USDA Natural Resources Conservation Service

Ecological site FX052X03X012
Dense Clay Sodic (Dcsd) Dry Shrubland

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General information

Provisional. A provisional ecological site description has undergone quality control and quality assurance review. It contains a working state and transition model and enough information to identify the ecological site.

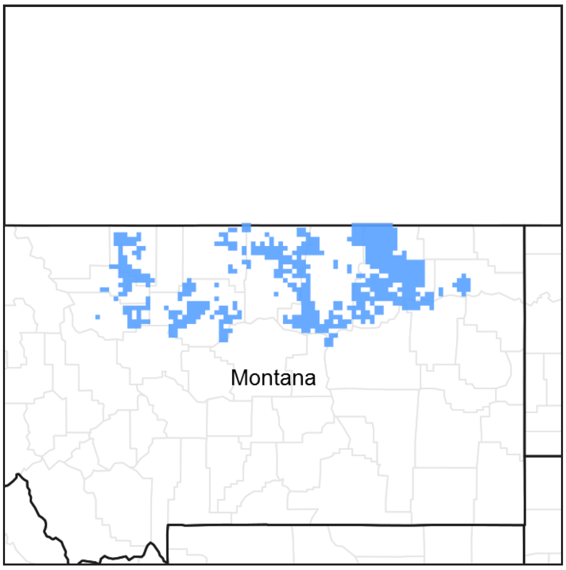

Figure 1. Mapped extent

Areas shown in blue indicate the maximum mapped extent of this ecological site. Other ecological sites likely occur within the highlighted areas. It is also possible for this ecological site to occur outside of highlighted areas if detailed soil survey has not been completed or recently updated.

MLRA notes

Major Land Resource Area (MLRA): 052X–Brown Glaciated Plains

The Brown Glaciated Plains, MLRA 52, is an expansive, agriculturally and ecologically significant area. It consists of approximately 14.5 million acres and stretches across 350 miles from east to west, encompassing portions of 15 counties in north-central Montana. This region represents the southwestern limit of the Laurentide Ice Sheet and is considered to be the driest and westernmost area within the vast network of glacially derived prairie pothole landforms of the northern Great Plains. Elevation ranges from 2,000 feet (610 meters) to 4,600 feet (1,400 meters).

Soils are primarily Mollisols, but Entisols, Inceptisols, Alfisols, and Vertisols are also common. Till from continental glaciation is the predominant parent material, but alluvium and bedrock are also common. Till deposits are typically less than 50 feet thick, and in some areas glacially deformed bedrock occurs at or near the soil surface (Soller, 2001). Underlying sedimentary bedrock largely consisting of Cretaceous shale, sandstone, and mudstone (Vuke et al., 2007) is commonly exposed on hillslopes, particularly along drainageways. Significant alluvial deposits occur along glacial outwash channels and major drainages, including portions of the Missouri, Teton, Marias, Milk, and Frenchman Rivers. Large glacial lakes, particularly in the western half of the MLRA, deposited clayey and silty lacustrine sediments (Fullerton et al., 2013).

Much of the western portion of this MLRA was glaciated towards the end of the Wisconsin age, with the maximum glacial extent occurring approximately 20,000 years ago (Fullerton et al., 2004). The result is a geologically young landscape that is predominantly a level till plain interspersed with lake plains and dominated by soils in the Mollisol and Vertisol orders. These soils are very productive and generally are well suited to dryland farming. Much of this area is aridic-ustic. Crop-fallow dryland wheat farming is the predominant land use. Areas of rangeland typically are on steep hillslopes along drainages.

The rangeland, much of which is native mixedgrass prairie, increases in abundance in the eastern half of the MLRA. The Wisconsin-age till in the north-central part of this area typically formed large disintegration moraines with steep slopes and numerous poorly drained potholes. A large portion of Wisconsin-age till occurring on level terrain that would typically be optimal for farming has large amounts of less-suitable sodium-affected Natrustalfs. Significant portions of Blaine, Phillips, and Valley Counties were glaciated approximately 150,000 years ago during the Illinoisan age. Due to erosion and dissection of the landscape, many of these areas have steeper slopes and more exposed bedrock than areas glaciated during the Wisconsin age (Fullerton and Colton, 1986).

While much of the rangeland in the aridic-ustic portion of MLRA 52 is classified as belonging to the “dry grassland” climatic zone, sites in portions of southern MLRA 52 may belong to the “dry shrubland” climatic zone. The dry shrubland zone represents the northernmost extent of the big sagebrush (Artemisia tridentata) steppe on the Great Plains. Because similar soils occur in both southern and northern portions of the MLRA, it is currently hypothesized that climate is the primary driving factor affecting big sagebrush distribution in this area. However, the precise factors are not yet fully understood.

Sizeable tracts of largely unbroken rangeland in the eastern half of the MLRA and adjacent southern Saskatchewan are home to the northern Montana population of greater sage grouse (Centrocercus urophasianus), and large portions of this area are considered to be a Priority Area for Conservation (PAC) by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service, 2013). This population is unique among sage grouse populations in the fact that many individuals overwinter in the big sagebrush steppe (dry shrubland) in the southern portion of the MLRA and then migrate to the northern portion of the MLRA, which lacks big sagebrush (dry grassland), to live the rest of the year (Smith, 2013).

Areas of the till plain near the Bearpaw and Highwood Mountains as well as the Sweetgrass Hills and Rocky Mountain foothills are at higher elevations, receive higher amounts of precipitation, and have a typic-ustic moisture regime. These areas have significantly more rangeland production than the drier aridic-ustic portions of the MLRA and have enough moisture to produce crops annually rather than just bi-annually, as in the drier areas. Ecological sites in this higher precipitation area are classified as the Moist Grassland climatic zone.

Classification relationships

NRCS Soil Geography Hierarchy
• Land Resource Region: Northern Great Plains
• Major Land Resource Area (MLRA): 052 Brown Glaciated Plains
• Climate Zone: Dry Shrubland

National Hierarchical Framework of Ecological Units (Cleland et al., 1997; McNab et al., 2007)
• Domain: Dry
• Division: Temperate Steppe
• Province: Great Plains-Palouse Dry Steppe Province 331
• Section: Northwestern Glaciated Plains 331D
• Subsection: Montana Glaciated Plains 331Dh
• Landtype Association/Landtype Phase: N/A

National Vegetation Classification Standard (Federal Geographic Data Committee, 2008)
• Class: Xeromorphic Woodland, Scrub and Herb Vegetation Class (3)
• Subclass: Cool Semi-Desert Scrub and Grassland Subclass (3.B)
• Formation: Cool Semi-Desert Scrub and Grassland Formation (3.B.1)
• Division: Cool Semi-Desert Scrub and Grassland Division (3.B.1.Ne)
• Macrogroup: Artemisia tridentata - Artemisia tripartita ssp. tripartita - Purshia tridentata Steppe and Shrubland Macrogroup (3.B.1.Ne.3)
• Group: Artemisia tridentata ssp. wyomingensis - Artemisia tridentata ssp. tridentata Steppe and Shrubland Group (3.B.1.Ne.3.a)

• Alliance: Artemisia tridentata ssp. wyomingensis Dry Steppe and Shrubland Alliance
• Association: No existing correlation

EPA Ecoregions
• Level 1: Great Plains (9)
• Level 2: West-Central Semi-Arid Prairies (9.3)
• Level 3: Northwestern Glaciated Plains (42)
• Level 4: North-Central Brown Glaciated Plains (42o) and Glaciated Northern Grasslands (42j)

Ecological site concept

This provisional ecological site occurs in the Dry Shrubland climatic zone of MLRA 52. Figure 1 illustrates the distribution of this ecological site based on current data. This map is approximate, is not intended to be definitive, and may be subject to change. Dense Clay Sodic Dry Shrubland is a moderately extensive ecological site occurring on alluvial landscapes throughout MLRA 52. It occurs on fans, drainageways, and terraces where clay and salts have accumulated.

