	9,621	44	4,233
Very Shallow	142,274	78,949	72	56,843

A summary of the field sampling efforts can be found in Table 14. In 2007, 113 of the randomly generated sample points were visited. Seventy four of these plots were rejected because they were mechanically disturbed and no longer contained native prairie. Eight of the randomly selected plots met the acceptance criteria however they were not sampled due to logistical constraints. The remaining 31 randomly generated sample points were sampled. In addition, 12 sample plots were established in identified pastures (non-random samples) to obtain better representation of grasslands occurring across ecological sites. On private lands, 29 plots were sampled with 3 additional plots accepted but not sampled and 26 plots were rejected. On USFWS lands, 8 plots were sampled, 2 plots were accepted but were not sampled, and 42 plots were rejected. On lands owned by The Nature Conservancy, 4 plots were sampled, 2 plots were accepted but were not sampled, and 1 plot was rejected. On South Dakota School lands, 2 plots were sampled, 1 plot was accepted but was not sampled, and 2 plots were rejected. On lands owned by SDGFP, 2 plots were rejected.

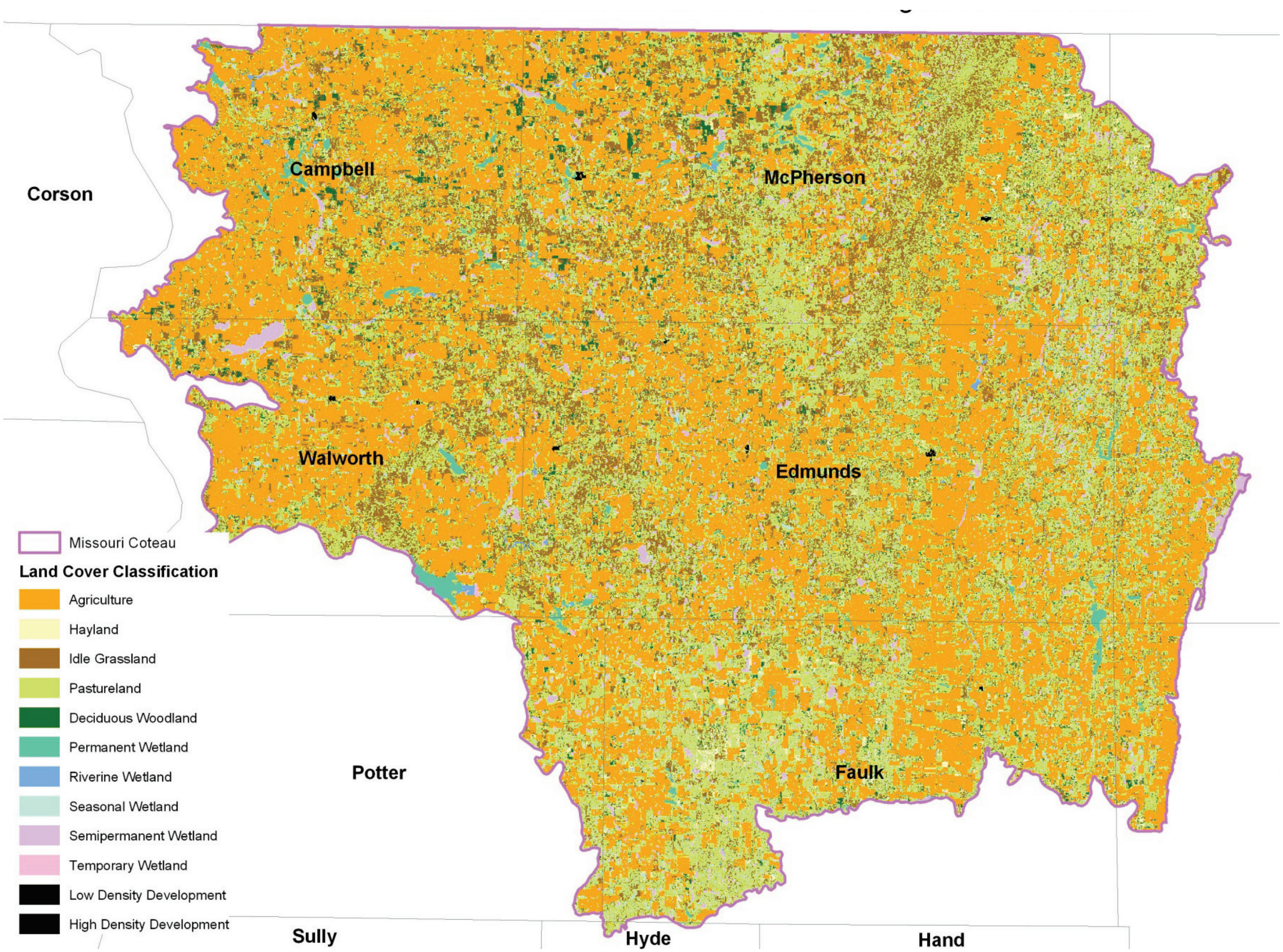

Figure40. Land cover classification as identified and mapped using South Dakota GAP data (SD GAP 2005).

Table 14. Summary of the ecological sites sampled during the 2007 field season.

