

Ecological site FX052X03X165 Thin Claypan (Tcp) Dry Shrubland

Last updated: 7/08/2019
Accessed: 05/03/2024

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.

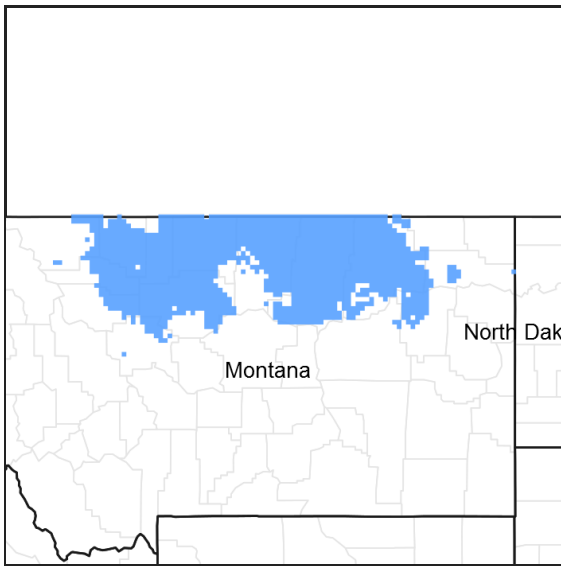


Figure 1. Mapped extent

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 the type of the 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 Illinoian 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* - *Artemisia tripartita* - *Purshia tridentata* Big Sagebrush Steppe and Shrubland Group (3.B.1.Ne.3.b)

- Alliance: *Artemisia tridentata* ssp. *wyomingensis* Mesic Steppe and Shrubland Alliance
- Association: *Artemisia tridentata* ssp. *wyomingensis* / *Pascopyrum smithii* Shrub Grassland

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. Onsite evaluations are necessary, particularly in boundary or intergrade areas where ecological sites from multiple climate zones may overlap. Thin Claypan Dry Shrubland is an extensive ecological site occurring on most landscapes in MLRA 52. It occurs on till plains, moraines, and fans, generally on slopes less than 8 percent. This site is typically associated with Loamy, Panspot, and Claypan ecological sites.

This site is characterized by a dense root restricting layer (evidenced by columnar structure) that is between 1 and 4 inches from the soil surface. The surface texture is typically loam or clay loam. Characteristic vegetation is Wyoming big sagebrush (*Artemisia tridentata* subsp. *wyomingensis*), western wheatgrass (*Pascopyrum smithii*), and blue grama (*Bouteloua gracilis*).

Associated sites

FX052X03X032	Loamy (Lo) Dry Shrubland This site occupies similar landscapes to the Thin Claypan Dry Shrubland ecological site. In the natric soils complex, Loamy is typically found on the highest micro-topography; whereas, Thin Claypan Dry Shrubland ecological site occupies lower positions.
FX052X03X006	Claypan (Cp) Dry Shrubland This site occupies similar landscapes to the Thin Claypan Dry Shrubland ecological site. In the natric soils complex, the Claypan Dry Shrubland ecological site is typically found in mid-level micro-topography, higher than Thin Claypan Dry Shrubland ecological site, but lower than Loamy Dry Shrubland ecological site.
FX052X03X145	Panspot (Pn) Dry Shrubland This site occupies similar landscapes to the Thin Claypan Dry Shrubland ecological site. In the natric soils complex, Panspot Dry Shrubland ecological site is found on the lowest micro-topography in the complex.

Similar sites

FX052X01X165	Thin Claypan (TcP) Dry Grassland This site differs from the Thin Claypan Dry Shrubland ecological site in that it has slightly cooler annual temperatures and supports silver sagebrush rather than big sagebrush.
FX052X03X032	Loamy (Lo) Dry Shrubland This site differs from the Thin Claypan Dry Shrubland ecological site in that the root restricting layer (evidenced by columnar structure) is either absent or greater than 10 inches below the soil surface. Deep rooted bunchgrasses are a major component of the plant community.
FX052X03X006	Claypan (Cp) Dry Shrubland This site differs from the Thin Claypan Dry Shrubland ecological site in that the root restricting layer (evidenced by columnar structure) is greater than 4 inches to 10 inches below the soil surface. Needle and thread occurs, but is not a major plant species.
FX052X03X145	Panspot (Pn) Dry Shrubland This site differs from the Thin Claypan Dry Shrubland ecological site in that the root restricting layer (evidenced by columnar structure) is 1 inch or less from the surface. Commonly occurs in small depressions or pits on the landscape.