The distinguishing characteristic of this site is that soils contain more than 35 percent clay in the upper 4 inches and that saline, sodic, or saline-sodic conditions are evident in the upper 20 inches of soil. Soils for this ecological site are typically very deep (more than 60 inches) and derived from clayey glaciolacustrine or outwash deposits. Soil textures in the upper 4 inches are typically clay, clay loam, silty clay or silty clay loam. Soils typically have an ochric epipedon. Characteristic vegetation is western wheatgrass (Pascopyrum smithii), saltbush (Atriplex spp.), and Wyoming big sagebrush (Artemisia tridentata subsp. Wyomingensis).

Associated sites

FX052X03X094	**Loamy Sodic (Losd) Dry Shrubland** This site occupies similar landscapes and slope positions as Dense Clay Sodic Dry Shrubland ecological site but occurs in areas where clay content is 35 percent or less.
FX052X99X091	**Saline Overflow (Sov)** This site is downslope from the Dense Clay Sodic Dry Shrubland ecological site. It typically is in perennial or intermittent drainages; whereas, the Dense Clay Sodic Dry Shrubland ecological site occurs in upland or ephemeral drainageways.

Similar sites

FX052X03X094	**Loamy Sodic (Losd) Dry Shrubland** This site differs from Dense Clay Sodic Dry Shrubland ecological site in that soils contain 35 percent or less clay in the upper 4 inches.
FX052X01X012	**Dense Clay Sodic (Dcsd) Dry Grassland** This site differs from Dense Clay Sodic Dry Shrubland ecological site in that it has slightly cooler annual temperatures and supports silver sagebrush rather than big sagebrush.
FX052X99X091	**Saline Overflow (Sov)** This site differs from Dense Clay Sodic Dry Shrubland ecological site in that it is found on higher order stream reaches and receives enough additional moisture to significantly increase production; whereas, the Dense Clay Sodic Dry Shrubland ecological site occurs in uplands or ephemeral drainageways and does not receive additional moisture to increase production.
FX052X03X010	**Dense Clay (DC) Dry Shrubland** This site differs from Dense Clay Sodic Dry Shrubland in that soils do not exhibit saline, sodic, or saline-sodic conditions in the upper 20 inches of the profile. This is evidenced by the lack of sodium-tolerant shrubs, such as saltbush and greasewood.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY708MT

Physiographic features

Dense Clay Sodic Dry Shrubland ecological site is moderately extensive, occurring on fans, drainageways, and terraces.

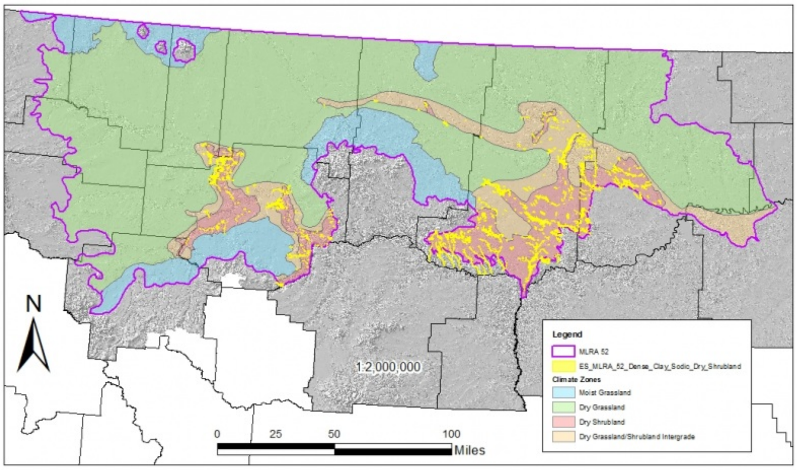

Figure 2. Figure 1. General distribution of the Dense Clay Sodic Dry Shrubland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Fan (2) Drainageway (3) Terrace
Elevation	2,000–3,870 ft
Slope	0–14%
Aspect	Aspect is not a significant factor

Climatic features

The Brown Glaciated Plains is a semi-arid region with a temperate continental climate that is characterized by frigid winters and warm to hot summers (Cooper et al., 2001). The average frost-free period for this ecological site is 125 days. The majority of precipitation occurs as steady, soaking, frontal system rains in late spring to early summer. Summer rainfall comes mainly from convection thunderstorms that typically deliver scattered amounts of rain in intense bursts. These storms may be accompanied by damaging winds and large-diameter hail and result in flash flooding along low-order streams. Severe drought occurs on average in 2 out of 10 years. Annual precipitation ranges from 10 to 14 inches, and 70 to 80 percent of this occurs during the growing season (Cooper et al., 2001). Extreme climatic variations, especially droughts, have the greatest influence on species cover and production (Coupland, 1958, 1961; Biondini et al., 1998).

During the winter months, the western half of MLRA 52 commonly experiences chinook winds, which are strong west to southwest surface winds accompanied by abrupt increases in temperature. The chinook winds are strongest on the western boundary of the MLRA near the Rocky Mountain foothills and decrease eastward. In addition to producing damaging winds, prolonged chinook episodes can result in drought or vegetation kills due to a reaction of plants to a “false spring” (Oard, 1993).

Table 3. Representative climatic features

Frost-free period (average)	125 days

Freeze-free period (average)	145 days
Precipitation total (average)	13 in

Climate stations used

- (1) CONTENT 3 SSE [USC00241984], Zortman, MT
- (2) FT BENTON [USC00243113], Fort Benton, MT
- (3) FT PECK PWR PLT [USC00243176], Fort Peck, MT
- (4) LOMA 1 WNW [USC00245153], Loma, MT
- (5) MALTA 7 E [USC00245338], Malta, MT
- (6) MALTA 35 S [USC00245340], Zortman, MT

Influencing water features

This is a semi arid upland site and the water budget is normally contained within the soil pedon. During intense precipitation events, precipitation rates frequently exceed infiltration rates and this site delivers moisture to downslope sites via surface runoff. Moisture loss through evapotranspiration exceeds precipitation for the majority of the growing season. Soil moisture levels are greatest in May and June, but rarely reach field capacity in the upper 40 inches.

Soil features

The soil series that best represent the central concept for this ecological site are Marvan and Vanda. The Dense Clay Sodic concept covers about 325,000 acres in MLRA 52. The Marvan soil is in the Haplusterts great group. Its underlying horizons exhibit strong shrink-swell characteristics, as evidenced by slickensides (USDA-NRCS, 2016). The Vanda soil is in the Ustorthents great group. Its underlying horizons exhibit some shrink-swell properties but do not exhibit slickensides. The particle-size family for both of these soils is fine, meaning that the soils contain between 35 and 60 percent clay in the particle-size control section, and minerology is smectitic. The typical parent material for these series is clayey alluvium. These and all soils in this concept are characterized by an accumulation of salts in the upper 20 inches and a surface horizon that lacks enough organic matter to have a mollic epipedon. The soil moisture regime for all soils in this ecological site concept is ustic bordering on aridic, which means that the soils are moist in some or all parts for either 180 cumulative days or 90 consecutive days during the growing season but are dry in some or all parts for over 90 cumulative days. These soils have a frigid soil temperature regime (Soil Survey Staff, 2014).

