Ecological site FX052X01X110
Sandy (Sy)
Dry Grassland

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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): 052X–Brown Glaciated Plains

The Brown Glaciated Plains, MLRA 52, is an expansive and agriculturally and ecologically significant area. It consists of around 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, and the maximum glacial extent occurred 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 level terrain that would typically be optimal for farming has large amounts of less-suitable sodium-affected Natrustalfs. Significant portions of Blaine, Phillips, and Valley Counties were glaciated approximately 150,000 years ago during the Illinoisan age. Due to erosion and dissection of the landscape, many of these areas have steeper slopes and more exposed bedrock than areas glaciated during the Wisconsin age (Fullerton and Colton, 1986). While much of the rangeland in the aridic ustic portion of MLRA 52 is classified as belonging to the “dry grassland” climatic zone, sites in portions of southern MLRA 52 may belong to the “dry shrubland” climatic zone. The dry shrubland zone represents the northernmost extent of the big sagebrush (Artemisia tridentata) steppe on the Great Plains. As 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 fully understood at this time. 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 Grassland 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: Mesomorphic Shrub and Herb Vegetation Class (2) •

Subclass: Temperate and Boreal Grassland and Shrubland Subclass (2.B) • Formation: Temperate Grassland, Meadow, and Shrubland Formation (2.B.2) • Division: Great Plains Grassland and Shrubland Division (2.b.2.Nb) • Macrogroup: Andropogon hallii - Calamovilfa longifolia - Artemisia filifolia Great Plains Sand Grassland & Shrubland Macrogroup (2.B.2.Nb.4) • Group: Andropogon hallii - Calamovilfa longifolia - Hesperostipa comata Sand Grassland Group (2.B.2.Nb.4.b) • Alliance: Calamovilfa longifolia Sand Prairie Alliance • Association: Calamovilfa longifolia - Hesperostipa comata 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) & Glaciated Northern Grasslands (42j)

Ecological site concept

This provisional ecological site occurs in the Dry Grassland 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. Sandy Dry Grassland is a moderately extensive ecological site on till plain landscapes in MLRA 52. This ecological site occurs on kames, eskers, and fans. Slopes are typically less than 25 percent but may be steeper in some areas. This site can occur on any slope shape or slope position, although talfs or rises on flats are the most common. The distinguishing characteristics of this site are coarse-loamy textures in the upper 4 inches of soil and a relatively undeveloped soil profile. Calcium carbonate (lime) concentration in the upper 5 inches of soil varies from 0 to 15 percent but is typically 5 percent or less. Soils are typically moderately deep to very deep (more than 20 inches to bedrock) and are primarily derived from glaciofluvial material or alluvium over glacial till. In dissected areas where bedrock is exposed this site can be formed in soft sandstone. Soils in some areas, but not all, have a mollic epipedon. Soil surface textures fall within the coarse-loamy textural family and have less than 18 percent clay and less than 70 percent sand. Underlying horizons commonly have a cambic horizon that exhibits minimal pedogenic development. Species composition is dominated by drought-tolerant plants with deep, extensive root systems. Production potential on this site is typically somewhat less than on a loamy soil due to the reduced available water-holding capacity (AWC). Characteristic vegetation is needle and thread (Hesperostipa comata), threadleaf sedge (Carex filifolia), prairie sandreed (Calamovilfa longifolia), and blue grama (Bouteloua gracilis).

Associated sites

FX052X01X032	**Loamy (Lo) Dry Grassland** This site is generally adjacent to Sandy Dry Grassland. The most typical example is where Sandy kames occur on the till plain which is dominated by the Loamy ecological site.
FX052X01X100	**Sands (Sa) Dry Grassland** This site occurs on undulating topography whereas Sandy Dry Grassland occurs on the fringes of the landscape. It may also be upslope of Sandy Dry Grassland where finer material has moved down the slope.
FX052X01X030	**Limy (Ly) Dry Grassland** This site is generally adjacent to Sandy Dry Grassland. The most typical example is on kame moraines where the Sandy site exists in sandy alluvium on lower backslope and footslope positions and the Limy site occurs on till on upper backslope and should positions.

Similar sites

FX052X03X110	**Sandy (Sy) Dry Shrubland** This site differs from Loamy Steep Dry Grassland in that it has slightly warmer annual temperatures and may support big sagebrush rather than silver sagebrush.
FX052X01X032	**Loamy (Lo) Dry Grassland** This site differs from Sandy Dry Grassland in that surface textures are in the fine-loamy family with a clay content of 18 to 35 percent and calcium carbonate equivalent is less than 5 percent. The Sandy ecological site contains less than 18 percent clay and 0 to 15 percent calcium carbonate equivalent.