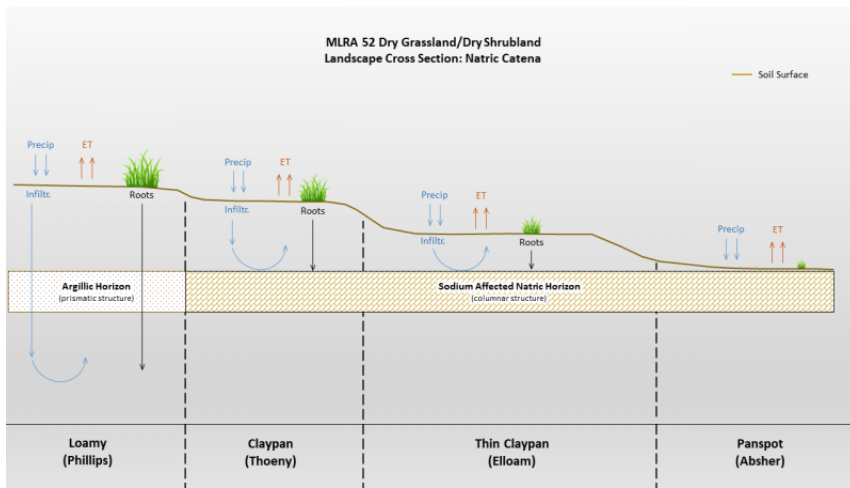


Figure 2. Figure 4. Associated and Similar Sites Diagram.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY731MT

Physiographic features

Thin Claypan Dry Shrubland is an extensive ecological site occurring primarily in the southern portions of MLRA 52. It occurs on till plains and moraines and is most prevalent on the Havre lobe and contiguous Malta sublobe, which stretch from southeastern Alberta and southwestern Saskatchewan through northeastern Hill, central Blaine, and southern Phillips Counties. Much of this lobe consists of an extensive ground moraine with slopes of 0 to 4 percent. The till incorporated physical and chemical properties of the underlying clayey Bearpaw Shale which tends to have appreciable amounts of sodium, magnesium and calcium sulfates but little to no calcium carbonate. It is hypothesized that during and immediately after deglaciation the combination of water-restricting bedrock underlying the sodium-rich clayey till at depths of 10 feet or less combined with the gentler slopes of the till plain created an ideal situation where water could pond and move by matric potential to concentrate enough salts to create the natric horizon and its distinctive columnar structure (Miller and Brierly, 2011). This site is typically found on linear and concave slope positions where slopes are less than 15 percent. The present-day hydrology of this site lacks a water table. Complex micro relief is normal on landforms dominated by natric soils. In relation to the Panspot ecological site, the Thin Claypan Dry Shrubland ecological site is found on microhighs; whereas, when in complex with Claypan Dry Shrubland or Loamy Dry Shrubland ecological sites is found on microlows.

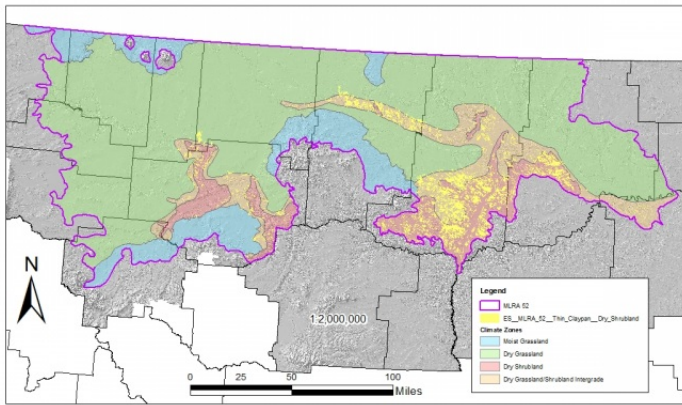


Figure 3. Figure 1. General distribution of the Thin Claypan Dry Shrubland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Till plain > Moraine (2) Till plain > Fan
Elevation	610–1,180 m
Slope	0–8%
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)	330 mm

