Ecological site R046XC609MT
Claypan (Cp) RRU 46-C 15-19 PZ

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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.

MLRA notes

Major Land Resource Area (MLRA): 046X–Northern and Central Rocky Mountain Foothills

Major Land Resource Area (MLRA): 046X–Northern Rocky Mountain Foothills

Major Land Resource Area (MLRA) 46, Rocky Mountain Foothills, is approximately 11.6 million acres. MLRA 46's extent has changed over recent years and is now primarily located in Montana and Wyoming with limited acres in Utah and Colorado. It spans from the Canadian border south to the Uinta Mountains of Northwest Colorado. MLRA 46 is a transitional MLRA between the plains and mountains of primarily non-forested rangeland. In Montana, 3 Land Resource Units (LRUs) exist based on differences in geology, landscape, soils, water resources, and plant communities. Elevations for this MLRA in Montana vary from a low of 3200 to 6500 feet (975 to 1981 m) however the elevations on the fringes of this MLRA may fall outside of that range in extremely small isolated areas where the boundaries between neighboring MLRAs are not easily defined. Annual precipitation ranges from 8 inches (254 mm) to, in very isolated areas, 42 inches (1083 mm). In general precipitation rarely exceeds 24 inches (610 mm). Frost-free days are variable from 50 days near the Crazy and Beartooth Mountains to 130 days in the foothills south of the Bear's Paw Mountains of Central Montana. The geology of MLRA 46 is generally Cretaceous and Jurassic marine sediments.

MLRA 46's plant communities are dominated by cool-season bunchgrasses with mixed shrubs. This MLRA is rarely forested; however, ponderosa and limber pine do occupy areas. Portions of this MRLA may have a subdominance of warm-season mid-statured bunchgrasses like little bluestem; however, the general concept of the MLRA does not have a large component of warm-season species. Wyoming big sagebrush, mountain big sagebrush, silver sagebrush, common snowberry, and shrubby cinquefoil tend to be the dominant shrub component. The kind and presences of shrubs tends to be driven by a combination of soils and climate. Due to the variable nature of the Land Resources Units, Climatic subsets will be necessary to describe the ecological sites and the variation of plant communities for this MLRA.

LRU notes

LRU C is generally located in Central Montana. It borders the Little Belt Mountains, Highwood Mountains, Snowy Mountains (Big and Little), Crazy Mountains, and Castle Mountains. Included in this LRU are the foothills of the island mountain groups of the Bear's Paw and Little Rocky Mountains. This LRU borders MLRAs 43B, 52 and 58. LRU C is the second largest of the LRUs located in Montana occupying approximately 2.6 million acres. Cities and towns located in this LRU includes Stanford, Lewistown, Grass Range, and Harlowton. Elevation ranges from 2880 feet (878 m) to 6783 feet (2068 m).

The geology is sedimentary in nature with the majority including the Colorado Shale Formation, Kootenai Formation (mixed sedimentary), Mississippian Formation (carbonatic sedimentary), terrace deposits (alluvium), Tertiary mixed sedimentary. Areas of the Claggett Formation (mudstone), Devonian (carbonatic sedimentary) as well as intrusive and extruvise volcanics (mixed) exist in the foothills of the island mountains. Landforms include hillslopes, drainage ways, fan remnants, valleys, and escarpments.

This LRU is dominated by deep, well drained soils. Soil depth is mixed with 45 percent moderately-deep, 45 percent very deep, and 10 percent other soil depth. Slopes are most frequently 0 to 15 percent and 15 to 30 percent, while higher sloping areas (30-45 percent) exist along the Little Belt and Highwood interfaces. Slightly Acid to Moderately Alkaline soils throughout. Small areas of Moderately Acid soils exist in places, in particular around Highwoods. Vast differences in soil texture within LRU exist likely due to the variation in parent material.

The climate of this LRU is classic to the MLRA concept. The precipitation falls primarily as rain in the spring however areas may receive high amounts of snowfall (i.e. Lewistown). Precipitation ranges are from 13.7 inches (348 mm) to a rare 37.4 inches (942 mm) with 18 inches as an average. This LRU has an average air temperature of 44 degrees Fahrenheit (6.75 degrees C) with a range of 38 degrees Fahrenheit (3.38 degrees C) to 47.3 degrees Fahrenheit (8.52 degrees C). Frost-free days tends to be one of the longest of the Montana LRUs with a range of 70 to 130 days. Soil moisture regime is Ustic with a Frigid soil temperature regime. Due to the variability in climate of this LRU, climatic subsets will be necessary to accurately describe the ecological processes.

Major watersheds within this LRU include Big Spring Creek, Judith River, Swimming Woman Creek, and Musselshell River. These watersheds provide irrigation water for production of small grains and hay. As these watersheds leave the neighboring MLRA 43B, these river systems offer fishing and other recreational opportunities.

