USDA Natural Resources Conservation Service

Ecological site FX052X01X001
Clayey (Cy) Dry Grassland

Last updated: 7/09/2019
Accessed: 05/06/2024

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.

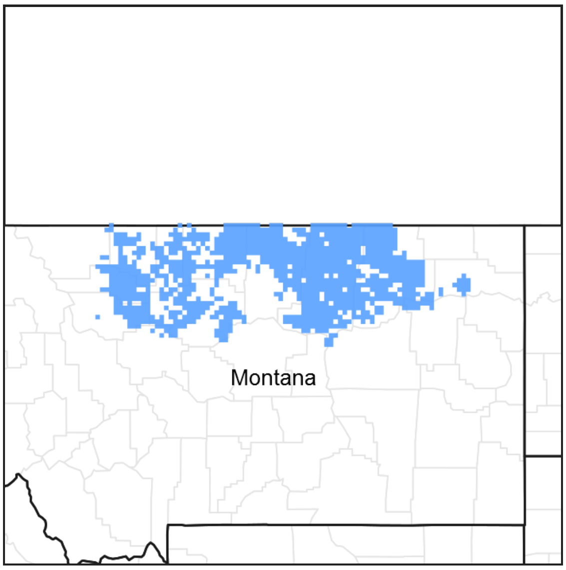

Figure 1. Mapped extent

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 and agriculturally and ecologically significant area. It consists of around 14.5 million acres that 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 drainage ways. Significant alluvial deposits occur along glacial outwash channels and major drainages which include 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.

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 found on level terrain that would typically be optimal for farming has large amounts of less-suitable sodium-affected Natrustalfs. Significant portions of Blaine, Phillips, and Valley Counties were glaciated approximately 150,000 years ago during the Illinoisan age. Due to erosion and dissection of the landscape, many of these areas have steeper slopes and more exposed bedrock than areas glaciated during the Wisconsin age (Fullerton et al. 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 because 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 a crop 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: Hesperostipa comata – Pascopyrum smithii – Festuca hallii Grassland Macrogroup (2.B.2.Nb.2)
• Group: Pascopyrum smithii – Hesperostipa comata – Schizachyrium scoparium – Bouteloua spp. Mixedgrass Prairie Group (2.B.2.Nb.2.c)
• Alliance: Pascopyrum smithii – Nassella viridula Northwestern Great Plains Herbaceous Alliance
• Association: Pascopyrum smithii - Nassella viridula Herbaceous Vegetation

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. Clayey Dry Grassland is a moderately extensive ecological site occurring on most landscapes throughout MLRA 52. It occurs on till plains, lake plains, and low hills where slopes are less than 15 percent. This site can be found on any slope shape concave or linear is most common.

The distinguishing characteristic of this site is that it contains greater than 35 percent, but not more than 45 percent, clay in the upper 4 inches of soil. Soils for this ecological site are typically moderately deep to very deep (more than 20 inches to bedrock) and derived from shale residuum, clayey till or glaciofluvial deposits. Soil surface textures (0 to 4 inches) are typically clay, clay loam, silty clay, or silty clay loam, and the soils typically have an ochric epipedon. This site is typically nonacid, with pH values greater than 5.6 throughout the soil profile. Characteristic vegetation is western wheatgrass (Pascopyrum smithii) and green needlegrass (Nassella viridula). Thickspike wheatgrass (Elymus lanceolatus) becomes more common in the northern extent of MLRA 52. The principal shrub on this site is silver sagebrush (*Artemisia cana*), which typically comprises 5 percent of the cover or less.

Preliminary studies indicate that there may also be an acid variant of this site. This variant appears to exhibit retarded shrub growth, reduced cover of cool season bunchgrasses, and increased cover of creeping juniper and prairie sandreed. At this time, this variant cannot be consistently identified as a separate ecological site concept and further investigation is required.

Associated sites

FX052X01X032	**Loamy (Lo) Dry Grassland** Loamy Dry Grassland is on similar landscapes and slope positions as the Clayey Dry Grassland but where clay content is greater than 35 percent.
FX052X01X005	**Clayey-Steep (Cystp) Dry Grassland** Clayey Steep Dry Grassland is found adjacent to Clayey Dry Grassland on slopes of 15 percent or greater. It typically occupies a backslope position downslope from the clayey Dry Grassland ecological site.
FX052X01X131	**Shallow Clay (Swc) Dry Grassland** Shallow Clay Dry Grassland is found adjacent to Clayey Dry Grassland where bedrock occurs near the soil surface. It typically occupies a backslope position downslope from the clayey Dry Grassland ecological site.