	Sampled Plots			Random Plots Visited But Not Sampled	
Ecological Site	Sample Size	Random	Not Random	Rejected	Accepted
Clayey	6	2	4	14	0
Thin Claypan	4	3	1	3	1
Loamy	12	11	1	33	6
Shallow Loamy	6	5	1	1	0
Sands	0	0	0	1	0
Sandy	6	5	1	2	0
Very Shallow	5	2	3	13	1

A total of 142 species from 34 families were identified (see Appendix B for a list of the plant species identified). The absolute cover of plants, litter, and bare ground are summarized in Table 15. Total cover of live vegetation ranged from 55.5% on sandy ecological sites to 87.4% on clayey ecological sites and was generally variable within an ecological site. Litter cover ranged from 59.2% to 83.4% and was also variable within an ecological site. Bare ground was generally low on the plots we sampled. In fact, only one ecological site (Sandy) had greater than 2% bare ground at 7.2%.

Table 15. Summary of canopy cover measurements, ± standard error of the mean, made on terrestrial ecological sites during the 2007 sampling season.

		Absolute Cover (%)		
Ecological Site	Sample Size	Plants	Litter	Bare Ground
Clayey	6	87.4 ± 12.7	79.7 ± 2.4	1.8 ± 0.9
Thin Claypan	4	65.4 ± 10.0	70.2 ± 12.6	1.8 ± 1.8
Shallow Loamy	6	85.2 ± 4.2	83.4 ± 1.1	0.7 ± 0.3
Loamy	12	63.1 ± 8.0	76.2 ± 3.3	0.8 ± 0.4
Sandy	6	55.5 ± 8.6	59.2 ± 8.9	7.2 ± 2.7
Very Shallow	5	62.1 ± 15.6	78.1 ± 2.1	0.9 ± 0.6

Dominant species found in the terrestrial ecological sites within the Missouri Coteau are listed in Table 16. Overall the most dominant species was Kentucky bluegrass (22.2%), followed by blue grama (8.1%), upland sedge species (8.0%), smooth brome (7.0%), western wheatgrass (4.6%), cumin ragweed (3.8%), needle and thread (3.7%), American bird's-foot trefoil (2.8%), white prairie aster (2.8%), and big bluestem (2.3%) (Figure 41). With the exception of Kentucky bluegrass, smooth brome, and crested wheatgrass, the dominant species in the sampled plots across ecological sites were native. The sampling protocol captured species preference for certain ecological sites. For example, upland sedges and needle and thread were found in higher proportions on sandy ecological sites, whereas sedge species that are typically associated with wetlands were more prevalent on thin claypan ecological sites.

Figure 41. Example of a clayey ecological site dominated by big bluestem, followed by smooth brome, and Kentucky bluegrass, 48.0%, 26.6%, and 19.0% absolute cover respectively.

Table 16. Dominant plant species in terrestrial ecological sites sampled in the Missouri Coteau in 2007.

	Relative Cover (%) of the 10 Most Dominant Species Found in Each Ecological Site					
Species	Clayey	Loamy	Sandy	Shallow Loamy	Thin Claypan	Very Shallow
American bird's foot trefoil	2.2	3.7	0.5	4.9	4.0	2.4
big bluestem	9.2	0.3	0.1	0.0	3.2	2.7
blue grama	10.3	7.1	12.1	11.3	3.4	7.5
blue lettuce	0.4	2.1	0.8	1.9	0.6	0.9
buffalograss	0.8	0.3	0.0	1.3	0.5	trace
crested wheatgrass	0.0	0.5	14.0	0.0	0.3	0.0
cuman ragweed	5.1	2.4	4.0	2.2	4.1	5.4
field sagewort	0.7	0.9	3.3	trace	0.0	0.0
green needlegrass	0.2	3.6	0.5	1.3	2.0	4.9
Kentucky bluegrass	25.3	30.3	4.9	19.6	24.5	8.4
little bluestem	0.1	0.1	0.1	1.3	0.0	6.6
needle and thread	1.9	3.0	13.6	3.1	1.0	1.1
saltgrass	5.0	0.0	0.0	0.5	0.0	0.1
smooth brome	5.7	7.5	0.2	11.3	3.9	10.1
sweetclover	2.6	0.0	0.0	1.1	0.6	6.1
western wheatgrass	6.7	5.9	3.6	3.5	7.4	3.5
white prairie aster	3.5	1.6	0.8	3.5	4.0	5.5
upland sedge species	5.7	7.7	17.7	9.5	5.7	4.9
wetland sedge species	0.1	0.0	0.0	0.0	9.0	0.0
sideoats grama	0.0	0.0	0.0	2.2	0.0	0.1
porcupinegrass	0.0	0.0	5.8	2.1	0.0	0.1
sand dropseed	0.0	Trace	2.5	0.1	0.0	0.2
stiff sunflower	0.3	0.3	0.0	1.3	0.1	3.1

Western snowberry was the dominant shrub encountered on terrestrial ecological sites in the Missouri Coteau, however shrubs were generally a minor component of the terrestrial ecosystems sampled (Table 17). In western portions of the Missouri Coteau planning area (i.e., Walworth County), larger patches of shrubs were encountered, especially western snowberry (Figure 42). However, encountering large (> 1 acre) shrub patches was rare. Other shrubs encountered include leadplant, prairie sagewort, false indigo, and prairie rose.

Table 17. Summary of shrub measurements, ± standard error of the mean, made on terrestrial ecological sites during the 2007 sampling season.