Cropland conversion is the largest land conversion within this LRU. Small grains such as wheat and barley are the most common particularly in Judith Basin County. Conversion to recreational property is becoming a more frequent occurrence, particularly near Lewistown.

Ecological site concept

The distinguishing characteristic of this site is the presence of a dense, root-restricting, sodium-affected (natric) horizon at depths between 5 and 10 inches from the soil surface. The natric horizon exhibits columnar structure, is very hard, and severely limits both root penetration and infiltration. Soils are typically moderately deep to very deep (more than 20 inches to bedrock), are derived from till, and occur on slopes of less than 8 percent. Soil surface horizons (0 to 4 inches) are very fine sandy loam to loam, and the natric horizon is clay or clay loam. The root-restrictive natric horizon favors shallow-rooted rhizomatous species, particularly the rhizomatous wheatgrasses, over deep-rooted bunchgrasses. Other common grasses include plains reedgrass (Calamagrostis montanensis), blue grama (Bouteloua gracilis), Sandberg bluegrass (Poa secunda), and needle and thread (Hesperostipa comata).

Associated sites

R046XC602MT	**Dense Clay (DC) RRU 46-C 15-19 PZ** The Dense Clay site is typically a neighboring site with similar plant community and state-and-transition model. The Dense Clay site tends to produce less above ground vegetation.

Similar sites

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Table 1. Dominant plant species

Tree	Not specified
Shrub	(1) *Artemisia cana* (2) *Artemisia tridentata*
Herbaceous	(1) *Pascopyrum smithii* (2) *Nassella viridula*

Physiographic features

Claypan ecological site occurs on the fringes of MLRA 46 where it meets with MLRA 58. The majority of the area is covered by a lacustrine deposit and foothills, and this ecological site largely occurs at higher elevations near the various mountain ranges. It mostly occurs on outwash fans or alluvial fans. The present-day hydrology of this site lacks a water table. As is the case with the Dense Clay (aka Thin Claypan) and Panspot ecological sites, complex micro-topography is typical on landforms dominated by natric soils. In relation to MLRA 52's Panspot and Thin Claypan ecological sites; the Claypan ecological site of MLRA 46 is found on microhighs, whereas when in complex with Loamy ecological sites it is found on microlows.

Table 2. Representative physiographic features

Landforms	(1) Foothills > Alluvial fan (2) Foothills > Outwash fan
Elevation	3,600–4,590 ft
Slope	0–8%
Aspect	Aspect is not a significant factor

Climatic features

The climate of the Claypan ecological site falls into Climatic Subset B. The central concept of Climatic Subset B is 15 to 19 inches Relative Effective Annual Precipitation (REAP) and 70 to 130 frost-free days. Calculated averages based on climate stations suggest that this ecological site receives just over 16 inches of precipitation with 96-121 frost-free days.

The soil temperature regime for this Claypan ecological site is frigid and the soil moisture regime is ustic

Table 3. Representative climatic features

Frost-free period (characteristic range)	88-103 days
Freeze-free period (characteristic range)	118-124 days
Precipitation total (characteristic range)	15-17 in
Frost-free period (actual range)	70-104 days
Freeze-free period (actual range)	116-130 days
Precipitation total (actual range)	15-19 in
Frost-free period (average)	96 days
Freeze-free period (average)	121 days
Precipitation total (average)	16 in