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 site is a semi-arid upland ecological site, but it has unique hydrology because infiltration is severely limited by the dense natric horizon 1 to 4 inches below the soil surface. Evapotranspiration exceeds precipitation on this site, and a state of moisture deficit persists for the majority of the year. In typical precipitation events, the upper 1 to 4 inches of the soil profile is filled to field capacity, then moisture amounts are quickly diminished by evapotranspiration. Abnormally wet years or very intense precipitation events can saturate the soil surface layer and cause very brief (less than 2 days) ponding and lateral flow via surface runoff into adjacent microlows. Lateral water movement is typically limited to a localized area due to the flat topography. Frequency and duration of saturation are not sufficient for the development of hydric soil features.

Soil features

The soil that best represents the central concept for this ecological site is the benchmark Elloam series which covers over 780,000 acres of MLRA 52. This soil is in the Natrustalfs Great Group and is characterized by a surface horizon that lacks enough organic matter to have a mollic epipedon and by a dense, root-limiting, non-cemented restrictive layer 1 to 4 inches below the soil surface. This restrictive layer is referred to as a natric horizon and is essentially an argillic horizon that has been affected by sodium salts. The natric horizon exhibits distinctive columnar structure that is especially visible when the soil is dry. The Elloam soil is in the fine family and has smectitic mineralogy. Clayey till (28 to 42 percent clay) is the typical parent material for this series but Thin Claypan Dry Shrubland ecological site also occurs on soils derived from glaciofluvial deposits, shale residuum, or till over residuum. The soil moisture regime for this and all other 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 textures found in this site are most frequently loam but can range from fine sandy loam to silty clay loam and usually contain between 15 to 30 percent clay. The underlying natric horizons typically contain 35 to 50 percent clay and have clay, clay loam, or silty clay loam textures. Organic matter in the surface typically ranges from 1 to 2 percent and moist colors vary from brown (10YR 5/3) to dark grayish brown (10YR 4/2). Depth to secondary carbonates and soluble sulfate salts is usually between 5 and 8 inches below the soil surface. Calcium carbonate equivalent in the surface 5 inches is typically less than 5 percent and typically less than 10 percent in lower horizons. In the surface 20 inches; electrical conductivity is at some point more than 2 and less than 8 and the sodium absorption ratio is typically less than 15. These salts lower the amount of plant available water. 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 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 less than 35 percent in the upper 20 inches of soil and are typically less than 15 percent.

Table 4. Representative soil features

Parent material	(1) Till (2) Glaciofluvial deposits (3) Residuum–shale
Surface texture	(1) Loam (2) Fine sandy loam (3) Silty clay loam
Drainage class	Well drained
Depth to restrictive layer	3–10 cm
Soil depth	51–183 cm
Available water capacity (0-101.6cm)	7.62–11.94 cm

Calcium carbonate equivalent (0-12.7cm)	0–4%
Electrical conductivity (0-50.8cm)	0–8 mmhos/cm
Sodium adsorption ratio (0-50.8cm)	2–14
Soil reaction (1:1 water) (0-101.6cm)	5.6–9
Subsurface fragment volume <=3" (0-50.8cm)	0–34%
Subsurface fragment volume >3" (0-50.8cm)	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 Thin Claypan 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 Thin Claypan 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 Thin Claypan Dry Shrubland ecological site. The historic ecosystem experienced relatively frequent lightning-caused fires. Historically, Native Americans also set frequent 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).

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; Harmony, 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 cool-season midgrasses and eventually a decrease in other cool-season graminoids and an increase in blue grama (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/or 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/or inadequate seasonal rotation moves over multiple years. Periods of extended drought can reduce mid-statured, cool-season grasses and shift the species composition of this community to one dominated by blue grama (Coupland, 1958, 1961). Further degradation of the site due to improper grazing can result in a community dominated by shortgrasses such as blue grama and Sandberg bluegrass. Cover of mid-statured grasses and sedges is severely reduced or absent. Cover of prairie sagewort can increase.