Surface horizon textures on this site are commonly clay, clay loam, or silty clay loam. The upper 4 inches of soil contains more than 35 percent clay. The underlying horizons typically contain 35 to 60 percent clay and have clay, clay loam, silty clay or silty clay loam textures. Organic matter in the surface horizon typically ranges from 0.5 to 2 percent organic matter, and moist colors vary from grayish brown (2.5Y 5/2) to dark grayish brown (2.5Y 4/2). Calcium carbonate equivalent is typically less than 15 percent throughout the soil profile. The upper 20 inches of soil contain accumulated salts, as evidenced by an electrical conductivity of 4 or more, a sodium absorption ratio of 13 or more, or both. Soil pH classes are moderately acid to slightly alkaline in the surface horizon and neutral to strongly alkaline in the subsurface horizons. The soil depth class for this is site can be moderately deep (between 20 and 40 inches to bedrock) in places where bedrock is present but is typically very deep (greater than 60 inches to bedrock). Coarse fragments are typically rare or absent in the upper 20 inches of soil.

Table 4. Representative soil features

Parent material	(1) Alluvium
Surface texture	(1) Clay (2) Clay loam (3) Silty clay loam
Drainage class	Well drained
Soil depth	20–72 in

Available water capacity (0-40in)	4–5.8 in
Calcium carbonate equivalent (0-5in)	0–9%
Electrical conductivity (0-20in)	4–16 mmhos/cm
Sodium adsorption ratio (0-20in)	13–40
Soil reaction (1:1 water) (0-40in)	5.6–9
Subsurface fragment volume <=3" (0-20in)	0–34%
Subsurface fragment volume >3" (0-20in)	0–34%

Ecological dynamics

The information in this ecological site description, including the state-and-transition model (STM), was developed based on historical data, current field data, professional experience, and a review of the scientific literature. As a result, all possible scenarios or plant species may not be included. Key indicator plant species, disturbances, and ecological processes are described to inform land management decisions.

The Dense Clay Sodic Dry Shrubland ecological site in MLRA 52 consists of five states: the Reference State (1), the Shortgrass State (2), the Invaded State (3), the Cropland State (4), and the Post-Cropland State (5). Plant communities associated with the Dense Clay Sodic Dry Shrubland ecological site evolved under the combined influences of climate, grazing, and fire. Extreme climatic variability results in frequent droughts, which can have the greatest influence on the relative contribution of species cover and production (Coupland, 1958, 1961; Biondini et al., 1998). Due to the dominance of cool-season graminoids, annual production is highly dependent upon mid- to late-spring precipitation (Heitschmidt and Vermeire, 2005; Anderson, 2006).

Native grazers also shaped these plant communities. American bison (Bison bison) were the dominant historic grazer, but pronghorn (Antilocapra americana), elk (Cervus canadensis), and deer (Odocoileus spp.) were also common. Small mammals such as prairie dogs (Cynomys spp.) and ground squirrels (Urocitellus spp.) also influenced this plant community (Salo et al., 2004). Grasshoppers and periodic outbreaks of Rocky Mountain locusts (Melanoplus spretus) also played an important role in the ecology of these communities (Lockwood, 2004).

Fire is a critical dynamic on the Dense Clay Sodic Dry Shrubland ecological site. The historic ecosystem experienced periodic lightning-caused fires. Historically, Native Americans also set periodic fires. The majority of lightning-caused fires occurred in July and August; whereas, Native Americans typically set fires during spring and fall to correspond with the movement of bison (Higgins, 1986). It is difficult to precisely determine the fire return interval in the Dry Shrubland climate zone, but estimates range from 6 to 25 years (Bragg, 1995) to 10 to 70 years (Howard, 1999). It is believed that the frequency and intensity of fire would be less on this ecological site than on adjacent sites due to the sparse vegetative cover. Generally, the herbaceous vegetation is resilient to fire and the primary effects of fire are reduction of litter and short term fluctuations in production (Vermeire et al., 2011, 2014). However, studies have shown that very short fire return intervals (less than 5 years) can have a negative effect, shifting species composition toward warm-season, short-statured grasses (Shay et al., 2001; Smith and McDermid, 2014). Conversely, fire has a significant effect on Wyoming big sagebrush cover. Wyoming big sagebrush is a non-sprouting shrub and is most often killed by fire (Howard, 1999). Often, it may take 30 years or more for a stand to recover following fire (Watts and Wambolt, 1996; Wambolt et. al., 2001). It is likely that fire return intervals shorter than 30 years will result in a reduction in Wyoming big sagebrush cover over the long term. Long-term fire suppression in the 20th century removed periodic fire from the ecosystem altogether. Very little is known how this has affected the Dry Shrubland ecosystem. Some studies suggest an increase in Wyoming big sagebrush cover, presumably due to fire suppression (Bloom-Cornelius, 2011). Increased decadence in Wyoming big sagebrush may also occur (Howard, 1999), but these results are inconclusive.

Lack of periodic fires can also result in an increase in litter accumulation and, in some cases, provide ideal conditions for seed germination and seedling establishment of non-native annual brome species, such as field or Japanese brome (*Bromus arvensis*) (Whisenant, 1990). These species have become naturalized in relatively undisturbed grasslands (Ogle et al., 2003; Harmoney, 2007) and can be present in any state within the scope of this ecological site. They typically do not have a significant ecological impact; however, their presence can reduce the production of cool-season perennial grasses in some cases (Haferkamp et al., 1997). Their abundance varies depending on precipitation and germination conditions. The fire-recovery cycle is a critical element in managing the Dry Shrubland ecosystem. Further study is needed in this area to determine a balanced and sustainable fire cycle.

Improper grazing of this site can result in a reduction in the cover of the mid-statured cool-season, rhizomatous wheatgrasses and an increase in shortgrasses (Smoliak et al., 1972; Smoliak, 1974). Improper grazing practices include any practices that do not allow sufficient opportunity for plants to physiologically recover from a grazing event or multiple grazing events within a given year, and that do not provide adequate cover to prevent soil erosion over time. These practices may include, but are not limited to, overstocking, continuous grazing, and inadequate seasonal rotation moves over multiple years. Periods of extended drought (approximately 3 years or more) can reduce mid-statured, rhizomatous wheatgrasses, triggering an increase in shortgrasses such as Sandberg bluegrass (*Poa secunda*) (Coupland, 1961; Clarke et al., 1947).

Further degradation of the site due to improper grazing can result in a community dominated by shortgrasses such as Sandberg bluegrass. Cover and vigor of mid-statured rhizomatous grasses and palatable shrubs are severely reduced. Unpalatable forbs such as curlycup gumweed (*Grindelia squarrosa*) are common. Cover of foxtail barley (*Hordeum jubatum*) can also increase. An invaded state occurs when non-native species invade the site. Potential invasive species on this site are curly dock (*Rumex crispus*) and non-native annual bromes. Invasive species dynamics are not well understood at this time and further investigation is needed to fully document ecological pathways and processes.

The Dense Clay Sodic Dry Shrubland ecological site is poorly suited to cropland. Regardless, many acres have been converted to cropland. Cereal grains such as wheat and barley are, at best, marginally successful on this site. Crop production typically ceases within a few years due to low yields and large input costs. More commonly, cropping operations are directed at increasing perennial hay production. Seeding of introduced grasses for hay production may be successful, particularly if salt-tolerant species such as RS, or hybrid, wheatgrass (*Elymus hoffmannii*) are used. Irrigation is sometimes used in an effort to increase production, but this site is poorly suited to irrigation practices due to accumulated salts and very low intake rates.

When taken out of production, the site is either allowed to revert back to perennial grassland or is seeded with introduced species. Sites left to undergo natural plant succession after cultivation can, over several decades, support cool-season rhizomatous wheatgrasses, although cover and production of these species are lower than in the Reference State (1). Those sites seeded with non-native species, particularly salt-tolerant grasses, may persist with this cover type indefinitely. When reseeded to native species, it may take over 75 years for the soil on productive sites to return to the pre-disturbed state (Dormaar and Willms, 1990). The Dense Clay Sodic Dry Shrubland ecological site may take longer due to the difficult growing conditions, but further investigation is needed to better evaluate this.