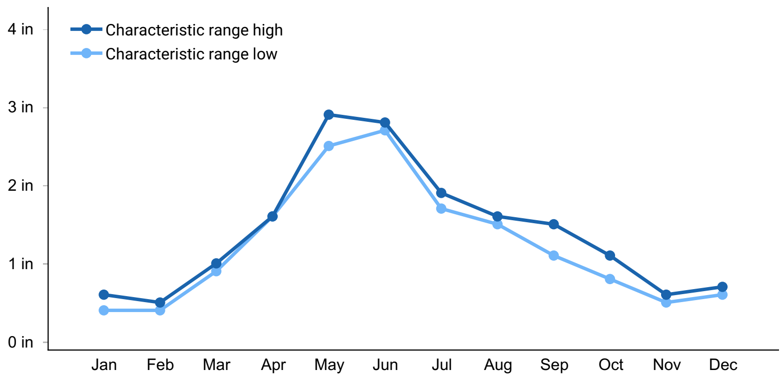

Figure 1. Monthly precipitation range

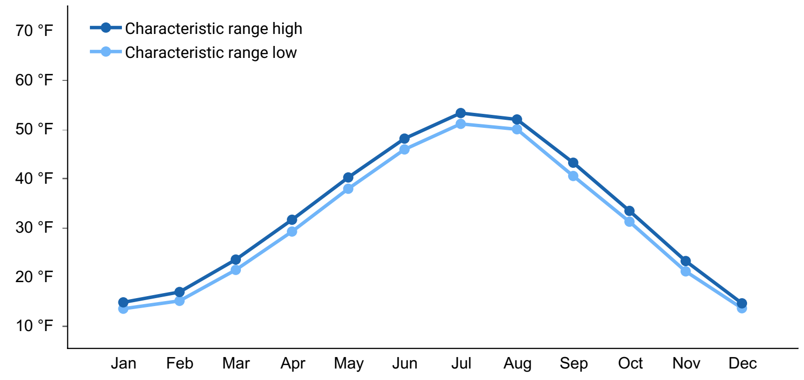

Figure 2. Monthly minimum temperature range

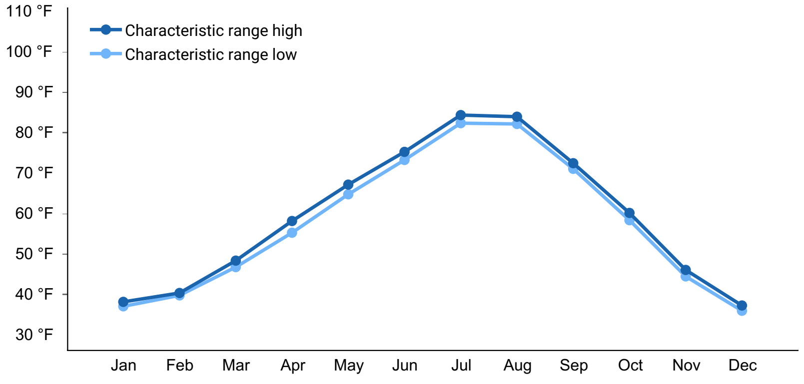

Figure 3. Monthly maximum temperature range

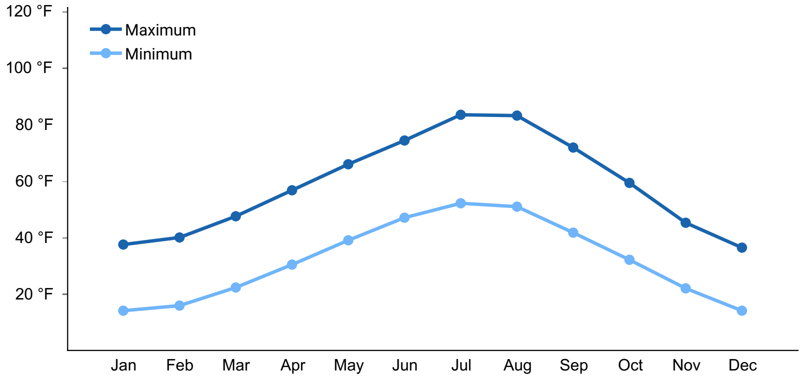

Figure 4. Monthly average minimum and maximum temperature

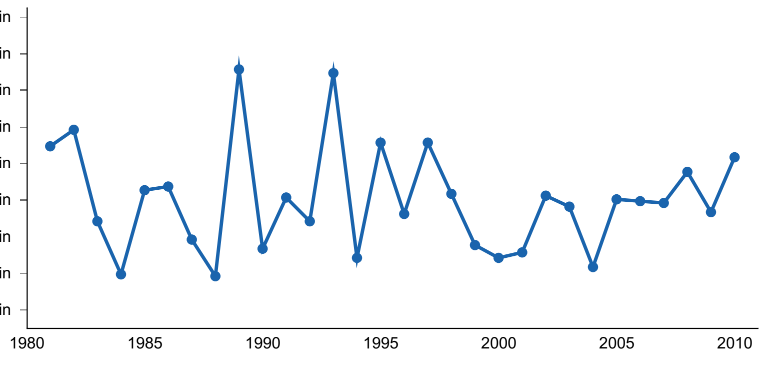

Figure 5. Annual precipitation pattern

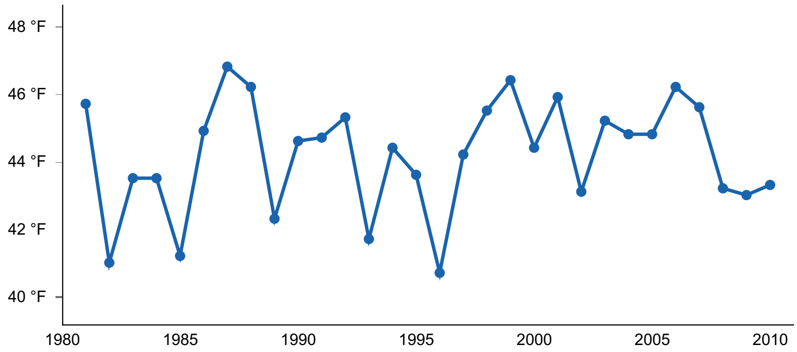

Figure 6. Annual average temperature pattern

Climate stations used

- (1) STANFORD [USC00247864], Stanford, MT
- (2) GERALDINE [USC00243445], Geraldine, MT
- (3) GRASS RANGE [USC00243727], Grass Range, MT
- (4) HARLOWTON [USC00243939], Shawmut, MT

