USDA Natural Resources Conservation Service

Ecological site FX052X02X165
Thin Claypan (Tcp) Moist 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.

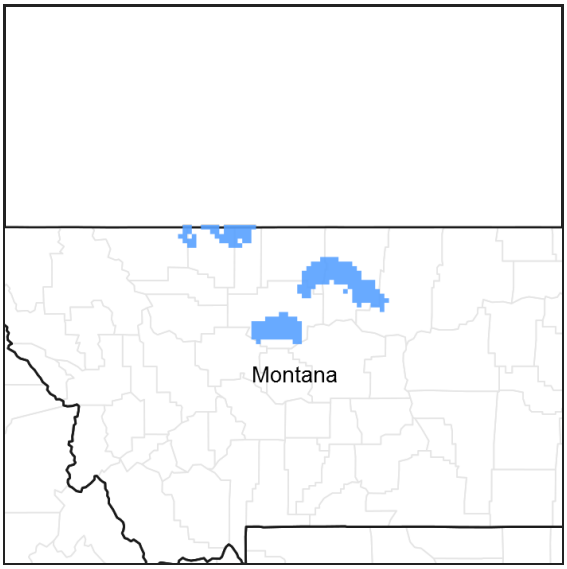

Figure 1. Mapped extent

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

MLRA notes

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

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

Soils are primarily Mollisols, but Entisols, Inceptisols, Alfisols, and Vertisols are also common. Till from continental glaciation is the predominant parent material, but alluvium and bedrock are also common. Till deposits are typically less than 50 feet thick, and in some areas glacially deformed bedrock occurs at or near the soil surface (Soller, 2001). Underlying the till is sedimentary bedrock largely consisting of Cretaceous shale, sandstone, and mudstone (Vuke et al., 2007). The bedrock 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 climatic 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 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 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 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: Moist 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* –Bouteloua gracilis – Carex filifolia 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)
Cherry Patch Moraines (42m)
Milk River Pothole Upland (42n)

Ecological site concept

This provisional ecological site occurs in the Moist 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. Onsite evaluations are necessary, particularly in boundary or intergrade areas where ecological sites from multiple climate zones may overlap. Thin Claypan Moist Grassland is a somewhat extensive ecological site occurring in on areas of the till plain near the various mountain ranges as well as the Sweetgrass Hills in MLRA 52. This ecological site occurs on till plains, moraines, outwash fans, and alluvial fans.

The distinguishing characteristic of this site is the presence of a dense, root-restricting, sodium-affected (natric) horizon at depths between 1 and 4 inches from the soil surface. The natric horizon exhibits columnar structure, is very hard, and severely limits both root penetration and infiltration. The root-restrictive natric horizon favors shallower-rooted rhizomatous species, particularly the rhizomatous wheatgrasses, over deep-rooted bunchgrasses. Other common grasses include prairie Junegrass (*Koeleria macrantha*), blue grama (Bouteloua gracilis), and Sandberg bluegrass (Poa secunda).

Associated sites

FX052X02X032	**Loamy (Lo) Moist Grassland** This site occupies similar landscapes to the Thin Claypan Moist Grassland ecological site. In the natric soils complex, the Loamy Moist Grassland ecological site is typically found on the highest micro-topography; whereas, the Thin Claypan ecological site occupies lower positions.
FX052X02X006	**Claypan (Cp) Moist Grassland** This site occupies similar landscapes to the Thin Claypan Moist Grassland ecological site. In the natric soils complex, the Claypan Moist Grassland ecological site is typically found in mid-level micro-topography, higher than the Thin Claypan and Panspot ecological sites, but lower than the Loamy Moist Grassland ecological sites.
FX052X02X145	**Panspot (Pn) Moist Grassland** This site occupies similar landscapes to the Thin Claypan Moist Grassland ecological site. In the natric soils complex, the Panspot Moist Grassland ecological site is found on the lowest micro-topography in the complex.