The state-and-transition model (STM) diagram (Figure 2) suggests possible pathways that plant communities on this site may follow as a result of a given set of ecological processes and management. The site may also support states not displayed in the STM diagram. Landowners and land managers should seek guidance from local professionals before prescribing a particular management or treatment scenario. Plant community responses vary across this MLRA due to variability in weather, soils, and aspect. The Reference State (1) may not necessarily be the management goal. The lists of plant species and species composition values are provisional and are not intended to cover the full range of conditions, species, and responses for the site. Species composition by dry weight is provided when available and is considered provisional based on the sources identified in the narratives associated with each community phase.

State 1: Reference State
The Reference State (1) contains three community phases characterized by mid-statured, rhizomatous wheatgrasses, saltbush, and Wyoming big sagebrush, a perennial, evergreen, non-sprouting shrub. Both western wheatgrass and thickspike wheatgrass (*Elymus lanceolatus*) can occur on this site, but western wheatgrass tends to be predominant in the Dry Shrubland due to its greater tolerance of higher temperatures and droughty conditions (Coupland 1961; Cooper et al., 2001; Heidel et al., 2000). This state evolved under the combined influences of

climate, grazing, and fire with climatic variation having the greatest influence on cover and production. In general, this state was resilient to grazing, although heavy grazing could influence species composition in localized areas.

Phase 1.1: Shrubland Community Phase
The Shrubland Community Phase (1.1) is dominated by western wheatgrass, saltbush, and Wyoming big sagebrush. Palatable shrubs such as Gardner saltbush (*Atriplex gardneri*), fourwing saltbush (*Atriplex canescens*), and winterfat (*Krascheninnikovia lanata*) are common. Short-statured grasses such as Sandberg bluegrass (*Poa secunda*) are not abundant in this phase but are generally present at low cover. Foxtail barley and greasewood (*Sarcobatus vermiculatus*) may also be present at low cover. Common forbs are American vetch (*Vicia americana*) and scarlet globemallow (*Sphaeralcea coccinea*). The principle shrub on this site is Wyoming big sagebrush; canopy cover is typically 5 to 15 percent. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*
Western wheatgrass 40%
Sandberg bluegrass 5%
Other native grasses 15%
Perennial forbs 10%
Wyoming big sagebrush 15% (canopy cover 5-15%)
Saltbush spp. 10%
Other shrubs/subshrubs 5%

Estimated Total Annual Production (lbs./ac)*
Low - 400
Representative Value - 550
High - 700
*Estimated based on current data – subject to revision

Phase 1.2: Post-Fire Community Phase
The Post-Fire Community Phase (1.3) occurs when the plant community is burned either by wildfire or prescribed fire and may persist for as long as 30 years after burning. It is characterized by a rhizomatous wheatgrass dominated plant community. Short-statured grasses such as Sandberg bluegrass (*Poa secunda*) are not abundant in this phase but are generally present at low cover. Foxtail barley may also be present at low cover. Total cover of shortgrasses is similar to the Shrubland Community Phase (1.1). Saltbush, particularly Gardner's saltbush, recovers rapidly after fire (Howard, 2003; Reed, 1993) and is common in this phase. Wyoming big sagebrush will be eliminated or nearly so immediately following fire. Recovery of Wyoming big sagebrush depends on many factors including climate, proximity to a seed source, and fire intensity. Typically, there is little or no regeneration for 5 to 10 years post-fire, then cover begins to increase gradually until an equilibrium level is reached (Watts and Wambolt, 1996). Generally recovery is prolonged, sometimes taking as long as 30 years (Wambolt et al., 2001).

Phase 1.3: At-Risk Community Phase
The At-Risk Community Phase (1.3) occurs when site condition declines due to drought, improper grazing management, or a combination of these factors. This community phase is characterized by an increase in shortgrasses such as Sandberg bluegrass and a decline in mid-statured grasses. The cover of shortgrasses equals or nearly equals cover of mid-statured grasses. Palatable shrubs sustain browsing damage and are beginning to decline in vigor in this phase. Unpalatable forbs such as curlycup gumweed also increase in this phase. Cover of Wyoming big sagebrush will vary depending on the length of time since the last burn.

Community Phase Pathway 1.1a
Fire will transition the Shrubland Community Phase (1.1) to the Post-Fire Community Phase (1.2). Wyoming big sagebrush is killed and perennial grasses will dominate the site.

Community Phase Pathway 1.1b
Drought, improper grazing management, or a combination of these factors can shift the Shrubland Community Phase (1.1) to the At Risk Community Phase (1.3). These factors favor an increase in shortgrasses and a decrease in cool-season midgrasses (Coupland, 1961). Wyoming big sagebrush cover will be similar to the Shrubland Community Phase (1.1).

Community Phase Pathway 1.2a
Thirty years or more of natural vegetative regrowth will transition the Post-Fire Community Phase (1.2) to the Shrubland Community Phase (1.1). Thirty years or more without fire permits Wyoming big sagebrush to recolonize the site.

Community Phase Pathway 1.2b
Drought, improper grazing management, or a combination of these factors can shift the Post-Fire Community Phase (1.2) to the At Risk Community Phase (1.3). These factors favor an increase in shortgrasses and a decrease in cool-season midgrasses (Coupland, 1961). Wyoming big sagebrush cover will be similar to the Post-Fire Community Phase (1.2).

Community Phase Pathway 1.3a
Less than 30 years post-fire; normal or above-average precipitation and proper grazing management transitions the At Risk Community Phase (1.3) to the Post-Fire Community Phase (1.2).

Community Phase Pathway 1.3b
Thirty years or more post-fire; normal or above-average precipitation and proper grazing management transitions the At Risk Community Phase (1.3) to the Shrubland Community Phase (1.1).

Transition T1A
Prolonged drought, improper grazing practices, or a combination of these factors weaken the resilience of the Reference State (1) and drive its transition to the Shortgrass State (2). The Reference State (1) transitions to the Shortgrass State (2) when mid-statured graminoids become rare and contribute little to production. Shortgrasses, particularly Sandberg bluegrass, and unpalatable forbs dominate the plant community.

Transition T1B
The Reference State (1) transitions to the Invaded State (3) when invasive plant species or noxious weeds invade the Shortgrass State (2). These communities are commonly adjacent to seeded pastures. Exotic plant species dominate the site in terms of cover and production. Site resilience has been substantially reduced. In addition, other rangeland health attributes, such as reproductive capacity of native grasses and soil quality, have been substantially altered from the Reference State (1).

Transition T1C
Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Reference State (1) to the Cropland State (4).

State 2: Shortgrass State
The Shortgrass State (2) consists of two community phases. The dynamics of this state are driven by long-term drought, improper grazing management, or a combination of these factors. Shortgrasses increase with long-term improper grazing at the expense of cool-season midgrasses (Coupland, 1961; Biondini and Manske, 1996; Derner and Whitman, 2009). Reductions in stocking rates can reduce shortgrass cover and increase the cover of cool-season midgrasses, although this recovery may take decades (Dormaar and Willms, 1990). Cover of Wyoming big sagebrush varies depending on fire frequency, with dynamics similar to the Reference State (1).

Phase 2.1: Shrub/Shortgrass Community Phase
The Shrub/Shortgrass Community Phase (2.1) occurs when site conditions decline due to long-term drought or improper grazing, and a fire has not occurred on the site for at least 30 years. In this phase, mid-statured rhizomatous wheatgrasses have been largely eliminated and replaced by short-statured species, such Sandberg bluegrass. Heavy browsing of palatable shrubs is common, and species such as Gardner saltbush and winterfat are rare and have poor vigor. Foxtail barley and unpalatable forbs such as curlycup gumweed may also become common in this phase. Cover of Wyoming big sagebrush is 5 to 15 percent.