Influencing water features

This is a semi-arid, upland ecological site, but it has unique hydrology because infiltration is severely limited by the dense natric horizon 5 to 10 inches below the soil surface. Evapotranspiration exceeds precipitation on this site, and a moisture deficit state persists for the majority of the year. In typical precipitation events, the upper 5 to 10 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.

Wetland description

n/a

Soil features

The soil series that best represents the central concept of this ecological site is Waltham. This soil is in the Natrustolls great group. It has a relatively dark mollic epipedon and a dense, root-limiting, non-cemented restrictive layer 5 to 10 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 Waltham soil has smectitic minerology and is in the fine family, meaning that it could contain between 35 and 60 percent clay in the particle-size control section. The soil moisture regime for these and all soils in this ecological site concept is typic ustic, 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 found in this site are most frequently loam but can range from fine sandy loam to silty clay loam and typically contain between 15 to 30 percent clay. The underlying natric horizons typically contain 35 to 45 percent clay and have clay, clay loam, or silty clay loam textures. Organic matter content in the surface horizon typically ranges from 2 to 5 percent, and moist colors vary from dark brown (10YR 3/3) to very dark brown (10YR 2/2). The surface of these soils does not typically react with hydrochloric acid. Calcium carbonate equivalent is typically less than 5 percent in the upper 5 inches and typically less than 10 percent in lower horizons. In the upper 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 is 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 to 40 inches to bedrock) in places where bedrock is present but is typically very deep (more than 60 inches to bedrock). Content of coarse fragments is less than 35 percent in the upper 20 inches of soil and typically less than 15 percent.

Table 4. Representative soil features

Parent material	(1) Alluvium–sedimentary rock
Surface texture	(1) Clay loam (2) Sandy clay loam (3) Silty clay loam
Family particle size	(1) Fine
Drainage class	Moderately well drained to well drained
Permeability class	Moderately slow to slow
Soil depth	20–100 in
Surface fragment cover <=3"	0–8%
Surface fragment cover >3"	0–2%
Available water capacity (3.8-5.4in)	3.8–5.4 in
Soil reaction (1:1 water) (0-5in)	7.8–9.6
Subsurface fragment volume <=3" (0-20in)	0–5%
Subsurface fragment volume >3" (0-20in)	0–1%

Ecological dynamics

The information in this ecological site description, including the state-and-transition model (STM) (Figure 2), 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 Claypan provisional ecological site in MLRA 46X 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 this ecological site evolved under the combined influences of climate, grazing, and fire. Extreme climatic variability results in frequent droughts, which 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. Bison (Bison bison) were the dominant historic grazer, but pronghorn (Antilocapra americana), elk (Cervus canadensis), and deer (Odocoileus spp.) were also common. Additionally, small mammals such as prairie dogs (Cynomys spp.) and ground squirrels (Urocitellus spp.) 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).

The historic ecosystem experienced periodic lightning-caused fires with estimated fire return intervals of 6 to 25 years (Bragg, 1995). 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). Generally, the mixedgrass ecosystem is resilient to fire and the primary effects of the historic fire return interval are reduction of litter and short-term fluctuations in production (Vermeire et al., 2011, 2014). However, studies have shown that shorter fire return intervals can have a negative effect, shifting species composition toward warm-season, short-statured grasses (Shay et al., 2001; Smith and McDermid, 2014).

Improper grazing of this site can result in a reduction in the cover of the cool-season, midgrasses 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 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 (approximately 3 years or more) 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 (Poa sandbergii). This site is also susceptible to invasion by non-native species. Non-native perennial bluegrasses (Poa spp.) are the most common invasive species. These species are widespread throughout the Northern Great Plains and appear able to invade any phase of the Reference State (1) (Toledo et al., 2014). Once established, they will displace native species and dominate the ecological functions of the site.

Due to the presence of a sodium-affected natric horizon, this ecological site is not generally regarded as productive cropland. Regardless, many acres have been cultivated and planted to cereal grain crops, such as winter wheat, spring wheat, and barley. When taken out of production, this site is either allowed to revert back to perennial grassland or is seeded back to perennial grass. Such seedings may be comprised of introduced grasses and legumes or a mix of native species. Sites left to undergo natural plant succession after cultivation can, over several decades, support native vegetation similar to the Reference State (1) (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). Sites seeded with non-native species may persist with this cover type indefinitely (Christian and Wilson, 1999). A mix of native species may also be seeded, however, a return to the Reference State (1) in a reasonable amount of time is unlikely.