		Shrub Cover (%)			
Ecological Site	Sample Size	Average	Minimum	Maximum	Western Snowberry
Clayey	6	0.4 ± 0.3	0.0	1.6	0.1
Claypan	4	4.1 ± 4.1	0.0	16.5	3.7
Loamy	12	0.7 ± 0.2	0.0	2.6	0.0
Sandy	6	2.4 ± 1.1	0.0	5.2	0.4
Shallow Loamy	6	2.9 ± 1.6	0.1	8.9	2.4
Thin Claypan	4	0.5 ± 0.5	0.0	1.9	0.0
Very Shallow	5	2.3 ± 0.6	0.2	3.9	0.1

Figure 42. Large patch of western snowberry in Walworth County, South Dakota, which was atypical of the shrub densities we encountered during our 2007 sampling season.

A summary of the plant community structure measurements can be found in Table 18. There was considerable structural diversity within and across the terrestrial ecological sites sampled. Grasses are the dominant functional group in the Missouri Coteau and given their growth stature, contribute to a sizeable portion of the plant community structure.

Table 18. Summary of the Robel and vegetation height measurements, ± standard error of the mean, made on terrestrial ecological sites during the 2007 sampling season.

			Vegetation Height (in)		
Ecological Site	Sample Size	Robel (in)	Forbs	Grasses	Shrubs
			- - - - - - - - - - - - inches - - - - - - - - - - - -		
Clayey	6	13.5 ± 5.3	14.6 ± 1.3	23.4 ± 3.7	9.6 ± 2.5
Claypan	3	10.3 ± 0.6	11.7 ± 3.1	23.6 ± 1.3	12.6 ± 4.0
Loamy	12	7.2 ± 1.0	11.5 ± 1.2	22.0 ± 2.2	8.7 ± 1.8
Sandy	6	8.1 ± 1.3	13.0 ± 1.4	25.5 ± 2.4	12.0 ± 1.3
Shallow Loamy	6	11.6 ± 2.1	15.0 ± 1.5	27.7 ± 1.5	12.2 ± 3.1
Thin Claypan	4	6.5 ± 1.1	14.2 ± 2.9	24.5 ± 3.2	10.2 ± 2.2
Very Shallow	5	6.6 ± 1.3	12.8 ± 1.6	21.5 ± 2.4	11.1 ± 1.9

Results of the 2007 field assessment of terrestrial ecological sites indicated that it is rare to find areas in the Missouri Coteau subregion that have not been mechanically disturbed and that have less than 10% introduced species. Extrapolating the results of the field sampling to the overall acres, only 27,255 acres were identified that could be classified as native grasslands with less than 10% introduced species (Table 19). Very shallow and sandy ecological sites proportionally had fewer plots rejected due to lower levels of introduced species, which is likely a result of where these ecological sites are located (e.g., in areas with more topographic relief), and in the case of very shallow sites, areas with shallow soils that are less productive. Figures 43a and 43b provide examples of hillsides in the Missouri Coteau that are more likely to be dominated by native plant species. In contrast, it was rare to find clayey and loamy ecological sites that had not been mechanically disturbed or that did not have high levels of introduced species. Clayey and loamy ecological sites in the Missouri Coteau were and continue to be considered prime agricultural land and are therefore preferentially converted from native grassland ecosystems to lands used for production agriculture.

Table 19. Acreage estimates for terrestrial ecological sites in the Missouri Coteau based on our GIS assessment of lands that have not been mechanically disturbed (i.e., Aerial Imagery Corrected Acres), our field assessment of randomly established sample plots, and sampled plots that had less than 10% relative cover of introduced species.

		Random Plots (not mechanically disturbed)		Sampled Plots (w/ <10% introduced species)	
Ecological Site	Aerial Imagery Corrected Acres	Acceptance Rate (%)	Corrected Acres	Acceptance Rate (%)	Corrected Acres
Clayey	111,311	14.3	15,917	0	0
Thin Claypan	3,162	57.1	1,806	0	0
Loamy	266,763	34.0	90,699	16.6	15,056
Shallow Loamy	30,415	83.3	25,336	16.6	4,206
Sands	4,233	0.0	0	0.0	0
Sandy	15,637	71.4	11,165	33.3	3,718
Very Shallow	56,843	18.8	10,686	40.0	4,275

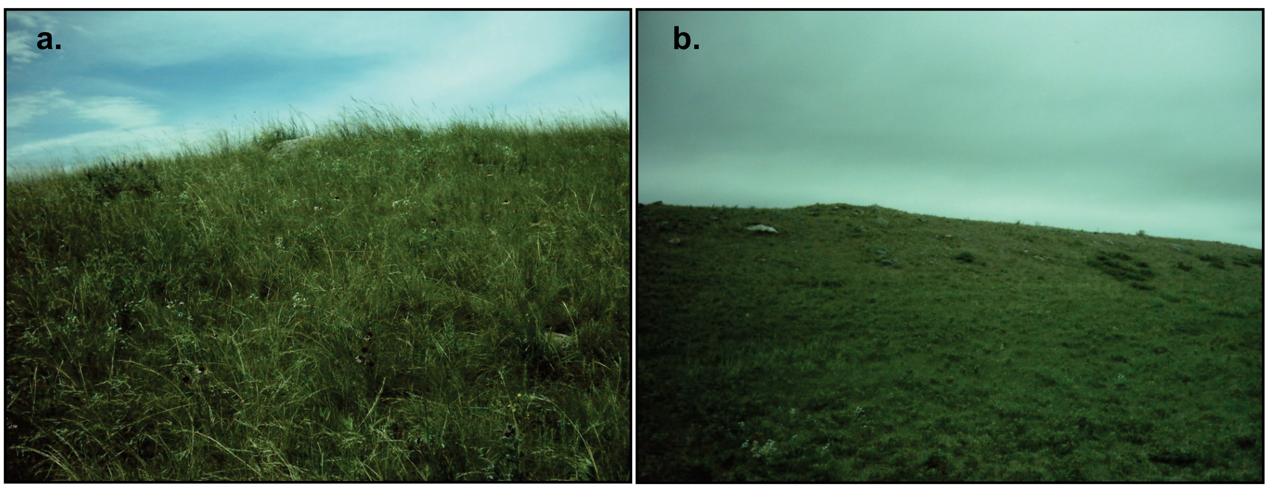

Figure 43 a, b. Example of hillsides in the Missouri Coteau subregion that are often found dominated by native plant species. Photo (a) taken in Campbell County and photo (b) in McPherson County.