Phase 2.2: Shortgrass Community Phase
The Shortgrass Community Phase (2.2) occurs when site conditions decline due to long-term drought or improper grazing, and a fire has occurred on the site less than 30 years prior. In this phase, mid-statured rhizomatous wheatgrasses have been largely eliminated and replaced by short-statured species, such Sandberg bluegrass. Heavy browsing of palatable shrubs is common, and species such as Gardner saltbush and winterfat are rare and have poor vigor. Foxtail barley and unpalatable forbs such as curlycup gumweed may also become common in this

phase. Wyoming big sagebrush is rare.

Community Phase Pathway 2.1a
Fire will transition the Shrub/Shortgrass Community Phase (2.1) to the Shortgrass Community Phase (2.2). Wyoming big sagebrush is killed and perennial grasses will dominate the site.

Community Phase Pathway 2.2a
It is believed that 30 years or more of natural vegetative regrowth could transition the Shortgrass Community Phase (2.2) to the Shrub/Shortgrass Community Phase (2.1). It is possible that this transition could occur over time, however, the processes are not fully understood at this time. Therefore, this pathway is considered hypothetical until further investigation can be completed.

Transition T2A
The Shortgrass State (2) transitions to the Invaded State (3) when invasive plant species invade the Reference State (1). These communities are commonly adjacent to seeded pastures. Exotic plant species dominate the site in terms of cover and production. Site resilience has been substantially reduced. In addition, other rangeland health attributes, such as reproductive capacity of native grasses and soil quality, have been substantially altered from the Reference State (1).

Transition T2B
Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Shortgrass State (2) to the Cropland State (4). The Dense Clay Sodic Dry Shrubland ecological site is poorly suited to cropland. Regardless, many acres have been converted to cropland. Cereal grains such as wheat and barley are, at best, marginally successful on this site. Crop production typically ceases within a few years due to low yields and large input costs. More commonly, cropping operations are directed at increasing perennial hay production.

Restoration Pathway R2A
A reduction in livestock grazing pressure alone may not be sufficient to reduce the cover of blue grama in the Shortgrass State (2) (Dormaar and Willms, 1990). Practices such as range seeding may be necessary (Hart et al., 1985), but these are management intensive and costly. Therefore, returning the Shortgrass State (2) to the Reference State (1) can require considerable energy and cost and may not be feasible within a reasonable amount of time.

State 3: Invaded State
The Invaded State (3) occurs when invasive plant species invade adjacent native grassland communities. Invasive species dynamics on this site are not well understood. Crested wheatgrass has been documented on this site, but it does not appear to overtake it as it does on other sites. Other invasive species that could be a concern are curly dock and annual bromes. Annual bromes are generally not a significant concern in MLRA 52, however, in the Dry Shrubland, there could be instances where they do significantly affect the site. More information is needed to assess this condition. Noxious weeds such as leafy spurge have not been documented on this site and it is not known if they would invade. These are very aggressive species that typically displace native species and dominate ecological function when they invade a site. Further study is needed to fully access the ecological dynamics of the Invaded State (3).

Transition T3A
Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Invaded State (3) to the Cropland State (4). The Dense Clay Sodic Dry Shrubland ecological site is poorly suited to cropland. Regardless, many acres have been converted to cropland. Cereal grains such as wheat and barley are, at best, marginally successful on this site. Crop production typically ceases within a few years due to low yields and large input costs. More commonly, cropping operations are directed at increasing perennial hay production.

State 4: Cropland State
The Cropland State (4) occurs when land is put into cultivation. Major crops in MLRA 52 include winter wheat, spring wheat, and barley. This site is poorly suited to crops, and cereal grain production is generally short lived.

Transition T4A

The transition from the Cropland State (4) to the Post-Cropland State (5) occurs with the cessation of cultivation. The site may also be seeded to perennial forage species. Such seedings may be comprised of introduced grasses and legumes, or a mix of native species.

State 5: Post-Cropland State
The Post-Cropland State (5) occurs when cultivated cropland is abandoned and allowed to either re-vegetate naturally or is seeded back to perennial species for grazing or wildlife use. This state can transition back to the Cropland State (4) if the site is put back into cultivation. No formal studies have been obtained regarding big sagebrush recovery following cultivation. Preliminary evidence suggests that, initially, silver sagebrush may replace big sagebrush in this state. Further investigation is needed to assess big sagebrush recovery in the Post-Cropland State (5).

Phase 5.1: Abandoned Cropland Phase
The Abandoned Cropland Phase (5.1) occurs in the absence of active management, the site can re-vegetate naturally and, over time, potentially return to a perennial grassland community with rhizomatous wheatgrasses and shortgrasses. Shortly after cropland is abandoned, annual and biennial forbs and annual brome grasses invade the site (Samuel and Hart, 1994). The site is highly susceptible to erosion due to the absence of perennial species. Eventually, these pioneering annual species are replaced by perennial species such as western wheatgrass. Depending on the historical management of the site, perennial bunchgrasses may also return; however, species composition will depend upon the seed bank. Invasion of the site by exotic species, such as crested wheatgrass and annual bromes, will depend upon the site’s proximity to a seed source.

Fifty or more years after cultivation, these sites may have species composition similar to phases in the Reference State (1). However, soil quality is consistently lower than conditions prior to cultivation (Dormaar and Smoliak, 1985; Christian and Wilson, 1999) and a shift to the Reference State (1) is unlikely within a reasonable timeframe.
Phase 5.2: Perennial Grass Phase
The Perennial Grass Phase (5.2) occurs when the site is seeded to perennial forage species, particularly introduced perennial grasses, this community phase can persist for several decades. Crested wheatgrass, in particular, is very aggressive and may form monocultures persisting for at least 60 years (Krzic et al., 2000; Henderson and Naeth, 2005). A mixture of native species may also be seeded to provide species composition and structural complexity similar to that of the contemporary Reference State (2). However, soil quality conditions have been substantially altered and will not return to pre-cultivation conditions within a reasonable timeframe (Dormaar et al., 1990).

Transition T5A
Tillage or application of herbicide followed by seeding of cultivated crops, such as winter wheat, spring wheat, and barley, transitions the Post-Cropland State (5) to the Cropland State (4). The Dense Clay Sodic Dry Shrubland ecological site is poorly suited to cropland. Regardless, many acres have been converted to cropland. Cereal grains such as wheat and barley are, at best, marginally successful on this site. Crop production typically ceases within a few years due to low yields and large input costs. More commonly, cropping operations are directed at increasing perennial hay production.