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 two community phases characterized by mid-statured rhizomatous wheatgrasses and mid-statured bunchgrasses, and shortgrasses such as blue grama. 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: Mixedgrass Community Phase
The Mixedgrass Community Phase (1.1) is characterized by mid-statured, cool-season rhizomatous grasses, which commonly comprise 50 percent or more of the total production on the site. Western wheatgrass (*Pascopyrum smithii*) is the predominant species, however thickspike wheatgrass (*Elymus lanceolatus*) may also occur and becomes more common in the northern extent of this site. Needle and thread is the predominant mid-statured bunchgrass on this ecological site and typically comprises approximately 10 percent of the total production. The mat-forming, warm-season perennial grass blue grama is the most common shortgrass in this phase, although prairie Junegrass (*Koeleria macrantha*) and Sandberg bluegrass may also be present. Common forbs are scarlet globemallow (*Sphaeralcea coccinea*), spiny, or Hood's, phlox (*Phlox hoodii*), and upright prairie coneflower (*Ratibida columnifera*). Shrubs and subshrubs such as prairie sagewort (*Artemisia frigida*) and silver sagebrush (*Artemisia cana*) occur at approximately 5 percent cover. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*

Rhizomatous Wheatgrass 50%
Needle and Thread 10%
Blue Grama 5%
Other Native Grasses 15%
Perennial Forbs 15%
Shrubs/Subshrubs 5%

Estimated Total Annual Production (lbs/ac)*
Low - 800
Representative Value - 1,100
High - 1,400
* Estimated based on current data – subject to revision

Phase 1.2: At-Risk Community Phase
The At-Risk Community Phase (1.2) occurs when site conditions decline due to drought or improper grazing management. Multiple fires in close succession can also transition the site to this phase. It is characterized by nearly equal proportions of rhizomatous wheatgrasses and shortgrasses. Rhizomatous wheatgrasses that are in decline have been substantially reduced in both cover and vigor. Mid-statured bunchgrasses such as needle and thread are rare or absent. Shortgrasses such as blue grama, Sandberg bluegrass, and prairie Junegrass are increasing. Prairie sagewort may also increase in this phase.

Community Phase Pathway 1.1a
Drought, improper grazing management, multiple fires in close succession, or a combination of these factors can shift the Mixedgrass Community Phase (1.1) to the At-Risk Community Phase (1.2). These factors favor an increase in shortgrasses such as blue grama and a decrease in midgrasses (Coupland, 1961; Shay et al., 2001).

Community Phase Pathway 1.2a
Normal or above-normal spring precipitation and proper grazing management transitions the At-Risk Community Phase (1.2) back to the Mixedgrass 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 grasses become rare and contribute little to production. Shortgrasses such as blue grama, prairie Junegrass, and Sandberg bluegrass 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 Reference State (1). The most common concerns are introduced bluegrasses, which are widespread invasive species in the northern Great Plains (Toledo et al., 2014). Studies have shown that exclusion of grazing and fire favors invasive bluegrass species (DeKeyser et al., 2013). 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 consists of one community phase. 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). Blue grama-dominated communities in particular, 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 shortgrass 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 cover varies from rare to abundant. Its dynamics are not well understood, however, and its abundance varies greatly from site to site without discernable reason. Therefore, it is not considered a reliable indicator of past grazing use (Montana State

College, 1949).

Phase 2.1: Shortgrass Community Phase
The Shortgrass Community Phase (2.1), occurs when site conditions decline due to long-term drought or improper grazing. 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. The subshrub, prairie sagewort is common.

Transition T2A
The Shortgrass State (2) transitions to the Invaded State (3) when aggressive perennial grasses or noxious weeds invade the Shortgrass State (2). The most common concerns are introduced bluegrasses, which are widespread invasive species in the northern Great Plains (Toledo et al., 2014). Decreased vigor of native species may be one factor that increases susceptibility to invasion. Studies have also shown that exclusion of grazing and fire favors invasive bluegrass species (DeKeyser et al., 2013). 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).