Introduced plant species have been identified as one of the greatest threats to the integrity and productivity of native ecosystem diversity and conservation of indigenous biodiversity (Mack 1981, DiTomaso 2000, Mack et al. 2000). Introduced species are a ubiquitous feature throughout the Missouri Coteau even in areas that have not been previously cultivated (Table 20). A total of 25 introduced species were found during the 2007 field sampling, 13 forbs, 9 grasses, and 3 legumes (see Appendix B for a complete listing of the introduced species identified). Of the introduced species found, leafy spurge and Canada thistle are classified as state noxious weeds and absinthium (Figure 44), bull thistle, and butter and eggs (i.e., yellow toadflax) are classified as local noxious weeds by the state of South Dakota. Introduced species were present in every plot sampled, often in high amounts. For example, 83.7% of the plots sampled had greater than 10% introduced species and 65.1% of the plots sampled had greater than 25% introduced species. It was rare to encounter situations where introduced species were a minor component of the plant community, in fact only 6 plots, or 14% of the plots sampled, had less than 5% relative cover of introduced species.

Figure 44. Dense wormwood (absinthium) patch in Walworth County, South Dakota.

The dominant introduced species in the Missouri Coteau were species that have been introduced as improved forage, including the five most dominant introduced species: Kentucky bluegrass, smooth brome, crested wheatgrass, alfalfa, and yellow sweet clover. Kentucky bluegrass was clearly the dominant introduced species, followed by smooth brome on most sites with the exception of sandy ecological sites that were dominated by crested wheatgrass (Table 16). Although alfalfa was an introduced species of secondary importance, it was often found in greater amounts on the rejected plots, along with smooth brome and Kentucky bluegrass.

Table 20. Introduced Species Cover ± standard error of the mean for terrestrial ecological sites in the Missouri Coteau.

		Introduced Species Cover (%)	
Ecological Site	Sample Size	Absolute	Relative
Clayey	6	26.9 ± 5.4	33.4 ± 7.7
Thin Claypan	4	19.3 ± 5.1	29.1 ± 4.6
Loamy	12	28.2 ± 7.3	42.8 ± 8.5
Shallow Loamy	6	30.3 ± 8.6	34.2 ± 9.6
Sandy	6	10.4 ± 3.1	21.4 ± 7.6
Very Shallow	5	11.1 ± 4.2	23.8 ± 10.1

Wetland and Riparian Ecosystem Diversity

Unfortunately the ability to characterize today's ecosystem diversity relative to the native wetland and riparian ecosystem diversity disturbance states described in this document, is limited at this time. Future inventories and assessments should strive to evaluate the existing disturbance state wherever native ecosystem conditions are identified on the landscape. Developing a clear understanding of the wetland and riparian ecosystem conditions present in the Missouri Coteau subregion today is an important step toward identifying and quantifying cumulative changes to native ecosystem diversity.

To initiate a better understanding of today's conditions, a reconnaissance survey of wetland and riparian ecosystems was undertaken in the summer of 2008 in the Missouri Coteau. The objectives of the survey were to obtain information on site variables important in the development of field sampling methodology that will allow wetland and riparian sites to be classified using the native ecosystem diversity classification described in previous sections of this document. The following discussion provides a summary of the methods used and the results obtained from the 2008 reconnaissance survey.

Developing Methods to Characterize Ecosystem Diversity

Methods

A reconnaissance survey was conducted in 2008 to assist in the development of field sampling methodology that will allow wetland and riparian sites to be classified using the native ecosystem diversity classification described previously. Prior to initiating the field season, public and private landowners were contacted throughout the Missouri Coteau to obtain permission to conduct surveys on their land. Field crews navigated to the non-random survey locations using maps and GPS points. Surveys were conducted to review as many wetland and riparian ecological sites as possible during the sampling period. Site surveys included testing and assessing the relevant site variables for determining geomorphic setting, hydrology and vegetation zones, fresh versus saline water chemistry, and grazing disturbance.

Results

Thirty five plots were surveyed in July 2008. The recommendations resulting from the reconnaissance surveys are summarized by the 5 site variables reviewed for their classification importance to the EDM framework.

- Hydrogeomorphic Setting

Each site surveyed was evaluated and classified relative to the hydrogeomorphic setting for lacustrine, depressional, riverine, and slope systems. These field classifications were then reviewed against GIS data for comparison. The results of this comparison indicate that the optimal system for determining hydrogeomorphic setting is to classify the ecological site prior to conducting the field survey using the GIS methodology described in the Mapping Wetland and Riparian Ecological Sites section and then validate this classification in the field. Areas of difficulty encountered during field surveys when only site evaluations were used, included differentiating larger depressional sites from smaller lacustrine sites and misclassification of depressional sites that are within the floodplain of riverine systems. Having sites classified for hydrogeomorphology prior to the field surveys will help the surveyor look for and evaluate additional site characteristics not always readily apparent without this additional information. Slope systems present a particular challenge to the geomorphic classification because they can occur as an independent system or as part of the other three systems. As discussed previously, the ability to accurately classify and map independent slope systems is difficult at this time. This is an area that will require additional research and coordination to address this problem both in GIS data and in field surveys.