The Thin Claypan Dry Shrubland ecological site is not generally considered suitable for cropland. However, a good portion of it has been converted to annual cropland despite the soil limitations. The most common crops are cereal grain crops, such as winter wheat, spring wheat, and barley. When taken out of production, the site is either allowed to revert back to perennial grassland or is seeded with introduced species. Seeding of introduced grasses, particularly crested wheatgrass (*Agropyron cristatum*), was a common practice on eroded and abandoned agricultural areas after the droughts of the 1930s (Rogler and Lorenz, 1983). Crested wheatgrass is a highly drought tolerant and competitive cool season, perennial bunchgrass (Lesica and DeLuca, 1996). Crested wheatgrass can invade relatively undisturbed grasslands, reducing cover and production of native cool-season midgrasses (Heidinga and Wilson, 2002; Henderson and Naeth, 2005). Russian wildrye (*Psathyrostachys juncea*), though less widespread, was introduced in the 1950s to provide forage for livestock (Dormaar et al., 1995). Although Russian wildrye is typically planted in monocultures, this species is not considered invasive. Under ideal conditions, it may be able to spread into adjacent degraded plant communities (Ogle et al., 2012), but such conditions are unlikely in MLRA 52. Sites left to undergo natural plant succession after cultivation can, over several decades, support native vegetation similar to the Reference State (Christian and Wilson, 1999), although it may take over 75 years for soil organic matter to return to its pre-disturbed state (Dormaar and Willms, 1990). However, those sites seeded with non-native species, particularly crested wheatgrass, may persist with this cover type indefinitely (Christian and Wilson, 1999).

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 community phase 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 and Wyoming big sagebrush, a perennial, evergreen, non-sprouting shrub. 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 and fire, although these factors could influence species composition in localized areas. Lesser spikemoss, also known as dense clubmoss (*Selaginella densa*), is frequently present and may constitute significant ground cover. Its dynamics are not well understood, however, and its abundance varies greatly from site to site without discernable reason.

Phase 1.1: Shrubland Community Phase

The Shrubland Community Phase (1.1) is dominated by western wheatgrass (*Pascopyrum smithii*) and Wyoming big sagebrush. Cool-season, mid-statured bunchgrasses such as, needle and thread (*Hesperostipa comata*) are

rare. The mat-forming, warm-season perennial grass, blue grama (*Bouteloua gracilis*) is commonly a subdominant component of this site, comprising approximately 15 percent cover. A number of other shortgrasses and sedges are present at low cover including prairie Junegrass (*Koeleria macrantha*), Sandberg bluegrass (*Poa secunda*), and needleleaf sedge (*Carex duriuscula*). Together, shortgrasses comprise about 25 percent cover, however, due to their short stature, they do not contribute as much to total production as mid-statured grasses. Common forbs are scarlet globemallow (*Sphaeralcea coccinea*) and spiny phlox (*Phlox hoodii*). The principle shrub on this site is Wyoming big sagebrush, canopy cover is typically 5 to 15 percent. The subshrubs prairie sagewort (*Artemisia frigida*) and winterfat (*Krascheninnikovia lanata*) commonly occur at low cover. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*

Western wheatgrass 40%

Blue grama 15%

Sandberg bluegrass 10%

Prairie junegrass 5%

Other native grasses 5%

Perennial forbs 5%

Wyoming big sagebrush 15% (canopy cover 5-15%)