Similar sites

FX052X02X032	**Loamy (Lo) Moist Grassland** This site differs from the Thin Claypan Moist Grassland ecological site in that the root restricting layer (evidenced by columnar structure) is either absent or greater than 10 inches below the soil surface. Deep rooted bunchgrasses are a major component of the plant community.
FX052X02X006	**Claypan (Cp) Moist Grassland** This site differs from the Thin Claypan Moist Grassland ecological site in that the root restricting layer (evidenced by columnar structure) is greater than 4 inches to 10 inches below the soil surface. Needle and thread occurs, but is not a major plant species.
FX052X02X145	**Panspot (Pn) Moist Grassland** This site differs from the Thin Claypan Moist Grassland ecological site in that the root restricting layer (evidenced by columnar structure) is 1 inch or less from the surface. Commonly occurs in small depressions or pits on the landscape.

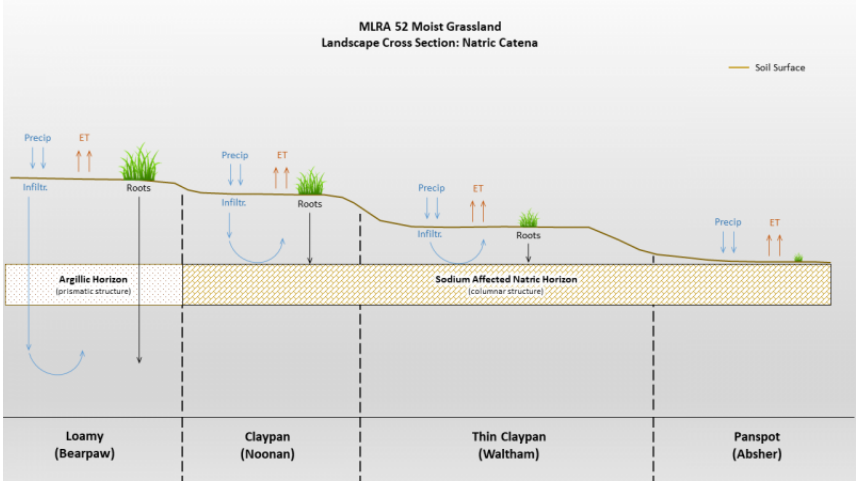

Figure 2.

Table 1. Dominant plant species

Tree	Not specified
Shrub	Not specified
Herbaceous	Not specified

Legacy ID

R052XY755MT

Physiographic features

Thin Claypan Moist Grassland is a somewhat extensive ecological site occurring in the moist areas of MLRA 52. The majority of MLRA 52 is covered by a broad till plain, and this ecological site largely occurs at higher elevations near the various mountain ranges and the Sweetgrass Hills. It mostly occurs on moraines (ground, recessional or end) but can also occur on outwash fans or alluvial fans. In particular it occurs on moraines underlain by the Bearpaw Shale Formation. The till incorporated physical and chemical properties of the underlying shale, which in MLRA 52 tends to have appreciable amounts of sodium, magnesium, and calcium sulfates but little to no calcium carbonate. It is hypothesized that during and immediately after deglaciation, the combination of water-restricting bedrock underlying the sodium-rich clayey till at depths of 10 feet or less and the gentler slopes of the till plain, water could pond and, by matric potential, concentrate enough salts to create the natric horizon and its distinctive columnar structure (Miller and Brierley, 2011). The present-day hydrology of this site lacks a water table. As is the case with the Claypan and Panspot ecological sites, complex micro-topography is typical on landforms dominated by natric soils. In relation to the Panspot ecological sites; the Thin Claypan ecological site is found on microhighs, whereas when in complex with Claypan and Loamy ecological sites is found on microlows.