- **Hydrology subclass and vegetation zones**

The hydrology of an ecological site should be evaluated and classified relative to vegetation zones. As described previously, vegetation zones are advocated as a valuable tool for determining average hydrological conditions for an ecological site (Stewart and Kantrud 1971) and this was further confirmed in the reconnaissance surveys. The vegetation zone determined to be the moistest zone under average conditions, will be used to determine the hydrological subclass as identified in the ecosystem diversity matrix framework.

- **Fresh versus saline water chemistry**

Each site surveyed was evaluated for obvious signs of fresh versus saline water chemistry. After evaluating multiple site variables discussed in the literature as possible salinity indicators such as alkali crusts, shoreline foam, and odor it was determined that none of these variables would be dependable indicators of fresh versus saline conditions during field surveys. Instead, plant species indicators were developed to help facilitate this process. Table 7 identifies species that have low (i.e., fresh water chemistry) and high (i.e., saline water chemistry) tolerance for saline conditions by vegetation zone. These indicators were developed using Stewart and Kantrud (1971). Ideally two or more indicator species in the fresh or saline category, and across multiple vegetation zones, would be present at a site to help confirm water chemistry.

- **Grazing**

Grazing influences should be evaluated at two levels; short-term impacts and long-term impacts. Short-term impacts such as pugging, bank erosion, water quality impacts, etc. should be noted during field surveys. The long-term effects of grazing on plant community species composition and structure is more appropriately determined using the dominant indicator species present at the site. The adjacent terrestrial ecological sites should also be evaluated where appropriate to help determine the long-term effects of grazing or no grazing on the plant species composition of the wetland/riparian ecosystem. The indicator species were presented in the description of native ecosystem diversity for ecological sites of the Missouri Coteau and should be evaluated against the species composition for each disturbance state provided in Appendix A.

CUMULATIVE CHANGES TO ECOSYSTEM DIVERSITY

Two primary types of ecosystem conversion or alteration occur within the Missouri Coteau subregion, which have contributed to the cumulative changes to native ecosystem diversity observed in the landscape today. These are: 1) the direct conversion of native ecosystems to some other land type or use, and 2) the indirect alteration of native ecosystems through the suppression of natural disturbance processes or alteration of species compositions, structures, or functions resulting from human activities and spread of non-native species. The primary causative agents for direct conversion of native ecosystems within the Missouri Coteau subregion include agriculture, roads, railroads, urban development, wetland draining and filling, dams and impoundments, etc. The primary causative agents for indirect alteration of ecosystems include fire suppression, altered grazing regimes, altered hydrological regimes, altered beaver activities, as well as accidental or intentional introduction of non-native species that cause changes to native species habitats and native ecosystems.

TERRESTRIAL ECOSYSTEMS

Direct Conversion of Ecosystems

Overall direct land conversion that can be estimated with a combination of remote sensing (SD GAP 2005) and field assessment, as described previously, within the terrestrial ecological sites of the Missouri Coteau subregion is very high at 2,196,858 acres or 90.5% of the total acres in the subregion. Table 22 identifies a breakdown of the terrestrial ecological site and type of conversion including cropland, urban/suburban development, roads/railroads, and woodlands. Loamy and clayey terrestrial ecological sites have received the highest amounts of overall conversion at 93% and 92%, repectively. The majority of the acres converted in the subregion have resulted from agricultural cropland conversion at 96% of the acres converted, followed distantly by woodland conversion at 2.5% of the total converted acres. Conversion estimates for roads and railroads were roughly based on a 4 m wide average surface impact for roads and a 25 m average surface impact for railroads. Roads and railroads are a permanent conversion of native ecosystem conditions. In addition to the direct loss of habitat, roads and railroads my also fragment existing habitat, contribute to direct mortality for some wildlife species, and are a mechanism for the spread of invasive plant species. The number of acres identified for roads in particular, was considered a conservative estimate of the surface impacts of roads as not all less traveled access roads were included in this estimate.

Table 22. The number of acres identified for each conversion type by terrestrial ecological site, as mapped and quantified using SD GAP (2005) remotely sensed data.

Conversion Type	Clayey	Thin Claypan	Loamy	Shallow Loamy	Sandy	Sands	Very Shallow
Cropland/Mechanical Disturbance	269,941	5,036	1,648,794	31,284	34,682	8,488	119,662
Urban/Suburban Development	120	0	891	13	7	0	45
Roads/Railroads	2,677	41	14,816	379	430	174	1,214
Woodlands	8,000	164	37,996	909	2,069	972	8,054
Total acres converted	**280,738**	**5,241**	**1,702,497**	**32,585**	**37,188**	**9,634**	**128,975**
% of ecological site converted	**92%**	**72%**	**93%**	**54%**	**75%**	**50%**	**91%**

Indirect Alteration of Native Ecosystems

The direct conversion of ecosystems of the Missouri Coteau subregion is relatively high at 63.6% when compared to other Great Plains ecoregions (Vodehnal and Haufler 2008). As a result, the number of acres present today that represent native ecosystem conditions is of great concern. While some land uses within the Missouri Coteau could still provide native ecosystem conditions such as pastureland or non-use, in many cases they exhibit different types and levels of disturbance relative to natural disturbance regimes resulting in different species compositions and structures from what occurred historically.