Other shrubs/subshrubs 5%

Estimated Total Annual Production (lbs./ac)*

Low - 350

Representative Value - 500

High - 650

Average Shrub Height (inches)*

Low - 5

Representative Value - 8

High - 11

*Estimated based on current data – subject to revision

Phase 1.2: Post-Fire Community Phase

The Post-Fire Community Phase (1.2) 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-blue grama plant community. The northern portion of MLRA 52 appears to include the area of transition in dominance between thickspike wheatgrass and western wheatgrass (Heidel et al., 2000; Cooper et al., 2001). Both western wheatgrass and thickspike wheatgrass can occur on this site, but western wheatgrass tends to be predominant due to its greater tolerance of higher temperatures and droughty conditions (Coupland 1961; Cooper et al., 2001). Blue grama is common and occurs at a cover of approximately 15 percent. Other species that occur in this phase include prairie Junegrass, Sandberg bluegrass, and sedges. Total cover of shortgrasses is similar to the Shrubland Community Phase (1.1). 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 or improper grazing management. Multiple fires in close succession can also transition the site to this phase. This community phase is characterized by an increase in shortgrasses, particularly the warm-season, mat-forming blue grama, and a decline in mid-statured grasses. If present on the site, cool-season bunchgrasses will become rare or disappear from the site. Prairie Junegrass, Sandberg bluegrass and the subshrub, prairie sagewort, also increase in this phase. The cover of shortgrasses equals or exceeds the cover of mid-statured grasses. 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 blue grama and a decrease in cool-season midgrasses (Coupland, 1961; Shay et al., 2001). 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, multiple fires in close succession, 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 blue grama and a decrease in cool-season midgrasses (Coupland, 1961; Shay et al., 2001). 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 such as blue grama, Sandberg bluegrass, and prairie Junegrass dominate the plant community.

Transition T1B

The Reference State (1) transitions to the Invaded State (3) when aggressive perennial grasses or noxious weeds invade the Shortgrass State (2). Crested wheatgrass, in particular, is a concern when native plant communities are 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 (Henderson and Naeth, 2005) and soil quality (Smoliak and Dormaar, 1985; Dormaar et al., 1995), 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. Blue grama increases with long-term improper grazing at the expense of cool-season midgrasses (Coupland, 1961; Biondini and Manske, 1996; Derner and Whitman, 2009). Once established, blue grama-dominated communities can alter soil properties, creating conditions that resist establishment of other grass species (Dormaar and Willms, 1990; Dormaar et al., 1994). Reductions in stocking rates can reduce blue grama cover and increase the cover of cool-season midgrasses, although this recovery may take decades (Dormaar and Willms, 1990; Dormaar et al., 1994). Dense clubmoss may or may not be present in the Shortgrass State (2). Its density is highly variable and the dynamics of this species are not well understood. 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 grasses have been largely eliminated and replaced by short-statured species, such as blue grama, prairie Junegrass, and Sandberg bluegrass. Blue grama resists grazing due to its low stature and extensive root system. Prairie sagewort may also increase in this phase. When clubmoss is absent, there can be a high amount of bare ground, which exposes the soil to wind and water erosion. 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 grasses have been largely eliminated and replaced by short-statured species, such as blue grama, prairie Junegrass, and Sandberg bluegrass. Blue grama resists grazing due to its low stature and extensive root system. Prairie sagewort may also increase in this phase. When clubmoss is absent, there can be a high amount of bare ground, which exposes the soil to wind and water erosion. 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 aggressive perennial grasses, noxious weeds, and other invasive plants invade the Shortgrass State (2). Exotic plant species dominate the site in terms of cover and production. Site resilience has been substantially reduced.

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).

Restoration Pathway R2A

Blue grama can resist displacement by other species (Dormaar and Willms, 1990; Laycock, 1991; Dormaar et al., 1994; Lacey et al., 1995). 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) and mechanical treatments may be necessary (Hart et al., 1985). Therefore, returning the Shortgrass State (2) to the Reference State (1) can require considerable cost, energy, and time.

State 3: Invaded State

The Invaded State (3) occurs when invasive plant species invade adjacent native grassland communities. Crested wheatgrass is a common concern, especially when native plant communities are adjacent to seeded pastures. An estimated 20 million acres of crested wheatgrass have been planted in the western U.S. (Holechek, 1981). Crested wheatgrass produces abundant seeds that can dominate the seed bank of invaded grasslands (Henderson and Naeth, 2005), although crested wheatgrass cover decreases with increasing distance from seeded areas (Heidinga and Wilson, 2002). The early growth of crested wheatgrass allows this species to take advantage of early season soil moisture, which may result in competitive exclusion of native cool-season rhizomatous wheatgrasses and bunchgrasses, such as needle and thread and prairie Junegrass (Christian and Wilson, 1999; Heidinga and Wilson, 2002; Henderson and Naeth, 2005). Reduced soil quality (Dormaar et al., 1995), reduced plant species diversity, and simplified structural complexity (Henderson and Naeth, 2005) result in a state that is substantially departed from the Reference State (1).