Similar sites

FX052X03X001	**Clayey (Cy) Dry Shrubland** This site differs from Clayey Dry Grassland in that it has slightly warmer annual temperatures and can support big sagebrush.
FX052X01X032	**Loamy (Lo) Dry Grassland** This site differs from Clayey Dry Grassland in that its soils contain 35 percent or less clay in the surface 4 inches whereas the clayey site soil contain more than 35 percent clay in the surface 4”.
FX052X01X005	**Clayey-Steep (Cystp) Dry Grassland** This site differs from Clayey Dry Grassland it is on slopes of 15 percent or greater whereas the clayey site is on slopes of less than 15 percent.
FX052X01X131	**Shallow Clay (Swc) Dry Grassland** This site differs from Clayey Dry Grassland in that depth to bedrock or paralithic bedrock is less than 20 inches.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY001MT

Physiographic features

Clayey Dry Grassland is a common ecological site on till plains, lake plains, and low hills. This site is moderately extensive in MLRA 52. This site is not affected by aspect.

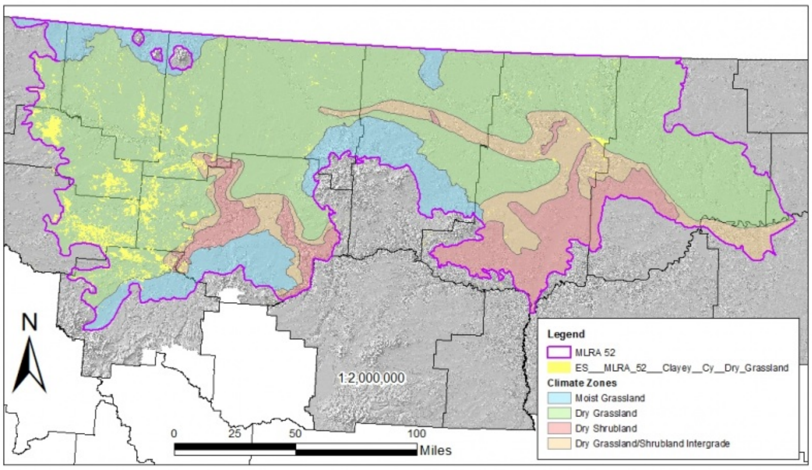

Figure 2. Figure 1. General distribution of the Clayey Dry Grassland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Till plain (2) Lake plain (3) Till plain > Low hill
Elevation	2,000–3,870 ft
Slope	0–14%
Aspect	Aspect is not a significant factor

Climatic features

The Brown Glaciated Plains is a semi-arid region with a temperate continental climate that is characterized by frigid winters and warm to hot summers (Cooper et al., 2001). The average frost-free period for this ecological site is 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)	12 in

Climate stations used

- (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 ecological site and the water budget is normally contained within the soil profile. During intense precipitation events, precipitation rates frequently exceed infiltration rates and this site delivers moisture to downslope sites via surface runoff. Moisture loss through evapotranspiration exceeds precipitation for the majority of the growing season. Soil moisture levels are greatest in May and June but rarely reach field capacity in the upper 40 inches. Soil moisture is the primary limiting factor for plant production on this ecological site.