It is important to note that while the ecosystem diversity matrix framework characterizes native ecosystem diversity relative to the natural disturbance processes of short and long-interval fires as well as the light, moderate, and heavy grazing by native herbivores, the conditions present on the landscape today are, for the most part, no longer influenced by these same disturbance processes. The results of the historical modeling effort indicates that historically 79% of the landscape burned at <15 year mean fire return intervals. Although, wildfires still occur and a few landowners have incorporated an occasional prescribed burn into their management toolbox, the extent and frequency of these fires today would not qualify as <15 year mean fire return intervals. Consequently, we have transitioned from a landscape averaging 21% representation by longer interval fires to nearly 100% representation. The large scale effects of this change on nutrient cycling and plant communities are not well understood at this time.

Grazing today is primarily by cattle and horses, with relatively uniform grazing levels applied across the landscape as compared with estimates of historical grazing patterns and pressure by bison and other herbivores. In many landscapes, the trend in recent years has been for grazing practices to be applied at primarily moderate to heavy levels (Fuhlendorf and Engle 2001, Haufler et al. 2008). Yet, the historical modeling results indicate moderate levels were the least common ecosystem conditions on the landscape historically. In addition, most ranchers today try to manage their grasslands to maintain the long-term productivity of their ranches, striving to spread out grazing through better distribution of water sources and monitoring numbers of animals using each pasture. The result has been less diversity in the levels and patterns of grazing across the landscape. Ecosystems present today that are relatively similar in species compositions to those present historically, are assumed for the purposes of this assessment, to provide similar habitat benefits to the wildlife species they historically supported. It becomes an apparent concern that these changes in disturbance regimes have likely resulted in profound effects on wildlife habitat and species occurrence, since the advent of Euro-American settlement.

Mapping and field sampling efforts to assess the existing conditions of terrestrial ecosystems in the Missouri Coteau indicate that there has been extensive loss in these ecosystems primarily through conversion to production agriculture, and introduced forages. The remaining terrestrial ecosystems that have not been cultivated or otherwise mechanically disturbed have high amounts of introduced species.

In fact only 7 out of the 111 plots that were visited in the field, or out of the 43 plots sampled (including 12 non-random plots), had less than 10% relative cover of introduced species. While a specific level of exotic species that would disqualify a site from being representative of native ecosystem conditions has not been set, a level of 10% exotics might be an appropriate upper level to consider.

The native ecosystem representation goal identified in the SDWAP was 10% of acreage of the maximum historical range of variability for terrestrial ecosystems of the Missouri Coteau, which was estimated to be 568,564 acres across the 8 terrestrial ecological sites. The field sampling results from 2007 suggest that the terrestrial ecological sites that meet this criterion could be as little as 27,255 acres or only an overall historical ecosystem representation level of less than 1%. Furthermore, when examined by ecological site, many specific ecosystems have virtually no existing representation of historical species compositions and structures and less than 10% introduced species, making them functionally lost as components of ecosystem diversity in this planning area.

WETLAND AND RIPARIAN ECOSYSTEMS

Direct Conversion of Ecosystems

Overall land conversion that can be documented with remote sensing (SD GAP 2005) within the wetland and riparian ecological sites of the Missouri Coteau subregion is relatively high at 141,824 acres or 27.1% of today's total acres in the subregion. The same limitations of the remotely sensed data discussed in the terrestrial section also apply to the wetland and riparian systems. Table 23 identifies a breakdown of the wetland and riparian ecological sites and types of conversion including cropland, urban/suburban development, and roads/railroads identified using remotely sensed data. The depressional-temporary and depressional–seasonal ecological sites have received the highest amounts of conversion at 51% and 29%, respectively. The majority of the acres converted in the subregion have resulted from agricultural cropland conversion at 97.6% of the acres converted, followed by roads/railroad conversion at 1.0% of the total converted acres. Wetland drainage (both surface and below-ground tile) to enhance cropland production has been identified as the primary factor resulting in the conversion of wetlands in the Missouri Coteau region (Tiner 1984, Millar 1989, Dahl and Johnson 1991).

Table 23. The number of acres identified for each conversion type by wetland and riparian ecological site, as mapped and quantified using SD GAP (2005) remotely sensed data.

	LACUSTRINE		DEPRESSIONAL					RIVERINE	
Converted Types	Permanent	Intermittent	Temporary	Seasonal	Semi-permanent	Permanent	Intermittent	Permanent	Intermittent
Cropland	138	2,937	21,681	43,233	18,239	492	235	1,135	50,340
Urban/Suburban	0	2	6	6	0	0	0	86	5
Roads/Railroad	6	130	267	980	502	11	10	46	1,337
Total converted acres	144	3,069	21,954	44,219	18,741	503	245	1,267	51,682
% of ecological site converted	6.2%	10.2%	51.0%	29.2%	19.1%	9.6%	21.0%	24.1%	27.5%

Indirect Alteration of Native Ecosystems

Direct conversion of wetland and riparian ecosystems in the Missouri Coteau was estimated at 27.1%, more concerning are the less obvious or indirect alterations of native ecosystems that have occurred over the last 150 years. Similar to the discussion of terrestrial ecosystems, there is considerable cause for concern as to how many native wetland and riparian ecosystem conditions occur on the landscape today. While some surrounding land uses such as pastureland or non-use within the Missouri Coteau could still provide native wetland and riparian ecosystem conditions, it is expected that in most cases they will exhibit different types and levels of disturbance relative to natural disturbance regimes. The result is different ecosystem compositions and structures from what occurred historically. In addition, the results of the terrestrial assessment would suggest that introduced species will be a significant problem for wetland and riparian ecosystems of the Missouri Coteau as well, and indeed introduced species were observed in every riparian/wetland site sampled in the reconnaissance survey.