Other invasive species that could be a concern are annual bromes and noxious weeds. Annual bromes are generally not a significant concern in MLRA 52, however, in the Thin Claypan Dry Shrubland ecological site, 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 are uncommon on this site, but they may also invade and displace native

species. Although very aggressive, these species can sometimes be suppressed through intensive management (herbicide application, biological control, or intensive grazing management). Control efforts are unlikely to eliminate noxious weeds, but their density can be sufficiently suppressed so that species composition, structural complexity, and soil quality are similar to that of the Reference State (1). However, cessation of control methods will most likely result in recolonization of the site by the noxious species.

Transition T3A

The Invaded State (3) will transition to the Cropland State (4) when the site is placed under cultivation.

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.

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 as crested wheatgrass and alfalfa, 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 when cropland is abandoned. In the absence of active management, the site can re-vegetate naturally and, over time, potentially return to a perennial grassland community with needle and thread and blue grama. 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 forbs and perennial shortgrasses, such as Sandberg bluegrass and blue grama. Depending on the historical management of the site, perennial bunchgrasses such as needle and thread may also return; however, species composition will depend upon the seed bank. Cover and production of cool-season rhizomatous wheatgrasses is low, even after several decades (Dormaar and Smoliak, 1985; Dormaar et al., 1994; Christian and Wilson, 1999). 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.

Thirty 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 cropping ceases and the site is seeded to perennial forage species. When the site is seeded to introduced perennial grasses, particularly crested wheatgrass; this community phase can persist for several decades. Monocultures of crested wheatgrass can persist 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 (1). 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 5A

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).