Soil features

Soils that best represent the central concept for this ecological site are Kobase and Bascovy, These soils occur on slopes of less than 15 percent. The clayey site concept covers about 390,000 acres in MLRA 52. The Kobase soil is in the Haplustepts great group. It is characterized by a surface horizon that lacks enough organic matter to have a mollic epipedon and by weakly developed underlying horizons that exhibit some shrink-swell properties. The Bascovy soil is in the Haplusterts great group. It also lacks enough organic matter to have a mollic epipedon. Its underlying horizons exhibit strong shrink-swell characteristics as evidenced by slickensides (USDA-NRCS, 2016). The particle-size family for both soils is fine, which means that the soils contain between 35 and 60 percent clay in the particle-size control section and that the minerology is smectitic. The typical parent materials for these series are clayey till, clayey alluvium, or clayey residuum. The soil moisture regime for these 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 commonly clay, silty clay, clay loam, or silty clay loam and contain greater than 35 percent, but not more than 45 percent, clay. The underlying horizons typically contain 35 to 60 percent clay and have clay, clay loam, or silty clay loam textures. Organic matter content in the surface horizon typically ranges from 1 to 2 percent, and moist colors vary from grayish brown (2.5Y 5/2) to dark grayish brown (2.5Y 4/2). The surface horizon of these soils does not typically react with hydrochloric acid. Depth to secondary carbonates, if present, is usually 10 inches or greater below the soil surface. Calcium carbonate equivalent is typically less than 15 percent throughout the soil profile. In the surface upper 20 inches, electrical conductivity is less than 4 and the sodium absorption ratio is less than 13. 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). Content of coarse fragments is less than 35 percent in the upper 20 inches of soil. Lower horizons may contain 15 to 60 percent soft parafragments.

Table 4. Representative soil features

Parent material	(1) Till (2) Alluvium (3) Residuum
Surface texture	(1) Clay (2) Silty clay (3) Clay loam (4) Silty clay loam
Drainage class	Well drained
Soil depth	20–72 in
Available water capacity (0-40in)	4–6.5 in
Calcium carbonate equivalent (0-5in)	0–14%
Electrical conductivity (0-20in)	0–3 mmhos/cm
Sodium adsorption ratio (0-20in)	0–12
Soil reaction (1:1 water) (0-40in)	5.6–9
Subsurface fragment volume <=3" (0-20in)	0–34%
Subsurface fragment volume >3" (0-20in)	0–34%

Ecological dynamics

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

The Clayey 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 the Clayey 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. 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; Lockwood, 2004) also played an important role in the ecology of these communities.

The historic ecosystem also experienced relatively frequent 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 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). Conversely, long-term fire suppression in the 20th century removed periodic fire from the ecosystem altogether. Lack of periodic fires can result in an increase in litter accumulation, which in some cases provides ideal conditions for seed germination and seedling establishment of non-native annual brome species, such as field, or Japanese, brome (*Bromus arvensis*; Whisenant, 1990). These species have become naturalized in relatively undisturbed grasslands (Ogle et al., 2003; Harmoney, 2007) and can be present in any state within the scope of this ecological site. They typically do not have a significant ecological impact; however, their presence can reduce the production of cool-season perennial grasses in some cases (Haferkamp et al., 1997). Their abundance varies depending on precipitation and germination conditions.

Improper grazing of this site can result in a reduction in the cover of the mid-statured bunchgrasses, an eventual decrease in cool-season wheatgrasses, and an increase in shortgrasses (Smoliak et al., 1972; Smoliak, 1974). Improper grazing practices include any practices that do not allow sufficient opportunity for plants to physiologically recover from a grazing event or multiple grazing events within a given year and/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 bunchgrasses and cool-season, rhizomatous wheatgrasses, triggering an increase in shortgrasses such as prairie Junegrass (Coupland, 1961).

Further degradation of the site due to improper grazing can result in a community dominated by shortgrasses such as prairie Junegrass and blue grama. The cover of mid-statured rhizomatous grasses and bunchgrasses is severely reduced or absent. The cover of prairie, or fringed sagewort, can also increase.

Much of the Clayey Dry Grassland ecological site has been converted into annual cropland. Seeding of introduced grasses, particularly crested wheatgrass (*Agropyron cristatum*), was a common practice in 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). It can invade relatively undisturbed grasslands, reducing cover and production of native cool-season midgrasses (Heidinga and Wilson, 2002; Henderson and Naeth, 2005).

When this site is taken out of production, the site is either allowed to revert back to perennial grassland or is seeded with introduced species. Sites left to undergo natural plant succession after cultivation can, over several decades, support blue grama and cool-season midgrasses, although cover and production of these species is lower than in the Reference State. However, those sites seeded with non-native species, particularly crested wheatgrass, may persist with this cover type indefinitely (Christian and Wilson, 1999). Even when the site is reseeded to native species, it may take over 75 years for soil organic matter to return to its pre-disturbed state (Dormaar et al., 1990).

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. 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 phase was resilient to grazing and fire, although these factors could influence species composition in localized areas. Vegetation is characterized by mid-statured cool-season rhizomatous grasses, mid-statured cool-season bunchgrasses, and short statured grasses.