In addition to the loss of historical disturbance regimes, indirect influences of current land use practices could also contribute to the alteration of native ecosystem conditions and loss of historical representation. These land use practices include: 1) construction activities such as dikes/impoundments, excavation, or partial draining and filling, 2) changes to water hydrology and connectivity between wetlands both through surface and sub-surface drainage, road construction, etc., 3) greater water-level fluctuations associated with increased runoff due to intensive agricultural activities in the surrounding landscape, 4) changes to normal water chemistry patterns due to these hydrological changes and unusual water-level fluctuations, and 5) increased sedimentation and nutrient loads to wetlands surrounded by agriculture. All of these land use influences could result in or contribute to the alteration or loss of representation of historical ecosystem conditions for wetland and riparian systems.

National Wetland Inventory data were used to assess the indirect impacts to wetland and riparian ecosystems relative to dike/impoundment, excavation, and partial draining activities. Those acres are presented in Table 24 by ecological site.

Table 24. Results of overlaying National Wetlands Inventory data with wetland and riparian ecological sites for the Missouri Coteau relative to identified human activities of constructing dikes/impoundments, wetland excavation, and partial draining activities.

	DEPRESSION				
	Temporary	Seasonal	Semi-permanent	Permanent	Intermittent
Diked/ Impounded	0.8	31.3	523.3	212.6	66.0
Excavated	15.9	20.5	1884.1	25.8	18.1
Partially drained	957.7	1551.8	741.9	6.6	0.0
Total	974.4	1603.6	3149.3	245.0	84.1
% of Ecosite	2.3	1.1	3.2	4.7	7.2

	LACUSTRINE	
	Permanent	Intermittent
Diked/ Impounded	514.7	1821.7
Excavated	7.4	62.2
Partially drained	15.5	23.8
Total	537.6	1907.7
% of Ecosite	23.1	6.3

	RIVERINE	
	Permanent	Intermittent
Diked/ Impounded	471.8	2950.4
Excavated	5.3	1045.9
Partially drained	18.0	1069.3
Total	495.1	5065.6
% of Ecosite	9.4	2.7

NATIVE ECOSYSTEM DIVERSITY RESTORATION

The results of this project demonstrate that a high percentage of native terrestrial ecosystems that were present historically are virtually absent from this landscape today or significantly reduced in functional quality. While native conditions may still be found across all ecological sites, they often represent a limited range of disturbance states and are frequently confined to small, fragmented areas, when considered relative to how they occurred historically. This is especially true of the historically dominant, most abundant ecological sites that have become so dramatically reduced in terms of their overall acres of native ecosystem diversity and functional quality. These changes are also believed to be true of the wetland and riparian ecological sites, although this project did not attempt to quantify these impacts at this time. In addition to land-use conversions, most ecological sites in this subregion have high levels of introduced species, a finding also reported by the U.S. Fish and Wildlife Service on national wildlife refuges (Grant et al. 2009) for the same area. A study conducted in the Thunder Basin of Wyoming (Haufler et al. 2008) revealed similar results. These and other studies reveal the extent and severity of both direct and indirect ecosystem changes and demonstrate the tremendous need to restore native ecosystem diversity in the Missouri Coteau subregion.

RESTORATION OBJECTIVES

The South Dakota Wildlife Action Plan identified a goal of maintaining or restoring 10% of the maximum historical range of variability for native ecosystem diversity across all South Dakota ecoregions. The results of the historical range of variability modeling effort for terrestrial ecosystems of the Missouri Coteau, provide the basis for calculating these acres (please refer to the SDWAP for a more detailed description of the 10% calculation). Table 25 identifies the number of terrestrial acres that should be maintained or restored in this subregion to achieve the 10% objectives of the SD WAP.

Due to the inability to model the historical range of variability in wetland and riparian systems, the number of acres identified for maintenance and restoration are calculated as 10% of the total acres in each ecological site divided by each of the natural disturbance states (Table 26). In those ecological sites where total acres are not identified, an initial restoration target of 50 acres is used until additional information can be developed.

Previous sections of this document describe historical state and transition models for each ecological site within the Missouri Coteau subregion. These models outlined the historical influences of natural disturbance processes and their interactions. Understanding these relationships allows for conservation

Table 25. The minimum number of acres for each native terrestrial ecosystem that should be maintained or restored in the Missouri Coteau subregion to achieve the objectives of the South Dakota Wildlife Action Plan.

	Clayey	Thin Claypan	Loamy	Shallow Loamy	Sandy	Sands	Very Shallow
MFRI <15 years							
Light Grazing	10,986		67,744	3,488	2,038	1,440	
Moderate Grazing	18,942		78,237	1,978	1,570	307	
Heavy Grazing	18,819		129,045	1,894	3,302	740	
MFRI ≥ 15 years							
Light Grazing	9,578	171	39,947	1,666	1,481	836	39,215
Moderate Grazing	5,386	260	13,254	770	362	76	23,798
Heavy Grazing	6,396	576	13,807	932	780	268	37,563
Total Acres	**70,107**	**1,007**	**342,034**	**10,728**	**9,533**	**3,667**	**100,576**

Table 26. The minimum number of acres for each native wetland and riparian ecosystem that should be maintained or restored in the Missouri Coteau subregion to achieve the objectives of the South Dakota Wildlife Action Plan (2006) (see text for description of methods to calculate acres).