FX052X01X100	**Sands (Sa) Dry Grassland** This site differs from Sandy Dry Grassland in that soil surface textures are in the sandy textural family with a clay content of less than 15 percent and a sand content of 70 percent or greater whereas the Sandy site contains less than 70 percent sand.
FX052X01X030	**Limy (Ly) Dry Grassland** This site differs from Sandy Dry Grassland in that soil surface textures are in the fine-loamy family (18 to 35 percent clay) and calcium carbonate equivalent is 5 percent or greater. Sandy Dry Grassland has surface textures in the coarse-loamy family and a calcium carbonate equivalent of 0 to 15 percent.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY110MT

Physiographic features

Sandy Dry Grassland is a moderately extensive ecological site occurring across the till plains and moraines of MLRA 52. The majority of MLRA 52 is covered by a broad till plain, and this ecological site largely occurs in areas where cracks in the continental ice sheet were filled with sand or areas of glacial outwash or along present-day streams or rivers. This site can occur on any slope or slope position on kames, eskers, outwash fans and terraces. Slopes are typically less than 25 percent but may be as steep as 45 percent in some areas.

Figure 1. Figure 1. General distribution of the Sandy Dry Grassland ecological site by map unit extent

Table 2. Representative physiographic features

Landforms	(1) Till plain > Kame (2) Till plain > Esker (3) Till plain > Outwash fan (4) Terrace
Elevation	610 – 1,180 m
Slope	0 – 50 %
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 120 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 ten 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 the reaction of plants to a “false spring” (Oard, 1993).

Table 3 Representative climatic features

Frost-free period (average)	120 days
Freeze-free period (average)	140 days
Precipitation total (average)	310 mm

- (1) CARTER 14 W [USC00241525], Floweree, MT
- (2) CHESTER [USC00241692], Chester, MT
- (3) TIBER DAM [USC00248233], Chester, MT
- (4) HARLEM [USC00243929], Harlem, MT
- (5) MALTA 7 E [USC00245338], Malta, MT
- (6) TURNER 11N [USC00248415], Turner, MT
- (7) CONRAD [USC00241974], Conrad, MT
- (8) SHELBY [USC00247500], Shelby, MT
- (9) GLASGOW [USW00094008], Glasgow, MT
- (10) HAVRE CITY CO AP [USW00094012], Havre, MT

Influencing water features

This is a dry upland site and the water budget is contained within the soil profile for the majority of the year. However, the site does function as a recharge site during the spring when rainfall is greatest, especially in wet years. Recharge is typically limited to a localized area and moisture is delivered to adjacent sites via deep percolation or surface runoff. Moisture loss through evapotranspiration exceeds precipitation for the majority of the growing season. Soil moisture levels are greatest in May and June, but the soil dries out quickly due to the low available water capacity (AWC). When placed into cultivated crops, this site can contribute recharge to saline seeps, which may be a significant concern on adjacent sites.

Soil features

Soils that best represent the central concept of this ecological site are Chinook, Fortbenton, and Busby. The Chinook and Fortbenton soils are in the Haplustolls great group. They have a relatively dark mollic epipedon and an underlying cambic horizon where pedogenic development is present but minimal. The Busby soil is in the Haplustepts great group. It also contains a cambic horizon but does not have a mollic epipedon. The Chinook and Busby soils are in the coarse-loamy family, while the Fortbenton soil is in the fine-loamy family. All three soils have mixed minerology. The soil moisture regime for these and all soils in this ecological site concept is ustic bordering on aridic, which means that the soils are moist in some or all parts for either 180 cumulative days or 90 consecutive days during the growing season but are dry in some or all parts for over 90 cumulative days. These soils have a frigid soil temperature regime (Soil Survey Staff, 2014).

Surface horizon textures in this site are typically sandy loam or fine sandy loam and contain less than 18 percent clay and less than 70 percent sand. Underlying horizons typically have weakly developed physical and chemical properties; they typically have textures of sandy loam, fine sandy loam, loamy sand, or sand; contain less than 18 percent clay and less than 95 percent sand. Organic matter content in the surface horizon typically ranges from 1 to 3 percent, and moist colors vary from brown (10YR 4/3) to very dark grayish brown (10YR 3/2). Depth to secondary carbonates is typically less than 16 inches below the soil surface. The upper 5 inches of these soils sometimes reacts strongly or violently with hydrochloric acid. The calcium carbonate equivalent in the upper 5 inches is typically 5 percent or less but may be as high as 10 percent in some cases. The soil depth class for this site can be moderately deep (more than 20 inches) where bedrock is present but is typically very deep. Coarse fragments in the upper 20 inches of soil are generally absent.