Restoration Pathway R2A
A reduction in livestock grazing pressure alone may not be sufficient to reduce the cover of shortgrasses in the Shortgrass State (2) (Dormaar and Willms, 1990). Blue grama in particular, can resist displacement by other species (Dormaar and Willms, 1990; Laycock, 1991; Dormaar et al., 1994; Lacey et al., 1995). Intensive management such as reseeding and mechanical treatment may be necessary (Hart et al., 1985), but these practices are labor 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. Introduced bluegrasses, such as Kentucky bluegrass (*Poa pratensis*) and Canada bluegrass (*Poa compressa*), are the most widespread concerns. Kentucky bluegrass, in particular, is widespread throughout the Northern Great Plains (Toledo et al., 2014). It is very competitive and displaces native species by forming dense root mats, altering nitrogen cycling, and creating allelopathic effects on germination (DeKeyser et al., 2013). Plant communities dominated by Kentucky bluegrass have significantly less cover of native grass and forb species (Toledo et al., 2014; Dekeyser et al., 2009). Effects on soil quality are still unknown at this time, but possible concerns are alteration of surface hydrology and modification of soil surface structure (Toledo et al., 2014). Invasive grass species appear to be capable of invading any phase of the Reference State (1), regardless of grazing management practices, and have been found to substantially increase under long-term grazing exclusion (DeKeyser et al., 2009, 2013; Grant et al., 2009). Reduced plant species diversity, simplified structural complexity, and altered biologic processes result in a state that is substantially departed from the Reference State (1).

Noxious weeds such as leafy spurge and Canada thistle are not widespread in MLRA 52, but they do have the potential to invade this site. These species are very aggressive perennials. They typically displace native species and dominate ecological function when they invade a site. In some cases, these species can 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 and structural complexity 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
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).

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 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. The Post-Cropland State (5) can transition back to the Cropland State (4) if the site is put back into cultivation.

Phase 5.1: Abandoned Cropland Community Phase
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 extremely 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 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 are 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 Kentucky bluegrass, 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 Community Phase
When the site is seeded to perennial forage species, particularly introduced perennial grasses, this community phase can persist for several decades. Some introduced species, such as smooth brome, are very aggressive, frequently form a monoculture, and can invade adjacent sites if conditions are favorable. A mixture of native species may also be seeded to provide species composition and structural complexity similar to that of the 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., 1994).

Transition 5A
The Post-Cropland State (5) transitions back to the Cropland State (4) when the site is converted