		Hydrogeomorphic Class (Water Source)	LACUSTRINE		DEPRESSIONAL (non-floodplain)					RIVERINE (flooplain)		SLOPE	
		Hydrology	Permanent	Intermittent	Temporary	Seasonal	Semi-permanent	Permanent	Intermittent	Permanent	Intermittent	Subirrigated	Seep/ saturated
Frequent Fire (MFI < 15 Years)	Low to Moderate Bison Grazing	Fresh	29		538	1893	1225	65		66	2346	50	50
		Saline	29	750	538	1893	1225	65	29	66	2346	50	
	Moderate to Heavy Bison Grazing	Fresh	29		538	1893	1225	65		66	2346	50	50
		Saline	29	750	538	1893	1225	65	29	66	2346	50	
Infrequent Fire (MFI ≤ 15 Years)	Low to Moderate Bison Grazing	Fresh	29		538	1893	1225	65		66	2346	50	50
		Saline	29	750	538	1893	1225	65	29	66	2346	50	
	Moderate to Heavy Bison Grazing	Fresh	29		538	1893	1225	65		66	2346	50	50
		Saline	29	750	538	1893	1225	65	29	66	2346	50	
Total Acres			**2,328**	**30,002**	**43,042**	**151,421**	**98,035**	**5,216**	**1,165**	**5,259**	**187,714**	**Unknown**	**Unknown**

of the full range of functional native ecosystems. Without such detailed attention to ecological relationships and identification of specifically needed ecosystems, the effectiveness of conservation efforts will be greatly reduced, resulting in questionable outputs in terms of biodiversity conservation. Understanding historical baseline conditions and how current conditions differ due to past land use practices, changing climate and drought patterns, and other factors will be critical if sustainable communities and biodiversity are to be maintained.

In addition to providing a valuable conservation planning tool, ecological sites have also proven to be valuable to agricultural producers interested in improving the sustainable productivity of their lands. To meet biodiversity needs in the Missouri Coteau subregion, involvement of agricultural producers will be essential. Demonstrating how conservation goals can be compatible with the goals of working farms and ranches will be necessary for conservation to be successful. If grassland restoration cannot be effectively incorporated into working farms and ranches, it is unlikely that substantial numbers of producers will voluntarily assist with restoration efforts. Voluntary involvement of producers is needed to reverse the declines of native ecosystems and the numerous species dependent on them, as well as prevent their future listing under the Endangered Species Act and the potential economic impacts that could result from such listings.

Implementing Restoration Goals

To reach the restoration goals identified in Tables 24 and 25, restoration objectives must be implemented on both public lands and working lands of willing agricultural producers using innovative incentive-based programs and practices to address this critical conservation need while respecting and addressing the needs of the producer. Innovative combinations of practices will need to be applied and monitored to document both conservation gains and projected increases in productivity. If overall productivity can be sufficiently increased or not impacted, it will be possible to incorporate new practices that would provide or simulate natural disturbance, while maintaining the overall productivity of a producer. Producing these gains, monitoring their occurrence, and documenting their effectiveness for dissemination to others are key components of developing restoration objectives in this landscape.

The desired native ecosystem conditions to be maintained or restored on each ecological site occurring within this landscape have been described in this document. Where possible, the historical state that has the least representation on the landscape today when compared with the amounts that were likely to have occurred historically should be targeted for restoration. For the Missouri Coteau, the historical state that is likely to be the least represented on the landscape today were conditions produced under frequent fire and light grazing. This is particularly true for the more productive terrestrial ecological sites, as a higher percentage of these sites have been converted to other uses. Targeting the light grazing/frequent fire community as a preferred state for setting restoration goals is further supported by the large number of species of concern associated with these conditions (SD WAP 2006).

A combination of practices need to be identified for each selected area and should be designed to produce the desired composition, structure, and processes. These practices may include: prescribed burning, control of introduced weeds, interseeding with desired native grass and forb species specific for each ecological site, planting to establish appropriate plant communities on any croplands or wetlands being restored, restoring hydrology, and prescribed grazing implemented through long-term grazing plans to maintain the desired conditions. Each site should be individually evaluated to determine the combination of practices that is most likely to produce the desired conditions.

Treatments developed for a particular site should be based on consideration of the underlying ecological site and the current condition on the site. For many areas, incorporating prescribed burning will be an important practice. Where feasible, the prescribed burning should be planned to simulate historical fire patterns for that ecological site. Introduced species will likely never be totally eliminated from restoration sites, but they should be suppressed to the extent that is practical and feasible. Suppression of introduced species may be achieved through herbicide application, prescribed burning, prescribed grazing, interseeding or planting of desired native species, or a combination of these treatments. No single prescription is envisioned as a universal solution, as the combination of site differences, current conditions, weather patterns, landscape influences, and other factors mean that treatment selection must be flexible, and responses will undoubtedly be variable.

Monitoring of all treatment sites should be conducted. Consistent monitoring of treatment effectiveness is necessary to document the responses that are produced in a scientific manner so that results can be disseminated to both professional and lay audiences. Permanent plots should be established whenever possible and measured prior to treatment, and then monitored after treatment.

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