Table 4. Representative soil features

Parent material	(1) Glaciofluvial deposits (2) Alluvium
Surface texture	(1) Sandy loam (2) Fine sandy loam
Drainage class	Well drained
Soil depth	50 – 180 cm
Available water capacity (0-101.6cm)	12.7 – 15.49 cm
Calcium carbonate equivalent (0-12.7cm)	0 – 10 %
Electrical conductivity (0-50.8cm)	Not specified
Sodium adsorption ratio (0-50.8cm)	0 – 10
Soil reaction (1:1 water) (0-101.6cm)	5.6 – 10
Subsurface fragment volume <=3" (0-50.8cm)	0 – 30 %
Subsurface fragment volume >3" (0-50.8cm)	0 – 30 %

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 Sandy provisional ecological site in MLRA 52 Dry Grassland consists of five states: The Reference State (1.0), the Shortgrass State (2.0), the Invaded State (3.0), the Cropland State (4.0), and the Post-Cropland State (5.0). 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; Lockwood, 2004) also played an important role in the ecology of these communities.

The historic ecosystem experienced relatively frequent lightning-caused fires with estimated fire return intervals of 6 to 25 years (Bragg, 1995). 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). Generally, the mixedgrass ecosystem is resilient to fire and the historic fire return interval had neutral or slightly positive effects on the plant community (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). It is not known how significant fire was on the Sandy ecological site. Further investigation of fire dynamics is needed to better assess this.

Improper grazing of this site can result in a reduction in the cover of the mid-statured bunchgrasses and an increase in blue grama (Smoliak et al., 1972; Smoliak, 1974). Eventually, improper grazing may also begin to reduce sedges. 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 (approximately 3 years or more) may have similar effects (Coupland, 1958, 1961). Further degradation of the At-Risk Community Phase due to improper grazing can result in a community dominated by shortgrasses such as blue grama.

Due to the coarse soil textures and the reduced water-holding capacity, 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 with introduced species. 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). Without vegetative cover, this ecological site is very susceptible to wind erosion and severe loss of topsoil is possible. Under such circumstances, a return to the Reference State in a reasonable amount of time is unlikely. Additionally, studies have shown that it may take over 75 years for soil organic matter to return to its pre-disturbed state even on more stable sites (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). 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 (DeLuca and Lesica, 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). Sandy ecological sites adjacent to these seeded areas are particularly prone to invasion.

The STM diagram 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 contains two community phases characterized by mid-statured bunchgrasses, sedges, and, in some areas, mid-statured warm-season grasses. 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 fire dynamics are not well understood on this site. Lesser spikemoss, also known as dense clubmoss (Selaginella densa), is typically absent on this site; however, it may occur in some cases and its dynamics on this site are not well understood.

Community Phase 1.1: Mixedgrass Community Phase

The reference plant community on this site is characterized by mid-statured bunchgrasses, sedges, and, in some areas, mid-statured warm-season grasses. The most dominant species appear to be needle and thread and threadleaf sedge. Western wheatgrass (Pascopyrum smithii) is typically uncommon on this site; however, it increases in abundance as soil textures become finer. Prairie sandreed and Indian ricegrass become common as soil textures become coarser, typically replacing western wheatgrass. The mat-forming, warm-season perennial grass blue grama is the most common shortgrass in this phase, although prairie Junegrass (Koeleria macrantha) may also be present. Shortgrasses rarely comprise more than 5 percent of the plant community. Common forbs are dotted blazing star (Liatris punctata) and scarlet globemallow (Sphaeralcea coccinea). Shrubs and subshrubs are rare on this site. On finer textured soils, prairie sagewort (Artemisia frigida) and silver sagebrush (Artemisia cana) can occur at about 5 percent cover. However, coarser textures typically only support trace amounts of prairie rose (Rosa arkansana). The approximate species composition of the reference plant community is as follows:

Percent composition by weight*
Needle and Thread 35%
Threadleaf Sedge 20%
Prairie Sandreed 0-20%
Western Wheatgrass 0-15%
Blue Grama 5%
Other Native Grasses 15%
Perennial Forbs 5%
Shrubs/Subshrubs 1-5%

Estimated Total Annual Production*
Low - Insufficient data
Representative Value
High - Insufficient data
* Estimated based on current data – subject to revision

Community Phase 1.2: At-Risk Community Phase
The At-Risk Community Phase is characterized by nearly equal proportions of shortgrasses and sedges. Mid-statured grasses have been reduced to low cover and are in decline. Shortgrasses such as blue grama are increasing. If present, prairie sandreed may also increase in this phase. When present, clubmoss can provide significant ground cover and may protect the soil surface from erosion; however, the dynamics of this species are not well understood.