State and transition model

Claypan

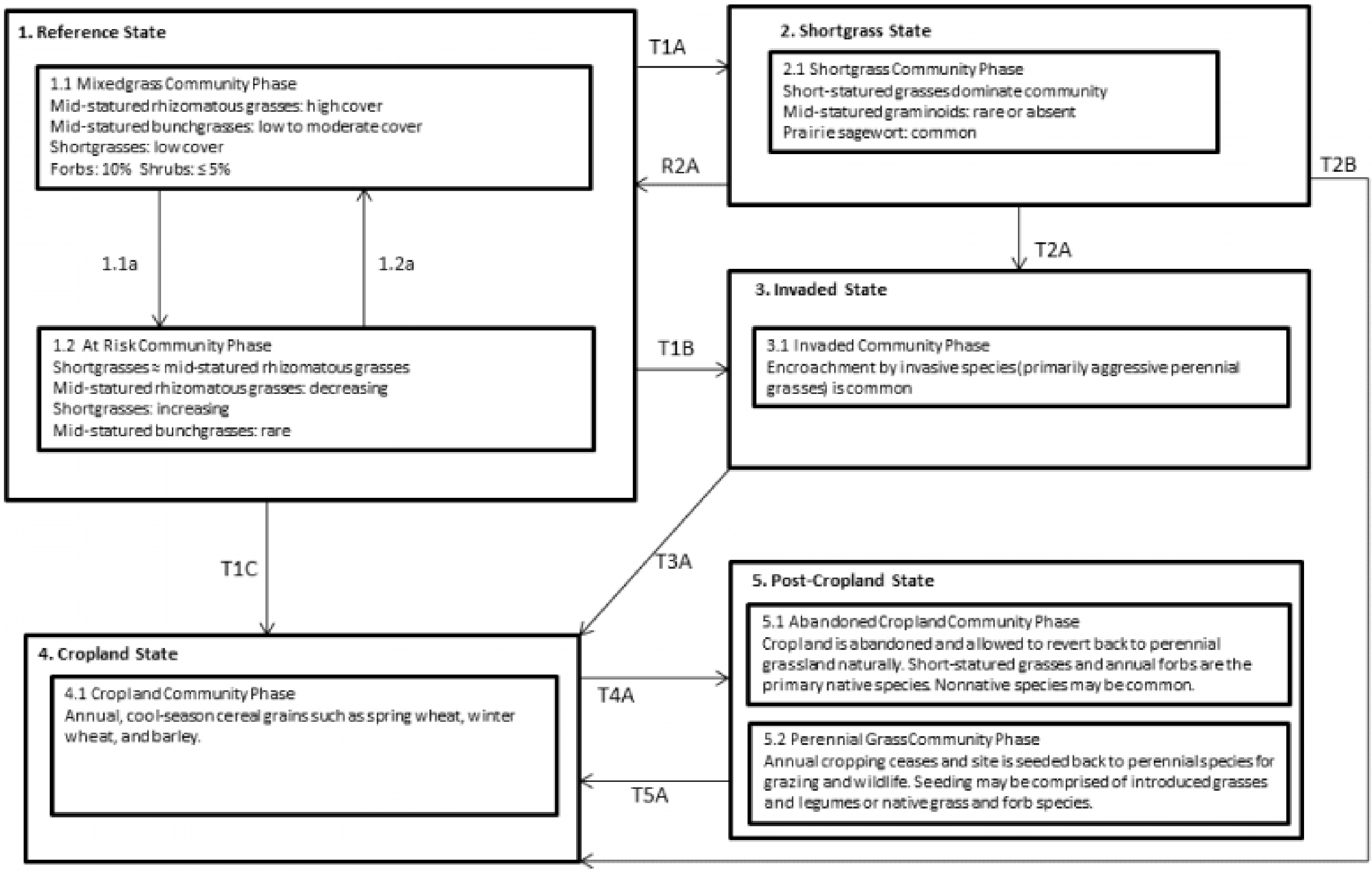

Figure 2. State and Transition Model Diagram.

Claypan

Legend

1.1a - drought, improper grazing management, multiple fires in close succession
1.2a - normal or above-normal spring moisture, proper grazing management
T1A - prolonged drought, improper grazing, or a combination of these factors
T1B - introduction of non-native invasive species (non-native grasses, noxious weeds, etc.)
T2A - introduction of weedy species; combined with drought and improper grazing management
R2A - range seeding, grazing land mechanical treatment, normal or above-normal moisture, proper grazing management (management intensive and costly)
T1C, T2B, T3A, T5A - conversion to cropland
T4A - cessation of annual cropping

Figure 2. State and Transition Model Diagram (Continued).

Animal community

Livestock Grazing Interpretations: Managed livestock grazing is suitable on this site as it has the potential to produce a limited amount of high quality forage. Grazing must be managed carefully on this site to be sure livestock drift onto the better, more productive, and more accessible sites is not excessive. Management objectives should include maintenance or improvement of the native plant community. Livestock accessibility is a significant limitation with this ecological site.

Using shorter grazing periods and providing for adequate re-growth after grazing are recommended for plant maintenance, health, and recovery. Continual non prescribed grazing of this site can be detrimental and will alter the plant composition and production over time. The result will be plant communities that resemble numbers 3 and 4, depending on how long this grazing management is used as well as other circumstances such as weather conditions and fire frequency.

Whenever Plant Community 2 (medium and short grasses) occurs, grazing management strategies that will prevent further degradation need to be implemented. This community is still stable, productive, and healthy provided it receives proper management. It will respond fairly quickly to improved grazing management, including increased growing season rest of key forage plants. Grazing management alone can usually move this back towards the potential / historic climax community.

Plant community 3 is the result of long-term, heavy, continuous grazing and/or annual, early spring seasonal grazing. Repeated heavy early spring grazing, especially during stem elongation (generally mid May through mid June), can also have detrimental affects on the taller, key forage species. Repeated spring grazing depletes stored carbohydrates, resulting in weakening and eventual death of the cool season tall and medium grasses. This plant community can occur throughout the pasture, on spot grazed areas, and around water sources where season-long grazing patterns occur.

It becomes critical at this point to implement a grazing strategy that will restore the stability and health of the site. Additional growing season rest, often combined with facilitating practices (e.g., water developments, fencing), is usually necessary for re-establishment of the desired native species and to restore the stability and health of the site.

Hydrological functions

The runoff potential for this site is very high depending on slope and ground cover/health. Runoff curve numbers generally range from 84 to 93. The soils associated with this ecological site are generally in Hydrologic Soil Group D. The infiltration rates for these soils will normally be very slow.

The hydrologic condition of this site has a significant affect on runoff. The hydrologic condition considers the effects of cover, including litter, and management on infiltration. Good hydrologic condition indicates that the site usually has a lower runoff potential. Plant cover and litter helps retain soil moisture for use by the plants. Maintaining a healthy stand of perennial native vegetation with deep root systems will optimize the amount of precipitation that is received, help maintain or increase infiltration rates and reduce runoff.

For arid and semi-arid rangelands, good hydrologic conditions exist if cover (grass, litter, and brush canopy) is greater than 70%. Fair conditions exist when cover is between 30 and 70%, and poor conditions exist when cover is less than 30%.