State and transition model

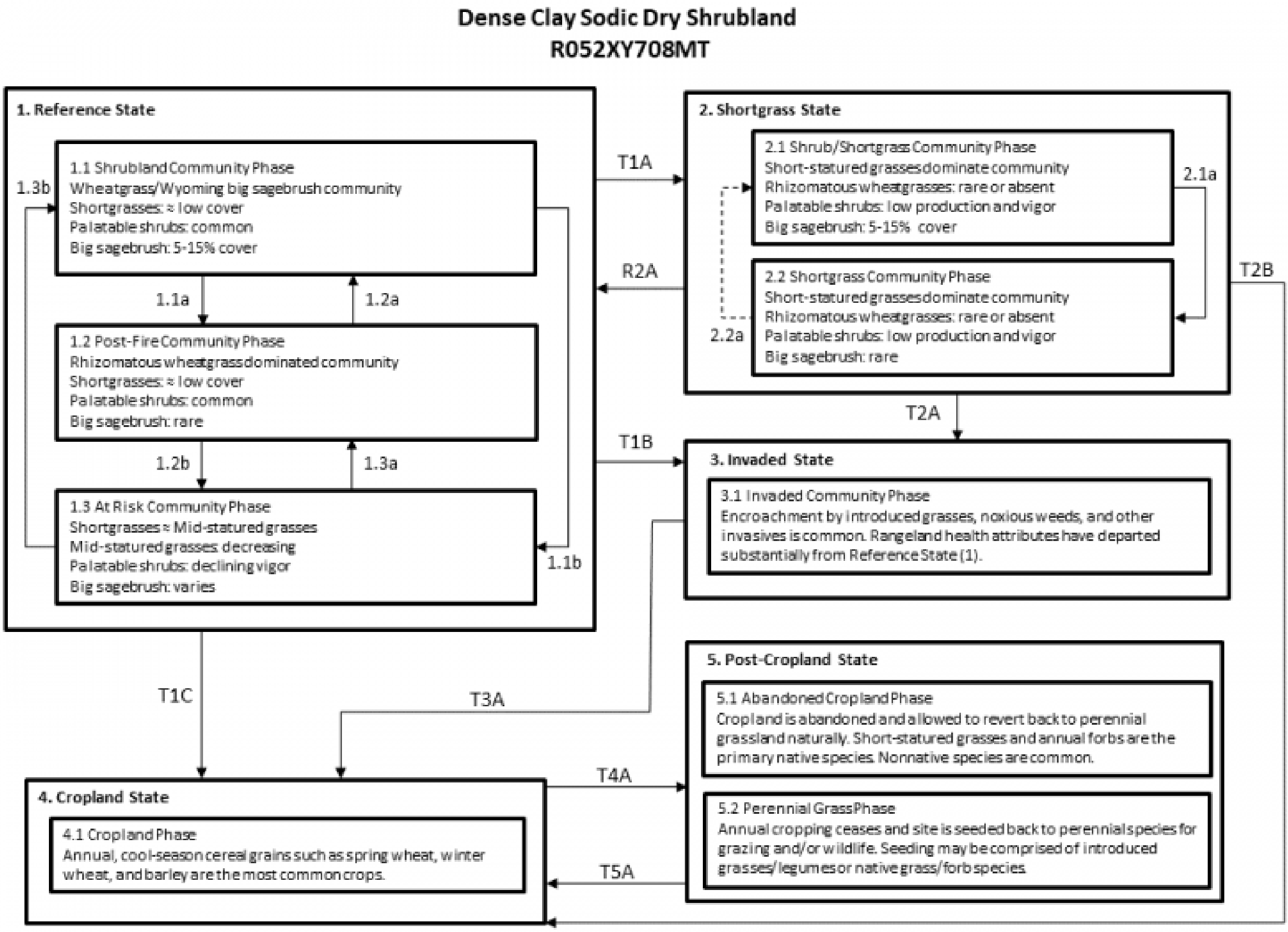

Figure 2. State-and-transition diagram.

Dense Clay Sodic Dry Shrubland
R052XY708MT

Legend

1.1a, 2.1a - fire
1.2a, 2.2a - approximately 30 years post-fire regrowth
1.1b - drought, improper grazing management
1.2b - drought, improper grazing management
1.3a - normal or above average precipitation, proper grazing management (< 30 years post fire)
1.3b - normal or above average precipitation, proper grazing management (≥ 30 years post fire)
T1A - prolonged drought, improper grazing, or a combination of these factors
T1B - introduction of non-native invasive species (crested wheatgrass, noxious weeds, etc.)
T2A - introduction of weedy species; combined with drought and/or improper grazing management
R2A - range seeding, grazing land mechanical treatment, timely moisture, proper grazing management (management intensive and costly)
T1C, T2B, T3A, T5A - conversion to cropland
T4A - cessation of annual cropping

Note: dashed arrows represent hypothesized pathways

Figure 3. State-and-transition legend.

Inventory data references

Data for this provisional ecological site was obtained from five medium intensity plots. These plots, in combination with professional experience and a review of the scientific literature, were used to approximate the reference plant community. Information for other states and community phases was obtained from a review of the scientific literature and professional experience. All community phases are considered provisional based on these plots and the sources identified in this ecological site description.

Other references

Adams, B.W., et al. 2013. Rangeland plant communities for the dry mixedgrass natural subregion of Alberta. Second approximation. Rangeland Management Branch, Policy Division, Alberta Environment and Sustainable Resource Development, Lethbridge, Pub. No. T/040.

Anderson, R.C. 2006. Evolution and origin of the central grassland of North America: Climate, fire, and mammalian grazers. Journal of the Torrey Botanical Society 133:626-647.

Baskin, J.M., and C.C. Baskin. 1981. Ecology of germination and flowering in the weedy winter annual grass Bromus japonicus. Journal of Range Management 34:369-372.

Biondini, M.E., and L. Manske. 1996. Grazing frequency and ecosystem processes in a northern mixed prairie, USA. Ecological Applications 6:239-256.

Biondini, M.E., B.D. Patton, and P.E. Nyren. 1998. Grazing intensity and ecosystem processes in a northern mixed-grass prairie, USA. Ecological Applications 8:469-479.

Bloom-Cornelius, I.V. 2011. Vegetation response to fire and domestic and native ungulate herbivory in a Wyoming big sagebrush ecosystem. M.S. thesis, Oklahoma State University. Stillwater, OK.

Bragg, T.B. 1995. The physical environment of the Great Plains grasslands. In: A. Joern and K.H. Keeler (eds.) The Changing Prairie, Oxford University Press, Oxford, pp. 49-81.

Branson, D.H., and G.A. Sword. 2010. An experimental analysis of grasshopper community responses to fire and livestock grazing in a northern mixed-grass prairie. Environmental Entomology 39:1441-1446.

Bylo, L.N., N. Koper, and K.A. Molloy. 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. Rangeland Ecology and Management 67:247-254.

Christian, J.M., and S.D. Wilson. 1999. Long-term ecosystem impacts of an introduced grass in the Northern Great Plains. Ecology 80:2397-2407.

Clarke, S.E, E.W. Tisdale, and N.A. Skoglund. 1947. The effects of climate and grazing practices on short-grass prairie vegetation in southern Alberta and southwestern Saskatchewan. Canadian Department of Agriculture Technical Bulletin No. 46.

Cleland, D.T., et al. 1997. National hierarchical framework of ecological units. In: M.S. Boyce and A. Haney (eds.) Ecosystem Management Applications for Sustainable Forest and Wildlife Resources, Yale University Press, New Haven, CT.

Cooper, S.V., C. Jean, and P. Hendricks. 2001. Biological survey of a prairie landscape in Montana’s glaciated plains. Report to the Bureau of Land Management. Montana Natural Heritage Program, Helena.

Coupland, R.T. 1950. Ecology of the mixed prairie of Canada. Ecological Monographs 20:271-315.

Coupland, R.T. 1958. The effects of fluctuations in weather upon the grasslands of the Great Plains. Botanical Review 24:273-317.

Coupland, R.T. 1961. A reconsideration of grassland classification in the Northern Great Plains of North America. Journal of Ecology 49:135-167.

Coupland, R.T., and R.E. Johnson. 1965. Rooting characteristics of native grassland species in Saskatchewan. Journal of Ecology 53:475-507.

Davis, S.K., R.J. Fisher, S.L. Skinner, T.L. Shaffer, and R.M. Brigham. 2013. Songbird abundance in native and planted grassland varies with type and amount of grassland in the surrounding landscape. Journal of Wildlife Management 77:908-919.

Derner, J.D., and R.H. Hart. 2007. Grazing-induced modifications to peak standing crop in northern mixed-grass prairie. Rangeland Ecology and Management 60:270-276.

Derner, J.D., and A.J. Whitman. 2009. Plant interspaces resulting from contrasting grazing management in northern mixed-grass prairie: Implications for ecosystem function. Rangeland Ecology and Management 62:83-88.