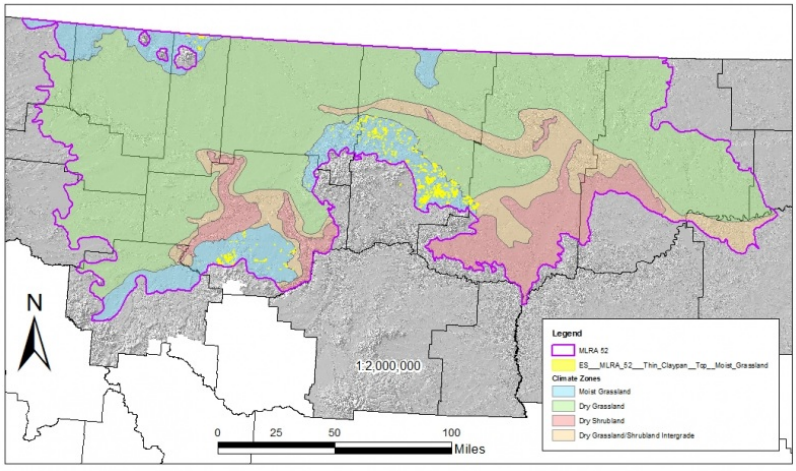

Figure 3. Figure 1. General distribution of the Thin Claypan Moist Grassland ecological site by map unit extent.

Table 2. Representative physiographic features

Landforms	(1) Till plain > Moraine (2) Till plain > Outwash fan (3) Alluvial fan
Elevation	1,097–1,399 m
Slope	0–8%
Aspect	Aspect is not a significant factor

Climatic features

The Brown Glaciated Plains is a semi-arid region with a temperate continental climate that is characterized by frigid winters and warm to hot summers (Cooper et al., 2001). The average frost-free period for this ecological site is 110 days. The majority of precipitation occurs as steady, soaking, frontal system rains in late spring to early summer. Summer rainfall comes mainly from convection thunderstorms that typically deliver scattered amounts of rain in intense bursts. These storms may be accompanied by damaging winds and large-diameter hail and result in flash flooding along low-order streams. Severe drought occurs on average in 2 out of 10 years. Annual precipitation ranges from 13 to 17 inches, 70 to 80 percent of which occurs during the growing season (Cooper et al., 2001). Extreme climatic variations, especially droughts, have the greatest influence on species cover and production (Coupland, 1958, 1961; Biondini et al., 1998).

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

Table 3. Representative climatic features

Frost-free period (average)	110 days
Freeze-free period (average)	135 days
Precipitation total (average)	381 mm

Climate stations used

- (1) GERALDINE [USC00243445], Geraldine, MT
- (2) GOLDBUTTE 7 N [USC00243617], Sunburst, 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 1 to 4 inches below the soil surface. Evapotranspiration exceeds precipitation on this site, and a state of moisture deficit persists for the majority of the year. In typical precipitation events, the upper 1 to 4 inches of the soil profile is filled to field capacity, then moisture amounts are quickly diminished by evapotranspiration. Abnormally wet years or very intense precipitation events can saturate the soil surface layer and cause very brief (less than 2 days) ponding and lateral flow via surface runoff into adjacent microlows. Lateral water movement is typically limited to a localized area due to the flat topography. Frequency and duration of saturation are not sufficient for the development of hydric soil features.

Soil features

The soil series that best represents the central concept of this ecological site is Waltham. This soil is in the Natrustalf great group and is currently misclassified as a fine, smectitic, frigid aridic Natrustalf in the Official Series