Sites in high similarity (Plant Communities 1 & 2) generally have enough plant cover and litter to optimize infiltration, minimize runoff and erosion, and have a good hydrologic condition. Erosion is minor for sites in high similarity. Rills and gullies should not be present. Water flow patterns, if present, will be barely observable. Plant pedestals are essentially non-existent. Plant litter remains in place and is not moved by erosion. Soil surfaces should not be compacted or crusted.

Sites in low similarity (Plant Communities 3 and 4) are generally considered to be in less than good hydrologic condition as the majority of plant cover is from shallow rooted species.

Inventory data references

Information presented was derived from NRCS inventory data, National Resources Inventory (NRI) data, literature, field observations, and personal contacts with range-trained personnel (i.e., used professional opinion of agency specialists, observations of land managers, and outside scientists).

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Contributors

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Approval

Kirt Walstad, 9/07/2023

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.

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Contact for lead author	grant.petersen@usda.gov
Date	03/01/2020
Approved by	Kirt Walstad
Approval date	
Composition (Indicators 10 and 12) based on	Annual Production

Indicators

1. **Number and extent of rills:** Rills are not present in the reference condition.

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2. **Presence of water flow patterns:** Water flow patterns are rarely present except after heavy rainfall events. If present, flow patterns will be short (less than 2 feet).

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3. **Number and height of erosional pedestals or terracettes:** Pedestals are not evident in the reference condition.

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4. **Bare ground from Ecological Site Description or other studies (rock, litter, lichen, moss, plant canopy are not bare ground):** Bare ground is less than 20%. It consists of small, randomly scattered patches.

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5. **Number of gullies and erosion associated with gullies:** Gullies are not present in the reference condition.

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6. **Extent of wind scoured, blowouts and/or depositional areas:** Wind scoured, or depositional areas are not evident in the reference condition.

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7. **Amount of litter movement (describe size and distance expected to travel):** Litter movement is not evident in the reference condition.

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8. **Soil surface (top few mm) resistance to erosion (stability values are averages - most sites will show a range of values):** The average soil stability rating is 4-5 under plant canopies and 3-4 in plant interspaces. The A horizon is 2-8 inches thick.

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9. **Soil surface structure and SOM content (include type of structure and A-horizon color and thickness):** Soil Structure at the surface is medium granular. A Horizon should be 2-8 inches thick with color, when wet, typically ranging in Value of 4 or less and Chroma of 2 or less.
Local geology may affect color, it is important to reference the Official Series Description (OSD) for characteristic range.

https://soilseries.sc.egov.usda.gov/osdname.aspx

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10. **Effect of community phase composition (relative proportion of different functional groups) and spatial distribution on infiltration and runoff:** Infiltration of the Clay Pan ecological site is slow to very slow. The site is well drained. An even distribution of mid stature bunchgrasses (35-40%), rhizomatous grass (35-40%), cool season shortgrasses (10-15%), forbs (1-5%), and shrubs (5-15%) optimizes infiltration and reduces runoff under normal moisture events.

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11. **Presence and thickness of compaction layer (usually none; describe soil profile features which may be mistaken for compaction on this site):** A compaction layer is not present in the reference condition. Soil profile may contain an abrupt transition to an Argillic horizon which can be misinterpreted as compaction, however, the soil structure will be strong medium subangular blocky, where a compaction layer will be platy or structureless (massive).

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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: Mid-statured, cool season, perennial bunchgrasses (bluebunch wheatgrass, green needlegrass) = rhizomatous grasses

    Sub-dominant: shortgrass grasses/grasslikes (blue grama, prairie Junegrass) ≥ shrubs > forbs

    Other:

    Additional:

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13. **Amount of plant mortality and decadence (include which functional groups are expected to show mortality or decadence):** Mortality in herbaceous species is not evident. Species with bunch growth forms may have some natural mortality in centers is 3% or less.

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14. **Average percent litter cover (%) and depth (in):** Total litter cover ranges from 25-30%. Most litter is irregularly distributed on the soil surface and is not at a measurable depth.

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15. **Expected annual annual-production (this is TOTAL above-ground annual-production, not just forage annual-production):** Average annual production is 1050. Low: 800 High 1200. Production varies based on effective precipitation and natural variability of soil properties for this ecological site.

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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:** Potential invasive (including noxious) species (native and non-native). Invasive species on this ecological site include (but not limited to) annual brome spp., spotted knapweed, crested wheatgrass, pale alyssum, field

pennycress (fanweed)
Native species such as broom snakeweed, Sandberg’s bluegrass, blue grama, prickly pear cactus, greasewood, etc. when their populations are significant enough to affect ecological function, indicate site condition departure.

17. **Perennial plant reproductive capability:** In the reference condition, all plants are vigorous enough for reproduction either by seed or rhizomes in order to balance natural mortality with species recruitment.