Derner, J.D., W.K. Lauenroth, P. Stapp, and D.J. Augustine. 2009. Livestock as ecosystem engineers for grassland bird habitat in the western Great Plains of North America. Rangeland Ecology and Management 62:111-118.

Dix, R.L. 1960. The effects of burning on the mulch structure and species composition of grasslands in western North Dakota. Ecology 41:49-56.

Dormaar, J.F., and S. Smoliak. 1985. Recovery of vegetative cover and soil organic matter during revegetation of abandoned farmland in a semiarid climate. Journal of Range Management 38:487-491.

Dormaar, J.F., S. Smoliak. and W.D. Willms. 1990. Soil chemical properties during succession from abandoned cropland to native range. Journal of Range Management 43:260-264.

Dormaar, J.F., and W.D. Willms. 1990. Effect of grazing and cultivation on some chemical properties of soils in the mixed prairie. Journal of Range Management 43:456-460.

Dormaar, J.F., B.W. Adams, and W.D. Willms. 1994. Effect of grazing and abandoned cultivation on a Stipa-Bouteloua community. Journal of Range Management 47:28-32.

Dormaar, J.F., M.A. Naeth, W.D. Willms, and D.S. Chanasyk. 1995. Effect of native prairie, crested wheatgrass (Agropyron cristatum) and Russian wildrye (Elymus junceus) on soil chemical properties. Journal of Range Management 48:258-263.

Fansler, V.A., and J.M. Mangold. 2010. Restoring native plants to crested wheatgrass stands. Restoration Ecology 19:16-23.

Federal Geographic Data Committee. 2008. The National Vegetation Classification Standard, Version 2. FGDC Vegetation Subcommittee. FGDC-STD-005-2008 (Version 2). pp. 126.

Fullerton, D.S., and R.B. Colton. 1986. Stratigraphy and correlation of the glacial deposits on the Montana Plains. U.S. Geological Survey.

Fullerton, D.S., R.B. Colton, C.A. Bush, and A.W. Straub. 2004. Map showing spatial and temporal relations of mountain and continental glaciations on the northern plains, primarily in northern Montana and northwestern North Dakota. U.S. Geologic Survey pamphlet accompanying Scientific Investigations Map 2843.

Fullerton, D.S., R.B. Colton, and C.A. Bush. 2013. Quaternary geologic map of the Shelby 1° x 2° quadrangle, Montana: U.S. Geological Survey Open-File Report 2012–1170, scale 1:250,000.

Haferkamp, M.R., R.K. Heitschmidt, and M.G. Karl. 1997. Influence of Japanese brome on western wheatgrass yield. Journal of Range Management 50:44-50.

Harmoney, K.R. 2007. Grazing and burning Japanese brome (Bromus japonicus) on mixed grass rangelands. Rangeland Ecology and Management 60:479-486.

Hart, M., S.S. Waller, S.R. Lowry, and R.N. Gates. 1985. Disking and seeding effects on sod bound mixed prairie. Journal of Range Management 38:121-125.

Heidel, B., S.V. Cooper, and C. Jean. 2000. Plant species of special concern and plant associations of Sheridan County, Montana. Report to U.S. Fish and Wildlife Service. Montana Natural Heritage Program, Helena, Montana.

Heidinga, L., and S.D. Wilson. 2002. The impact of an invading alien grass (Agropyron cristatum) on species turnover in native prairie. Diversity and Distributions 8:249-258.

Heitschmidt, R.K., and L.T. Vermeire. 2005. An ecological and economic risk avoidance drought management decision support system. In: J.A. Milne (ed.) Pastoral Systems in Marginal Environments, XXth International Grasslands Congress, July 2005, p. 178.

Henderson, A.E., and S.K. Davis. 2014. Rangeland health assessment: A useful tool for linking range management and grassland bird conservation? Rangeland Ecology and Management 67:88-98.

Henderson, D.C., and M.A. Naeth. 2005. Multi-scale impacts of crested wheatgrass invasion in mixed-grass prairie. Biological Invasions 7:639-650.

Herrick, J.E., J.W. Van Zee, K.M. Havstad, L.M. Burkett, and W.G. Whitford. 2009. Monitoring manual for grassland, shrubland and savanna ecosystems. U.S. Department of Agriculture, Agricultural Research Service, Jornada Experimental Range, Las Cruces, NM.

Higgins, K.F. 1986. Interpretation and compendium of historical fire accounts in the Northern Great Plains. U.S. Fish and Wildlife Service Resource Publication 161.
Holechek, J.L. 1981. Crested wheatgrass. Rangelands 3:151-153.

Howard, J.L. 1999. Artemisia tridentata subsp. wyomingensis. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service http://www.fs.fed.us/database/feis/plants/shrub/arttriw/all.html accessed (8/11/2016).

Howard, J.L. 2003. *Atriplex canescens*. In: Fire Effects Information System, U.S. Department of Agriculture, Forest Service http://www.fs.fed.us/database/feis/plants/shrub/atrcan/all.html accessed (9/13/2016).

Joern, A. 2005. Disturbance by fire frequency and bison grazing modulate grasshopper assemblages in tallgrass prairie. Ecology 86:861-873.

Knopf, F.L. 1996. Prairie legacies—birds. In: F.B. Samson and F.L. Knopf (eds.) Prairie Conservation: Preserving North America's Most Endangered Ecosystem, Island Press, Washington, DC, pp. 135-148.

Knopf, F.L., and F.B. Samson. 1997. Conservation of grassland vertebrates. In: F.B. Samson and F.L. Knopf (eds.) Ecology and Conservation of Great Plains Vertebrates: Ecological Studies 125, Springer-Verlag, New York, NY, pp. 273-289.

Krzic, M., K. Broersma, D.J. Thompson, and A.A. Bomke. 2000. Soil properties and species diversity of grazed crested wheatgrass and native rangelands. Journal of Range Management 53:353-358.

Lacey, J., R. Carlstrom, and K. Williams. 1995. Chiseling rangeland in Montana. Rangelands 17:164-166.

Lauenroth, W.K., O.E. Sala, D.P. Coffin, and T.B. Kirchner. 1994. The importance of soil water in recruitment of Bouteloua gracilis in the shortgrass steppe. Ecological Applications 4:741-749.

Laycock, W.A. 1988. History of grassland plowing and grass planting on the Great Plains. In: J.E. Mitchell (ed.) Impacts of the Conservation Reserve Program in the Great Plains—Symposium Proceedings, September 16-18, 1987. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-158.

Laycock, W.A. 1991. Stable states and thresholds of range condition on North American rangelands. Journal of

Range Management 44:427-433.

Lesica P. and T.H. DeLuca. 1996. Long-term harmful effects of crested wheatgrass on Great Plains grassland ecosystems. Journal of Soil and Water Conservation 51:408-409.

Lockwood, J.A. 2004. Locust: The devastating rise and mysterious disappearance of the insect that shaped the American frontier. Basic Books, New York, NY.

Looman, J., and D.H. Heinrichs. 1973. Stability of crested wheatgrass pastures under long-term pasture use. Canadian Journal of Plant Science 53:501-506.

Madden, E.M., R.K. Murphy, A.J. Hansen, and L. Murray. 2000. Models for guiding management of prairie bird habitat in northwestern North Dakota. American Midland Naturalist 144:377-392.

McNab, W.H., et al. 2007. Description of ecological subregions: Sections of the conterminous United States [CD-ROM]. USDA Forest Service, General Technical Report WO-76B.

Miller, J.J., and J.A. Brierley. 2011. Solonetzic soils of Canada: Genesis, distribution, and classification. Canadian Journal of Soil Science 91:889-902.

Montana State College. 1949. Similar vegetative rangeland types in Montana. Montana State College, Agricultural Experiment Station.