Description database. The correct classification is a fine, smectitic, frigid typic Natrustalf. It is characterized by a surface horizon that lacks enough organic matter to have a mollic epipedon and by a dense, root-limiting, non-cemented restrictive layer 1 to 4 inches below the soil surface. This restrictive layer is referred to as a natric horizon and is essentially an argillic horizon that has been affected by sodium salts. The natric horizon exhibits distinctive columnar structure that is especially visible when the soil is dry. The 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. Clayey till (28 to 42 percent clay) is the typical parent material for this series but the Thin Claypan Moist Grassland ecological site can also occur on soils derived from glaciofluvial deposits, shale residuum, or till over residuum. The soil moisture regime for this 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 1 to 2 percent, and moist colors vary from light olive brown (2.5Y 5/3) to dark grayish brown (2.5Y 4/2). Depth to secondary carbonates and soluble sulfate salts is usually between 5 and 8 inches below the soil surface. Calcium carbonate equivalent in the surface 5 inches is typically less than 5 percent and typically less than 10 percent in lower horizons. In the 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 (more than 20 inches) in places where bedrock is present but is typically very deep. 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) Till (2) Glaciofluvial deposits (3) Residuum
Surface texture	(1) Loam (2) Fine sandy loam (3) Silty clay loam
Drainage class	Well drained
Depth to restrictive layer	3–10 cm
Soil depth	51–183 cm
Available water capacity (0-101.6cm)	11.68–15.49 cm
Calcium carbonate equivalent (0-12.7cm)	0–4%
Electrical conductivity (0-50.8cm)	2–8 mmhos/cm
Sodium adsorption ratio (0-50.8cm)	0–14
Soil reaction (1:1 water) (0-101.6cm)	5.6–9
Subsurface fragment volume <=3" (0-50.8cm)	0–34%
Subsurface fragment volume >3" (0-50.8cm)	0–34%

Ecological dynamics

The information in this ecological site description, including the state-and-transition model (STM) (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 Thin Claypan Moist Grassland provisional ecological site in MLRA 52 Dry Grassland 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/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) 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. This site is also susceptible to invasion by non-native species. Non-native grasses such as 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 shortgrasses such as prairie Junegrass and 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. Cool-season, mid-statured bunchgrasses such as, needle and thread (*Hesperostipa comata*) are rare. 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. Together, shortgrasses comprise about 25 percent cover, however, due to their short stature, they do not contribute as much to total production as mid-statured grasses. Common forbs are scarlet globemallow (*Sphaeralcea coccinea*), spiny, or Hood's, phlox (*Phlox hoodii*), and Indian breadroot (Pediomelum spp.). Shrubs and subshrubs such as prairie sagewort (*Artemisia frigida*) and silver sagebrush (*Artemisia cana*) occur at about 5 percent cover. The approximate species composition of the reference plant community is as follows:

Percent composition by weight*
Rhizomatous Wheatgrass 50%
Blue grama 10%
Prairie junegrass 10%
Sandberg bluegrass 5%
Other Native Grasses 10%
Perennial Forbs 10%
Shrubs/Subshrubs 5%

Estimated Total Annual Production (lbs/ac)*
Low - 600
Representative Value - 800
High - 1,000
* 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 condition declines due to drought or improper grazing management. Multiple fires in close succession can also transition the site to this phase. This community phase is characterized by an increase in shortgrasses, such as blue grama, Sandberg bluegrass, and prairie Junegrass and a decline in mid-statured, cool-season rhizomatous grasses. The cover of shortgrasses equals or exceeds the cover of mid-statured grasses. 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 (Dekayser 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.

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

State 2: Shortgrass State
The Shortgrass State (2) consists of 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 (Dekayser 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.

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, 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 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. This state can transition back to the Cropland State (4) if the site is put back into cultivation.

Phase 5.1: Abandoned Cropland Community Phase
The Abandoned Cropland Community Phase (5.1) occurs in the absence of active management. The site can re-vegetate naturally and, over time, potentially return to a perennial grassland community with 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 Sandberg bluegrass and blue grama. Depending on the historical management of the site, perennial bunchgrasses such as needle and thread may also return; however, species composition will depend upon the seed bank. Cover and production of cool-season rhizomatous wheatgrasses 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
The Perennial Grass Community Phase (5.2) occurs when the site is seeded to perennial forage species. This community phase can persist for several decades, particularly when seeded to introduced perennial grasses. Some introduced species, such as crested wheatgrass or 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 to cropland.