State and transition model

**Thin Claypan Dry Shrubland
R052XY731MT**

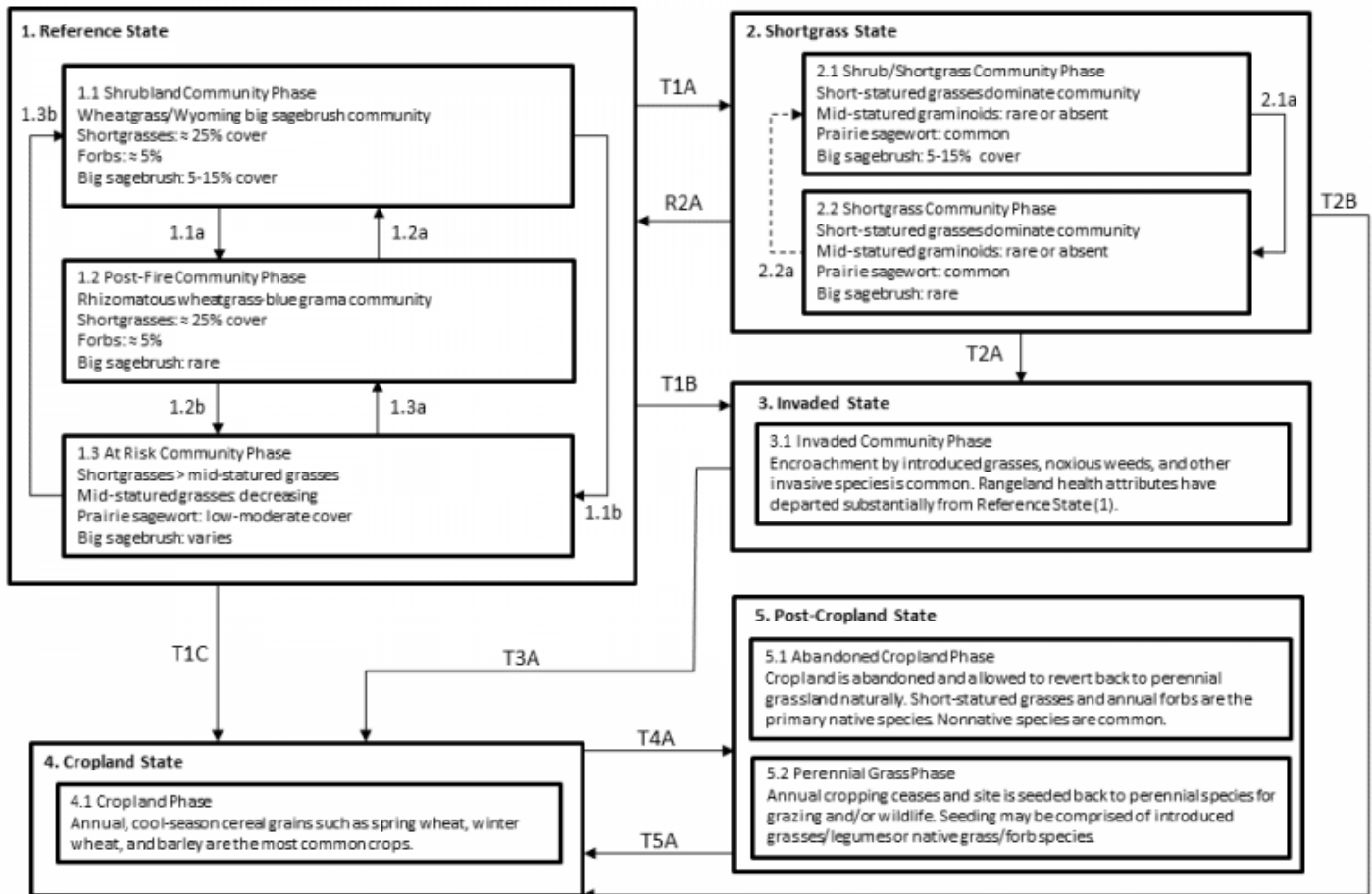


Figure 2. State-and-transition diagram.

**Thin Claypan Dry Shrubland
R052XY731MT**

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, multiple fires in close succession
- 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
- > - Hypothesized Pathway

Figure 3. State-and-transition legend.

Inventory data references

Data for this provisional ecological site was obtained from a total of seven plots ranging from low to high intensity. The Reference State (1) was represented by the following: two high intensity plots, two medium intensity plots, and

two low intensity plots. The Shortgrass State (2) was represented by one low intensity plot. Shrub height was determined from two high intensity plots and one low intensity plot. Information for other states and community phases were 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 the narratives associated with each community phase.

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.
- Dormaer, 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.
- Dormaer, 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.
- Dormaer, 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.
- Dormaer, 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.
- Dormaer, 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/artriw/all.html> accessed (8/11/2016).
- 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. Solonchic 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, D., et al. 2012. Plant guide for Russian wildrye (*Psathyrostachys juncea*). USDA Natural Resources Conservation Service, Aberdeen Plant Materials Center.

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.

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 southwestern 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>

Contributors

Scott Brady
Stuart Veith

Approval

Scott Brady, 7/08/2019

Acknowledgments

This provisional ecological site description could not have been completed without the contributions of Karen Newlon. She conducted an extensive literature review, which provided most of the background information for this project as well as many of the references. She also co-authored the Loamy and Thin Claypan Dry Grassland ecological sites previously prepared in MLRA 52.

A number of USDA-NRCS and USDI-BLM staff supported this project. Staff contributions are as follows:

Soil Concepts, Soils Information, and Field Descriptions
Charlie French, USDA-NRCS
Josh Sorlie, USDI-BLM

NASIS Reports, Data Dumps, and Soil Sorts
Bill Drummond, USDA-NRCS
Pete Weikle, USDA-NRCS

Peer Review and Beta Testing
Kirt Walstad, USDA-NRCS
Kyle Steele, formerly USDA-NRCS
Kelsey Molloy, USDA-NRCS
Rick Caquelin, USDA-NRCS
Josh Sorlie, USDI-BLM
BJ Rhodes, USDI-BLM

Editing
Ann Kinney, USDA-NRCS
Jenny Sutherland, USDA-NRCS

Quality Control
Kirt Walstad, USDA-NRCS

Quality Assurance
Stacey Clark, USDA-NRCS

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:**
-