Community Phase 1.1 Mixedgrass Phase
The Mixedgrass Community Phase is typically dominated by western wheatgrass and green needlegrass. Thickspike wheatgrass may also be present, becoming abundant in the northern extent of this ecological site. Green needlegrass is by far the most abundant bunchgrass. Short-statured grasses such as prairie Junegrass (*Koeleria macrantha*) and blue grama (*Bouteloua gracilis*) are not abundant in this phase but are generally present

at low cover. Needleleaf sedge (*Carex duriuscula*) and plains muhly (*Muhlenbergia cuspidata*) may also be present at low cover. Common forbs are American vetch (*Vicia americana*), spiny, or Hood's, phlox (*Phlox hoodii*), and common yarrow (*Achillea millefolium*). Silver sagebrush (*Artemisia cana*) is the most common shrub and may comprise up to 5 percent of canopy cover. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*
Rhizomatous Wheatgrass 35%
Green Needlegrass 25%
Prairie Junegrass 5%
Blue Grama 5%
Other Native Grasses 15%
Perennial Forbs 10%
Shrubs/Subshrubs 5%

Estimated Total Annual Production (lbs/ac)*
Low - 400
Representative Value - 650
High - 900
* Estimated based on current observation – subject to revision

Community Phase 1.2 At Risk Phase
In the At Risk Community Phase, mid-statured bunchgrasses, especially green needlegrass, have been nearly eliminated. Rhizomatous wheatgrasses are in decline and are in nearly equal proportion to shortgrasses. Shortgrasses such as prairie Junegrass, Sandberg bluegrass, and blue grama are increasing. Needleleaf sedge and prairie, or fringed, sagewort (*Artemisia frigida*) may also increase in this phase.

Community Phase Pathway 1.1a
Drought, improper grazing management, 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 a decrease in cool-season midgrasses and an increase in shortgrasses (Coupland, 1961).

Community Phase Pathway 1.2a
The At Risk Community Phase (1.2) can return to the Mixedgrass Community Phase (1.1) with normal or above-normal spring precipitation and proper grazing management.

Transition T1A
Improper grazing practices, prolonged drought (approximately 3 years or more), 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 transitions to the Shortgrass State when cool-season midgrasses become rare and contribute little to production. Shortgrasses, particularly prairie Junegrass, Sandberg bluegrass, and the warm-season, mat-forming blue grama dominate the plant community.

Transition T1B
The Reference State (1) transitions to the Invaded State (3) when invasive plant species, particularly crested wheatgrass, invade the Reference State (1). These communities are often 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 T2C
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 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 site is dominated by shortgrasses

while mid-statured grasses have been eliminated or nearly so. Blue grama is common but does not appear to dominate the Clayey ecological site as it does the Loamy ecological site. Studies have shown that prairie Junegrass will significantly increase (Clarke et al., 1947), but this requires further investigation. 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).

Phase 2.1: Shortgrass Community Phase
The Shortgrass Community Phase is dominated by shortgrasses such as prairie Junegrass, blue grama, and Sandberg bluegrass. Prairie sagewort also becomes common in this phase.

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 Invaded State (3) to the Cropland State (4).

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

State 3: Invaded State
The Invaded State (3) occurs when invasive plant species invade adjacent native grassland communities. 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 seedbank 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).

Noxious weeds such as leafy spurge are uncommon on this site but are capable of invading if a seed source is present. These species are very aggressive. They typically displace native species and dominate ecological function when they invade a site. Sometimes, 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. 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 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. Depending on the historical management of the site, perennial bunchgrasses may also return; however, species composition will depend upon the seed bank. Invasion of the site by exotic species such as crested wheatgrass and annual bromes will depend upon the site's proximity to a seed source.