Community Phase Pathway 1.1a
Drought, improper grazing management, or a combination of these factors can shift the reference community phase (1.1) to the At-Risk Community Phase (1.2). These factors favor an increase in blue grama and a decrease in midgrasses (Coupland, 1961).

Community Phase Pathway 1.2a
Normal or above-normal spring precipitation with proper grazing management transitions the At-Risk Community Phase (1.2) back to the reference 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, particularly the warm-season, mat-forming blue grama, 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). 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.

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. The Shortgrass Community Phase (2.1) is dominated by short-statured grasses such as blue grama. Mid-statured grasses have been eliminated or nearly so, and their vigor and production are low. Once established, blue grama-dominated communities can alter soil properties and create conditions that resist establishment of other grass species (Dormaar and Willms, 1990; Dormaar et al., 1994). Dense clubmoss is typically absent; however, there are also cases where it constitutes significant ground cover. Its dynamics are not well understood on this site, and further investigation is required.

Community Phase 2.1: Shortgrass Community Phase
In the Shortgrass Community Phase, mid-statured grasses such as needle and thread and rhizomatous wheatgrasses have been largely eliminated and replaced by short-statured species such as blue grama. Threadleaf sedge has also decreased in abundance and exhibits declining vigor and production. Erosional patterns and plant pedestaling are evident.

Transition T2A
The Shortgrass State (2) 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.

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). Intensive management treatments may be necessary (Hart et al., 1985), but practices such as mechanical treatment of grazing land and range seeding should be used with caution on this site due to its susceptibility to wind erosion. Therefore, returning the altered 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 primarily when aggressive, introduced perennial grasses invade adjacent native grassland communities. Crested wheatgrass, in particular, is a concern, especially where 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 and the result is 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). Once established, monocultures of crested wheatgrass can persist for at least 60 years (Krzic et al., 2000; 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).

Noxious weeds such as leafy spurge are uncommon on this site but 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 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. This state can transition back to the Cropland State (4) if the site is put back into cultivation.

Phase 5.1: Abandoned Cropland 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, blue grama, and possibly prairie sandreed. 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 and the coarse soil textures. Eventually, these pioneering annual species are replaced by perennial forbs and perennial shortgrasses such as blue grama. Prairie sandreed is also known to be a pioneer species on sandy sites, although its abundance in MLRA 52 has not been fully studied. 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 crested wheatgrass, and annual bromes will depend upon the site's proximity to a seed source.

Fifty or more years after cultivation, these sites may have species composition similar to phases in the Reference State (1). However, soil quality is consistently lower than conditions prior to cultivation (Dormaar and Smoliak, 1985; Christian and Wilson, 1999) and a shift to the Reference State (1) is unlikely within a reasonable timeframe.

Phase 5.2: Perennial Grass Phase
When the site is seeded to perennial forage species, particularly introduced perennial grasses, this community phase can persist for several decades. Crested wheatgrass, in particular, is very aggressive and may form monocultures persisting for at least 60 years (Krzic et al., 2000; Henderson and Naeth, 2005). A mixture of native species may also be seeded to provide species composition and structural complexity similar to that of the 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
The Post-Cropland State (5) transitions back to the Cropland State (4) when the site is converted to cropland.

State and transition model

Additional community tables

Inventory data references

Three low-intensity plots and 1 Alberta rangeland reference area were available for this provisional ecological site. These data represented the Reference State (1) and the Invaded State (3). No other community phases were supported with quantitative data analysis. Information for alternate states was obtained from professional experience and a review of the scientific literature. All community phases are considered provisional based these plots and the sources identified in the narratives associated with each community phase.

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Contributors

Scott Brady
Stuart Veith

Approval

Scott Brady, 7/11/2019

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Rangeland health reference sheet

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

Author(s)/participant(s)	
Contact for lead author	
Date	
Approved by	
Approval date	

Composition (Indicators 10 and 12) based on	Annual Production

Indicators

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

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

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

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

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

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

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

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

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

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

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

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

    Dominant:

Sub-dominant:

Other:

Additional:

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

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

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

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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:**

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17. **Perennial plant reproductive capability:**