Mushet, D.M., N.H. Euliss, Jr., and C.A. Stockwell. 2012. A conceptual model to facilitate amphibian conservation in the Northern Great Plains. Great Plains Research 22:45-58.

Nesser, J.A., G.L. Ford, C.L. Maynard, and D.S. Page-Dumroese. 1997. Ecological units of the Northern Region: Subsections. USDA Forest Service, Intermountain Research Station, General Technical Report INT-GTR-369.

Oard, M.J. 1993. A method of predicting chinook winds east of the Montana Rockies. Weather and Forecasting 8:166-180.

Ogle, S.M., W.A. Reiners, and K.G. Gerow. 2003. Impacts of exotic annual brome grasses (Bromus spp.) on ecosystem properties of the northern mixed grass prairie. American Midland Naturalist 149:46-58.

Reed, W.R. 1993. *Atriplex gardneri*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service. http://www.fs.fed.us/database/feis/plants/shrub/atrgar/all.html accessed (9/13/2016)

Roath, L.R. 1988. Implications of land conversions and management for the future. In: J.E. Mitchell (ed.) Impacts of the Conservation Reserve Program in the Great Plains—Symposium Proceedings, September 16-18, 1987. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-158.

Rogler, G.A., and R.J. Lorenz. 1983. Crested wheatgrass: Early history in the United States. Journal of Range Management 36:91-93.

Romo, J.T. 2011. Clubmoss, precipitation, and microsite effects on emergence of graminoid and forb seedlings in the semiarid northern mixed prairie of North America. Journal of Arid Environments 75:98-105.

Rowe, J.S. 1969. Lightning fires in Saskatchewan grassland. Canadian Field Naturalist 83:317-327.

Salo, E.D., et al. 2004. Grazing intensity effects on vegetation, livestock and non-game birds in North Dakota mixed-grass prairie. Proceedings of the 19th North American Prairie Conference, Madison, Wisconsin.

Samuel, M.J., and R.H. Hart. 1994. Sixty-one years of secondary succession on rangelands of the Wyoming High Plains. Journal of Range Management 47:184-191.

Semlitsch, R.D. 2000. Principles for management of aquatic-breeding amphibians. Journal of Wildlife Management 64:615-631.

Shay, J., D. Kunec, and B. Dyck. 2001. Short-term effects of fire frequency on vegetation composition and biomass in mixed prairie in south-western Manitoba. Plant Ecology 155:157-167.

Smith, B., and G.J. McDermid. 2014. Examination of fire-related succession within the dry mixed-grass subregion of Alberta with the use of MODIS and Landsat. Rangeland Ecology and Management 67:307-317.

Smith, R.E. 2013. Conserving Montana's sagebrush highway: Long distance migration in sage-grouse. M.S. thesis, University of Montana, Missoula.

Smoliak, S. 1974. Range vegetation and sheep production at three stocking rates on Stipa-Bouteloua prairie. Journal of Range Management 27:23-26.

Smoliak, S., and J.F. Dormaar. 1985. Productivity of Russian wildrye and crested wheatgrass and their effect on prairie soils. Journal of Range Management 38:403-405.

Smoliak, S., J.F. Dormaar, and A. Johnston. 1972. Long-term grazing effects on Stipa-Bouteloua prairie soils. Journal of Range Management 25:246-250.

Soil Survey Staff. 2014. Keys to soil taxonomy, 12th edition. USDA Natural Resources Conservation Service.

Soller, D.R. 2001. Map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains. U.S. Geological Survey Miscellaneous Investigations Series I-1970-E, scale 1:3,500,000.

Stephens, S.E., J.J. Rotella, M.S. Lindberg, M.L. Taper, and J.K. Ringelman. 2005. Duck nest survival in the Missouri Coteau of North Dakota: Landscape effects at multiple spatial scales. Ecological Applications 15:2137-2149.

Umbanhowar, Jr., C.E. 2004. Interactions of climate and fire at two sites in the Northern Great Plains. Palaeogeography, Palaeoclimatology, and Palaeoecology 208:141-152.
USDA-NRCS. Glossary of Landform and Geologic Terms. In: National soil survey handbook, title 430-VI. Part 629.02c http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/ref/?cid=nrcs142p2_054242 accessed (4/13/2016).

U.S. Fish and Wildlife Service. 2013. Greater sage-grouse (Centrocercus urophasianus) conservation objectives: Final report.

Van Dyne, G.M., and W.G. Vogel. 1967. Relation of Selaginella densa to site, grazing, and climate. Ecology 48:438-444.

Vaness, B.M., and S.D. Wilson. 2007. Impact and management of crested wheatgrass (Agropyron cristatum) in the northern Great Plains. Canadian Journal of Plant Science 87:1023-1028.

Vermeire, L.T., J.L. Crowder, and D.B. Wester 2011. Plant community and soil environment response to summer fire in the northern Great Plains. Rangeland Ecology and Management 64:37-46.

Vermeire, L.T., J.L. Crowder, and D.B. Wester 2014. Semiarid rangeland is resilient to summer fire and postfire grazing utilization. Rangeland Ecology and Management 67:52-60.

Vuke, S.M., K.W. Porter, J.D. Lonn, and D.A. Lopez. 2007. Geologic map of Montana - information booklet: Montana Bureau of Mines and Geology Geologic Map 62-D.

Wambolt, C.L., K.S. Walhof, and M.R. Frisina. 2001. Recovery of big sagebrush communities after burning in south-western Montana. Journal of Environmental Management 61:243-252.

Watts, M.J. and C.L. Wambolt. 1996. Long-term recovery of Wyoming big sagebrush after four treatments. Journal of Environmental Management 46:95-102.

Whisenant, S.G. 1990. Postfire population dynamics of Bromus japonicus. American Midland Naturalist 123:301-308.

Wilson, S.D., and J.M. Shay. 1990. Competition, fire, and nutrients in a mixed-grass prairie. Ecology 71:1959-1967.

With, K.A. 2010. McCown's longspur (Rhynchophanes mccownii). In: A. Poole (ed.) The Birds of North America (online), Cornell Lab of Ornithology, Ithaca. http://bna.birds.cornell.edu/bna/species/09.

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Approval

Scott Brady, 7/02/2019

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Rangeland health reference sheet

Interpreting Indicators of Rangeland Health is a qualitative assessment protocol used to determine ecosystem condition based on benchmark characteristics described in the Reference Sheet. A suite of 17 (or more) indicators are typically considered in an assessment. The ecological site(s) representative of an assessment location must be known prior to applying the protocol and must be verified based on soils and climate. Current plant community cannot be used to identify the ecological site.

Author(s)/participant(s)	
Contact for lead author	
Date	
Approved by	
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:**

2. **Presence of water flow patterns:**

3. **Number and height of erosional pedestals or terracettes:**

4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):**

5. **Number of gullies and erosion associated with gullies:**

6. **Extent of wind scoured, blowouts and/or depositional areas:**

7. **Amount of litter movement (describe size and distance expected to travel):**

8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):**

9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):**

10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:**

11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):**

12. **Functional/Structural Groups (list in order of descending dominance by above-ground annual-production or live foliar cover using symbols: >>, >, = to indicate much greater than, greater than, and equal to):**

    Dominant:

    Sub-dominant:

    Other:

    Additional:

13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):**

14. **Average percent litter cover (%) and depth (in):**

15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):**

16. **Potential invasive (including noxious) species (native and non-native). List species which BOTH characterize degraded states and have the potential to become a dominant or co-dominant species on the ecological site if their future establishment and growth is not actively controlled by management interventions. Species that become dominant for only one to several years (e.g., short-term response to drought or wildfire) are not invasive plants. Note that unlike other indicators, we are describing what is NOT expected in the reference state for the ecological site:**

17. **Perennial plant reproductive capability:**