Fifty or more years after cultivation, these sites may have species composition similar to phases in the Reference State (1). However, soil quality is consistently lower than under 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 those of the contemporary Reference State (1). However, soil quality conditions have been substantially altered and are unlikely to 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

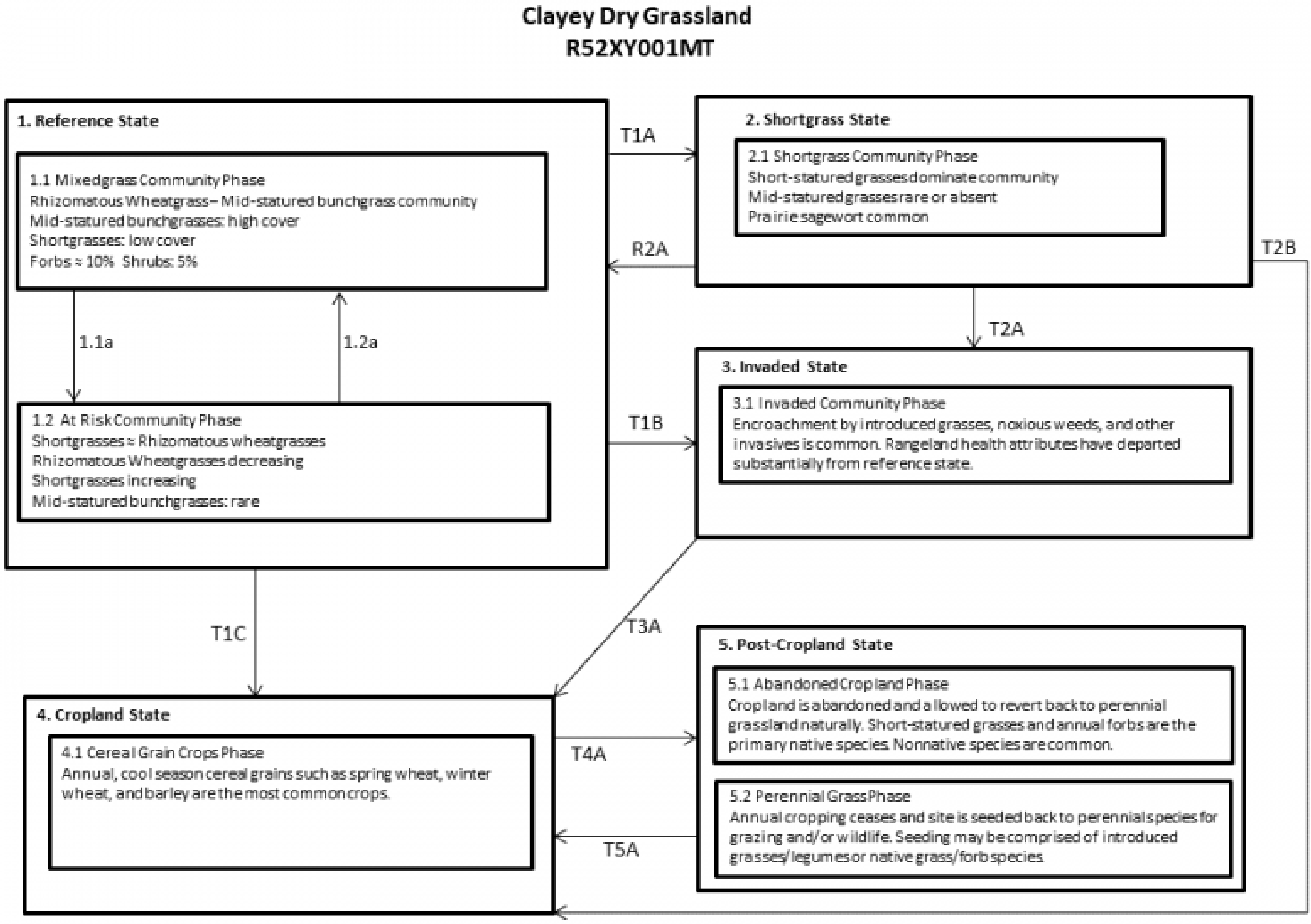

Figure 2: State and Transition Diagram

Clayey Dry Grassland
R52XY001MT

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 (primarily crested wheatgrass)
- T2A introduction of weedy species; combined with drought and/or 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 3. State-and-transition legend

Inventory data references

One medium-intensity plot representing the Reference State was available for this provisional ecological site. No quantitative data were obtained for other community phases. Information for these phases was based on professional experience and a review of the scientific literature. All community phases are considered provisional based on available data and the sources identified in the narratives associated with each community phase.

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Approval

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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
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Rangeland health reference sheet

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

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

Indicators

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

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

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

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

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

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

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

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

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

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

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

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

    Dominant:

    Sub-dominant:

    Other:

    Additional:

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

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

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

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

17. **Perennial plant reproductive capability:**