State and transition model

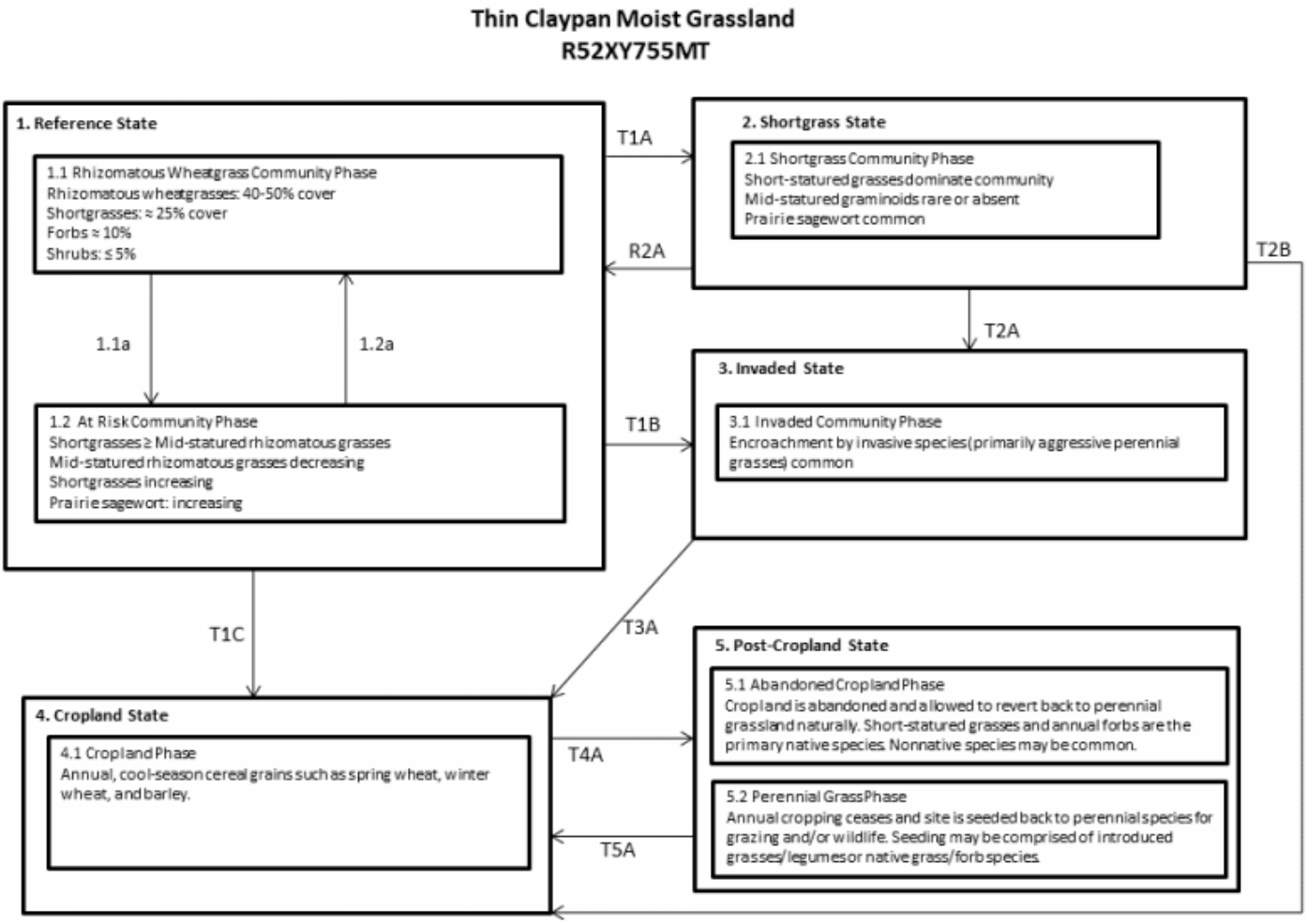

Figure 2. State-and-transition diagram

Thin Claypan Moist Grassland
R52XY755MT

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/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

Inventory data references

One low-intensity plot was available for this provisional ecological site. This plots was used in conjunction with a review of the scientific literature and professional experience to approximate the reference plant community. Information for remaining states was obtained from professional experience and a review of the scientific literature. All community phases are considered provisional based on these plots and the sources identified in this ecological site description.

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Approval

Scott Brady, 8/28/2019

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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:**
